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Report to Congress:

Study of Discharges Incidental to Normal Operation of Commercial Fishing Vessels and Other Non-Recreational Vessels Less than 79 Feet

ACKNOWLEDGMENTS

The EPA Office of Wastewater Management (OWM) presents this draft Vessels Study Report to Congress conducted to meet the obligations of EPA under Public Law (P.L.) 110-299 (July 31, 2008). EPA would like to thank the numerous trade associations and individual companies who contributed to this project. Those groups who provided assistance to EPA are listed in Chapter 2 of this report. The project could not have been successful without the support by EPA Region 2, 3, and 5 laboratories, EPA Gulf Ecology Division and other EPA program offices. EPA would also like to thank the United States Coast Guard for providing both logistical support and review of many of the report's elements. Finally, EPA would also like to acknowledge the contractor support for this project provided by individuals from Great Lakes Environmental Center, Inc., Eastern Research Group, and Abt Associates.

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EXECUTIVE SUMMARY

This report to Congress provides information collected by the U.S. Environmental Protection Agency (EPA) on the types of wastewater discharged from commercial fishing vessels and nonrecreational vessels less than 79 feet in length. The report also provides information on the primary pollutant concentrations in these discharges and the likelihood of any resulting environmental impacts based on rate, frequency, volume, and location discharged. This study was conducted to meet the obligations of EPA under Public Law (P.L.) 110-299 (July 31, 2008). The law provided for a temporary two-year moratorium on National Pollutant Discharge Elimination System (NPDES) permitting of discharges from commercial fishing vessels, regardless of size, and other nonrecreational vessels less than 79 feet long that were subject to the 40 CFR 122.3(a) exclusion. Except for ballast water discharges (evaluated and assessed elsewhere in other Agency reports), discharges from these vessels are not currently covered under the EPA's Vessel General Permit (VGP). During the two-year moratorium, which began July 31, 2008, EPA was required to study the relevant discharges. EPA believes that the results from this study will serve as an objective source of information that Congress can use for statutory decision-making and will provide other readers valuable technical analyses of these vessels' incidental discharges. EPA requested public comment on this draft report in March, 2010: this final report incorporates changes made in response to these comments.

As directed by Congress, the goal of the study was to obtain sufficient information to address the following six core objectives:

- A characterization of the nature, type, and composition of discharges for representative single vessels and for each class of vessel.
- A determination of the volumes of those discharges, including the average volumes for representative single vessels and for each class of vessel.
- A description of the locations, including the more common locations, of the discharges;
- An analysis of the nature and extent of the potential effects of the discharges, including determinations of whether the discharges pose risks to human health, welfare, or the environment, and the nature of those risks.
- A determination of the benefits to human health, welfare, and the environment from reducing, eliminating, controlling, or mitigating the discharges.
- An analysis of the extent to which the discharges are currently subject to regulation under federal law or a binding international obligation of the United States.

EPA designed and conducted a sampling program of discharges from commercial fishing vessels and other nonrecreational vessels less than 79 feet in length to provide information to achieve the first two objectives of the study. As required in P.L. 110-299, the study specifically evaluated the impacts of any 1) discharge of effluent from properly functioning marine engines; 2) discharge of laundry, shower, and galley sink wastes; and 3) other discharges incidental to these vessels' normal operation. In addition, EPA supplemented sample collection and analysis with the collection of contemporaneous information regarding the shipboard processes, equipment, materials, and operations that contribute to the discharges, as well as the discharge rates, duration, frequency, and location.

EPA found that commercial fishing vessels and nonrecreational vessels discharge a wide variety of effluents during their normal operation. The Agency decided to focus its evaluation on discharges from engines, bilges, fish holds, decks, and graywater activities because such discharges can release oils, heavy metals, toxic organics, oxygen-depleting substances, nutrients, and endocrine-disrupting compounds to ambient waters in quantities that may exceed National Recommended Water Quality Criteria (NRWQC). In some circumstances, some of these vessel discharges to water bodies have the potential to impact the aquatic environment.

Vessel Types

EPA estimates there are between 118, 000 and 140,000 vessels in the United States subject to the permitting moratorium (i.e., study vessels).[1] Figure ES. 1 presents the estimated number of study vessels by vessel types (service). Approximately one-half of these vessels are commercial fishing vessels involved in activities such as fish catching (e.g., longliner, shrimper, trawler), fish processing, fishing tending, and charter fishing. The other half is distributed among a variety of vessel classes, including passenger vessels (e.g., water taxis, tour boats, harbor cruise ships, dive boats), utility vessels (e.g., tug/tow boats, research vessels, offshore supply boats), and freight barges.

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[1] Based on the U.S. Coast Guard Marine Information for Safety and Law Enforcement (MISLE) database. See discussion in Chapter 1 and Appendix B of this report for detailed discussions about vessel estimates and limitations of these estimates.

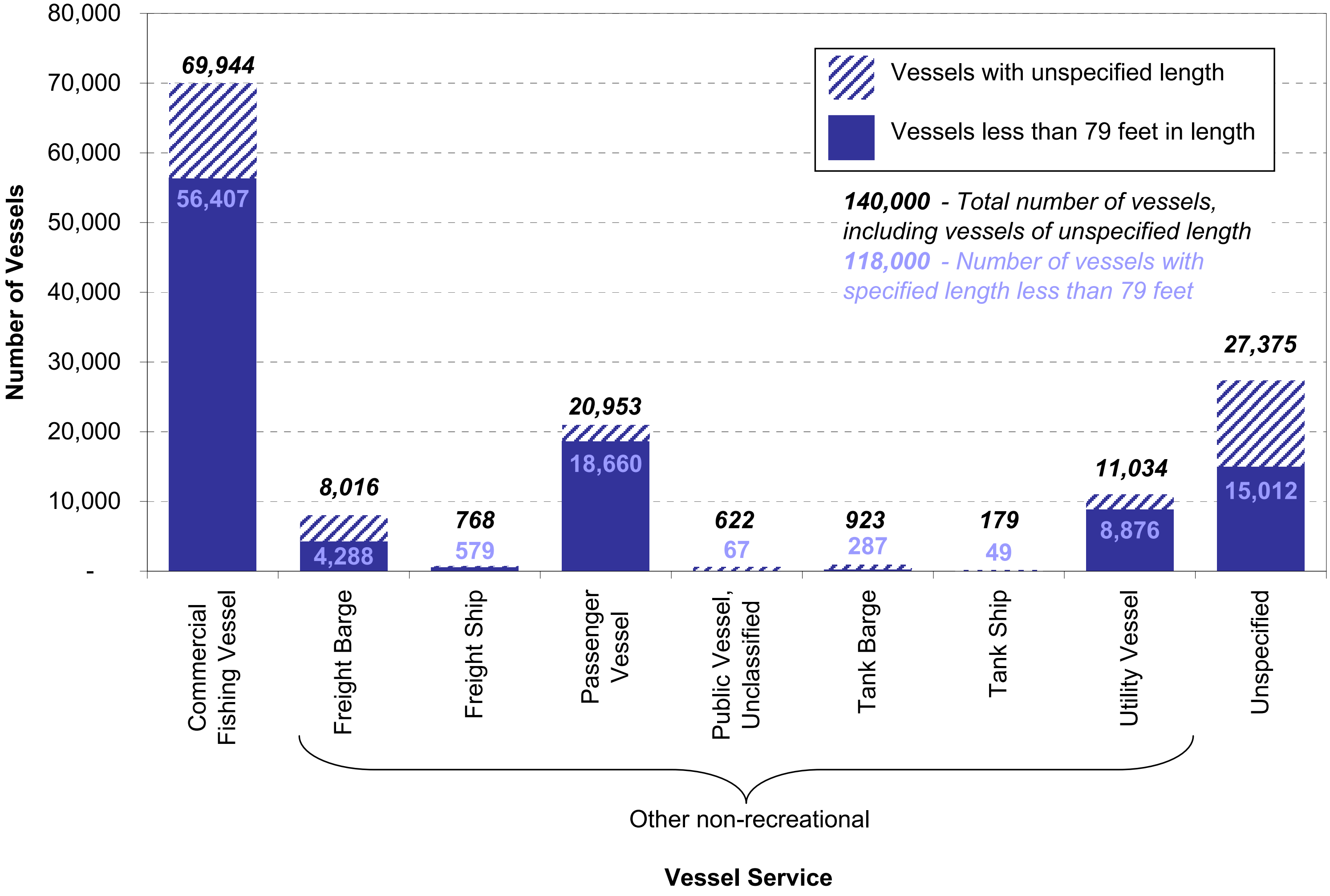

Figure ES.1. Estimated Number of Study Vessels by Vessel Service (Type)

To select specific vessel classes for sampling, EPA first developed a list of commercial vessel classes based on published information and industry experience. Next, due to limited time and resources, EPA eliminated those vessel classes believed to consist primarily of vessels greater than 79 feet in length, with the exception of commercial fishing vessels. Examples of vessel classes eliminated because of their size included cable laying ships, cruise ships, large ferries, and oil and petroleum tankers. Next, EPA eliminated vessel classes that have historically been subject to NPDES permitting, including stationary seafood processing vessels and vessels that can be secured to the ocean floor for mineral or oil exploration. After screening out these vessel classes, EPA selected a subset of priority vessel classes to study, including commercial fishing boats, tug/tow boats, water taxis, tour boats, recreational vessels used for nonrecreational purposes, and industrial support boats less than 79 feet in length. EPA selected these vessel classes because they represent a cross section of discharges and have the potential to release a broad range of pollutants.

EPA sampled wastewater discharges and gathered shipboard process information from 61 vessels in nine vessel classes. Vessels were sampled in 15 separate cities and towns in nine states across multiple geographic regions, including New England, the Mid-Atlantic, the Gulf Coast, the

Mississippi River, and Alaska. Table ES.1 presents the types of vessels from which EPA sampled and gathered shipboard process information for this study. EPA sampled more commercial fishing vessels than any other vessel class due to the large number of fishing vessels subject to the P.L. 110-299 permitting moratorium. EPA also sampled a few recreational vessels used for commercial purposes (e.g, towboats) to: 1) provide a semiquantitative comparison of the discharges from these vessels and the other study vessels, and 2) collect additional information for EPA's related Clean Boating Act (P.L. 110-288) work.

Table ES.1. Vessels Sampled by EPA

Vessel Class	Number of Vessels Sampled
Fishing:	
Gillnetter	5
Lobster Tank	1
Longliner	3
Purse Seiner	5
Shrimp Trawler	6
Tender	3
Trawler	4
Troller	6
Tugboat	9
Water Taxi	4
Tour Boat	3
Tow/Salvage [1]	6
Research [1]	2
Fire Boat	1
Supply Boat	1
Recreational	2
Total	**61**

(1) Consists primarily of recreational vessels used for commercial or governmental purposes.

Sampled Discharges

EPA sampled a total of nine discharge types from the various vessel classes listed above. These included:

- Bilgewater
- Stern tube packing gland effluent
- Deck runoff and/or washdown
- Fish hold effluent (both refrigerated seawater effluent and ice slurry)
- Effluent from the cleaning of fish holds
- Graywater
- Propulsion and generator engine effluent
- Engine dewinterizing effluent
- Firemain

EPA typically sampled one to four discharge types on each vessel, depending on applicability, accessibility, and logistical considerations. Vessel discharge samples were analyzed for a variety of pollutants, including classical pollutants such as biochemical oxygen demand (BOD_5), total suspended solids (TSS), residual chlorine, and oil and grease; nutrients; total and dissolved metals; volatile and semivolatile organic compounds (VOCs and SVOCs); nonylphenols (used as surfactants in detergents), which are endocrine-disrupting compounds; and pathogen indicators (i.e., *E. coli*, enterococci, fecal coliforms).

Summary of Findings

EPA found that the sampled discharges with the greatest potential to impact surface water quality include deck washdown, fish hold effluent, graywater, bilgewater, and marine engine effluent. Though these discharges may have the potential to impact surface water quality, particularly on a localized scale, a screening level model of a hypothetical large harbor indicates that most of these discharges in and of themselves would not cause exceedences of national water quality criteria in large water bodies (see additional discussion under environmental impacts below). Review of available literature also indicates that leachate from antifouling hull coatings used on certain vessels to prevent buildup of organisms, such as barnacles and algae, as well as underwater hull cleaning, likely impact surface water quality in some situations.

Deck washdown from utility vessels such as tug/tow boats, tour boats, water taxis, and supply boats had elevated dissolved and total metal concentrations (e.g., aluminum) likely associated with particulate metal washing off metal decks or decks with significant metal components. Certain deck washdown samples also contained pollutants such as BOD_5, TSS, nonylphenols, total phosphorous, and total residual chlorine, all of which are associated with detergents and disinfectants.

Fish hold effluent, which is either refrigerated seawater or ice slurry water found on fishing boats, had BOD_5 and chemical oxygen demand (COD) concentrations that were several times higher than concentrations typically measured in raw domestic sewage. Nutrient levels in many fish hold effluent samples were also similar to the concentrations normally found in raw domestic sewage, and ammonia nitrogen was occasionally detected at concentrations acutely toxic to aquatic life. While small fishing boats periodically discharge only a few hundred gallons of fish hold wastewater, large fishing vessels, such as offshore trawlers, can discharge thousands of gallons of fish hold wastewater in a matter of minutes.

Most fishing vessel owners also clean the fish hold tanks with a detergent and/or disinfectant after the fish have been off-loaded. Detergents are suspected of containing nonylphenols, which are endocrine-disrupting compounds. Disinfectants such as chlorine bleach contain high concentrations of total residual chlorine, which is toxic to aquatic organisms. The samples of fish hold cleaning effluent contained nonylphenols and total residual chlorine, along with the same pollutants measured in the fish hold effluent.

Galleys, sinks, showers, and laundry facilities onboard commercial vessels generate graywater, which is typically discharged overboard. Graywater volumes vary considerably depending on the class of vessel and its intended use, vessel size, the number of crew and passengers onboard, and the types of graywater-generating activities. Pollutants associated with the various graywater sources depend on a variety of factors, such as the amount of food waste flushed into the graywater system, the level of soiling on clothing being washed in the onboard laundry, and the use of showers. EPA did not sample graywater mixed with sewage, so the results for this study are for graywater only. EPA's sampling data found pathogens to be the primary pollutant of concern in graywater. The sampling data show that at least one of the pathogenic organisms (fecal coliforms, enterococci, and *E. coli*) was found in all graywater samples, and that levels of these indicators in most of these samples exceeded the water quality benchmarks, some by as much as four orders of magnitude.

Bilgewater effluent consists of the water that collects in the bottom of the vessel from sources such as precipitation and spray, fuel spills, leaking sewage and graywater piping, condensates, and deck washing. Bilgewater contained the greatest variety (although not necessarily the highest concentrations) of priority pollutants, including both total and dissolved metals, VOCs, and SVOCs. It also contained pathogenic bacteria, nonylphenols, sulfide, total phosphorous, BOD_5, TSS, and residual chlorine. Both total arsenic and dissolved copper concentrations in bilgewater were consistently above the most conservative screening benchmarks (e.g., EPA's 2006 NRWQC), and total arsenic concentrations were nearly 1,000 times the safe human health standard.

Propulsion and generation engine effluent varied dependent upon the type of engine. EPA found that inboard propulsion engines discharge more pollutants in their cooling water than outboard propulsion engines or generators. EPA also found that VOCs and SVOCs are the primary pollutants of concern found in marine engine cooling water discharges. These pollutants (e.g., benzene and several PAHs, including some that are carcinogenic, or cancer causing) are present in fuels and are products of incomplete combustion. Dissolved copper was also measured in most inboard engine effluents at concentrations that exceed the NRWQC. Some vessel owners in cold climates also add a solution of propylene glycol (antifreeze) to the internal cooling system of inboard engines to protect them from freezing during winter. In spring, the antifreeze solution may be discharged as the cooling system is refilled with ambient water. EPA's sampling data showed that the spent antifreeze solution discharged to surface water contained relatively high levels of metals, which are likely a result of corrosion within the engine's cooling system.

Stern tube packing gland effluent (from tug boats) and firemain discharges (limited to just two tug boats, three tour boats, and a fireboat) contained elevated levels of some metals (e.g., dissolved copper, total aluminum, total arsenic). For both of these discharges (firemain in particular), the effluent samples contained relatively small concentrations of pollutants, most of which could be attributed to the ambient surrounding water predominating the discharge. For example, stern tube systems have a continual drip of ambient water while the shaft is turning to provide both cooling and lubrication for the system. The source of the additional metals in stern tube packing gland effluent is likely mechanical system wear or lubricants used in the vessels' power trains.

Although not directly sampled, EPA gathered existing information from the literature to characterize discharges from antifouling hull coatings. Antifouling hull coatings are specialized paints and other coatings intended to retard the growth of algae; weeds; and encrusting organisms, such as barnacles and zebra mussels, on the underwater portion of vessel hulls. The coatings retard growth by continuously leaching biocides into surrounding waters. The most commonly used biocide is cuprous oxide. The biocide enters the water column through both passive leaching and underwater hull cleaning and can accumulate in the water of poorly flushed boat basins to levels that may harm marine life. For example, the leaching of copper from antifouling hull coatings used on recreational boats is a major source of copper pollution in several large boat basins in Southern California. Copper from antifouling coatings has created documented water quality concerns in areas such as the Chesapeake Bay; Port Canaveral, Florida; and several harbors in the state of Washington.

Environmental Impacts

Using the results obtained from this study, EPA modeled a large hypothetical harbor to evaluate the environmental impacts from the nine above mentioned vessel discharge types that EPA sampled. The screening-level model indicated that the study vessels' discharges would not, in themselves, exceed the aquatic life or human health NRWQC; however, the model did not account for background loadings. Certain pollutants (e.g., total arsenic, dissolved copper) are more likely to contribute to a water quality criterion being exceeded under real-world conditions in large-scale water bodies. Additionally, many pollutants present in the vessel discharges were at concentrations that exceed an NRWQC at end of pipe; therefore, they have the potential to contribute to an environmental effect in the receiving water on a more localized scale. Based on the study results and literature reviews, EPA believes that total arsenic and dissolved copper represent the greatest environmental concern in vessel discharges, and that they are more likely than other pollutants to contribute to exceedances of water quality standards. This is especially true if there are other sources of these pollutants (e.g., stormwater runoff) or high concentrations of vessels in confined waters, or the receiving waters already have high background concentrations.

Other notable pollutants of concern were found in fish hold effluent from fishing vessels. These pollutants include total phosphorus, BOD, COD, reactive nitrogen compounds, and pathogens. These pollutants can exacerbate eutrophication in bays and estuaries, leading to poor surface water quality.

Analysis of Applicable Regulations

This report to Congress includes EPA's analysis of existing laws and treaties that apply to vessels and their discharges. This analysis describes numerous domestic laws, including the Act to Prevent Pollution from Ships (APPS); the Clean Water Act (CWA); the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA); and the Organotin Antifouling Paint Control Act (OAPC). It also summarizes key elements of several international treaties, including the International Convention for the Prevention of Pollution from Ships (MARPOL 73/78), the International Convention on the Control of Harmful Anti-Fouling Systems on Ships, the International Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter (London Convention), and the International Convention on Oil Pollution, Preparedness, Response and Cooperation (OPRC). The purpose of this analysis is to summarize these existing regulations and international obligations and examine the extent to which these discharges are subject to these obligations.

Conclusion

Some vessel discharges from commercial fishing vessels and commercial vessels less than 79 feet in length may have the potential to impact the aquatic environment and/or human health. As noted above, using the results obtained in this study, EPA modeled a large, hypothetical harbor to evaluate how the nine vessel discharge types EPA sampled may impact water quality. Based on this evaluation, EPA determined that the incidental discharges from study vessels to a relatively large water body are not likely to solely cause an exceedance of any NRWQC. This finding suggests that these discharges are unlikely to pose acute or chronic exceedances of the NRWQC across an entire large water body. However, since many of the pollutants present in the vessel discharges were at end-of-pipe concentrations that exceeded an NRWQC, there is the potential for these discharges to contribute a water quality impact on a more localized scale. The study results indicate that total arsenic and dissolved copper are the most significant water quality concerns for the study vessels as a whole, and that they are more likely than other pollutants to contribute to exceedances of water quality criteria. This is especially true if there are high concentrations of vessels in confined waters or other sources of pollutants or the receiving water already has high background concentrations.

Like an individual house in an urban watershed, most individual vessels have only a minimal environmental impact. As in urban waters, however, the impacts caused by these vessels are potentially significant where there is high vessel concentration, low water circulation, or there are environmentally stressed water bodies. Targeted reduction of certain discharges or pollutants in discharges from these vessels in waters sensitive to the introduction of pollutants from vessels may result in important significant environmental benefits to those waters.

CHAPTER 1
INTRODUCTION TO THE REPORT

1.1. CONGRESSIONAL STUDY CHARGE

On July 31, 2008, Public Law (P.L.) 110-299[1] was signed into law. It provides a two-year moratorium for nonrecreational vessels less than 79 feet in length and all commercial fishing vessels regardless of length, from the requirements of the National Pollutant Discharge Elimination System (NPDES)[2] program to obtain a permit for discharges incidental to the normal operation of those vessels.[3] Additionally, P.L. 110-299 directs the United States Environmental Protection Agency (EPA) to study the environmental impacts of discharges incidental to the normal operation of those vessels. Specifically, the law directs the agency to study and evaluate the impacts of:

(1) Any discharge of effluent from properly functioning marine engines
(2) Any discharge of laundry, shower, and galley sink wastes
(3) Any other discharge incidental to the normal operation of a vessel

Congress mandated that EPA include the following elements in the study:

(1) Characterizations of the nature, type, and composition of the discharges for:
    a. Representative single vessels
    b. Each class of vessels
(2) Determinations of the volume (including average volumes) of those discharges for:
    a. Representative single vessels
    b. Each class of vessels
(3) A description of the locations (including the more common locations) of the discharges.
(4) Analyses and findings as to the nature and extent of the potential effects of the discharges, including determinations of whether the discharges pose a risk to human health, welfare, or the environment, and the nature of those risks.
(5) Determinations of the benefits to human health, welfare, and the environment from reducing, eliminating, controlling, or mitigating the discharges.
(6) Analyses of the extent to which the discharges are currently subject to regulation under federal law or a binding international obligation of the United States.

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[1] P.L. 110-299, along with its companion law for recreational vessels, P.L. 110-288 ("The Clean Boating Act") are presented in Appendix C of this report.

[2] The NPDES program requires a permit when a point source discharges a pollutant to waters of the US. A NPDES permit contains conditions and limitations on the rates, concentrations, and mass of a pollutant that can be discharged to a water body. The limitations are based on available pollution control technologies and water quality standards that are established to protect the designated uses of a water body, such as fishing or swimming.

[3] Although this report focuses on the discharges from vessels subject to the moratorium, the Agency became aware during interaction with congressional staff that some members may be interested in additional information on discharges incidental to the normal operation of a larger universe of vessels—in particular, vessels currently subject to the NPDES General Permit for Discharges Incidental to the Normal Operation of a Vessel ("Vessel General Permit"). Therefore, EPA has included some additional information and analysis regarding those vessels where possible.

The law expressly excludes certain discharges from the scope of the study: discharges from vessels owned and operated by the Armed Forces;[4] discharges of sewage[5] from vessels, other than the discharge of graywater from vessels operating on the Great Lakes; and discharges of ballast water.

EPA conducted the study required by P.L. 110-299 and is publishing this report to present its findings. Due to the accelerated timeframe required to complete the study, EPA designed this analysis to be accomplished quickly with existing resources. Limitations in the study design are discussed in Chapter 2 of this report. Due to these factors, EPA focused its sampling efforts on the vessels that P.L. 110-299 specifically exempted. EPA henceforth refers to these vessels and vessel types as study vessels. EPA sampled discharges from a few other vessel types, including commercial vessels that were manufactured primarily for pleasure, where resources and logistics allowed.

1.2. ORGANIZATION OF THIS REPORT

The report is organized into seven chapters. In Chapter 1, EPA describes the universe of vessels with discharges subject to the study, the types of discharges generally thought to originate from those vessels, and the types of pollutants or other constituents generally found in those vessel discharges. In Chapter 2, EPA discusses the methods for sampling, the types of vessels sampled, the Quality Assurance and Quality Control (QA/QC) measures taken in the course of sampling, and the limitations of this study. Chapter 3 is the most technical portion of the report, presenting the results from EPA's sampling and other information gathered from literature reviews about the vessel discharges. Chapter 4 presents the results of EPA's screening-level model, which was designed to look at the large-scale, cumulative impacts of these vessel discharges on large harbor or estuarine systems in order to provide an initial evaluation of the threat the discharges pose to these ecosystems. Chapter 5 discusses the results and identifies those key areas where EPA found discharges most likely to be a concern to human health, welfare, or the environment. Chapter 6 provides a summary of federal law and binding international obligations to which discharges within the scope of the study are potentially subject. To a certain extent, Chapter 6 also discusses discharges described in the study that might be beyond the scope of the permitting moratorium in some circumstances. Chapter 7 lists report references.

1.3. CLASSES OR TYPES OF VESSELS

The study required by P.L. 110-299 could potentially include numerous classes or types of vessels that vary greatly in size. The smallest vessels include recreational boats used for commercial purposes, which can be less than 20 feet in length. The largest vessels, such as super oil tankers, can be more than 1,200 feet in length. Characteristics of these vessels, including construction material, designed purpose, onboard activities, crewing requirements, engine type and power, and days in

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[4] The Clean Water Act defines "vessel of the Armed Forces" as any vessel owned or operated by the Department of Defense, other than a time or voyage chartered vessel; and any vessel owned or operated by the Department of Transportation that is equivalent to one owned by the Department of Defense. 33 U.S.C. § 1322(a)(14).

[5] "Sewage" is defined as "human body wastes and the wastes from toilets and other receptacles intended to receive or retain body wastes except that, with respect to commercial vessels on the Great Lakes, such term shall include graywater." 33 U.S.C. § 1322(a) (6).

operation vary widely. Consequently, the types and volumes of discharges generated by these different classes or types of vessels also vary to a great extent.

EPA identified many classes or types of nonrecreational vessels in the development of the 2008 Vessel General Permit (VGP). Examples include tank ships that transport large volumes of bulk liquids, container ships that transport containerized cargo, barges that transport bulk goods, and large cruise vessels that transport hundreds or thousands of passengers. In the VGP, EPA defines a "Cruise Ship" as a passenger ship that is used commercially for pleasure cruises and provides overnight accommodations to passengers. In a separate study, EPA prepared an extensive cruise ship discharge assessment report characterizing five different discharge types from these vessels.[6]

The moratorium of P.L. 110-299 applies to discharges from nonrecreational vessels less than 79 feet in length and all commercial fishing vessels. For some vessel classes or types, such as barges or cruise ships, the majority of that class or type are vessels longer than 79 feet. For other classes or types, such as container ships or oil tankers, all the vessels would be expected to be longer than 79 feet. EPA did not include such vessel classes in this study, as resources did not allow for representative sampling of the larger vessels to provide an assessment of the discharges from those classes and still adequately sample and assess the vessels specifically exempted by P.L. 110-299. In this study, EPA focused on sampling discharges from the most prevalent classes or types of vessels defined by the moratorium parameters, but sampled other vessels if the opportunity presented itself. The following subsections briefly describe key characteristics of some of the vessels considered for sampling in the study, but this list is not intended to be comprehensive.

1.3.1. Commercial Fishing Vessels

As defined in P.L. 110-299, commercial fishing vessels are vessels that commercially engage in the catching, taking, or harvesting of fish or an activity that can reasonably be expected to result in the catching, taking, or harvesting of fish. Commercial fishing vessels include any vessels harvesting fish, crab, lobster, shrimp, or other aquatic organisms for commercial sale. Commercial fishing vessels may employ various methods of collection including nets, trawls, traps, or hook-and-line to capture the target species.

The commercial fishing industry is highly diverse, spanning a wide array of ocean and nearshore conditions, differing by both region and fishery. For example, the State of Alaska alone manages 68 fisheries, and there are over three hundred combinations of species, gear, and regions. Approximately half of the nearly 10,000 Alaska State permitted vessels are endorsed for only one fishery; vessels working multiple distinct fisheries can be set up in a totally different manner depending on the target species (United Fishermen of Alaska, 2010 and Alaska Trollers Association, 2010). Types of fishing vessels include, but are not limited to:

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[6] This report is available at: www.epa.gov/owow/oceans/cruise_ships/pdf/0812cruiseshipdischargeassess.pdf.

Purse Seiner: Purse seiners catch fish that school close to the surface, such as salmon, herring, and sardines, by encircling them with a long net and drawing (pursing) the bottom closed to capture the fish. The net is retrieved using a winch. When most of the net has been retrieved, with the remainder laying in a "bag" alongside the vessel, the fish are dipped from the bag and into the vessel's hold. Seine-caught fish are delivered whole. Purse seiners are limited by Alaska law to 58 feet to more precisely manage their fishing effort (Alaska Department of Fish and Game, 2007).

Purse Seiner Fishing Vessel.

Troller: Troll vessels catch fish such as salmon and tuna by "trolling" bait or lures on lines through feeding concentrations of fish. Trolling vessels come in a variety of sizes and configurations, ranging from small, hand-trolling skiffs to large, ocean-going power trolling vessels of 50 feet or more in length (Alaska Department of Fish and Game, 2007). Hand trollers fish fewer lines and bring fish aboard with hand operated gurdies or rod and reel; power trollers use hydraulic gurdies to land their catch. Fish caught in the troll fishery are landed one at a time. Most troll-caught fish are immediately gilled, gutted, and iced; some are landed in the round and held in slush ice; and a small component is frozen at sea. In Alaska, the troll fishery occurs nearly year-round; however, the vast majority of fish are delivered between July 1 and September 30 (Alaska Trollers Association, 2010).

Troller Fishing Vessel.

Crabber/Lobster: Crabbers and lobster boats target crabs (Dungeness, King, Tanner, and Blue) and lobsters using twine or wire-meshed steel pots (traps). A line extends from each pot to a surface buoy that marks its location; a power winch is used to retrieve the pots. Baited pots are left to “soak” for up to several days before retrieval. Once onboard, the pots are opened and sorted with legal crabs/lobsters retained in aerated seawater tanks. Crabs/lobsters are delivered live to shore stations and retail outlets. Crab and lobster boats come in a variety of shapes and sizes, from aluminum skiffs with outboard motors that fish the inside waters, to seagoing vessels 100 or more feet in length that fish the Bering Sea and the Gulf of Alaska for King Crab (Alaska Department of Fish and Game, 2007).

Gillnetter: Gillnetters catch a variety of fish, such as salmon, herring, and chum, by setting curtain-like nets perpendicular to the direction in which the fish are traveling as they migrate along the coast toward their natal streams. Nets can be set in place, such as at or near the mouths of rivers, or allowed to drift freely in deep water. Mesh openings are just large enough to allow the male fish, which are usually larger, to get their heads suck in the mesh. Gillnet vessels are usually 30 to 40 feet long and are easily recognized by the drum on either the bow or the stern on which the net is rolled. Net retrieval is by hydraulic power which turns the drum. Fish are removed from the net by hand as the net is reeled aboard. Gillnet-caught fish are usually iced for delivery (Alaska Department of Fish and Game, 2007).

Gillnetter Fishing Vessel.

Trawler: Trawlers, also occasionally called draggers, typically catch large quantities of mid-water species, such as pollock or pink shrimp, and bottom-fish, such as flounder, by towing a large, cone-shaped net. The net is retrieved using winches and rolled onto a drum. The end of the net ("bag") holds the fish and is pulled onto the back of the vessel via a slanted stern ramp. Fish such as flounder may be processed onboard into fillets or minced. Shrimp are sorted by size and species and frozen either whole or headed. Trawlers range in size from small shrimp trawlers to large 600-foot ocean pollock trawlers that possess onboard processing facilities (Alaska Department of Fish and Game, 2007).

Trawler Fishing Vessel.

Longliner: Longliners catch fish (primarily halibut, black cod, swordfish, and tuna) via a longline that is either laid on the bottom or suspended in the water column. Each longline can be up to a mile in length and have thousands of baited hooks. A longline vessel typically sets several lines for a 24-hour "soak." The lines are retrieved over a side roller with a power winch, and the caught fish are packed in ice in the vessel's hold and are delivered whole and bled, whole and gutted, or headed and gutted dressed (Alaska Department of Fish and Game, 2007). Longliners range in size from 18-foot open skiffs to 80-foot schooners (Alaska Longline Fishermen's Association, 2010).

Longliner Fishing Vessel.

Fishing Dredge: A fishing dredge, also known as a scallop dredge or oyster dredge, is a device that is towed along the bottom of the sea by a fishing vessel to collect scallops, oysters, clams, crabs, and even in some cases, sea cucumbers. The dredge is winched up into the vessel and emptied onto the deck. Dredge boats used to collect clams, oysters, and crabs in near-shore estuarine waters range from 24 to 50 feet long. Large off-shore dredges used to collect sea scallops can be as long as 190 feet.

Fish Tender: A fish tender vessel supports fishing vessels by providing supplies and storing, refrigerating, or transporting fish, fish products, or other materials.

Tender Vessel.

1.3.2. Tugs/Towing Vessels

Tugboats and towboats serve many functions and include vessels that operate solely in river systems to ocean-going vessels. Tugboats can be utilized to push or tow barges and rafts. Tugboats often assist larger vessels in docking maneuvers in harbors and are generally powerful relative to their size. Although tugboats and towboats can be over 200 feet in length, many are in the 40- to 100-foot range.

Tugboat/Push Boat.

1.3.3. Water Taxis/Small Ferries

Water taxis and small ferries (or water busses) are vessels employed to provide public transport of people from one location to another. Small ferries are vessels for hire that are designed to carry passengers and/or vehicles between two ports, usually in inland, coastal, or near-shore waters. Many of these vessels can be found in the coastal harbors of New York, Baltimore, Boston, San Diego, Seattle, and others. The sizes of the vessels in this class vary and can surpass 100 feet in length.

1.3.4. Tour Boats

This vessel class encompasses a variety of vessels used for activities such as dinner cruises, ecotourism, whale watching excursions, and sightseeing trips. Vessels in this class can range from small private vessels with just a few passengers to large vessels carrying 50 or more passengers. Large tour boats designed for extended excursions can include galley facilities, overnight accommodations, and laundry.

A Tour Boat (left) and a Water Taxi (right).

1.3.5. Recreational Vessels Used for Non-Recreational Purposes

This class includes vessels manufactured as recreational vessels that are used for nonrecreational purposes, such as law enforcement vessels, fire/rescue vessels, towing and salvage vessels (not to be confused with towboats above), and research vessels. This vessel class encompasses a broad range of vessel types and sizes. Under the Clean Boating Act of 2008 (P.L. 110-288), vessels that are manufactured or used primarily for pleasure are "recreational vessels" subject to regulation under that Act.

Recreational Vessel Modified for Towing/ Salvage.

1.4. VESSEL POPULATION

As discussed in Section 1.1, P.L. 110-299 requires EPA to characterize discharges for representative single vessels and for each class of vessel in terms of its nature; type and composition; average volume; location; nature and extent of the potential effects; and benefits of reducing, eliminating, controlling, or mitigating the discharges. EPA focused its attention on the commercial fishing vessels and other nonrecreational vessels less than 79 feet in length covered by the moratorium. Understanding the characteristics of discharges from all commercial fishing vessels and nonrecreational vessels less than 79 feet in length requires considering these vessels in term of their number, vessel type, onboard equipment, type of service, and area of operation. A brief overview of the analysis on vessel type and size is presented in this section. A more complete analysis, including a discussion regarding vessel location (which impacts the location of vessel discharges) and other vessel characteristics, is presented in Appendix B of this report.

1.4.1. Vessel Characteristics Data

In evaluating and describing the vessel population, EPA primarily relied on data gathered by the U.S. Coast Guard. The primary data source used in the vessel population analysis is the U.S. Coast Guard's Marine Information for Safety and Law Enforcement (MISLE) database (USCG, 2009). MISLE provides a wide range of information regarding vessel and facility characteristics, accidents, marine pollution incidents, and other pertinent information tracked by the U.S. Coast Guard. Where possible, EPA complemented the data available in MISLE with information obtained from published sources or from consultations with U.S. Coast Guard personnel or port authorities.

MISLE includes data for nearly 1 million vessels that operate in U.S. waters. The database covers a wide ensemble of vessels (e.g., recreational vessels, commercial fishing vessels, freight barges, tank barges, tank ships, passenger vessels, utility vessels), and provides data on various characteristics for each individual vessel. These data include:

- Identification number(s)
- Vessel category (e.g., class, type, subtype, service)
- Size (e.g., tonnage, length, breadth, depth)
- Area of operation (e.g., hailing port, route type)
- Passenger and crew capacity
- Propulsion (i.e., method, engine type, and horsepower)
- Construction material and design (e.g., hull material, design type, hull configuration/shape)
- Year built or age

In compiling MISLE data, the U.S. Coast Guard largely relies on documents submitted by vessel owners or operators in accordance with vessel documentation requirements (e.g., certificate of documentation) or on information gathered by U.S. Coast Guard staff directly (e.g., during inspections, vessel boardings, or accident investigations). While the database scope is not limited to a certain size or class of vessel, the scope of the data included in MISLE is driven in part by the regulatory requirements to which different types of vessels are subject or by activities conducted by Coast Guard offices.

MISLE, therefore, is generally most comprehensive for those vessels that are documented, state registered, and/or subject to inspection requirements.

While MISLE represents the most comprehensive national dataset currently available, it does not capture the entire universe of vessels operated on U.S. waters. As discussed at greater length in Appendix B, only limited information is available for certain classes of vessels, such as smaller recreational vessels, due to the way in which vessel data are gathered. Most recreational vessels are not subject to documentation or regular inspection requirements and thus are not captured in MISLE.[7] The MISLE data set currently contains approximately 700,000 recreational vessels, approximately 36 percent of which are documented vessels; the other recreational vessels are present in MISLE because of other U.S. Coast Guard activities, such as boardings, nonmandatory inspections (e.g., voluntary inspection program), or incident investigations.[8] Shortcomings of the database mostly regard small recreational vessels. Since recreational vessels are covered separately under the Clean Boating Act of 2008 (P.L. 110-288) and are therefore not the primary focus of this report, EPA believes that data limitations do not preclude the use of the MISLE data for the current analysis to generally describe the characteristics of study vessels.

Additionally, while MISLE captures a wide range of characteristics for each vessel, the information is at times incomplete (e.g., length may be missing or recorded as zero) or may be outdated (e.g., a vessel may no longer be operating while its status in the database remains “active”). Consequently, the information provided by the database should be seen as approximate and as indicative of the general characteristics of different populations or classes of vessels that operate in U.S. waters.

1.4.2. Overview of Vessel Universe

Information is provided in MISLE for a total of 993,863 vessels. Based on information recorded in the database, 976,649 of these vessels are presumed currently operational, of which 918,469 vessels are identified as U.S.-flagged vessels (referred to as “domestic” vessels in the remainder of the section).[9,10] Nearly 80 percent of the 918,469 operational domestic vessels recorded in MISLE are recreational vessels (722,522 vessels), while 7.6 percent are identified as commercial fishing vessels. The remainder of the MISLE universe is composed of other types of nonrecreational vessels (10.5 percent) such as freight and tank barges and ships, passenger vessels, and utility vessels, and vessels of unspecified service (3 percent). Figure 1.1. presents the MISLE population of operational, domestic vessels for all vessel service categories, excluding recreational vessels. While the P.L. 110-299

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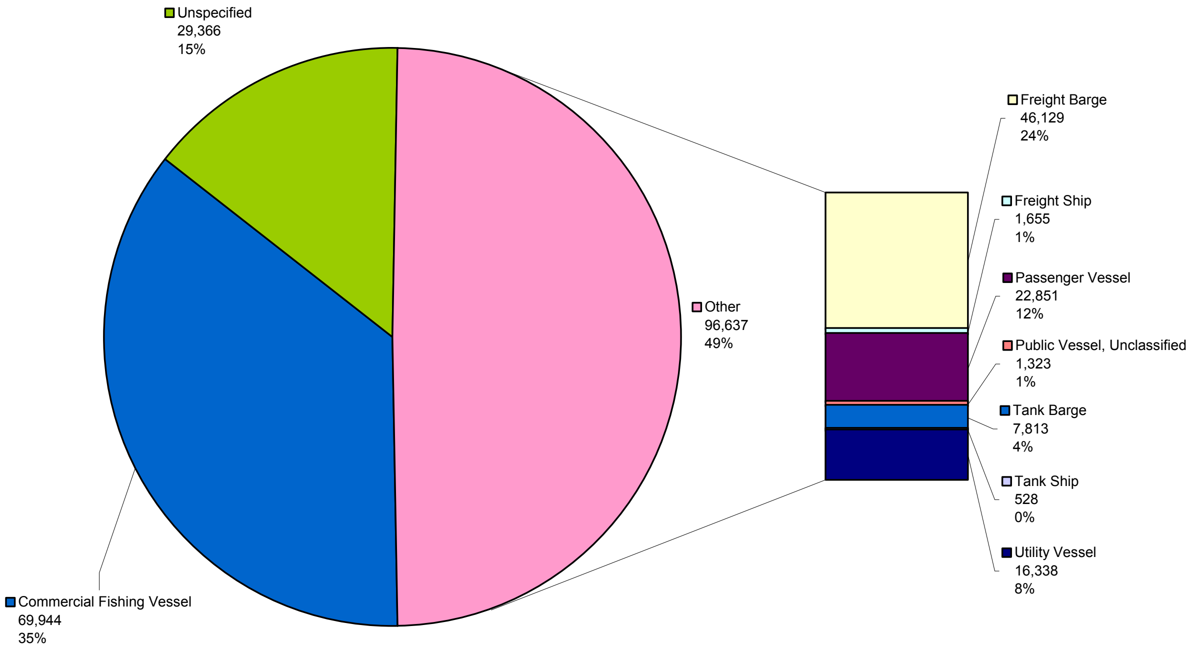
[7] While the number of recreational vessels recorded in MISLE is high (over 700,000), the database accounts for only a small fraction of the 16.9 million recreational vessels estimated to operate in U.S. waters, according to EPA’s Economic Impact Analysis of the Recreational Vessel Permit (USEPA, 2008a) and to the National Marine Manufacturers Association’s (NMMA’s) 2007 U.S. Recreational Boat Registration Statistics (NMMA, 2009).

[8] Personal communication with U.S. Coast Guard Representative, LCDR Scott Muller, on May 15, 2009.

[9] Approximately 355,000 vessels do not provide a vessel status and 5,000 have an "unknown" status. Following guidance from a Coast Guard representative (*Source:* Personal email communication with Harold Krevait of the U.S. Coast Guard. March 13, 2009), EPA assumed that these vessels are currently operational.

[10] This count is based on the flag of the vessel. However, the MISLE database records a U.S. hailing port for some vessels that are foreign flagged. Additionally, approximately 57,000 vessel records do not identify the vessel flag. EPA assumed that these are domestic vessels.

moratorium will generally apply to discharges from the vessel service categories shown in the figure, many of the vessels presented in Figure 1.1. are not subject to the P.L. 110-299 permitting moratorium since the law is limited to commercial fishing vessels (regardless of size) and other nonrecreational vessels 79 feet or less. Approximately one-third of the operational, domestic, nonrecreational vessels are commercial fishing vessels. The next largest vessel service category is freight barges, with approximately 24 percent of vessels; however, many of these barges may exceed the 79-foot length restriction.



Source: U. S. Coast Guard, MISLE database, 2009.

Note; The chart includes all commercial fishing vessels recorded in MISLE (69,944) and all 96,637 other non-recreational vessels, regardless of length.

Figure 1.1. MISLE Population of Operational, Domestic Non-Recreational Vessels by Vessel Service[11,12]

Table 1.1 further characterizes the vessel population in terms of length greater than or equal to or less than 79 feet within each vessel service category. As shown in both Table 1.1 and Figure 1.1., the vast majority of vessels contained in MISLE are less than 79 feet in length. For example, nearly 77 percent of commercial fishing vessels (54,176 vessels out of 69,944) recorded in MISLE have a

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[11] This figure does not include the 722,522 recreational vessels included in the MISLE population of operational, domestic vessels.

[12] Approximately 74,000 vessels have a vessel service indicated as "unclassified", "unknown", or "unspecified" in MISLE. In approximately 44,000 of those instances, EPA was able to assign a vessel service for the purpose of this analysis based on information provided in other data fields (i.e., using vessel class, vessel type, or vessel subtype information).

length less than 79 feet.[13] Vessels less than 79 feet also are a vast majority (94 percent) of the recreational vessels. Only the other nonrecreational vessel service category counts a majority of vessels 79 feet or longer.

Table 1.1. Population of Operational, Domestic MISLE Vessels by Vessel Length

	Recreational	Commercial Fishing	Other Non-Recreational	Unspecified
Greater than or Equal to 79 ft	2,256	2,231[(2) (3)]	54,142	1,991
Less than 79 ft	676,915	54,176	32,799	15,011
Zero or Null(1)	43,351	13,537	9,696	12,364
Total	722,522	69,944	96,637	29,366

Source: U. S. Coast Guard, MISLE database, 2009
(1) MISLE indicates a length of zero or the vessel length field is blank.
(2) A separate estimate provided by U.S. Coast Guard personnel suggests that commercial fishing vessels 79 feet long or greater number approximately 1,800 to 1,900 vessels.[14]
(3) Columns with yellow background represent study vessels.

Recreational vessels are generally excluded from many parts of our analysis because a separate act (the Clean Boating Act of 2008 (P.L. 110-288)) exempts discharges incidental to the normal operation of these vessels from NPDES permitting requirements. The Clean Boating Act defines recreational vessels as those that are either 1) manufactured or used primarily for pleasure or 2) leased, rented, or chartered to a person for the pleasure of that person. Furthermore, vessels that are subject to U.S. Coast Guard inspection and that are either engaged in commercial use or that carry paying passengers are not considered recreational vessels under the Clean Boating Act. This definition does not necessarily correspond to the service categories used in MISLE to identify recreational versus nonrecreational vessels because MISLE categories are based on the type of service the vessel is used for rather than original manufacture purpose. There are additional instances in which MISLE may differ from Clean Boating Act definitions, making the distinction between vessels listed in the database that are within and outside the scope of this study not always clear. For example, certain vessels that would appear to fall under the Clean Boating Act definition of recreational vessels because they are described as uninspected vessels carrying fewer than 6 passengers are classified as "passenger vessels" in MISLE; however, MISLE does not provide further specifications on whether the vessels are leased, rented or chartered to a person or whether they carry paying passengers. A second example would include charter fishing vessels. Often, these vessels are manufactured or used primarily for pleasure, or leased, rented, or chartered to a person for the pleasure of that person. Many are not inspected by the US Coast Guard. Charter fishing vessels which are not inspected are exempted from NPDES permitting requirements by the Clean Boating Act (P.L. 110-288). Other charter fishing vessels are inspected by the US Coast Guard. These inspected, non-recreational vessels are not exempted from NPDES by the Clean Boating Act, and are study vessels only if they are less than 79 feet. Since EPA is unable to determine whether certain charter fishing vessels are study vessels or Clean Boating Act vessels based on the information in MISLE, all charter fishing vessels listed in MISLE are included in the following estimates of study vessels.

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[13] According to a U.S. Coast Guard representative, the overall fraction of commercial fishing vessels that are less than 79 feet in length is estimated to be approximately 95 percent (Personal communication with Jack Kemerer, Fishing Vessel Safety Program, May 26, 2009).

[14] Personal communication with Jack Kemerer, Fishing Vessel Safety Program, May 26, 2009.

1.4.2.1. Study Vessel Type

Once commercial, non-fishing vessels longer than 79 feet are removed from the analysis, the relative makeup of the study vessels changes. EPA estimates there are between 118,000 and 140,000 vessels in the United States subject to the permitting moratorium established by P.L. 110-299.[15] Figure 1.2. presents the estimated distribution of vessels within the study vessel population by vessel service (type). Approximately one-half of these vessels are commercial fishing vessels involved in such activities as fish catching (e.g., longliner, shrimper, and trawler), fish processing, fishing tenders, and charter fishing. The other one-half are distributed among a variety of vessel classes, including passenger vessels (e.g., water taxis, tour boats, harbor cruise ships, dive boats), utility vessels (e.g., tug/tow boats, research vessels, offshore supply boats), and freight barges.

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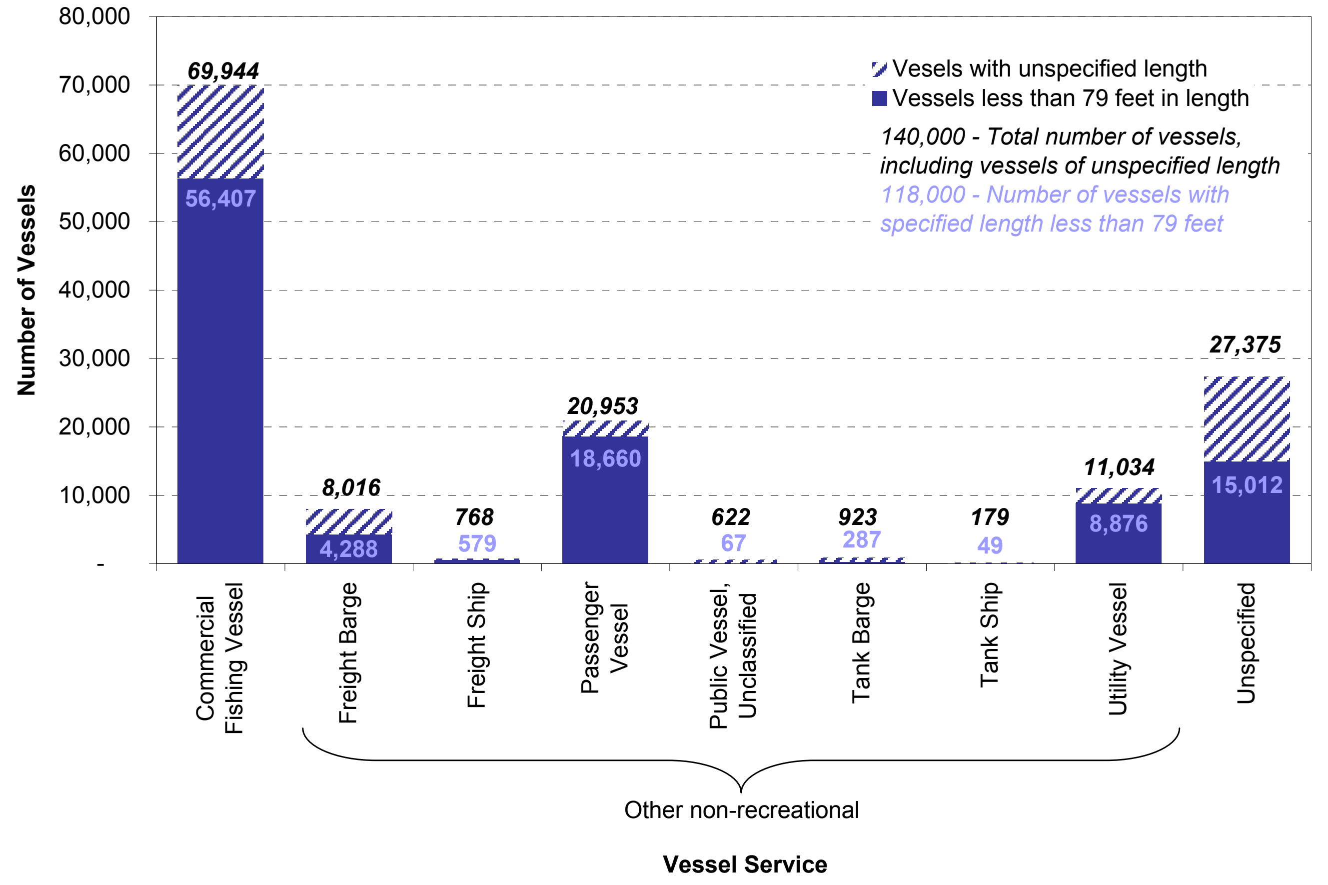
[15] The range accounts for the exclusion and inclusion, respectively, of other non-recreational vessels for which MISLE does not record the length or for which the recorded length is zero.



Note: The figure is based on operational, U.S.-flagged commercial fishing vessels (regardless of length) and other nonrecreational vessels less than 79 feet in length.

Commercial fishing vessels also include *fish processing vessels* and *fishing vessels*. Passenger vessels include *passenger (inspected*), *passenger (uninspected), passenger barge (inspected), passenger barge (uninspected),* and *passenger ships*. Public vessel, unclassified includes military and other public service vessels. EPA notes that military vessels are specifically excluded in P.L. 110-299. Utility vessels include *towing vessels (i.e., tugs), school ships, research vessels/ships, mobile offshore drilling units, offshore vessels, offshore supply vessels, oil recovery vessels,* and *industrial vessels*. EPA notes that not all of all the vessels represented in this table are subject to the moratorium at all times (e.g., small mobile offshore drilling units when engaged in industrial activity are required to have permits). Freight barges include *general barges*, *dry cargo barges*, *container barges*, *flat deck barges*, and *unspecified* vessel types that operate in freight barge service. Tank barges include *bulk liquid (cargo) barges, bulk liquefied gas barges,* and *unspecified* vessel types that operate in tank barge service. Some vessel service categories did not fall into one of the listed categories. Therefore, based on the other classification fields (class, type, subtype), EPA determined an appropriate service category.
Source: U. S. Coast Guard, MISLE database, 2009

Figure 1.2. Number of Study Vessels Recorded in MISLE, by Vessel Service (Type)

Commercial Fishing Vessels

As shown in Figure 1.2., approximately 70,000 commercial fishing vessels represent the largest category of study vessels. Based on this information, EPA sampled more commercial fishing vessels than other nonrecreational vessels less than 79 feet in length (see discussion in Section 2.2.1). According to the vessel service categories used by the U.S. Coast Guard in MISLE, “commercial fishing vessels” are vessels involved in such activities as fish catching (e.g., longliner, shrimper, trawler), fish processing, and charter fishing.[16]

The U.S. Coast Guard generally describes commercial fishing vessels as including fishing vessels, fish tender vessels, and fish processing vessels as follows:

- Fish processing vessel[17] means a vessel that commercially prepares fish or fish products other than by gutting, decapitating, gilling, skinning, shucking, icing, freezing, or brine chilling.
- Fish tender vessel means a vessel that commercially supplies, stores, refrigerates, or transports fish, fish products, or materials directly related to fishing or the preparation of fish to and from a fishing, fish processing, or fish tender vessel or a fish processing facility.
- Fishing vessel means a vessel that commercially engages in the catching, taking, or harvesting of fish or an activity that can reasonably be expected to result in the catching, taking, or harvesting of fish.

While there is some overlap in service use for commercial fishing vessels and other vessel categories, such as passenger vessels (e.g., charter fishing), EPA assumed that the categorization used in MISLE generally follows the U.S. Coast Guard definition of commercial fishing vessels.[18]

<u>Other Nonrecreational Vessels</u>

Excluding the approximately 27,000 “unspecified” vessels shown in Figure 1.2., “passenger vessels” have the second highest number of study vessels with approximately 21,000 vessels (approximately 19,000 of these vessels have a length recorded as 79 feet or less). These vessels are further divided into subtypes according to the types of activities in which they are involved (e.g., diving vessels, charter fishing vessels, ferry, harbor cruise vessels, sailing vessels). Approximately 7,833 vessels are categorized as inspected under 46 CFR (7,753 under part T (small passenger vessels under 100 gross tons), 69 vessels under part K (small passenger vessels carrying more than 150 passengers or with overnight accommodations for more than 49 passengers), and 11 vessels under part H (passenger vessels 100 or more gross tons)[19]). The remaining 13,120 vessels are recorded as uninspected passenger vessels.[20]

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[16] Several charter fishing vessels are categorized as “commercial fishing vessels” in MISLE even though they are generally not considered commercial fishing vessels by the U.S. Coast Guard Fishing Vessel Safety Program. That program considers these vessels to be passenger vessels (Source: Personal communication with Jack Kemerer, Fishing Vessel Safety Program, May 26, 2009). According to the Coast Guard definition, the key difference between vessels formally classified as commercial fishing vessels and recreational vessels or passenger vessels that may be used in fishing activities is whether the catch is sold.

[17] The moratorium provided by P.L. 110-299 applies only to discharges incidental to the normal operation of a vessel when operating in a capacity as a means of transportation. EPA requires NPDES permits for seafood processing vessel discharges when they are engaged in the processing of seafood (an industrial activity).

[18] The MISLE classification also depends on the information provided directly by the vessel owner or operator on the application for documentation or renewal (*Source:* Personal communication with Jack Kemerer, Fishing Vessel Safety Program, May 26, 2009).

[19] This last category appears to contain vessels potentially misclassified since their indicated gross tonnage is less than 100 gross tons.

[20] The definition of passenger vessels used in MISLE is broader than vessels subject to inspection under 46 CFR parts T, K, and H. Therefore, depending on how these vessels are operated (e.g., whether they carry paying passengers only or leased,

The service category labeled “public vessel, unclassified” accounts for up to 600 study vessels (e.g., lighthouse tender vessels, hospital ships, law enforcement vessels, ice breakers). The “utility vessels” category covers remaining types of vessels, including tug/tow boats, school ships, research vessels/ships, mobile offshore drilling units, offshore vessels, offshore supply vessels, oil recovery vessels, and industrial vessels. As many as 11,000 vessels are classified as utility vessels in MISLE.[21] Freight barges (4,288 to 8,016 vessels), freight ships (579 to 768 vessels), tank barges (67 to 622 vessels), and tank ships (49 to 179 vessels) account for the remaining nonrecreational study vessels.[22]

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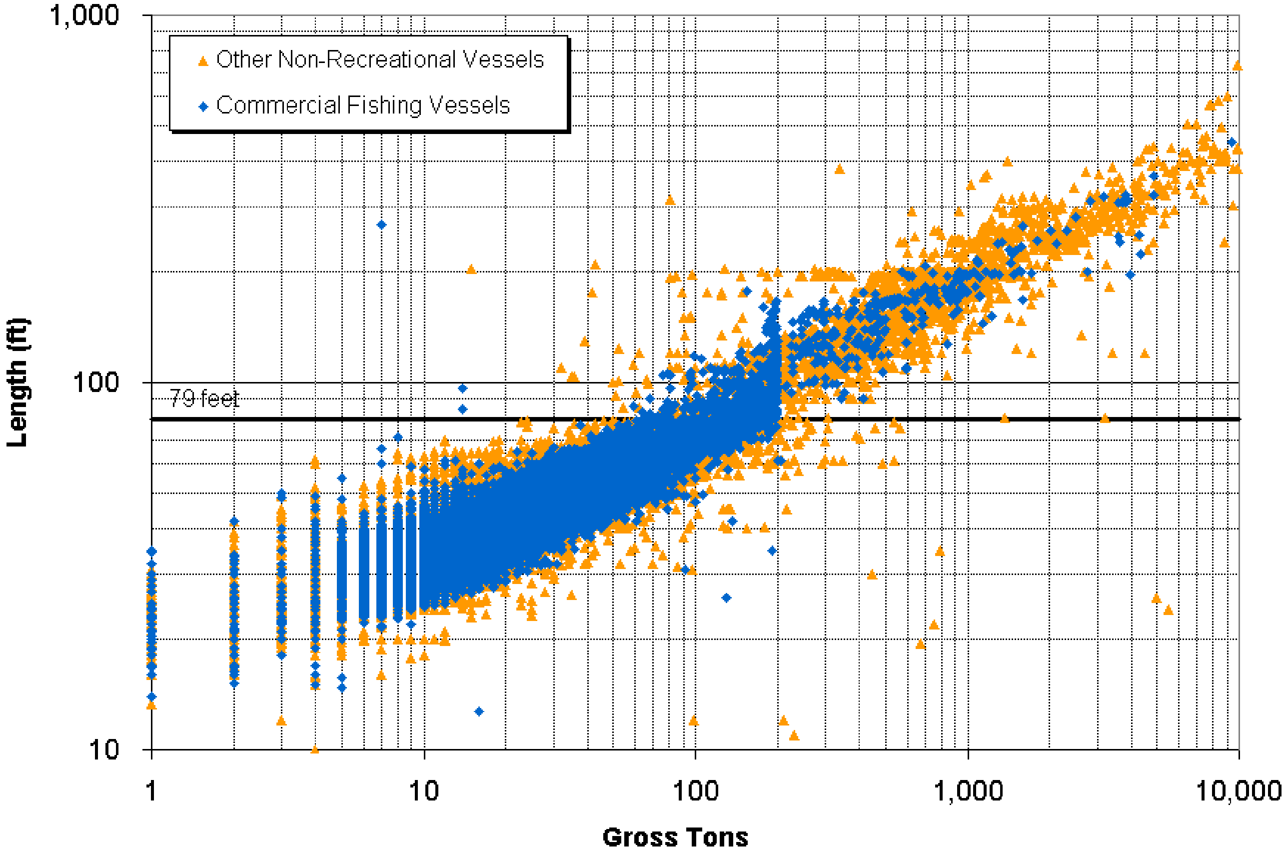
rented or are chartered to a person for the pleasure of that person), they could fall under the Clean Boating Act definition of recreational vessels and would therefore be outside the scope of the permitting moratorium.

[21] Some vessel service categories did not fall into one of the listed categories. EPA determined an appropriate service category based on information provided in other vessel classification fields (class, type, subtype).

[22] For each range, the minimum value represents the number of vessels for which the length is non null or zero and is less than 79 feet while the maximum value represents the total number of vessels when including vessels for which the length is unspecified or zero.

1.4.2.2. Vessel Size

Vessels can be characterized by size according to two metrics: length and gross tons. The two metrics are related to each other (gross tonnage is a function of the ship's enclosed spaces as measured to the outside of the hull framing), and Figure 1.3 presents a scatter plot of gross tons and lengths for commercial fishing vessels and other nonrecreational vessels obtained from MISLE. In general, most nonrecreational vessels in MISLE have a length ranging between 26 and 50 feet, which translates into a tonnage generally below 50 gross tons. The 79-foot length threshold for other nonrecreational vessels (the criterion for applicability of P.L. 110-299 moratorium) corresponds roughly to a tonnage of 150 gross tons. In Chapter 6 of this report, EPA uses this information in determining whether certain vessels may be subject to regulation under federal law or a binding international obligation of the United States.

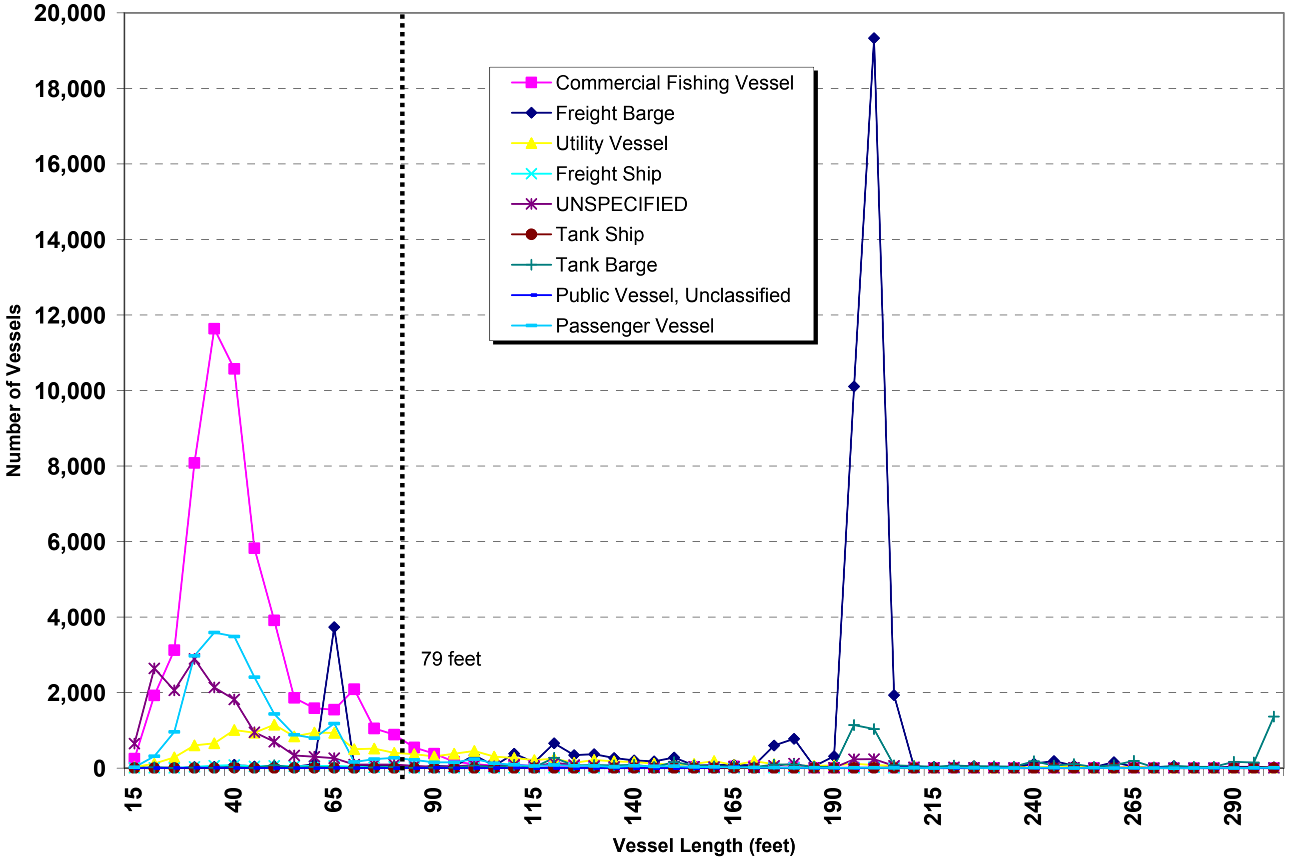


Note: This chart is based on all operational, U.S.-flagged commercial fishing vessels and other nonrecreational vessels, regardless of length.

Source: U. S. Coast Guard, MISLE database, 2009

Figure 1.3. Relationship Between Vessel Gross Tons and Length

Approximately half of vessels documented in MISLE fall within the 26- to 50-foot-length category, they have an average vessel length of 41 feet. Figure 1.4 and Figure 1.5 illustrate the distribution of vessel length for commercial fishing vessels and other nonrecreational vessels in terms of the vessel count (Figure 1.4) and cumulative distribution (Figure 1.5). In analyzing the cumulative distribution of vessels by length (Figure 1.5), tank ships are the only vessel service category with a large percentage of vessels longer than 300 feet.[23] Several other vessel service categories have a significant fraction of vessels above the 79 feet threshold. Steps in the cumulative distribution (Figure 1.5) indicate common lengths for certain categories of vessels: freight barges are generally around 200 feet in length, while tank barges tend to be 200 feet or 300 feet in length. For almost all other vessel service categories (commercial fishing vessels, passenger vessels, utility vessels and unspecified vessels), vessels less than 79 feet represent the majority of vessels within the overall population.



Note: This figure is based on operational, U.S.-flagged commercial fishing vessels and all other nonrecreational vessels (no size exclusion).

Source: U.S. Coast Guard, MISLE database, 2009

Figure 1.4. Distribution of MISLE Vessels by Length and Vessel Service (Type)

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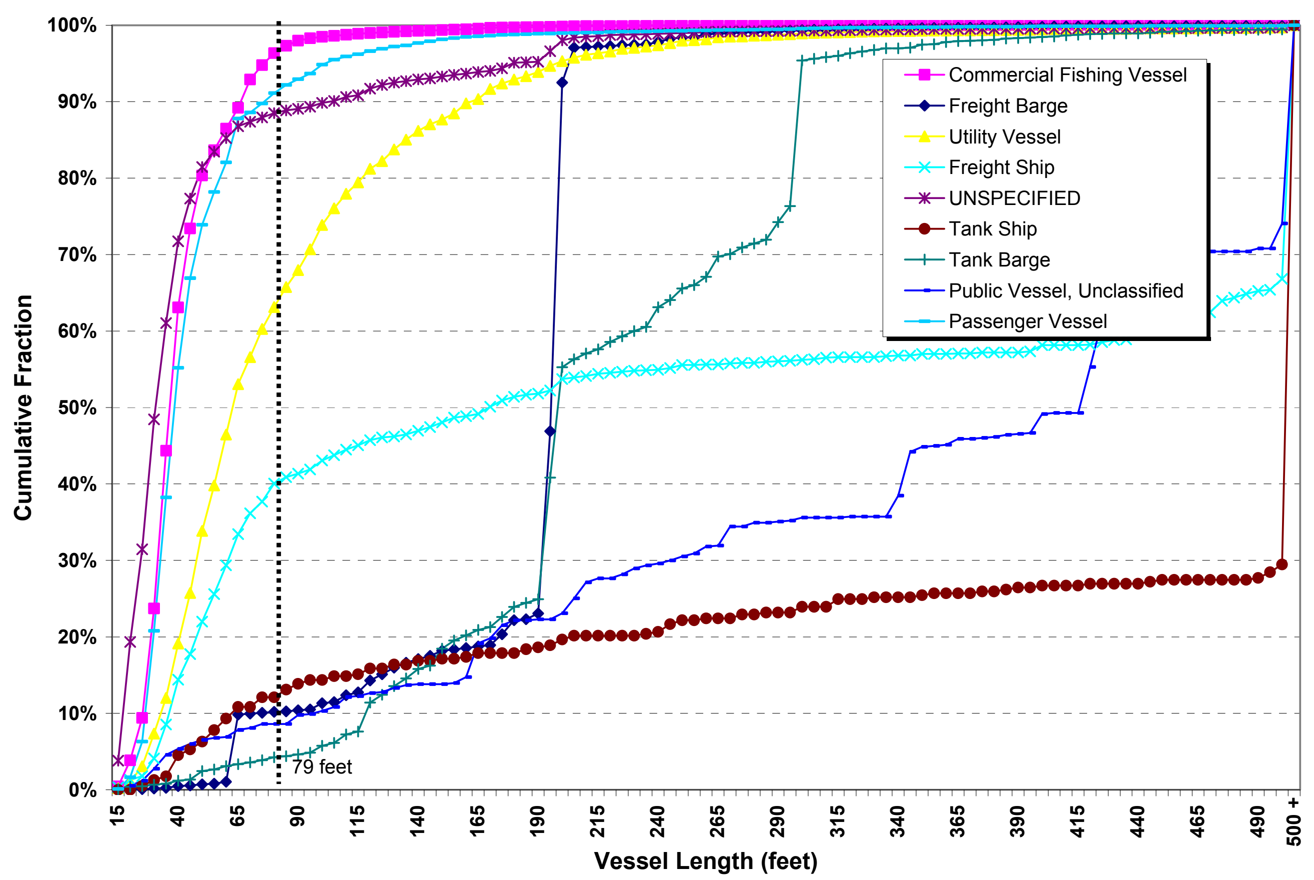
[23] Although a large *percentage* of tank ships are listed as greater than 300 feet long, this accounts for a very small *number* of vessels when compared to the overall universe of vessels in the selected service categories; approximately 300 of the 391 tank ships that list a vessel length are longer than 300 feet.



Note: This figure is based on operational, U.S.-flagged commercial fishing vessels and all other nonrecreational vessels (no size exclusion).

Source: U. S. Coast Guard, MISLE database, 2009

Figure 1.5. Cumulative Distribution of MISLE Vessels by Length and Vessel Service (Type)

As shown in the two previous figures, there is significant variability in vessel length across categories of nonrecreational vessels. Most freight barges reported in MISLE are about 200 feet in length and relatively few (10 percent) are under 79 feet in length.[24] Hence, most freight barges are not subject to the moratorium in P.L. 110-299 and are currently eligible for coverage under the VGP. In contrast, the majority of utility vessels (e.g., towing vessels), passenger vessels, and commercial fishing vessels overall are less than 79 feet in length. Figure 1.6 shows the distribution of all commercial fishing vessels and only nonrecreational vessels less than 79 feet in length by length and vessel service (focusing on the study vessels). The majority of commercial fishing vessels are relatively small compared to other nonrecreational vessels such as barges or utility vessels, with 70 percent of commercial fishing vessels for which the length is specified in MISLE in the 26- to 50-foot range. The length of other nonrecreational vessels varies among the subcategories, with as many as 66 percent of

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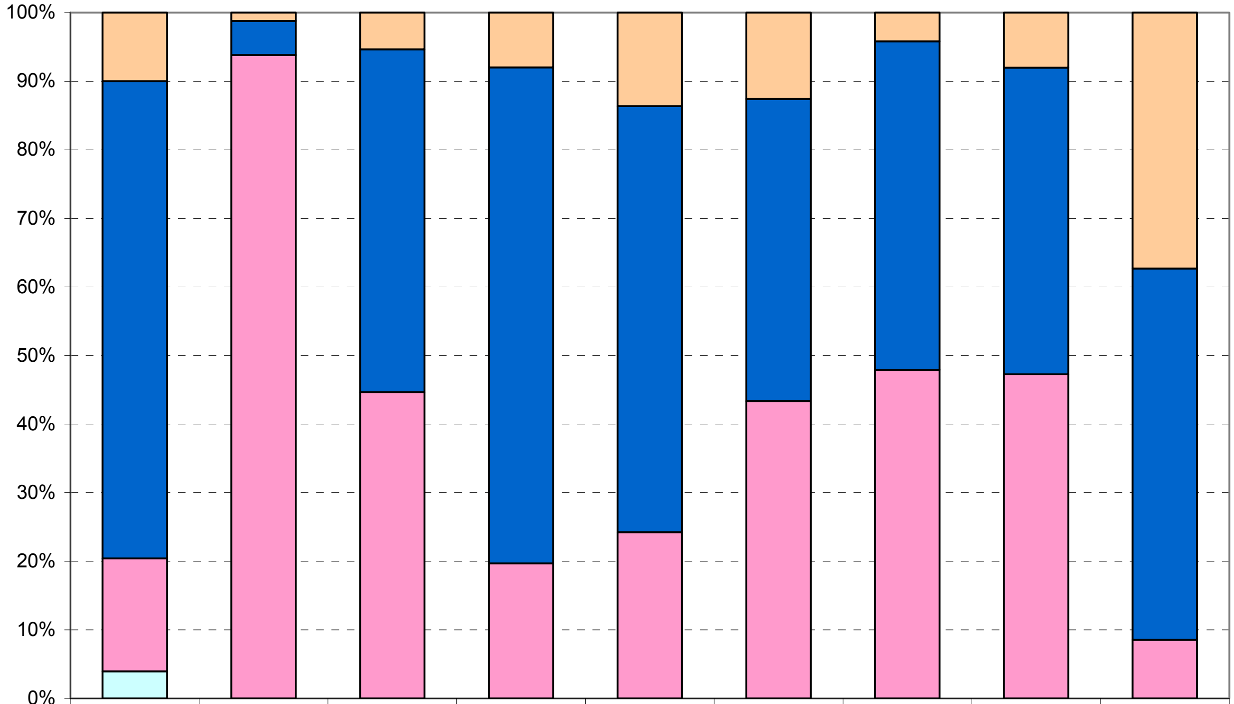
[24] Freight barges less than 79 feet in length include a wide range of vessels used for freight barge service, as classified in MISLE. These include, for example, barges operated by oil spill response companies or by dredging companies to transfer recovered oil or dredged material.

passenger vessels in the 26- to 50-foot range, compared to less than 1 percent of freight barges within that same range (most freight barges less than 79 feet in length fall in the 50- to 79-feet range).



	Commercial Fishing Vessel	Freight Barge	Freight Ship	Passenger Vessel	Public Vessel, Unclassified	Tank Barge	Tank Ship	Utility Vessel	Unspecified
🟧 Less than 26	5,631	52	31	1,489	9	36	2	713	5,598
🟦 26-50	39,262	214	289	13,496	41	126	23	3,966	8,129
🟪 50-79	9,283	4,021	258	3,674	16	124	23	4,196	1,284
□ 79 or more	2,231	NOT INCLUDED IN SELECTED POPULATION							

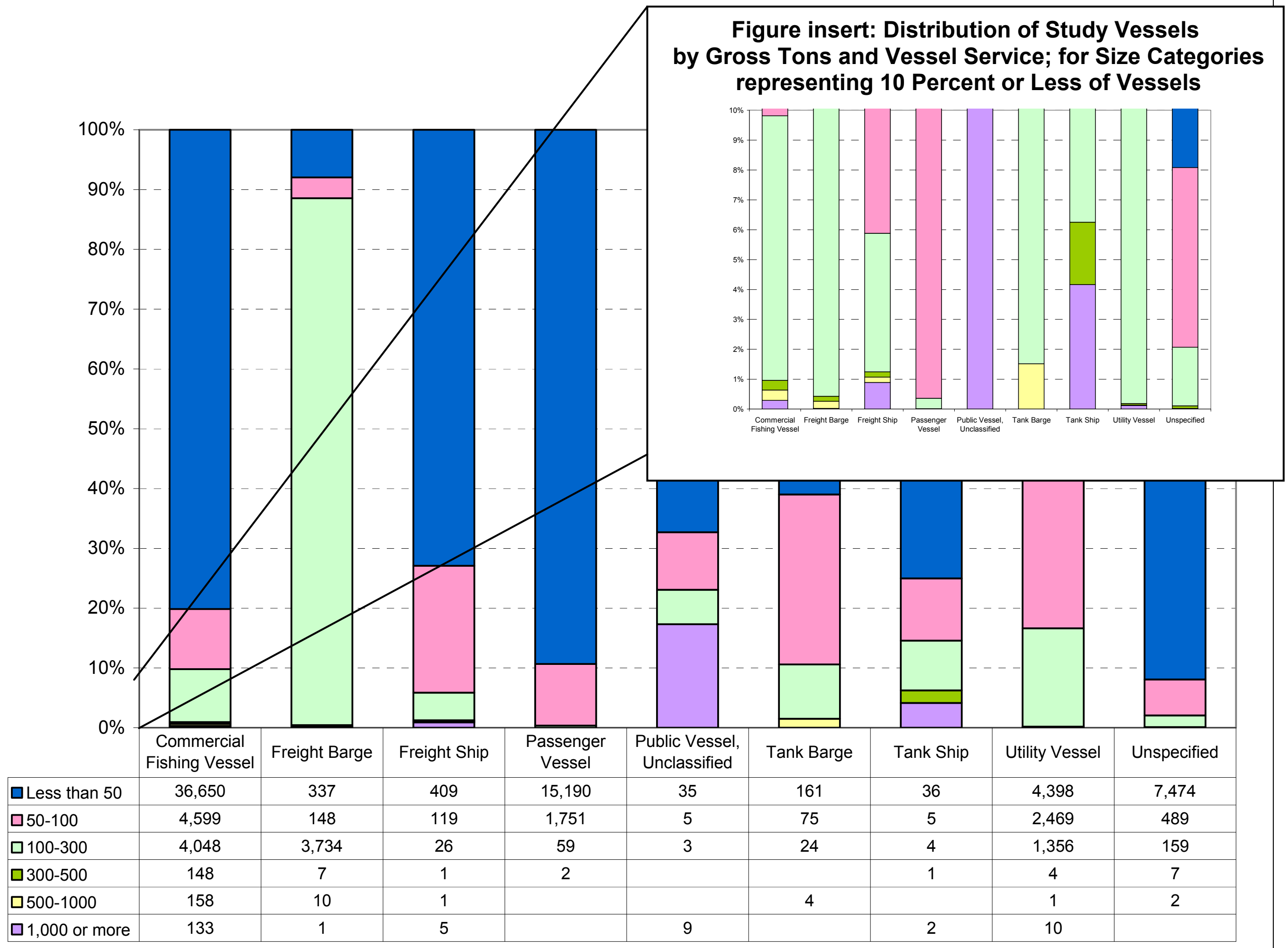
Note: This figure is based on operational, U.S.-flagged commercial fishing vessels and other nonrecreational vessels less than 79 feet in length.

The length field is not reported or provides a value of zero for approximately 36,000 vessels.

Source: U. S. Coast Guard, MISLE database, 2009

Figure 1.6. Distribution of Study Vessels by Length (in Feet) and Vessel Service (Type)

Figure 1.7 presents the distribution of study vessels by gross tons and vessel service. Overall, nearly 77 percent of study vessels are less than 50 gross tons, while the remaining vessels generally fall within the 50- to 300-gross-tons range. Very few vessels (less than 1 percent) within the selected vessel population are greater than 300 gross tons. Note that some vessel service categories appear underrepresented because the gross tons field is blank or is listed as zero in MISLE for approximately 56,000 vessels.



	Commercial Fishing Vessel	Freight Barge	Freight Ship	Passenger Vessel	Public Vessel, Unclassified	Tank Barge	Tank Ship	Utility Vessel	Unspecified
■ Less than 50	36,650	337	409	15,190	35	161	36	4,398	7,474
■ 50-100	4,599	148	119	1,751	5	75	5	2,469	489
□ 100-300	4,048	3,734	26	59	3	24	4	1,356	159
■ 300-500	148	7	1	2			1	4	7
□ 500-1000	158	10	1			4		1	2
■ 1,000 or more	133	1	5		9		2	10	

Note: This chart is based on operational, U.S.-flagged commercial fishing vessels and other nonrecreational vessels less than 79 feet in length.

The gross tons field is not reported or provides a value of zero for approximately 56,000 vessels.

Source: U. S. Coast Guard, MISLE database, 2009

Figure 1.7. Distribution of Study Vessels by Gross Tons and Vessel Service (for which gross ton data are given in MSLE)

To select specific vessel classes for sampling, EPA first developed a list of commercial vessel classes based on published information and industry experience. Next, EPA eliminated those vessel classes believed to consist of vessels greater than 79 feet in length, with the exception of commercial fishing vessels. Examples of vessel classes eliminated because of their size include cable laying ships, cruise ships, large ferries, and oil and petroleum tankers. Next, EPA eliminated vessel classes not subject to VGP permitting, including stationary seafood processing vessels and vessels that can be secured to the ocean floor for mineral or oil exploration (the CWA regulations separately require NPDES permits for industrial operations onboard vessels). After screening out these vessel classes, EPA selected a subset of priority vessel classes to study, including commercial fishing boats, tug and tow boats, water taxis, tour boats, recreational vessels used for nonrecreational purposes, and industrial support boats less than 79 feet in length. EPA selected these vessel classes because they provide a cross section of discharges and a broad range of potential pollutants.

1.4.2.3. Additional Vessel Characteristic Information

Other vessel characteristics such as vessel age and engine power (horsepower ahead) likely influence the characteristics and the volume of many vessel discharges. Intuitively, where a vessel is located and operated can determine the impacts. Additionally, where there are more vessels, there is a greater likelihood of cumulative impacts (e.g., where there are more vessels, there will be a greater impact from vessel discharges).

Appendix B presents additional vessel characteristic information, including summaries of vessel subtypes, the hailing port of domestically flagged vessels, and information on construction and propulsion of these vessels, including the vessel age and horsepower ahead. Appendix B also discusses limitations in using the MISLE data. Appendix B lists the most common subtypes of vessel within each vessel type. For example, towing vessels are the most common type of utility vessel. Appendix B also shows where concentrations of vessel activities occur and what vessels are most predominant in those assemblages. For example, the hailing port of New Orleans has the most registered vessels, including significant numbers of commercial fishing vessels and other nonrecreational vessels. Finally, Appendix B shows that most study vessels are relatively old, with the majority of them being more than 25 years old. These analyses helped EPA qualitatively and quantitatively analyze the cumulative impact of many vessels' discharges (see Chapter 4 of this report), and to put the numbers and locations of study vessels into perspective relative to other vessels, such as recreational vessels and other non-study vessels (e.g., nonrecreational, noncommercial vessels greater than 79 feet in length).

1.5. DISCHARGES FROM VESSELS

EPA developed a substantial list of discharges from vessels and pollutants of concern in each of those discharges during the development and issuance process of the VGP in 2008. Starting with this list, EPA developed a subset of discharges prevalent on fishing vessels and nonrecreational vessels less than 79 feet in length that are expected to have pollutants of concern. The subset of discharges that EPA selected included: bilgewater, deck washdown and runoff, propulsion engine effluent, generator engine effluent, firemain systems, fish hold effluent, fish hold cleaning effluent, graywater, and shaft packing gland effluent. While EPA did not sample antifouling hull-coating leachate, this discharge is discussed as well because this is a significant discharge from many vessels and has been documented to cause water quality impacts (see Section 3.2.8).

EPA recognizes that there are additional discharges[25] that also sometimes are present on study vessels. Some of these were not conducive to sampling, such as cathodic protection, underwater ship husbandry, and oil-to-sea interfaces. Some discharges are generally combined with other discharges and

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[25] EPA lists many discharges and descriptions of those discharges in the VGP and the accompanying fact sheet. Due to the timeframe and resource limitations of this study, EPA chose to focus on the nine discharges that were a) conducive to sampling and b) most likely to cause or contribute to impacts to human health, welfare, or the environment.

are not typically available for independent sampling. An example of this is refrigeration system condensate that is drained to the bilge. Other discharges are not expected to be commonly generated on commercial fishing vessels or nonrecreational vessels less than 79 feet in length. These discharges are typically associated with larger vessels, such as those covered by the VGP, and were not sampled for in this study due to resource limitations. Some examples include aqueous film-forming foam, distillation and reverse osmosis brine, exhaust gas scrubber effluent, elevator pit effluent, and boiler/economizer blowdown. A detailed discussion on the discharges EPA decided not to sample is provided in Chapter 2.

1.5.1. Bilgewater

Bilgewater is defined as the water that collects in the bottom of a vessel's hull. This includes water from rough seas, rain, minor leaks (designed or accidental) in the hull or stuffing box, condensate from various types of equipment, spills onboard the vessel, and leaks from pumps and seals. Bilgewater can be found on almost every vessel; if too much water accumulates, it could threaten the safety and stability of the vessel. For example, the U.S. Coast Guard requires that certain commercial fishing vessels and fish-processing vessels have automated bilge pumping systems as part of their basic safety features (46 CFR Part 28.255).

A number of oily and non-oily wastewater sources sometimes drain intentionally or unintentionally into the bilge. Oily wastewater sources include oil, fuel, and antifreeze leaks from engine and machinery operation and maintenance. To prevent floating oils typically found in bilgewater from being discharged overboard, vessels can either use oil-adsorbent pads in the bilge compartment or pump the bilgewater through a properly operating oil-water separation system or oil absorbent filter prior to overboard discharge.

Non-oily wastewater sources include non-oily leaks from engine and machinery operation and maintenance and various condensates. Vessels can have numerous sources of non-oily machinery wastewater, including chilled water condensate drains, fresh- and saltwater pump drains, potable water tank overflows, and leaks from propulsion shaft seals. Large vessels typically have separate systems to collect non-oily machinery wastewater in dedicated drip pans, funnels, and deck drains for subsequent direct discharge. Small vessels can also generate non-oily machinery wastewater; however, these wastewaters likely drain into the bilge.

1.5.2. Deck Washdown and Deck Runoff

Deck washdowns are typically performed to prevent slip and fall hazards; to prevent dirt, grit, or other materials from harming the integrity of the deck surface; or to clean the deck after pulling in a catch or unloading cargo. Deck washdown is typically performed using hoses and mops that move the deck washdown water and cleaning agents (if any) to the scuppers through which the water is discharged overboard. Deck cleaning often occurs while the vessel is underway but is also performed pierside, generally after loading or unloading catch or cargo.

Deck runoff is typically related to either precipitation or surface water spray that lands on the deck and flows to the scuppers where it is discharged overboard. Operators of the vessel do not have control over the volume of discharge related to precipitation events or sea sprays, but they can minimize the pollutants carried by the runoff by utilizing appropriate maintenance practices.

Deck washdown and deck runoff have the potential to contain a variety of pollutants, including oil and grease, nutrients, solids, metals, detergents, and solvents. Some or all of these pollutants could be introduced to the deck from shipboard activities, storage of material on the deck, maintenance activities, and the decking material itself.

Deck Washdown Activity of a Water Taxi (left) and a Towing and Salvage Vessel (right).

1.5.3. Engine Effluent

Engines found on commercial vessels are typically used for two purposes: propulsion and electricity generation. Engines used for vessel propulsion can be either outboard or inboard engines. Outboard engines are self-contained units designed to be mounted outside the vessel hull at the stern (rear) of the vessel. Inboard engines are enclosed within the hull of the vessel, usually connected to a propulsion screw by a drive shaft. Outboard engines are typically fueled by gasoline, while inboard motors can use either gasoline or diesel fuel. Gasoline or diesel engines can be either two stroke, which require small amounts of oil to be mixed with the fuel to create a mixture that both lubricates and provides combustion, or four stroke, which have separate lubrication systems.

All combustion engines require cooling systems to remove excess heat. Direct-cooled marine engines draw raw water (either freshwater or seawater in which the vessel is floating) into the engine and rely on the raw water to absorb the heat directly from the engine. Biocides sometimes are added to the raw water to prevent biofouling of the heat exchange system (biofouling prevention). Indirect-cooled marine engines use an enclosed cooling system that requires circulation of a freshwater-coolant solution through the engine to absorb heat. The coolant solution passes through a closed heat exchanger where the raw water absorbs the heat from the coolant solution and is then discharged.

Vessels also use keel-cooling systems for indirectly cooling marine engines. A keel cooler is essentially a heat exchanger mounted outside the vessel's hull beneath the waterline. Hot water from the marine engines is pumped through the keel cooler, which is in constant contact with the seawater. This closed-circuit cooling system eliminates the need for an inboard heat exchanger, raw water pumps, and strainers and does not result in a discharge.

Some engines also use water to cool and quiet their exhaust, referred to as boat engine wet exhaust. These engines inject spent cooling water from the engine into the exhaust stream, which results in some of the gaseous and solid components of the exhaust being entrained into the cooling water discharge.

Vessels that require significant lighting or have electrical equipment, such as appliances and/or electric motors, are likely equipped with engines used for electricity generation. Electrical generators on these vessels are typically powered by diesel engines. The size of the electrical generators depends on the electrical load requirements for the vessel, but could range from small generators used to power navigation equipment and galley appliances to large generators used to power electric motors on deck winches and cranes. Similar to vessel engines, electrical generators will require direct or indirect cooling.

Collecting a Sample of Engine Effluent at Full Speed.

Inboard Engine (left) and Outboard Engine (right)

1.5.4. Firemain Systems

Some vessels are equipped with firemain systems to supply water for firefighting and to supply water to other vessel systems. Vessels use either "wet type" or "dry type" firemain systems. The wet type firemain piping is normally filled with water. Wet type systems are particularly used on vessels where the firemain water is used frequently, typically for maintenance activities such as deck washdown. In a dry type system, the piping is normally empty. Water is only introduced to the pipes when actual firefighting takes place, or for testing or training.

Aqueous film-forming foam (AFFF) can also be used on vessels as a fire suppression agent. AFFFs are a combination of fluorochemical surfactants, hydrocarbon surfactants, and solvents (Koetter, 2008) that are injected into the water stream of a fire hose. These film-forming agents are capable of forming water solution films on the surface of flammable liquids, separating the fuel from the air (oxygen). Systems that use AFFFs do not appear to be common on smaller vessels.

Firemain System on a Fire Boat.

Fire Boat.

1.5.5. Fish Hold and Fish Hold Cleaning Effluent (Refrigerated Seawater Discharge or Fish Ice Slurry Discharge)

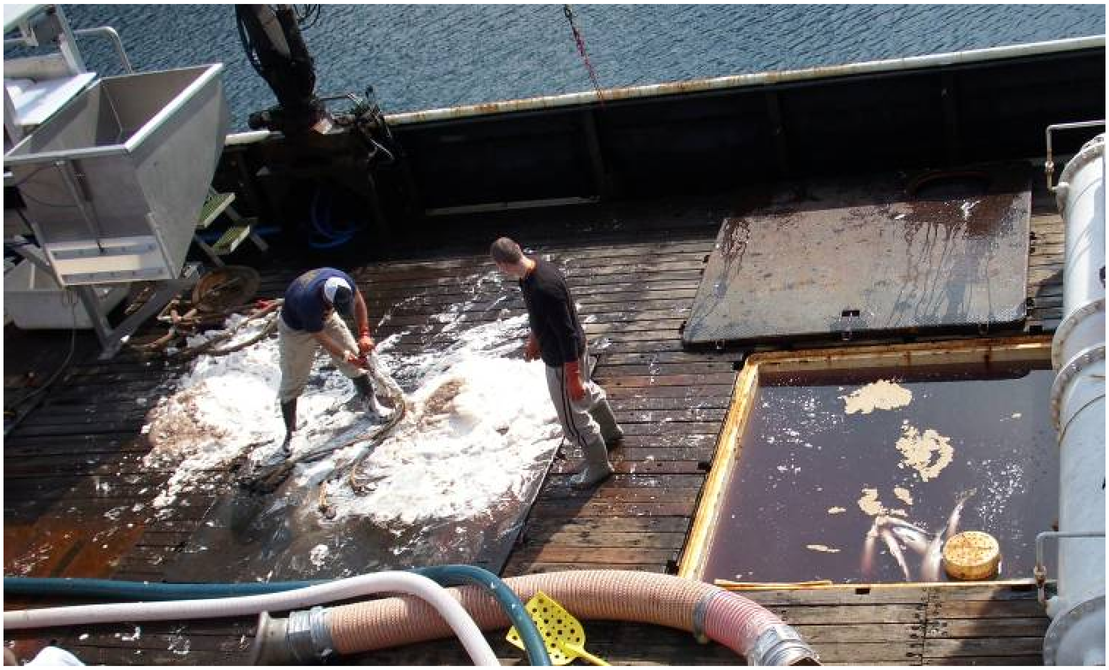
Commercial fishing vessels utilize different methods to keep seafood fresh after it is caught. Most seafood is either dead when brought onboard or is killed shortly thereafter, before being stored in a refrigerated seawater holding tank, with the exception of certain shellfish (e.g., crab, lobster), which must be kept alive. The two most common methods of cooling seawater are by mechanical refrigeration or by adding ice. Mechanical refrigeration is common on tenders, purse seiners, and trawlers, while chipped and slurry ice tanks are more common on trollers, longliners, gillnetters, and some trawlers.

For vessels with refrigerated seawater tanks, fish are typically extracted using a vacuum system that removes both the fish and refrigerated seawater simultaneously. Any excess refrigerated seawater that is not required to assist in fish extraction is pumped overboard pierside. Vessels that use chipped or slurry ice generally remove the seafood and then discharge the spent ice overboard pier side. Occasionally, vessels that store their catch in ice slurry also use vacuum filtration systems (e.g., some shrimping boats in the Gulf of Mexico). These discharges often contain pollutants generated by the catch, such as biological wastes.

Tanks used to keep lobster and crab catch alive pump surrounding water into the tank constantly to maintain the highest water quality possible. The flow rate through these systems results in a nearly continuous discharge of fish hold effluent. Because the majority of the seafood product remains alive, however, there is little biological decay or degradation in the tank. Furthermore, because these tanks have reasonably rapid flushing times and a continuous discharge, there is a little accumulation of pollutants.

Fish holds are also often cleaned or disinfected by vessel crews between catches. To rinse the tank, vessel crews use either municipal water from the pier or dock or they pump water from the surrounding ambient water. Cleaning may simply involve rinsing the tanks with this water, or crews sometimes add detergents or disinfectants. Crews also often use scrub brushes to clean the walls and floor of the fish hold to maximize the removal of organic material. Fish hold cleaning effluent is a combination of residual fish hold water and ambient or municipal water and often contains soaps or detergents.

Shoveling Fish Hold Ice Overboard From Ice Tank.



View of a Full Refrigerated Seawater Tank.

1.5.6. Graywater

Graywater is generated onboard vessels from domestic activities such as dish washing, food preparation, laundry, and bathing. Graywater is discharged through either a single discharge port from a collection system or through multiple, separate discharge ports for each graywater source (e.g., sink, shower, washing machine). Graywater discharge is intermittent and occurs only when the specific activity is performed. Most graywater processes use onboard potable water (service water).

Smaller vessels can sometimes not generate any graywater. Many of these vessels are for day use and do not provide any overnight quarters or heads (toilets). Smaller vessels that do generate graywater (e.g., those that have accommodations, sinks, or showers) generally discharge graywater directly overboard via ports typically located above the waterline. Most larger vessels used for overnight or multiday travel have numerous graywater sources, including showers, bathroom and kitchen sinks, and laundry. On these vessels, graywater discharges overboard by draining through gravity to either a discharge port above the water line or to a small collection tank located in the vessel hull, where it is immediately pumped to a discharge port above the waterline. Other vessels can collect their graywater and treat it along with sewage in Marine Sanitation Devices (MSDs).

Typical pollutants found in graywater often include metals, pathogens, total suspended solids, biochemical oxygen demand, chemical oxygen demand, oil, grease, ammonia, nitrogen, and phosphates. Graywater does not include sewage, or “blackwater”, which is exclusively human waste from toilets and urinals. Sewage is regulated under Section 312 of the Clean Water Act and 40 CFR Part 140 (see Chapter 6 of this report for further discussion).

Collecting Graywater (Shower) Effluent.

1.5.7. Shaft Packing Gland Effluent

For vessels with propeller shafts, a packing gland, or stuffing box, is used to provide a seal around a propeller shaft at the point where it exits a boat's hull underwater. This is a common method for preventing water from entering the hull while still allowing the propeller shaft to turn. In a conventional packing gland, the seal itself is provided by packing rings made of greased flax that is packed or wound tightly around the propeller shaft and compressed in place with a threaded nut and spacer. The gland can also be fitted with an opening for periodic insertion of grease between the rings, and sometimes includes a small grease reservoir.

A packing gland packed with flax rings is designed to leak a small amount of water—a few drops per minute—to provide lubrication when the shaft is turning. Water that leaks through the seal sometimes drips into a non segregated bilge or collects in a segregated area to avoid contact with oily wastewaters. In the case of a segregated area, the water that collects (referred to as shaft packing gland effluent) is automatically pumped overboard when levels reach a preset depth to prevent overflow.

1.5.8. Antifouling Hull Coatings[26]

Vessel hulls are often coated with antifouling compounds to prohibit the attachment and growth of aquatic life. Coatings are formulated for different conditions and purposes, and many contain biocides. Those that contain biocides prevent the attachment of aquatic organisms to the hull by continuously leaching substances into the surrounding water that are toxic to aquatic life. While a variety of different biocides are used, the most commonly used is copper. Hull cleaning activities often can cause additional releases of biocides, particularly if hulls are cleaned within the first 90 days following application of the antifouling coating.

A second metal-based biocide is organotin-based, typically tributyltin (TBT), which was historically applied to vessel hulls. TBT and other organotins cause deformities in aquatic life, including defects that disrupt or prevent reproduction. TBT and other organotins are also stable and persistent, resisting natural degradation in water bodies. As discussed in Chapter 6 of this report, the use of TBTs and other organotins as biocides has been phased out on all vessels by domestic law and international treaty.

1.6. POLLUTANTS POTENTIALLY FOUND IN VESSEL DISCHARGES

EPA developed groupings of pollutants of concern in the issuance process of the VGP in 2008. EPA recognizes that while some discharges from all sizes of vessels are essentially the same, many will vary due to the specific machinery and activities conducted on these vessels. EPA used slightly different groupings of the pollutants from the discharges sampled for this report to address differences from the discharges covered by the VGP. The pollutants and constituents of concern are broken down into the following groups: classical pollutants, nutrients, pathogen indicators, metals, volatile organic compounds (VOCs), semivolatile organic compounds (SVOCs), and nonylphenols. Not all pollutants are expected to be found in each discharge. For each discharge, EPA attempted to identify which pollutant groups are of concern.

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[26] Though antifoulant hull coatings are present on some study vessels, particularly those operating in areas where there is a significant potential for fouling, it was not feasible to sample discharges from these coatings for this study (see Chapter 2 for further discussion).

1.6.1. Classical Pollutants

For purposes of this report, EPA uses the term “classical pollutants” for the following 14 pollutants: temperature; conductivity; salinity; turbidity; dissolved oxygen; total suspended solids (TSS); biochemical oxygen demand (BOD); chemical oxygen demand (COD); total organic carbon (TOC); oil and grease; pH; sulfide; and total residual chlorine (TRC). These include the CWA conventional pollutants plus other common pollutants that are of general concern in a wide variety of contexts.

Temperature changes can directly affect aquatic organisms by altering their metabolism, ability to survive, and ability to reproduce effectively. Increases in temperature are frequently linked to acceleration in the biodegradation of organic material in a water body, which increases the demand for dissolved oxygen and can stress local aquatic communities. Thermal impacts from vessel discharges are generally much smaller than those from traditional point sources, and the vessel discharge with the greatest potential to alter receiving water temperature is engine cooling water.

Conductivity and salinity measurements are related to ionic strength and can indicate what specific ions are present in water or wastewater. Conductivity is a measure of the ability of water to pass an electrical current. Conductivity in water is affected by the presence of inorganic dissolved solids (or ions). Organic compounds like oil, phenol, alcohol, and sugar do not conduct electrical current very well and therefore have a low conductivity when in water. Conductivity is also affected by temperature; the warmer the water, the higher the conductivity. Salinity is a measure of the mass of dissolved salts (ions) in solution. Ions commonly found in water include calcium, magnesium, potassium, and sodium cations and bicarbonate, carbonate, chloride, nitrate, and sulfate anions. The average ocean salinity is approximately 35 parts per thousand (ppt), while freshwater salinity is generally less than 0.5 ppt. The salinity of brackish water, such as estuaries, is between 0.5 ppt and 17 ppt. Conductivity is a good measure of salinity in water and vice versa.

Both turbidity and TSS are assessments of the amount of suspended solids present in the water column. Turbidity is an indicator of water clarity, measuring how much the material suspended in water decreases the passage of light through the water. Higher turbidity increases water temperatures because suspended particles absorb more heat. Suspended materials, also measured as the mass of TSS, can clog fish gills, reducing resistance to disease in fish, lowering growth rates, and affecting egg and larval development. As the particles settle, they can smother fish eggs and benthic macroinvertebrates on the bottom substrate. Vessel discharges with relatively high turbidity and TSS concentrations include fish hold effluent, bilgewater, graywater, and deck washdown.

The oxygen content of water or wastewater is measured in its dissolved form as dissolved oxygen (DO). Low DO levels (hypoxia) can impair animal growth or reproduction, and the complete lack of oxygen (anoxia) will kill aquatic organisms. Organic material found in vessel discharges (e.g., fish waste, bilgewater, graywater) that are easily biodegraded will result in depressed DO concentrations in ambient receiving waters. The ability of the organic material in vessel discharges to biodegrade and depress oxygen levels is measured as either BOD or COD. BOD measures the amount of oxygen used by naturally occurring microorganisms to metabolize the organic material in the vessel discharge, while COD measures the oxygen needed to chemically oxidize the organic material in the vessel discharge. If there is a large quantity of organic waste in water, there will also be a lot of bacteria present working to decompose this waste. In this case, the demand for oxygen will be high (due to all the bacteria), so the BOD level will be high. COD levels can often be correlated with BOD levels, though they are generally higher because the measurement examines chemicals that are both biologically and chemically oxidized. As the waste is consumed or dispersed through the water, BOD levels will begin to decline.

Oil and grease are other known components of vessel discharges with potentially harmful impacts to humans and to aquatic life. Oil and grease are measured using hexane extractable material (HEM) and silica gel treated (SGT)-HEM. Vessels sometimes discharge oil, including lubricating oils, hydraulic oils, and vegetable or organic oils, in everyday operation. Oils produce a visible slick or sheen[27] on the water surface, which decreases natural oxygen transfer, resulting in depressed DO concentrations. Also, oils might contain heavy metals and SVOCs, which can bioaccumulate in fish, birds, marine mammals, and ultimately humans. Bilgewater, fish hold effluent (fish oils), and graywater (galley wastewater) are the vessel discharges most likely to contain oil and grease.

The term pH is used to indicate the alkalinity or acidity of a substance as ranked on a scale from 1.0 to 14.0. Substances with lower pH (i.e., less than 7) are acidic, while substances with higher pH (i.e., greater than 7) are basic. pH affects many chemical and biological processes in the water. The largest variety of aquatic animals prefers a range of 6.5 to 8.0. pH outside this range can reduce diversity because it stresses the physiological systems of most organisms. Low pH can allow toxic elements and compounds to become mobile and “available” for uptake by aquatic plants and animals. This can produce conditions that are toxic to aquatic life, particularly sensitive species. Many vessel-cleaning wastewaters can be either acidic (e.g., metal cleaners and tub, toilet, and sink cleaners) or basic (e.g., degreasers).

Sulfide is a strong reducing agent typically generated during anaerobic decomposition of organic materials. Sulfides are naturally present in groundwater as a result of leaching from sulfur-containing mineral deposits. Surface water does not usually contain high sulfide concentrations. Sulfide is a pollutant that is commonly elevated in water distribution systems as well as sewers. Sulfur-reducing bacteria, which use sulfur as an energy source, are believed to be the primary producers of large quantities of hydrogen sulfide. Ecologically, these bacteria are common in anaerobic environments (e.g., plumbing systems). For vessels, possible sources of sulfide include trace constituents in the fuel, products of incomplete combustion, or formations in anaerobic systems onboard the vessel. Sulfide generated from anaerobic decomposition is suspected in graywater, bilgewater, and fish holds. Sulfide may also be formed during fuel combustion in a vessel’s engine. Sulfide, typically found as hydrogen sulfide, poses a potential long-term hazard to aquatic life (USEPA, 1986b) at low concentrations.

Chlorine is commonly used as a disinfectant in wastewater and drinking water. Chlorine, measured as TRC, though toxic to humans at high concentrations, is of much greater concern to aquatic species, which can experience respiratory problems, hemorrhaging, and acute mortality. TRC is present in potable water supplies, and consequently, any vessel systems that use potable water could potentially

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[27] Visible slick or sheen means a “silvery” or “metallic” sheen, gloss, or increased reflectivity; visual color; iridescence, or oil slick on the surface (58 FR 12507*)*.

discharge TRC while conducting graywater activities and deck washing. Chlorine bleach can also used as a disinfectant in cleaning activities, such as cleaning the fish hold, general vessel cleaning, and laundry.

Measuring Total Residual Chlorine Immediately After Sample is Taken.

1.6.2. Nutrients

Nutrients, including nitrogen, phosphorus, and numerous micronutrients, are constituents of vessel discharges. Though traditionally associated with discharges from sewage treatment facilities and runoff from agricultural and urban stormwater sources, small quantities of nutrients from vessels are discharged from deck runoff, graywater, bilgewater, and fish hold tanks, among other sources. Although outside the scope of this report, sewage discharge (blackwater) is likely one of the primary sources of nutrients from vessels.

When excessive amounts of phosphorus and nitrogen are added to the water, algae and aquatic plants can be produced in large quantities and cause eutrophication of lakes or ponds. Eutrophication is a natural process whereby primary producers (algae and aquatic plants) exhibit extreme growth due to increased nutrient loading. Eutrophication can be greatly accelerated by human activities that increase the rate at which nutrients enter the water. Increased nutrient discharges from human sources are a major source of water quality degradation throughout the United States.

Total nitrogen is a measure of all the various forms of nitrogen (nitrate, nitrite, and ammonia) that are found in a water sample. Nitrification is the biological oxidation of nitrogen compounds in both water and soil: ammonia is oxidized to nitrite (via Nitrosomas bacteria) and further oxidized to nitrate via Nitrobacter bacteria. Nitrite and ammonia are relatively toxic forms of nitrogen, while nitrate is relatively nontoxic. Nitrogen in natural waters is usually found in the form of nitrate.

Phosphorus can be measured in either the particulate phase or the dissolved phase. Particulate matter includes living and dead plankton, precipitates of phosphorus, phosphorus adsorbed to particulates, and amorphous phosphorus. The dissolved phase includes inorganic phosphorus and organic phosphorus. Phosphorus in natural waters is usually found in the form of phosphates. Phosphates can be in inorganic form (including orthophosphates and polyphosphates) or organic form (organically bound phosphates).

1.6.3. Pathogen Indicators

Pathogens are microbes that cause disease. They include a few types of bacteria, viruses, protozoa, and other organisms. Bacteria associated with human and animal waste (e.g., total and fecal coliforms, *E. coli,* enterococci) are often monitored in water and wastewater, and the detection of these organisms can be a reliable indicator that other dangerous pathogens might be present. Pathogens are often found in discharges from vessels, particularly in vessel sewage and graywater.

1.6.4. Metals

Metals are a diverse group of pollutants, many of which are toxic to aquatic life and humans. While some metals, including copper, nickel, and zinc, are known to be essential to organism function, many others, including thallium and arsenic, are nonessential and/or are known to have only adverse impacts. Even essential metals can do serious damage to organism function in sufficiently elevated concentrations. Adverse impacts can include impaired organ function, impaired reproduction, birth defects, and at extreme concentrations, acute mortality. For example, copper can inhibit photosynthesis in plants and interfere with enzyme function in both plants and animals in concentrations as low as 4 μg/l. Additionally, through a process known as bioaccumulation, metals can accumulate in predator organisms further up the food chain, including commercially harvested fish species.

The toxic potential of a metal depends on its bioavailability in a given aquatic environment. A metal's bioavailability is determined by the characteristics of the surrounding environment (e.g., temperature, pH, salinity, TOC) and the species of the affected organism. The environmental conditions determine a metal's tendency to either adsorb to suspended organic matter and clay minerals or to precipitate out of solution and settle to the sediments. Benthic organisms can bioaccumulate metals by consuming metal-enriched sediments and suspended particles or by uptaking ambient water containing the dissolved form of the metal.

Vessel discharges can contain a variety of metal constituents, which can come from a variety of onboard sources. Graywater, bilgewater, and firemain systems have been shown to contain numerous metals, the exact constituents of which vary depending on onboard activities and the materials used in the construction of the vessel. Other metals, such as copper, are known to leach from the antifoulant coatings on vessel hulls and can cause exceedances of water quality standards.

1.6.5. Volatile and Semivolatile Organic Compounds

A variety of organic compounds have been found in vessel discharges, many of which are known to have a broad array of adverse impacts on aquatic species and human health. For this study, EPA measured VOCs and SVOCs, which can dissolve other substances and evaporate readily at room temperature and atmospheric pressure. These carbon-containing compounds include a wide range of chemicals, such as aldehydes, ketones, and hydrocarbons, and are present in oily materials such as gasoline, motor oil, engine coolants, and lubricants used on vessels. VOCs such as benzene, which is found in fuel, have acute hematological toxicity (ATSDR, 2007) and many SVOCs such as benzo(a)pyrene are persistent, bioaccumulative, and toxic compounds.

EPA measured VOCs and SVOCs in vessel discharges from engines, bilges, and firemains for this study. The most significant rates and levels of detection were phthalates (plasticizers added to plastics to make them flexible) and components of or products of incomplete combustion of oil and fuel. For example, VOCs and SVOCs detected in engine effluent included multiple polycyclic aromatic hydrocarbons (PAHs), straight-chain hydrocarbons, phenol and methyl phenols, trimethylbenzene, phthalates, and the volatile constituents of fuel, commonly referred to as “BTEX” (benzene, toluene, ethylbenzene, xylene). Many of these compounds are known to cause adverse impacts on aquatic species and human health.

1.6.6. Nonylphenols

The general term nonylphenols in this report represents two distinct subsets of the broader family of alkylphenols that are commonly used in many products such as liquid detergents and soaps. They can degrade to total nonylphenol, or NP, which is toxic to aquatic life. There are different types of alkylphenols, such as nonylphenol polyethoxylates (NPEOs) and octylphenol polyethoxylates (OPEOs). Because NPEOs and OPEOs are in the same family, they have similar chemical properties. These two distinct subsets of alkylphenols (nonylphenols and the closely related octylphenols) exist in these and other commercial products as mixtures of isomers (polyethoxylates) of different length chains. Different isomers are distinguished by length of the branched alkyl side chain. The longer chain nonylphenol polyethoxylates (of which there are 18 isomers distinguished by number, e.g., NP18EO) and octylphenol polyethoxylates (of which there are 12 isomers, e.g., OP12EO) eventually will degrade in the environment to isomers with shorter chained ethoxylate groups and ultimately, total nonylphenol (NP), which, as discussed above, is toxic to aquatic life. In general, the hydrophobicity, persistence, and toxicity of the substance all increase as the ethoxylate chain becomes shorter. The short-chained isomers may be quite persistent once they are buried in the sediment, and bottom-feeding fish can be significantly exposed to these persistent and toxic compounds. Long- and short-chain NPEOs and OPEOs are expected to be found in several vessel discharges, including graywater, deck washing wastewater, and bilgewater.

1.7. CHAPTER CONCLUSIONS

The information summarized and referenced in this chapter provides an introduction to the study vessel universe. It describes the universe of study vessels, the types of discharges generally thought to originate from those vessels, and the types of pollutants or other constituents generally found in those vessel discharges. It also references information contained in Appendix B of this report, which provides more detailed information on the study vessel universe, such as vessel locations and characteristics. EPA estimates that there are between 118,000 and 140,000 vessels in the United States subject to the NPDES permitting moratorium established by P.L. 110-299. This chapter concludes that commercial fishing vessels are the most common type of study vessels, although there are significant numbers of other commercial study vessels.

The information contained in this chapter helped inform EPA's decisions of which discharges to sample and the relative importance of each discharge (see Chapters 3, 4, and 5 for additional discussion). Based on EPA's experience gained during the VGP process, the Agency believes bilgewater, graywater, deck washdown, fish hold, engine effluent, and antifouling hull coating leachate are the primary vessel discharges that could impact surface water quality. Pollutants in these discharges might include metals, organics, nonylphenols, nutrients, oxygen depleting compounds, and pathogens. The following chapters of this report present the methodology EPA used to characterize discharges from vessels subject to the NPDES permitting moratorium, the results of that characterization, and the potential environmental impacts to ambient waters that could be caused by these discharges.

CHAPTER 2

STUDY DESIGN

This chapter documents the methodology that EPA used to conduct this study of discharges incidental to normal operation of study vessels. It describes the steps EPA took to collect information on the nature and potential impacts of vessel discharges.

2.1 DATA SOURCES

EPA collected data from a variety of sources, including existing data from other EPA data collection efforts, meetings and telephone contacts with trade association representatives, vessel visits and sampling, literature reviews, and other governmental data sources. Each of these data sources is discussed below.

2.1.1 Existing EPA Data Sources

A significant source of existing data regarding vessel discharges is EPA's administrative record supporting EPA's 2008 Vessel General Permit (VGP). The administrative record is a collection of all materials EPA considered in developing the VGP, including supporting documents, references, and comments received on the proposed VGP. As a first step in conducting this study, EPA reviewed these existing data sources to determine whether and to what extent the data and information from these sources could be used to satisfy the study objectives. This review also identified data and information gaps for EPA to target for additional data collection efforts. In general, these existing data sources provided useful information regarding the types of vessel discharges generated by vessel class, as well as the shipboard processes that contribute to their generation; however, the existing data sources contained little or no information regarding the nature, composition, and volume of discharges.

Other existing data sources evaluated for this study included supporting documents and other materials from EPA's Uniform National Discharge Standards (UNDS) (USEPA, 1999) and cruise ship discharges (USEPA, 2008c) programs. These sources, which pertain to armed forces vessels and large cruise ships, respectively, have limited applicability to commercial fishing vessels and nonrecreational vessels less than 79 feet in length; however, these data sources did provide supplemental information regarding shipboard processes that result in wastewater generation, as well as information regarding the types and amounts of pollutants that may be found in selected vessel discharges such as graywater and bilgewater. One source directly applicable to this study, however, is the UNDS document, *Final Sampling Episode Report for Small Boat Engine Wet Exhaust Discharge from Compression Ignition Engines* (USEPA, 2008b), which provides pollutant data and other relevant information (e.g., vessel power levels) for wet exhaust discharges from two compression ignition engines. EPA used this report as a primary source of information and data for this vessel discharge.

2.1.2 Industry Participation

EPA was contacted by or contacted, met with, or otherwise collaborated with trade associations and individual companies. In the course of these meetings, EPA gathered the following types of information regarding vessel discharges:

- Vessel classes within and outside the scope of this study.
- Typical vessel lengths by vessel class.
- Vessel operating seasons and locations.
- Shipboard systems and operations that contribute to vessel discharges.
- Vessel discharges and locations by vessel class.
- Volume, frequency, and nature of discharges.
- Vessel tours to inspect and observe vessel systems and operations that contribute to vessel discharges.

Note that none of the trade associations or individual companies contacted were able to provide pollutant data for vessel discharges.

The trade associations that contacted EPA or that EPA contacted included:

- American Waterways Operators (represents over 250 members that operate carriers, tug boats, towboats, and barges).
- Passenger Vessel Association (represents approximately 600 members that operate vessels such as ferries, dinner cruises, whale watching expeditions, site seeing tours, and water taxis).
- National Association of Charterboat Operators (represents over 3,300 charterboat owner and operators who provide fishing, sailing, diving, eco-tours, and other excursion vessels that carry passengers for hire, as well as recreational for-hire vessels).
- Conference of Professional Operators for Response Towing (C-PORT) (represents over 170 members of the commercial marine assistance industry, providing services such as jump starts, fuel delivery, and towing to boaters).
- Pacific Seafood Processors Association (represents 10 seafood processing companies in Alaska, Washington, and Oregon).
- At-Sea Processors Association (represents five companies that own and operate 19 U.S.-flag catcher/processor vessels in the Alaskan pollock and West Coast Pacific whiting fisheries).
- Alaskan Longline Fishermen’s Association (represents about 60 members of longline fishing vessel companies and salmon fishing vessels that operate in southeast Alaska).
- United Fishermen of Alaska (represents about 37 commercial fishing organizations and associations concentrated in Alaska representing thousands of fishing companies operating as harvesters throughout Alaska waters and the adjoining Exclusive Economic Zone).
- Southeast Alaska Fishermen's Alliance (represents commercial fishermen and the commercial fishing industry in southeast Alaska).

- Northeast Seafood Coalition (represents commercial groundfish fishermen and shore-side businesses from mid-coast Maine to Long Island, New York).
- Southern Shrimp Alliance (alliance of shrimp fishermen and processors in Alabama, Florida, Georgia, Louisiana, Mississippi, North Carolina, South Carolina, and Texas).
- Petersburg Vessel Owners Association (represents fishermen in Petersburg, Alaska).
- Alaska Trollers Association (represents southeastern Alaska trollers).
- Cordova District Fisherman United (represents Cordova, Alaska, area fishermen).

Individual companies that provided additional information (generally after being contacted by their respective trade groups) included:

- Potomac Marine, Woodbridge, Virginia.
- Vane Brothers Company, Mid-Atlantic.
- Potomac Riverboat Company, Alexandria, Virginia.
- Northeast Seafood Processors, Gloucester, Massachusetts.
- Vulcan Materials Company, Havre de Grace, Maryland.
- Sea Tow, Pensacola, Florida.
- EPA Gulf Ecology Division Laboratory, Gulf Breeze, Florida.
- Sea Tow, Slidell, Louisiana.
- AEP River Operations, Convent, Louisiana.
- Shrimp Charters, Pass Christian, Louisiana.
- Baltimore Water Taxi, Baltimore, Maryland.
- Sitka Sound Seafoods, Sitka, Alaska.
- Seafood Producers Co-op, Sitka, Alaska.
- Silver Bay Seafoods, Sitka, Alaska.
- Argosy Cruises, Seattle, Washington.
- Tidewater Marine, LLC, Gulf Coast.
- E.N. Bisso & Son, Lower Mississippi River.
- Foss Maritime Company, California, Washington, Oregon, the Columbia River, and the Snake River.
- Taku Smokeries, Juneau, Alaska.
- Upper River Services, St. Paul, Minnesota.
- JB Marine Service, St. Louis, Missouri.
- Osage Marine Services, St. Louis, Missouri.
- AEP River Operations, New Orleans, Louisiana.
- Smith Shipyard, Baltimore, Maryland.
- Norfolk Tug Company, Norfolk, Virginia.
- Dann Marine, Baltimore, Maryland.
- Cape Fear Riverboats, Wilmington, North Carolina.

2.1.3 Vessel Sampling

EPA identified a critical need for pollutant data for vessel discharges following its review of existing data sources. To satisfy this requirement, EPA designed and implemented a vessel discharge sampling program, which is described in detail in Section 2.2 of this document. Through this sampling program, EPA collected wastewater pollutant characterization data for nine vessel discharges sampled from a total of 61 vessels (one to four discharges sampled per vessel). These samples were collected in 15 different towns/cities in nine separate states, representing several of the major regions of the United States. Another critical component of EPA's sampling program was the collection of information regarding the shipboard processes, equipment, materials, and operations that contribute to the discharges, as well as the discharge rates, duration, frequency, and location.

2.1.4 Literature Review

EPA was not able to sample and characterize all study vessel classes and discharges (discussed further in Section 2.3). To fill this data gap, EPA searched the literature (i.e., scientific and engineering journals or other academic publications) for relevant information. In general, these searches provided only general information regarding vessel classes and discharges and little or no specific information, such as discharge composition and volumes. EPA did, however, identify many relevant literature sources regarding vessel antifouling leachate. EPA used these literature sources as the primary sources of information and data for this vessel discharge.

2.1.5 Other Governmental Data Sources

EPA's primary data source for vessel information regarding population and other vessel characteristics is the U.S. Coast Guard's Marine Information for Safety and Law Enforcement (MISLE) database. The MISLE provides data for nearly 1 million vessels that operate in U.S. waters and is used to support the investigation and inspection activities of the U.S. Coast Guard throughout the United States and its territories. Of the 1 million vessels identified in the database, approximately 139,814 vessels comprise the study vessel population (see Chapter 1 for additional discussion). Relevant vessel characteristics tracked in this database are vessel type, length, geographical area of operation, age, hull material type, propulsion method and type, and horsepower ahead.

EPA used a screening-level analysis of a hypothetical estuarine harbor to evaluate the potential environmental impacts from multiple vessels discharging to large U.S. water bodies, specifically estuaries and brackish harbors (see Section 4.2). EPA used the characteristics of harbor salinity, volume, and freshwater inflow from a variety of U.S. estuaries that receive vessel discharges to develop the characteristics for the hypothetical estuary. EPA compiled these characteristics from the following online sources:

- National Oceanic and Atmospheric Administration BookletChart™ List
- National Oceanographic Data Center World Ocean Database 2005 (WOD05)
- Southeast Environmental Research Center, Biscayne Bay Water Quality Monitoring Network, Miami, Florida.
- Cronick, T., and A. McGuire. *Temperature and Salinity of the Yaquina Bay Estuary and the Potential Range of Carcinus maenas*, Corvallis, Oregon.
- Massachusetts Department of Environmental Protection, Total Maximum Daily Loads of Bacteria for Little Harbor, Worchester, Massachusetts.
- U.S. Geological Survey National Hydrography Dataset Plus.
- U.S. Geological Survey National Water Information System Surface Water Annual Statistics.

2.2 EPA VESSEL DISCHARGE SAMPLING PROGRAM

EPA conducted a sampling program of discharges from commercial fishing vessels and other nonrecreational vessels less than 79 feet in length. EPA's sampling program was designed to provide information to achieve the first two objectives of the study mandated by P.L. 110-299:

- A characterization of the nature, type, and composition of discharges for representative single vessels, and for each class of vessel.
- A determination of the volumes of those discharges, including the average volumes for representative single vessels, and for each class of vessel.

Accordingly, EPA's sampling program included the sampling of large numbers and varieties of vessel classes, vessels, and discharges, and the analysis of target analytes as discussed in the following subsections. In addition, EPA supplemented sample collection and analysis with the collection of information regarding the shipboard processes, equipment, materials, and operations that contribute to the discharges, as well as the discharge rates, duration, frequency, and location.

Though the Agency was still in the final stages of drafting the 2008 VGP, EPA began designing and planning the sampling program soon after enactment of P.L. 110-299. These activities included developing the size and scope of the program considering overall program schedule and resources; identifying priority locations, vessel classes, discharges, and analyte classes for sampling; developing a detailed Generic Sampling Analysis Plan and Quality Assurance Project Plan; procuring EPA regional laboratory and contract laboratory and sampling support; and soliciting industry input and volunteers for participation in the program. Sample collection was conducted from March through July 2009. The remainder of this section provides a further description of the sampling program, including the vessels sampled and their locations, sampled discharges, target analytes, sampling methods, and quality assurance/quality control.

2.2.1 Vessels Sampled and Locations

EPA sampled discharges from a total of 61 vessels in nine vessel classes (see Table 2.1). To select vessel classes for evaluation, EPA first developed a list of commercial vessel classes based on published information and the EPA team's existing understanding of vessels. Next, EPA narrowed the sampling scope to focus largely on those vessel classes believed to consist primarily of vessels less than 79 feet in length. Some examples of vessel classes on which EPA did not focus, due to their size, include cable laying ships, cruise ships, large ferries, oil and petroleum tankers, and freight ships/barges (most vessels in these classes are typically greater than 80 feet in length). Next, EPA eliminated vessel classes outside the scope of study vessels, including stationary seafood processing vessels and vessels that can be secured to the ocean floor for mineral or oil exploration, because the industrial discharges from these vessels were outside the scope of the previous 40 CFR Part 122.3(a) exclusion (USEPA, 2008d). After eliminating these vessels, the following common vessel classes were prioritized for evaluation:

- Commercial fishing vessels and tenders
- Tugs/towing vessels
- Water taxis/small ferries
- Tour boats

Purse Seiner in Alaska (left) and a Shrimp Trawler in Louisiana (right).

A Tugboat in Maryland (left) and a Tow/Salvage Vessel in Virginia (right).

A Water Taxi in Virginia (left) and a Tour Boat in Virginia (right).

Table 2.1. Number of Vessels Sampled by Vessel Class and Discharge

Vessel Class	Number of Vessels Sampled	Number of Vessels Sampled by Discharge								
		Bilge Water	Stern Tube Packing Gland	Deck Washdown	Fish Hold	Cleaning of Fish Hold	Graywater	Propulsion Engine Effluent	Generator Engine Effluent	Firemain
Fishing:										
Gillnetter	5			1	3			1		
Lobster [1]	1				1					
Longliner	3	1			3	1				
Purse Seiner	5				5	1		1	1	
Shrimp Trawler	6	1		6	2		1			
Tender	3				3	2				
Trawler	4			2	3	4				
Troller	6			2	6	1				
Tugboat	9		9	9			5			2
Water Taxi	4	2		1			1	4	1	
Tour Boat	3	1		2				3	2	3
Tow/Salvage	6	3		6				5		
Research	2							2		
Fire Boat	1			1				1	1	1
Supply Boat	1			1						
Recreational	2			1			1	2		
Total	61	8	9	32	26	9	8	19	5	6

(1) Sampled the lobster hold tank on a trawler.

Additionally, EPA sampled recreational vessels used for nonrecreational purposes as part of this study. This sampling was done for two purposes: 1) to provide a semiquantitative comparison of the discharges from these vessels and the other study vessels, and 2) to collect additional information for EPA's related work on the Clean Boating Act (P.L. 110-288). During the execution of the sampling program, EPA also conducted opportunistic sampling of additional non-priority vessel classes (e.g., fire boats, recreational boats, a supply boat) when EPA had access to these vessels and the resources to sample them. See Section 1.3 of this document for a short description of different vessel classes or types.

As discussed in Section 2.1.2, EPA was contacted by or otherwise developed contacts with trade associations and individual companies. Many of these entities relayed the purpose of the study to their constituents or peers, some of whom contacted EPA. Consequently, EPA obtained a pool of individual companies who were willing to volunteer their vessels for the sampling program. EPA then selected specific companies and vessels within the volunteer pool for sampling to obtain a variety of vessel classes, vessel platforms, companies, and geographic distribution. In general, EPA selected the entire volunteer pool within the following geographic areas to maximize the number and variety of sampled vessels based on available resources: New England (Gloucester/New Bedford, Massachusetts); Mid-Atlantic (Woodbridge, Virginia; Alexandria Virginia; Baltimore, Maryland; Havre de Grace, Maryland; and Philadelphia, Pennsylvania); Gulf Coast (Gulf Breeze, Florida; Pensacola, Florida; Bayou la Batre, Alabama; Pass Christian, Mississippi; Slidell, Louisiana; La Fitte, Louisiana; and Convent, Louisiana); and Sitka, Alaska.

EPA's vessel selection approach for commercial fishing vessels differed from that of other vessel classes due to the nature of this industry. During the fishing season, fishing trips typically last for multiple days with no preset schedule. The captain of each vessel determines the end of each fishing trip, returns to the seafood processor or tender to offload the catch, and then typically immediately returns to the fishing grounds. Therefore, EPA identified seafood processors, rather than specific fishing companies and vessels, as the means to obtain a pool of active fishing vessels for sampling. Sampling was conducted at the docks of the seafood processors during the offloading process, and EPA sampled all vessels that arrived while the EPA sampling crew was at the docks (with the permission of the captains). In this way, sampling of individual commercial fishing vessels was random. However, EPA did contact the seafood processing facilities prior to sampling to provide sampling details (e.g., nature of the study, discharges of interest, sampling dates). It was the facilities' discretion whether or not to share this information with the vessel fleets that use their offloading facilities.

Due to the assistance of trade groups and others, vessel owner/operators were generally very cooperative with EPA sampling teams. For example, the EPA vessel team found that most of the fishermen with whom they spoke in Sitka, Alaska, were aware of the study and that EPA would be sampling in the area during the summer. Other vessel owner/operators took EPA underway to sample engine effluent, waited to wash their dishes or take showers until EPA was able to collect the graywater discharge, and assisted EPA scientists in answering questions about their vessel operations.

During the public comment period for this report, EPA received comments noting that the types of vessels sampled for this study were not necessarily representative of the industry as a whole, specifically for commercial fishing vessels. Based on public comments, EPA evaluated the representativeness of the sampled commercial fishing vessels in terms of size, class, and geographic distribution. The commercial fishing industry is highly diverse (spanning a wide array of ocean and nearshore conditions, differing by both region and fishery). With respect to vessel size, EPA notes that the sampled commercial fishing vessel population does not represent discharges from vessels less than 26 feet in length, which comprise an estimated 10% of the overall commercial fishing vessel population. However, though EPA did not physically sample these vessels, we visually observed that these small vessels typically store their catch in coolers (which do not have a discharge) rather than in refrigerated seawater or ice holding tanks, which is a function of their relatively short fishing voyages. For larger fishing vessels, EPA believes the sampled vessel population is reasonably representative of the overall vessel population, albeit somewhat more heavily weighted toward the largest of commercial fishing vessels (i.e., 50 feet or more).

With respect to vessel class, EPA's sampled commercial fishing vessel population includes vessels in all of the fishing vessel classes. Furthermore, the percentage of sampled vessels by class is similar to or greater than the percentage of the overall vessel population by class for all vessel classes except for Pot/Trap vessels. Pot/Trap vessels include many of the smallest commercial vessels that are not represented by EPA's sampled vessel population. EPA also notes that it sampled a much higher percentage of Seiners than the overall vessel population (15% of vessels sampled versus only 2% of the overall vessel population). Sampling in Sitka, AK occurred at the start of the salmon fishing season, resulting in a preponderance of Seiners at the docks of seafood processers.

Finally, with respect to geographic distribution, EPA sampled commercial fishing vessels in the following regions: Alaska (21 vessels); Gulf Coast (6 vessels); and New England (6 vessels). According to the National Marine Fisheries Service, in 2008 these three areas combined represented approximately 77% of U.S. domestic commercial landings in 2008. Among the remaining geographic regions that EPA was unable to sample, the Pacific Coast (excluding Alaska) has the greatest landings in 2008 at 13% of U.S. domestic commercial landings; commercials fishing vessels in this region are expected to be similar to those in Alaska. Finally, many of other remaining geographic regions that EPA was unable to sample, such as the Chesapeake Bay, Middle Atlantic, and the Great Lakes, are likely dominated by small fishing vessels that most likely have low volumes of or no fish hold effluent discharges.

Hence, with the exception of the smallest commercial fishing vessels, EPA believes that the sampled vessel population is a representative cross-section of vessels and is adequate to evaluate the vessel population for the purpose of this study.

2.2.2 Sampled Discharges

EPA sampled a total of nine discharge types during the sampling program (see Table 2.1). To identify priority discharges for sampling, EPA first developed a list of vessel discharges based on information collected from discussions with industry representatives (see Section 2.1.2), as well as EPA's understanding of vessel discharges. Next, EPA prioritized the list to focus on the following discharges that are commonly generated by the vessel classes of interest and that are amenable to sampling (see Chapter 1 for descriptions and locations of these discharges):

- Bilgewater
- Stern tube packing gland effluent
- Deck runoff and/or washdown
- Fish hold effluent (including both refrigerated seawater effluent and ice slurry)
- Effluent from the cleaning of fish holds
- Graywater
- Propulsion engine effluent
- Generator engine effluent
- Firemain discharges

Vessels routinely use ambient waters to conduct normal operational and cleaning activities that lead to the generation of above discharges. EPA collected samples of ambient water where the vessels were operating. EPA also collected potable water used onboard the vessels (service water) to characterize any background concentrations of pollutants that might be detected in discharges from vessel operations that use service water.

Various Discharges Through Hull Discharge Ports.

EPA did not select non-oily machinery wastewater as a priority discharge for sampling because it was not expected to be discharged separately from bilgewater. The vessels that EPA sampled during this program use the bilge system to manage non-oily machinery wastewater (if there is any), such as fresh- and saltwater pump drains, chilled water condensate drains, and potable water tank overflows, rather than installing dedicated drip pans, funnels, and deck drains to provide for segregated discharge. Note, however, that EPA has not performed a comprehensive investigation of whether or not certain non-oily machinery wastewaters may have segregated discharges on other study vessels.

EPA did not select the discharges listed below as priority discharges for sampling because they were not reasonable or practical to sample within the overall program schedule and available resources.

- Anti-fouling hull coatings.
- Cathodic protection.
- Controllable pitch propeller and thruster hydraulic fluid and other oil-to-sea interfaces.
- Underwater ship husbandry.

EPA did not select the discharges listed below as priority discharges for sampling because they were not expected to be commonly generated on commercial fishing vessels or nonrecreational vessels less than 79 feet in length.

- Aqueous film-forming foam
- Boiler/economizer blowdown
- Distillation and reverse osmosis brine
- Elevator pit effluent
- Exhaust gas scrubber wash water
- Freshwater layup
- Gas turbine wash water
- Motor gasoline and compensating discharge
- Sonar dome discharge
- Welldeck discharges
- Graywater mixed with sewage

None of these discharges were sampled during the sampling program because none of the 61 vessels that EPA selected for sampling generated these discharges. Note, however, that EPA has not performed a comprehensive investigation of whether or not these discharges are applicable to other study vessels.

2.2.3 Target Analytes

EPA's vessel discharge sampling and analysis program included 301 target analytes in the following eight analyte groups:[1]

- Microbiologicals (pathogen indicators)
- Volatile and semivolatile organic compounds
- Total and dissolved metals
- Oil and grease
- Sulfide
- Long and short chain nonylphenol and octylphenol ethoxylates (i.e., alkylphenol ethoxylates) and total nonylphenol (NP)
- Nutrients
- Other physical/chemical parameters

Appendix D lists the target analytes included in each group, along with the analytical methods. EPA selected this comprehensive list of analytes to perform a screening-level analysis of the presence or absence of almost all priority pollutants (listed at 40 CFR Part 423, Appendix A), conventional pollutants defined at Section 304(a)(4) of the Clean Water Act, and toxic pollutants from EPA's 2006 National Recommended Water Quality Criteria for freshwater and saltwater aquatic life and human health, as well as many other nonconventional pollutants. Nearly half of these analytes (147) were never detected in any vessel discharge sample (see Chapter 3).

EPA did not analyze all vessel discharges for all selected analyte groups (see Table 2.2). Analyte groups were selected for analysis based on their possible presence in discharges, as determined from existing data sources and EPA's understanding of what constituents are possibly present in the different vessel discharges. For example, long-chain nonylphenol and octylphenol ethoxylates were only analyzed for in those discharges with the potential to contain detergents (i.e., bilgewater, packing gland, deck washdown, fish hold cleaning effluent, and graywater). Furthermore, short-chain nonylphenol and octylphenol ethoxylates and NP were only analyzed for in those discharges for which the long-chain structural isomers of these two subsets of alkylphenol ethoxylates were analyzed, and that also had a holding time onboard the vessel that would allow for the possible degradation of the long-chain isomers to the short-chain isomers and NP (e.g., bilgewater held in the bilge, graywater stored in a holding tank).

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[1] Due to overall program resource constraints and other factors, not all analyte groups of possible concern were selected for this study (see Section 2.3.3).

Table 2.2. Analyte Groups by Discharge

Vessel Class and Priority Discharge	Microbiologicals	Volatile and Semi-volatile Organic Compounds	Metals (Total and Dissolved)	Oil and Grease	Sulfide	Short-Chain Alkylphenol Ethoxylates and NP	Long-Chain Alkylphenol Ethoxylates	Nutrients	BOD_5, COD, TOC (a)	Total Suspended Solids	Other Physical/Chemical Parameters (b)
Bilgewater	√ (c)	√	√	√	√	√	√	√	√	√	√
Stern tube packing gland effluent		√	√	√	√	√	√	√	√	√	√
Deck runoff and/or washdown	√ (d)		√	√			√	√	√	√	√
Fish hold effluent (including both refrigerated seawater effluent and ice slurry)	√		√	√	√			√	√	√	√
Effluent from the cleaning of fish holds	√		√	√	√		√	√	√	√	√
Graywater	√		√	√	√	√ (e)	√	√	√	√	√
Propulsion engine effluent		√	√	√	√					√	√
Generator engine effluent		√	√	√	√					√	√
Firemain systems		√	√								√

(a) Biochemical oxygen demand (BOD_5), chemical oxygen demand (COD), and total organic carbon (TOC).

(b) Other physical/chemical parameters include: conductivity; dissolved oxygen; pH; salinity; temperature; total residual chlorine; turbidity; and observations of odor, color, and floating and settleable material.

(c) Microbiologicals analyzed for only those vessels with potential for a source of these pollutants to enter the bilge (e.g., graywater piping, fish hold effluent).

(d) Microbiologicals analyzed for only commercial fishing vessels.

(e) Short-chain alkylphenol ethoxylates (i.e., nonylphenol and octylphenol ethoxylates) and NP analyzed only for graywater that has been stored in a holding tank prior to discharge.

2.2.4 Sampling Methods

EPA used a variety of sample collection methods depending on the nature of the discharge. This section describes the most commonly used sampling methods.

Discharge from a discharge port well above the water line.

Samples of these types of discharges were typically collected directly into a 5-gallon utility bucket lined with a new pail liner. For some samples, the bucket could be lowered by hand, while for other samples, the bucket was lowered by rope. The sample in the pail liner was then poured into the individual sample bottles. Whenever possible, samples for analysis of oil and grease were collected directly into the sample bottles (either held by hand or attached to a pole) to avoid the possible loss of oils to the sides of the sample transfer jar and pail liner. However, when oil and grease sample bottles were filled directly by attaching to a pole, it was typically necessary to "top off" the sample bottles with sample from the pail liner to ensure adequate sample volume for analysis.

Sample Collection Well Above the Water Line.

Discharge from a discharge port at or below the water line.

Typically, samples of these types of discharges were impossible or too unsafe to collect. In a few cases, however, EPA was able to collect samples upstream of the discharge port via a sampling port. For example, on one vessel, engine effluent could be accessed from a petcock valve on the muffler. Samples of these types of discharges were preferentially collected directly into sample bottles. In some cases, the clearance between the sampling port and the vessel hull was insufficient to accommodate the sample bottles and instead, required sample collection directly into a new pail liner; the sample in the pail liner was then poured into the individual sample bottles.

Close-up of Petcock Valve.

Deck washdown and runoff.

Deck washdown and runoff wastewater is discharged through scuppers located along the perimeter of the deck. To collect samples of this discharge, EPA generally directed the discharge to one or more (up to four) select scuppers using a variety of methods. On some vessels, deck washdown water naturally flowed by gravity to one or more scuppers at the lowest end of the deck. On other vessels, EPA used either the spray from the hose used to wash the deck or the broom used to wash the deck to direct the deck washwater to one or more selected scuppers. Finally, on some vessels, EPA arranged the deck washing hose on the vessel deck such that it directed and pooled deck washdown water to one or more selected scuppers. To collect the discharge from a selected scupper, EPA held a new pail liner against the hull of the vessel to capture the deck washdown water as it drained through the scupper. If deck washdown water was discharged through multiple scuppers, EPA filled the pail liners proportionally from each scupper (e.g., half from each of two scuppers, one-third from each of three scuppers). The sample in the pail liner was then poured into the individual sample bottles.

Deck Cleaning and Collecting Deck Washdown Sample.

Collecting Deck Washdown Sample with Close-up of Scupper (Indicated with Red Arrow).

For select fishing vessels, EPA attempted to collect samples of runoff during actual fishing operations. EPA arranged to travel with an overnight shrimping vessel on the Gulf Coast; however, due to a temporary seasonal shrimp fishery closing, EPA obtained a research permit to collect runoff from "demonstration" operations. Because these were demonstration operations and the shrimp fishermen would be unable to keep the catch, the vessel operator used a smaller net for shorter durations and did not handle the catch as he normally would. As a result, these samples only partially resemble normal operations. While in Alaska, the U.S. Coast Guard assisted EPA in attempting to sample deck washdown from fishing vessels immediately after they pulled in their catch. EPA and the Coast Guard attempted to sample three to five vessels during this operation. Due to weather conditions, however, they were only able to sample one vessel successfully.

Fish hold tanks.

Three types of fish hold tanks were sampled during the program: tanks containing refrigerated seawater, tanks containing ice slurry, and tanks containing chipped ice. Refrigerated seawater tanks were common to tenders, purse seiners, and trawlers, while slurry and chipped ice tanks were common to trollers, long-liners, gillnetters, and some trawlers. For vessels with refrigerated seawater tanks, fish are typically extracted using a vacuum system that removes both the fish and refrigerated seawater simultaneously. Both fish and refrigerated seawater are transferred to the seafood processing plant. The refrigerated seawater is generally recycled back to the fish hold tank to provide the liquid needed to operate the vacuum system. Any excess refrigerated seawater that is not required to assist in fish extraction is pumped overboard pier side. EPA collected samples of the refrigerated seawater directly into a 5-gallon utility bucket lined with a new pail liner as the water was pumped overboard. The sample in the pail liner was then poured into the individual sample bottles. Because removal of fish and refrigerated seawater can take several hours depending on the vessel size, EPA collected the sample approximately mid-way through the fish removal process. For vessels such as trollers and long-liners, which use chipped or slurry ice, EPA collected a sample of the ice or slurry once the fish had been removed from the fish hold tank. Ice/slurry was collected into a new pail liner and allowed to melt. Once melted, the sample was poured from the pail liner into the individual sample bottles.

Collecting Fish Hold Sample with a Lined Bucket.

Fish hold cleaning.

After the fish hold has been evacuated, the vessel crew cleans the fish hold as described in Section 1.3. For vessels with refrigerated seawater tanks or chipped ice tanks, the fish hold cleaning wastewater is pumped overboard. EPA collected samples of the fish hold cleaning wastewater directly into a 5-gallon utility bucket lined with a new pail liner as the cleaning water was pumped overboard.

Firemain.

EPA used valving on the firemain system to throttle the flow rate to allow firemain samples to be collected from the fire hose directly into sample containers. None of the vessels visited by EPA for this study tests its firemain system more frequently than once every two weeks, and none operates its system for secondary purposes such as deck washing. Of the six firemain systems sampled, five were wet systems (the firemain piping is normally filled with water) and one was a dry system (the firemain piping is normally filled with air). The resulting sampling data are applicable to firemain systems that are operated infrequently with intake provided by surrounding water and without additions to the discharge (e.g., no addition of foam-forming agents).

Composite samples of multiple wastewaters.

To better characterize some discharges, EPA decided to combine multiple samples of wastewaters into a single sample for analysis. The most common example is a vessel that operates its engines at multiple power levels—idle at the pier, half-speed when motoring through the no wake zone, and three-quarter speed when performing harbor tours. Another example is a vessel that generates two types of graywater—wastewater from a galley sink and wastewater from a shower. In these cases, EPA filled a new pail liner proportionally based on the number of wastewater sources (e.g., one-third from each of three power levels, half from each of sink and shower water) using one or more of the sample collection methods described above. The sample in the pail liner was then poured into the individual sample bottles. Whenever possible, EPA collected and analyzed separate samples for each discharge for oil and grease and for volatile organics, rather than using the composite sample; this minimized the possible loss of these target analytes from volatilization during sample transfer among multiple sampling equipment or due to adherence of oils to the sides of multiple sampling equipment.

Collecting Engine Effluent with a Transfer Jar.

Compositing the Sample in a Lined Bucket.

2.2.5 QA/QC

Quality assurance/quality control (QA/QC) procedures applicable to EPA's vessel sampling program are outlined in the *Quality Assurance Project Plan for Discharges from Commercial Fishing Vessels and Other Non-Recreational Vessels Less Than 79 Feet* (QAPP), which is included in the docket of the Federal Register notice announcing this study. This section describes the QC practices used to assess the precision and accuracy of the analytical data.

2.2.5.1 Analytical Quality Control

Analytical chemistry support for this program was provided by EPA's own laboratories in Regions 2, 3, and 5, as well as several subcontract laboratories. The EPA Regions were responsible for the quality of the work generated by their laboratories and for verifying that laboratory performance was acceptable by conducting QC checks of the analytical data as specified by the QAPP. Subcontract laboratories functioned within the quality system of EPA's sampling contractor, who verified the acceptability of subcontract laboratory performance by conducting QC checks of the analytical data as specified by the QAPP. Based on the data quality review and evaluation of the analytical data under this sampling program, all analytical data were deemed within or sufficiently close to the target analytical QC limits established for the study to assure the data could be used for the specified intentions. QC failures were generally attributed to matrix interference; these results are not uncommon for complex wastewater samples. Furthermore, the sample collection, handling, preparation, and analysis process utilized in this sampling program was deemed acceptable for the matrices and conditions sampled.

2.2.5.2 Field Quality Control

Field QA/QC measures and results for the bottle blanks, equipment blanks, trip blanks, field blanks, and field duplicates are discussed in this subsection.

Bottle blank.

A representative bottle and cap from the first lot of bottles purchased for collection of samples for analysis of pathogen indicators were analyzed for wide-spectrum contamination prior to their use in the sampling program. Bottles were filled with sterile deionized water, and 100–milliliter (mL) aliquots were filtered by membrane filtration. The filters were placed on water agar, nutrient agar, modified mTEC agar (for *E. coli* cultures), and mEL agar (for enterococci cultures). No pathogen indicators or other organisms (water or nutrient agar) were detected in the bottle blank, indicating that the bottles were sterile.

Equipment blanks.

Two equipment blanks were prepared and analyzed for volatile and semivolatile organic compounds (SVOC), total and dissolved metals, nutrients, soaps and detergents, and other physical/chemical parameters to assess the potential introduction of contaminants by sample collection equipment. The sample collection equipment used to collect the equipment blanks was the same as that used at the sampling points: 1) a new, factory-cleaned, Teflon® PFA pail liner from the first lot of bags purchased from the vendor, and 2) a 3-foot segment of silicone tubing connected to a 25-foot segment of Teflon tubing used in the peristaltic pump (only used on three samples throughout the entire project). The pail liner equipment blank was prepared by rinsing the bag with high performance liquid chromatography (HPLC) water and then pouring it into sample bottles. The pump tubing equipment blank was prepared by pumping HPLC water through this equipment and collecting directly into sample bottles. Of the 459 equipment blank sample results, 29 (6.3 percent) were above the method reporting limit (RL). Of the cases where the equipment blank exceeded the RL, 15 were for SVOC analytes and seven were for VOC analytes. In all 22 of these cases, however, the analytes were tentatively identified compounds (TICs), which are appropriately labeled in the analytical database as such. The remaining cases where the equipment blank exceeded the RL were as follows: biochemical oxygen demand (BOD) (two instances), chemical oxygen demand (COD) (two instances), total Kjeldahl nitrogen (TKN) (one instance), nitrate/nitrite nitrogen (one instance), and zinc (one instance). In each instance, the vast majority (greater than 90 percent) of the associated discharge sample amounts were significantly higher than the equipment blank levels.

Trip blanks.

Trip blanks were prepared and analyzed for volatile organics to evaluate possible contamination during shipment and handling of samples. These samples consisted of HPLC water poured into the sample bottles and transported unopened to the field and finally to the laboratory. One trip blank was prepared for each location-specific sampling event (e.g., Gulf Coast, New England). Evaluation of the trip blanks indicated that of the 612 VOC results for these samples, only two analytes were detected (tetramethylsilanol and tetrahydrofuran), and these were at levels below the RL. Neither of these analytes was detected in any vessel discharge samples, indicating that there was no sample contamination during transport, field handling, and storage.

Field blanks.

Field blanks were prepared and analyzed for all target analytes to monitor for the contamination of samples during sample collection and handling. These samples were prepared aboard selected vessels at the location of greatest potential for contamination (e.g., the vessel bilge space). The samples were prepared by pouring HPLC water into the sample bottles. One field blank was prepared for each location-specific sampling event (e.g., Gulf Coast, New

England). Only six target analytes (conductivity, dissolved organic carbon, nitrate/nitrite, TKN, turbidity, and total zinc) were detected in any of the 670 field blank results (0.3 percent) at levels above the RL. In each instance, the associated discharge sample amounts were significantly higher than the field blank levels.

Field duplicates.

Field duplicate samples were collected and analyzed for all target analytes to assess the precision of the entire sample collection, handling, preparation, and analysis process. Field duplicate samples were collected simultaneously from the same location as the original samples (i.e., poured from the pail liner as a split sample or sampled sequentially when collecting samples directly into sample bottles from discharge ports). The relative percent difference (RPD) between the two duplicate sample results was calculated and compared to the data quality objective. The occurrence of field duplicate samples (number of samples exceeding out of total number of duplicate samples) where one or more analytes within an analyte type (VOCs, SVOCs, dissolved metals) exceeded the target RPD was 89 of 356 pairs of field duplicate samples, or 25 percent. The higher RPDs were calculated in samples where the concentrations of the analytes were detected at levels at or near the detection level for the respective methods, mainly for VOCs, Silica Gel Treated N-Hexane (SGT-HEM), and residual chlorine. For these methods, the analytical variability increases as analyte concentrations approach their detection limits. These results are not uncommon in complex wastewater samples.

2.2.5.3 Database Development

An Access database was created in which to collect and organize all analytical results. This database contained data and associated qualifier information. Although a number of EPA and contractor staff were involved in reviewing the results, only one person had the authority to make any changes to the database during its development. This one-person control system eliminated the possibility of someone accidentally creating more than one current version of the database and minimized the risk of errors. Each time the database was updated, the current date and time stamp were used to name the new version, which was uploaded to a secure FTP server.

After each sampling event, the chains of custody (COC) and field data sheets were used to manually enter information into the “COC Information” table. This table contained identifiers given to samples in the field (FieldIDs) associated with vessel name, location, and discharge information, as well as the sample date and time. A second person performed a 100-percent check of the data entered to ensure there were no transcription errors or mistakes made during data entry.

Four analytical chemistry and subcontract laboratories —EPA Region 2 (Edison, New Jersey), EPA Region 3 (EPA Environmental Science Center, Fort Meade, Maryland), TriMatrix (Grand Rapids, Michigan), and Admiralty (Juneau, Alaska)—provided EPA’s contractor with electronic data deliverables (EDDs) in either Excel or delimited text format. EDDs were first imported into the database as new tables that remained unaltered while the fields of interest, contained therein, were appended to a table called "Vessel Results." The remaining fields were populated using queries. Ten percent of the data in the Vessel Results table from three of the four laboratories were compared to the original hard copy reports, if provided. This ensured consistency between the EDD and hard copy report, as well as validated the importing procedure. As a further quality assurance measure, a 100-percent check was done comparing these PDF reports to database entries derived from the fourth lab's EDD reports.

Data that were not received in EDD format (i.e., hard copies, PDFs, and field data sheets) were manually entered directly into the Vessel Results table. These data were provided by six additional analytical chemistry and subcontract laboratories: EPA Region 5 (Chicago, Illinois), Biomarine (Gloucester, Massachusetts), EnviroChem (Mobile, Alabama), QC Laboratories (Southampton, Pennsylvania), Northeast Environmental Laboratory (Danvers, Massachusetts), and Sitka Water Treatment Plant (Sitka, Alaska). As with the COC information, a second person did a 100-percent check of the accuracy of data entry.

In addition to checking for reporting accuracy, a check of laboratory QC procedures was performed. EPA examined laboratory QC parameters, including method type, hold times, laboratory blanks and duplicates, laboratory control samples, and surrogate recovery, where applicable, for all subcontract laboratories.

2.3 DATA CONSIDERATIONS AND STUDY LIMITATIONS

2.3.1 Voluntary Nature of the Sampling Program

All vessel sampling performed for this study was conducted on a voluntary basis (i.e., vessel owners/operators voluntarily allowed EPA to sample their vessels). As such, the selection process was not completely random from within the universe of study vessels, nor were the vessels sampled unannounced, with the possible exception of fishing vessels (see Section 2.2.1). These issues raise potential concerns regarding the representativeness of the sampling and the statistical uncertainty of the resulting data analyses. To minimize these concerns, EPA provided study volunteers with guidance for participation in the sampling program. This guidance stressed EPA's desire to sample normal discharge cycles/events and requested that volunteers not alter vessel operations from normal (typical) operation. The guidance specifically instructed that volunteers should not perform any special cleaning in preparation for sampling, add or eliminate or alter any typical discharges, or increase or decrease the volume or other characteristics of discharges, etc. Also, as EPA preferred to collect samples pierside rather than underway, EPA instructed volunteers to inform the Agency if conducting sampling pierside compromised, in any way, the characteristics of discharges (sources, volumes, composition).

As a further consideration, EPA assumed that most of the volunteers were generally ‘good actors’ who would have the best maintained vessels and be in compliance with all existing applicable regulations, which could also affect the representativeness of the data collected for the vessel class as a whole.

2.3.2 Vessels/Discharges Not Sampled

While this study included the sampling of a large number of discharges from a large number of vessels, certain vessel classes and discharges were either not sampled at all or received only limited sampling due to overall program schedule and resource constraints or other factors (see Sections 2.2.1 and 2.2.2). EPA supplemented its sampling program with information and data collected from other data sources to the extent possible; however, the Agency acknowledges remaining gaps in achieving the study objectives for certain segments of the industry. In particular, EPA has little or no information or data regarding freight barges, freight ships, tank barges, and tank ships less than 79 feet in length (estimated to represent 7 percent of study vessels). In addition, EPA has little information or data regarding the applicability of several discharges listed in Section 2.2.2 to study vessels.

EPA’s ability to fully characterize certain discharges was limited by some practical considerations. For example, on many vessels, discharges were too close to the waterline, or even under the waterline, precluding the ability to collect an uncontaminated sample. Installation of sample taps upstream of these discharge ports was either impossible (i.e., would compromise system integrity) or impractical within time constraints for the sampling events. On other vessels, collection of vessel discharges under normal operations was either impossible or unsafe. These conditions included:

- Vessel configurations blocking access to discharge ports
- Discharge volumes insufficient for sampling
- Discharges not generated during the sampling event
- Systems such as generators not operational during the sampling event
- Systems operated only during emergency
- Discharges requiring underway sampling
- Fishing vessel platforms inactive during the sampling schedule
- Fishing seasons closed or outside the sampling schedule
- Inability to sample all U.S. fisheries

As an example, EPA was able to sample bilgewater on only eight of the 61 sampled vessels (13 percent). Bilgewater sampling was infeasible for approximately three quarters of the remaining vessels for three reasons. First, automatic bilge pumps operating while the vessel was underway resulted in an empty bilge when the vessel returned to pier. Manual activation of the bilge pump on these vessels did not result in any discharge or only a small volume of discharge. Second, as a matter of policy, many vessels restrict bilgewater discharges to only while underway or when outside U.S. waters due to possible concerns of exceeding existing Clean Water Act § 311 requirements. Third, some bilgewater discharges were too close to the waterline for sampling. For the remaining one quarter of vessels, sampling was not performed because the vessels never discharge bilgewater. On these vessels, a contractor steam cleans the bilges once per month, and the resulting cleaning waste is removed from the vessels for shoreside disposal.

2.3.3 Pollutants Not Sampled

A few candidate analyte groups (pesticides, polychlorinated biphenyls, dioxins/furans, flame retardants, uranium, and asbestos) were not selected for analysis, as they are not anticipated to be present in the vessel discharges due to the lack of a readily apparent source for these pollutants.

While EPA's list of target analytes includes many persistent, bioaccumulative, and toxic chemicals (PBTs), many other PBTs were not analyzed for due to the lack of test methods or resources. In general, these unanalyzed compounds either have no known use or source onboard vessels or have no readily available means to enter the vessel discharges. Mercury was not selected for analysis because it requires specialized sampling techniques inapplicable to vessel sampling to minimize the potential for sample contamination (e.g., vessel sampling cannot be conducted away from sources of metals or sources of airborne contamination such as engines or generators).

Test methods for pharmaceuticals and personal care products (PPCPs) have recently been developed; however, EPA did not select this analyte group for analysis due to a lack of resources. These compounds are most likely to be found in sewage, which is outside the scope of this study; however, they can also be expected to be found in graywater sources, such as sink and shower wastewater, albeit at very low concentrations.

Although ballast water, and its assessment as a vector for aquatic invasive species, was specifically excluded from this study by the statutory language in P.L. 110-299 (see Appendix C), EPA recognizes that other vessel discharges, such as bilgewater; stern tube packing gland effluent; fish hold effluent; and discharges from vessel hulls, propellers, and other exposed surfaces are also potential vectors for the spread of aquatic invasive species. EPA excluded any aquatic invasive species characterization as part of this study in consideration of overall program schedule and resources.

2.3.4 Application to Other Vessels, Including Larger Vessels Not Sampled for this Study

EPA's primary objective in conducting the vessel sampling program was to characterize discharges specific to commercial fishing vessels and nonrecreational vessels less than 79 feet (i.e., study vessels). Some data are applicable to other vessels, however, including larger vessels not sampled for this study. This subsection discusses EPA's consideration of the applicability of these sample data to other vessels, as well as factors that data users should consider in determining the broader applicability of the data.

Bilgewater.

The composition and volume of bilgewater is highly dependent on the specific sources of wastewater that accumulate in bilge, as well as vessel size, hull design and construction, vessel operation, and a variety of additional factors (see Section 1.3). Any researcher, regulator, or other stakeholder who subsequently uses the data collected in this study should evaluate and compare the characteristics of the vessels sampled for this study to those of other vessels to determine the applicability of EPA's sampling data. In general, EPA believes that the design, construction, and operation of vessels not sampled for this study (e.g., cruise ships, ferries, barges, tankers) differ considerably from those of the sampled vessels, which would result in significantly different bilgewater characteristics. Hence, EPA cautions against applying the limited bilgewater results from this study to all vessels.

Stern tube packing gland effluent.

This discharge applies to vessels that collect the ambient water that leaks through the stuffing box and packing gland that surround the propeller shaft in a segregated area from the general bilge. During this study, EPA observed this segregated discharge onboard tugboats but not on any other vessel classes. On tugboats, the stuffing box is packed with greased flax rings. EPA's stern tube packing gland effluent data should be applicable to other vessel classes (if any) that use this same type of stern tube packing gland and that collect the resulting wastewater for segregated discharge.

Deck runoff and/or washdown.

Factors contributing to the volume and composition of deck runoff and/or washdown include deck equipment and operations, deck surface material, and method of washing the deck (see Section 1.3). Data users should evaluate and compare the characteristics of the vessels sampled for this study to those of other vessels to determine the applicability of EPA's sampling data. In general, EPA believes that deck operations performed on vessels outside the scope of this study differ significantly from those of the sampled vessels. For example, deck washdown generated by fishing vessels might be applicable only to this industry, particularly in cases where these vessels are washing significant organic material from fishing operations overboard. As another example, only one sampled vessel, a supply boat, is used to support the transfer and handling of non-fish cargo. On the other hand, deck washdown from sampled passenger vessels might apply to other vessels, such as larger tour boats, water taxis, and possibly cruise ships.

Fish hold effluent (including both refrigerated seawater effluent and ice slurry) and effluent from the cleaning of fish holds.

Since only commercial fishing vessels or tenders use fish holds for storing seafood products or fish, EPA believes that fish hold effluent discharges are unique to commercial fishing operations and are not applicable to other vessels.

Graywater.

The graywater sources sampled by EPA for this study are "domestic" in nature, such as sink water from washing hands and dishes, wastewater from shower stalls, and laundry water from domestic washing machines. EPA cautions the data user against applying these sampling data to non-domestic graywater operations, such as large-scale industrial dishwashing and laundry equipment. In addition, the graywater sources sampled by EPA were discharged immediately upon generation; therefore, these data do not represent graywater that has been retained in collection or storage tanks or graywater mixed with sewage. Finally, EPA's graywater data do not apply to wastewater discharges from food waste processing operations, such as food grinders or food pulping systems.

Propulsion and generator engine effluent.

For this study, EPA sampled propulsion and generator effluent from a large number and variety of engines. These include:

- Inboard and outboard.
- Two-stroke and four-stroke.
- Spark ignition and compression ignition.
- Diesel- and gasoline-fueled.
- New and existing.
- Direct cooling systems (raw water directly cools the engine) and indirect cooling systems (raw water cools antifreeze, which cools the engine).
- With and without wet engine exhausts (some raw water is injected into the exhaust to cool and quiet the exhaust).
- Variety of manufacturers, sizes, and engine horsepower.
- Operation at varying engine power levels (i.e., idle, slow troll, half throttle, three-quarters throttle, and full throttle) depending on vessel use.

EPA also observed a number of vessels, such as tug boats and larger commercial fishing vessels, that use keel-cooled propulsion engines and generators. The closed-loop cooling systems used on these engines do not discharge any wastewater.

Based on an evaluation of the engine effluent sampling results, EPA observed significant differences in the nature and composition of discharges from inboard and outboard propulsion engines and from generators. EPA may also have observed differences between diesel- and gasoline-fueled inboard propulsion engines; however, the data set was too small to be conclusive. Based on these findings, EPA believes the engine effluent data are applicable only to engines of similar types, specifically inboard propulsion versus outboard propulsion versus generators and diesel- versus gasoline-fueled engines.

Firemain systems.

EPA sampled relatively few firemain systems for this study. Firefighting equipment requirements are specified by the U.S. Coast Guard and differ by vessel type, size, construction (e.g., open decks versus enclosed spaces with potential to entrap explosives, flammable gases, or vapors), whether or not the vessel carries passengers for hire, and many other factors. Not all vessels within the scope of this study are required to carry firefighting equipment. For those vessels that require firefighting equipment, these requirements are often satisfied by carrying hand-portable fire extinguishers rather than firemain systems. For vessels outfitted with firemain systems, the systems are used during emergency and testing. None of the vessels visited by EPA for this study tests its firemain system more frequently than once every two weeks, and none operates its system for secondary purposes such as deck washing. Operating personnel from three tour boats and two tugboats that EPA visited agreed to engage their firemain systems for EPA sampling. Most operated wet rather than dry systems. The resulting sampling data apply primarily to wet-type firemain systems that are operated infrequently, with intake provided by surrounding water and without additions to the discharge (e.g., no addition of foam-forming agents).

Firemain System on a Passenger Vessel.

EPA also sampled the firefighting system onboard a fire boat; however, these sampling data may only apply to fire boats or other vessels equipped with high-pressure/high-volume fire pumps.

CHAPTER 3

ANALYSIS OF DISCHARGES AND POTENTIAL IMPACT TO HUMAN HEALTH AND THE ENVIRONMENT

This chapter summarizes the results of the wastewater characterization data for the nine types of vessel discharges sampled from the 61 vessels identified in Chapter 2. It includes the characterization of the nature, type, and composition of discharges for each class of vessel, as well as other relevant information collected regarding shipboard processes, equipment, materials, and operations that might contribute to the level or explain the presence of pollutants in these discharges.

This chapter begins with a description of the approach used for the analyses of contaminants in the various discharges of the vessel classes of interest in this sampling program, and the specific procedures used to reduce, present, and interpret these data. Each section in the chapter presents and discusses in detail the results found for each discharge type selected for evaluation in the vessel classes of interest and summarizes the major findings for the discharges associated with each major vessel type. The final section discusses anti-foulant hull coating, which warrants discussion based on the results of other studies conducted on this discharge type even though EPA did not sample this discharge in this study.

3.1 APPROACH TO ANALYSES

EPA's approach was designed to ensure that the analyses conducted under this study would be as comprehensive as possible and provide results that would represent the different vessels and discharges to the greatest extent possible. EPA included the discharge data collected from the vessels selected for this study (primary data) and any relevant data collected from other studies (secondary data) (e.g., engine effluent from small Armed Forces vessels covered under EPA's sampling program for the Uniform National Discharge Standards (UNDS) rulemaking). Where appropriate, EPA also assessed ambient (harbor) and potable waters at each geographic location where vessels were sampled.

EPA's analysis attempted to make full use of the primary and secondary data collected for this study, including data collected from ambient (harbor) and source (vessel service[1] or city water supply) waters. However, EPA recognizes that the analyses are based on a limited number of samples; in some cases, on a sample size of fewer than five. These results should be regarded as preliminary in nature due to statistical considerations related to small sample sizes.

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[1] Service water here means the vessel potable water supply. For study vessels, vessel service water generally originates from municipal water supply rather than produced on board.

EPA also attempted to identify where the analyses and results from this study could be reasonably extrapolated to vessels other than those vessels sampled in this study. Many of the discharges are not unique to vessels subject to the P.L. 110-299 moratorium in terms of the expected pollutants or volumes and may also be found on larger nonrecreational vessels or recreational vessels.

3.1.1 Data Reduction and Presentation

EPA compiled the data collected for the nine vessel discharges sampled from the 61 vessels (see Chapter 2, Section 2.2.5.3) into a Microsoft (MS) Access database developed specifically for this study. For each discharge type, EPA reduced the data for summary according to the following procedure.

First, data were retrieved from MS Access by discharge group, using a query developed specifically for this task. The queried data included the analytical result with the corresponding screening benchmark (defined in Section 3.1.3) and ambient and source water concentrations. For each discharge group, the queried data were exported to MS Excel, and then resaved as tab-delimited ASCII text (*.txt) files. Record counts were compared between the discharge group-filtered MS Access query and the MS Excel and ASCII files to ensure that data were not lost.

The ASCII data for each discharge group were read into an Interactive Data Language (IDL) (Research Systems Inc., 2003) program that carried out a series of calculations for each analyte, based on the following algorithm:

1. Identify and average concentrations measured for field replicate samples, including replacing below-detection concentrations with 1/2 of the reporting limit[2] when at least one replicate was detected.
2. Identify and average concentrations measured for laboratory replicate samples, including replacing below-detection concentrations with 1/2 of the reporting limit when at least one replicate was detected.
3. Identify and average concentrations measured for vessel replicate samples (e.g., multiple deck wash, graywater, engine effluent samples from a single vessel), including replacing below-detection concentrations with 1/2 of the reporting limit when at least one replicate was detected.
4. Calculate potential hazard quotients (PHQs) by dividing the vessel average concentration by the corresponding screening benchmark, if one was available (see further details provided in Section 3.1.3).

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[2] Laboratory analyses for low concentration pollutants report a detection limit (the presence or absence of a pollutant) and a reporting limit (the level at which the concentration of a pollutant can be quantified with appropriate certainty). Statistical methods often require replacement of values that are below the detection and reporting limits of an analytical method (especially for zero values). EPA has established conventions on how to conduct this replacement. In this study, certain labs were able to provide a reporting limit for only certain analytes, which is not uncommon. For consistency, EPA chose to use a convention of replacing the nondetects with a value of ½ of the reporting limit. These are referred to as replacement values below.

5. Output vessel-average results to a comma-separated value (CSV) text file.
6. Calculate nonparametric percentiles of the distribution of vessel-average analyte concentrations using the algorithm of Hyndman and Fan (2003). Note that below-detection vessel average concentrations were not replaced at this step.
7. Replace below-detection vessel average concentrations for those analytes where at least one concentration was detected with 1/2 of the reporting limit. Calculate detected proportion of vessel concentrations for each analyte.
8. Output vessel-average results to a CSV text file.
9. Calculate average discharge group analyte concentrations from the vessel average concentrations, including replacement values.
10. Output statistics for each analyte (number of samples, number and proportion detected, average, and nonparametric percentiles) to a CSV text file.
11. Read vessel-average results (including replacement) into SYSTAT Version 6.1 (SPSS, 1996) to generate box and density plots for each analyte class (see Section 3.2.1 below).
12. Read these results into MS Excel and then reassemble into a workbook with the database query exported from MS Access. Generate summary data tables from these workbooks.
13. For each discharge category, reproduce by hand the data reduction and statistical calculations identified above for two or more randomly selected analytes as a QA procedure.

All discharge-specific analytes summarized in subsequent sections of this chapter are organized into the following major groups: classical pollutants[3], metals, nonylphenols, nutrients, pathogen indicators, semivolatile organic compounds, and volatile organic compounds. For each discharge type, the analyte groups are generally presented according to the order of highest expected significance or risk in that specific discharge (e.g., the graywater section begins with pathogen indicators). The specific list of target analytes by group is provided in Appendix D. EPA did not analyze all vessel discharges for all selected analyte groups; see Table 2.2 for target analyte groups by discharge type.

3.1.2 Summary Statistics and Box Plots

This chapter includes, for each analyte group within a specific discharge type (e.g., bilgewater, deck washdown water), tables that summarize the number of samples analyzed, the number of times a specific analyte within an analyte group was detected, the average concentration (when only one sample was analyzed, the average is equal to the measurement), and additional standard summary statistics related to the measured analyte concentrations (median, min, max and selected (10th, 25th, 75th, and 90th) percentiles). These additional statistics were only calculated when a sufficient number of samples had detected values for any given

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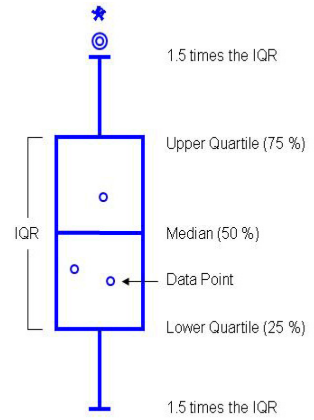
[3] The classical pollutants group of analytes combines several standard water quality parameters such as conductivity, salinity, temperature, etc. with other parameters EPA defines as conventional pollutants (biochemical oxygen demand (BOD), total suspended solids (TSS), pH, fecal coliform, and oil and grease). For convenience, this group also includes other common analytes such as total residual chlorine, or TRC. For simplicity, these conventional and other common analytes and water quality parameters have all been grouped under the term "classical pollutants."

analyte (usually five detected values or greater). In cases where some of the concentrations of an analyte were reported as nondetect (censored), the concentration of that sample was estimated as ½ of the reporting limit for purposes of calculating average concentrations[4].

In addition to the summary tables, this section includes figures that graphically present the analyte-specific concentrations that were detected (as well as any replacement values for nondetects) for each analyte group within a discharge to better identify data trends related to analytes of potential concern. These figures are shown as box and dot plots, with the names of the analytes along the x (independent)-axis and their associated vessel average concentrations along the y(dependent)-axis.

What is a Box Plot?

A box plot is a useful, simple statistical tool used to show basic characteristics of a data set. A box plot can show the approximate center of a data set and how those data are spread over a range in values – in this case, a range of concentrations. Below is an example box plot indicative of the type of graphical data display used throughout this chapter.



For box plots, the bottom and top of the box displays the 25th and 75th percentile concentrations defined as the interquartile range or IQR (i.e., the “box” contains 50 percent of the data values), respectively. The median is displayed as the horizontal line within the box. The “whiskers” show the relative distribution of data points outside of the IQR and represent 1.5 times the IQR. Superimposed over each box plot are the actual data points, shown as small open circles. Circles surrounded by large circles are outliers greater or less than 1.5 times the IQR. Circles covered by asterisks are outliers greater or less than three times the IQR.

3.1.3 Calculation of Potential Hazard Quotients

To provide a context for the level of contaminant concentrations presented, EPA used National Recommended Water Quality Criteria (NRWQC)[5] and several other benchmarks as a

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[4] See footnote 2.

[5] National Recommended Water Quality Criteria (NRWQC) include acute (short-term) and chronic (long-term) criteria (toxicity threshold values) for the protection of aquatic life, as well as Human Health criteria for protection of humans from consumption of contaminated water or contaminated water and aquatic organisms. EPA's most recent compilation of NRWQC (2006) is presented as a summary table containing recommended water quality criteria for the protection of aquatic life and human health in surface water for approximately 150 pollutants. These criteria are published pursuant to Section 304(a) of the Clean Water Act (CWA) and provide guidance for states and

preliminary screen for all discharge data with the potential to cause or contribute to the nonattainment of a water quality standard in a given receiving water body. The "screening-level" benchmarks chosen for this purpose are shown in Table 3.1 at the end of this subsection, and generally represent EPA's most conservative (protective) concentration available for the specific analyte of interest. Several "legacy" standards (for BOD, TSS and total phosphorus) are also included with the screening benchmarks. For BOD and TSS, these benchmarks are EPA's secondary treatment effluent limits for sewage treatment plants[6]. For total phosphorus, the benchmark of 0.1 mg/L is from EPA's Gold Book (USEPA, 1986b) and represents a concentration recommended to prevent nuisance algal blooms resulting from eutrophication in flowing waters. EPA did not consider it appropriate to apply ecoregional nutrient criteria for this project.

EPA's NRWQC are recommended concentrations of analytes in a water body that are intended to protect human health, aquatic organisms and the water body uses from unacceptable effects from exposures to these pollutants. The NRWQC are not directly related to analyte concentrations in a discharge for a number of reasons. First, NRWQC not only have a concentration component, but also a duration and frequency component. Second, it is not always necessary to meet all water quality criteria within the discharge pipe to protect the integrity of a water body (USEPA, 1991). Under EPA's regulations at 40 CFR 122.44(d)(1)(ii), when determining whether a discharge causes, has the reasonable potential to cause, or contributes to an in-stream excursion above a narrative or numeric criteria within a state water quality standard, the permitting authority will use procedures that account for, where appropriate, the dilution of the effluent in the receiving water. A mixing zone allows for ambient concentrations above the criteria in small areas near outfalls while dilution occurs. To ensure mixing zones do not impair the integrity of the water body, the permitting authority will determine the mixing zone such that it does not cause lethality to passing organisms and, considering likely pathways of exposure, significant human health risks.

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tribes to use in adopting water quality standards. EPA's 2006 NRWQC are available at: http://www.epa.gov/waterscience/criteria/wqctable/, hereafter referred to as EPA's 2006 NRWQC.

[6] Secondary treatment standards for sewage treatment plants were technology-based limits developed in the late 1970s and early 1980s, and are not the same as the water-quality-based criteria in the 2006 NRWQC. Thus, the PHQs for BOD and TSS calculated as described below are not directly comparable to the PHQs based on criteria designed to protect aquatic life or human health but, by design, such standards are imposed to limit ecological impacts.

Nevertheless, comparing analyte concentrations in vessel discharges to NRWQC (or other equivalent screening benchmark) provides a conservative screen of whether these discharges cause, have the reasonable potential to cause, or contribute to nonattainment of the water quality standards in a water body. EPA calculated hazard quotients (HQs) by dividing the concentration of a particular analyte[7] by its corresponding water quality criterion or other benchmark as an initial screen for the discharge-specific water sample data. If the concentration of a given analyte in vessel discharge is less than the applicable screening criterion or benchmark values (HQ<1), the discharge would likely not cause, have the reasonable potential to cause, or contribute to nonattainment of a water quality standard based on that value, particularly after considering assimilation and/or dilution by the receiving water. If the HQ value is greater than one, then there is the possibility of ecological or human health risk as the concentration of a given analyte in vessel discharge is greater than the applicable screening criterion or benchmark values (USEPA, 1997). However, because discharges in this study are measured at the "end of pipe" before being released into a harbor where they are subsequently diluted, HQ values of greater than one do not necessarily indicate that a discharge poses a significant risk or would be likely to cause or contribute to a water quality standard exceedance. Further, the presence of additional environmental factors such as dissolved organic carbon can reduce the toxicity of certain pollutants (e.g., metals and many organic pollutants) and reduce the likelihood of ecological or health risk. Because of these additional considerations, EPA uses the term potential hazard quotients (PHQs) instead to indicate this difference, as the PHQs are only intended to indicate that a screening benchmark was exceeded and the discharge thus warrants further consideration regarding the potential to cause or contribute to nonattainment of water quality standards[8].

Mitigating Conditions/Circumstances in a Water Body

Compared to the volume of a typical harbor, the effluent volume of any particular vessel discharge is small (see Chapter 4). Therefore, even when pollutant concentrations of a particular effluent are high, the total loading of that pollutant on the receiving water of the harbor can be relatively small. Furthermore, most harbors are continually flushed by freshwater and tidal activity. These dilution factors, in addition to the mitigating capacity of saltwater cations and organic matter, may reduce the toxicity of many of these pollutants.

Mobile sources such as vessels complicate the analysis because they discharge into many different water bodies, but in general, greater mixing and dilution would be expected for discharges from vessels than from stationary sources when they are in motion while discharging. EPA acknowledges that vessel discharges to areas with high vessel traffic, areas with a low

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[7] PHQs were also calculated using replacement values for nondetected concentrations, so that such results would be represented in the box and scatter plots. Note: all PHQ values in box plots that were calculated with replacement values throughout this chapter are circled.

[8] EPA does not consider a PHQ that exceeds 1 to signal that these discharges pose a potential risk to cause or contribute to the non-attainment of a water quality standard when the PHQ is based on replacement values for nondetected concentrations.

degree of flushing, or impaired water bodies could reduce mixing and dilution. With these factors in mind and assuming the data from this study are representative of the class of vessels as a whole, a PHQ marginally above a value of 1 is most likely not of significant concern. On the other hand, a PHQ value substantially above 1 (e.g., 10 or 100) may be more likely to be of concern, particularly if the discharge is of significant volume, is in an area of low flushing, is in an area where there is a high degree of vessel traffic, or is in a waterbody that is already impaired or under other stress.

EPA recognizes that one of the key factors in evaluating metal toxicity is the bioavailability of the metal to an organism. Exposure to metals at toxic levels can cause a variety of changes in biochemical, physiological, morphological, and behavioral patterns in aquatic organisms. In the aquatic environment, elevated concentrations of dissolved metals can be toxic to many species of algae, crustaceans, and fish. Some metals have a strong tendency to adsorb to suspended organic matter and clay minerals or to precipitate out of solution, thus removing the metal from the water column. The tendency of a given metal to adsorb to suspended particles is typically controlled by the pH and salinity of the water body, as well as the organic carbon content of the suspended particles. If the metal is highly sorbed to particulate matter, then it is not likely to be in a dissolved form that aquatic organisms can process (i.e., bioavailable)[9].

Accordingly, NRWQC for the protection of aquatic life for metals are typically expressed in the dissolved form. Therefore, a high concentration of a metal measured in its total form (dissolved and particulate) may not be an accurate representation of its toxic potential to aquatic organisms. In contrast, human health criteria (for the consumption of organisms) for metals are commonly expressed in the total metal form because human exposure to pollutants is assumed to be through the consumption of organisms, where the digestive process is assumed to transform all forms of metals to the dissolved phase, thus increasing the amount of biologically available metals. EPA was mindful of this distinction between aquatic life and human health criteria for metals when comparing the dissolved and total metals concentration data in the various discharges to NRWQC and when calculating PHQs using the screening benchmarks. In particular, in considering the potential for vessel discharges to pose a risk to human health, EPA also noted the likelihood of human exposure to such discharges (e.g., potential for receiving water to be used as drinking water source).

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[9] Note that the bioavailability of metals is a relative term and depends on many factors. For example, particulate metals complexed to suspended organic matter or clay minerals may be recycled into the water column and become bioavailable due to physical resuspension (dredging activities) of bed sediments or bioturbation (the stirring or mixing of sediment particles by benthic animals). Depending on conditions in the water column and microbiological activity within the surficial sediment and overlying water surface layers, these physical and biological actions might remobilize the metals in the dissolved bioavailable form for potential uptake by aquatic organisms. Likewise, certain benthic organisms called deposit feeders might consume particulate-bound metals and re-release metals via digestion and excretion or introduce metals into the food chain when consumed by predators.

EPA chose to include the major cations calcium, magnesium, potassium and sodium in the metals analysis to further characterize the vessel discharges. As common ions in surface waters, the concentrations of these ions are indicative of the sample matrix (i.e., freshwater, saltwater, brackish water) rather than pollutant loadings. Accordingly, major cation concentrations are typically elevated (up to three orders of magnitude higher) relative to other metals included in the metals analysis (e.g., copper, lead, and zinc). For example, the typical concentrations of major cations in full and partial (brackish) strength seawater and in freshwater of various total water hardness levels are listed in Tables 3.2 and 3.3 below. Major cations are not toxic except at extreme, uncommon levels.

For convenience, data tables for metals in this chapter segregate the presentation of major cation concentration data from that of the other metals to clearly distinguish between the naturally occurring cations and other metals of potential concern in vessel discharges. It is worth noting that many of the samples collected for this study consist entirely or partially of sea water; consequently, these samples can have high concentrations of components (e.g., salts) that can interfere with the analytical measurement of the chemical of interest. EPA evaluated whether measured concentrations of selenium and arsenic may have exhibited "positive interference" (i.e., the measured concentration is higher than the actual concentration in the sample – see text box for more technical information). EPA found that trace metal analysis using a conventional ICP-MS-based analytical method may have resulted in positive interference for some samples of selenium, and to a lesser extent, arsenic. However, for the majority of samples analyzed in this study, either the samples contained few interferences (i.e., samples were from freshwater) or alternate instrumentation, which had the capability of minimizing sample interferences, was used for analyte measurement. Hence, the majority of arsenic and selenium results did not have positive interference. EPA identified the few samples analyzed using the conventional ICP-MS method, which may have yielded artificially high values for the measured concentration of arsenic and selenium. Therefore, while such positive interferences were not found to influence the overall findings presented in this study, the selenium and arsenic concentrations potentially affected by positive interference are identified (noted by footnote in each instance) throughout this chapter.

Explanation of Possible Positive Interference on Select Arsenic and Selenium Measurements

Positive interference occurs when components of a sample, other than the analyte, affect the measurement of the analyte of interest by yielding an artificially high value. This occurs when components in the sample interfere with the analytical methodology. Some of the components of sea water (e.g., calcium, magnesium, potassium, sodium), are known to cause positive interference with certain trace elements, such as arsenic and selenium. The potential for interference is based on the analytical method and instrumentation used for the measurement. In these situations, alternate sample preparation or analytical instrumentation may be required to eliminate or reduce sample interferences, in order to maintain analyte sensitivity.

Table 3.1. Water Quality and Other Benchmark Values Used to Screen the Vessel Discharge Data

Analyte	Screening Benchmarks	Units	Source[1]
1,1,2,2-Tetrachloroethane	0.17	μg/L	2006 NRWQC HH W+O
1,1,2-Trichloroethane	0.59	μg/L	2006 NRWQC HH W+O
1,1-Dichloroethene	330	μg/L	2006 NRWQC HH W+O
1,2,4,5-Tetrachlorobenzene	0.97	μg/L	2006 NRWQC HH W+O
1,2,4-Trichlorobenzene	35	μg/L	2006 NRWQC HH W+O
1,2-Dichlorobenzene	420	μg/L	2006 NRWQC HH W+O
1,2-Dichloroethane	0.38	μg/L	2006 NRWQC HH W+O
1,2-Dichloropropane	0.5	μg/L	2006 NRWQC HH W+O
1,2-Diphenyl hydrazine	0.036	μg/L	2006 NRWQC HH W+O
1,3-Dichlorobenzene	320	μg/L	2006 NRWQC HH W+O
1,3-Dichloropropane	0.34	μg/L	2006 NRWQC HH W+O
1,4-Dichlorobenzene	63	μg/L	2006 NRWQC HH W+O
2,3,7,8-TCDD (Dioxin)	5.0E-09	μg/L	2006 NRWQC HH W+O
2,4,5-Trichlorophenol	1800	μg/L	2006 NRWQC HH W+O
2,4,6-Trichlorophenol	1.4	μg/L	2006 NRWQC HH W+O
2,4-Dichlorophenol	77	μg/L	2006 NRWQC HH W+O
2,4-Dimethylphenol	380	μg/L	2006 NRWQC HH W+O
2,4-Dinitrophenol	69	μg/L	2006 NRWQC HH W+O
2,4-Dinitrotoluene	0.11	μg/L	2006 NRWQC HH W+O
2-Chloronaphthalene	1000	μg/L	2006 NRWQC HH W+O
2-Chlorophenol	81	μg/L	2006 NRWQC HH W+O
2-Methyl-4,6-Dinitrophenol	13	μg/L	2006 NRWQC HH W+O
3,3'-Dichlorobenzidine	0.021	μg/L	2006 NRWQC HH W+O
4,4'-DDD	0.00031	μg/L	2006 NRWQC HH Org Only
4,4'-DDE	0.00022	μg/L	2006 NRWQC HH Org Only
4,4'-DDT	0.0010	μg/L	2006 NRWQC CCC
4,6-Dinitro-2-methylphenol	13	μg/L	2006 NRWQC HH W+O
Asbestos	7000000	fibers/L	2006 NRWQC HH W+O
Acenaphthene	670	μg/L	2006 NRWQC HH W+O
Acrolein	6.0	μg/L	2006 NRWQC HH W+O
Acrylonitrile	0.051	μg/L	2006 NRWQC HH W+O
Aldrin	1.3	μg/L	2006 NRWQC SW CMC
Alkalinity	20000	μg/L	2006 NRWQC FW CCC
alpha-BHC	0.0026	μg/L	2006 NRWQC HH W+O
alpha-Endosulfan	0.0087	μg/L	2006 NRWQC SW CCC
Aluminum, Total	87	μg/L	2006 NRWQC FW CCC
Ammonia As Nitrogen (NH3-N)	1.2	mg/L	2006 NRWQC SW CCC
Anthracene	8300	μg/L	2006 NRWQC HH W+O
Antimony, Total	5.6	μg/L	2006 NRWQC HH W+O
Arsenic, Total	0.018	μg/L	2006 NRWQC HH W+O
Arsenic, Dissolved	36	μg/L	2006 NRWQC SW CCC
Barium, Total	1000	μg/L	2006 NRWQC HH W+O
Benzene	2.2	μg/L	2006 NRWQC HH W+O
Benzidine	0.000086	μg/L	2006 NRWQC HH W+O

Analyte	Screening Benchmarks	Units	Source[1]
Benzo(a)Anthracene	0.0038	µg/L	2006 NRWQC HH W+O
Benzo(a)Fluoranthene	0.0038	µg/L	2006 NRWQC HH W+O
Benzo(a)pyrene	0.0038	µg/L	2006 NRWQC HH W+O
Benzo(b)fluoranthene	0.0038	µg/L	2006 NRWQC HH W+O
Benzo(k)Fluoranthene	0.0038	µg/L	2006 NRWQC HH W+O
beta-BHC	0.0091	µg/L	2006 NRWQC HH W+O
beta-Endosulfan	0.0087	µg/L	2006 NRWQC SW CCC
Biochemical Oxygen Demand (BOD)	30	mg/L	1984 Secondary Treatment Effluent Limits
Bis (2-Chloroethyl) ether	0.030	µg/L	2006 NRWQC HH W+O
Bis (2-chloroisopropyl)ether	1400	µg/L	2006 NRWQC HH W+O
Bis(2-Chloroethyl)ether	0.030	µg/L	2006 NRWQC HH W+O
Bis(2-Ethylhexyl) phthalate	1.2	µg/L	2006 NRWQC HH W+O
Bromodichloromethane	0.55	µg/L	2006 NRWQC HH W+O
Bromoform	4.3	µg/L	2006 NRWQC HH W+O
Bromomethane	47	µg/L	2006 NRWQC HH W+O
Butyl benzyl Phthalate	1500	µg/L	2006 NRWQC HH W+O
Cadmium, Dissolved	0.25	µg/L	2006 NRWQC FW CCC
Carbon tetrachloride	0.23	µg/L	2006 NRWQC HH W+O
Chlordane	0.0040	µg/L	2006 NRWQC SW CCC
Chloride	230000	µg/L	2006 NRWQC FW CCC
Chlorobenzene	130	µg/L	2006 NRWQC HH W+O
Dibromochloromethane	0.40	µg/L	2006 NRWQC HH W+O
Chloroform	5.7	µg/L	2006 NRWQC HH W+O
Chlorophenoxy Herbicide (2,4,5,-TP)	10	µg/L	2006 NRWQC HH W+O
Chlorophenoxy Herbicide (2,4-D)	100	µg/L	2006 NRWQC HH W+O
Chloropyrifos	0.0056	µg/L	2006 NRWQC SW CCC
Chromium, Dissolved	11	µg/L	2006 NRWQC FW CCC
Chrysene	0.0038	µg/L	2006 NRWQC HH W+O
Copper, Dissolved	3.1	µg/L	2006 NRWQC SW CCC
Copper, Total	1300	µg/L	2006 NRWQC HH W+O
Cyanide	1.0	µg/L	2006 NRWQC SW CMC
Demeton	0.10	µg/L	2006 NRWQC FW and SW CCC
Diazinon	0.17	µg/L	2006 NRWQC FW CMC and CCC
Dibenz(a,h)Anthracene	0.0038	µg/L	2006 NRWQC HH W+O
Chlorodibromomethane	0.40	µg/L	2006 NRWQC HH W+O
Dichlorobromomethane	0.55	µg/L	2006 NRWQC HH W+O
Dieldrin	0.0019	µg/L	2006 NRWQC SW CCC
Diethyl Phthalate	17000	µg/L	2006 NRWQC HH W+O
Dimethyl phthalate	270000	µg/L	2006 NRWQC HH W+O
Di-n-butyl phthalate	2000	µg/L	2006 NRWQC HH W+O
Dinitrophenols	69	µg/L	2006 NRWQC HH W+O
E. Coli by MPN	126	MPN/100 ml	1986 NRWQC B FW
Endosulfan Sulfate	62	µg/L	2006 NRWQC HH W+O
Endrin	0.0023	µg/L	2006 NRWQC SW CCC
Endrin Aldehyde	0.29	µg/L	2006 NRWQC HH W+O
Enterococci by MPN	33	MPN/100 ml	1986 NRWQC B FW
Ether, Bis(Chloromethyl)	0.00010	µg/L	2006 NRWQC HH W+O
Ethylbenzene	530	µg/L	2006 NRWQC HH W+O

Analyte	Screening Benchmarks	Units	Source[1]
Fecal Coliform by MF	14	MPN/100 ml	1976 QCW SH
Fluoranthene	130	µg/L	2006 NRWQC HH W+O
Fluorene	1100	µg/L	2006 NRWQC HH W+O
Gamma-BHC (Lindane)	0.16	µg/L	2006 NRWQC SW CMC
Guthion	0.010	µg/L	2006 NRWQC FW and SW CCC
Heptachlor	0.0036	µg/L	2006 NRWQC SW CCC
Heptachlor Epoxide	0.0036	µg/L	2006 NRWQC SW CCC
Hexachlorobenzene	0.00028	µg/L	2006 NRWQC HH W+O
Hexachlorobutadiene	0.44	µg/L	2006 NRWQC HH W+O
Hexachlorocyclo-hexane-Technical	0.0123	µg/L	2006 NRWQC HH W+O
Hexachlorocyclopentadiene	40	µg/L	2006 NRWQC HH W+O
Hexachloroethane	1.4	µg/L	2006 NRWQC HH W+O
Hexane Extractable Material (HEM)	15	mg/L	MARPOL 73/78
Ideno(1,2,3-cd)Pyrene	0.0038	µg/L	2006 NRWQC HH W+O
Iron, Total	300	µg/L	2006 NRWQC HH W+O
Isophorone	35	µg/L	2006 NRWQC HH W+O
Lead, Dissolved	2.5	µg/L	2006 NRWQC FW CCC
Malathion	0.1	µg/L	2006 NRWQC FW and SW CCC
Manganese	50	µg/L	2006 NRWQC HH W+O
Mercury	0.77	µg/L	2006 NRWQC FW CCC
Methoxychlor	0.03	µg/L	2006 NRWQC SW CCC
Methylene chloride	4.6	µg/L	2006 NRWQC HH W+O
Mirex	0.001	µg/L	2006 NRWQC FW and SW CCC
Nickel, Dissolved	8.2	µg/L	2006 NRWQC SW CCC
Nickel, Total	610	µg/L	2006 NRWQC HH W+O
Nitrates	10000	µg/L	2006 NRWQC HH W+O
Nitrobenzene	17	µg/L	2006 NRWQC HH W+O
Nitrosamines	0.0008	µg/L	2006 NRWQC HH W+O
Nitrosodibutylamine,N	0.0063	µg/L	2006 NRWQC HH W+O
Nitrosodiethylamine,N	0.0008	µg/L	2006 NRWQC HH W+O
Nitrosopyrrolidine,N	0.016	µg/L	2006 NRWQC HH W+O
N-Nitroso Di-n-propylamine	0.005	µg/L	2006 NRWQC HH W+O
N-Nitrosodimethylamine	0.00069	µg/L	2006 NRWQC HH W+O
N-Nitrosodiphenylamine	3.3	µg/L	2006 NRWQC HH W+O
Parathion	0.013	µg/L	2006 NRWQC FW CCC
Pentachlorobenzene	1.4	µg/L	2006 NRWQC HH W+O
Pentachlorophenol	7.9	µg/L	2006 NRWQC SW CCC
Phenol	21000	µg/L	2006 NRWQC HH W+O
Phorphorus (as phosphate)	0.1	mg/L	EPA 1986 Goldbook
Polychlorinated Biphenyls (PCBs)	0.000064	µg/L	2006 NRWQC HH W+O
Pyrene	830	µg/L	2006 NRWQC HH W+O
Selenium, Dissolved	5	µg/L	2006 NRWQC FW CCC
Selenium, Total	170	µg/L	2006 NRWQC HH W+O
Silica Gel Treated HEM (SGT-HEM)	15	mg/L	MARPOL 73/78
Silver, Dissolved	1.9	µg/L	2006 NRWQC SW CMC
Solids Dissolved and Salinity	250000	µg/L	2006 NRWQC HH W+O
Sulfide-Hydrogen Sulfide	0.002	mg/L	2006 NRWQC FW and SW CCC
Tetrachloroethene	0.69	µg/L	2006 NRWQC HH W+O

Analyte	Screening Benchmarks	Units	Source[1]
Thallium, Total	0.24	µg/L	2006 NRWQC HH W+O
Toluene	1300	µg/L	2006 NRWQC HH W+O
Total Nonylphenols	1.7	µg/L	2006 NRWQC SW CCC
Total Phosphorus	0.1	mg/L	1986 NRWQC
Total Polychlorinated Biphenyls	0.000064	µg/L	2006 NRWQC HH Org Only
Total Suspended Solids (TSS)	30	mg/L	1984 Secondary Treatment Effluent Limits
Total Residual Chlorine (TRC)	0.0075	mg/L	2006 NRWQC SW CCC
Toxaphene	0.0002	µg/L	2006 NRWQC FW and SW CCC
trans-1,2-Dichloroethene	140	µg/L	2006 NRWQC HH W+O
Tributyltin (TBT)	0.0074	µg/L	2006 NRWQC SW CCC
Trichloroethene	2.5	µg/L	2006 NRWQC HH W+O
Vinyl chloride	0.025	µg/L	2006 NRWQC HH W+O
Zinc, Dissolved	81	µg/L	2006 NRWQC SW CCC
Zinc, Total	7400	µg/L	2006 NRWQC HH W+O

(1) Sources:
MARPOL 73/78: International Convention for the Prevention of Pollution From Ships, 1973 as modified by the Protocol of 1978 (MARPOL 73/88, 1978).
1976 QCW SH (shellfish harvesting): Note MPN is most probable number and approximates the unit of measure for fecal coliform in this study of CFU (colony forming units) (USEPA, 1976).
1984 Secondary Treatment Effluent Limits: 49 FR 37006, Sept. 20, 1984.
1986 NRWQC B FW (bathing (full body contact) recreational waters – fresh water): (USEPA, 1986).
Quality Criteria for Water 1986 (Goldbook) (USEPA, 1986b).
2006 NRWQC FW CCC (freshwater chronic): (USEPA, 2006).
2006 NRWQC SW CCC (saltwater chronic) (USEPA, 2006).
2006 NRWQC SW CMC (saltwater acute) (USEPA, 2006).
2006 NRWQC HH Org Only (human health for the consumption of organism only) (USEPA, 2006).
2006 NRWQC HH W+O (human health for the consumption of water + organism) (USEPA, 2006).

Table 3.2. Major Cation Concentrations in Seawater

Seawater Salinity Level	Calcium, mg/L	Magnesium, mg/L	Potassium, mg/L	Sodium, mg/L
Full Strength [1] (35 ppt salinity)	400	1,350	380	10,500
Brackish [2] (10 ppt salinity)	114	386	109	3,000

(1) Source: Mowka, 2009.
(2) Calculated from full strength seawater concentrations, assuming dilution by ion-free water.

Table 3.3. Major Cation Concentrations in Freshwater

Freshwater Hardness Level	Calcium, mg/L	Magnesium, mg/L	Potassium, mg/L	Sodium, mg/L
Soft (40-48 mg $CaCO_3$/L) [1]	6.99	6.06	1.05	13.1
Moderately Hard (80-100 mg $CaCO_3$/L) [1]	14.0	12.1	2.10	26.3
Hard (160-180 mg $CaCO_3$/L) [1]	27.9	24.2	4.20	52.5

(1) Source: USEPA, 2007.

3.2 CHARACTERIZATION OF DISCHARGES

Each subsection of Section 3.2 presents in detail the observed results for the discharge types selected for evaluation in the study vessels: bilgewater; stern tube packing gland effluent; deck runoff and/or washdown; fish hold effluent (both refrigerated seawater effluent and ice slurry) and effluent from the cleaning of fish holds; graywater; propulsion (inboard and outboard) and generator engine effluent; and discharges from firemain systems. Tables and figures are presented at the end of each subsection.

3.2.1 Bilgewater

Bilgewater can be found on board every vessel and describes the water that collects in the bottom of a vessel. This water may be from rough seas, rain, minor leaks in the hull or stuffing box, etc. Depending on the ship's design and function, bilgewater sometimes contains contaminants such as oil, fuel, graywater, detergents, solvents, chemicals, pitch, and particulates. For this study, EPA collected bilgewater samples from seven vessels: two tow/salvage vessels, two water taxis, one longline fishing vessel, one shrimping vessel, and one tour boat.

Based on data and field observations from EPA’s vessel sampling program, as well as information from secondary data sources, EPA estimates many commercial vessels generate, on average, between 10 and 15 gallons per day (gpd) of bilgewater depending on the vessels’ configuration and intended use; however, EPA noted that vessels might generate as little as 2 gallons of bilgewater or as much as 750 gallons of bilgewater per day. For vessels such as small tow/salvage vessels or water taxis with open bows, bilgewater pump-out can occur frequently throughout the day, resulting in small volumes during each pump-out cycle (1-2 gallons). Larger vessels such as commercial fishing boats are likely to pump less frequently due to larger storage capacity in the bilge; however, the bilgewater discharge volume can be hundreds of gallons. For example, EPA noted that a 26-foot, center console Boston Whaler being used as a tow/salvage vessel had accumulated only 2 gallons of bilgewater following a tow activity. However, a 62-foot shrimp boat sampled by EPA in the Gulf of Mexico discharged approximately 750 gallons of bilgewater during the daily pump-out.

In general, the volume of bilgewater generated by commercial fishing boats and commercial vessels depends on the following factors:

- Hull and deck construction
- Vessel size
- Precipitation
- Frequency of deck cleaning
- Amount of spray reaching the deck(s)
- Accidental spills
- Integrity of hull and below-deck piping systems
- Potential for condensate formation in below-deck areas.

Commercial vessels with open bow and stern areas (e.g., commercial fishing and tow/salvage vessels) have relatively large deck areas that are exposed to precipitation, spray, and cleaning water, which results in greater bilgewater volumes compared to vessels such as tour boats or water taxis that have less exposed deck. Other sources that contribute to bilgewater onboard commercial vessels include small leaks in potable water, graywater and sewage piping systems, and condensates from the interior of the hull or refrigeration systems. The volume of these additional bilgewater sources is also highly vessel-specific.

In this vessel sampling program, EPA collected single grab samples of bilgewater discharge from selected vessels for laboratory analysis. The results of the analysis were intended to be representative of bilgewater pollutant concentrations over the range of normal vessel operations. Collecting bilgewater samples proved difficult for EPA for a number of reasons including: (1) automatic bilge pumps would discharge insufficient volumes of bilgewater in a single operating cycle, (2) vessel operators were generally reluctant to discharge bilgewater for fear of exceeding existing CWA § 311 requirements (oily discharges), and (3) sampling was often impractical because bilgewater was typically discharged via thru-hull openings located at or near the vessel's waterline.

Bilgewater samples were analyzed for a wide range of pollutants including metals, classical pollutants, pathogen indicators, nutrients, semivolatile and volatile organic compounds, and nonylphenols. Results for each class of pollutant are presented and discussed in the following subsections.

3.2.1.1 Metals

Bilgewater samples were analyzed for dissolved[10] and total (dissolved plus particulate) concentrations of metals. The analytical results are summarized in Table 3.1.1 for dissolved metals and in Table 3.1.2 for total metals that were detected in at least one bilgewater sample. The following metals were measured in all bilgewater samples:

- Total aluminum
- Total arsenic[11]
- Dissolved and total barium
- Dissolved and total calcium
- Dissolved and total copper
- Dissolved and total magnesium
- Dissolved and total manganese
- Dissolved and total potassium

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[10] Dissolved metals were obtained by filtering the water sample.

[11] Note that for three of the seven bilgewater samples analyzed, EPA suspects that the measured arsenic concentrations are likely to be overestimated due to the positive interference of major cations in seawater (see discussion on page 74).

- Dissolved and total sodium
- Dissolved and total zinc.

Concentrations of other metals were measured in 50 percent or more of the samples analyzed:

- Dissolved aluminum
- Dissolved arsenic[12]
- Dissolved and total chromium
- Total iron
- Total lead
- Dissolved and total nickel
- Dissolved and total selenium[13].

Dissolved versus Total Metals

EPA recommends using dissolved metal to set and measure compliance with water quality standards because dissolved metal more closely approximates the bioavailable fraction of metal in the water column than does total recoverable metal (USEPA, 1993). EPA considers that the primary mechanism for toxicity to organisms that live in the water column to be adsorption to or uptake across the respiratory surfaces of aquatic organisms (i.e., the gills) as well as the carapace of certain invertebrates, and this physiological process requires metal to be in a dissolved form. This is not to suggest that particulate metals are nontoxic; rather, because toxicity of particulate metals are primarily restricted to direct ingestion via dietary exposure, they are less toxic overall compared to dissolved metal (USEPA, 1996). There are exceptions, however, particularly for bottom feeding organisms, and for metals that bioaccumulate (also see footnote in Section 3.1.3 regarding physical and biological recycling of particulate metals). Dissolved metal is *operationally defined* as that which passes through a 0.45-µm or a 0.40-µm filter and particulate metal is *operationally defined* as total recoverable metal minus dissolved metal. EPA typically uses the dissolved fraction, or f_d, to express the fraction of the total chemical concentration in water that is dissolved. To calculate f_d, divide the dissolved concentration by the total concentration. A chemical that is entirely in the dissolved phase has a f_d of 1, while a chemical that is entirely in the particulate phase has a f_d of 0.

Figure 3.1.1 presents the range of concentrations measured for dissolved metals in the bilgewater samples. The plots show that dissolved metals concentrations range over six orders of magnitude. Calcium, magnesium, potassium and sodium were the dissolved metals measured at the highest concentrations. As discussed in Chapter 1 and Section 3.1.3, these cations naturally occur in seawater and their levels in the discharges are similar to levels seen in ambient seawater. As many discharges use ambient water for onboard activities, and spray would contribute to other discharges, it was not unexpected to find these levels of cations in the bilgewater samples as most vessels were sampled in coastal areas. At these concentrations, these cations are generally not toxic to aquatic organisms, which is why there there are no NRWQC for these metals, and therefore, no PHQs were calculated (see Section 3.1.3 for additional explanation). Dissolved aluminum, barium, copper, manganese, selenium[13] and zinc were also measured at relatively high concentrations (tens to hundreds of

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[12] Note that for three of the six bilgewater samples where dissolved arsenic was detected, EPA suspects that the measured arsenic concentrations are likely to be overestimated due to positive interference (see discussion on page 74)

[13] Note: EPA suspects positive interference for all concentrations of total and dissolved selenium detected in bilgewater samples (see discussion on page 74). Reported values could be entirely due to this positive interference.

µg/L) in most bilgewater samples; dissolved arsenic[14] and iron were also measured at concentrations greater than 100 µg/L in individual samples. Among the vessels from which bilgewater was sampled, a tow/salvage boat had the highest concentrations of the most dissolved metals (seven analytes), while the water taxi had only one dissolved metal.

Figure 3.1.2 shows the total metals concentrations in the bilgewater samples. The box plots show that the relative ranges of total metals concentrations are comparable to the concentrations of dissolved metals. Among the vessels from which bilgewater was sampled, the shrimper had the highest concentrations of the most total metals (11), while the longliner and the water taxi had the fewest (one each). In general, total concentrations for each metal are similar to or slightly higher than the dissolved concentrations. To explore this relationship further, EPA calculated the average dissolved fraction f_d of each metal in the bilgewater samples to better understand the potential for aquatic organism impacts. The metals with the highest average dissolved fractions (f_d > 90 percent) included barium, calcium, magnesium, potassium, selenium (see footnote 13), and zinc. Metals having intermediate average dissolved fractions (90 percent > f_d > 50 percent) included antimony, arsenic (see footnotes 11 and 12), cadmium, chromium, cobalt, copper, iron, manganese, and nickel. Aluminum, lead, and vanadium had the lowest average dissolved fractions (f_d < 50 percent).

Figure 3.1.3 shows the distributions of PHQs based on the most conservative screening benchmark for each of the dissolved metals. Per Section 3.1.3 above, points on this plot above the dashed line (demarcating a PHQ of one) indicate a dissolved metal concentration exceeding the benchmark; two of the dissolved metals (cadmium and copper) have PHQs that include values greater than 10, indicating that the measured concentrations were one (or more) order of magnitude greater than the screening benchmark. EPA suspects that the high PHQs for a third dissolved metal in this discharge (selenium) was elevated due to positive interference due to the major seawater cations in these samples. The highest PHQ (113) was for dissolved copper, measured in the bilgewater sample from the tour boat. EPA also found PHQs exceeding one for dissolved arsenic, chromium, lead, nickel, and zinc, bringing to eight the number of dissolved metals that exceeded the most stringent 2006 NRWQC in one or more bilgewater sample. Dissolved copper concentrations, ranging from 6.6 to 350 µg/L, exceeded the saltwater acute (4.8 µg/L) and chronic (3.1 µg/L) criteria in all seven bilgewater samples; concentrations in all but one bilgewater sample also exceeded the freshwater acute (13 µg/L) and chronic (9 µg/L) criteria. The single elevated dissolved cadmium concentration (10 µg/L) exceeded the freshwater acute (2.0 µg/L) and chronic (0.25 µg/L) criteria, and the saltwater chronic (8.8 µg/L) criterion. In addition, the highest dissolved arsenic concentration (230 µg/L) exceeded the 36 µg/L saltwater chronic criterion. For the other dissolved metals (chromium, lead, nickel, and zinc),

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[14] As noted in footnote 11, some dissolved arsenic samples may experience positive interference. Dissolved arsenic samples not suspected of having positive interference include the measured dissolved arsenic concentration of 230 µg/L for the tow/salvage vessel, the dissolved arsenic concentration of 10 µg/L for the tour boat as well as the relatively low dissolved arsenic concentration of 1.1 µg/L for a sample of bilgewater from a tow/salvage vessel.

concentrations in one or more bilgewater samples exceeded saltwater and/or freshwater criteria, although in each of these cases the PHQs were less than five.

Three of the total metals (aluminum, arsenic[15], and iron) exceeded the most stringent 2006 NRWQC[16] in one or more bilgewater samples as shown in Figure 3.1.4. PHQs for total arsenic (those not suspected of significant positive interference) ranged from 306 to 16,170. The total arsenic concentrations in samples associated with these PHQs all greatly exceeded the human health criterion for consumption of water plus organism of 0.018 µg/L, as well as the human health criterion for organism consumption alone, 0.14 µg/L. PHQs for aluminum and iron did not exceed 11. Five of the seven total aluminum concentrations measured in bilgewater (at concentrations ranging from 332 to 940 µg/L) exceeded the freshwater chronic criterion (87 µg/L, expressed as total recoverable metal). For total iron, concentrations in two of three bilgewater samples exceeded the human health criterion for water plus organism consumption of 300 µg/L; PHQs for total iron ranged from 0.17 to 6.3.

To further evaluate the significance of the dissolved and total metals concentrations in the bilgewater samples, EPA compared them to ambient dissolved and total metal concentrations in surface water samples collected near the vessels. This was done because surface water might occasionally leak into certain vessel bilges, be used onboard the vessel, or splash onto the vessel and drain into the bilge. In these cases, the concentrations of metals (as well as other analytes) measured in the bilgewater samples might be similar to or significantly influenced by the ambient concentrations. Indeed, EPA found that the concentrations of many of the metals (including aluminum, barium, calcium, chromium, magnesium, manganese, nickel, potassium, selenium, and sodium) measured in multiple bilgewater samples were no more than double the ambient concentrations. The similarity in the concentrations of many of these metals in bilgewater and ambient samples suggests that some proportion of the water sampled in the vessel bilges may be from ambient water. It is less clear whether the significant background ambient metals concentrations in the sampled harbors reflect the loading from the cumulative discharges of the many vessels that operate there, or loadings from other point and/or nonpoint pollutant sources to these water bodies.

On the other hand, the highest concentrations of some of the dissolved and total metals measured in bilgewater were substantially elevated above the corresponding ambient concentrations. For dissolved copper, the ambient concentration that accompanied the highest bilgewater concentration (350 µg/L from a tour boat) was below the detection limit. The next two highest dissolved copper concentrations in bilgewater (119 and 120 µg/L) were from water taxis with a somewhat higher corresponding ambient concentration of 24 µg/L.

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[15] Measured total arsenic concentration where no positive interference is evident include 291 µg/L for a tow/salvage vessel, 19 and 5.5 µg/L for the tour boat and longliner fishing vessel, respectively, and 1.3 µg/L for a sample of bilgewater from a tow/salvage vessel.

[16] PHQs for total metals are based on NRWQC for human health and not aquatic life, as stated in Section 3.1.3.

For dissolved aluminum, the ambient concentration that accompanied the highest bilgewater concentration (520 µg/L from the longliner) was 870 µg/L; in this case, and several others, even the highest concentration for a metal in bilgewater was exceeded by the ambient concentration.

The data for total metals also demonstrate considerable variability in the relationships between bilgewater and ambient concentrations. The highest total arsenic concentration in bilgewater (291 µg/L from a tow/salvage boat) exceeded the corresponding ambient concentration (12 µg/L) by a considerable margin. The ambient concentration that accompanied the next highest total arsenic concentration in bilgewater (32 µg/L from the shrimper) was a comparable 29 µg/L, although this moderately high concentration of total arsenic measured in the bilgewater sample from the shrimper is likely an overestimate due to positive interference (see discussion on page 74).

The results shown here illustrate that relationships between metals concentrations in bilgewater and ambient samples are quite variable, even for the highest concentrations of metals measured in bilgewater. EPA acknowledges that such variability could be due to type of bilgewater production and dilution onboard. For example, a shrimper might have used a substantial amount of ambient water for washdown as compared to a tow boat, and thus, dilute what might be a similar actual bilge sample absent the washdown. Clearly the potential for metals in bilgewater discharges to pollute receiving waters may be overestimated if the ambient metals concentrations and other considerations (type and dilution of bilgewater) are not appropriately considered.

In summary, metals were frequently detected in bilgewater samples. EPA found relatively high concentrations of a number of dissolved and total metals in these samples. Total arsenic and dissolved copper concentrations were significantly elevated above the most conservative screening benchmarks in individual samples, with PHQ values from greater than 10 to over 1,000. Dissolved cadmium concentrations in a single bilgewater sample also generated PHQs in this range. For these and other metals (including total aluminum and iron and dissolved chromium, lead, nickel, and zinc), concentrations measured in one or several bilgewater samples exceeded saltwater and/or freshwater criteria. EPA found that the concentrations of many of the metals measured in bilgewater samples (except for dissolved copper and total arsenic) were comparable to the ambient receiving water concentrations.

Table 3.1.1. Results of Bilgewater Sample Analyses for Dissolved Metals[1]

Analyte	Units	No. samples	No. detected	Detected Proportion (%)	Average Conc.	Median Conc.	Minimum Conc.	10%	25%	75%	90%	Maximum Conc.	Screening BM[2]
Heavy and Other Metals													
Aluminum	µg/L	7	6	86	150	37			9.7	420	520	520	NA
Antimony	µg/L	5	1	20	0.66					0.65	1.3	1.3	NA
Arsenic[3]	µg/L	7	6	86	41	10			1.1	21	230	230	36
Barium	µg/L	5	5	100	49	43	38	38	39	62	64	64	NA
Cadmium	µg/L	7	1	14	1.9						10	10	0.25
Chromium	µg/L	7	5	71	12	1.6				17	56	56	11
Cobalt	µg/L	5	2	40	1.0					1.8	2.5	2.5	NA
Copper	µg/L	7	7	100	100	56	6.6	6.6	25	120	350	350	3.1
Iron	µg/L	5	1	20	75					87	170	170	NA
Lead	µg/L	7	3	43	2.3					4.2	7.2	7.2	2.5
Manganese	µg/L	7	7	100	34	28	3.9	3.9	13	50	79	79	NA
Nickel	µg/L	7	6	86	9.2	8.8			4.7	14	15	15	8.2
Selenium[4]	µg/L	7	4	57	24	30				36	57	57	5
Vanadium	µg/L	5	1	20	0.62					0.55	1.1	1.1	NA
Zinc	µg/L	7	7	100	130	100	53	53	72	190	250	250	81
Cationic Metals													
Calcium	µg/L	7	7	100	76000	76000	33000	33000	47000	100000	140000	140000	NA
Magnesium	µg/L	7	7	100	180000	180000	8300	8300	14000	310000	420000	420000	NA
Potassium	µg/L	5	5	100	67000	65000	9800	9800	37000	98000	120000	120000	NA
Sodium	µg/L	5	5	100	1400000	1400000	120000	120000	730000	2000000	2700000	2700000	NA

Notes:

(1) Nondetect (censored) concentrations were replaced with ½ of the reporting limit for calculating average concentrations. The remaining statistics in this table were only calculated when analytes were detected at a sufficient frequency. For example, if an analyte was detected in fewer than 50% of samples, then a median concentration was not calculated. A blank cell reflects a situation when a median or percentile could not be computed based on detected concentrations. The percentiles are the concentrations of each analyte below which at least that percentage of the values fall. So the 10th percentile is the concentration below which at least 10% of the observations were found.

(2) Screening BM represents the screening benchmark referred to in Section 3.1.3, and is the most stringent 2006 NRWQC or other conservative benchmark used to calculate PHQs.

(3) See footnotes 11 and 12.

(4) See footnote 13.

Table 3.1.2. Results of Bilgewater Sample Analyses for Total Metals[1]

Analyte	Units	No. samples	No. detected	Detected proportion (%)	Average Conc.	Median Conc.	Minimum Conc.	10%	25%	75%	90%	Maximum Conc.	Screening BM[2]
Heavy and Other Metals													
Aluminum	µg/L	7	7	100	370	330	26	26	28	640	940	940	87
Antimony	µg/L	5	1	20	1.3					0.65	1.3	1.3	5.6
Arsenic[3]	µg/L	7	7	100	53	12	1.3	1.3	5.5	32	290	290	0.018
Barium	µg/L	5	5	100	50	44	38	38	38	66	67	67	1000
Cadmium	µg/L	7	1	14	2.6						12	12	NA
Chromium	µg/L	7	6	86	25	3.5			2	37	96	96	NA
Cobalt	µg/L	5	1	20	1.3					0.7	1.4	1.4	NA
Copper	µg/L	7	7	100	150	130	8.5	8.5	50	210	430	430	1300
Iron	µg/L	5	3	60	520	250				1100	1900	1900	300
Lead	µg/L	7	6	86	9.6	7.5			2.3	18	26	26	NA
Manganese	µg/L	7	7	100	53	52	7.4	7.4	37	79	97	97	100
Nickel	µg/L	7	6	86	12	9.4			6.2	17	24	24	610
Selenium[4]	µg/L	7	4	57	25	25				38	66	66	170
Vanadium	µg/L	5	2	40	2.6					1.4	1.7	1.7	NA
Zinc	µg/L	7	7	100	160	87	56	56	72	260	360	360	7400
Cationic Metals													
Calcium	µg/L	7	7	100	76000	77000	36000	36000	47000	110000	130000	130000	NA
Magnesium	µg/L	7	7	100	180000	180000	9200	9200	14000	310000	390000	390000	NA
Potassium	µg/L	5	5	100	68000	65000	9600	9600	37000	100000	130000	130000	NA
Sodium	µg/L	5	5	100	1400000	1400000	120000	120000	740000	2000000	2600000	2600000	NA

Notes:

(1) Nondetect (censored) concentrations were replaced with ½ of the reporting limit for calculating average concentrations. The remaining statistics in this table were only calculated when analytes were detected at a sufficient frequency. For example, if an analyte was detected in fewer than 50% of samples, then a median concentration was not calculated. A blank cell reflects a situation when a median or percentile could not be computed based on detected concentrations. The percentiles are the concentrations of each analyte below which at least that percentage of the values fall. So the 10th percentile is the concentration below which at least 10% of the observations were found.

(2) Screening BM represents the screening benchmark referred to in Section 3.1.3, and is the most stringent 2006 NRWQC or other conservative benchmark used to calculate PHQs.

(3) See footnotes 11 and 12.

(4) See footnote 13.

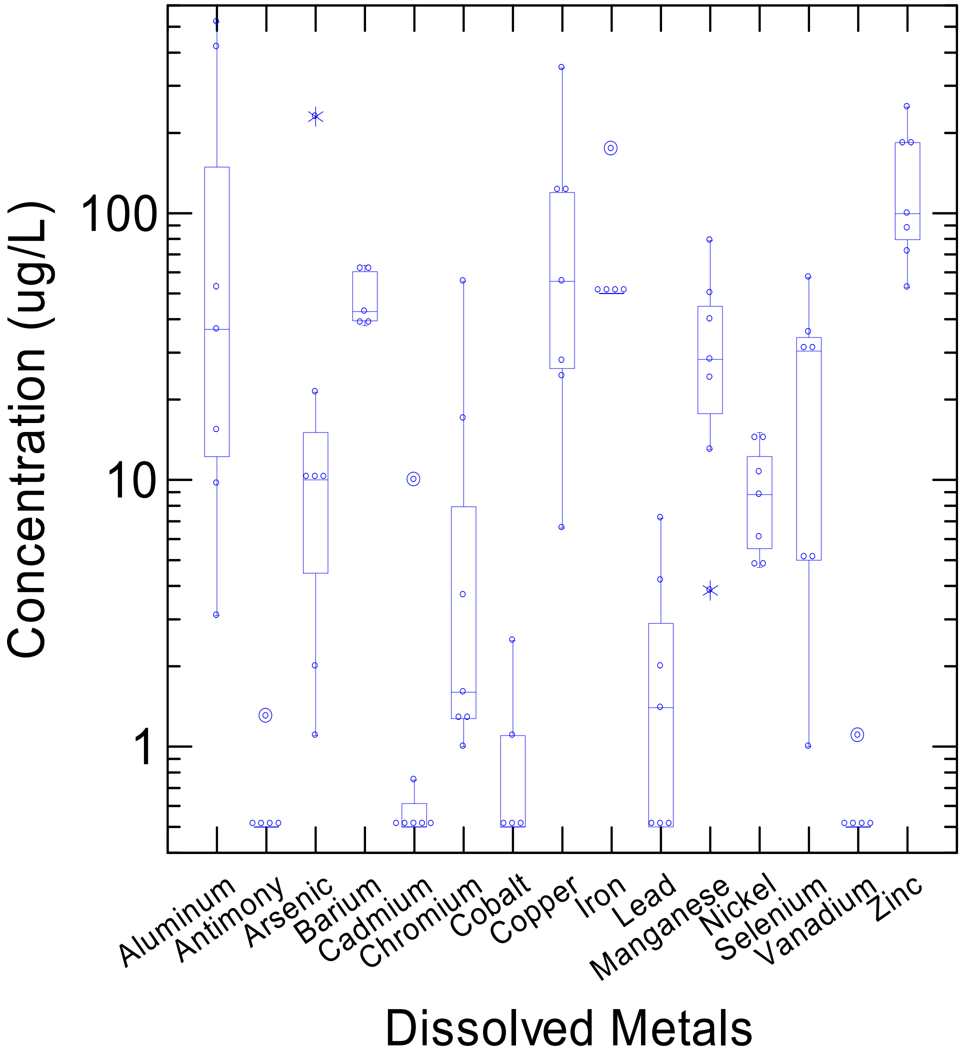

Figure 3.1.1. Box and Dot Density Plot of Dissolved Metals Concentrations Measured in Samples of Bilgewater
(Note: As discussed in footnotes 12 and 13, all but possibly one of the bilgewater samples analyzed for dissolved selenium and three of the bilgewater samples analyzed for dissolved arsenic may be elevated due to positive interference. The measured dissolved arsenic concentration of 230 µg/L for the tow/salvage vessel and measured dissolved arsenic concentration of 10 µg/L for the tour boat are not expected to have had positive interference).

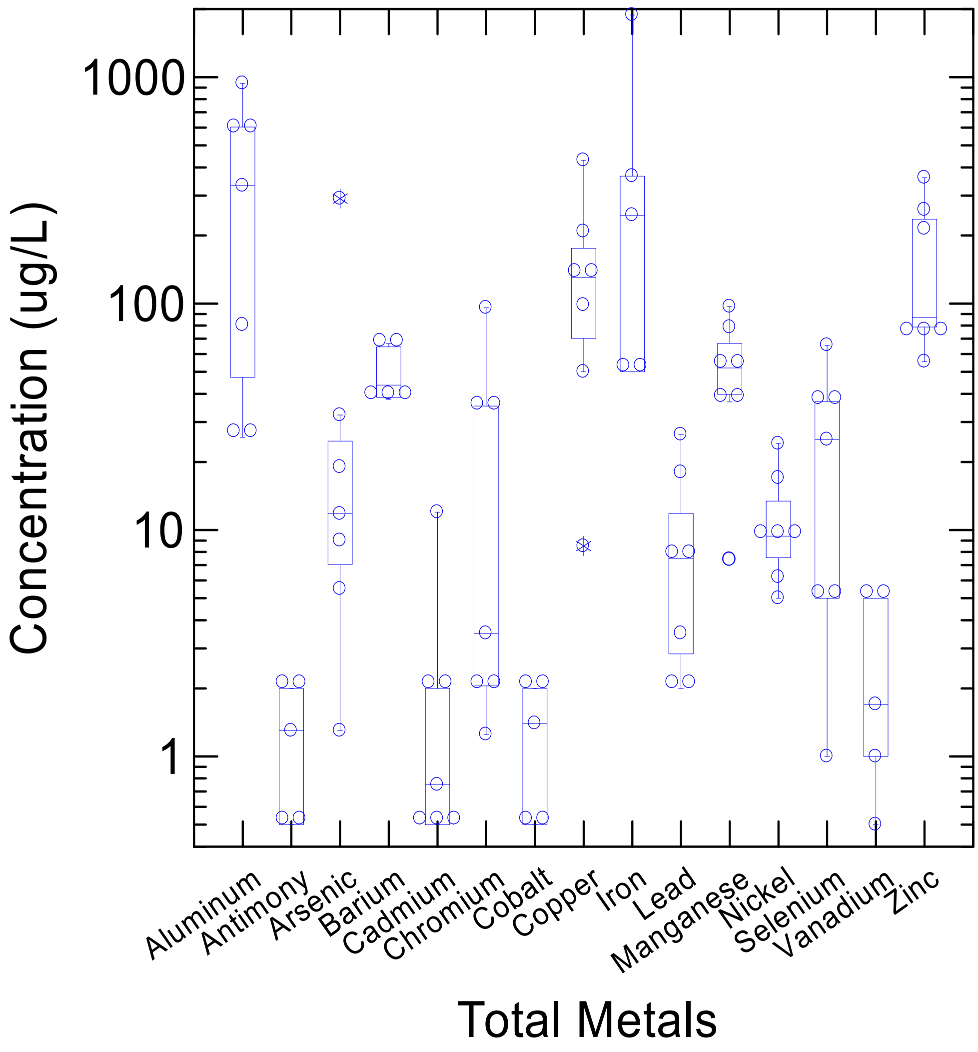

Figure 3.1.2. Box and Dot Density Plot of Total Metals Concentrations Measured in Samples of Bilgewater

(Note: As discussed in footnotes 11 and 13, all but one of the bilgewater samples analyzed for total selenium and three of the bilgewater samples analyzed for total arsenic may be elevated due to probability of positive interference. Exceptions are the total arsenic concentration of 291 µg/L for the tow/salvage vessel, concentrations of 19 and 5.5 µg/L for the tour boat and longliner fishing vessel, respectively, as well as the concentration of 1.3 µg/L for a sample of bilgewater from a tow/salvage vessel).

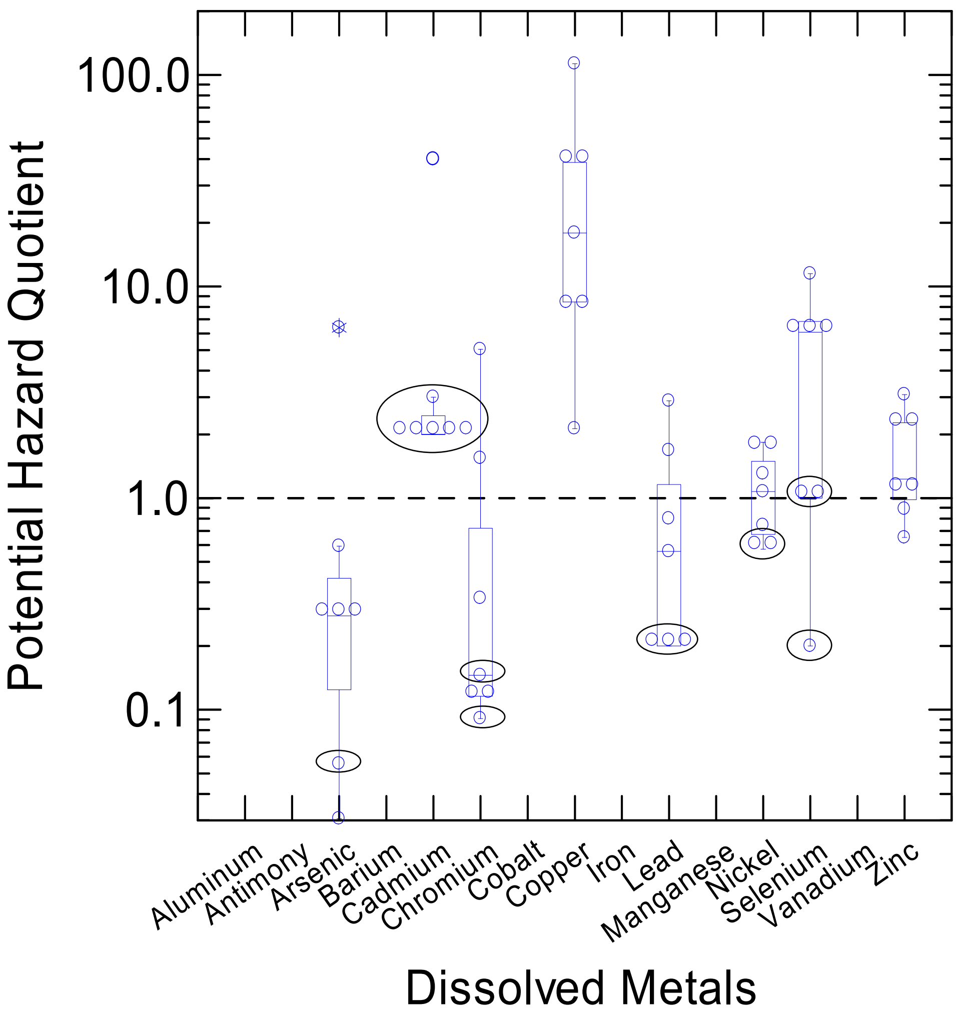

Figure 3.1.3. Box and Dot Density Plot of Potential Hazard Quotients for Dissolved Metals in Samples of Bilgewater

(Note: Values circled here and throughout the rest of this chapter indicate PHQs calculated based on replacement values for non-detects. Non-detect (censored) concentrations were replaced with ½ of the reporting limit for use in these plots. Also, as discussed in footnotes 11 and 13, all but one of the bilgewater samples analyzed for total selenium and three of the bilgewater samples analyzed for total arsenic may be elevated due to probability of positive interference).

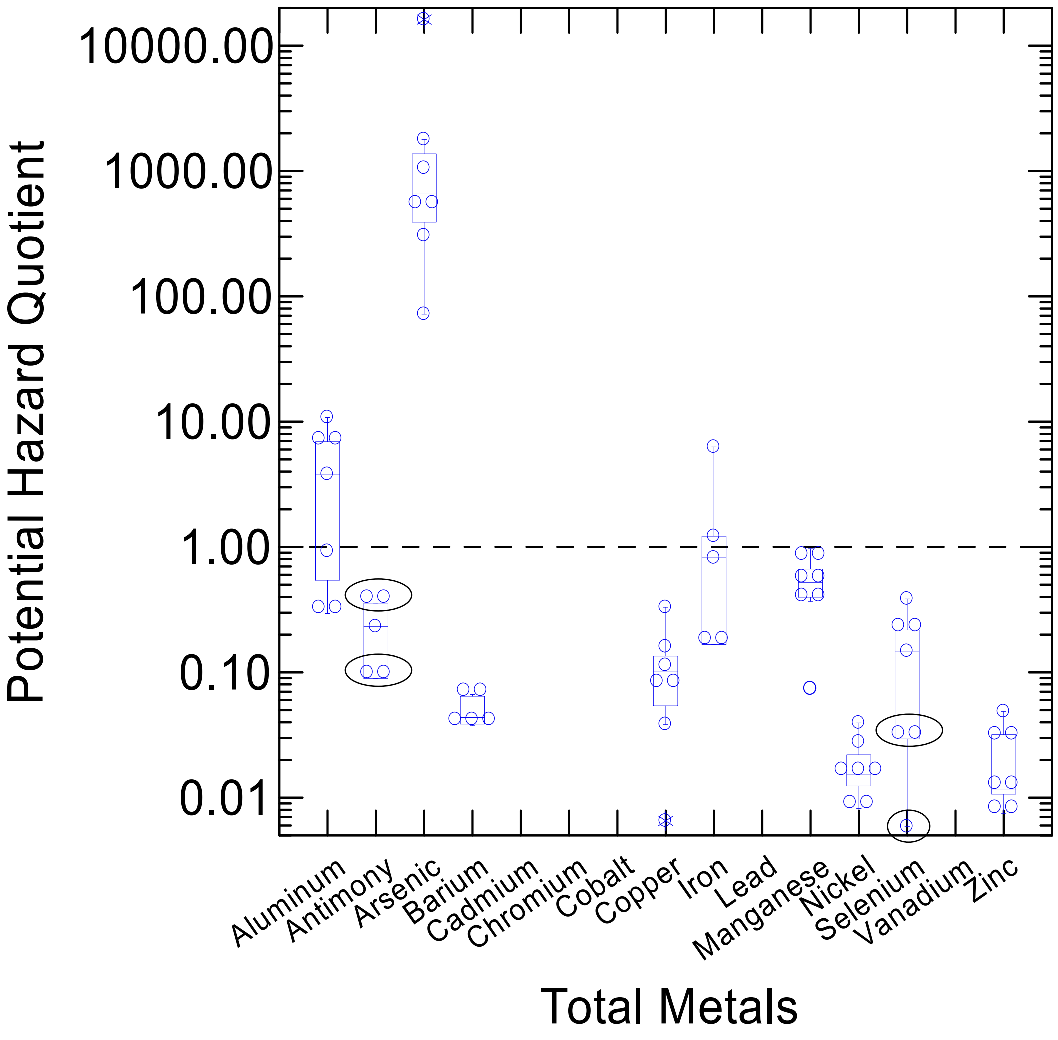

Figure 3.1.4. Box and Dot Density Plot of Potential Hazard Quotients for Total Metals in Samples of Bilgewater

(Note: Replacement values for non-detects are circled. Also, as discussed in footnotes 11 and 13, all but one of the bilgewater samples analyzed for total selenium and three of the bilgewater samples analyzed for total arsenic may be elevated due to probability of positive interference).

3.2.1.2 Classical Pollutants

Bilgewater samples were analyzed for 14 classical pollutants (see Table 3.1.3). These pollutants include measurements that are qualitatively quite different: physical properties (pH, temperature, conductivity, salinity, turbidity, TOC, TSS), oxygen consumption (BOD and COD), oil and grease (hexane extractable material (HEM) and silica-gel treated hexane extractable material (SGT-HEM)), as well as concentrations of several chemicals (sulfide, DO, TOC and TRC).[17] Figure 3.1.5 illustrates the variability of the concentrations/values measured for the classical pollutant in bilgewater. The highest concentrations of BOD, COD and TOC (770, 2970, and 732 mg/L, respectively), as well as HEM, SGT-HEM, and TRC, were measured in a single bilgewater sample from a tow/salvage boat. BOD and TOC concentrations were highly variable among the bilgewater samples, ranging from 2 to 770 mg/L for BOD and from 9 to 730 mg/L for TOC.

Oil and grease were measured as HEM and petroleum hydrocarbons were measured as SGT-HEM. HEM and SGT-HEM were detected in all of the bilgewater samples, with concentrations ranging from 1.1 to 43.6 mg/L (HEM) and 1.1 to 18.2 mg/L (SGT-HEM). These concentrations were compared to the existing international and U.S. regulatory limit of 15 mg/L of oil and grease that can be discharged from a moving ship when within 12 nautical miles from land[18]. Some type of oil collector (sorbent pad, rags, etc.) was used on four of the seven vessels sampled for bilgewater. A single value taken from the tow/salvage boat exceeded the 15-mg/L benchmark by threefold. Oil and grease discharges at this concentration are significant enough to cause a visible sheen. The tow/salvage boat had no equipment or management practices in place to remove oil or other pollutants prior to overboard discharge of bilgewater.

Sulfide was detected in two bilgewater samples, at concentrations of 0.015 and 0.2 mg/L. These concentrations exceeded the NRWQC of 2 μg/L (0.002 mg/L) by factors of 7.5 to 100. Sulfide (hydrogen sulfide) is a pollutant that is commonly elevated in water distribution systems as well as sewers. Sulfur-reducing bacteria, which use sulfur as an energy source, are believed to be the primary producers of large quantities of hydrogen sulfide in bilgewater. Ecologically, these bacteria are common in anaerobic environments (e.g., plumbing systems). Sulfur-reducing bacteria are apparently present in at least some of the vessels, because sulfide was not detected in the ambient water sampled at the vessel locations.

Figure 3.1.6 presents box and dot density plots of the PHQs for classical pollutants. PHQs were calculated for the six classical pollutants for which benchmarks were available. As this figure shows, all of the detected TRC concentrations exceeded the saltwater chronic

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[17] See Section 3.1.1 this chapter for the rationale to use this term for this large group of conventional, nonconventional, and other physico-chemical factors.

[18] International Convention for the Prevention of Pollution from Ships, 1973, as modified by the Protocol of 1978 relating thereto (MARPOL).

NRWQC benchmark of 0.0075 mg/L and yielded PHQs ranged from 6.7 to 21. The highest TRC concentration (0.16 mg/L) was measured in a bilgewater sample collected from a tour boat.

EPA compared classical pollutant concentrations in the bilgewater samples to ambient concentrations in surface water samples collected near the vessels. Concentrations of a number of the classical parameters (including conductivity, pH, salinity, temperature, and (to a varying degree) turbidity in bilgewater were comparable with ambient water. This was expected, considering the likelihood of ambient water leaking into vessel bilges. The concentration of DO measured in one bilgewater sample (1.8 mg/L in the longliner) was hypoxic (<2 mg/L), although the ambient DO value at this location (Sitka, Alaska) was also very low (1.0 mg/L). TRC concentrations were elevated at 0.1 mg/L in two of the seven bilge samples; for the remaining samples, TRC concentrations were comparable between bilgewater and ambient samples. For the remaining classical pollutants (BOD, COD, HEM, SGT-HEM, sulfide, TOC, and TSS) the concentrations measured in bilgewater greatly exceeded those measured in ambient samples. BOD concentrations in three of the bilgewater samples (189, 325, and 770 mg/L) were high enough to be comparable to values typical of raw domestic sewage (110 to 400 mg/L; Metcalf and Eddy, 1979). These three bilgewater samples also exceed EPA's secondary treatment effluent limit of 30 mg/L for BOD. COD concentrations in four of the bilgewater samples (430, 546, 780, and 2,970 mg/L) were again high enough to compare with values for raw domestic sewage (250 to 1,000 mg/L; Metcalf and Eddy, 1979). These high levels of BOD and COD in bilgewater discharges could potentially cause stress on a water body (e.g., where there are many sources of oxygen demand, where there may be limited circulation or flushing, or where the water body is under existing hypoxic or anoxic stress). Although TSS concentrations in bilgewater were not as high as values for raw sewage, four of the bilgewater samples exceeded the 30 mg/L effluent limit for TSS by factors ranging from 1.2 to 3. EPA realizes that these effluent limits are based upon the high removal efficiencies for BOD and TSS that are achievable by land-based sewage treatment plants, and may be overly conservative as benchmarks for vessel discharge. However, as discussed in Section 3.1.3, the benchmarks are still useful in a screening level analysis as a starting point for evaluating the potential of these pollutants to cause or contribute to ecological stress on a water body.

Table 3.1.3. Results of Bilgewater Sample Analyses for Classical Pollutants[1]

Analyte	Units	No. samples	No. detected	Detected Proportion (%)	Average Conc.	Median Conc.	Minimum Conc.	10%	25%	75%	90%	Maximum Conc.	Screening BM[2]
Biochemical Oxygen Demand (BOD)	mg/L	7	7	100	190	14	2.0	2.0	4.1	330	770	770	30
Chemical Oxygen Demand (COD)	mg/L	7	7	100	740	430	91	91	98	780	3000	3000	NA
Conductivity	mS/cm	6	6	100	5.0	6.9	0.017	0.017	0.56	9.3	14	14	NA
Dissolved Oxygen	mg/L	6	6	100	5.3	5.5	1.8	1.8	3.4	6.9	11	11	NA
Hexane Extractable Material (HEM)	mg/L	7	7	100	9.3	5.2	1.1	1.1	1.2	7.0	44	44	15
pH	SU	7	7	100	7.2	7.0	6.9	6.9	6.9	7.3	8.0	8.0	NA
Salinity	ppt	6	6	100	5.5	4.5	0.40	0.40	3.1	8.9	13	13	NA
Silica Gel Treated HEM (SGT-HEM)	mg/L	7	7	100	4.4	2.4	1.1	1.1	1.2	3.5	18	18	15
Sulfide	mg/L	7	2	29	0.034					0.015	0.20	0.20	0.0020
Temperature	C	7	7	100	20	21	9.0	9.0	14	27	28	28	NA
Total Organic Carbon (TOC)	mg/L	5	5	100	200	110	8.9	8.9	16	440	730	730	NA
Total Residual Chlorine	mg/L	7	3	43	0.077					0.13	0.16	0.16	0.0075
Total Suspended Solids (TSS)	mg/L	7	7	100	39	38	3.7	3.7	5.5	71	88	88	30
Turbidity	NTU	7	7	100	41	20	3.5	3.5	5.2	41	160	160	NA

Notes:

(1) Nondetect (censored) concentrations were replaced with ½ of the reporting limit for calculating average concentrations. The remaining statistics in this table were only calculated when analytes were detected at a sufficient frequency. For example, if an analyte was detected in fewer than 50% of samples, then a median concentration was not calculated. A blank cell reflects a situation when a median or percentile could not be computed based on detected concentrations. The percentiles are the concentrations of each analyte below which at least that percentage of the values fall. So the 10th percentile is the concentration below which at least 10% of the observations were found.

(2) Screening BM represents the screening benchmark referred to in Section 3.1.3, and is the most stringent 2006 NRWQC or other conservative benchmark used to calculate PHQs.

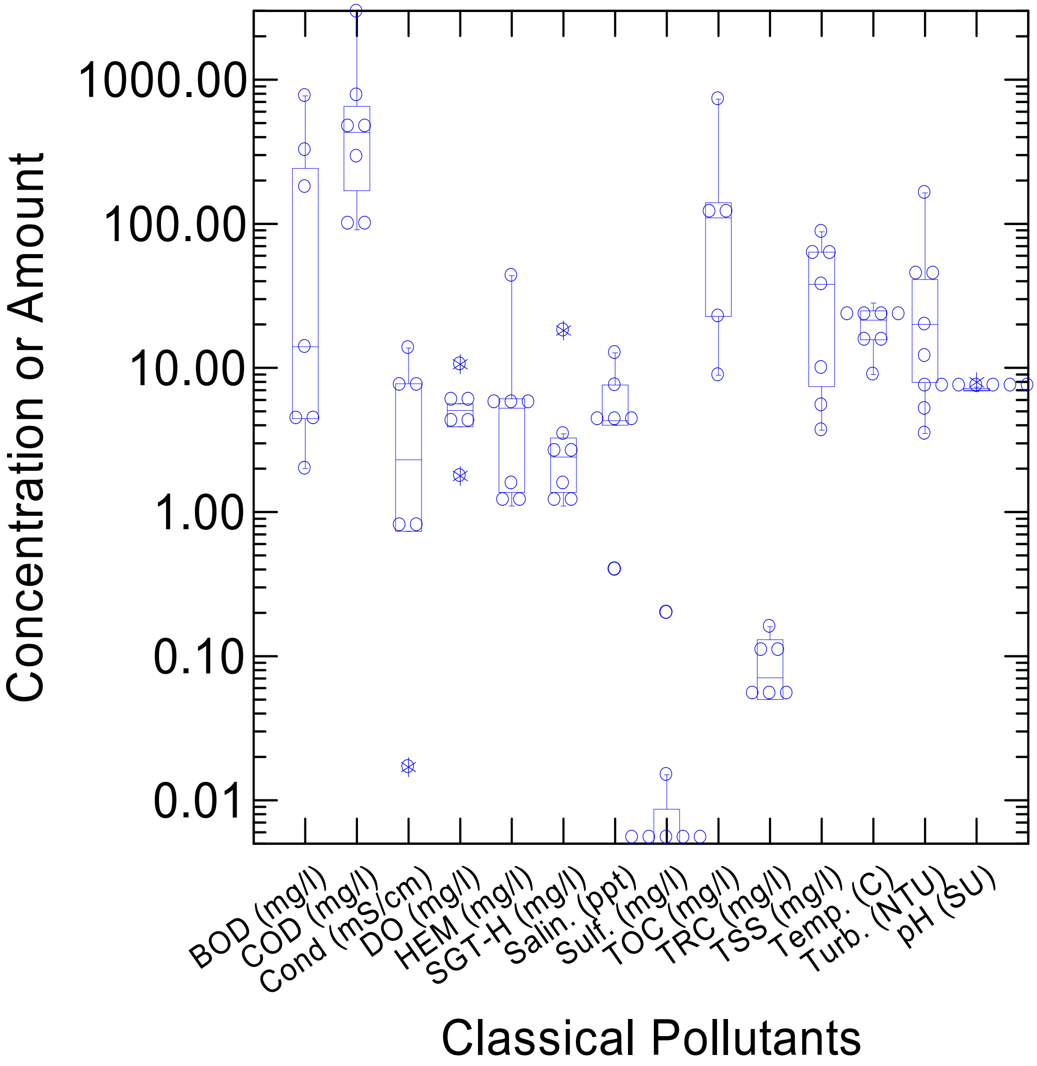

Figure 3.1.5. Box and Dot Density Plot of Classical Pollutant Concentrations Measured in Samples of Bilgewater

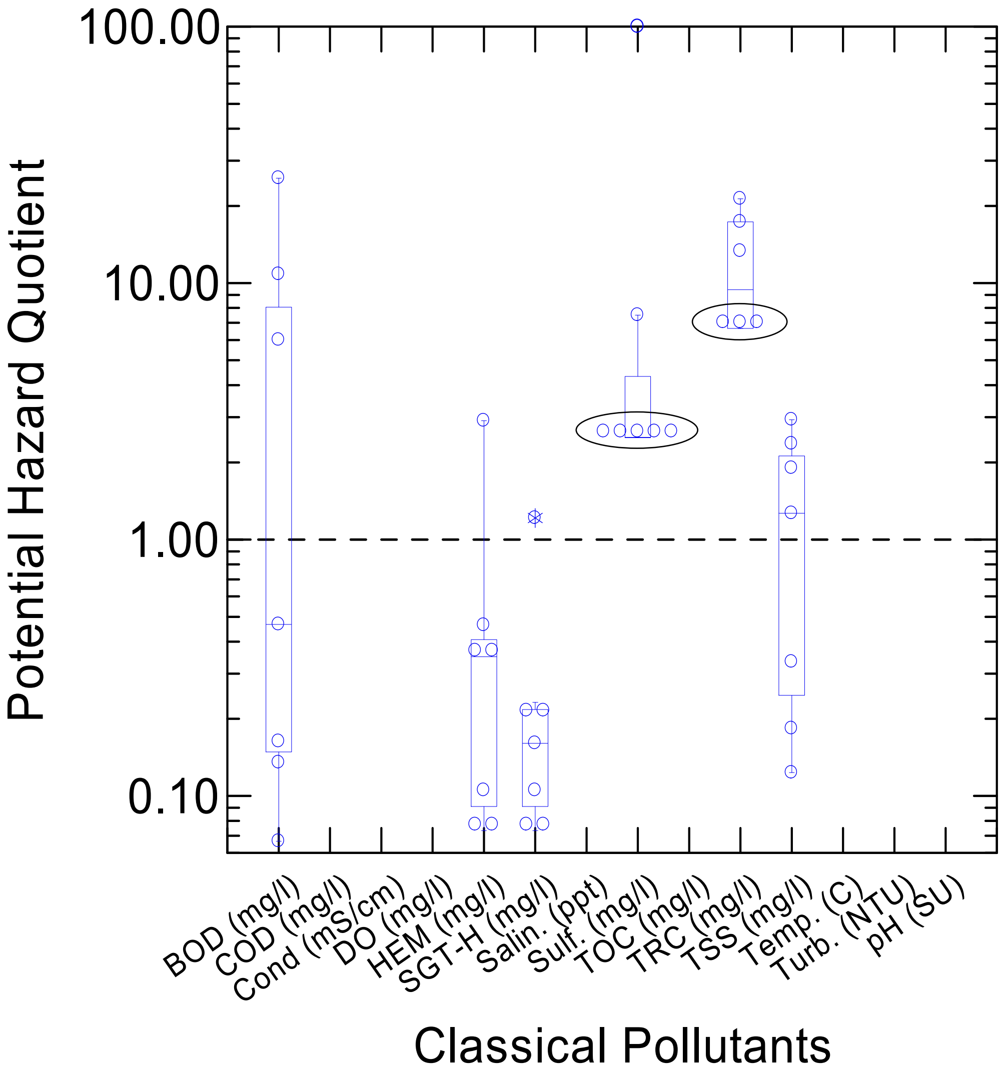

Figure 3.1.6. Box and Dot Density Plot of Potential Hazard Quotients for Classical Parameters in Samples of Bilgewater
(Note: Replacement values for non-detects are circled).

3.2.1.3 Pathogen Indicators (Microbiologicals)

Bilgewater samples[19] from two commercial fishing vessels were analyzed for the pathogen indicator bacteria *E. coli*, enterococci, and fecal coliform (commercial fishing vessels only) (see Table 3.1.4). *E. coli* and enterococci were detected in a bilgewater sample collected from a shrimping vessel, and fecal coliform were detected in bilgewater from two fishing vessels (a longliner and the shrimper).

The NRWQC for pathogen indicators references the bacteria standards in EPA's 1986 *Quality Criteria for Water*, commonly known as the Gold Book. NRWQC standards for bacteria are described in terms of three different water body use criteria: freshwater bathing, marine water bathing, and shellfish harvesting waters.

For each of the pathogen indicators, the lowest NRWQC was exceeded in one of the bilgewater samples. The *E. coli* value (393 MPN/100 mL) exceeds the freshwater bathing NRWQC of 126 MPN/100 mL. The enterococci value (4,100 MPN/100 mL) exceeds the bathing NRWQCs of 33 CFU/100 mL for fresh water and 35 CFU/100 mL for salt water. One of the two fecal coliform values (118 CFU/100 mL) exceeds the NRWQC of 14 MPN/100 mL for shellfish harvesting[20].

Values of the pathogen indicators measured in these bilgewater samples exceed the values measured in nearby *ambient* surface water samples by factors ranging from 4 (for enterococci) to 15 (*E. coli*), suggesting that leakage or other entry of ambient water is not a significant source of these pathogen indicators in bilgewater. EPA is unsure as to the source of pathogen indicators in bilgewater.

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[19] Logistics prevented EPA from delivering all bilgewater samples to laboratories within allowable holding times.

[20] MPN is most probable number and approximates the unit of measure for fecal coliform in this study of CFU (colony forming units).

Table 3.1.4. Results of Bilgewater Sample Analyses for Pathogen Indicators[1]

Analyte	Units[2]	No. Samples	No. detected	Detected Proportion (%)	Average Conc.	Median Conc.	Minimum Conc.	10%	25%	75%	90%	Maximum Conc.	Screening BM[3]
E. Coli	MPN/100 ml	1	1	100	390								130
Enterococci	MPN/100 ml	1	1	100	4100								33
Fecal Coliform	CFU/100 ml	2	2	100	61	120	4.0	4.0	4.0	120	120	120	14

Notes:

(1) Nondetect (censored) concentrations were replaced with ½ of the reporting limit for calculating average concentrations. The remaining statistics in this table were only calculated when analytes were detected at a sufficient frequency. For example, if an analyte was detected in fewer than 50% of samples, then a median concentration was not calculated. A blank cell reflects a situation when a median or percentile could not be computed based on detected concentrations. The percentiles are the concentrations of each analyte below which at least that percentage of the values fall. So the 10th percentile is the concentration below which at least 10% of the observations were found.

(2) MPN = Most Probable Number; CFU = Colony Forming Units.

(3) Screening BM represents the screening benchmark referred to in Section 3.1.3, and is the most stringent 2006 NRWQC or other conservative benchmark used to calculate PHQs.

3.2.1.4 Nutrients

Bilgewater samples were analyzed for four nutrient-related parameters: ammonia nitrogen, nitrate/nitrite, total Kjeldahl nitrogen (TKN), and total phosphorus (see Table 3.1.5). The box and dot density plots in Figure 3.1.7 illustrate the variability of the nutrient concentrations measured in bilgewater. Ammonia, TKN and total phosphorus concentrations were elevated in a single bilgewater sample collected from a longliner fishing vessel. The elevated nutrient concentrations may be attributable to seepage from the/ice slurry in the fish hold of the longliner. Water containing biological material (e.g., fish waste tissues, excreta) might seep down into the bilge compartment, resulting in an increase in nutrient discharge.

Ammonia is the only nutrient for which there are currently numeric NRWQC. EPA established these numeric criteria based on chronic toxicity to aquatic life, not nutrient enrichment. An ammonia-nitrogen concentration of 7.6 mg/L, measured in the bilgewater sample from the longliner fishing vessel, exceeded the NRWQC chronic criteria in both salt water (1.2 mg/L) and fresh water (1.24 mg/L). Three of the five bilgewater samples for total phosphorous exceeded EPA's 0.1 mg/L 1986 Gold Book criterion. The highest total phosphorus concentration, 13 mg/L, exceeded the benchmark by a factor of 130. Figure 3.1.8 presents box and dot density plots of the PHQs calculated for the nutrient data.

EPA compared nutrient concentrations in the bilgewater samples to ambient concentrations in surface water samples collected near the vessels. Ammonia was detected in one of the ambient samples at a concentration of 0.11 mg/L, comparable (within a factor of two) to the concentration in the corresponding bilgewater sample, 0.13 mg/L. TKN was detected in three ambient samples; in one, the ambient concentration of 0.60 mg/L marginally exceeded the bilgewater concentration of 0.55 mg/L. However, ambient TKN concentrations were less than the bilgewater concentrations in the other two cases. For total phosphorus, the comparison showed the concentrations detected in two ambient samples were comparable to the corresponding bilgewater concentrations; however, total phosphorus was not detected in the ambient samples corresponding to the three bilgewater samples having the highest total phosphorus concentrations. Thus, although ambient nutrient concentrations appear to be comparable to the *lower* concentrations of nutrients in bilgewater and may be a partial source of these nutrients in some samples, they cannot explain the sources of the *higher* nutrient concentrations measured in other samples.

Table 3.1.5. Results of Bilgewater Sample Analyses for Nutrients[1]

Analyte	Units	No. samples	No. detected	Detected Proportion (%)	Average Conc.	Median Conc.	Minimum Conc.	10%	25%	75%	90%	Maximum Conc.	Screening BM[2]
Ammonia As Nitrogen (NH3-N)	mg/L	5	4	80	1.7	0.24			0.064	4.0	7.6	7.6	1.2
Nitrate/Nitrite (NO3/NO2-N)	mg/L	7	5	71	0.38	0.18				0.36	1.9	1.9	NA
Total Kjeldahl Nitrogen (TKN)	mg/L	5	5	100	16	2.5	0.55	0.55	1.0	39	73	73	NA
Total Phosphorus	mg/L	5	5	100	3.0	0.47	0.084	0.084	0.093	7.1	13	13	0.10

Notes:

(1) Nondetect (censored) concentrations were replaced with ½ of the reporting limit for calculating average concentrations. The remaining statistics in this table were only calculated when analytes were detected at a sufficient frequency. For example, if an analyte was detected in fewer than 50% of samples, then a median concentration was not calculated. A blank cell reflects a situation when a median or percentile could not be computed based on detected concentrations. The percentiles are the concentrations of each analyte below which at least that percentage of the values fall. So the 10th percentile is the concentration below which at least 10% of the observations were found.

(2) Screening BM represents the screening benchmark referred to in Section 3.1.3, and is the most stringent 2006 NRWQC or other conservative benchmark used to calculate PHQs.

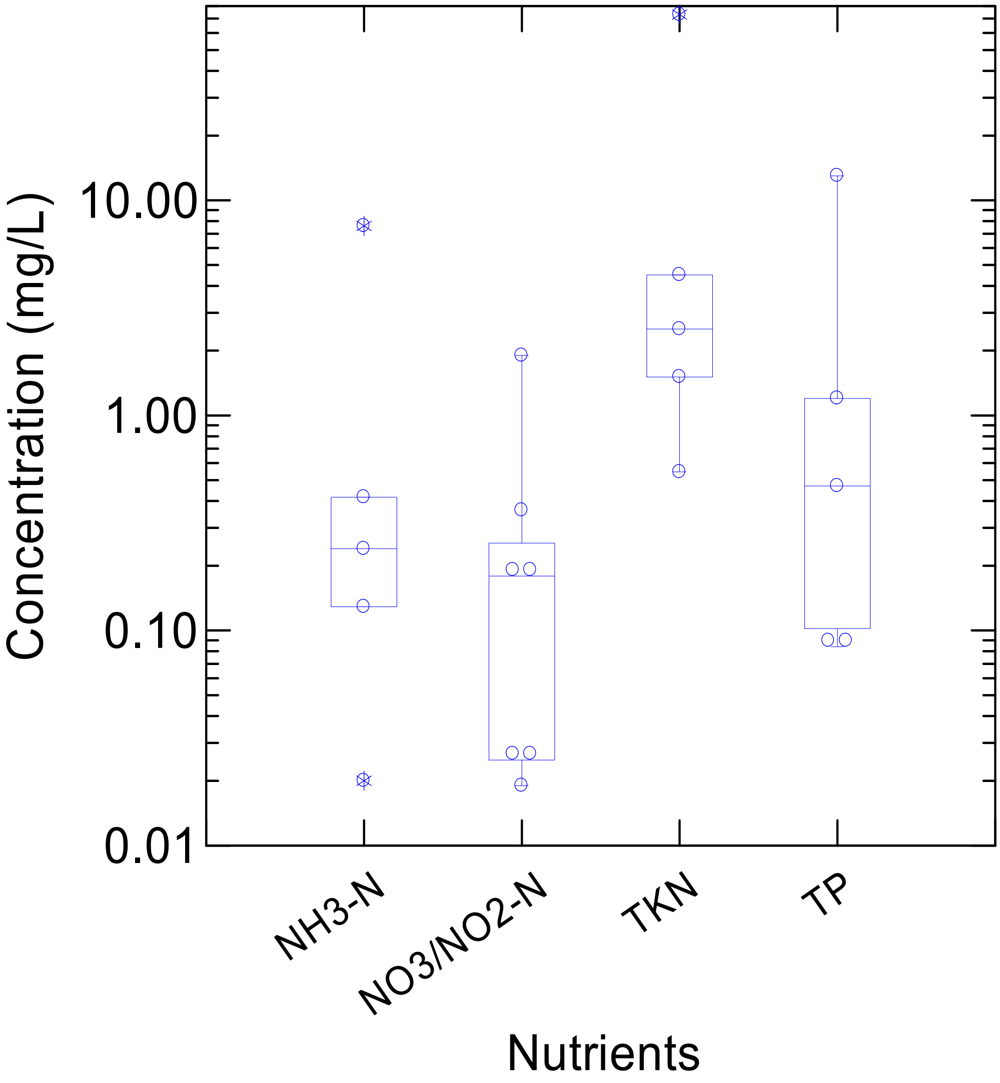

Figure 3.1.7. Box and Dot Density Plot of Nutrient Concentrations Measured in Samples of Bilgewater

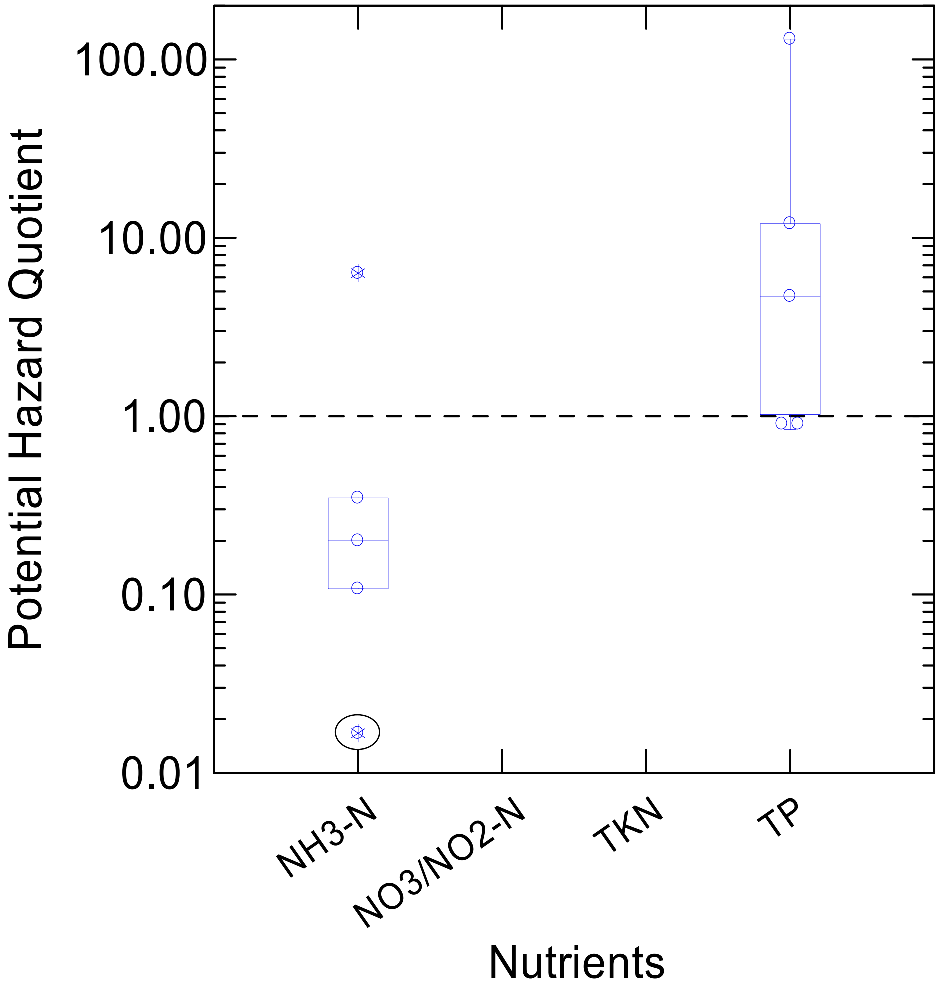

Figure 3.1.8. Box and Dot Density Plot of Potential Hazard Quotients for Nutrients in Samples of Bilgewater

(Note: Replacement values for non-detects are circled).

3.2.1.5 Semivolatile Organic Compounds (SVOCs)

Bilgewater samples were analyzed for 79 SVOCs. Out of the 79 analytes, 56 were not detected in any of the bilgewater samples. Of the remaining 23 SVOCs, 18 were only detected in a single bilgewater sample and five were found in multiple samples (see Table 3.1.6). Of these, bis(2-ethylhexyl) phthalate was detected in more than 50 percent of the samples. This SVOC is a manufactured chemical that is commonly added to plastics to make them flexible and can be found in a variety of products used on vessels such as hoses, tubing, and gaskets. Di-n-butyl phthalate, di-n-octyl phthalate, naphthalene, and phenanthrene were also detected in more than one bilgewater sample. There was no obvious trend in the occurrence of SVOCs based on the type of vessel sampled.

Figure 3.1.9 presents the range of concentrations measured for SVOCs in the bilgewater samples. Concentrations of five SVOCs (2-butoxy ethanol, 2- methyl-naphthalene, dimethyl phthalate, indole, and naphthalene) exceeded 100 µg/L in single (but not the same) bilgewater samples. It was difficult for EPA to compare the concentration distributions between SVOCs because the majority were detected in a single sample. Bis(2-ethylhexyl) phthalate and phenanthrene concentrations ranged over nearly two orders of magnitude.

The distributions of PHQs, based on the most conservative screening benchmarks, are displayed for each SVOC in Figure 3.1.10. PHQs for two SVOCs, 2,4,6-trichlorophenol and bis(2-ethylhexyl) phthalate, exceeded the screening threshold of one. The 2,4,6-trichlorophenol concentration (24 µg/L) measured in a single bilgewater sample from a tour boat exceeded the 1.4 µg/L human health (water and organism consumption) criterion by a factor of 17[21]. Bis(2-ethylhexyl) phthalate was detected in four of the seven bilgewater samples, at concentrations that exceeded the 1.2 µg/L human health (water and organism consumption) criterion by factors that ranged from 1.1 to 59. As shown in Figure 3.1.10, the PHQs for four other SVOCs were orders of magnitude less than 1, and therefore, likely pose little risk as pollutants from bilgewater discharges.

SVOCs were detected in two ambient samples, and for these chemicals (bis(2-ethylhexyl) phthalate and Di-n-butyl phthalate) the ambient concentrations were only comparable to the lowest concentrations measured in bilgewater.

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[21] Because of elevated reporting limits for this SVOC in several samples, replacement values for the nondetected concentrations exceed the benchmark (e.g., PHQ >1). However, these values were not based on measured concentrations and are therefore uncertain.

Table 3.1.6. Results of Bilgewater Sample Analyses for SVOCs[1]

Analyte	Units	No. samples	No. detected	Detected Proportion (%)	Average Conc.	Median Conc.	Minimum Conc.	10%	25%	75%	90%	Maximum Conc.	Screening BM[2]
2,4,6-Trichlorophenol	µg/L	7	1	14	7.0						24	24	1.4
2-Butoxy ethanol	µg/L	1	1	100	260								NA
2-Methylnaphthalene	µg/L	5	1	20	39					88	180	180	NA
3-Methyl-butanoic acid	µg/L	1	1	100	57								NA
4-Methyl-pentanoic acid	µg/L	1	1	100	38								NA
Benzeneacetic acid	µg/L	1	1	100	29								NA
Benzenepropanoic acid	µg/L	1	1	100	32								NA
Benzothiazole	µg/L	1	1	100	45								NA
Bis(2-ethylhexyl) phthalate	µg/L	7	4	57	15	1.4				21	71	71	1.2
Cholesterol	µg/L	1	1	100	88								NA
Dimethyl phthalate	µg/L	7	1	14	24						140	140	270000
Di-n-butyl phthalate	µg/L	7	2	29	4.0					1.4	4.9	4.9	2000
Di-n-octyl phthalate	µg/L	7	2	29	4.1					3.1	3.5	3.5	NA
Heptadecane	µg/L	1	1	100	56								NA
Indole	µg/L	1	1	100	160								NA
Naphthalene	µg/L	7	3	43	100					2.3	700	700	NA
n-Hexadecane	µg/L	1	1	100	39								NA
Nonadecane	µg/L	1	1	100	49								NA
p-Cresol	µg/L	5	1	20	7.7					8.7	17	17	NA
Phenanthrene	µg/L	7	2	29	12					1.3	69	69	NA
Phenol	µg/L	7	1	14	18						100	100	21000
Pyrene	µg/L	7	1	14	6.8						34	34	830
Triethyl Phosphate	µg/L	1	1	100	20								NA

Notes:

(1) Nondetect (censored) concentrations were replaced with ½ of the reporting limit for calculating average concentrations. The remaining statistics in this table were only calculated when analytes were detected at a sufficient frequency. For example, if an analyte was detected in fewer than 50% of samples, then a median concentration was not calculated. A blank cell reflects a situation when a median or percentile could not be computed based on detected concentrations. The percentiles are the concentrations of each analyte below which at least that percentage of the values fall. So the 10th percentile is the concentration below which at least 10% of the observations were found.

(2) Screening BM represents the screening benchmark referred to in Section 3.1.3, and is the most stringent 2006 NRWQC or other conservative benchmark used to calculate PHQs.

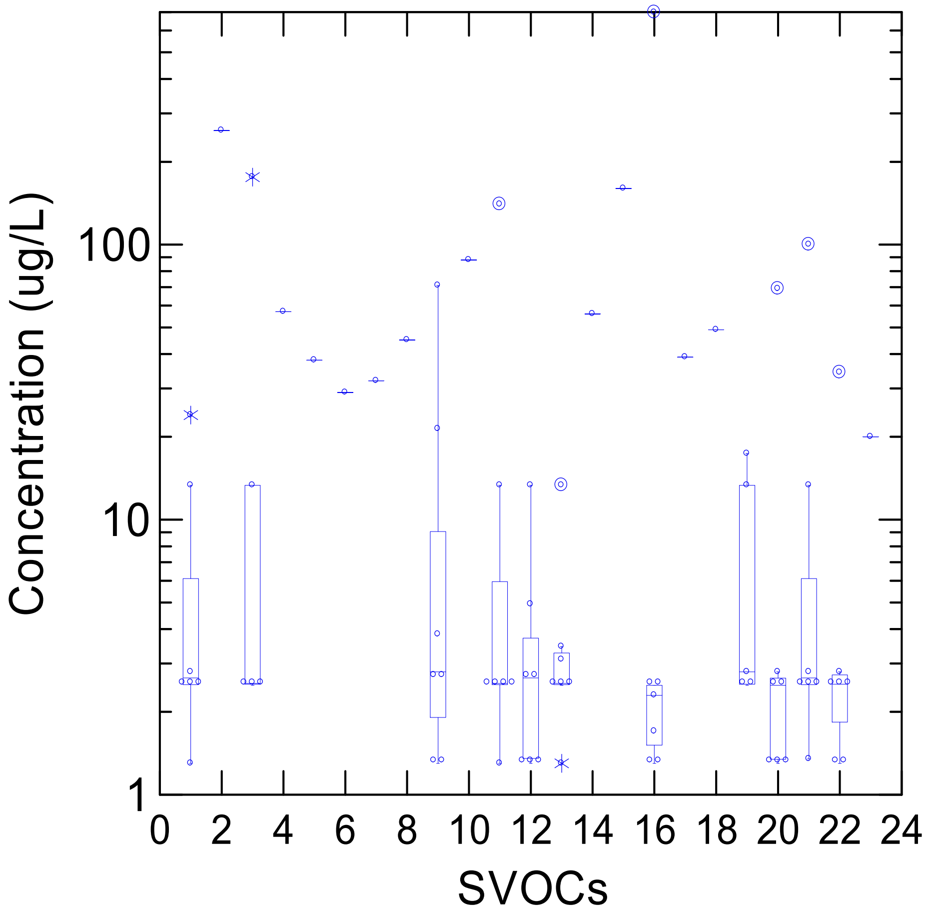

Figure 3.1.9. Box and Dot Density Plot of SVOC Concentrations Measured in Samples of Bilgewater

SVOCs are identified as follows (replacement values for non-detects are circled):

(1) 2,4,6-Trichlorophenol
(2) 2-Butoxy Ethanol
(3) 2-Methylnaphthalene
(4) 3-Methyl-Butanoic Acid
(5) 4-Methyl-Pentanoic Acid
(6) Benzeneacetic Acid
(7) Benzenepropanoic Acid
(8) Benzothiazole
(9) Bis(2-Ethylhexyl) Phthalate
(10) Cholesterol
(11) Dimethyl Phthalate
(12) Di-N-Butyl Phthalate
(13) Di-N-Octyl Phthalate
(14) Heptadecane
(15) Indole
(16) Naphthalene
(17) N-Hexadecane
(18) Nonadecane
(19) P-Cresol
(20) Phenanthrene
(21) Phenol
(22) Pyrene
(23) Triethyl Phosphate

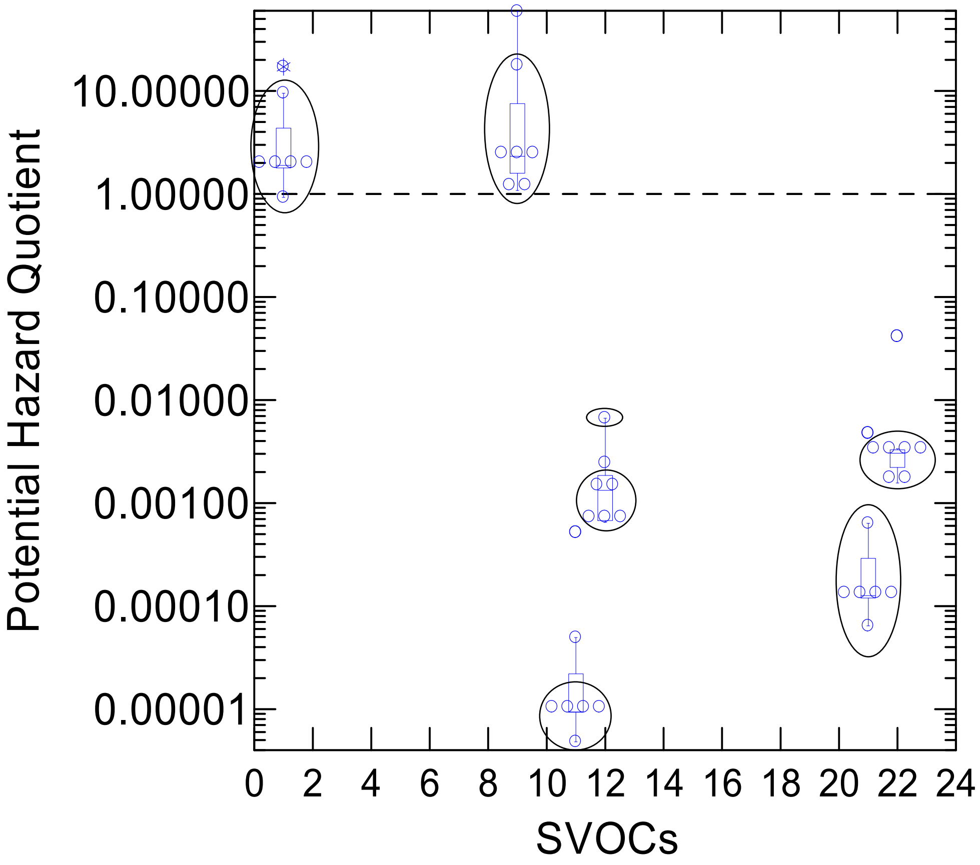

Figure 3.1.10. Box and Dot Density Plot of Potential Hazard Quotients for SVOCs in Samples of Bilgewater

SVOCs are identified as follows (replacement values for non-detects are circled):

(1) 2,4,6-Trichlorophenol
(2) 2-Butoxy Ethanol
(3) 2-Methylnaphthalene
(4) 3-Methyl-Butanoic Acid
(5) 4-Methyl-Pentanoic Acid
(6) Benzeneacetic Acid
(7) Benzenepropanoic Acid
(8) Benzothiazole
(9) Bis(2-Ethylhexyl) Phthalate
(10) Cholesterol
(11) Dimethyl Phthalate
(12) Di-N-Butyl Phthalate
(13) Di-N-Octyl Phthalate
(14) Heptadecane
(15) Indole
(16) Naphthalene
(17) N-Hexadecane
(18) Nonadecane
(19) P-Cresol
(20) Phenanthrene
(21) Phenol
(22) Pyrene
(23) Triethyl Phosphate

3.2.1.6 Volatile Organic Compounds (VOCs)

Bilgewater samples were analyzed for 72 VOCs. Out of the 72 analytes, 46 VOCs were not detected in any of the bilgewater samples. Of the remaining 26 VOCs, 11 were detected in more than one bilgewater samples and 15 were detected only in one bilgewater sample (see Table 3.1.7). Of the 11 VOCs that were detected in more than one bilgewater sample, the following were detected in more than 50 percent of the samples:

- 1,2,4-Trimethylbenzene
- 1,3,5-Trimethylbenzene
- Acetone
- Benzene
- m-,p-Xylene (sum of isomers)
- Methylene chloride
- O-Xylene.

2-butanone, ethylbenzene, styrene, and toluene were also detected in more than one bilgewater sample.

Figure 3.1.11 presents the range of concentrations measured for VOCs in the bilgewater samples. The VOC concentrations measured in bilgewater samples varied widely, with concentrations of a half-dozen VOCs ranging over three orders of magnitude. The maximum concentrations of four VOCs (1,2,4-trimethylbenzene, m-,p-xylene, o-xylene and toluene) exceeded 1,000 µg/L (1 mg/L), while the maximum concentrations of four other VOCs (1,3,5-trimethylbenzene, benzene, ethylbenzene and n-propylbenzene) exceeded 100 µg/L. Each of these maximum VOC concentrations was measured in the bilgewater sampled from one tow/salvage boat. These VOCs are commonly constituents of petroleum products, refining by-products, and gasoline additives, and are used as solvents.

Figure 3.1.12 presents the distributions of PHQs for each VOC, based on the most conservative screening benchmarks. The maximum PHQ for benzene, based on the 2.2 µg/L human health (water plus organism consumption) criterion benchmark, was 187. The maximum PHQ for toluene was marginally higher than one; the highest concentration of toluene (1,700 µg/L) exceeded the human health (water and organism consumption) criterion of 1,300 µg/L. For two other VOCs (chloroform and tetrachloroethene), only one of seven sample concentrations were detected, and these detected concentrations were below the screening benchmark. However, because the method detection limits for these two compounds were more than double their respective screening benchmarks, the resulting PHQs for these compounds, as reported in Figure 3.1.12, are greater than one when concentrations equal to ½ of the detection limit are included. Because these PHQ values were not based on detected concentrations, EPA considers them highly uncertain.

Finally, two VOCs (acetone and methylene chloride) were measured in ambient samples at concentrations comparable to the corresponding bilgewater concentration. However, these ambient concentrations were only comparable to the lowest concentrations of these VOCs measured in some bilgewater samples. Therefore, it is unlikely that leakage or other entry of ambient water is a significant source of the elevated acetone and methylene chloride concentrations measured in bilgewater.

Table 3.1.7. Results of Bilgewater Sample Analyses for VOCs[1]

Analyte	Units	No. samples	No. detected	Detected Proportion (%)	Average Conc. [3]	Median Conc.	Minimum Conc.	10%	25%	75%	90%	Maximum Conc. [3]	Screening BM [2]
1,2,4-Trimethylbenzene	µg/L	5	3	60	220	0.50				540	1100	1100	NA
1,3,5-Trimethylbenzene	µg/L	5	3	60	65	0.10				160	320	320	NA
2-Butanone	µg/L	5	2	40	2.6					2.8	3.7	3.7	NA
4-Isopropyltoluene	µg/L	5	1	20	3.3					3.3	6.5	6.5	NA
Acetone	µg/L	5	5	100	13	10	2.3	2.3	4.3	23	31	31	NA
Benzene	µg/L	7	4	57	61	0.10				1.3	410	410	2.2
Biphenyl	µg/L	5	1	20	4.5					0.87	1.7	1.7	NA
Carbon disulfide	µg/L	5	1	20	2.0					0.050	0.10	0.10	NA
Chloroform	µg/L	7	1	14	3.3						4.1	4.1	5.7
cis-1,2-Dichloroethene	µg/L	5	1	20	2.3					0.75	1.5	1.5	NA
Cyclohexane	µg/L	5	1	20	5.8					9.5	19	19	NA
Ethylbenzene	µg/L	7	3	43	68					1.3	460	460	530
Isopropylbenzene	µg/L	5	1	20	9.9					20	40	40	NA
m-,p-Xylene (sum of isomers)	µg/L	5	3	60	370	0.50				930	1900	1900	NA
Methyl tertiary butyl ether (MTBE)	µg/L	5	1	20	2.0					0.050	0.10	0.10	NA
Methylcyclohexane	µg/L	5	1	20	5.4					8.5	17	17	NA
Methylene chloride	µg/L	7	4	57	1.6	0.10				0.20	0.30	0.30	4.6
Nonanal	µg/L	1	1	100	3.1								NA
n-Pentadecane	µg/L	1	1	100	58								NA
n-Propylbenzene	µg/L	5	1	20	26					60	120	120	NA
O-Xylene	µg/L	5	3	60	240	0.20				590	1200	1200	NA
Styrene	µg/L	5	2	40	11					20	39	39	NA
Tetrachloroethene	µg/L	7	1	14	2.6						0.40	0.40	0.69
Toluene	µg/L	7	3	43	240					0.30	1700	1700	1300
Trichloroethene	µg/L	7	1	14	2.6						0.30	0.30	2.5
Trichlorofluoromethane	µg/L	7	1	14	3.5						5.5	5.5	NA

Notes:

(1) Nondetect (censored) concentrations were replaced with ½ of the reporting limit for calculating average concentrations. The remaining statistics in this table were only calculated when analytes were detected at a sufficient frequency. For example, if an analyte was detected in fewer than 50% of samples, then a median concentration was not calculated. A blank cell reflects a situation when a median or percentile could not be computed based on detected concentrations. The percentiles are the concentrations of each analyte below which at least that percentage of the values fall. So the 10th percentile is the concentration below which at least 10% of the observations were found.

(2) Screening BM represents the screening benchmark referred to in Section 3.1.3, and is the most stringent 2006 NRWQC or other conservative benchmark used to calculate PHQs.

(3) In some cases, the detected concentration(s) for an analyte could be lower than the replacement value (½ of the reporting limit) for a concentration that was nondetected. In an extreme (but possible) case, this could result in an average concentration for an analyte that is greater than the maximum detected concentration.

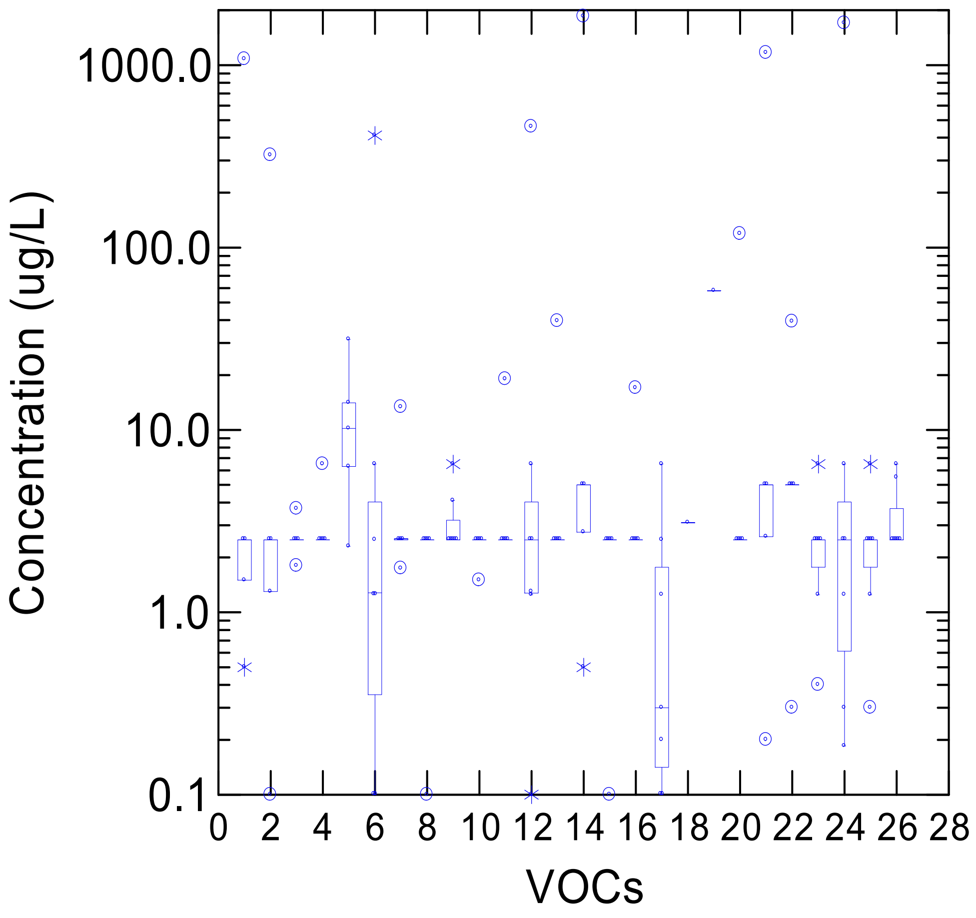

Figure 3.1.11. Box and Dot Density Plot of VOC Concentrations Measured in Samples of Bilgewater

VOCs are identified as follows:

(1) 1,2,4-Trimethylbenzene
(2) 1,3,5-Trimethylbenzene
(3) 2-Butanone
(4) 4-Isopropyltoluene
(5) Acetone
(6) Benzene
(7) Biphenyl
(8) Carbon Disulfide
(9) Chloroform
(10) Cis-1,2-Dichloroethene
(11) Cyclohexane
(12) Ethylbenzene
(13) Isopropylbenzene
(14) M-,P-Xylene (sum of isomers)
(15) Methyl Tertiary Butyl Ether (Mtbe)
(16) Methylcyclohexane
(17) Methylene Chloride
(18) Nonanal
(19) N-Pentadecane
(20) N-Propylbenzene
(21) O-Xylene
(22) Styrene
(23) Tetrachloroethene
(24) Toluene
(25) Trichloroethene
(26) Trichlorofluoromethane

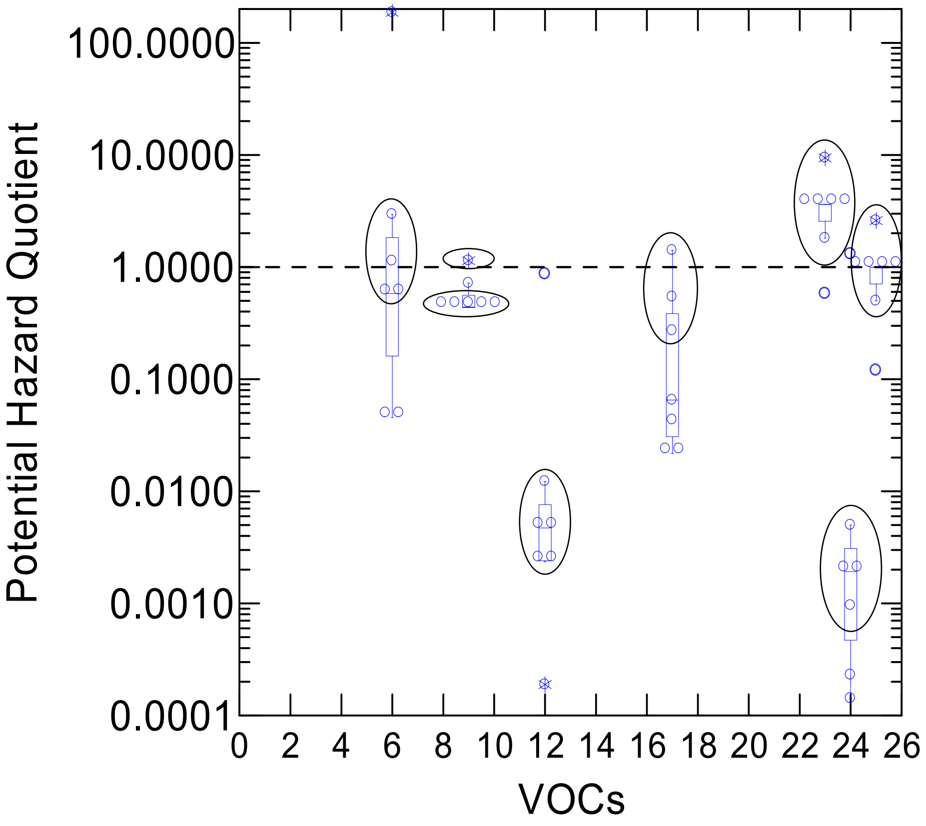

Figure 3.1.12. Box and Dot Density Plot of Potential Hazard Quotients for VOCs in Samples of Bilgewater

VOCs are identified as follows (replacement values for non-detects are circled):

(1) 1,2,4-Trimethylbenzene
(2) 1,3,5-Trimethylbenzene
(3) 2-Butanone
(4) 4-Isopropyltoluene
(5) Acetone
(6) Benzene
(7) Biphenyl
(8) Carbon Disulfide
(9) Chloroform
(10) Cis-1,2-Dichloroethene
(11) Cyclohexane
(12) Ethylbenzene
(13) Isopropylbenzene
(14) M-,P-Xylene (sum of isomers)
(15) Methyl Tertiary Butyl Ether (Mtbe)
(16) Methylcyclohexane
(17) Methylene Chloride
(18) Nonanal
(19) N-Pentadecane
(20) N-Propylbenzene
(21) O-Xylene
(22) Styrene
(23) Tetrachloroethene
(24) Toluene
(25) Trichloroethene
(26) Trichlorofluoromethane

3.2.1.7 Nonylphenols

Bilgewater samples were analyzed for 34 long- and short-chain nonylphenol and octylphenol ethoxylates (two discrete subsets of alkylphenol ethoxylates), as well as total nonylphenol. Of these analytes, 14 alkylphenol ethoxylates were not detected and 20 were detected in a single bilgewater sample (see Table 3.1.8). Of the 20 distinct alkylphenol ethoxylates detected, 16 were detected in the bilgewater from a tour boat, three were detected in the bilgewater from a tow/salvage boat, and one was detected in the bilgewater from a shrimper. Measured concentrations of ethoxylates in bilgewater ranged from less than 1 µg/L for three of the octylphenol ethoxylate isomers (OP10EO, OP12EO, and OP11EO) to 1,050 µg/L for total nonylphenol polyethoxylates (sum of NPEOs – NP5EO through NP18EO). This latter maximum concentration was measured in the bilgewater sample from the tour boat. According to the operator(s), the bilgewater discharged from this vessel is expected to possibly contain oil, grease, fuel, cleaning solvents, detergent and water from deck washdown. Of these pollutants, detergents are the most common source of NPEOs. Although there is no NRWQC for the sum of alkylphenol ethoxylates, they can degrade to total nonylphenol, which does have a NRWQC, in fresh and salt water.

The one detected concentration for total nonylphenol (NP, representative of the same nonylphenol isomers in the commercial mixture upon which EPA's NRWQC is based – CAS #84852-15-3) of 4.9 µg/L exceeded the saltwater chronic criterion of 1.7 µg/L by a factor of 2.9. Although the vessel operators added dish soap to the bilgewater prior to overboard discharge, this detergent is not necessarily the primary or only source of the detected nonylphenol. Lubricants also contain alkylphenol ethoxylates, and oil, grease, and fuel also might accumulate in bilgewater. The operators of three of the other vessels where bilgewater was sampled also reported using commercial bilge cleaners, yet NP was not detected in samples from those vessels. Furthermore, the operator of the tour boat from which 16 of the long- and short-chain alkylphenol ethoxylates were detected made no comment about using bilge cleaners. It is unlikely that ambient water is the source of NP to bilgewater in the detected sample.

Table 3.1.8. Results of Bilgewater Sample Analyses for Nonylphenols[1]

Analyte	Units	No. samples	No. Detected	Detected Proportion (%)	Average Conc.[3]	Median Conc.	Minimum Conc.	10%	25%	75%	90%	Maximum Conc.[3]	Screening BM[2]
Long-Chain Alkylphenol Ethoxylates													
Total Nonylphenol Polyethoxylates	μg/L	5	1	20	260					530	1100	1100	NA
Nonylphenol octodecaethoxylate (NP18EO)	μg/L	5	1	20	0.78					1.8	3.6	3.6	NA
Nonylphenol heptadecaethoxylate (NP17EO)	μg/L	5	1	20	1.8					4.2	8.4	8.4	NA
Nonylphenol hexadecaethoxylate (NP16EO)	μg/L	5	1	20	3.6					8.2	16	16	NA
Nonylphenol pendecaethoxylate (NP15EO)	μg/L	5	1	20	6.8					16	31	31	NA
Nonylphenol tetradecaethoxylate (NP14EO)	μg/L	5	1	20	12					28	56	56	NA
Nonylphenol tridecaethoxylate (NP13EO)	μg/L	5	1	20	20					44	88	88	NA
Nonylphenol dodecaethoxylate (NP12EO)	μg/L	5	1	20	27					61	120	120	NA
Nonylphenol undecaethoxylate (NP11EO)	μg/L	5	1	20	35					77	150	150	NA
Nonylphenol decaethoxylate (NP10EO)	μg/L	5	1	20	35					77	150	150	NA
Nonylphenol nonaethoxylate (NP9EO)	μg/L	5	1	20	33					70	140	140	NA
Nonylphenol octaethoxylate (NP8EO)	μg/L	5	1	20	28					57	110	110	NA
Nonylphenol heptaethoxylate (NP7EO)	μg/L	5	1	20	22					42	83	83	NA
Nonylphenol hexaethoxylate (NP6EO)	μg/L	5	1	20	16					27	53	53	NA
Nonylphenol pentaethoxylate (NP5EO)	μg/L	5	1	20	9.7					14	27	27	NA
Octylphenol dodecaethoxylate (OP12EO)	μg/L	5	1	20	0.97					0.25	0.49	0.49	NA
Octylphenol undecaethoxylate (OP11EO)	μg/L	5	1	20	1.4					0.38	0.77	0.77	NA
Octylphenol decaethoxylate (OP10EO)	μg/L	5	1	20	3.2					0.39	0.78	0.78	NA
Short-Chain Nonylphenols													
Bisphenol A	μg/L	4	1	25	5.3					11	15	15	NA
Nonylphenols													
NP	μg/L	4	1	25	9.2					3.7	4.9	4.9	1.7

Notes:

(1) Nondetect (censored) concentrations were replaced with ½ of the reporting limit for calculating average concentrations. The remaining statistics in this table were only calculated when analytes were detected at a sufficient frequency. For example, if an analyte was detected in fewer than 50% of samples, then a median concentration was not calculated. A blank cell reflects a situation when a median or percentile could not be computed based on detected concentrations. The percentiles are the concentrations of each analyte below which at least that percentage of the values fall. So the 10th percentile is the concentration below which at least 10% of the observations were found.

(2) Screening BM represents the screening benchmark referred to in Section 3.1.3, and is the most stringent 2006 NRWQC or other conservative benchmark used to calculate PHQs.

(3) In some cases, the detected concentration(s) for an analyte could be lower than the replacement value (½ of the reporting limit) for a concentration that was nondetected. In an extreme (but possible) case, this could result in an average concentration for an analyte that is greater than the maximum detected concentration.

3.2.1.8 Summary of the Characterization of Bilgewater Discharge

Table 3.1.9 summarizes the specific analytes within bilgewater effluent that may have the potential to pose risk to human health or the environment for these types of vessels based on these samples. EPA's interpretation of a realized risk likely posed by these analytes, relative to pollutant loadings, background ambient and source water contaminant levels and characteristics, and other relevant information useful for this assessment, is presented in Chapter 5.

In summary, among the metals, dissolved copperand zinc were consistently measured at concentrations exceeding the most stringent NRWQC in fishing vessels, tow/salvage vessels, water taxis, and tour vessels; total arsenic was also measured at concentrations exceeding the most stringent NRWQC in a Longliner fishing vessel, a tow/salvage vessel, and tour vessel. The classical pollutants BOD, COD, sulfide, TSS, and TRC exceeded the screening benchmarks in at least one of the fishing vessels, tow/salvage vessels, water taxis, and tour vessels. Among the pathogen indicators, enterococcus, *E. coli* and fecal coliform bacteria were all present at concentrations exceeding NRWQC; these samples were collected only from fishing boats. Total phosphorus was the only nutrient to exceed a screening benchmark in bilgewater from all vessel types, while ammonia exceeded the screening benchmark in a fishing vessel (longliner). Concentrations of the SVOC bis(2-ethylhexyl) phthalate exceeded NRWQC in the bilgewater discharges of fishing vessels, tow/salvage vessels, water taxis, and tour vessels, while 2,4,6-trichlorophenol exceeded the screening benchmark in only the tour vessel. Benzene and toluene sampled from tow/salvage vessels were the only VOCs found at concentrations exceeding the most stringent NRWQC. The screening benchmark for total nonylphenol was exceeded in a single sample collected from a fishing vessel.

Table 3.1.9. Characterization of Bilgewater Discharge and Summary of Analytes that May Have the Potential to Pose Risk

Vessel Type (no. vessels)	**Analytes that May Have the Potential to Pose Risk in Bilgewater Discharge and Vessel Sources**[1, 2]												
	Microbiologicals	**Volatile Organic Compounds**	**Semivolatile Organic Compounds**	**Metals (dissolved)**	**Metals (total)**	**Oil and Grease**	**Sulfide**	**Short-Chain Alkylphenol Ethoxylates and NP**	**Long-Chain Alkylphenol Ethoxylatess**	**Nutrients**	**BOD, COD, and TOC**	**Total Suspended Solids**	**Other Physical/Chemical Parameters**
Fishing (2)	**enterococcus,** *E. coli*, Fecal Coliform			**Cu**, Zn	**As**		**x**	**x**		**TP,** Ammonia	BOD, COD, TOC	x	**TRC**
Tow/Salvage (2)		**Benzene,** Toluene	**Bis(2-ethylhexyl)-phthalate**	**Cu**, Zn	**As**	x	x			TP	**BOD, COD, TOC**	x	TRC
Water Taxis (2)			Bis(2-ethylhexyl)-phthalate	**Cu**, Zn	As								TRC
Tour (1)			**Bis(2-ethylhexyl)-phthalate,** **2,4,6-Trichloro-phenol**	**Cu, Cd**, Zn	**As**				**x**	**TP**	BOD, COD, TOC	x	**TRC**

(1) Analytes are generally **bolded** when a large proportion of the samples have concentrations exceeding the NRWQC (e.g., 25 to 50 percent), when several of the samples have PHQs > 10 (e.g., two or three of five), when a few samples result in PHQs greatly exceeding the screening benchmark (i.e., 100s to 1,000s), or, in the case of oil and grease and for nonylphenol, when one or more samples exceed an existing regulatory limit by more than a factor of 2. See text in Section 3.1.3 for a definition of PHQs and Table 3.1 for screening benchmarks used to calculate these values.

(2) EPA notes that the conclusion of potential risk is drawn from a small sample size, in some cases a single vessel, for certain discharges sampled from some vessel classes. EPA included these results in the tables to provide a concise summary of the data collected in the study, but strongly cautions the reader that these conclusions, where there are only a few samples from a given vessel class, should be considered preliminary and might not necessarily represent pollutant concentrations from these discharges from other vessels in this class.

3.2.2 Stern Tube Packing Gland Effluent

The packing gland or stuffing box surrounds the propeller shaft at the point it exits a boat's hull underwater. Based on the vessels sampled for this analysis, using a packing gland is a common method for preventing water from entering the hull while still allowing the propeller shaft to turn. A stuffing box packed with greased flax rings is designed to leak a few drops per minute of ambient water to cool the gland when a vessel is underway. Stuffing boxes are also used to seal rudder stocks that penetrate the hull below the waterline. The packing gland effluent water is often collected in a segregated section of the bilge that generally contains an automatic bilge pump.

During this study, EPA observed this segregated discharge onboard tugboats but not on any other vessel classes. In most of the other vessels sampled, the packing gland effluent dripped directly into the bilge. Possible constituents of concern in the packing gland effluent include metals (from contact of the discharge with the drive shaft), hydraulic fluid, grease or lubricants found in the gland, and fuel constituents since the packing gland is located in the engine compartment.

Based on field observations from EPA's vessel sampling program, EPA estimated the drip rate into the stuffing box at approximately 10 drips per minute, which is consistent with the literature data (Casey, 2007; Chin, 2005). This equates to a stern tube effluent generation rate of between 2 and 4 gpd. Since most tugboats had dual propeller systems, these boats are expected to generate between 4 and 8 gpd of stern tube effluent.

For this study, EPA collected samples from the packing gland effluent from nine tugboats. Samples on these vessels were analyzed for metals (dissolved and total), classical pollutants, nutrients, VOCs, SVOCs, and nonylphenols. Packing gland effluent samples were collected by placing a glass transfer jar under the shaft to collect any water dripping and then compositing the sample in a Teflon-lined pail. In some cases, EPA dipped the transfer jar into the segregated bilge compartment. If the vessels had a dual propeller system, EPA collected samples from each for the composite. However, samples for analysis of oil and grease and VOCs are not appropriate to composite, so these samples were collected separately.

3.2.2.1 Metals

Packing gland effluent samples were analyzed for both total and dissolved concentrations of 22 metals. Of the 22 metals, 18 total metals and 15 dissolved metals were detected in the EPA sample set (see Table 3.2.1). Antimony, beryllium, silver, and cadmium were not detected in any samples in the total or dissolved form, while cobalt, iron, thallium, and vanadium were not detected in the dissolved form. Figures 3.2.1 and 3.2.2 present box and dot density plots of the detected results for dissolved and total metals, respectively. The box and density plots in Figures

3.2.3 and 3.2.4 present these same detected results for dissolved and total metals, respectively, normalized by the lowest NRWQC where applicable. Points on these plots above the dashed line (demarking a PHQ of 1) indicate metals concentrations exceeding the benchmark. With a few exceptions, the metal concentrations normalized by the lowest NRWQC were below the PHQ of 1.

Dissolved and total aluminum were found in all nine samples analyzed. Dissolved aluminum was detected at concentrations ranging from 7.8 to 150 μg/L in the packing gland effluent; however, no screening benchmark is available for dissolved aluminum. Total aluminum was detected at concentrations ranging from 50.7 to 6,400 μg/L and exceeded the screening benchmark of 87 μg/L eight times. Arsenic, both total and dissolved, was detected in three of nine samples in the packing gland effluent, although the sample with the highest measured total and dissolved arsenic concentrations may be elevated resulting from positive interference (see discussion in Section 3.1.3). All three total arsenic values exceeded the screening benchmark of 0.018 μg/L (based on the human health criterion for drinking water plus fish consumption) with values of 2.8, 4.4, and 15.3 μg/L. None of the three detected dissolved arsenic values (1.2, 1.4 and 14.7 μg/L) exceeded the screening benchmark of 36 μg/L (based on the saltwater chronic criterion for the protection of aquatic life). Dissolved copper was detected in four of nine samples with values ranging from16.2 to 92 μg/L. All four sample values exceeded the screening benchmark of 3.1 μg/L. Total copper was detected in seven of the nine samples from the packing gland effluent, with values ranging from 7 to 891 μg/L. None of the total copper values exceeded the screening benchmark of 1,300 μg/L.

Dissolved and total nickel was detected in six of nine and eight of nine packing gland effluent samples respectively. Two of the total nickel results (1,670 and 3,230 μg/L) exceeded the screening benchmark of 610 μg/L, while all of the dissolved nickel values exceeded the screening benchmark of 8.2 μg/L. Zinc was found in seven of nine samples in the dissolved form and eight of nine samples in the total form. One sample value of 120 μg/L for dissolved zinc exceeded the screening benchmark of 81 μg/L. Selenium was found in three of nine samples in the dissolved form and only one of nine samples in the total form (the latter an exceptionally high concentration of 42.1 μg/L suspected of reflecting positive interference). Dissolved chromium and lead were also detected in several samples. Chromium values exceeded the benchmark criteria of 11 μg/L in four detected samples. Dissolved lead was detected at a concentration of 4.9 μg/L, which slightly exceeded the benchmark of 2.5 μg/L.

Total iron, manganese, and thallium were all detected at levels below the screening benchmarks, except for one sample for total thallium that was detected at the reporting level of 1 μg/L. This sample exceeded the benchmark of 0.24 μg/L for thallium and has a PHQ of 4.17 as shown on Figure 3.2.4. Barium, sodium, and potassium, in both forms (total and dissolved) were detected in three of three samples, but did not exceed benchmark criteria. The metals magnesium and calcium, in both forms (total and dissolved); cobalt and vanadium (in total); and dissolved manganese were detected in one or more samples but no screening criteria exists for these compounds.

EPA analyzed ambient metal concentrations to determine if dissolved and total aluminum concentrations found in packing gland effluent were contributed primarily by the vessel or reflected contributions primarily by background ambient concentrations. For both dissolved and total aluminum, sample concentrations were moderately influenced by ambient background concentrations, with ambient concentrations as high as 130 µg/L (dissolved aluminum) and 3,950 µg/L (total aluminum). For both dissolved and total arsenic, sample concentrations from stern tube packing gland effluent were strongly influenced by ambient background concentrations. Ambient dissolved and total arsenic concentrations as high as 16.1 and 15.4 µg/L, respectively, were measured in water surrounding one of the three vessels sampled (a vessel sampled in Baltimore, Maryland), although these measured concentrations may be elevated due to positive interference. Ambient background concentrations of both dissolved and total copper were comparatively low relative to the packing gland effluent sample concentrations and therefore of little influence (i.e., dissolved and total copper concentrations were largely from packing gland effluent). As in the case of copper, nickel was not found at high levels in the surrounding ambient water; thus, nickel is another metal that may have a significant source from the packing gland effluent. All of the selenium values were consistent with concentrations in the surrounding water. Neither chromium nor lead was strongly influenced by ambient concentrations in the surrounding water. The concentrations barium, sodium, potassium, magnesium, calcium cobalt, vanadium, and manganese generally reflect the concentrations in the surrounding water.

Table 3.2.1. Results of Packing Gland Effluent Sample Analyses for Metals[1]

Analyte	Units	No. samples	No. detected	Detected Proportion (%)	Average Conc.	Median Conc.	Minimum Conc.	10%	25%	75%	90%	Maximum Conc.	Screening BM[2]
Heavy and Other Metals													
Aluminum, Dissolved[4]	µg/L	9	9	100	88	110	7.8	7.8	31	140	150	150	NA
Aluminum, Total[4]	µg/L	9	9	100	1200	300	51	51	170	1500	6400	6400	87
Arsenic, Dissolved[3]	µg/L	9	3	33	3.3					1.3	15	15[5]	36
Arsenic, Total[3]	µg/L	9	3	33	3.8					3.6	15	15[5]	0.018
Barium, Dissolved[3]	µg/L	3	3	100	53	63	30	30	30	66	66	66	NA
Barium, Total[3]	µg/L	3	3	100	88	98	32	32	32	140	140	140	1000
Chromium, Dissolved	µg/L	9	5	56	19	3.8				20	110	110	11
Chromium, Total	µg/L	9	8	89	230	130			9.7	440	760	760	NA
Cobalt, Total[4]	µg/L	3	2	67	3.0	2.9				5.6	5.6	5.6	NA
Copper, Dissolved	µg/L	9	4	44	22					38	92	92	3.1
Copper, Total	µg/L	9	7	78	140	20			3.5	150	890	890	1300
Iron, Total[4]	µg/L	3	3	100	3900	2700	710	710	710	8300	8300	8300	300
Lead, Dissolved[4]	µg/L	9	1	11	1.8						4.9	4.9	2.5
Lead, Total	µg/L	9	3	33	7.9					8.9	43	43	NA
Manganese, Dissolved[4]	µg/L	9	8	89	44	9.6			2.9	53	250	250	NA
Manganese, Total[4]	µg/L	9	9	100	160	110	79	79	93	230	350	350	100
Nickel, Dissolved	µg/L	9	6	67	210	13				370	1000	1000	8.2
Nickel, Total	µg/L	9	8	89	610	45			12	970	3200	3200	610
Selenium, Dissolved[3]	µg/L	9	3	33	8.1					1.2	41	41[5]	5
Selenium, Total[3]	µg/L	9	1	11	8.6						42	42[5]	170
Thallium, Total[4]	µg/L	3	1	33	0.67					1.0	1.0	1.0	0.24
Vanadium,Total[3]	µg/L	3	1	33	4.6					13	13	13	NA
Zinc, Dissolved[4]	µg/L	9	7	78	34	18			3.3	53	120	120	81
Zinc, Total	µg/L	9	8	89	70	73			11	120	180	180	7400
Cationic Metals													
Calcium, Dissolved[3]	µg/L	9	9	100	36000	24000	23000	23000	23000	35000	110000	110000	NA
Calcium, Total[3]	µg/L	9	9	100	37000	24000	22000	22000	23000	39000	110000	110000	NA

Table 3.2.1. Results of Packing Gland Effluent Sample Analyses for Metals[1]

Analyte	Units	No. samples	No. detected	Detected Proportion (%)	Average Conc.	Median Conc.	Minimum Conc.	10%	25%	75%	90%	Maximum Conc.	Screening BM[2]
Magnesium, Dissolved[3]	µg/L	9	9	100	40000	7800	6200	6200	6500	11000	290000	290000	NA
Magnesium, Total[3]	µg/L	9	9	100	39000	7900	6000	6000	6300	12000	280000	280000	NA
Potassium, Dissolved[3]	µg/L	3	3	100	39000	4700	4000	4000	4000	110000	110000	110000	NA
Potassium, Total[3]	µg/L	3	3	100	37000	4600	4600	4600	4600	100000	100000	100000	NA
Sodium, Dissolved[3]	µg/L	3	3	100	810000	20000	18000	18000	18000	2400000	2400000	2400000	NA
Sodium,Total[3]	µg/L	3	3	100	810000	20000	17000	17000	17000	2400000	2400000	2400000	NA

Notes:

(1) Nondetect (censored) concentrations were replaced with ½ of the reporting limit for calculating average concentrations. The remaining statistics in this table were only calculated when analytes were detected at a sufficient frequency. For example, if an analyte was detected in fewer than 50% of samples, then a median concentration was not calculated. A blank cell reflects a situation when a median or percentile could not be computed based on detected concentrations. The percentiles are the concentrations of each analyte below which at least that percentage of the values fall. So the 10th percentile is the concentration below which at least 10% of the observations were found.

(2) Screening BM represents the screening benchmark referred to in Section 3.1.3, and is the most stringent 2006 NRWQC or other conservative benchmark used to calculate PHQs.

(3) Sample concentrations are strongly influenced by background concentrations in ambient water, accounting for greater than 90% of sample concentrations in the majority of samples.

(4) Sample concentrations are moderately influenced by background concentrations in ambient water, accounting for between 50 and 90% of sample concentrations in the majority of samples.

(5) Maximum concentrations may be elevated as a result of positive interference.

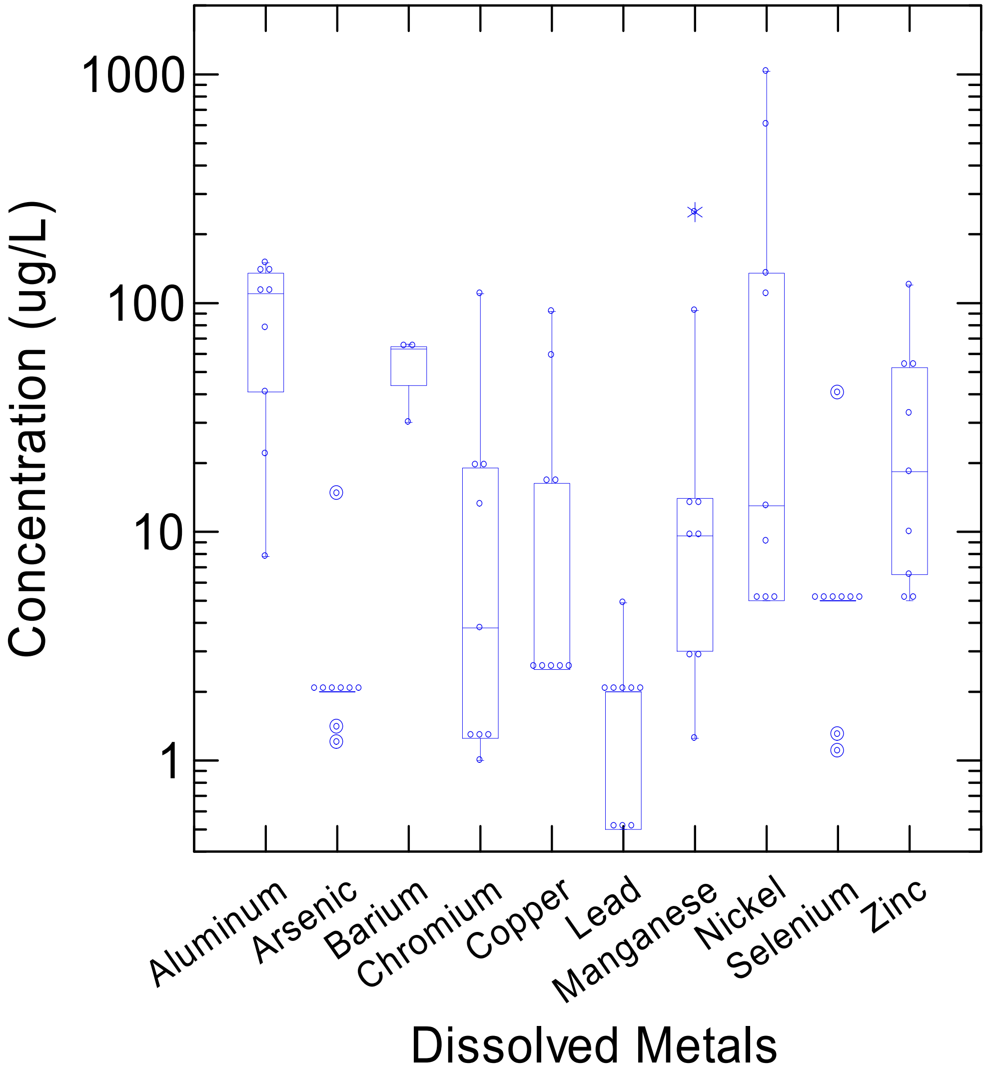

Figure 3.2.1. Box and Dot Density Plot of Dissolved Metals Concentrations Measured in Samples of Packing Gland Effluent

(Note: Maximum concentrations of arsenic and selenium may be elevated as a result of positive interference).

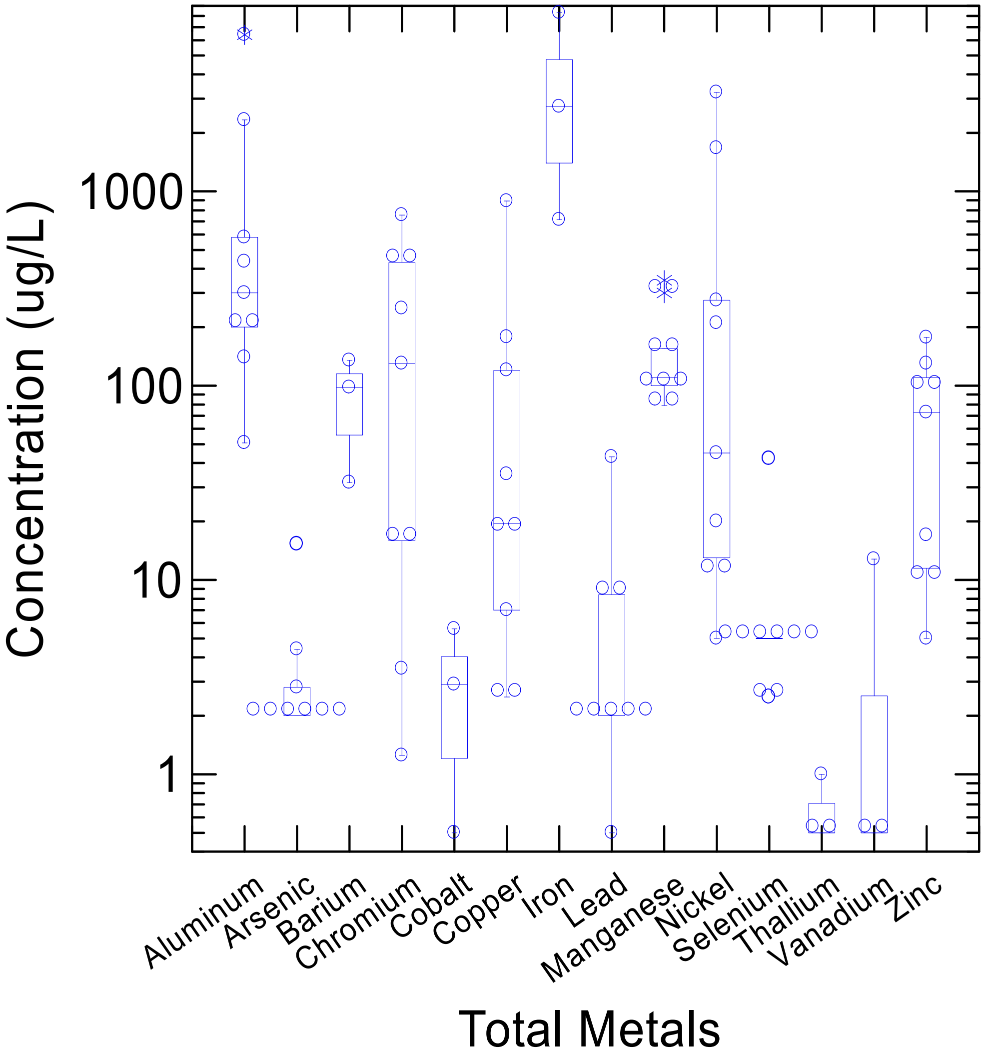

Figure 3.2.2. Box and Dot Density Plot of Total Metals Concentrations Measured in Samples of Packing Gland Effluent
(Note: Maximum concentrations of arsenic and selenium may be elevated as a result of positive interference).

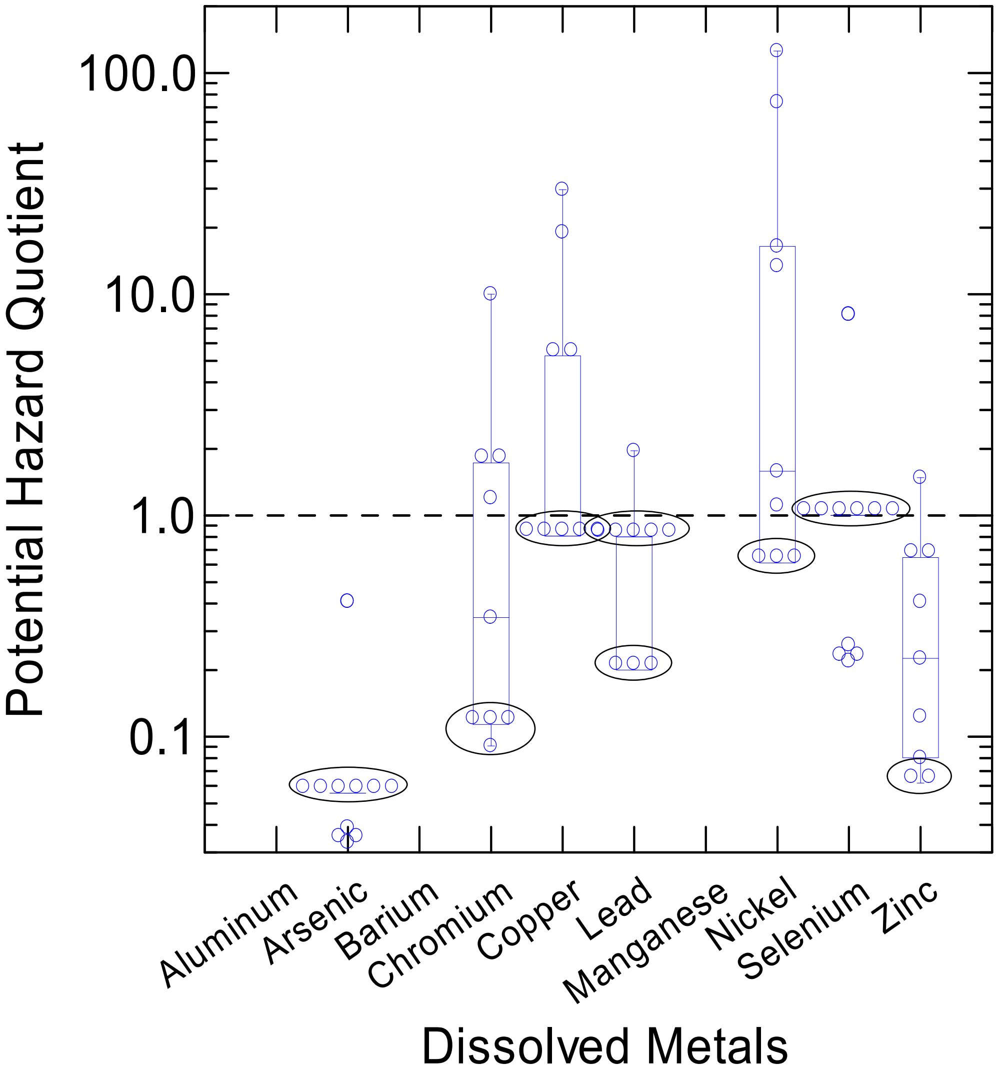

Figure 3.2.3. Box and Dot Density Plot of Potential Hazard Quotients for Dissolved Metals in Samples of Packing Gland Effluent

(Note: Replacement values for non-detects are circled. Also, maximum concentrations of arsenic and selenium may be elevated as a result of positive interference.)

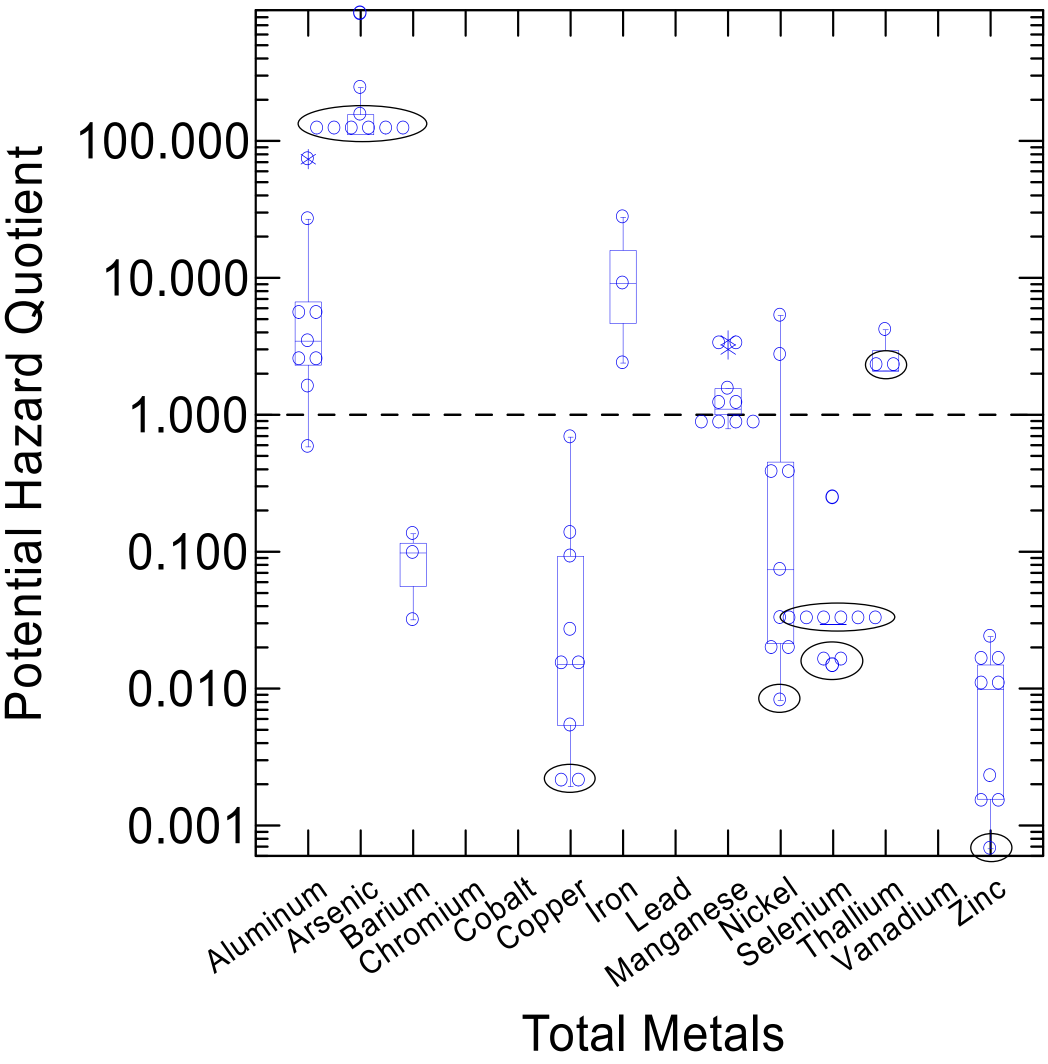

Figure 3.2.4. Box and Dot Density Plot of Potential Hazard Quotients for Total Metals in Samples of Packing Gland Effluent

(Note: Replacement values for non-detects are circled. Also, maximum concentrations of arsenic and selenium may be elevated as a result of positive interference).

3.2.2.2 Classical Pollutants

EPA sampled the packing gland effluent for numerous classical pollutants to further characterize this discharge type for the tugboats sampled under this program. The classical pollutants include measurements that are physical properties (temperature, conductivity, salinity, turbidity, TSS), oxygen consumption (BOD, COD), oil and grease (HEM and SGT-HEM), as well as chemical concentrations (pH, sulfide, DO, and TRC). Table 3.2.2 presents the data for these parameters.

Figure 3.2.5 illustrates the varied concentrations of measured for these parameters in the packing gland effluent. Most of the concentrations and values reported reflect the concentrations and values in the ambient water surrounding the vessel, as this water is the source of the drive shaft water. Two parameters (sulfide and TRC) were not detected in any samples.

The PHQs were calculated for the classical pollutants for which they were available. Only two pollutants exceeded these PHQ screening benchmarks (see Figure 3.2.6): oil and grease and TSS. One of the vessel samples had values which exceeded the screening benchmark for oil and grease measured as both HEM and petroleum hydrocarbon (SGT-HEM). The concentrations detected were 66.7 mg/L for HEM and 55.8 mg/L for SGT-HEM, both of which exceeded the benchmark of 15 mg/L. EPA noted a visible oily sheen on the surface of this effluent and evidence of settled hydrocarbons on the bottom of the tank as this sample was collected. Based upon conversations with the vessel engineer, the likely source is an oil leak that was somehow making its way into this effluent. This seems a plausible explanation given that background concentrations of HEM and SGT-HEM in surrounding ambient water were very low (< 1.5 mg/L) relative to the measured sample concentrations.

Total suspended solids were detected in all nine samples collected from the packing gland effluent. Two samples with concentrations of 269 and 134 mg/L exceeded the screening benchmark of 98 mg/L.

Table 3.2.2. Results of Packing Gland Effluent Sample Analyses for Classical Pollutants[1]

Analyte	Units	No. samples	No. detected	Detected Proportion (%)	Average Conc.	Median Conc.	Minimum Conc.	10%	25%	75%	90%	Maximum Conc.	Screening BM[2]
Conductivity	mS/cm	9	9	100	1.6	0.30	0.22	0.22	0.22	0.55	12	12	NA
Dissolved Oxygen	mg/L	9	9	100	8.3	8.4	5.3	5.3	7.2	9.3	11	11	NA
Total Organic Carbon (TOC)	mg/L	7	7	100	3.5	3.5	2.2	2.2	2.6	4.8	4.9	4.9	NA
Biochemical Oxygen Demand (BOD)	mg/l	9	9	100	11	7.2	3.3	3.3	4.3	13	35	35	30
Chemical Oxygen Demand (COD)	mg/l	9	4	44	31					53	88	88	NA
Hexane Extractable Material (HEM)	mg/l	9	5	56	14	1.65				23	67	67	15
pH	SU	9	9	100	7.1	7.5	2.4	2.4	7.3	8.0	8.2	8.2	NA
Salinity	ppt	8	7	88	0.14	0.20			0.10	0.20	0.20	0.20	NA
Silica Gel Treated HEM (SGT-HEM)	mg/l	9	5	56	13	1.7				19	56	56	15
Temperature	C	9	9	100	20	20	9.3	9.3	18	23	26	26	NA
Total Suspended Solids (TSS)	mg/l	9	9	100	59	28	5.6	5.6	13	81	270	270	30
Turbidity	NTU	9	9	100	46	18	9.0	9.0	13	70	190	190	NA

Notes:

(1) Nondetect (censored) concentrations were replaced with ½ of the reporting limit for calculating average concentrations. The remaining statistics in this table were only calculated when analytes were detected at a sufficient frequency. For example, if an analyte was detected in fewer than 50% of samples, then a median concentration was not calculated. A blank cell reflects a situation when a median or percentile could not be computed based on detected concentrations. The percentiles are the concentrations of each analyte below which at least that percentage of the values fall. So the 10th percentile is the concentration below which at least 10% of the observations were found.

(2) Screening BM represents the screening benchmark referred to in Section 3.1.3, and is the most stringent 2006 NRWQC or other conservative benchmark used to calculate PHQs.

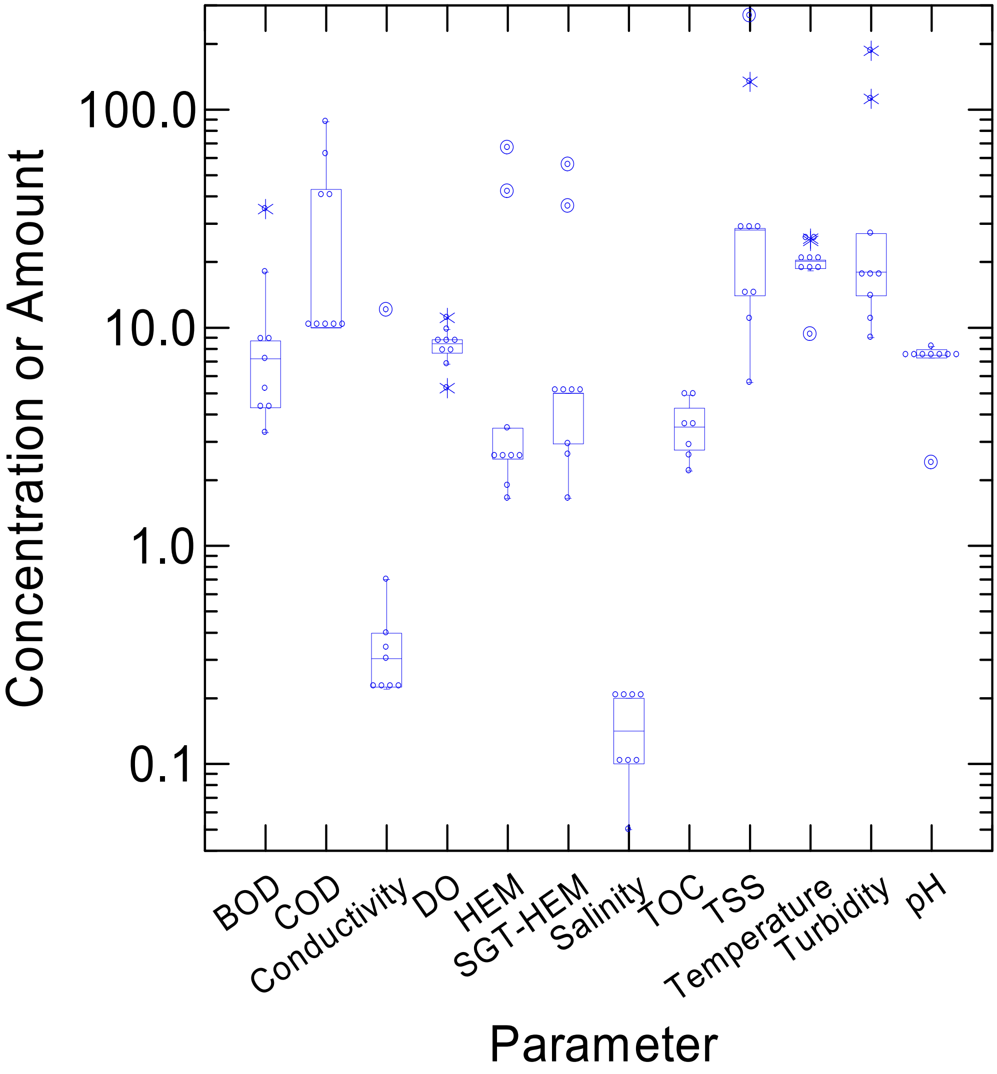

Figure 3.2.5. Box and Dot Density Plot of Classical Pollutants Measured in Samples of Packing Gland Effluent

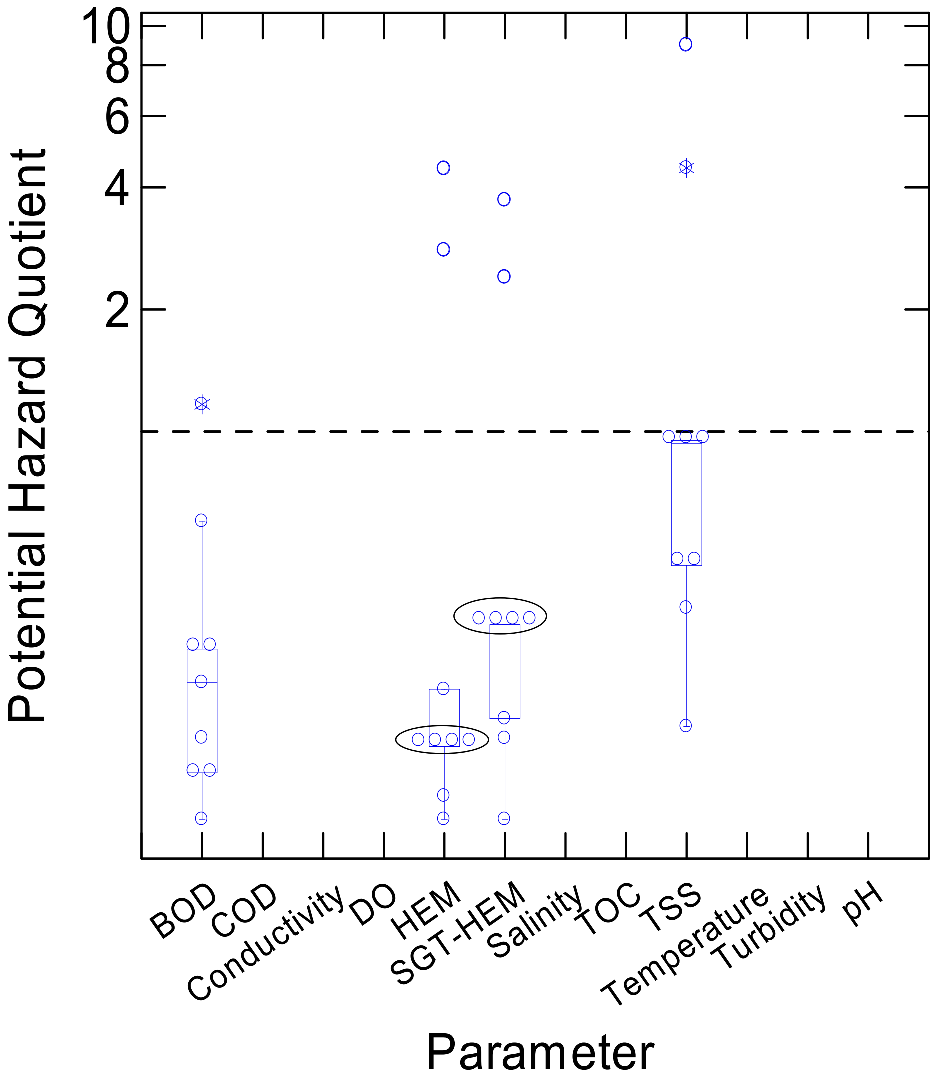

Figure 3.2.6. Box and Dot Density Plot of Potential Hazard Quotients for Classical Pollutants in Samples of Packing Gland Effluent
(Note: Replacement values for non-detects are circled).

3.2.2.3 Nutrients

Packing gland effluent samples were analyzed for four nutrient-related parameters: ammonia nitrogen, nitrate/nitrite, TKN, and total phosphorus (see Table 3.2.3). Figures 3.2.7 and 3.2.8 illustrate the variability of the nutrients in the packing gland effluent. Ammonia, nitrate/nitrite, and TKN were detected in most of the samples analyzed, but in relatively low concentrations. Phosphorus was detected in seven of the nine tugboat samples collected.

Only ammonia has a current numeric NRWQC value. The results for ammonia detected in the packing gland effluent range from 0.07 to 0.23 mg/L, well below the benchmark of 1.2 mg/L. TKN and nitrate/nitrite were detected in all of the nine tugboat samples, with values ranging from 0.40 to 1.8 mg/L for TKN to 0.62 to 1.5 mg/L for nitrate/nitrite. Total phosphorus was detected in seven of the nine samples for packing gland effluent. The detected concentrations ranged from 0.06 to 0.25 mg/L and only two values, 0.19 and 0.25 mg/L, exceed the 0.1 mg/L benchmark.

Most of these values for ammonia, TKN, and nitrate/nitrite are consistent with ambient background results in each location. The background ambient for these total phosphorus samples reported values from 0.06 to 0.19 mg/L, indicating a moderate influence of surrounding ambient water on sample concentrations.

In general, it appears that nutrient concentrations from packing gland effluent are generally low and the wastestream does not appear to be adding significant nutrients to the surrounding waters. Nutrient addition from packing gland effluent was not considered a likely concern in this discharge relative to metals from contact of the discharge with the drive shaft, hydraulic fluid, grease or lubricants from the gland, and fuel constituents.

Table 3.2.3. Results of Packing Gland Effluent Sample Analyses for Nutrients[1]

Analyte	Units	No. samples	No. detected	Detected Proportion (%)	Average Conc.	Median Conc.	Minimum Conc.	10%	25%	75%	90%	Maximum Conc.	Screening BM[2]
Ammonia As Nitrogen (NH3-N)	mg/L	9	7	78	0.10	0.10			0.034	0.14	0.23	0.23	1.2
Nitrate/Nitrite (NO3/NO2-N)	mg/L	9	9	100	0.69	0.62	0.085	0.085	0.58	0.80	1.5	1.5	NA
Total Kjeldahl Nitrogen (TKN)	mg/L	9	9	100	1.1	1.4	0.41	0.41	0.69	1.4	1.8	1.8	NA
Total Phosphorus	mg/L	9	7	78	0.13	0.10			0.030	0.22	0.25	0.25	0.10

Notes:

(1) Nondetect (censored) concentrations were replaced with ½ of the reporting limit for calculating average concentrations. The remaining statistics in this table were only calculated when analytes were detected at a sufficient frequency. For example, if an analyte was detected in fewer than 50% of samples, then a median concentration was not calculated. A blank cell reflects a situation when a median or percentile could not be computed based on detected concentrations. The percentiles are the concentrations of each analyte below which at least that percentage of the values fall. So the 10th percentile is the concentration below which at least 10% of the observations were found.

(2) Screening BM represents the screening benchmark referred to in Section 3.1.3, and is the most stringent 2006 NRWQC or other conservative benchmark used to calculate PHQs.

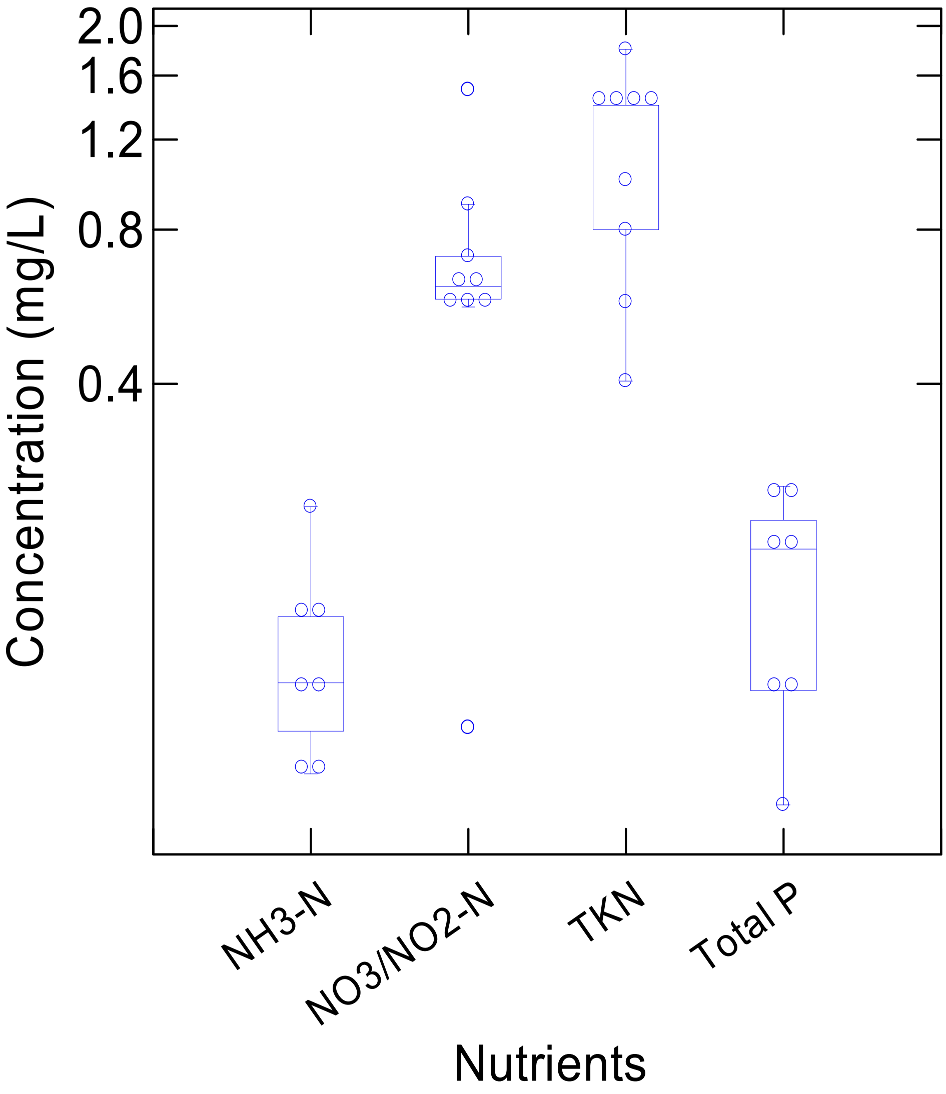

Figure 3.2.7. Box and Dot Density Plot of Nutrient Concentrations Measured in Samples of Packing Gland Effluent

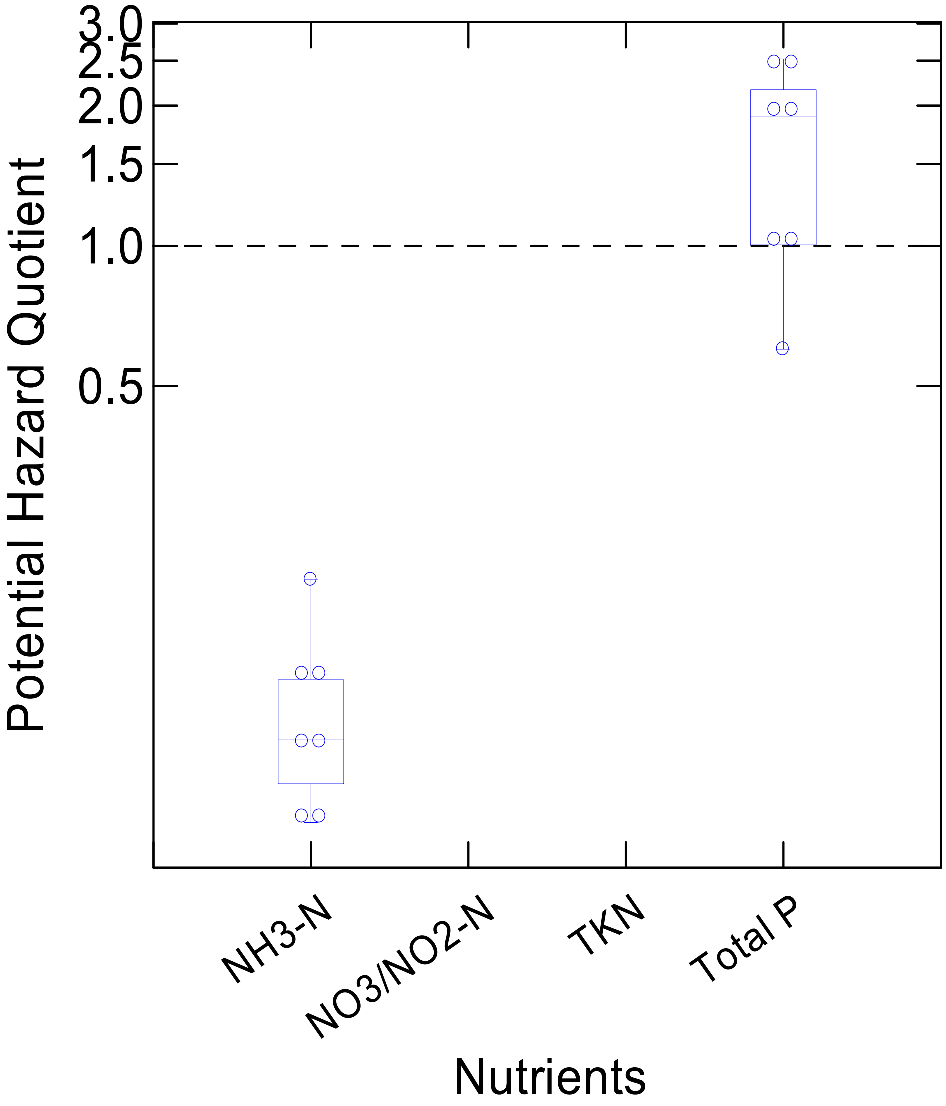

Figure 3.2.8. Box and Dot Density Plot of Potential Hazard Quotients for Nutrients in Packing Gland Effluent

3.2.2.4 Volatile and Semivolatile Organic Chemicals

Packing gland effluent samples were analyzed for 70 VOCs and 73 SVOCs in nine tugboats (see Table 3.2.4). Of the analytes tested, six VOC compounds and 10 SVOC compounds were detected in the samples. Figures 3.2.9 and 3.2.10 illustrate the range of concentrations measured for SVOCs and VOCs, respectively.

Three VOCs, m-p-xylene, acetone, and methylene chloride, were detected in more than one sample. Eight of the 10 SVOCs detected were found in one sample. Bis(2-ethylhexyl) phthalate was found in the effluent of three vessels sampled and n-hexadecane was found in the effluent of two of the vessels sampled. Bis(2-ethylhexyl) phthalate was detected at notably high (compared to ambient surrounding water) values of 2.8, 5.4, and 23.5 µg/L. The only other compound with a screening benchmark is di-n-butyl phthalate, which was detected in one sample with a concentration of 2.45 µg/L, which is well below the screening benchmark of 2,000 µg/L. These two phthalate compounds are used as plasticizers, and bis(2-ethylhexyl) phthalate is used as a hydraulic fluid and as a dielectric fluid in capacitors.

Figure 3.2.12 presents the distributions of PHQs, based on the most conservative screening benchmarks, for each VOC; none of the detected values exceed the screening threshold[22] . PQH was above one for all three samples of bis(2-ethylhexyl) phthalate, based on the screening benchmark of 1.2 µg/L (Figure 3.2.11).

Of the six VOC and 10 SVOC compounds detected in packing gland effluent samples, bis(2-ethylhexyl) phthalate was the only compound whose measured concentrations in the discharge was substantially higher than in ambient water; all other VOCs and SVOCs detected in packing gland effluent appear to reflect the similar concentrations found in surrounding water.

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[22] PHQs for benzene, methylene chloride and tetrachloroethene in multiple packing gland effluent samples were based on replacement values of ½ of the reporting limit for nondetected concentrations. In Figure 3.2.12 the PHQs based on replacement values for nondetected concentrations have been circled for identification. EPA does not consider PHQs that exceed 1 to signal that these discharges pose a potential risk to cause or contribute to the non-attainment of a water quality standard when the PHQs are based on replacement values for nondetected concentrations.

Table 3.2.4. Results of Packing Gland Water Sample Analyses for SVOCs and VOCs[1]

Analyte	Units	No. samples	No. detected	Detected Proportion (%)	Average Conc.[3]	Median Conc.	Minimum Conc.	10%	25%	75%	90%	Maximum Conc.[3]	Screening BM[2]
SVOCs													
2,6,10,14-Tetramethyl Pentadecane	µg/L	1	1	100	12								NA
3,6-Dimethylundecane	µg/L	1	1	100	8.7								NA
5-Butyl-Hexadecane	µg/L	1	1	100	6.7								NA
Bis(2-ethylhexyl) phthalate	µg/L	9	3	33	4.7					4.1	24	24	1.2
Di-n-butyl phthalate	µg/L	9	1	11	1.7						2.5	2.5	2000
Dodecane	µg/L	1	1	100	5.0								NA
Eicosane	µg/L	1	1	100	5.4								NA
n-Hexadecane	µg/L	2	2	100	5.5	6.0	5.0	5.0	5.0	6.0	6.0	6.0	NA
Nonanoic Acid	µg/L	1	1	100	4.3								NA
VOCs													
Acetone	µg/L	3	3	100	2.9	2.7	2.7	2.7	2.7	3.2	3.2	3.2	NA
Benzene	µg/L	9	1	11	1.4						0.20	0.20	2.2
m-,p-Xylene (sum of isomers)	µg/L	3	2	67	1.7	0.10				0.10	0.10	0.10	NA
Methylene chloride	µg/L	9	2	22	1.2					0.10	0.20	0.20	4.6
n-Pentadecane	µg/L	1	1	100	11								NA
Sulfur dioxide	µg/L	1	1	100	13								NA
Tetrachloroethene	µg/L	9	1	11	1.4						0.20	0.20	0.69

Notes:

(1) Nondetect (censored) concentrations were replaced with ½ of the reporting limit for calculating average concentrations. The remaining statistics in this table were only calculated when analytes were detected at a sufficient frequency. For example, if an analyte was detected in fewer than 50% of samples, then a median concentration was not calculated. A blank cell reflects a situation when a median or percentile could not be computed based on detected concentrations. The percentiles are the concentrations of each analyte below which at least that percentage of the values fall. So the 10th percentile is the concentration below which at least 10% of the observations were found.

(2) Screening BM represents the screening benchmark referred to in Section 3.1.3, and is the most stringent 2006 NRWQC or other conservative benchmark used to calculate PHQs.

(3) In some cases, the detected concentration(s) for an analyte could be lower than the replacement value (½ of the reporting limit) for a concentration that was nondetected. In an extreme (but possible) case, this could result in an average concentration for an analyte that is greater than the maximum detected concentration.

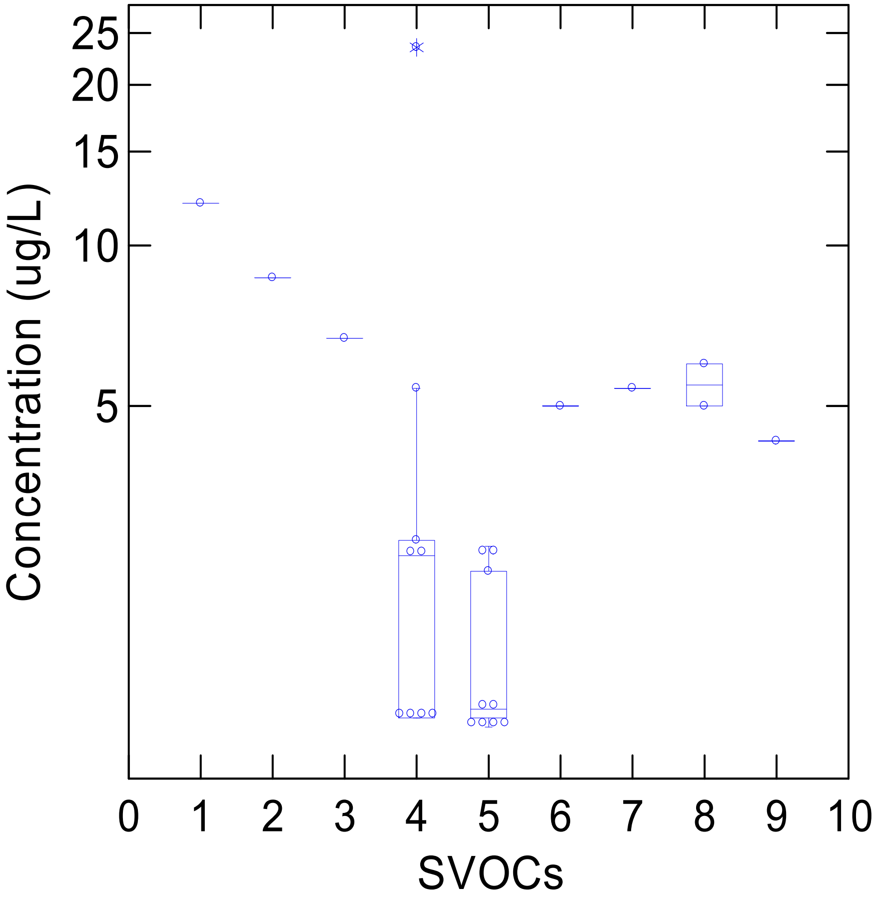

Figure 3.2.9. Box and Dot Density Plot of SVOC Concentrations Measured in Samples of Packing Gland Effluent Samples

SVOCs are identified as follows:
(1) 2,6,10,14-Tetramethyl Pentadecane
(2) 3,6-Dimethylundecane
(3) 5-Butyl-Hexadecane
(4) Bis(2-ethylhexyl) phthalate
(5) Di-n-butyl phthalate
(6) Dodecane
(7) Eicosane
(8) n-Hexadecane
(9) Nonanoic acid

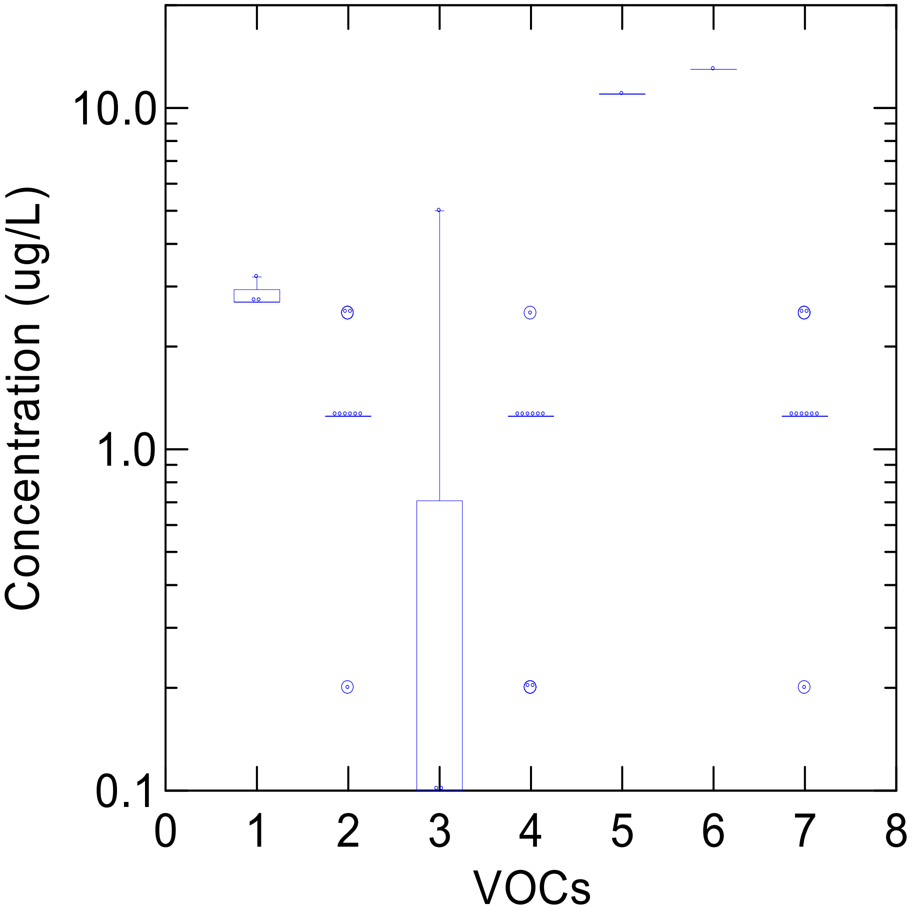

Figure 3.2.10. Box and Dot Density Plot of VOC Concentrations Measured in Samples of Packing Gland Effluent Samples

VOCs are identified as follows:
(1) Acetone
(2) Benzene
(3) m-,p-Xylene (sum of isomers)
(4) Methylene chloride
(5) n-Pentadecane
(6) Sulfur dioxide
(7) Tetrachloroethene

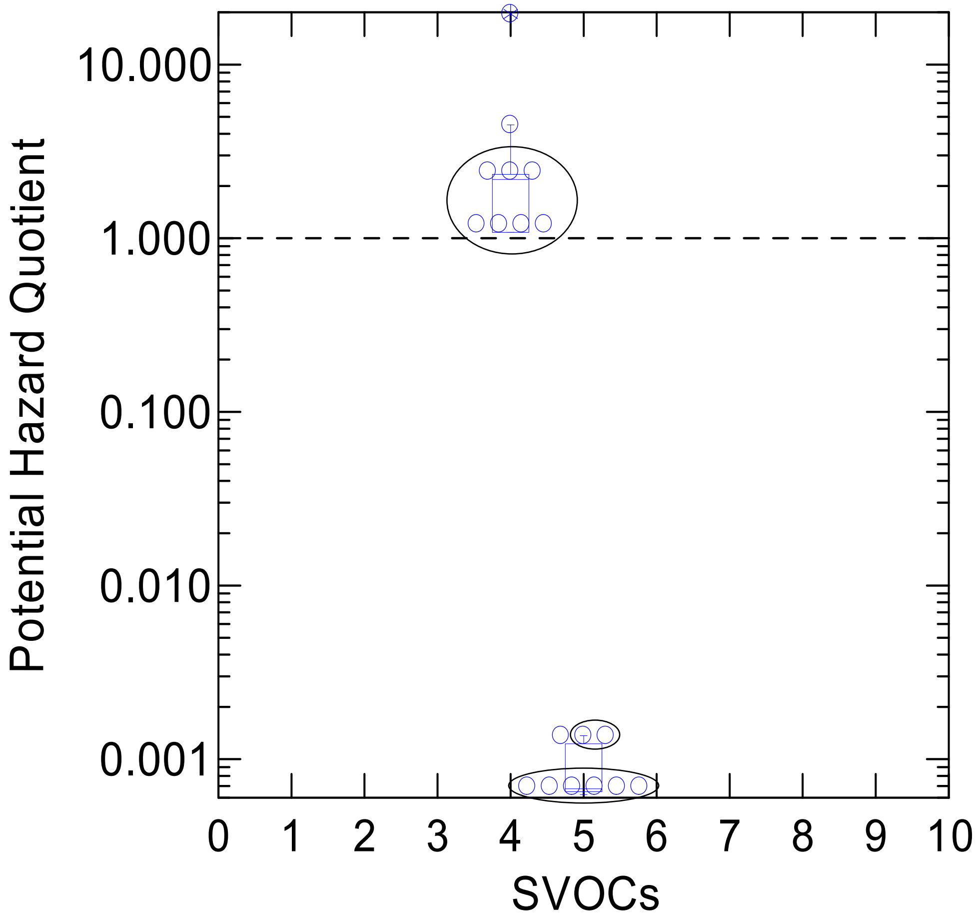

Figure 3.2.11. Box and Dot Density Plot of Potential Hazard Quotients for SVOCs in Samples of Packing Gland Effluent

SVOCs are identified as follows (replacement values for non-detects are circled):
(1) 2,6,10,14-Tetramethyl Pentadecane
(2) 3,6-Dimethylundecane
(3) 5-Butyl-Hexadecane
(4) Bis(2-ethylhexyl) phthalate
(5) Di-n-butyl phthalate
(6) Dodecane
(7) Eicosane
(8) n-Hexadecane
(9) Nonanoic Acid

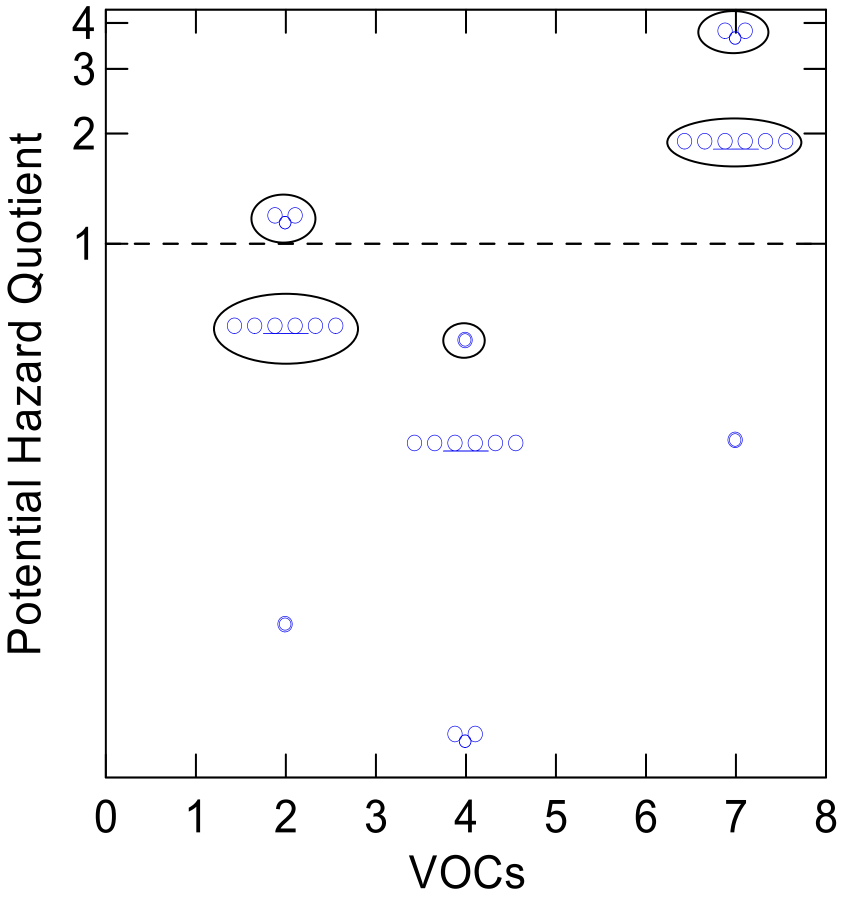

Figure 3.2.12. Box and Dot Density Plot of Potential Hazard Quotients for VOCs in Samples of Shaft Packing Gland Effluent

VOCs are identified as follows (replacement values for non-detects are circled):

(1) Acetone
(2) Benzene
(3) m-,p-Xylene (sum of isomers)
(4) Methylene chloride
(5) n-Pentadecane
(6) Sulfur dioxide
(7) Tetrachloroethene

3.2.2.5 Nonylphenols

EPA analyzed samples of shaft packing gland effluent for long and short chain nonylphenol and octylphenol ethoxylates and NP because of the possibility of alkylphenol-containing water from the bilge or other areas of the vessel leaking into the shaft packing gland effluent compartment. Table 3.2.5 presents the detected results.

Of the nine samples for which long- and short-chain nonylphenol and octylphenol ethoxylates were analyzed, only six long-chain isomers of the octylphenol polyethoxylate (OPEO) type were detected: OP12EO, OP11EO, OP10EO, OP9EO, OP8EO, and OP7EO. All of the detected OPEOs are long-chain octylphenols and were found in one tugboat sampled. The OPEO with the longest ethoxylate chain (OP12EO) was detected at the lowest concentration (Figure 3.2.13). The OPEO isomers showed the trend of increasing concentrations as the size of the ethoxylate chain is reduced (from OP12EO to OP7EO), indicating moderately advanced degradation of the long-chain OPEOs in the packing gland.

Average concentrations of OPEOs with the longest ethoxylate chains (OP12EO through OP10EO) were similar to bilgewater effluent (see Table 3.1.8). In contrast to bilgewater effluent, however, NP was not detected in packing gland effluent.

None of the OPEOs detected in the packing gland effluent sample were detected in ambient water, indicating a probable source from onboard the vessel (tugboat) – possibly from seepage from the bilge. Another possible source of OPEOs in packing gland effluent could be from the use of lubricants for which octylphenol ethoxylates are common constituents.

Table 3.2.5. Results of Packing Gland Water Sample Analyses for Nonylphenols[1]

Analyte	Units	No. samples	No. detected	Detected Proportion (%)	Average Conc.	Median Conc.	Minimum Conc.	10%	25%	75%	90%	Maximum Conc.	Screening BM[2]
Octylphenol dodecaethoxylate (OP12EO)	µg/L	9	1	11	1.7						12	12	NA
Octylphenol undecaethoxylate (OP11EO)	µg/L	9	1	11	2.6						15	15	NA
Octylphenol decaethoxylate (OP10EO)	µg/L	9	1	11	4.8						22	22	NA
Octylphenol nonaethoxylate (OP9EO)	µg/L	9	1	11	5.3						26	26	NA
Octylphenol octaethoxylate (OP8EO)	µg/L	9	1	11	10						30	30	NA
Octylphenol heptaethoxylate (OP7EO)	µg/L	9	1	11	13						28	28	NA

Notes:
(1) Nondetect (censored) concentrations were replaced with ½ of the reporting limit for calculating average concentrations. The remaining statistics in this table were only calculated when analytes were detected at a sufficient frequency. For example, if an analyte was detected in fewer than 50% of samples, then a median concentration was not calculated. A blank cell reflects a situation when a median or percentile could not be computed based on detected concentrations. The percentiles are the concentrations of each analyte below which at least that percentage of the values fall. So the 10th percentile is the concentration below which at least 10% of the observations were found.
(2) Screening BM represents the screening benchmark referred to in Section 3.1.3, and is the most stringent 2006 NRWQC or other conservative benchmark used to calculate PHQs.

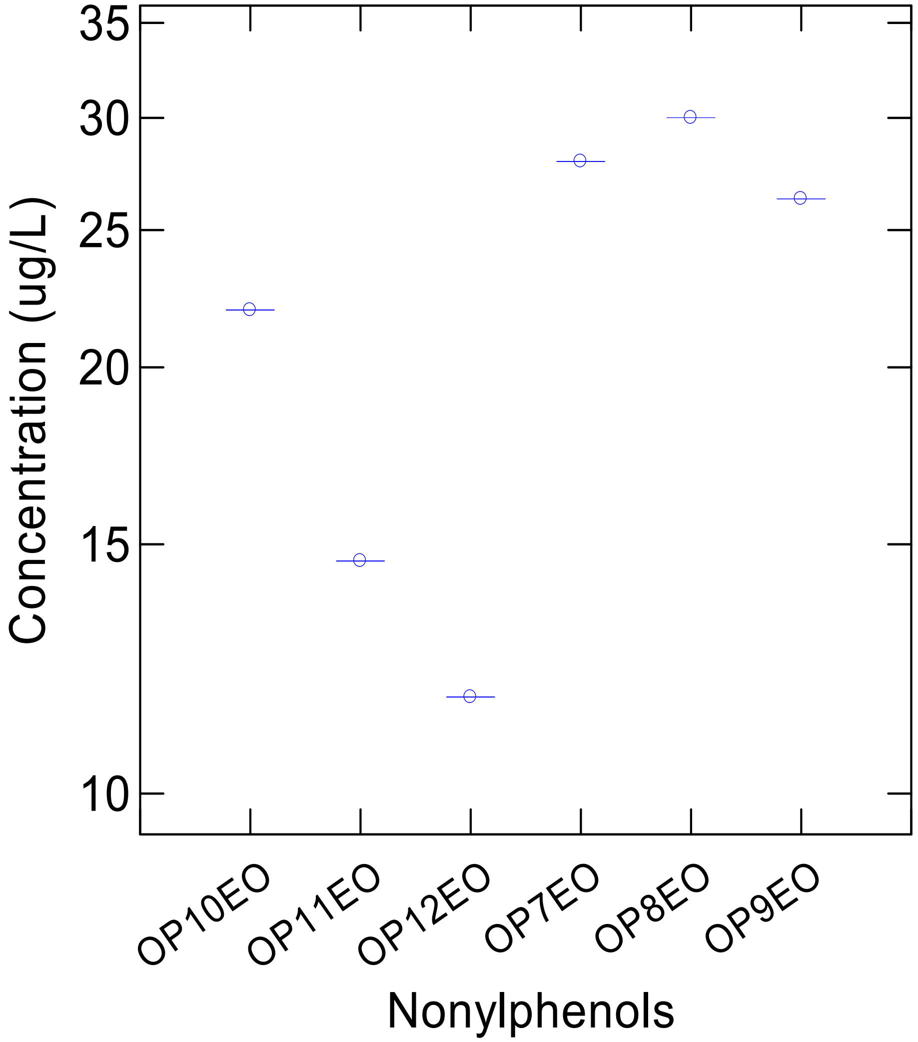

Figure 3.2.13. Box and Dot Density Plot of Nonylphenol Concentrations Measured in Samples of Packing Gland Effluent

3.2.2.6 Summary of the Characterization of Packing Gland Discharge

Table 3.2.6 summarizes the specific analytes within packing gland effluent that may have the potential to pose risk to human health or the environment for these types of vessels based upon these samples. EPA's interpretation of a realized risk likely posed by these analytes, relative to pollutant loadings, background ambient and source water contaminant levels and characteristics, and other relevant information useful for this assessment, is presented in Chapter 5.

To summarize the results of packing gland discharge measured in the nine tugboats, metals were the constituents found most frequently and with the highest magnitudes of exceedance of their respective screening benchmarks. Among the dissolved forms of metals, concentrations of copper, chromiumand nickel exceeded the most stringent NRWQC benchmarks. Among the total forms of metals, aluminum, arsenic, iron, manganese and nickel exceeded the most stringent NRWQC benchmarks. However, concentrations of total iron and total manganese in surrounding (ambient) waters were similar to concentrations measured in packing gland discharge. Among the classical pollutants, most of the concentrations and values reported reflect the concentrations and values in the ambient water surrounding the vessel, as this water is the source of the drive shaft water. Exceptions were two samples for oil and grease (HEM and SGT-HEM) values which exceeded screening benchmarks. Two (of nine) total phosphorus samples also exceeded the screening benchmark; however, these concentrations were similar to total phosphorus concentrations in the surrounding waters. Among the remaining contaminants, the SVOC bis(2-ethylhexyl) phthalate had a PHQ of >10 for one of the vessels sampled, and six of the relatively long-chained octylphenols were measured in one of the nine vessels sampled.

Table 3.2.6. Characterization of Packing Gland Effluent and Summary of Analytes that May Have the Potential to Pose Risk

Vessel Type (no. vessels)	**Analytes that May Have the Potential to Pose Risk in Packing Gland and Vessel Sources[1]**												
	Microbiologicals	**Volatile Organic Compounds**	**Semivolatile Organic Compounds**	**Metals (dissolved)**	**Metals (total)**	**Oil and Grease**	**Sulfide**	**Short-Chain Alkylphenol Ethoxylates and NP**	**Long-Chain Alkylphenol Ethoxylates**	**Nutrients**	**BOD, COD, and TOC**	**Total Suspended Solids**	**Other Physical/Chemical Parameters**
Tugboats (9)			Bis(2-ethylhexyl)-phthalate	**Cu,** Cr, **Ni**	Al, **As**, Ni	x			x		TP	x	

(1) Analytes are generally **bolded** when a large proportion of the samples have concentrations exceeding the NRWQC (e.g., 25 to 50 percent), when several of the samples have PHQs > 10 (e.g., two or three of five), when a few samples result in PHQs greatly exceeding the screening benchmark (i.e., 100s to 1,000s), in the case of oil and grease and for nonylphenol, when one or more samples exceed an existing regulatory limit by more than a factor of 2, or when concentrations of analytes are sufficiently high that they may have the potential to pose risks to local water bodies. See text in Section 3.1.3 for a definition of PHQs and Table 3.1 for screening benchmarks used to calculate these values.

3.2.3 Deck Washdown

Deck washdowns involve removing dirt, grit, or other materials that can impact the integrity of the deck surface (for aesthetic and safety reasons) and are a common vessel maintenance task. The process uses hoses and/or swabs (mops) to move the deck washdown water, debris, and cleaning agents (if any) to the scuppers, which then discharge the water overboard. EPA collected samples of deck water as it is drained through the scupper against the hull of the vessel (see Section 2.2.4 Sampling Methods). More than half the vessels sampled reported using detergents (dish soaps, ZEP™, Simple Green™) or other cleaners (chlorine bleach) during the washdown process. Depending on the vessel's design and function, deck washdown water sometimes contains contaminants such as detergents, metals, oil, particulates, and pathogens (the latter primarily from catch brought onboard fishing vessels).

Deck washdowns can occur at any time onboard these classes of vessels. Fishing vessels most often discharge while underway either into the nearshore (< 3 Nm from shore) or farshore (> 3 Nm from shore). Washdowns are usually performed on fishing vessels after nets are pulled, fish are brought onboard and cleaned, while returning to port, and after offloading the catch. EPA notes that the majority of deck washdown samples from fishing vessels were taken while the vessel was shoreside, and do not reflect constituents of deck washdown while the vessel is engaged in fishing operations. Decks are washed less frequently for other types of vessels such as water taxis, tour boats, and tow boats. Wash locations are generally pierside after excursions or within the harbor for these types of vessels.

The volume of deck washdown water generated by a vessel depends on the frequency of deck washdown, the flow rate from the hose, and the washdown time. Since most vessels use a common garden-hose for deck washdowns, EPA estimated the flow rate to be between 10 and 12 gallons per minute (gpm). The time required for deck washdown varies depending on the type of vessel and size. EPA observed during the vessel sampling program that most deck washdowns were generally 15 minutes or less.

Vessels such as tour boats, water taxis, and tow boats would generate an average deckwash water volume between 20 and 30 gpd during the peak summer season, assuming their decks are washed once every week. Deckwash water volume for fishing boats varies depending on the type of boat. For example, trollers, trawlers, gill netters, and purse seiners sometimes wash their decks three to four times per day while fishing, plus one additional time after unloading seafood at the processing facility. For these vessels, deckwash volumes might range between 750 and 900 gpd.

Collecting Deck Washdown Samples from a Tow and Salvage Vessel

Deck Washdown Sample Collected in a Lined Bucket

For this study, EPA collected deck washdown samples from 32 vessels: 11 fishing vessels (gillnetter, trawlers, and trollers), nine tugboats, six tow/salvage vessels, two tour boats, a water taxi, a fire boat, a supply boat, and a recreational boat (see Table 2-1). EPA collected single grab samples from one or more scuppers (composited sample if more than one accessible scupper) on selected vessels for laboratory analysis in order to determine representative pollutant concentrations for deck washdown across the range of normal vessel operations.

EPA also sampled a deck runoff discharge during a rain event. Deck runoff differs from washdown in that the runoff discharge occurs because of precipitation or spray landing on the deck in sufficient quantities to mobilize pollutants on the deck surface rather than an intentional introduction of washdown water (often including detergents). However, deck runoff incorporates pollutants that would have been included in an eventual washdown so the samples are comparable. The deck runoff sample was collected from a fishing trawler that was being unloaded at a fish processing facility in the Northeastern United States.

EPA focused its sampling effort on the following analyte groups in deck washdown/runoff that were expected to be present in the discharge: metals, classical pollutants, pathogen indicators (commercial fishing vessels only), nutrients, nonylphenols, and semivolatile and volatile organic compounds (tow/salvage vessels only). Results for each class of pollutant are presented and discussed in the subsections below.

3.2.3.1 Metals

Deck washdown water samples were analyzed for dissolved and total metals. The analytical results are summarized in Table 3.3.1. The following metals were detected in 90 percent or more of the deck washdown water samples:

- Dissolved and total aluminum
- Dissolved and total barium
- Total chromium
- Total cobalt
- Dissolved and total copper
- Total iron
- Total lead
- Dissolved and total manganese
- Dissolved and total zinc.

Concentrations of a number of other metals were detected in 50 percent or more of the samples analyzed:

- Total antimony

- Dissolved and total arsenic[23] [24]
- Dissolved chromium
- Dissolved cobalt
- Dissolved iron
- Dissolved and total nickel
- Dissolved selenium[25]
- Dissolved and total vanadium.

Figure 3.3.1 presents the concentration ranges for dissolved metals detected in the samples. These plots show that dissolved metals concentrations span three orders of magnitude. Aside from the alkali and alkali earth metals that are the major cations in seawater (Na, K, Ca, Mg), average dissolved concentrations of iron, aluminum, and zinc were highest, followed by dissolved barium, manganese, and copper. Concentrations of total metals are displayed in Figure 3.3.2, and follow the same general pattern, but are much higher than their corresponding dissolved metal concentrations (f_ds substantially <1.0), except for Na, K, Ca, and Mg, which exist almost entirely in their dissolved forms (see Table 3.3.1).

For all metals, the mean ratios of dissolved to total metal concentrations (fds) in a particular sample range from a low of 0.11 for aluminum to 0.89 for selenium (Table 3.3.2). The fds for the 13 (out of 14) metals for which corresponding data are available are approximately equal to or less than 50 percent, indicating that at least half of the total metal concentration in deck washdown water samples is in particulate form. Such results were expected from certain vessels (e.g., tugboats and supply boats) where particulate material was readily visible on deck surfaces. Particulate metal is less biologically available than dissolved metals, and therefore less likely to cause an immediate toxic effect in aquatic organisms.

Dissolved cadmium concentrations were detected in two of the 31 vessels sampled - a supply and tow/salvage boat. The concentrations were 1.2 (supply boat) and 22.4 µg/L (tow/salvage boat), which exceeded the saltwater chronic aquatic life criterion (8.8 µg/L) in the case of the tow/salvage boat and the freshwater chronic aquatic life criterion (0.25 µg/L) in both cases.

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[23] Even though a dissolved metal is detected in 50% of the samples, it does not mean that the total metal value (which includes dissolved and particulate metals) is considered to be detected in the laboratory analyses. All dissolved metal detections are not considered total metal detections because the detection limits differ for a given sample based on dissolved versus total recoverable metal analyses. For example, in the case of selenium, the detection limit for total recoverable selenium was 5 µg/L for the analysis. In contrast, the detection limit for dissolved selenium in these analyses was as low as 1 µg/L.

[24] EPA suspects that in a very limited number of deck wash samples (deck wash samples from two shrimping vessels), measured concentrations of dissolved and total arsenic may be elevated due to positive interference from major seawater cations.

[25] EPA suspects that in a limited number of deck wash samples (i.e., deck wash samples from two shrimping vessels and two tow/salvage vessels), measured concentrations of dissolved and total selenium may be elevated due to positive interference from major seawater cations.

Deck washdown water samples collected from 29 of the 31 vessels sampled contained dissolved copper concentrations that exceeded the saltwater chronic aquatic life criterion of 3.1 µg/L. Dissolved copper concentrations ranged from 2.5 µg/L for a tug and fishing (trawler) boat to 204 µg/L for the supply boat. The dissolved copper concentrations in deck washdown samples from the tug and assorted fishing boats were evenly distributed across the entire range of measured dissolved copper concentrations, while the tow/salvage, fire, taxi, tour, and supply boats all had relatively high dissolved copper concentrations (above 30 µg/L).

Dissolved lead concentrations exceeding the freshwater chronic aquatic life criterion (2.5 µg/L) were limited to just three (of nine) tugboats, five (of six) tow/salvage boats, one of the two tour boats, and the fire and supply boats. Dissolved lead concentrations exceeding chronic aquatic life criterion concentrations ranged from 2.9 µg/L for one of the tugboats to 53.5 µg/L for the supply boat.

Similar to dissolved copper, dissolved zinc in deck washdown samples collected from the majority of vessels sampled (22 of 31) exceeded the most stringent 2006 NRWQC - the saltwater chronic aquatic life criterion of 81 µg/L. In contrast to dissolved copper, however, only the deck washdown samples from the various types of fishing boats appeared to be evenly distributed throughout the entire measured dissolved zinc concentration range, while dissolved zinc in deck washdown water samples collected from all the tugboats exceeded the criterion. Dissolved zinc concentrations in deck washdown water samples ranged from 16 µg/L for a fishing vessel (the gillnetter) to 1,200 µg/L for one of the tugboats. All but one of the tow/salvage boats produced dissolved zinc in deck washdown water samples exceeding the criterion, as did the tour, fire, and supply boats (the last with a measured dissolved zinc concentration of 465 µg/L).

For the other dissolved metals (chromium, nickel, and selenium) where measured concentrations exceeded the saltwater and/or freshwater criteria in one or more of the deck washdown water samples, the PHQs were generally less than two (most likely less than one for dissolved selenium after considering there may be elevated measured concentrations as a result of positive interference for the four samples with measured dissolved selenium concentrations exceeding 5 µg/L). For both chromium and nickel, the tow/salvage vessel type had the greatest number of dissolved metal concentration exceedances for their respective most stringent criteria. No information was available concerning the frequency of deck washdowns for the supply vessel, although this particular vessel is known to transport petroleum products, and its deck appeared visibly “soiled” to the samplers. According to the surveys, the tow/salvage boats generally undergo deck washdowns once to twice per week, about the same frequency as tugboats, but less frequent than the fishing and tour boats.

Four of the total metals (aluminum, arsenic, iron, and manganese) exceeded the most stringent 2006 NRWQC in approximately half (manganese) or all the deck washdown water samples (aluminum, arsenic, and iron), although sample concentrations of these metals appear to be greatly influenced by surrounding ambient water concentrations (see Table 3.3.3). This pattern was identical to the one observed for bilgewater discharge. In contrast to the bilgewater samples, about half the deck washdown water samples for a fifth metal (antimony) exceeded the most stringent 2006 NRWQC in the deck washdown water samples, as shown in Figure 3.3.4. PHQs for total arsenic ranged from 56 to 4,600. All of the total arsenic concentrations exceeded the most stringent human health (water plus organism consumption) criterion of 0.018 µg/L, as well as the human health criterion for organism consumption alone, 0.14 µg/L. The protective human health criteria values for total arsenic are driven by the carcinogenic potential of this metalloid. However, when compared to the less stringent saltwater chronic aquatic life criterion for arsenic of 36 µg/L, only five of the 31 vessels produced total arsenic concentrations in deck washdown water samples that exceeded this less stringent criterion, and the corresponding PHQs ranged only from 1.0 to 2.3. These total arsenic exceedances were found on a shrimping vessel (positive interference may have elevated the measured concentration, see footnote 24), three (of the six) tow/salvage vessels, and the fire boat. In fact, the total arsenic concentrations in deck washdown water samples from all six of the tow/salvage boats were close to or within the upper quartile of samples.

Figure 3.3.3 displays the distribution of PHQs based on the most conservative (most protective) screening benchmark for each of the dissolved metals. PHQs for four of the dissolved metals (cadmium, copper, lead, and zinc) include values from greater than 10 to over 100, indicating that the measured concentrations were one or more orders of magnitude greater than the most conservative screening benchmark. In addition, although the mean dissolved selenium PHQ was less than one, there were two measured occurrences where PHQ exceeded 10, however, the high measured concentration of dissolved selenium in these two samples are likely due to positive interference, see footnote 25). PHQs exceeding one were also observed for dissolved chromium and nickel, bringing to seven the number of dissolved metals that exceeded the most stringent 2006 NRWQC in one or more deck washdown water samples.

PHQs for total aluminum were also high, ranging from 7.5 to 150, followed closely by total iron, with PHQs ranging from 3.1 to 48. For both metals, the majority of tug and tow/salvage boats were consistently above the median (middle concentration of the range) of total metal concentrations (in addition to the fire and supply boats), while the fishing boats were below the respective median total metal concentrations. Conversely, only three of the PHQs for total manganese exceeded a value of 5 (a tugboat, the supply boat, and the water taxi).

The frequency of PHQ exceedances for antimony, like total arsenic, are driven by the low human health (water plus organism consumption) criterion of 5.6 µg/L (the human health criterion for organism consumption alone (640 µg/L) is much higher). Only five of the 19 vessels from which deck washdown water samples were obtained had PHQ below 1, and were collected from the supply, fire, recreational, and two of the salvage vessels. Among the PQHs for antimony that were greater than 1, the low PHQ of 5.2 corresponded with the supply boat, and the high PHQ of 47 corresponded with a tow/salvage vessel – a PHQ value three times higher than in the recreational vessel (PHQ = 15).

From the perspective of potential risk, the discharges of metals where dissolved and total concentrations exceed EPA's most stringent criteria correlate most strongly to utility, passenger, or general service vessels such as the supply boat, tow/salvage boats, tugboats, water taxi, and fire boat. Commercial fishing vessels may not be a source of concern except for metals such as dissolved copper.

EPA tested the hypothesis that the utility, service, and passenger vessels (referred to as nonfishing vessels) discharged metals at higher concentrations than fishing vessels per discharge event using two approaches. For both approaches, 20 nonfishing vessels (the tow/salvage boats, tugboats, tour vessels, fire boat, water taxi, and supply vessels) were compared to the 10 fishing vessels (six shrimping vessels, two trawlers, one troller, and a gillnetter). For the analysis, when multiple minimum detection limits were reported for a particular metal, the minimum concentration was set to ½ of the highest reporting limit. This more conservative approach was chosen to reduce the likelihood of detecting a difference that was not a "true" difference (Type I error).

For the first approach, a subset of the metals with the highest frequencies of screening benchmark (NRWQC) exceedance from the nonfishing vessels were compared to those from the fishing vessels. Although there is no NRWQC for total lead, this metal was used in these analyses because of the high proportion of nondetects in the dissolved form. This analysis was performed using modified t-tests for unequal sample sizes and uneven variances (see Table 3.3.4). Concentrations of dissolved zinc and total lead were significantly higher in deck washdown discharges of non-fishing vessels (e.g., tug boats) than fishing vessels. Although concentrations of total arsenic were not significantly different between nonfishing and fishing vessels, when the six tow/salvage vessels were compared to the remaining 24 vessels, total arsenic concentrations in the tow/salvage vessels were significantly higher than in other vessels (Table 3.3.4). When this analysis was performed for dissolved lead despite the occurrence of nondetects, the results were the same (i.e., concentrations of dissolved lead in industrial vessels were higher than in fishing vessels).

For the second approach, mean concentrations for both dissolved and total forms of the heavy metals (cadmium, chromium, copper, lead, nickel, zinc) were compared using an exact binomial test. This approach assumes that, even if the difference in mean concentrations between nonfishing and fishing vessels for any given metal is not statistically significant, if the mean metal concentrations from a particular vessel class are always or nearly always lower than those of another class of vessels, then the overall trend may be statistically significant. Both dissolved and total metals concentrations of all six heavy metals were higher in nonfishing vessel discharges than in fishing vessel discharges (see Table 3.3.5). A binomial test was then performed to determine whether the overall pattern of lower mean metal concentrations in fishing vessel discharges could be attributed to chance, assuming an equal likelihood that concentrations in fishing vessels or industrial vessels would be lower. The probability that mean concentrations of all six metals (either dissolved or total) would be lower in fishing vessels compared to nonfishing vessels, given an equal likelihood of either outcome occurring, was statistically significant (P = 0.016). The probability of concentrations being lower in fishing vessels for all 12 comparisons (six dissolved metals + six total metals) was also statistically significant (P = 0.0002). The mean concentrations of these heavy metals by vessel class are shown in Table3.3.5. Results of this analysis support the assertion that metals from deck washdown discharges from nonfishing (utility, service, and passenger) vessels tend to be higher than metals from deck washdown discharges from fishing vessels for each discharge event.

One possible explanation for the higher metal concentrations in nonfishing vessels is that the frequent washing of fishing vessels' decks may prevent metal build-up and keep metal concentrations lower in each individual deck washdown discharge.

With regard to assessing potential risk, it is important to understand that, for most of the metals identified above as of potential concern in deck washdown water, maximum metal concentrations in the ambient or potable water used for deck washdown (see left two thirds of Table 3.3.3) were higher than the median metal concentrations in deck washdown water samples (Table 3.3.1). The ambient receiving waters to which these deck washdown waters are being discharged have metal concentrations that often exceed the most stringent NRWQC (see far right column of Table 3.3.3). The relatively high metals concentrations for four dissolved metals (copper, manganese, nickel, zinc) in potable water and four total metals (aluminum, arsenic, iron, lead) in ambient water can at least partially account for the high concentrations of metals found in some of the deck wash discharges. Furthermore, based on corresponding concentrations of the major seawater cations (calcium, magnesium, sodium, and potassium) in the deck washdown water samples (see Table 3.3.1), few, if any, of the potentially toxic dissolved metal concentrations are likely to be bioavailable to biological organisms because of the high hardness values, which reduce metal bioavailability.

In summary, metals were frequently detected in deck washdown water samples, with certain metals occurring much more frequently at levels that may have potential for risk than others. EPA found high concentrations of a number of dissolved and total metals in these samples. Dissolved cadmium, copper, lead, nickel and zinc were consistently elevated above the most conservative screening benchmarks, with all the PHQ values in the 1 to 100 range. However, dissolved cadmium concentrations measured in deck washdown water samples were only detected in two of 31 vessels. For these and other metals (total aluminum, arsenic, iron, and manganese), concentrations measured in most if not all of the water samples exceeded saltwater and/or freshwater criteria, however they generally did not exceed concentrations in the ambient or potable water used for washdown, and would generally not be bioavailable to organisms in seawater.

Table 3.3.1. Results of Deck Washdown/Runoff Sample Analyses for Metals[1]

Analyte	Units	No. samples	No. detected	Detected Proportion (%)	Average Conc.	Median Conc.	Minimum Conc.	10%	25%	75%	90%	Maximum Conc.	Screening BM[2]
Heavy and Other Metals													
Aluminum, Dissolved	µg/L	31	28	90	420	260		1.7	31	570	1100	1900	NA
Aluminum, Total	µg/L	31	30	97	3400	1900		820	990	4700	8300	13000	87
Antimony, Dissolved	µg/L	19	9	47	7.3					4.2	13	91	NA
Antimony, Total	µg/L	19	13	68	26	1.9				29	86	260	5.6
Arsenic, Dissolved[3]	µg/L	31	19	61	6.4	2.3				9.8	13	28	36
Arsenic, Total[3]	µg/L	31	23	74	18	8.3				29	49	83	0.018
Barium, Dissolved	µg/L	19	19	100	63	42	23	27	33	69	96	280	NA
Barium, Total	µg/L	19	19	100	270	100	52	59	70	160	1300	1400	1000
Cadmium, Dissolved	µg/L	31	2	6	1.3							22	0.25
Cadmium, Total	µg/L	31	5	16	2.0						1.7	36	NA
Chromium, Dissolved	µg/L	31	17	55	5.1	2.3				9.1	16	18	11
Chromium, Total	µg/L	31	29	94	34	24		3.1	8.3	55	84	130	NA
Cobalt, Dissolved	µg/L	19	12	63	2.7	1.3				3.9	8.2	14	NA
Cobalt, Total	µg/L	19	18	95	6.0	4.1		1.1	2.0	6.7	20	26	NA
Copper, Dissolved	µg/L	31	29	94	42	23		5.6	7.2	59	120	200	3.1
Copper, Total	µg/L	31	31	100	130	110	6.4	12	47	160	340	530	1300
Iron, Dissolved	µg/L	19	12	63	520	190				1100	1100	3000	NA
Iron, Total	µg/L	19	18	95	4400	2300		950	1700	5300	13000	15000	300
Lead, Dissolved	µg/L	31	15	48	6.0					4.7	19	54	2.5
Lead, Total	µg/L	31	30	97	48	23		3.6	8.0	42	160	260	NA
Manganese, Dissolved	µg/L	31	29	94	60	35		2.7	11	91	200	240	NA
Manganese, Total	µg/L	31	28	90	210	98		4.3	55	300	540	1300	100
Nickel, Dissolved	µg/L	31	19	61	6.9	4.8				8.2	13	17	8.2
Nickel, Total	µg/L	31	25	81	16	12			6.2	18	27	100	610
Selenium, Dissolved[4]	µg/L	31	17	55	8.9	1.1				2.1	25	82	5.0
Selenium, Total[4]	µg/L	31	12	39	9.5					1.8	23	96	170
Thallium, Dissolved	µg/L	19	1	5	0.64							3.2	NA
Vanadium, Dissolved	µg/L	19	14	74	1.9	1.3				2.0	5.2	7.6	NA
Vanadium,Total	µg/L	19	16	84	9.8	6.2			2.9	9.8	20	58	NA

Table 3.3.1. Results of Deck Washdown/Runoff Sample Analyses for Metals[1]

Analyte	Units	No. samples	No. detected	Detected Proportion (%)	Average Conc.	Median Conc.	Minimum Conc.	10%	25%	75%	90%	Maximum Conc.	Screening BM[2]
Zinc, Dissolved	µg/L	31	31	100	260	120	16	35	51	430	620	1200	81
Zinc, Total	µg/L	31	31	100	580	330	20	52	150	720	1400	4000	7400
Cationic Metals													
Calcium, Dissolved	µg/L	31	31	100	73000	34000	5900	25000	32000	83000	190000	320000	NA
Calcium, Total	µg/L	31	31	100	77000	39000	7300	27000	34000	88000	190000	310000	NA
Magnesium, Dissolved	µg/L	31	31	100	130000	14000	6600	7000	7900	59000	510000	1000000	NA
Magnesium, Total	µg/L	31	31	100	130000	19000	6800	7800	9200	59000	510000	1000000	NA
Potassium, Dissolved	µg/L	19	19	100	30000	8000	3300	4000	5400	24000	140000	180000	NA
Potassium, Total	µg/L	19	19	100	30000	8100	3600	3900	5600	25000	130000	180000	NA
Sodium, Dissolved	µg/L	19	19	100	510000	79000	26000	38000	45000	410000	2800000	3600000	NA
Sodium,Total	µg/L	19	19	100	510000	78000	24000	38100	45000	400000	2600000	3600000	NA

Notes:

(1) Nondetect (censored) concentrations were replaced with ½ of the reporting limit for calculating average concentrations. The remaining statistics in this table were only calculated when analytes were detected at a sufficient frequency. For example, if an analyte was detected in fewer than 50% of samples, then a median concentration was not calculated. A blank cell reflects a situation when a median or percentile could not be computed based on detected concentrations. The percentiles are the concentrations of each analyte below which at least that percentage of the values fall. So the 10th percentile is the concentration below which at least 10% of the observations were found.

(2) Screening BM represents the screening benchmark referred to in Section 3.1.3, and is the most stringent 2006 NRWQC or other conservative benchmark used to calculate PHQs.

(3) See footnote 24.

(4) See footnote 25.

Table 3.3.2. Dissolved-to-Total Metal Ratios (f_ds) in Paired Deck Washdown/Runoff Samples

Metal	Summary Statistics of Dissolved:Total Metal Ratios Calculated for Select Metals			
	Geomean	Median	Min	Max
Aluminum	0.10	0.12	0.010	1.00
Iron	0.12	0.090	0.050	0.33
Lead	0.14	0.18	0.030	0.62
Chromium	0.16	0.13	0.060	0.76
Vanadium	0.25	0.26	0.12	1.13
Manganese	0.25	0.28	0.010	0.93
Antimony	0.30	0.34	0.14	0.64
Copper	0.33	0.34	0.050	1.04
Arsenic	0.38	0.47	0.060	0.93
Cadmium	0.48	0.49	0.36	0.62
Nickel	0.50	0.53	0.17	0.93
Cobalt	0.53	0.52	0.26	1.25
Zinc	0.54	0.54	0.18	2.95
Selenium	0.89	0.89	0.61	1.30

Table 3.3.3. Minimum and Maximum Dissolved and Total Metal Concentrations in Vessel Source[1] and Ambient[2] (Harbor) Water Relative to Median Sample Concentrations and Most Stringent Screening Benchmarks

Metal	Source Water Conc. (min)	Source Water Conc. (max)	N	Median Conc. From Table 3.3.1	Ambient Conc. (min)	Ambient Conc. (max)	N	Most Stringent Screening BM
Aluminum, Dissolved	6.3	310	6	258	0	870	12	NA
Aluminum, Total	8.6	250	6	1900	44.5	3950	15	87
Arsenic, Dissolved	0	1.9	3	2.3	2	26	8	36
Arsenic, Total	0	1.8	3	8.3	2.9	28.9	8	0.018
Copper, Dissolved	2.4	36	5	23.1	0	24.2	10	3.1
Copper, Total	2.6	51	4	109	0	23.3	11	1300
Iron, Dissolved	0	0	1	189.5	226	259	2	NA
Iron, Total	0	801	4	2330	114	4180	8	300
Lead, Total	1.2	6	2	23	0	3.1	3	2.5**
Manganese, Dissolved	0	33	6	34.8	0	106	11	NA
Manganese, Total	3.6	37	6	97.8	8.3	165	13	100
Nickel, Dissolved	0	3	4	4.8	2.3	7.2	10	8.2
Nickel, Total	0	2.7	4	12	2.4	16.7	11	610
Selenium, Dissolved	0	1.6	3	1.1	1.7	75.5[3]	8	5

Table 3.3.3. Minimum and Maximum Dissolved and Total Metal Concentrations in Vessel Source[1] and Ambient[2] (Harbor) Water Relative to Median Sample Concentrations and Most Stringent Screening Benchmarks

Metal	Source Water Conc. (min)	Source Water Conc. (max)	N	Median Conc. From Table 3.3.1	Ambient Conc. (min)	Ambient Conc. (max)	N	Most Stringent Screening BM
Selenium, Total	0	1.9	2	0	19.4[3]	86.5[3]	6	170
Zinc, Dissolved	4.1	1200	6	124	0	116	13	81
Zinc, Total	4.1	1100	6	331	0	23.9	15	7400

N = sample size.

(1) Ambient water was collected from background water surrounding the vessel sampled.

(2) Source water was collected from the city tap water supply while pierside, except for one tugboat in Havre De Grace, Maryland, where source water was collected from a potable water storage tank on the vessel (service water) that was filled with city water.

(3) As discussed in footnote 25, EPA suspects positive interference may have resulted in these high measured concentrations of total and dissolved selenium detected in ambient deck wash samples.

Table 3.3.4. Comparison of Metal Concentrations in Deck Washdown Discharge Between Fishing Vessels and Non-Fishing Vessels[1]

Metal	Form	Average Metal Concentration (µg/L) by Vessel Type		Welch's Modified 2-Sample t-Test		
		Fishing	Non-Fishing	t	df	$P<\lvert t_{\alpha/2}\rvert$
Copper	Dissolved	27.7	50.7	-1.68	18.2	0.110
Nickel	Dissolved	6.19	7.23	-1.05	20.7	0.306
Zinc	Dissolved	161	314	-2.15	14.9	**0.049**
Arsenic[2]	Total	14.0	20.5	-0.49	19.8	0.629
Lead	Total	5.48	70.7	-3.76	19.1	**0.001**

Notes:

(1) Nonfishing vessels defined as tow/salvage vessels, tugboats, tour vessels, fire boat, water taxis, and supply vessels. The recreational vessel is not a study vessel and was excluded from these analyses.

(2) Total arsenic concentrations discharged from the six tow/salvage boats were significantly higher than for the other 24 vessels (Welch's Modified 2-Sample t-test, t=-5.26, P<0.001, on 16.7 df).

Table 3.3.5. Mean Concentrations of Dissolved and Total Heavy Metals from Deck Wash Discharges from Fishing Vessels and Nonfishing Vessels[1,2]

Metal	Form	Conc. (µg/L) in			Conc. (µg/L) in		
		Fishing Vessels	n	Not Det. (%)	Non-Fishing Vessels	n	Not Det. (%)
Cadmium	Dissolved	0.750	10	100	1.86	20	90
Chromium	Dissolved	3.79	10	70	5.93	20	35
Copper	Dissolved	27.7	10	0	50.7	20	0
Lead	Dissolved	2.00	10	100	8.85	20	45
Nickel	Dissolved	6.19	10	40	7.23	20	40
Zinc	Dissolved	161	10	0	314	20	0
Cadmium	Total	2.00	10	100	3.77	20	90
Chromium	Total	15.7	10	20	42.3	20	0
Copper	Total	93.2	10	0	157	20	0
Lead	Total	5.48	10	10	70.7	20	0
Nickel	Total	8.65	10	40	19.4	20	10
Zinc	Total	207	10	0	791	20	0

Notes:

(1) Nonfishing vessels defined as tow/salvage vessels, tugboats, tour vessels, fire boat, water taxis, and supply vessels. The recreational vessel is not a study vessel and was excluded from these analyses.

(2) For these comparisons, minimum concentrations were set at ½ of the reporting limit of the highest minimum detection level, when multiple detection limits were present. Average concentrations of dissolved and total forms of all six heavy metals were lower in fishing vessels than in nonfishing vessels.

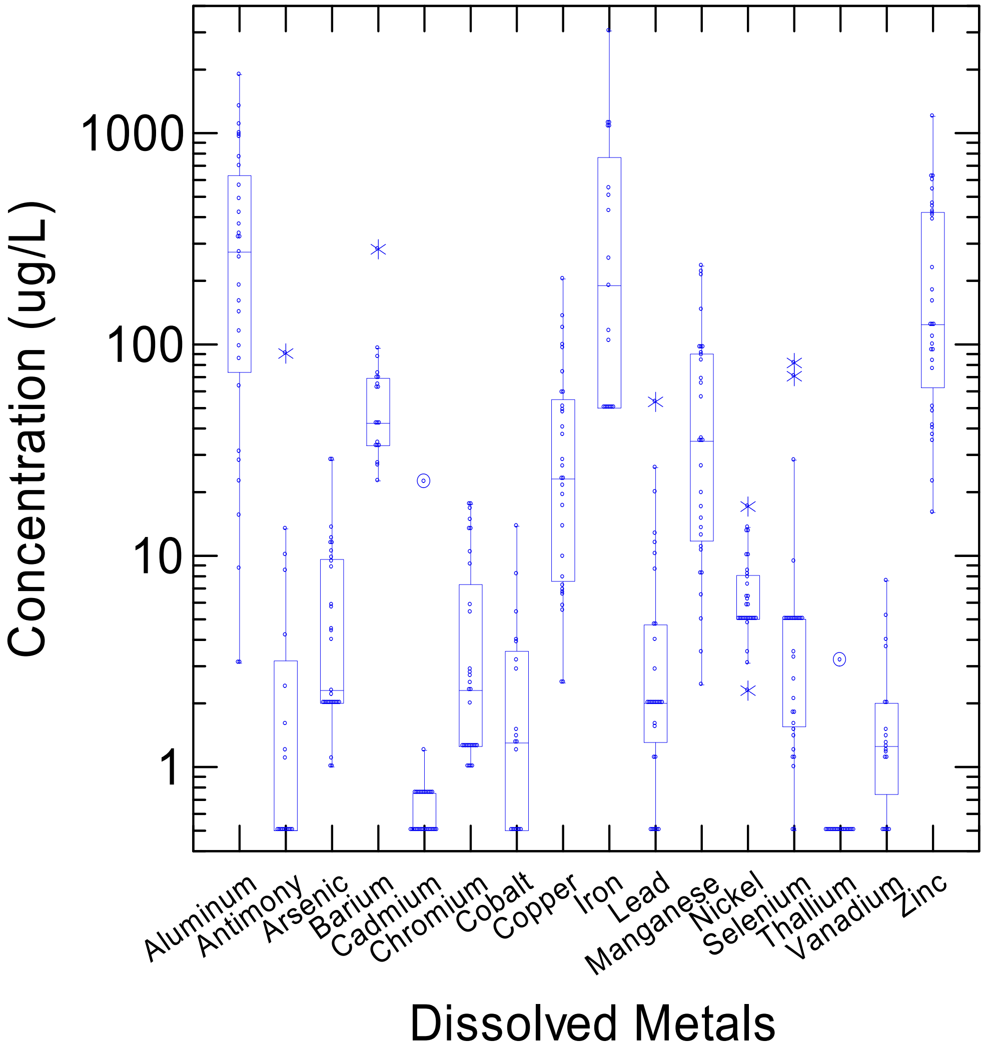

Figure 3.3.1. Box and Dot Density Plot of Dissolved Metals Concentrations Measured in Samples of Deck Washdown Water
(Note: As discussed in footnotes 24 and 25, EPA suspects positive interfence may have resulted in elevated measured concentrations for a limited number of deck wash samples analyzed for dissolved arsenic and dissolved selenium).

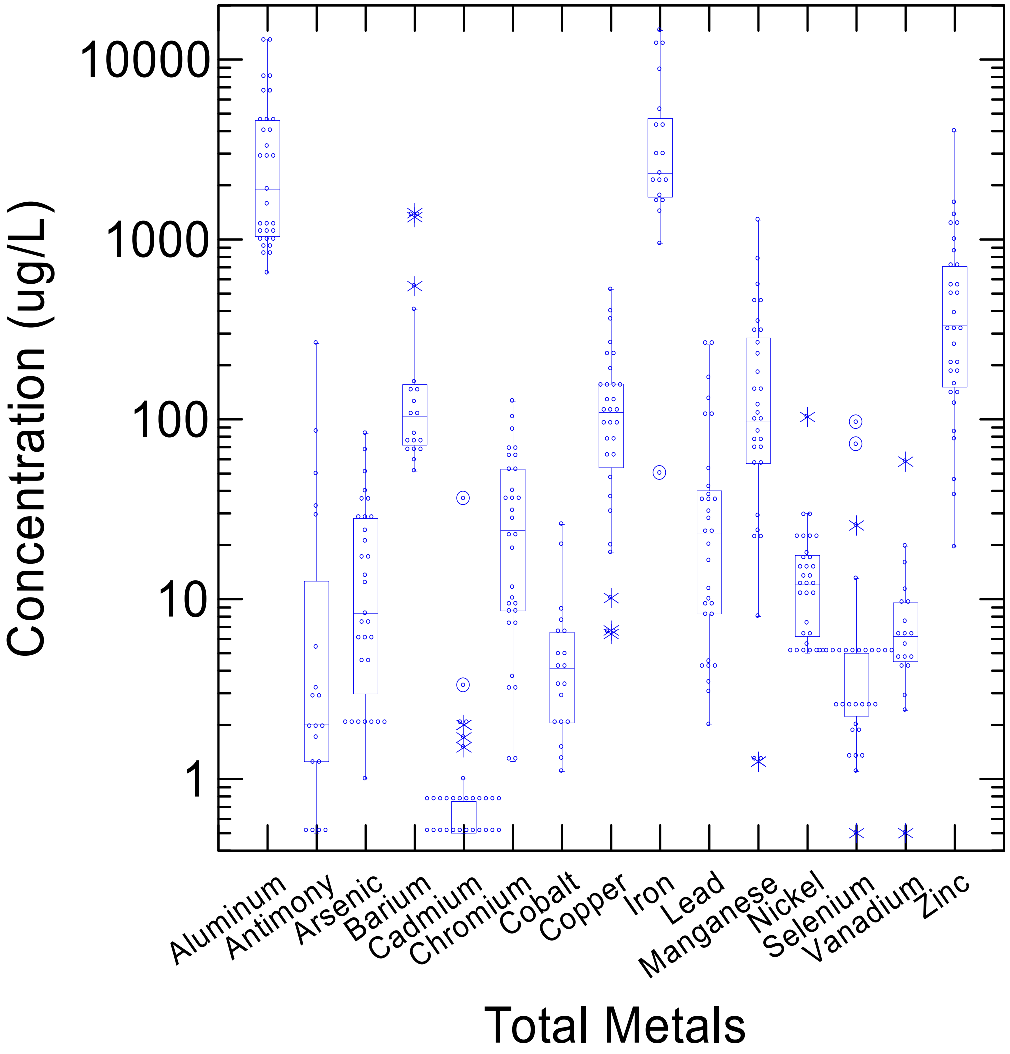

Figure 3.3.2. Box and Dot Density Plot of Total Metals Concentrations Measured in Samples of Deck Washdown Water

(Note: As discussed in footnotes 24 and 25, EPA suspects positive interfence may have resulted in elevated measured concentrations for a limited number of deck wash samples analyzed for total arsenic and dissolved selenium).

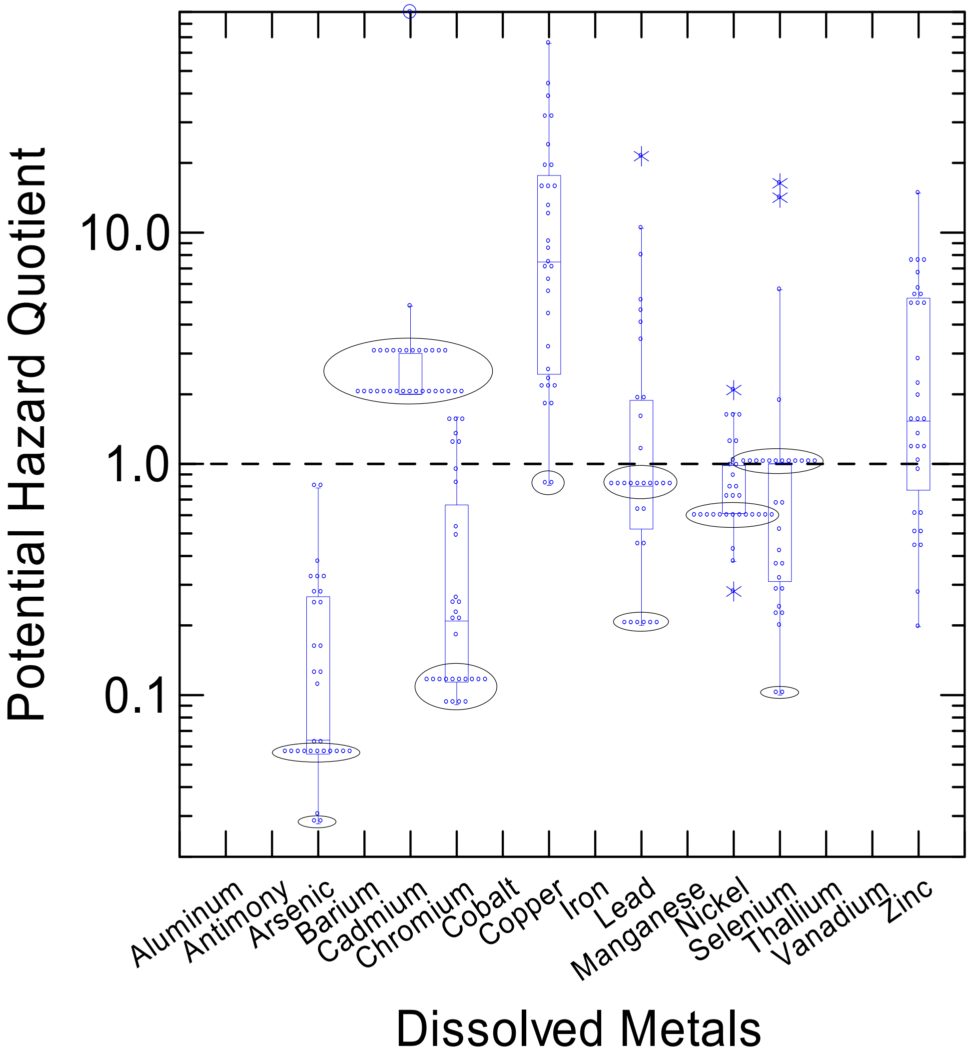

Figure 3.3.3. Box and Dot Density Plot of Potential Hazard Quotients for Dissolved Metals in Samples of Deck Washdown Water
(Note: Replacement values for non-detects are circled. Also, as discussed in footnotes 24 and 25, EPA suspects positive interfence may have resulted in elevated measured concentrations for a limited number of deck wash samples analyzed for dissolved arsenic and dissolved selenium).

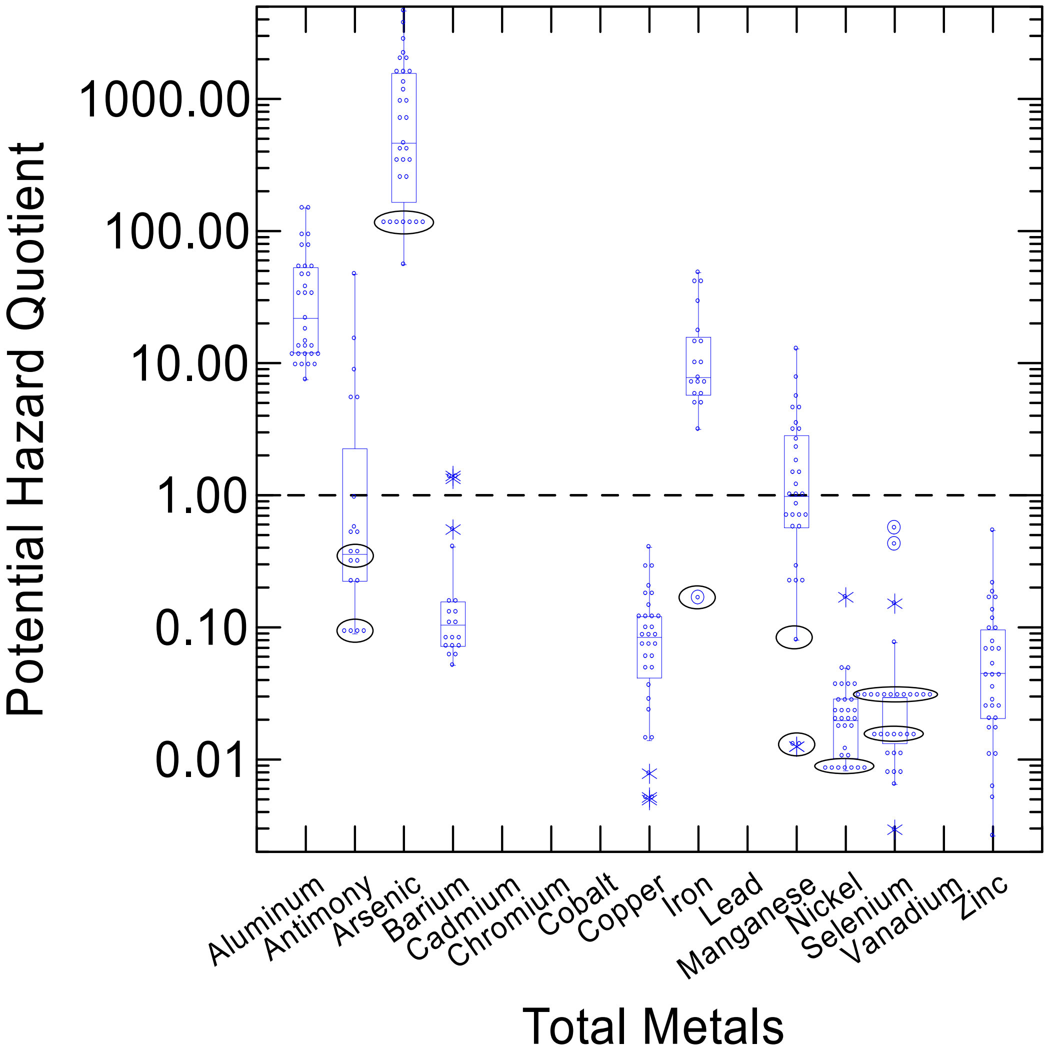

Figure 3.3.4. Box and Dot Density Plot of Potential Hazard Quotients for Total Metals in Samples of Deck Washdown Water

(Note: Replacement values for non-detects are circled. Also, as discussed in footnotes 24 and 25, EPA suspects positive interfence may have resulted in elevated measured concentrations for a limited number of deck wash samples analyzed for total arsenic and dissolved selenium).

3.2.3.2 Classical Pollutants

Deck washdown water samples from 32 vessels were analyzed for 14 classical pollutants (see Table 3.3.6). The classical pollutants include measurements that are physical properties (temperature, conductivity, salinity, turbidity, TSS), oxygen consumption (BOD, COD), oil and grease (HEM and SGT-HEM), as well as chemical concentrations (pH, sulfide, DO, and TRC).

Measured values of the physical properties of the discharge (conductivity, dissolved oxygen, pH, temperature, salinity) are unremarkable and appear to reflect conditions at the time (seasonality) and location (geographical) of sampling. For instance, conductivity and salinity in deck washdown water appear to reflect the type of source water used (ambient or potable service/city[26] water), as shown by the measured values of these two parameters. Half the fishing vessels appear to have used ambient saltwater during normal operations (six of 11 vessels), while the remaining fishing boats and nearly all other vessel types (tugs, tow/salvage, tour, supply boats) used a freshwater source (aboard the vessel or pierside). Levels of pH were generally about neutral (between 7 and 8), with the only exceptions being two tugboats where the pH was 9.1 and 9.8 (relatively high). Temperature of the deck washdown water ranged from 7.5 to 32 ^{o}C and varied according to month (season) sampled and geographic location (warmer water samples in southern United States and colder in mid-Atlantic and northern states). Dissolved oxygen (DO) in deck washdown samples was sufficiently saturated (50 percent plus; DO ranged from 5.5 to 10.5 mg/L) in all samples, except for low DO concentrations from three fishing vessels participating in the north Pacific fishery, which ranged from 1.6 to 1.9 mg/L.

Figure 3.3.5 illustrates the variability of the values measured for the classical pollutants in deck washdown water. Turbidity (measure of water clarity) and TSS are clearly related and range from 4.1 to 460 NTU and 31 to 530 mg/L, respectively. Measured values above the median concentrations were dominated by the tug, tow/salvage, supply, fire, and water taxi boats for both parameters, while measured values below the median were largely from the fishing boats (with only a few exceptions). EPA notes that the majority of deck washdown samples from fishing vessels were taken while the vessel was shoreside, and do not reflect constituents of deck washdown while the vessel is engaged in fishing operations. Potable water measured during the study was low in turbidity (0 to 16 NTU) and TSS (0 mg/L), as was ambient (harbor) water, except for waters sampled in the Gulf Coast (Louisiana). Ambient turbidity and TSS were as high as 186 NTU and 98 mg/L, respectively, in a sample collected from one harbor in Louisiana.

Of the remaining parameters, BOD, COD, and TOC have quite high concentrations (see Figure 3.3.5). While the measured values for these parameters in deck washdown water samples were generally evenly distributed for the different vessel types across the entire concentration

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[26] Service water here means the vessel potable water supply. For study vessels, vessel service water generally originates from municipal water supply rather than produced on board. When deck washdown is performed pierside most vessels used city water as their source water. Many fishing vessels and at least one tugboat use ambient water as their water source when performing deck washdown offshore or underway.

range, a select few vessels were clear standouts: three tugboats, a fishing (shrimping) vessel, and the supply boat. The concentrations of all three parameters were highly variable and span two orders of magnitude. In contrast, measured sulfide concentrations from deck washdown water samples collected from two fishing boats and a tow/salvage boat were all relatively low, but, when compared to the most stringent NRWQC of 0.002 mg/L, had PHQs ranging from 2.5 to 8.5 (moderate exceedance - data not shown).

PHQs were calculated for three additional classical pollutants for which benchmarks were available and are shown in Figure 3.3.6. As the figure shows, the TRC concentrations where TRC was detected above the reporting limit of 0.10 mg/L greatly exceeded the benchmark (most stringent NRWQC of 0.0075 mg/L, the saltwater chronic aquatic life criterion) by factors that ranged from 23 (tow/salvage vessel) to 106 (exceedance by 2 orders of magnitude – a fishing vessel). These concentrations (ranging from 0.17 to 0.80 mg/L) were measured in deck washdown water samples collected from three (of the 11) fishing vessels, the two tour boats, a tugboat, and the tow/salvage boat. It is worth pointing out that in one instance (i.e., for a tugboat with a high TRC concentration of 0.39 mg/L), the measured TRC concentration in the source (potable) water was 0.70 mg/L. It is also worth noting that only one of 11 respondents (a fishing vessel) indicated using chlorine bleach while washing decks, and this particular vessel had a measured TRC concentration in the deck washdown sample of 0.38 mg/L and a PHQ of 51.

TSS in most of the deck washdown water samples collected exceeded the secondary treatment effluent limitation benchmark of 30 mg/L. However, 27 of 32 PHQs calculated for these samples were below 10 (Figure 3.3.6), and all five TSS samples with PHQs>10 (max PHQ = 17.7) were associated with tugboats. As discussed above, in the one potable water sample for which TSS was measured, TSS was not detected.

BOD was measured in 22 deck washdown water samples that exceeded EPA's secondary treatment effluent limit of 30 mg/L (Figure 3.3.6). As indicated above, the vessels with the highest level of exceedance (PHQs > 5) were associated with three tugboats, a fishing (shrimping) vessel, and the supply boat.

EPA compared HEM and SGT-HEM concentrations measured in deck washdown samples to the existing international and U.S. regulatory limit of 15 ppm (15 mg/L) for oil and grease discharge. HEM and SGT-HEM were detected in all of the deck washdown water samples, with concentrations ranging from 1.2 to a very high 133 mg/L for HEM and 0.91 to a comparably high 84 mg/L for SGT-HEM. Based on the regulatory limit of 15 mg/L, PHQs exceeded one in only six of 29 vessels sampled for HEM and two in the 29 vessels sampled for SGT-HEM. The highest PHQs for both parameters corresponded with the supply boat and a tugboat, with PHQs of 4.7 and 8.9 for HEM and 1.2 and 5.6 for SGT-HEM, respectively. Note, oil and grease were not detected in the two potable water samples collected in this sampling program.

To summarize, just under a third of the vessels sampled had concentrations of TRC in deck washdown samples above the reporting limit of 0.10 mg/L. Of these seven samples, the measured TRC concentrations (as high as 0.80 mg/L) that exceeded the screening benchmark were not associated with any one particular class of vessel. For TSS, however, one vessel type (tugboats) had the highest number of exceedances. The elevated TSS in deck washdown water samples from tugboats may be caused by a less frequent washdown on these vessels compared with vessels such as fishing vessels. Just over two-thirds of vessels (22 out of 32) exceeded the most stringent screening benchmark for BOD; however, as in the case with TRC, no one particular class of vessels had a higher number of exceedances than other classes.

Oil and grease are generally not of concern for this type of discharge, nor are any of the other physical parameters that were measured (conductivity, dissolved oxygen, pH, temperature, salinity). TOC was detected in all samples ranging from 3.6 to a very high 350 mg/L (one of the tugboats with high HEM). Organic carbon strongly complexes metals in both freshwater and saltwater matrices, and like the competing cations such as calcium and magnesium, renders dissolved metals less bioavailable and less likely to be rapidly available for biological organisms.

Table 3.3.6. Results of Deck Washdown Water Sample Analyses for Classical Pollutants[1]

Analyte	Units	No. samples	No. detected	Detected Proportion (%)	Average Conc.	Median Conc.	Minimum Conc.	10%	25%	75%	90%	Maximum Conc.	Screening BM[2]
Biochemical Oxygen Demand (BOD)	mg/L	32	30	94	110	56		4.7	14	92	370	830	30
Chemical Oxygen Demand (COD)	mg/L	32	32	100	390	160	24	52	90	570	1200	1800	NA
Conductivity	mS/cm	26	26	100	7.7	1.0	0.24	0.37	0.50	13	30	47	NA
Dissolved Oxygen	mg/L	26	26	100	7.2	7.7	1.6	1.8	6.3	8.9	9.7	11	NA
Hexane Extractable Material (HEM)	mg/L	29	26	90	14	2.8			1.7	12	39	130	15
pH	SU	30	30	100	7.7	7.6	7.0	7.0	7.2	7.9	8.5	9.8	NA
Salinity	ppt	24	24	100	4.9	0.60	0.10	0.20	0.23	8.0	21	28	NA
Silica Gel Treated HEM (SGT-HEM)	mg/L	29	22	76	7.0	1.7			0.45	3.8	13	84	15
Sulfide	mg/L	3	2	67	0.011	0.011				0.017	0.017	0.017	NA
Temperature	C	31	31	100	21	21	7.5	9.0	13	29	31	32	NA
Total Organic Carbon (TOC)	mg/L	25	25	100	44	24	3.6	5.0	7.1	52	96	350	NA
Total Residual Chlorine	mg/L	31	7	23	0.12						0.37	0.80	0.0075
Total Suspended Solids (TSS)	mg/L	32	32	100	170	120	27	31	59	250	470	530	30
Turbidity	NTU	31	31	100	150	110	4.1	36	58	190	380	463	NA

Notes:

(1) Nondetect (censored) concentrations were replaced with ½ of the reporting limit for calculating average concentrations. The remaining statistics in this table were only calculated when analytes were detected at a sufficient frequency. For example, if an analyte was detected in fewer than 50% of samples, then a median concentration was not calculated. A blank cell reflects a situation when a median or percentile could not be computed based on detected concentrations. The percentiles are the concentrations of each analyte below which at least that percentage of the values fall. So the 10th percentile is the concentration below which at least 10% of the observations were found.

(2) Screening BM represents the screening benchmark referred to in Section 3.1.3, and is the most stringent 2006 NRWQC or other conservative benchmark used to calculate PHQs.

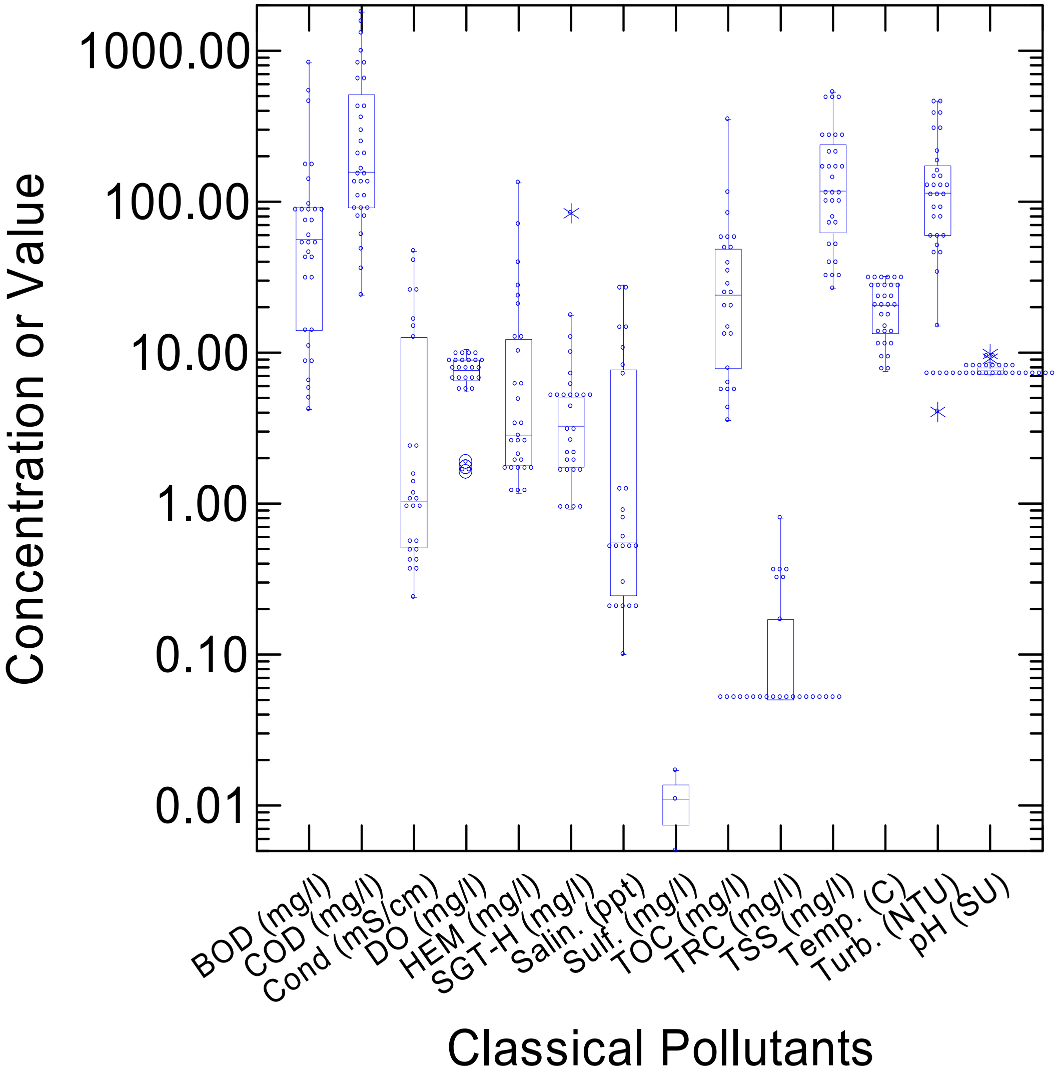

Figure 3.3.5. Box and Dot Density Plot of Classical Pollutants Measured in Samples of Deck Washdown Water

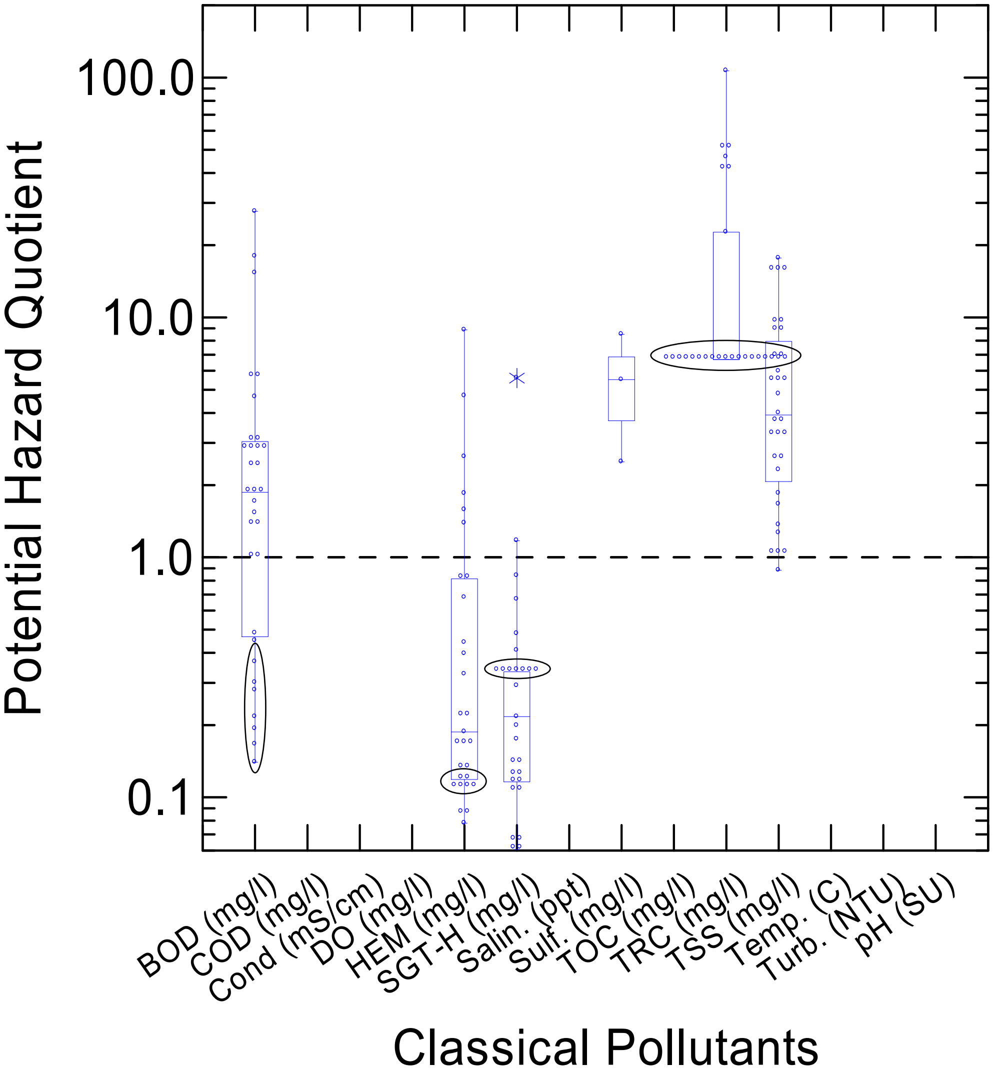

Figure 3.3.6. Box and Dot Density Plot of Potential Hazard Quotients for Classical Pollutants in Samples of Deck Washdown Water

(Note: Replacement values for non-detects are circled. Also, PHQs for sulfide are not shown in the figure, but are mentioned in the text).

3.2.3.3 Pathogen Indicators (Microbiologicals)

Selected deck washdown water samples were analyzed for the pathogen indicator bacteria *E. coli*, enterococci, and fecal coliform. Sampling for pathogens was limited to fishing vessels since EPA could not identify likely potential sources of pathogens in deck washdown discharges on other vessel types. EPA targeted select fishing vessels to attain the best cross-representation possible based on available funding and proximity to qualified subcontractor laboratories to meet sample hold times (< 6 hours). The types of fishing vessels sampled included three shrimping (trawler) boats in Louisiana, two ground fishery trawlers in Massachusetts, and a gillnetter boat in Alaska. All vessels indicated that their decks are washed frequently throughout the day (after or between catches, after unloading, etc.), and while pierside and underway (nearshore and farshore). Table 3.3.7 summarizes the analytical results. Concentrations were determined for each pathogen using the same (*E. coli*, enterococci) or comparable methods (fecal coliform).

Figure 3.3.7 shows the variability of the values measured for the pathogens in deck washdown water samples from the various fishing vessels. Measured concentrations of *E. coli* range from 20 MPN/100 ml for one of the shrimping trawlers to 8,336 MPN/100 ml for one of the ground fishery trawlers in Massachusetts. It should be noted, however, that the water the ground fishery trawler used for desk washing was ambient (harbor) water receiving stormwater and combined sewer overflow from a storm event. The measured concentration of *E. coli* in the ambient water at that location was 24,200 MPN/100 ml. Excluding this outlier, the concentration of *E. coli* from only one vessel (shrimper; concentration = 650 MPN/100 ml) exceeded EPA's most stringent freshwater bathing NRWQC of 126 MPN/100 ml by more than a factor of five (PHQ = 5.1), as illustrated in Figure 3.3.8. EPA collected multiple samples from another shrimping vessel in Louisiana to measure *E. coli* in prefishing deck washdown water, postfishing water, without catch rinse water, and with catch rinse water. For this vessel, *E. coli* concentrations ranged from a low of 10 (prefishing sample) to a high of only 50 MPN/100 ml (without catch rinse). The concentrations of *E. coli* were largely unaffected by either the addition of catch to the vessel (as *E. coli* concentrations in prefishing and postfishing deck washdown samples were similar) or the process of rinsing the catch while on deck.

The enterococci values measured in a deck washdown water samples ranged from 1.5 to 1,300 MPN/100 ml, and follow the same general pattern as *E. coli* (Figure 3.3.7). Excluding the previously described example of the trawler in Massachusetts, which was directly influenced by high levels of enterococci in the ambient water resulting from storm-related combined sewage overflow (5,100 MPN/100 ml), the deck washdown water samples from two vessels (both shrimpers; concentrations = 637 and 914 MPN/100 ml, respectively) exceeded EPA's most stringent bathing NRWQC for enterococci of 33 MPN/100 ml (freshwater) and 35 MPN/100 ml (saltwater) by factors of nearly 20 and 30 respectively (Figure 3.3.8). In contrast to *E. coli*, however, analysis of the multiple samples collected for enterococci in prefishing deck washdown water (540 MPN/100 ml), postfishing water (8 MPN/100 ml), without catch rinse (1,200 MPN/100 ml), and with catch rinse (801 MPN/100 ml) for the shrimping vessel in Louisiana indicate that their deck washing process appeared to reduce the presence of the pathogen in deck washdown discharge.

The concentrations of fecal coliform bacteria measured in a deck washdown water samples are all substantial (ranging from 91 to 600 CFU/100 ml[27]), except for the very low concentration of 0.75 CFU/100 ml for the gillnetting vessel in Alaska (Figure 3.3.7). The associated PHQs for fecal coliform range from 0.05 (gillnetter) to 43 (one of the shrimping boats), as illustrated in Figure 3.3.8. The PHQs for this pathogen are based on the NRWQC of 14 MPN/100 ml for shellfish harvesting. As with enterococci, the multiple samples measured for fecal coliform bacteria in prefishing deck washdown water (0 CFU/100 ml), postfishing water (6 CFU/100 ml), without catch rinse (1,630 CFU/100 ml), and with catch rinse (620 CFU/100 ml) for the shrimping vessel indicate that their deck washing process did not increase (and seemed to reduce) the presence of this pathogen in deck washdown discharge. The single potable water sample taken while onboard a shrimping vessel pierside in Louisiana was free of all pathogens.

The data collected for this study show that, while the three groups of pathogens are present in deck washdown discharge samples from commercial fishing vessels, concentrations are variable, and the source of the water used for deck washdown can greatly influence the background bacteria levels. Of the three pathogen groups, fecal coliform are present at concentrations exceeding EPA's most stringent criteria more often than enterococci and *E. coli*, in that order.

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[27] Excluding the outlier value of 8,050 CFU/ml from the ground fishery trawler in Maine influenced by the storm event.

Table 3.3.7. Results of Deck Washdown Water Sample Analyses for Pathogen Indicators[1]

Analyte[2]	Units[3]	No. samples	No. detected	Detected Proportion (%)	Average Conc.	Median Conc.	Minimum Conc.	10%	25%	75%	90%	Maximum Conc.	Screening BM[4]
E. Coli by MPN	MPN/100 ml	5	5	100	1900	160	20	20	62	4500	8300	8300	130
Enterococci by MPN	MPN/100 ml	5	5	100	580	640	1.5	1.5	27	1100	1300	1300	33
Fecal Coliform by MF	CFU/100 ml	6	6	100	1600	560	0.75	0.75	68	2500	8100	8100	14

Notes:

(1) Nondetect (censored) concentrations were replaced with ½ of the reporting limit for calculating average concentrations. The remaining statistics in this table were only calculated when analytes were detected at a sufficient frequency. For example, if an analyte was detected in fewer than 50% of samples, then a median concentration was not calculated. A blank cell reflects a situation when a median or percentile could not be computed based on detected concentrations. The percentiles are the concentrations of each analyte below which at least that percentage of the values fall. So the 10th percentile is the concentration below which at least 10% of the observations were found.

(2) MPN = Most Probable Number; MF = Membrane Filtration.

(3) CFU = Colony Forming Units.

(4) Screening BM represents the screening benchmark referred to in Section 3.1.3, and is the most stringent 2006 NRWQC or other conservative benchmark used to calculate PHQs.

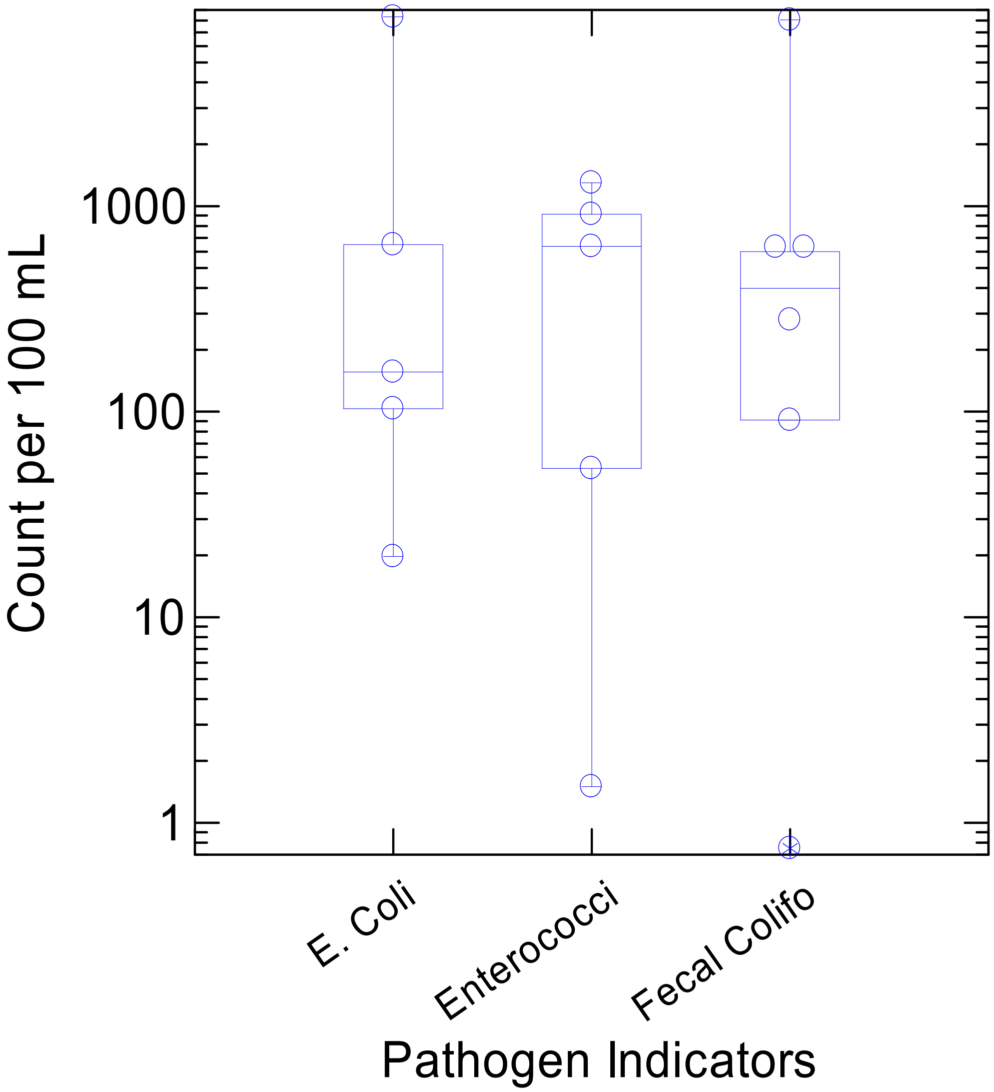

Figure 3.3.7 Box and Dot Density Plot of Pathogen Indicator Concentrations Measured in Samples of Deck Washdown Water
(Note: Corresponding units are MPN/100 ml for *E. coli* and enterococci, and CFU/100 ml for fecal coliform).

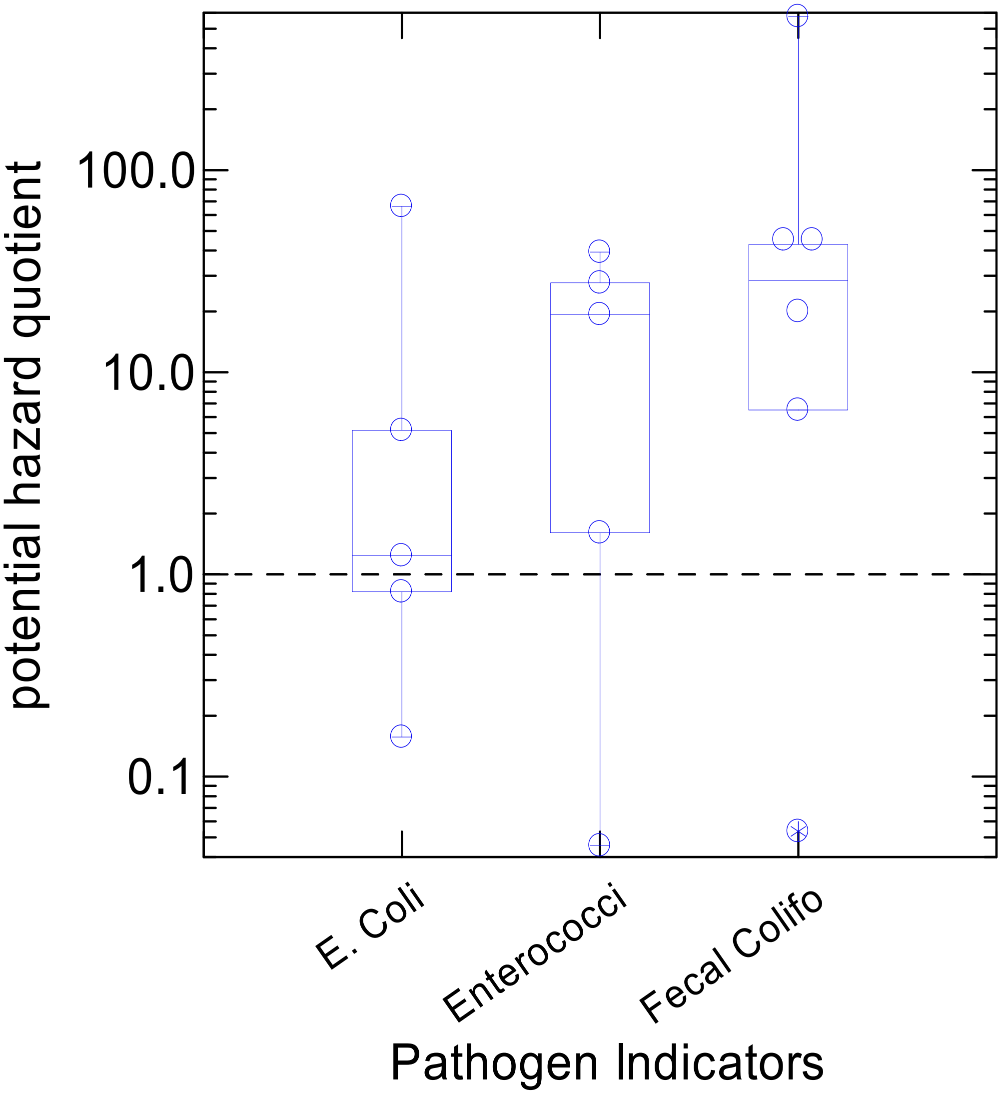

Figure 3.3.8. Box and Dot Density Plot of Potential Hazard Quotients for Pathogens in Samples of Deck Washdown Water

3.2.3.4 Nutrients

Deck washdown discharge was also characterized for nutrient levels. Nutrient pollution, including nitrogen, phosphorus, and numerous micronutrients, is a component of certain vessel discharges and a major source of water quality degradation throughout the United States (USGS, 1999). Deck washdown discharges from all vessel types were expected to contain potentially high levels of phosphorus because of the wide-spread use of detergents for deck cleansing. Deck washdown discharges from commercial fishing vessels were also expected to contain potentially elevated ammonia concentrations for the same reason, as well as from biological wastes from fish and shellfish catch. In addition to total phosphorus and total ammonia (as nitrogen), deck washdown water samples were also analyzed for nitrate/nitrite nitrogen (inorganic nitrogen) and TKN, the sum of organic nitrogen (including toxic ammonia nitrogen) (see Table 3.3.8).

Concentrations of nitrate/nitrite nitrogen in deckwash discharge samples range from 0.025 to 6.5 mg/L (see Figure 3.3.9). An interesting note is that the deck washdown water samples for commercial fishing vessels of all types did not exceed 0.50 mg/L while all other vessels exceeded this value. The five highest nitrate/nitrite concentrations (ranging from 2.5 to 6.5 mg/L) were analyzed in samples from three tugs and two tow/salvage vessels. It is important to note, however, that most samples of deck washdown on fishing vessels were collected onboard fishing vessels pierside and not when fishing activity was occurring. In the two cases where deck washdown samples were collected where fishing activities were taking place, the samples were collected towards the end of the deck washdown activity and may not have captured potentially higher levels of nitrate/nitrite from biological wastes.

The concentrations determined for TKN (sum of organic nitrogen) show the concentration range spans two orders of magnitude, from 0.05 to 40 mg/L (see Figure 3.3.9). In contrast to the nitrate/nitrite samples, the TKN concentrations from all vessels were evenly distributed across the entire concentration range. The two highest TKN concentrations (by more than a factor of two) correspond to a trolling vessel and a tugboat, with TKN concentrations of 28 and 40 mg/L, respectively.

Ammonia is the only nutrient form for which there are currently numeric NRWQC established to protect against its toxic effects. Only five of 31 vessels contained ammonia in deck washdown water samples slightly above (1.2 to 1.8 mg/L ammonia as nitrogen) the most stringent 2006 NRWQC of 1.2 mg/L, the freshwater chronic aquatic life criterion for total ammonia as nitrogen (see Figure 3.3.10). These values correspond with deck washdown water samples collected from two tow/salvage boats, two fishing vessels, and the recreational vessel.

The benchmark for total phosphorus of 0.1 mg/L from the 1986 EPA Gold Book was exceeded in samples collected from all but one of the 31 vessels. The highest total phosphorus concentration of 22 mg/L from a tugboat exceeded the benchmark by a factor of 220 (see Figure

3.3.10). This concentration was 6.5 times higher then the next highest measured concentration of 3.4 mg/L from a trolling vessel. The deck washdown water samples for phosphorus from all vessels were generally evenly distributed across the entire concentration range.

Total ammonia in ambient and service water ranged from below detection to 0.93 mg/L and from below detection to 0.73 mg/L, respectively (all below the most stringent 2006 NRWQC of 1.24 mg/L). Total phosphorus in ambient and service water ranged from below detection to 2.0 mg/L and from below detection to 0.52 mg/L, respectively (compared to 0.1 mg/L from the 1976 EPA Red Book).

In summary, out of the four nutrient parameters, only total phosphorus is likely a potential concern from deck washdown effluent. Twelve of the 19 respondents confirmed using standard liquid detergents aboard their vessels for deck washing, the expected source of total phosphorus in deck washdown discharges. However, ambient and domestic service water are also likely sources of phosphorus in a meaningful percentage of instances.

Table 3.3.8. Results of Deck Washdown Water Sample Analyses for Nutrients[1]

Analyte	Units	No. samples	No. detected	Detected Proportion (%)	Average Conc.	Median Conc.	Minimum Conc.	10%	25%	75%	90%	Maximum Conc.	Screening BM[2]
Ammonia As Nitrogen (NH3-N)	mg/L	31	31	100	0.53	0.32	0.058	0.074	0.10	0.81	1.5	1.8	1.2
Nitrate/Nitrite (NO3/NO2-N)	mg/L	32	27	84	1.4	1.5			0.16	1.9	2.7	6.5	NA
Total Kjeldahl Nitrogen (TKN)	mg/L	31	30	97	6.0	3.6		1.4	1.8	6.6	11	40	NA
Total Phosphorus	mg/L	31	31	100	1.7	0.79	0.060	0.15	0.44	1.6	2.9	22	0.10

Notes:

(1) Nondetect (censored) concentrations were replaced with ½ of the reporting limit for calculating average concentrations. The remaining statistics in this table were only calculated when analytes were detected at a sufficient frequency. For example, if an analyte was detected in fewer than 50% of samples, then a median concentration was not calculated. A blank cell reflects a situation when a median or percentile could not be computed based on detected concentrations. The percentiles are the concentrations of each analyte below which at least that percentage of the values fall. So the 10th percentile is the concentration below which at least 10% of the observations were found.

(2) Screening BM represents the screening benchmark referred to in Section 3.1.3, and is the most stringent 2006 NRWQC or other conservative benchmark used to calculated PHQs.

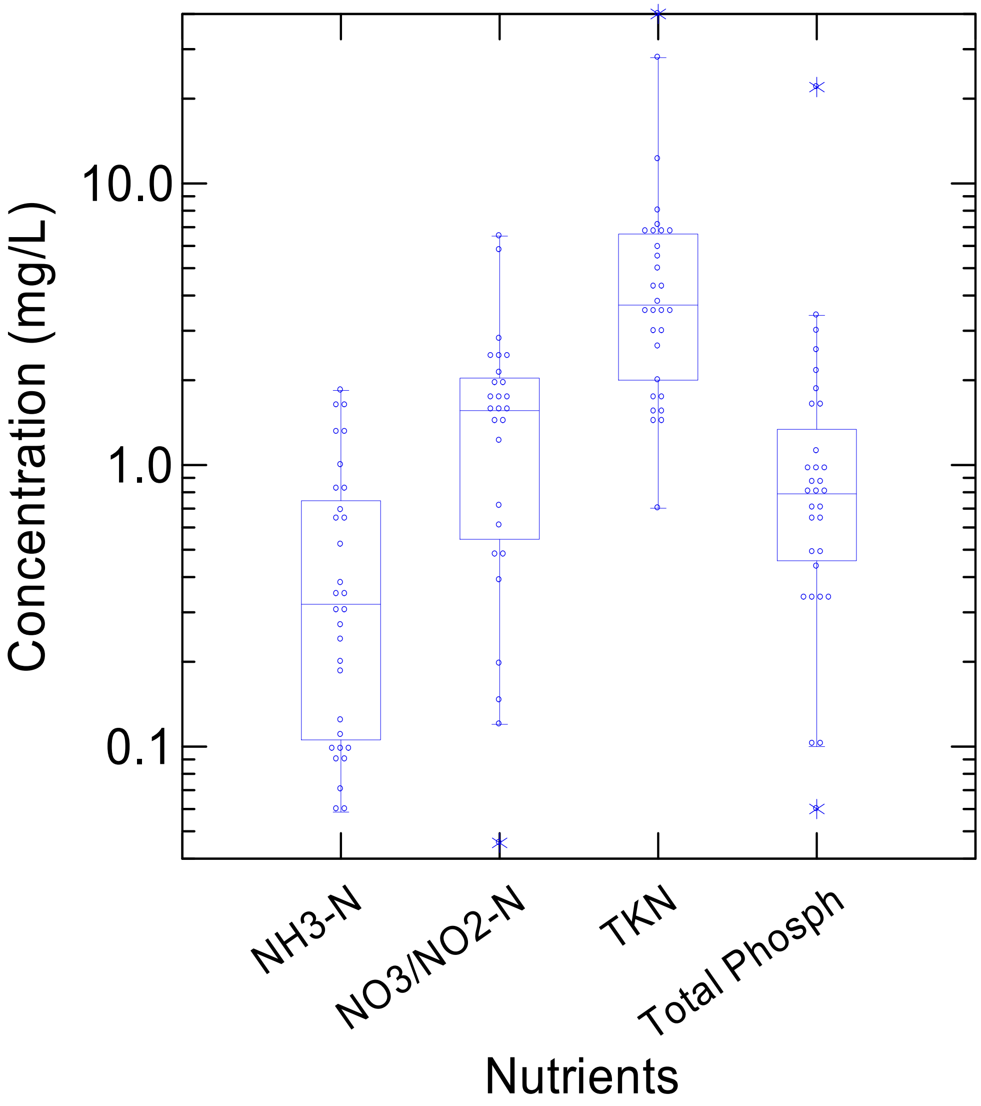

Figure 3.3.9. Box and Dot Density Plot of Nutrient Concentrations Measured in Samples of Deck Washdown Water

(Note: NH3-N=Ammonia as Nitrogen, NO3/NO2-N= Nitrate/Nitrite Nitrogen, TKN=Total Kjeldahl Nitrogen, and Total Phosph (truncated)=Total Phosphorus).

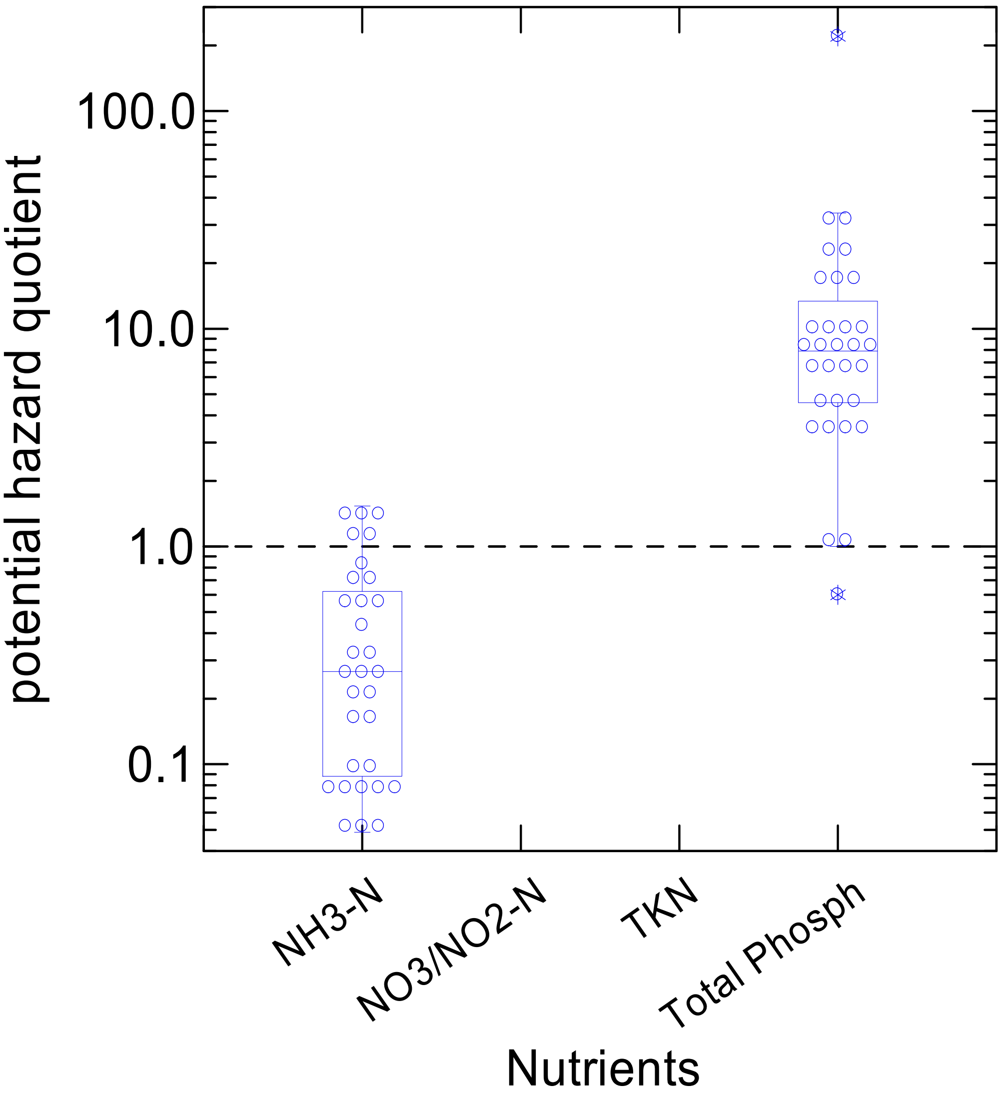

Figure 3.3.10. Box and Dot Density Plot of Potential Hazard Quotients for Nutrients in Samples of Deck Washdown Water

(Note: NH3-N=Ammonia as Nitrogen, NO3/NO2-N= Nitrate/Nitrite Nitrogen, TKN=Total Kjeldahl Nitrogen, and Total Phosph (truncated)=Total Phosphorus).

3.2.3.5 Long-Chain Nonylphenols

Deck washdown water samples from 29 vessels were analyzed for 27 long-chain alkylphenol ethoxylates: 16 NPEOs and 5 OPEOs (see Table 3.3.9). The NPEOs with the longest ethoxylate chains (i.e., less degraded products (NP18EO through NP10EO)) were detected in slightly under a third of the vessels (nine of 29), with concentrations increasing as ethoxylate chain is reduced (i.e., concentrations increasing from NP18EO to NP10EO because the longer-chain products found in commercial formulations are quickly degraded). The OPEO with the longest ethoxylate chain (OP12EO) was also detected in about a third of the vessels (see Table 3.3.9). As with NPEOs, the OPEO concentrations generally increase as the ethoxylate chain is reduced, except that no OPEOs with ethoxylate chains smaller than OP7EO were detected (similar to the situation in packing gland effluent; see Section 3.2.2.5).

Of the several vessels where NPEOs were detected in the longer (NP18EO through NP10EO) ethoxylated compounds, only three of those vessels also had detectable concentrations of NPEOs of the shortest chain (NP3EO), albeit at very low concentrations ranging from 0.80 to 29 µg/L. These were tow/salvage vessels, one of which confirmed using liquid detergent (Palmolive™) for deck washing (NP3EO concentration of 29 µg/L in deck washdown sample). A tugboat had the only measured concentration of OP8EO in its deck washdown water sample at a concentration of 19 µg/L.

Total NPEO concentrations could be calculated from summed concentrations of individual chain lengths for five of the 29 vessels: three tow/salvage vessels and two tour boats (see Figure 3.3.11). The concentrations of total NPEOs ranged from 30 to 8,330 µg/L.

As discussed in previous subsections (see Sections 3.2.1.7 (bilgewater) and 3.2.2.5 (packing gland effluents)), while there are no NRWQC for the sum of individual ethoxylate chains of NPEOs or OPEOs, these compounds will ultimately degrade to NP in fresh and salt water over time under all conditions. The NRWQC for NP in salt water based on chronic toxicity to aquatic organisms is 1.7 µg/L. EPA is uncertain as to exactly how much NP might be generated from the degradation of NPEO and OPEO isomers under a given harbor scenario and water quality condition (see Section 1.6.6 of this report). However, neither total NPEO or OPEO, nor any of the different isomers, were detected in ambient water at the locations where the vessels were sampled. Service water (generally city tapwater pierside) was not analyzed for long- or short- chain nonylphenol and octylphenol ethoxylates.

Table 3.3.9. Results of Deck Washdown Water Sample Analyses for Long-Chain Nonylphenols[1]

Analyte	Units	No. samples	No. detected	Detected Proportion (%)	Average Conc.	Median Conc.	Minimum Conc.	10%	25%	75%	90%	Maximum Conc.	Screening BM[2]
Total Nonylphenol Polyethoxylates	µg/L	29	5	17	540						1400	8300	NA
Nonylphenol octodecaethoxylate (NP18EO)	µg/L	29	12	41	1.5					0.15	5.0	21	NA
Nonylphenol heptadecaethoxylate (NP17EO)	µg/L	29	9	31	3.4					0.21	13	41	NA
Nonylphenol hexadecaethoxylate (NP16EO)	µg/L	29	10	34	7.4					0.89	27	87	NA
Nonylphenol pendecaethoxylate (NP15EO)	µg/L	29	9	31	14					0.91	55	160	NA
Nonylphenol tetradecaethoxylate (NP14EO)	µg/L	29	9	31	25					1.8	75	290	NA
Nonylphenol tridecaethoxylate (NP13EO)	µg/L	29	9	31	44					2.9	180	480	NA
Nonylphenol dodecaethoxylate (NP12EO)	µg/L	29	8	28	64					4.5	260	760	NA
Nonylphenol undecaethoxylate (NP11EO)	µg/L	29	9	31	86					6.1	350	1100	NA
Nonylphenol decaethoxylate (NP10EO)	µg/L	29	9	31	91					6.9	350	1300	NA
Nonylphenol nonaethoxylate (NP9EO)	µg/L	29	8	28	88					3.1	330	1300	NA
Nonylphenol octaethoxylate (NP8EO)	µg/L	29	8	28	75					3.2	280	1100	NA
Nonylphenol heptaethoxylate (NP7EO)	µg/L	29	7	24	61					0.99	220	950	NA
Nonylphenol hexaethoxylate (NP6EO)	µg/L	29	6	21	34						140	440	NA
Nonylphenol pentaethoxylate (NP5EO)	µg/L	29	6	21	19						40	270	NA
Nonylphenol tetraethoxylate (NP4EO)	µg/L	29	4	14	11						2.6	120	NA
Nonylphenol triethoxylate (NP3EO)	µg/L	29	3	10	4.9						0.80	30	NA
Octylphenol dodecaethoxylate (OP12EO)	µg/L	29	8	28	1.4					0.98	2.4	8.8	NA
Octylphenol undecaethoxylate (OP11EO)	µg/L	29	2	6.9	1.8							7.8	NA
Octylphenol decaethoxylate (OP10EO)	µg/L	29	4	14	3.6						1.8	2.1	NA
Octylphenol nonaethoxylate (OP9EO)	µg/L	29	5	17	3.8						1.3	9.6	NA
Octylphenol octaethoxylate (OP8EO)	µg/L	29	1	3.4	10							19	NA

Notes:

(1) Nondetect (censored) concentrations were replaced with ½ of the reporting limit for calculating average concentrations. The remaining statistics in this table were only calculated when analytes were detected at a sufficient frequency. For example, if an analyte was detected in fewer than 50% of samples, then a median concentration was not calculated. A blank cell reflects a situation when a median or percentile could not be computed based on detected concentrations. The percentiles are the concentrations of each analyte below which at least that percentage of the values fall. So the 10th percentile is the concentration below which at least 10% of the observations were found.

(2) Screening BM represents the screening benchmark referred to in Section 3.1.3, and is the most stringent 2006 NRWQC or other conservative benchmark used to calculate PHQs.

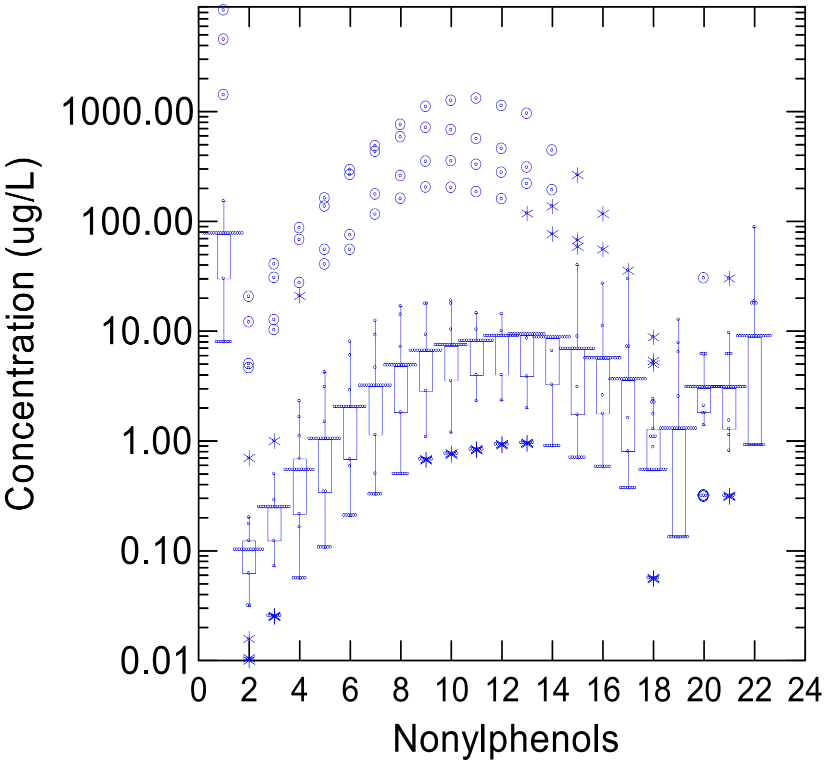

Figure 3.3.11. Box and Dot Density Plot of Nonylphenol Concentrations Measured in Samples of Deck Washdown Water

Nonylphenol parameters are identified as follows:

(1) Total Nonylphenol Polyethoxylates
(2) Nonylphenol octodecaethoxylate (NP18EO)
(3) Nonylphenol heptadecaethoxylate (NP17EO)
(4) Nonylphenol hexadecaethoxylate (NP16EO)
(5) Nonylphenol pendecaethoxylate (NP15EO)
(6) Nonylphenol tetradecaethoxylate (NP14EO)
(7) Nonylphenol tridecaethoxylate (NP13EO)
(8) Nonylphenol dodecaethoxylate (NP12EO)
(9) Nonylphenol undecaethoxylate (NP11EO)
(10) Nonylphenol decaethoxylate (NP10EO)
(11) Nonylphenol nonaethoxylate (NP9EO)
(12) Nonylphenol octaethoxylate (NP8EO)
(13) Nonylphenol heptaethoxylate (NP7EO)
(14) Nonylphenol hexaethoxylate (NP6EO)
(15) Nonylphenol pentaethoxylate (NP5EO)
(16) Nonylphenol tetraethoxylate (NP4EO)
(17) Nonylphenol triethoxylate (NP3EO)
(18) Octylphenol dodecaethoxylate (OP12EO)
(19) Octylphenol undecaethoxylate (OP11EO)
(20) Octylphenol decaethoxylate (OP10EO)
(21) Octylphenol nonaethoxylate (OP9EO)
(22) Octylphenol octaethoxylate (OP8EO)

3.2.3.6 Volatile and Semivolatile Organic Chemicals

VOCs and SVOCs were not targeted for deck washdown water sample collection in this study because these compounds were not expected to be found in common deck washdown on most vessels[28]. In two cases during scheduled cleanings of the decks of two tow/salvage vessels, however, there was a noticeable oily sheen and where fuel was spilled at the fueling location while samplers were onboard the vessels. Samples of deck washdown water were taken in these instances and analyzed for VOCs and SVOCs (see Table 3.3.10).

Of the 70 VOCs that were analyzed for in the two deck washdown samples, only 12 were detected in one or more of the two samples. Of these 12 VOCs, only acetone, chloroform, and toluene were detected in both samples. In one sample from the vessel with the oily sheen; acetone was detected at 20 µg/L. Figure 3.3.12 contains all the samples that were detected, the other five samples were detected with very low values. Benzene, ethylbenzene, and xylene (compounds associated with fuel oil spills) were detected in one of the two samples at surprisingly low levels. The PHQ of 13 for the benzene sample that was below detection levels was an artifact of the relatively high reporting limit of 25µg/L compared to the screening benchmark of 2.2 µg/L. PHQs for only two VOCs, dibromochloromethane and bromodichloromethane exceeded the benchmark (see Figure 3.3.13), which were artifacts of the reporting limits which were as high as 25µg/L compared to the screening benchmarks of 0.4 µg/L and 0.55 µg/L, respectively. Both these were formerly used as flame retardants and as an intermediate in chemical manufacturing.

Similarly, of the 62 SVOCs that were analyzed for in the two deck washdown samples, only three were detected in one or more of the two samples: bis(2-ethylhexyl) phthalate, caprolactam, and di-n-butyl phthalate (data not shown due to so few analytes detected). Levels detected in the latter two SVOCs are unremarkable. The concentration of bis(2-ethylhexyl) phthalate in the one sample where it was detected (i.e., the tow/salvage vessel with the oily sheen), however, was sufficiently high (6.7 µg/L) such that the associated PHQ, based on the most conservative screening benchmark of 1.2 µg/L (human health criteria), was 5.6 (data not shown). As previously noted, bis(2-ethylhexyl) phthalate is a manufactured chemical that is commonly added to plastics to make them flexible. Phthalates in general are known to interfere with reproductive health and liver and kidney function in both animals and humans (Sekizawa et

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[28] It is worth noting that solvents in cleaning agents may be used for certain activities such as above-water-line hull cleaning. Samples associated with above-water-line hull cleaning were not collected during this study because none of the vessels engaged in such an activity while EPA's sampling crew was aboard the vessel. During a survey collected while onboard the vessels, however, 11 of 16 respondents confirmed that they do perform above-water-line hull cleaning occasionally on their vessels.

al., 2003; DiGangi et al., 2002). Bis(2-ethylhexyl) phthalate was not detected in the associated ambient water sample collected at the site corresponding with the two tow/salvage vessels, but di-n-butyl phthalate was (ambient concentration of 1.1 µg/L).

Di-n-butyl phthalate was the only SVOC detected in ambient water samples collected in association with the deck washdown samples collected in the study. No VOCs were detected in ambient samples.

Table 3.3.10. Results of Deck Washdown Water Sample Analyses for VOCs and SVOCs[1]

Analyte	Units	No. samples	No. detected	Detected Proportion (%)	Average Conc.	Median Conc.	Minimum Conc.	10%	25%	75%	90%	Maximum Conc.	Screening BM[2]
VOCs													
1,2,4-Trimethylbenzene	µg/L	2	1	50	13	0.30				0.30	0.30	0.30	NA
1,3,5-Trimethylbenzene	µg/L	2	1	50	13	0.090				0.090	0.090	0.090	NA
Acetone	µg/L	2	2	100	13	20	5.5	5.5	5.5	20	20	20	NA
Benzene	µg/L	2	1	50	13	0.3				0.3	0.3	0.3	2.2
Bromodichloromethane	µg/L	2	1	50	13	1.2				1.2	1.2	1.2	0.55
Chloroform	µg/L	2	2	100	1.3	1.5	1.0	1.0	1.0	1.5	1.5	1.5	5.7
Dibromochloromethane	µg/L	2	1	50	13	0.7				0.70	0.70	0.70	0.4
Ethylbenzene	µg/L	2	1	50	13	0.10				0.10	0.10	0.10	530
m-,p-Xylene (sum of isomers)	µg/L	2	1	50	25	0.40				0.40	0.40	0.40	NA
O-Xylene	µg/L	2	1	50	25	0.20				0.20	0.20	0.20	NA
Toluene	µg/L	2	2	100	0.65	0.70	0.60	0.60	0.60	0.70	0.70	0.70	1300
SVOCs													
Bis(2-ethylhexyl) phthalate	µg/L	2	1	50	4.7	6.7				6.7	6.7	6.7	1.2
Caprolactam	µg/L	2	2	100	79	100	56	56	56	100	100	100	NA
Di-n-butyl phthalate	µg/L	2	1	50	2.5	2.4				2.4	2.4	2.4	2000
Naphthalene	µg/L	2	1	50	13	0.40				0.40	0.40	0.40	NA

Notes:

(1) Nondetect (censored) concentrations were replaced with ½ of the reporting limit for calculating average concentrations. The remaining statistics in this table were only calculated when analytes were detected at a sufficient frequency. For example, if an analyte was detected in fewer than 50% of samples, then a median concentration was not calculated. A blank cell reflects a situation when a median or percentile could not be computed based on detected concentrations. The percentiles are the concentrations of each analyte below which at least that percentage of the values fall. So the 10th percentile is the concentration below which at least 10% of the observations were found.

(2) Screening BM represents the screening benchmark referred to in Section 3.1.3, and is the most stringent 2006 NRWQC or other conservative benchmark used to calculate PHQs.

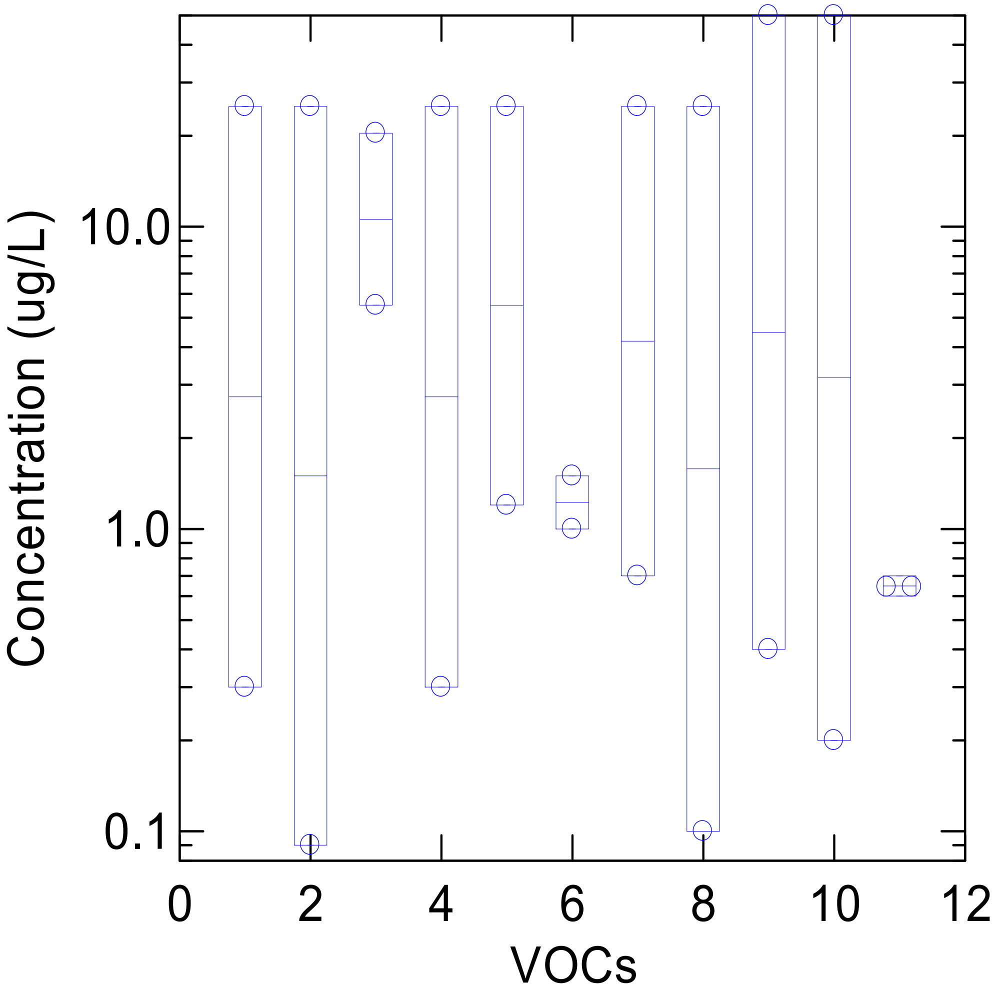

Figure 3.3.12. Box and Dot Density Plot of Volatile Organic Chemical Concentrations Measured in Samples of Deck Washdown Water

VOCs are identified as follows:

(1) 1,2,4-Trimethylbenzene
(2) 1,3,5-Trimethylbenzene
(3) Acetone
(4) Benzene
(5) Bromodichloromethane
(6) Chloroform
(7) Dibromochloromethane
(8) Ethylbenzene
(9) m-,p-Xylene (sum of isomers)
(10) O-Xylene
(11) Toluene

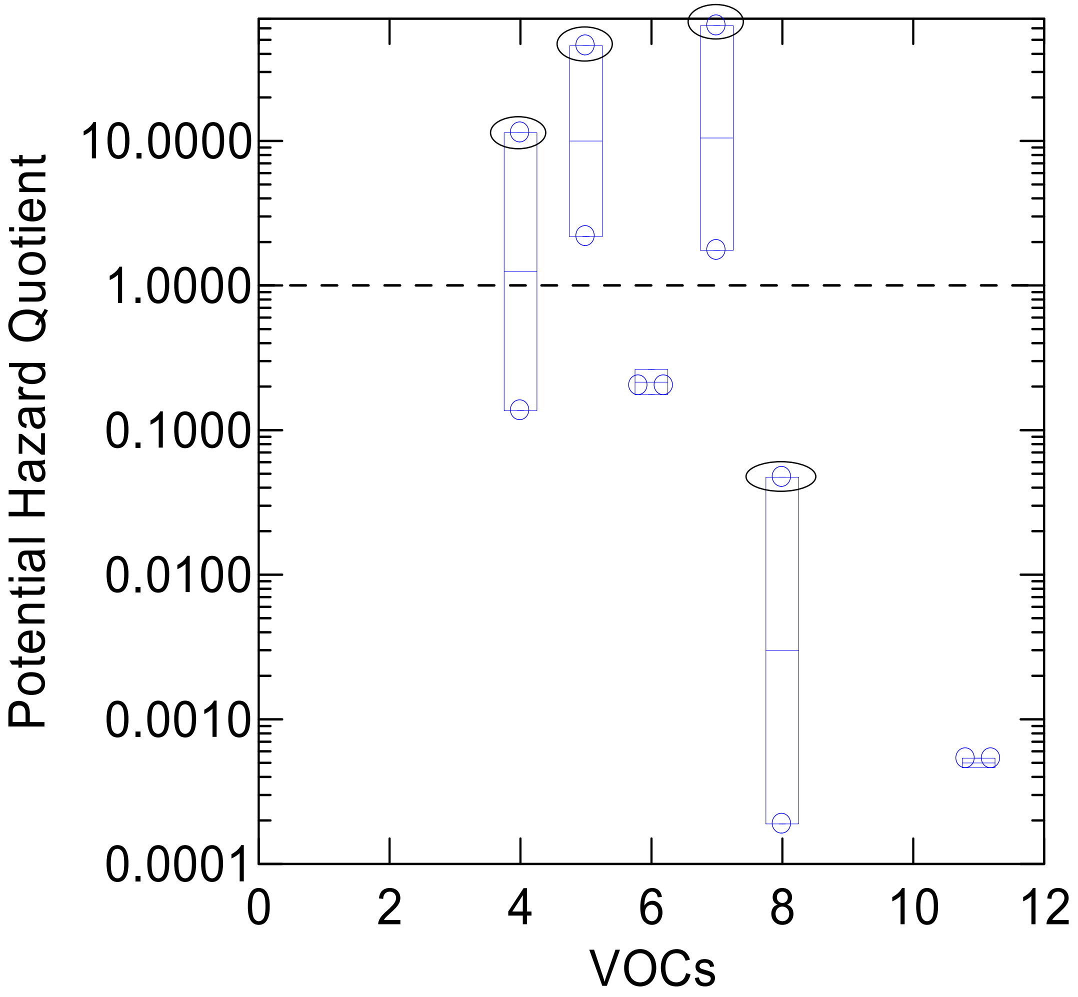

Figure 3.3.13. Box and Dot Density Plot of Potential Hazard Quotients for VOCs in Samples of Deck Washdown Water

VOCs are identified as follows (replacement values for non-detects are circled):

(1) 1,2,4-Trimethylbenzene
(2) 1,3,5-Trimethylbenzene
(3) Acetone
(4) Benzene
(5) Bromodichloromethane
(6) Chloroform
(7) Dibromochloromethane
(8) Ethylbenzene
(9) m-,p-Xylene (sum of isomers)
(10) O-Xylene
(11) Toluene

3.2.3.7 Summary of the Characterization of Deck Washdown Water

Table 3.3.11 summarizes the specific analytes within deck washdown and runoff water that may have the potential to pose risk to human health or the environment. EPA's interpretation of a realized risk likely posed by these analytes, relative to pollutant loadings, background ambient and source water contaminant levels and characteristics, and other relevant information useful for this assessment, is presented in Chapter 5.

Metals were the class of pollutants found most frequently and at concentrations that exceeded national water quality criteria in samples of deck washdown discharge. Several dissolved metals were measured at PHQs>10, relative to the most stringent benchmarks. Among the dissolved metals, copper was the most prevalent, and was measured at PHQ>10 in tow/salvage, fire, taxi, tour, and supply vessels. Dissolved cadmium was rarely detected, but had the highest exceedance, in a tow/salvage vessel. Dissolved lead exceeded NRWQC benchmarks in five of six salvage vessels, three of nine tugboats, one of two tour vessels, the one fire vessel, and the one supply vessel. Dissolved zinc exceeded NRWQC benchmarks in five of six tow/salvage vessels, as well as in tug, tour, fire, and supply vessels. Among the total metals, arsenic and aluminum were the most prevalent, particularly in deck washdown discharges of tow/salvage boats (both metals), tugboats (aluminum), and fishing and fire vessels (arsenic). Total iron exceedances were also common, with the highest PHQs for total iron occurring in tugboats and tow/salvage vessels. Finally, total antimony and manganese exceedances were relatively rare, with PHQs in those instances associated mainly with the nonfishing vessels. In general, metal discharges were higher in the industrial nonfishing vessels compared to fishing vessels.

Among the conventional pollutants, TRC was the most prevalent, with regard to high concentrations and frequency of exceedance of the discharge. The highest PQHs for TRC were observed in three of the 11 fishing vessels, the two tour boats, a tow/salvage vessel, and a tugboat. TSS and turbidity were the next most important classical pollutants, with high occurrences distributed across all vessel classes, but particularly tugboats. The highest exceedances of BOD were found in three tugboats, one shrimp vessel, and the supply boat. COD and TOC concentrations were similar to BOD concentrations. Oil and grease and sulfide were high in only a select few samples (in tugboat, tow/salvage boat, and the supply boat).

Samples for pathogens were taken from only fishing vessels, with fecal coliform and enterococci potentially having the highest concentrations. Levels were high in all vessels except for the gillnetting vessel in Alaska. Differences in pathogen loads could be related to location or method of fishing (gillnetting vs. trawling). Pathogen loads in deck wash declined after washing in all cases.

Total phosphorus was the only nutrient of potential concern, with high levels found in almost all samples, presumably due to the use of detergents in the deck wash practices. Long-chain nonylphenol polyethoxylates of the smallest chain (i.e., NP3EO, most degraded form) were found in only three of the tow/salvage vessels, and total nonylphenol polyethoxylates were found at high concentrations in two tour vessels. Finally, a moderately high PHQ of 5.6 for bis(2-ethylhexyl) phthalate was found in the discharge of a tow/salvage vessel with a noticeably oily sheen.

Table 3.3.11. Characterization of Deck Washdown and Runoff Water and Summary of Analytes that May Have the Potential to Pose Risk

Vessel Type (no. vessels)	Analytes that May Have the Potential Risk to Pose Risk in Deck Washdown and Runoff Water and Vessel Sources [1,2,3,4,5]												
	Microbiologicals	**Volatile Organic Compounds**	**Semivolatile Organic Compounds**	**Metals (dissolved)**	**Metals (total)**	**Oil and Grease**	**Sulfide**	**Short-Chain Alkylphenol Ethoxylates and NP**	**Long-Chain Alkylphenol Ethoxylates**	**Nutrients**	**BOD, COD, and TOC**	**Total Suspended Solids**	**Other Physical/Chemical Parameters**
Fishing (11)	**Fecal coliform** **Enterococci** *E. coli*			**Cu**,Zn	Al,**As**,Fe		x			**TP**, NH3-N	**BOD, COD, TOC**	x	**TRC**, DO
Tugboats (9)				**Cu**,Pb,**Zn**	**Al,** As,**Fe**,Mn	x				**TP** (including one very high PHQ =220)	**BOD, COD, TOC**	**x**	TRC, turbidity
Tow/Salvage (6)			Bis(2-ethylhexyl) phthalate	**Cu**,**Cd**,Cr,**Pb**, Ni,Zn,	**Al**, **As**, **Fe**,Sb		x		x	**TP**, NH3-N	BOD, COD, TOC	x	TRC, turbidity
Tour (2)				**Cu**,Pb,Zn	Al,**As**				x	**TP**	BOD, COD, TOC	x	**TRC**
Water Taxi (1)				**Cu**	**Al,As**,Fe,**Mn**							x	
Fire (1)				**Cu**,Cr,Pb	**As**,**Al**,**Fe**,Sb					TP	BOD, COD, TOC	x	turbidity
Supply (1)				**Cu**,Cd,**Pb**, Ni,Zn	**Al, As**, **Fe**,**Mn**,Sb	x				TP	BOD, COD, TOC	x	TRC, turbidity
Recreational (1)				Cu,Ni	Al, **As**					TP	BOD, COD, TOC	x	turbidity

Notes:

(1) Analytes are generally **bolded** when a large proportion of the samples have concentrations exceeding the NRWQC (e.g., 25 to 50 percent), when several of the samples have PHQs > 10 (e.g., two or three of five), when a few samples result in PHQs greatly exceeding the screening benchmark (i.e., 100s to 1,000s), or, in the case of oil and grease and for nonylphenol, when one or more samples exceed an existing regulatory limit by more than a factor of 2. See text in Section 3.1.3 for a definition of PHQs and Table 3.1 for screening benchmarks used to calculate these values.

(2) EPA notes that the conclusion of potential risk is drawn from a small sample size, in some cases a single vessel, for certain discharges sampled from some vessel classes. EPA included these results in the tables to provide a concise summary of the data collected in the study, but strongly cautions the reader that these conclusions, where there are only a few samples from a given vessel class, should be considered preliminary and might not necessarily represent pollutant concentrations from these discharges from other vessels in this class. (3) All dissolved metals identified as possible risks are potentially influenced by the dissolved metal concentrations measured in source water (generally city tap water; used by all vessel types), particularly dissolved Cu and Zn.

(4) All total metals identified as possible risks are influenced by total metal concentrations measured in surrounding ambient water (relevant only for vessels where ambient water is used for deck washdown (i.e., many fishing vessels performing deck washdown while offshore, certain tug boats (as indicated in vessel survey)).

(5) Elevated total phosphorus concentrations in deck washdown samples likely influenced by ambient and source water concentrations.

3.2.4 Fish Hold and Fish Hold Cleaning Effluent (Refrigerated Seawater and Ice Slurry)

Refrigerated seawater and ice/ice slurry are the two commonly used methods for preserving fish in the fish hold of many fishing vessels. EPA noted that some vessels (e.g., large shrimping vessels in the Gulf of Mexico) use dry freezers to preserve their catches; however, these vessels do not produce significant amounts of effluent from the hold that comes into contact with seafood product and that is later discharged. Lobster and crab boats have seawater flow-through tanks used to keep lobsters and crabs alive. Both the freezers and flow-through tanks might contain residual seafood material that sometimes is discharged when the vessels clean their holds.

The analytes and parameters detected in fish hold effluent come from the vessel, ambient water and potable/service water. Additionally, many of the constituents can come from the seafood product itself. If the seafood (e.g., fish, shrimp) are not frozen, but preserved in refrigerated seawater or ice slurry, small quantities of organic material from the fish (e.g., lipids, protein) will be released as the fish degrade, thereby increasing the concentration of those constituents in the discharge. Furthermore, different volumes of blood, mucus, and other matter can drain from the seafood into the hold, depending on how the fish is butchered or cleaned on deck. For example, salmon, when caught via gillnets on gillnetting vessels, are cut at the gills and bled and then placed into the refrigerated sea water tanks/on ice before being cleaned (resulting in their internal organs and some blood leaking into the water). In contrast, salmon caught on trollers are cleaned while the fishing vessel is still at sea and the internal organs are discharged into the surrounding waters. Hence, on the salmon trollers, the organs and most of the residual blood are not in contact with refrigerated water/ice, and consequently, lower quantities of these materials are discharged when the vessel empties its hold at the dock.

The volume of fish hold water generated by a fishing vessel depends on the size of the vessel and the method used for keeping the product fresh. Vessels such as small salmon trollers or long-liners that frequent Alaska waters have around 1,500 gallons of fish hold storage. Assuming a hold is occupied by approximately 50 percent fish and 35 to 40 percent ice when the vessel off-loads at the seafood processing facility, the ice, which is thrown overboard daily after the fish are unloaded, would result in a fish hold discharge of between 500 and 600 gallons for these types of fishing vessels every three to seven days (70 to 200 gpd).

Collecting Fish Hold Ice from a Long Liner

Fish Hold Ice from a Trawler

Mid-size fishing vessels, such as gill netters, and purse seiners found in Alaska, and shrimp boats in the Gulf of Mexico, have fish hold volumes of between 3,000 and 5,000 gallons. Assuming a hold contains between 35 and 40 percent of ice/water slurry, a vessel discharges between 1,000 and 2,000 gallons of fish hold water every two to three days (333 to 1,000 gpd).

Larger fishing vessels such as off-shore trawlers found off the coast of New England and tenders found in Alaska can have refrigerated seawater holding tanks or ice hold tanks with capacities as large as 15,000 gallons. Assuming these fish hold tanks contain 30 to 40 percent refrigerated seawater or ice after the seafood is unloaded, the fish hold discharge would be between 4,500 and 6,000 gallons. These vessels are expected to unload seafood and discharge the fish hold water every three to five days (900 to 2,000 gpd).

Two Examples of Full Fish Hold Tanks on a Tender Vessel

EPA collected effluent samples from 31 commercial fishing vessels for this study. Samples were collected from the fish holds that were in use on 26 of these vessels. EPA generally collected single grab samples from these vessels while the vessels were dockside. These samples were usually collected while the effluent was being discharged, but they were occasionally collected directly from the fish hold. EPA analyzed samples for both total and dissolved metals, classical pollutants, pathogens, and nutrients. EPA also analyzed three samples from fish holds for nonylphenols.

The fish hold tank is cleaned after the catch has been off-loaded at the seafood processing facility, so the frequency of fish hold cleaning depends on the type and amount of fish being caught. For example, off-shore trawlers in New England might only clean the fish hold tank every three to five days when they return to the fish processing facility. Small fishing vessels such as salmon trollers and long-liners in Alaska off-load the catch every three to seven days. Fish tenders and purse seiners with refrigerated seawater tanks might clean the tanks every couple of days when they return to the fish processing facility.

On small fishing boats such as trollers and long-liners, and mid-size fishing boats such as gill netters, fish holds are typically cleaned using a garden hose at a flow rate of between 10 and 12 gpm. Fish hold cleaning is completed in 15 minutes or less, resulting in a discharge of between 150 and 200 gallons per day. Larger vessels such as off-shore trawlers found in New England and large tenders in Alaska also use a garden hose to wash down the fish hold tanks; however, cleaning these tanks requires approximately 30 minutes. EPA estimated the volume of fish hold cleaning water discharge for these vessels ranges between 300 and 400 gallons per cleaning (60 to 200 gpd depending on frequency).

EPA was able to collect samples of the fish hold cleaning water discharge from nine vessels. These samples were analyzed for the same constituents as fish hold effluent plus nonylphenols. Nonylphenols are suspected pollutants associated with cleaning products.

3.2.4.1 Metals

Fish Hold Effluent

Samples of refrigerated cooling water and ice slurry from 26 fish holds were analyzed for dissolved and total concentrations of 22 metals. The analytical results are summarized in Table 3.4.1 (total metals data) and Table 3.4.2 (dissolved metals data) for the 19 metals that were detected in one or more fish hold effluent samples. Figures 3.4.1 and 3.4.2 present these same results for total and dissolved metals, respectively, normalized by the lowest NRWQC where applicable. The following metals were detected in all fish hold water samples:

- Total aluminum
- Dissolved and total barium
- Dissolved and total calcium
- Dissolved and total cobalt
- Dissolved and total iron
- Dissolved and total potassium
- Dissolved and total sodium
- Dissolved and total vanadium
- Dissolved and total zinc

Concentrations of a number of other metals were measured for 50 percent or more of the samples analyzed:

- Dissolved aluminum
- Total arsenic
- Dissolved and total copper
- Dissolved and total magnesium
- Dissolved and total manganese
- Dissolved and total potassium
- Total silver.

Several metals for which EPA tested had concentrations that were notable. These metals include dissolved and total arsenic, and dissolved copper, selenium, and zinc (see Figures 3.4.1 and 3.4.2). A small percentage of the samples contained all the metals which EPA regularly analyzes; however, metals such as lead, nickel, and selenium were, with a few notable exceptions, in concentrations below PHQs at the point of discharge (see Figures 3.4.3 and 3.4.4). EPA analyzed for and detected dissolved and total barium, cobalt, iron, potassium, silver, sodium, and vanadium in only two samples. All of the detected concentrations in the two samples were low, except for iron. EPA also analyzed for antimony, beryllium, and thallium in these two samples and did not detect any of these metals.

The concentrations of many of the metals that were detected in fish hold discharges are not unexpected as fish holds generally have numerous exposed metal surfaces. In addition, the pumps used to add water to the hold might also add low concentrations of metals. Finally, metallic fishing equipment, deck surfaces, and other materials sometimes come in contact with the fish or water that runs into the hold.

Some metal concentrations, particularly mineral salts, appear to be primarily a result of background concentrations in the ambient water. For example, aluminum, barium, calcium, iron, magnesium, sodium, and potassium appear to be primarily influenced by background concentrations. Other metals that had measurable concentrations (e.g., arsenic, copper, manganese, and zinc) appear to result largely from mechanically refrigerated water used to cool the sea water to preserve seafood catch, adding ice to do the same, or possibly, from the seafood catch itself, or from any combination of the three.

Several metals were detected in at least one sample of fish hold effluent with PHQ values of greater than 1 (see Figures 3.4.3 and 3.4.4). For total metals, this included aluminum, arsenic, copper, iron, and manganese. However, as discussed above, aluminum concentrations appear to be primarily influenced by ambient water background concentrations. Total copper concentrations exceeded the total copper benchmark based on human health (for consumption of water and aquatic organisms) of 1,300 µg/L by a small fraction in two samples (Table 3.4.1). These total concentrations, however, could pose potential risk to the aquatic environment because the human health criteria of 1,300 µg/L is significantly higher than the 3.1 µg/L benchmark used for dissolved copper based on the saltwater chronic ambient water quality criterion for the protection of aquatic life. When high levels of particulate copper are discharged, some of the particulate copper will likely convert to dissolved copper and be made bioavailable to aquatic life. EPA collected only two samples for analysis of total iron, one of which had a PHQ value of five and the other eight.

Another metal with high PHQ values is total arsenic. The PHQ values for total arsenic ranged from between more than 100 to more than 20,000 (Figure 3.4.3)[29]. One reason for these extreme PHQ values is the exceptionally low screening benchmark of 0.018 µg/L for total arsenic. Nonetheless, concentrations of total arsenic in the upper end ranges of these measurements are a possible environmental concern. These discharges may have the potential to cause or contribute to exceedances of water quality standards, particularly in areas where multiple fishing vessels discharge their holds into the same waters within the same time period.

Several dissolved metals, including arsenic, cadmium, copper, iron, nickel, and selenium, also had PHQs above 1 (see Figure 3.4.4). Dissolved arsenic samples resulted in PHQs of approximately 9-10 for two discharges; one was from a shrimping vessel from the Gulf Coast and the other from a ground fishery vessel in New England, while a third boat ground fishery vessel in New England had a PHQ value of just over 2. There was also only one sample which had a PHQ value for cadmium of approximately 5. Only

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[29] While EPA suspects the highest concentration of total arsenic (and total selenium) from a shrimping vessel might be slightly elevated due to positive interference, measured concentrations of arsenic in fish hold effluent from other similar vessels were absent positive interference and nearly as high. Therefore, EPA believes the measured concentrations of total arsenic (and to a lesser extent selenium) from the shimping vessel to reasonably represent true effluent concentrations for the discharge.

four of the 26 values exceeded a PHQ value of 1 for dissolved nickel, and none exceeded a value of 2. Dissolved selenium had 6 samples exceed a PHQ value of 1 (the highest value of which was approximately 12). Dissolved zinc had numerous PHQ values of greater than 1, but none greater than 10. Dissolved copper had numerous samples that exceeded the PHQ value of 1, with more than 25 percent of these samples having a PHQ value of greater than 10.

The high dissolved arsenic concentrations were observed exclusively from three vessels; a shrimping boat (345 µg/L)[30] and two ground fishery trawlers (74 and 310 µg/L). Ambient water concentrations indicate that the arsenic likely did not come from the surrounding water, although dissolved arsenic was measured at a substantial level of 26 µg/L in the ambient water where the shrimping vessel was sampled. Another possible explanation is entrainment of arsenic contaminated sediments on nets. Each of the vessels with high arsenic values (trawlers and shrimp boats) use nets that drag the ocean floor. When nets are retrieved and emptied on the deck of the vessel, entrained sediments from the ocean floor could migrate into the fish holds along with the fish and shrimp. One other possible source includes organic arsenic compounds that are primarily found in organisms living in the sea. Based on the limited data collected, EPA cannot identify the specific source(s) of the high dissolved arsenic values at this time.

In summary, some samples of dissolved copper in fish hold effluent discharges were well above the PHQ screening benchmark of 3.1 µg/L based on the 2006 NRWQC saltwater chronic aquatic life criterion. Many of these concentrations resulted in PHQs of greater than 10, with some upwards of 200. The three elevated concentrations of dissolved arsenic could potentially pose an environmental concern, particularly if these arsenic concentrations are common in these vessel discharges. Finally, concentrations of total arsenic are also high relative to the benchmark, resulting in high PHQ values and may have the potential to pose risks to human health if discharged into drinking water sources, though almost all fishing vessels operate in marine or estuarine environments that are not used for drinking water.

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[30] While EPA suspects the highest concentration of dissolved arsenic (and dissolved selenium) from a shrimping vessel might be slightly elevated due to positive interference from major seawater cations, measured concentrations of arsenic in fish hold effluent from other similar vessels were nearly as high, but absent positive interference. Therefore, EPA believes the measured concentrations of dissolved arsenic (and to a lesser extent selenium) from the shimping vessel to reasonably represent true effluent concentrations for the discharge.

Table 3.4.1. Results of Fish Hold Effluent Sample Analyses for Total Metals[1]

Total Metal	Units	No. samples	No. detected	Detected Proportion (%)	Average Conc.	Median Conc.	Minimum Conc.	10%	25%	75%	90%	Maximum Conc.	Screening BM[2]
Heavy and Other Metals													
Aluminum	µg/L	26	26	100	827	840	89	180	420	900	1800	2400	87
Arsenic	µg/L	26	16	62	40	4.8				13	210	380	0.018
Barium	µg/L	2	2	100	98	110	83	83	83	110	110	110	1000
Cadmium	µg/L	26	3	12	0.99						1.9	3.3	NA
Chromium	µg/L	26	7	27	4.3					2.6	19	35	NA
Cobalt	µg/L	2	2	100	3.7	4.4	2.9	2.9	2.9	4.4	4.4	4.4	NA
Copper	µg/L	26	24	92	190	40		5.8	12	140	710	1700	1300
Iron	µg/L	2	2	100	2000	2500	1600	1600	1600	2500	2500	2500	300
Lead	µg/L	26	9	35	7.1					5.6	31	42	NA
Manganese	µg/L	26	15	58	24	6.6				17	130	140	100
Nickel	µg/L	26	5	19	7.7						17	30	610
Selenium	µg/L	26	7	27	12					13	29	90	170
Silver	µg/L	2	1	50	2.4	2.7				2.7	2.7	2.7	NA
Vanadium	µg/L	2	2	100	9.2	10	8.1	8.1	8.1	10	10	10	NA
Zinc	µg/L	26	26	100	340	230	27	46	100	450	940	1700	7400
Cationic Metals													
Calcium	µg/L	26	26	100	150000	190000	1900	3000	15000	270000	300000	310000	NA
Magnesium	µg/L	26	25	96	450000	580000		1800	14000	840000	980000	1100000	NA
Potassium	µg/L	2	2	100	330000	480000	190000	190000	190000	480000	480000	480000	NA
Sodium	µg/L	2	2	100	1200000	1900000	370000	370000	370000	1900000	1900000	1900000	NA

Notes:

(1) Nondetect (censored) concentrations were replaced with ½ of the reporting limit for calculating average concentrations. The remaining statistics in this table were only calculated when analytes were detected at a sufficient frequency. For example, if an analyte was detected in fewer than 50% of samples, then a median concentration was not calculated. A blank cell reflects a situation when a median or percentile could not be computed based on detected concentrations. The percentiles are the concentrations of each analyte below which at least that percentage of the values fall. So the 10th percentile is the concentration below which at least 10% of the observations were found.

(2) Screening BM represents the screening benchmark referred to in Section 3.1.3, and is the most stringent 2006 NRWQC or other conservative benchmark used to calculate PHQs.

Table 3.4.2. Results of Fish Hold Effluent Sample Analyses for Dissolved Metals[1]

Dissolved Metal	Units	No. samples	No. detected	Detected Proportion (%)	Average Conc.	Median Conc.	Minimum Conc.	10%	25%	75%	90%	Maximum Conc.	Screening BM[2]
Heavy and Other Metals													
Aluminum	µg/L	26	24	92	490	670		20	60	850	970	1000	NA
Arsenic	µg/L	26	10	38	31					5.7	150	350	36
Barium	µg/L	2	2	100	64	84	44	44	44	84	84	84	NA
Cadmium	µg/L	26	1	4	0.77							1.4	0.25
Chromium	µg/L	26	3	12	1.9						5.8	7.9	11
Cobalt	µg/L	2	2	100	1.8	2.0	1.6	1.6	1.6	2.0	2.0	2.0	NA
Copper	µg/L	26	23	88	96	15			6.0	38	390	920	3.1
Iron	µg/L	2	2	100	350	360	340	340	340	360	360	360	NA
Lead	µg/L	26	3	12	2.3						4.4	8.0	2.5
Manganese	µg/L	26	19	73	22	11				28	80	110	NA
Nickel	µg/L	26	4	15	6.1						13	17	8.2
Selenium	µg/L	26	6	23	9.2					2.5	20	61	5.0
Silver	µg/L	2	2	100	1.3	1.5	1.0	1.0	1.0	1.5	1.5	1.5	1.9
Vanadium	µg/L	2	2	100	3.4	3.5	3.2	3.2	3.2	3.5	3.5	3.5	NA
Zinc	µg/L	26	26	100	180	120	24	31	55	240	450	790	81
Cationic Metals													
Calcium	µg/L	26	26	100	160000	180000	1200	1900	9000	290000	300000	310000	NA
Magnesium	µg/L	26	25	96	480000	560000		770	11000	920000	990000	1100000	NA
Potassium	µg/L	2	2	100	330000	470000	180000	180000	180000	470000	470000	470000	NA
Sodium	µg/L	2	2	100	1200000	2000000	360000	360000	360000	2000000	2000000	2000000	NA

Notes:

(1) Nondetect (censored) concentrations were replaced with ½ of the reporting limit for calculating average concentrations. The remaining statistics in this table were only calculated when analytes were detected at a sufficient frequency. For example, if an analyte was detected in fewer than 50% of samples, then a median concentration was not calculated. A blank cell reflects a situation when a median or percentile could not be computed based on detected concentrations. The percentiles are the concentrations of each analyte below which at least that percentage of the values fall. So the 10th percentile is the concentration below which at least 10% of the observations were found.

(2) Screening BM represents the screening benchmark referred to in Section 3.1.3, and is the most stringent 2006 NRWQC or other conservative benchmark used to calculate PHQs.

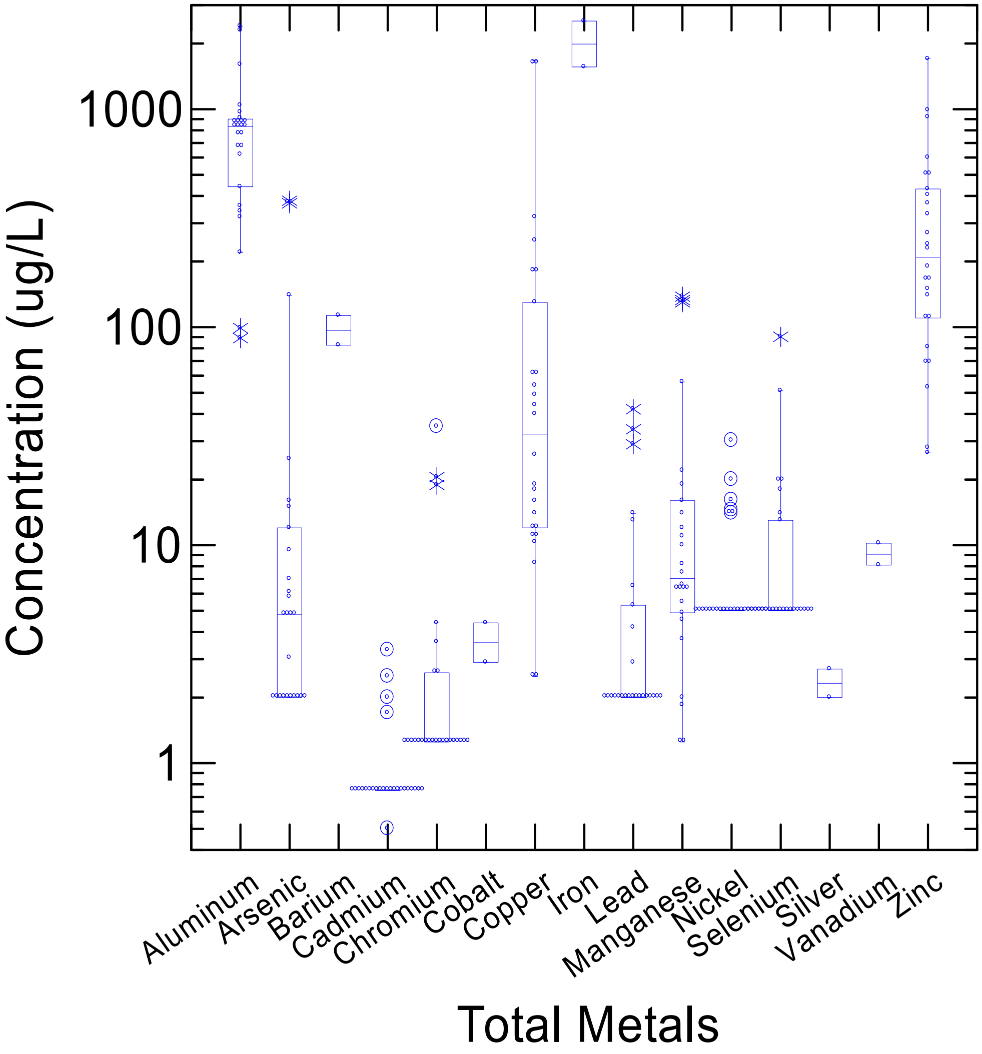


Figure 3.4.1. Box and Dot Density Plot of Total Metals Concentrations Measured in Samples of Fish Hold Effluent

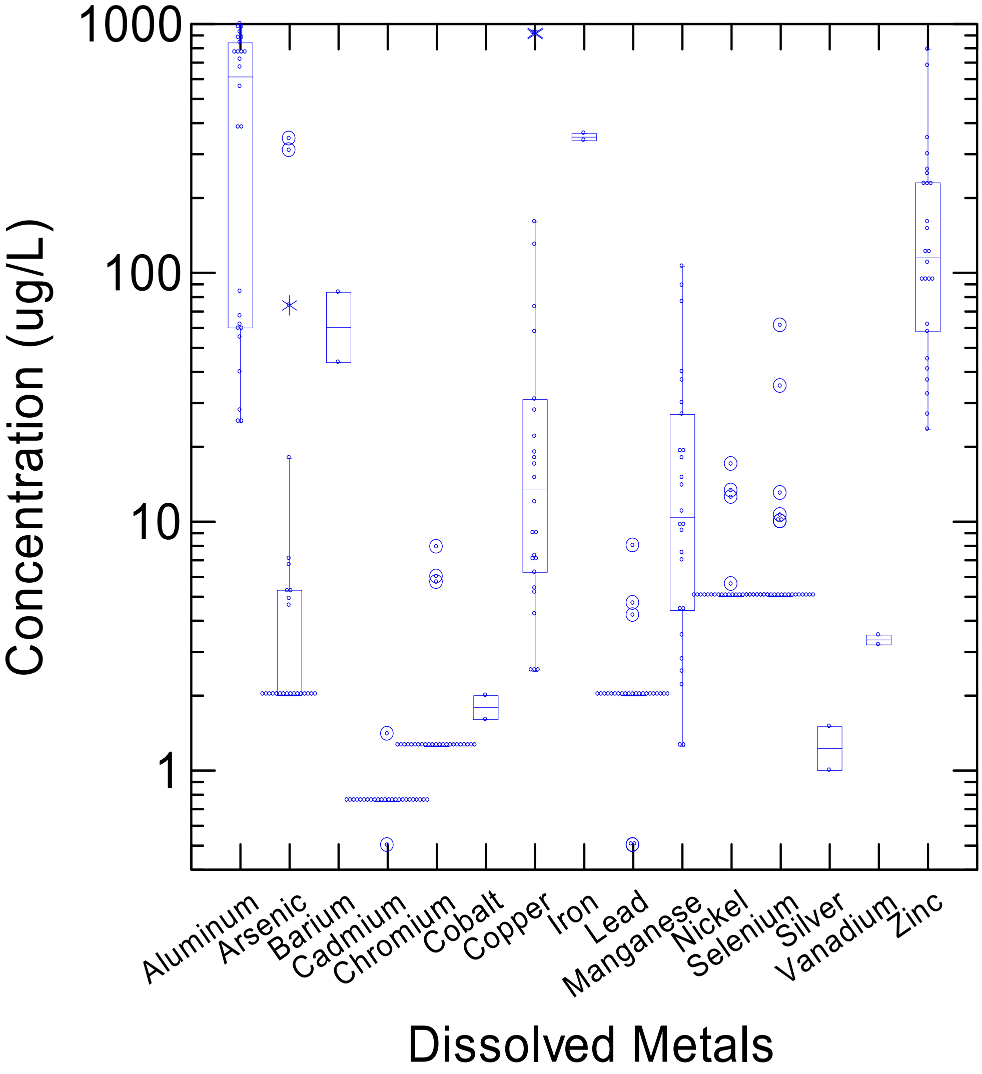


Figure 3.4.2. Box and Dot Density Plot of Dissolved Metals Concentrations Measured in Samples of Fish Hold Effluent

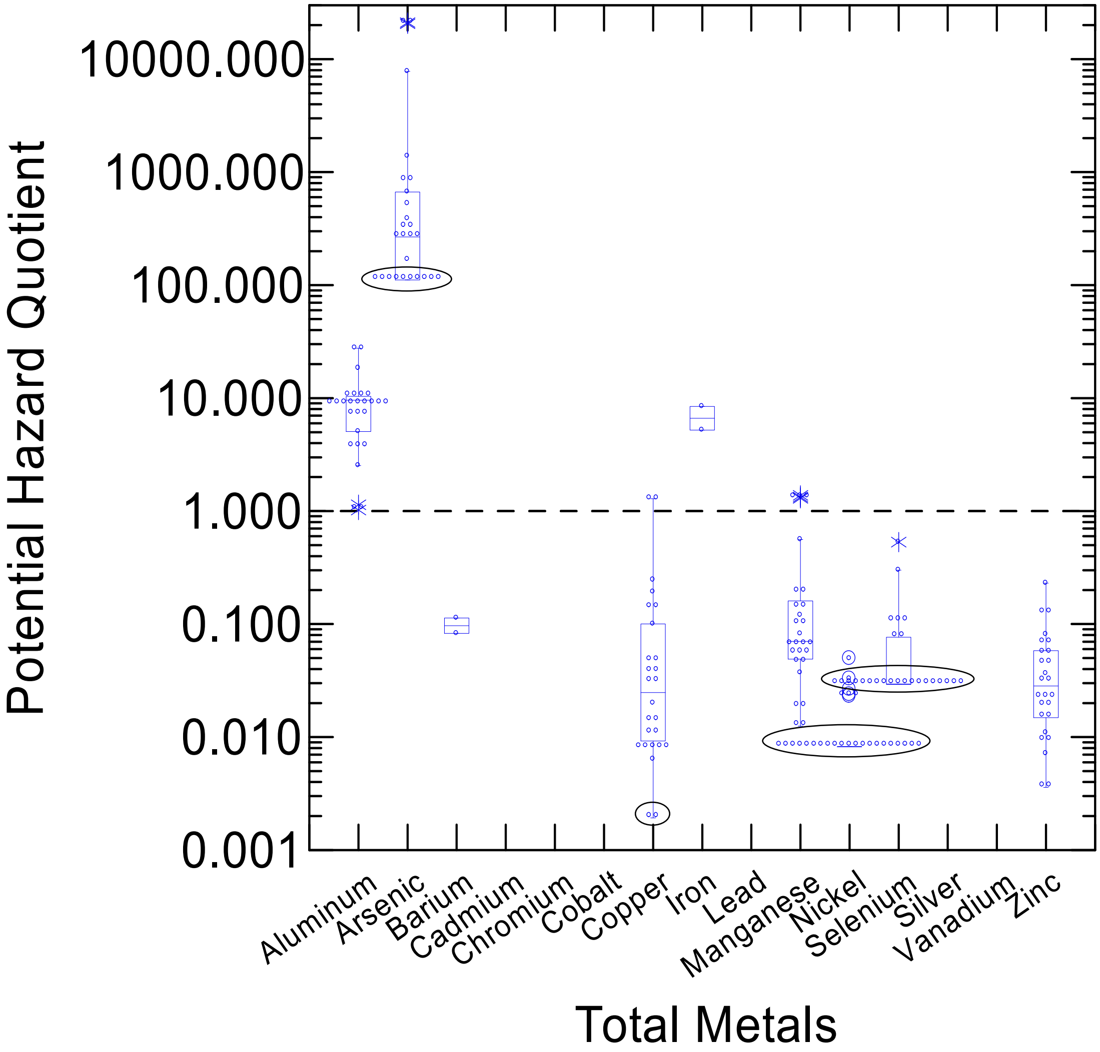


Figure 3.4.3. Box and Dot Density Plot of Potential Hazard Quotients for Total Metals in Samples of Fish Hold Effluent

(Note: Replacement values for non-detects are circled. Also, as discussed in the text above, total arsenic is a potential concern; however, the exceptionally high PHQ values are due in part to the low human health value for total arsenic used as a benchmark).

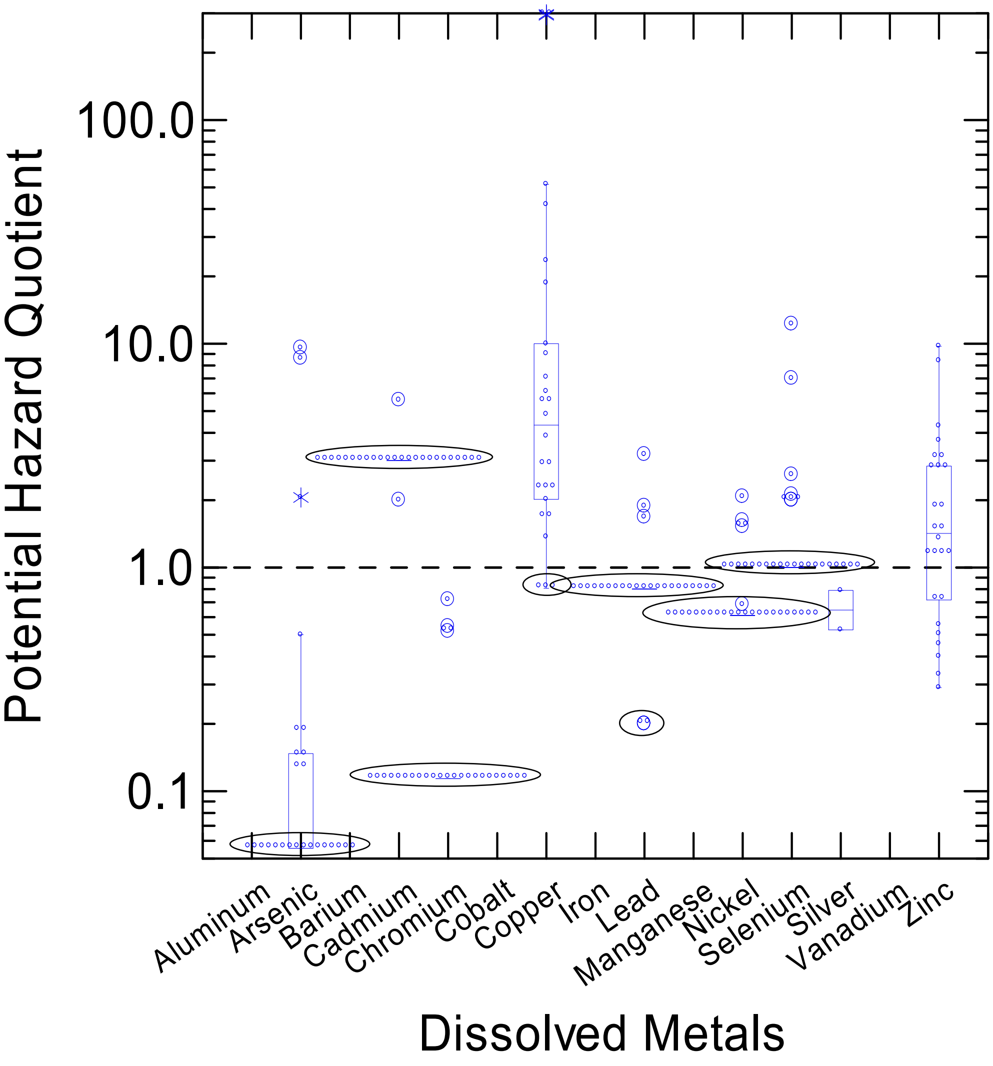


Figure 3.4.4. Box and Dot Density Plot of Potential Hazard Quotients for Dissolved Metals in Samples of Fish Hold Effluent

(Note: Replacement values for non-detects are circled).

Fish Hold Cleaning Effluent

EPA expected effluent from the cleaning of fish holds to be fundamentally similar to fish hold effluent with two exceptions: 1) many vessels used a soap or disinfectant, which would not be expected to be present in the hold, and 2) cleaning fish holds brings in either potable water from the local municipality via a pierside hose (service water) or ambient water pumped from the surrounding waters. Table 3.4.3 presents summary statistics for fish hold cleaning effluent. Figures 3.4.6 and 3.4.7 show the detected results for total and dissolved metal concentrations, respectively, and Figures 3.4.8 and 3.4.9 shows the PHQ values for total and dissolved concentrations, respectively, where applicable.

Generally, average and maximum total and dissolved metals concentrations for fish hold cleaning were slightly lower than for fish hold effluent. These lower values could be due to any number of reasons: less contact time with the vessel for fish hold cleaning effluent, differences in source water (mechanically refrigerated and ice versus city tap water), less contact time (or none at all) with the seafood product or its residuals, etc.

The lower concentrations of metals for fish hold cleaning effluent resulted in lower overall PHQ values for both total and dissolved forms, as well as a lower percentage of samples that exceed a PHQ of 1. Not surprisingly, the metals (dissolved copper, dissolved and total arsenic) identified as having high PHQs for fish hold effluent also exhibited higher PHQ values in fish hold cleaning effluent. Likewise, dissolved copper occurs in fish hold cleaning effluent at concentrations mostly above a PHQ value of one, and dissolved arsenic was found in two samples with PHQ values above one. Dissolved zinc was also found in several samples with PHQ values above one, the maximum being a PHQ value just below 10 (Figure 3.4.8).

Table 3.4.3. Results of Fish Hold Cleaning Effluent Sample Analyses for Metals[1]

Metal	Units	No. samples	No. detected	Detected Proportion (%)	Average Conc.	Median Conc.	Minimum Conc.	10%	25%	75%	90%	Maximum Conc.	Screening BM[2]
Heavy and Other Metals													
Aluminum, Dissolved	µg/L	9	9	100	780	880	74	74	760	950	1000	1000	NA
Aluminum, Total	µg/L	9	9	100	1100	930	850	850	860	1500	1700	1700	87
Arsenic, Dissolved	µg/L	9	5	56	22	5.3				38	97	97	36
Arsenic, Total	µg/L	9	5	56	35	8.7				64	150	150	0.018
Cadmium, Total	µg/L	9	1	11	1.0						3.0	3.0	NA
Chromium, Dissolved	µg/L	9	1	11	1.5						3.4	3.4	11
Chromium, Total	µg/L	9	3	33	4.6					5.4	23	23	NA
Copper, Dissolved	µg/L	9	8	89	34	12			8.6	32	180	180	3.1
Copper, Total	µg/L	9	9	100	57	25	6.4	6.4	11	61	290	290	1300
Lead, Dissolved	µg/L	9	1	11	2.7						8.7	8.7	2.5
Lead, Total	µg/L	9	4	44	19					37	79	79	NA
Manganese, Dissolved	µg/L	9	4	44	21					39	64	64	NA
Manganese, Total	µg/L	9	5	56	33	4.8				61	110	110	100
Selenium, Dissolved	µg/L	9	1	11	6.0						14	14	5.0
Selenium, Total	µg/L	9	2	22	7.4					7.0	18	18	170
Zinc, Dissolved	µg/L	9	8	89	190	53			19	420	640	640	81
Zinc, Total	µg/L	9	8	89	470	140			17	890	1800	1800	7400
Cationic Metals													
Calcium, Dissolved	µg/L	9	9	100	250000	270000	11000	11000	240000	300000	320000	320000	NA
Calcium, Total	µg/L	9	9	100	260000	280000	13000	13000	260000	310000	320000	320000	NA
Magnesium, Dissolved	µg/L	9	9	100	790000	860000	12000	12000	750000	990000	1000000	1000000	NA
Magnesium, Total	µg/L	9	9	100	780000	880000	13000	13000	710000	1000000	1000000	1000000	NA

Notes:

(1) Nondetect (censored) concentrations were replaced with ½ of the reporting limit for calculating average concentrations. The remaining statistics in this table were only calculated when analytes were detected at a sufficient frequency. For example, if an analyte was detected in fewer than 50% of samples, then a median concentration was not calculated. A blank cell reflects a situation when a median or percentile could not be computed based on detected concentrations. The percentiles are the concentrations of each analyte below which at least that percentage of the values fall. So the 10th percentile is the concentration below which at least 10% of the observations were found.

(2) Screening BM represents the screening benchmark referred to in Section 3.1.3, and is the most stringent 2006 NRWQC or other conservative benchmark used to calculate PHQs.

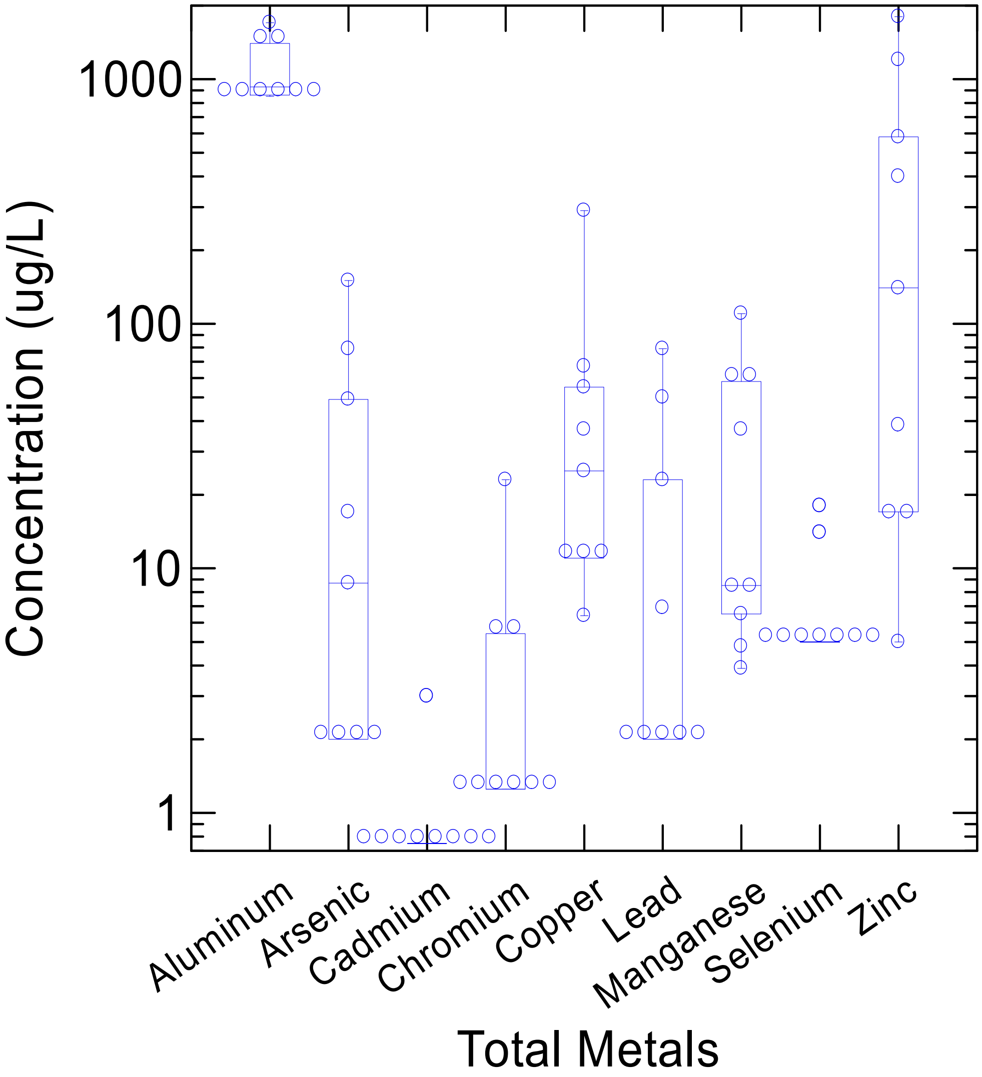


Figure 3.4.5. Box and Dot Density Plot of Total Metals Concentrations Measured in Samples of Fish Hold Cleaning Effluent

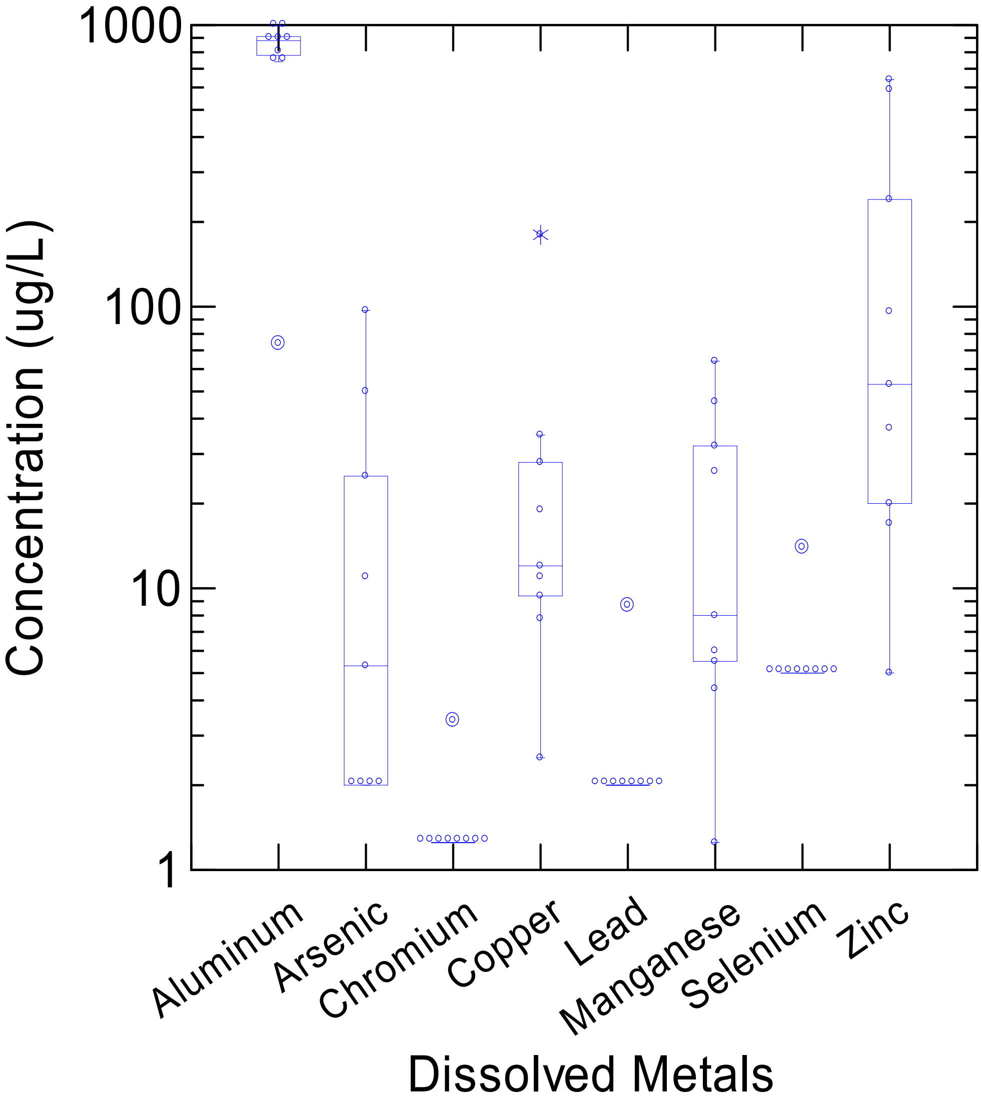


Figure 3.4.6. Box and Dot Density Plot of Dissolved Metals Concentrations Measured in Samples of Fish Hold Cleaning Effluent

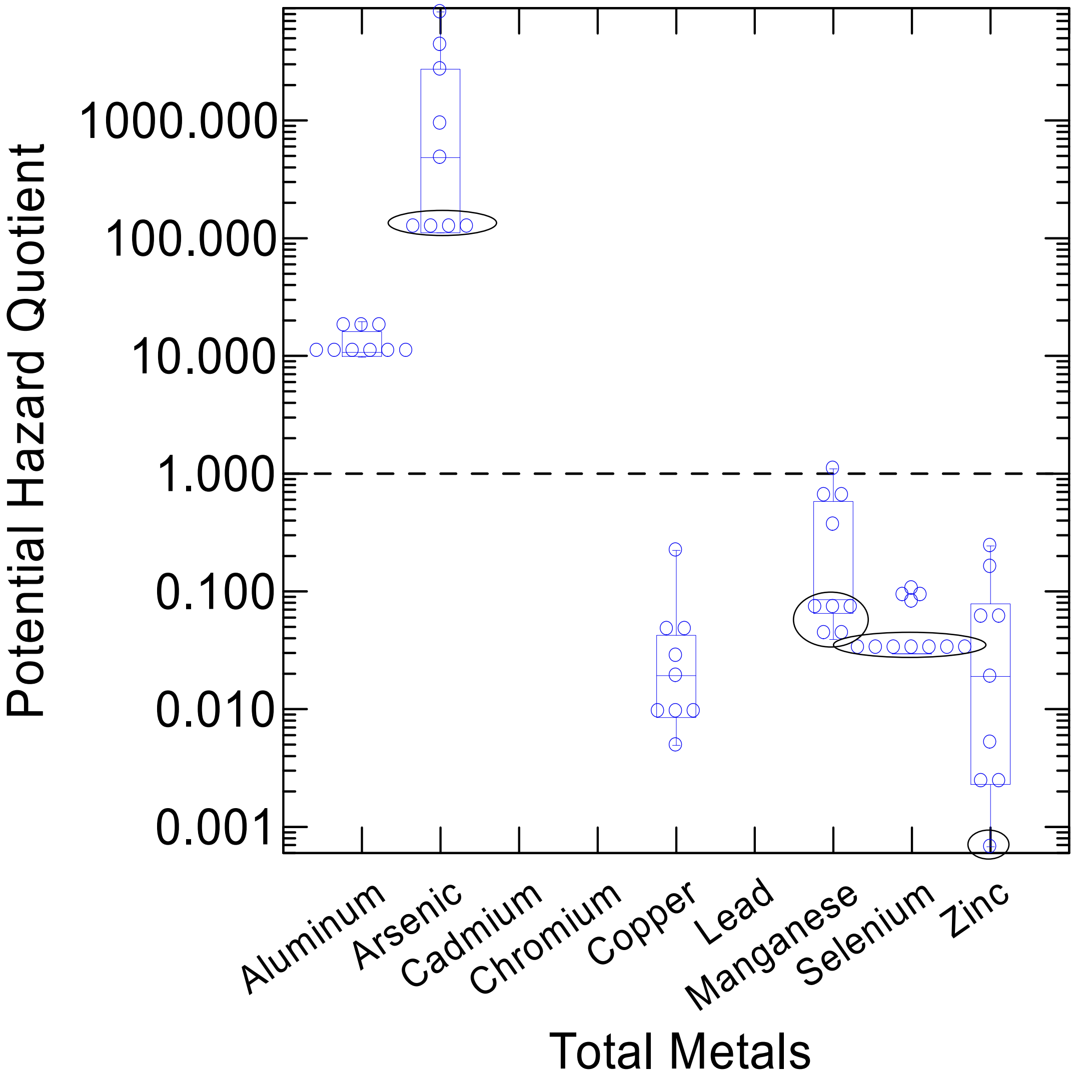


Figure 3.4.7. Box and Dot Density Plot of Potential Hazard Quotients for Total Metals in Samples of Fish Hold Cleaning Effluent
(Note: Replacement values for non-detects are circled).

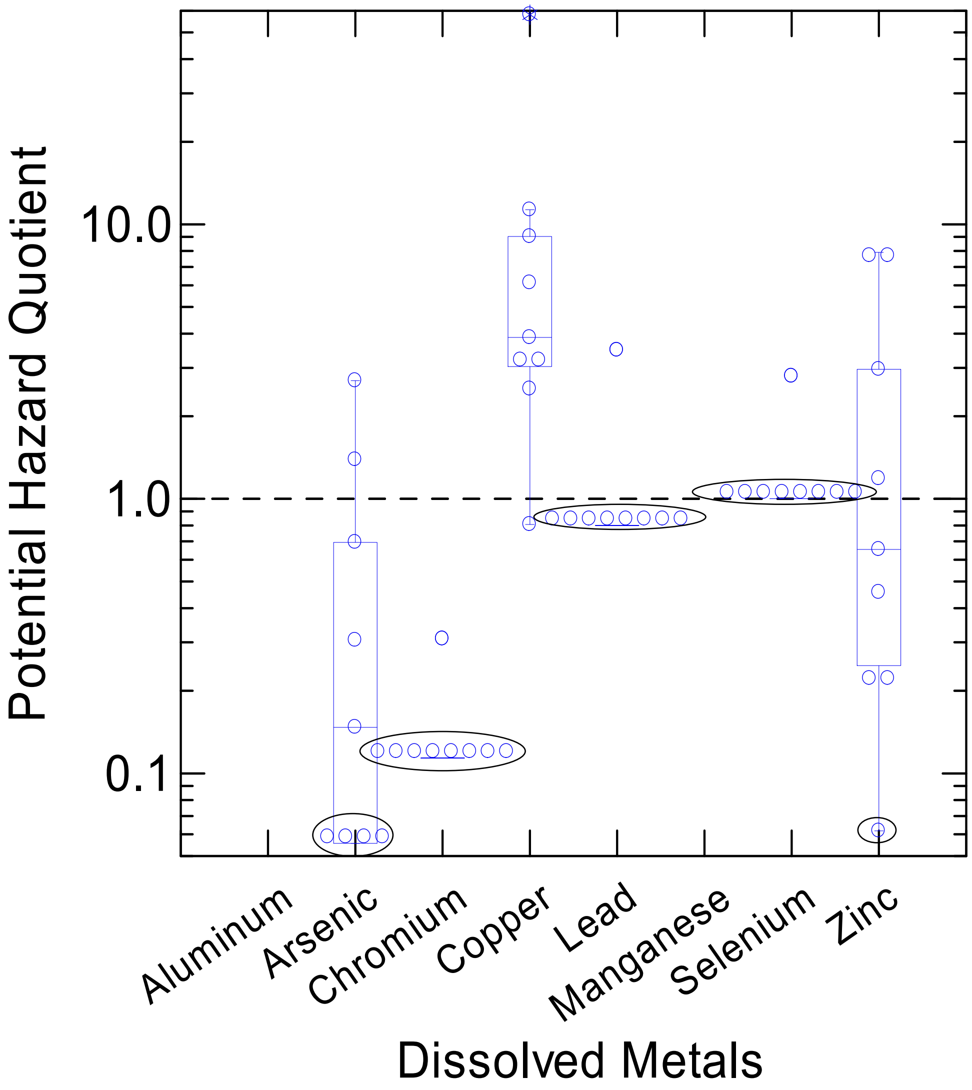


Figure 3.4.8. Box and Dot Density Plot of Potential Hazard Quotients for Dissolved Metals in Samples of Fish Hold Cleaning Effluent
(Note: Replacement values for non-detects are circled).

3.2.4.2 Classical Pollutants

Table 3.4.4 presents analytical results for 14 classical pollutants detected in samples from fish hold effluent (all classical pollutants analyzed for in the study were detected). These detected results are also shown in Figure 3.4.9.

Except for dissolved oxygen, other physical parameters measured (conductivity, pH, salinity, and temperature) did not have results that were likely to result in any impact on receiving water quality. Dissolved oxygen concentrations were low in several samples of fish hold effluent: hypoxic (< 2 mg/L) in three cases and marginal (<5 mg/L) in 19 additional cases. These low oxygen conditions may be driven by the high BOD concentrations found in many of the fish holds. Effluent with low dissolved oxygen concentrations were also noted in the fish hold cleaning effluent, with six of nine samples (67 percent) having concentrations of less than 5 mg/L (see Table 3.4.5 and Figure 3.4.10).

EPA found BOD and COD to be highly elevated in fish hold effluent (Table 3.4.4). BOD was measured in several samples in concentrations in the thousands of mg/L. High levels of BOD are almost certainly caused by the decay of the organic material associated with the seafood product. As shown in Figure 3.4.9, the majority of these concentrations are generally higher than those of raw sewage (which can range up to a few hundred mg/L), and almost all are higher than a wastewater treatment plant's secondary treatment limit of 30 mg/L for BOD. The median value for BOD discharge was approximately 471 mg/L, indicating that BOD discharge from fish holds are abnormally elevated (see Figure 3.4.11). The highest BOD value of 5,130 mg/L approximates the concentrations found in sewage sludge (Metcalf and Eddy, 1979).

These high levels of BOD in discharges could potentially pose environmental problems in certain circumstances. For example, high BOD concentrations in fish hold effluents are potentially ubiquitous, and discharges could result in impacts to receiving waters where there are numerous fishing vessels, poor flushing, or high levels of existing hypoxic (low oxygen) stress in the water body. In stratified waters with hypoxic or anoxic (no oxygen) conditions, the risk associated with elevated BOD is most likely to occur in deeper waters under a thermocline or picnocline. When using refrigerated seawater systems, fish hold effluent may be as saline (or more saline) than the surrounding water. Where it is also cooler than the surrounding water, the fish hold effluent would be more likely to sink to the bottom of the stratified water under the warmer water. This may deliver the BOD load to the deeper layers of the water body where oxygen levels are likely to be lower in eutrophic waters. In contrast, where ice is used to cool fish in the fish hold, the BOD load may be more likely to stay in the surface layers since fresh water is less dense than salt water. Thus, a low salinity fish hold effluent discharge may prevent the BOD loading from having as significant an impact to aquatic organisms in the receiving waters.

The considerable variability in BOD concentrations from the 26 fish hold effluent samples may be due to how fish are kept. The average concentration of BOD is lowest for the lobster tank compared with the other fish hold types, which is logical since lobster tanks have continuously circulating ambient water with live seafood inside. Hence, the water is constantly being refreshed, while the seafood product generally has not begun the process of degrading or bleeding into the tank. There could be other differences in BOD concentrations based upon whether fish are kept on top of ice, in ice water slurry, or in refrigerated seawater. New England trawlers and Gulf Coast shrimp boats had several vessels with exceptionally high BOD concentrations.

Whereas BOD measures oxygen demand from biodegradable material, COD measures oxygen demand for both biodegradable material and nonbiodegradable oxidizable material. Like BOD, COD discharge is elevated in fish hold effluent and fish hold cleaning effluent (Tables 3.4.4 and 3.4.5). Occasionally, these values are exceptionally high, which could potentially cause stress on a water body where there are many discharges from fish holds and where there may be low circulation or flushing or existing hypoxic or anoxic stress in the water body.

Oil and grease as measured by HEM and SGT-HEM are generally discharged in low concentrations from fish hold effluent, with the vast majority of samples from both fish hold effluent and fish hold cleaning effluent having HEM and SGT-HEM being discharged in quantities below 5 mg/L. However, there are a few discharges where the concentrations exceed 15 mg/L. The highest of these values for either fish hold or fish hold cleaning effluent (the HEM concentration was approximately 28 mg/L - slightly less than twice the regulatory limit of 15 mg/L) are from the samples taken during a fish hold cleaning event while onboard a New England ground fishing vessel. These values demonstrate that while oil and grease discharges from fish holds sometimes occasionally occur at elevated concentrations, they were generally not observed at concentrations that are of particular concern.

The concentrations of the classical pollutants EPA measured that are associated with sediment or cloudiness (i.e., TSS and turbidity) were roughly equivalent to concentrations observed in raw sewage effluent, but considerably lower than stormwater runoff from construction sites or highly urbanized streams. TSS was elevated in both fish hold effluent and fish hold cleaning effluent; however, concentrations were generally not sufficiently elevated to alone exceed water quality standards. Just under 90 percent of samples exceed the secondary treatment concentration of 30 mg/L for TSS (the value used to establish the PHQ benchmark), with a maximum concentration of 1,100 mg/L in a fish hold effluent sample. As with BOD, TSS appears to be more diluted in fish hold cleaning effluent than in fish hold effluent. While it did not test for volatile suspended solids (VSS) in this sampling program, EPA assumed that a significant percentage of the TSS concentration is directly caused by organic material related to the seafood product. Similar to TSS, turbidity concentrations were elevated in both fish hold effluent and fish hold cleaning effluent, and slightly more concentrated in fish hold effluent than in fish hold cleaning effluent.

The concentrations of sulfide in fish hold and fish hold cleaning effluent were low in most samples, with most values falling below a reporting limit value of 0.01 mg/L. Sulfide was detected in only seven of 25 samples where the parameter was tested, and in only four of seven fish hold cleaning samples. However, a few samples had significantly elevated sulfide concentrations, including a maximum fish hold concentration of 0.16 mg/L (PHQ value of 80) from fish hold discharges, and a maximum fish hold cleaning value of 0.48 mg/L (PHQ value of 240). These high sulfide values cannot be attributed to high background concentrations. A relatively higher percentage of detectable sulfide concentrations were noted in New England ground fishery trawlers compared with other areas (seven out of the 11 detections). EPA is unable to determine why the New England fishery vessels have higher concentrations of sulfide compared with vessels using other fishing platforms or from other areas; however, one possible explanation is that the New England fishery vessels are at sea for seven to 10 days, whereas Alaskan fishing vessels are off loaded once every one to two days.

TRC was detected with some prevalence (roughly a third to two thirds of the samples for fish hold and fish hold cleaning effluent, respectively), with maximum concentrations of 0.3 mg/L (fish hold effluent) and 1.51 mg/L (fish hold cleaning effluent). PHQs for the fish hold and fish cleaning effluent ranged from one to 40 and one to 200, respectively (data not shown). Such high concentrations might be expected considering the source water (e.g., bag ice for keeping catch cold in fish holds) or use of chlorine bleach for cleaning and disinfection (fish hold cleaning effluent). In both cases, effluent volume is low relative to receiving waters for this volatile compound, and as such, EPA does not expect significant risk to human health or the environment.

TOC was detected in all of the 25 of the fish hold effluent samples for which it was tested and all nine fish hold cleaning samples. Concentrations ranged from a low of 1.8 mg/L to an extreme high of 2,200 mg/L (see Table 3.4.4). Background concentrations of TOC (i.e., from mechanically refrigerated water or ice) are much lower (in the range of 2 to 19 mg/L) and do not appear to be a significant cause of the high TOC loads in the effluent. TOC levels are likely elevated by decay and residuals from the seafood product.

Table 3.4.4. Results of Fish Hold Effluent Sample Analyses for Classical Pollutants[1]

Parameter	Units	No. samples	No. detected	Detected Proportion (%)	Average Conc.	Median Conc.	Minimum Conc.	10%	25%	75%	90%	Maximum Conc.	Screening BM[2]
Biochemical Oxygen Demand (BOD)	mg/L	26	24	92	840	440		25	140	830	3100	5100	30
Chemical Oxygen Demand (COD)	mg/L	26	26	100	1500	940	52	340	660	1900	2600	8700	NA
Conductivity	mS/cm	26	26	100	25	30	0.20	0.35	3.3	43	46	61	NA
Dissolved Oxygen	mg/L	26	26	100	4.3	3.9	1.7	2.0	2.8	5.7	8.2	9.2	NA
Hexane Extractable Material (HEM)	mg/L	26	18	69	3.2	1.5				2.9	6.4	16	15
pH	SU	26	26	100	7.0	6.8	6.0	6.3	6.5	7.5	7.8	8.3	NA
Salinity	ppt	26	26	100	13	17	0.10	0.47	1.4	25	28	28	NA
Silica Gel Treated HEM (SGT-HEM)	mg/L	26	15	58	3.4	0.98				2.2	3.7	4.4	15
Sulfide	mg/L	25	7	28	0.017					0.011	0.045	0.16	0.0020
Temperature	C	26	26	100	7.0	6.9	-0.16	0.098	3.0	9.5	16	26	NA
Total Organic Carbon (TOC)	mg/L	25	25	100	290	140	1.8	8.3	48	260	970	2200	NA
Total Residual Chlorine	mg/L	26	10	38	0.096					0.13	0.22	0.30	0.0075
Total Suspended Solids (TSS)	mg/L	26	26	100	210	130	10	29	71	190	690	1100	30
Turbidity	NTU	26	26	100	96	63	9.0	16	25	120	310	450	NA

Notes:

(1) Nondetect (censored) concentrations were replaced with ½ of the reporting limit for calculating average concentrations. The remaining statistics in this table were only calculated when analytes were detected at a sufficient frequency. For example, if an analyte was detected in fewer than 50% of samples, then a median concentration was not calculated. A blank cell reflects a situation when a median or percentile could not be computed based on detected concentrations. The percentiles are the concentrations of each analyte below which at least that percentage of the values fall. So the 10th percentile is the concentration below which at least 10% of the observations were found.

(2) Screening BM represents the screening benchmark referred to in Section 3.1.3, and is the most stringent 2006 NRWQC or other conservative benchmark used to calculate PHQs.

Table 3.4.5. Results of Fish Hold Cleaning Effluent Analyses for Classical Pollutants[1]

Parameter	Units	No. samples	No. detected	Detected Proportion (%)	Average Conc.	Median Conc.	Minimum Conc.	10%	25%	75%	90%	Maximum Conc.	Screening BM[2]
Biochemical Oxygen Demand (BOD)	mg/L	9	6	67	470	300				770	1800	1800	30
Chemical Oxygen Demand (COD)	mg/L	9	9	100	1100	960	490	490	530	1600	2400	2400	NA
Conductivity	mS/cm	8	8	100	35	41	2.6	2.6	27	45	46	46	NA
Dissolved Oxygen	mg/L	9	9	100	5.6	2.9	1.4	1.4	1.6	9.6	15	15	NA
Hexane Extractable Material (HEM)	mg/L	9	6	67	5.4	1.4				4.2	28	28	15
pH	SU	9	9	100	7.6	7.6	6.9	6.9	7.2	8.1	8.6	8.6	NA
Salinity	ppt	9	9	100	48	24	1.3	1.3	19	27	260	260	NA
Silica Gel Treated HEM (SGT-HEM)	mg/L	9	4	44	4.9					2.8	12	12	15
Sulfide	mg/L	7	4	057	0.10	0.019				0.17	0.48	0.48	0.0020
Temperature	C	9	9	100	9.2	8.2	4.7	4.7	5.7	12	15	15	NA
Total Organic Carbon (TOC)	mg/L	9	9	100	210	74	1.9	1.9	5.1	430	730	730	NA
Total Residual Chlorine	mg/L	9	6	67	0.29	0.11				0.29	1.5	1.5	0.0075
Total Suspended Solids (TSS)	mg/L	9	9	100	190	84	16	16	26	400	460	460	30
Turbidity	NTU	9	9	100	100	59	0.20	0.20	1.0	210	330	330	NA

Notes:

(1) Nondetect (censored) concentrations were replaced with ½ of the reporting limit for calculating average concentrations. The remaining statistics in this table were only calculated when analytes were detected at a sufficient frequency. For example, if an analyte was detected in fewer than 50% of samples, then a median concentration was not calculated. A blank cell reflects a situation when a median or percentile could not be computed based on detected concentrations. The percentiles are the concentrations of each analyte below which at least that percentage of the values fall. So the 10th percentile is the concentration below which at least 10% of the observations were found.

(2) Screening BM represents the screening benchmark referred to in Section 3.1.3, and is the most stringent 2006 NRWQC or other conservative benchmark used to calculate PHQs.

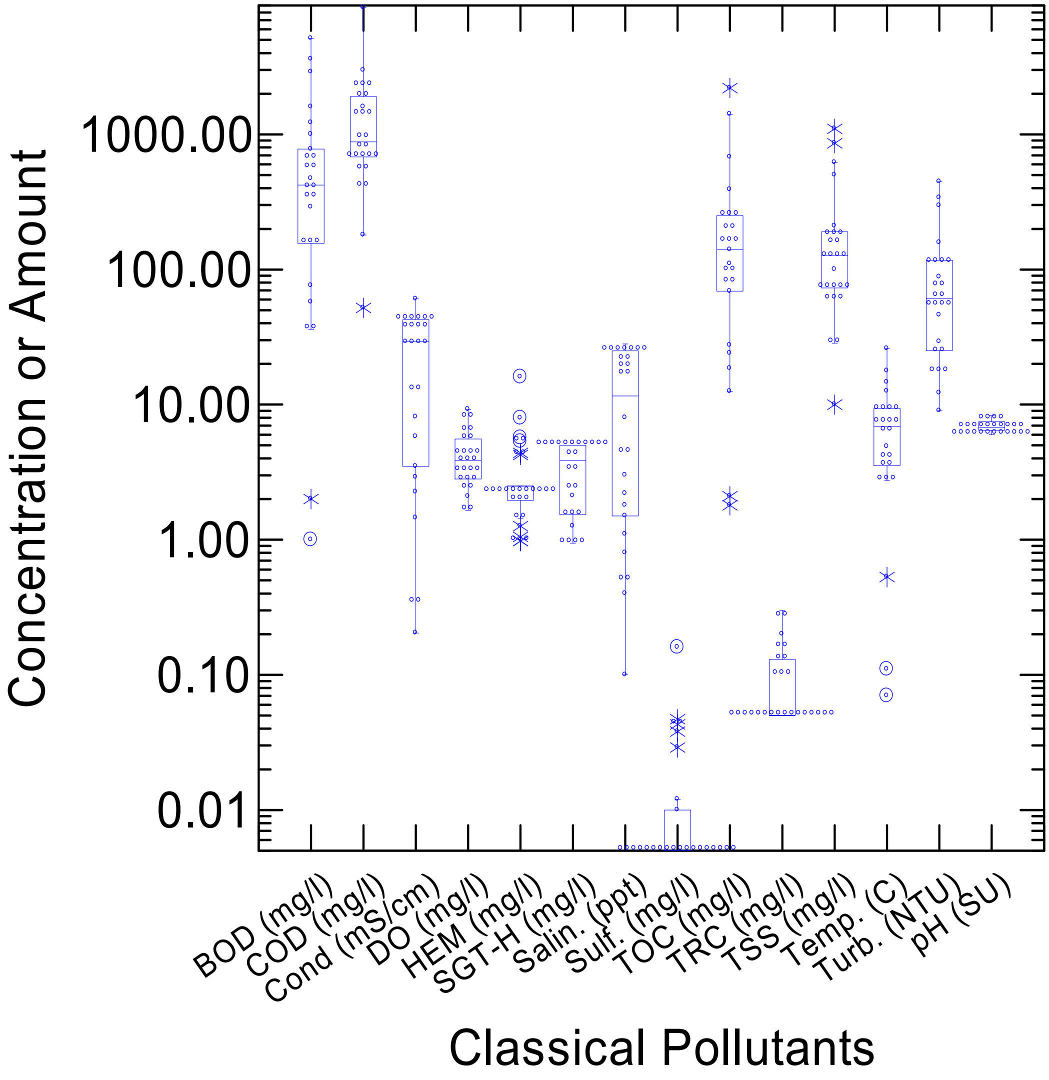


Figure 3.4.9. Box and Dot Density Plot of Classical Pollutant Concentrations/Values Measured in Samples of Fish Hold Effluent

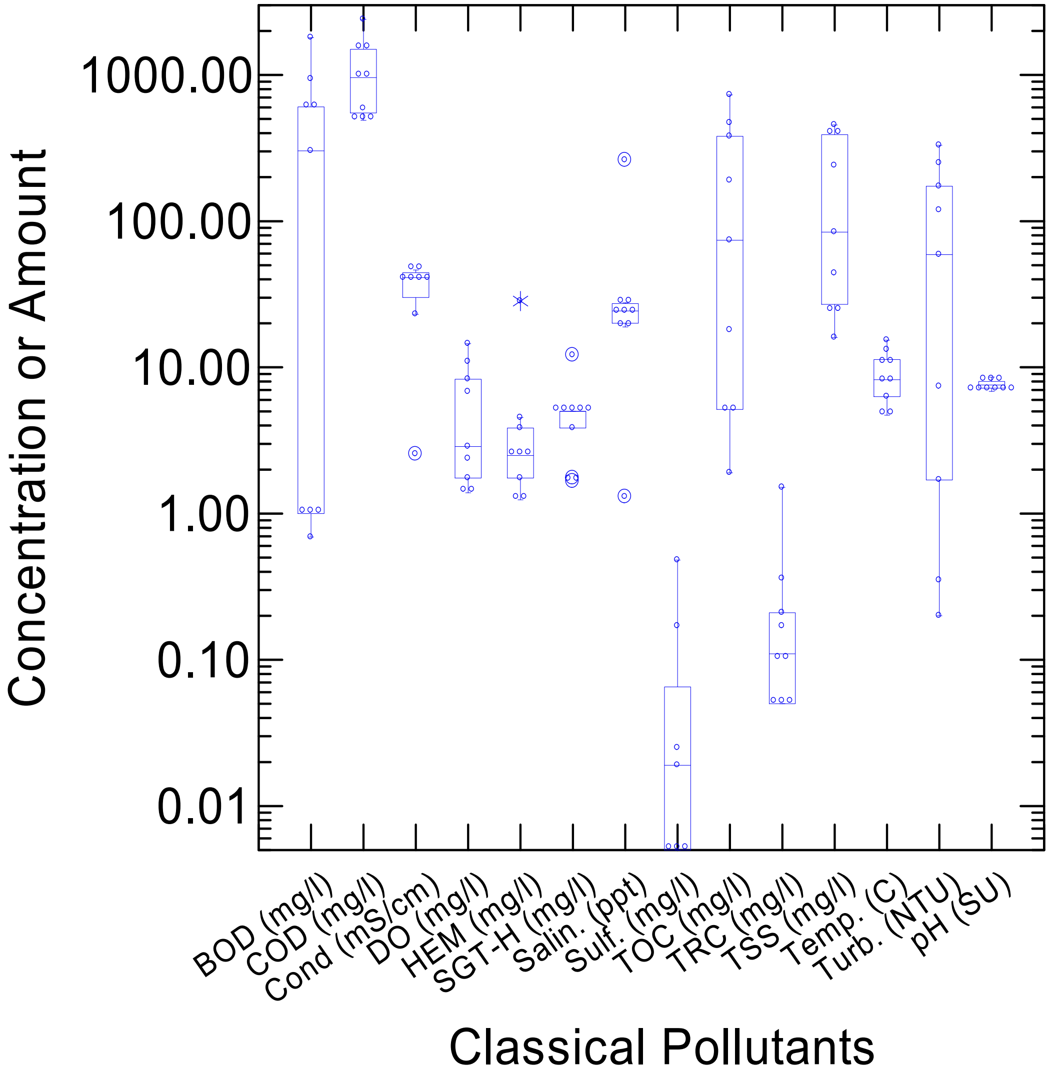
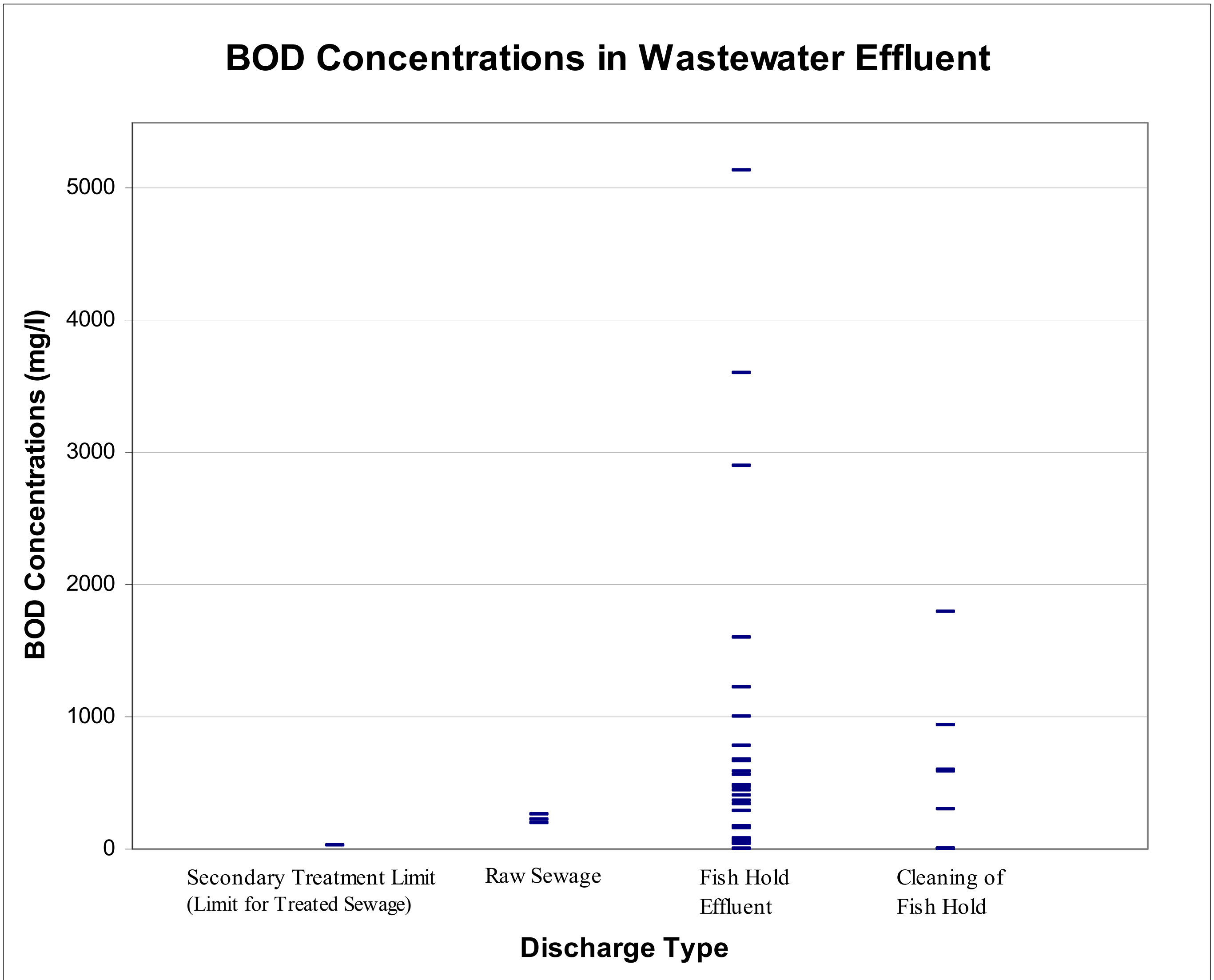


Figure 3.4.10. Box and Dot Density Plot of Classical Pollutant Concentrations/Values Measured in Samples of Fish Hold Cleaning Effluent



Raw Sewage Data Sources: Orford and Matusky (1959). Henry (1996). Medium value from Metcalf and Eddy (1979).

Figure 3.4.11. Comparison Between the BOD Secondary Treatment Limit from Sewage Treatment Facilities (30 mg/L), Average BOD Raw Sewage Concentrations, and BOD Concentrations from Fish Hold Effluent and Fish Hold Cleaning Effluent

3.2.4.3 Pathogen Indicators (Microbiologicals)

Sampling pathogen indicators from fish holds presented logistical challenges for the EPA sampling team. Many fishing vessels were sampled in locations remote from laboratories and the holding times of tests for these three pathogens (< 6 hours) prevented EPA from analyzing these samples from many of the sampling events. Nonetheless, EPA was able to test for *E. coli* and enterococci in seven fish hold effluent samples and for fecal coliform in 11 fish hold effluent samples. The results are summarized in Table 3.4.6 (upper half of table) and shown graphically in Figure 3.4.12.

Of these fish hold effluent samples, EPA detected bacteria concentrations above the most stringent screening benchmarks for one (of the seven) *E. coli* samples, four (of the seven) enterococci samples, and three (of the 11) fecal coliform samples. However, EPA strongly suspects that all of these exceedances were due primarily or exclusively due to background concentrations. For example, the fish hold effluent from a fishing vessel sampled in Gloucester, Massachusetts, exceeded all three stringent screening benchmarks for *E. coli*, enterococci, and fecal coliform. However, ambient water concentrations collected earlier in the day exceeded the concentrations in the later sample taken from the fish hold. The likely source of the pathogenic bacteria in this case was a combined sewer overflow (CSO) a few hundred feet above the location of the fishing vessel. The fishing vessel used ambient water to wash off its deck while unloading cargo (see section 3.2.3.3). Some of this water likely made its way into the fish hold before EPA sampled the fish hold effluent again at the later time period; hence, in this case, EPA strongly doubts that the vessel was the source of the extremely high pathogen levels.

What are Combined Sewer Overflows (CSOs) and Sanitary Sewer Overflows (SSOs)?

Combined sewer systems are sewers that are designed to collect rainwater runoff, domestic sewage, and industrial wastewater in the same pipe. Most of the time, combined sewer systems transport all of their wastewater to a sewage treatment plant, where it is treated and then discharged to a water body. During periods of heavy rainfall or snowmelt, however, the wastewater volume in a combined sewer system can exceed the capacity of the sewer system or treatment plant. For this reason, combined sewer systems are designed to overflow occasionally and discharge excess wastewater directly to nearby streams, rivers, or other water bodies. These overflows, called combined sewer overflows (CSOs), contain not only stormwater but also untreated human and industrial waste, toxic materials, and debris.

Properly designed, operated, and maintained sanitary sewer systems are meant to collect and transport all of the sewage that flows into them to a publicly owned treatment works (POTW). However, occasional unintentional discharges of raw sewage from municipal sanitary sewers occur in almost every system. These types of discharges are called sanitary sewer overflows (SSOs). SSOs have a variety of causes, including but not limited to severe weather, improper system operation and maintenance, and vandalism. EPA estimates that there are at least 40,000 SSOs each year. The untreated sewage from these overflows can contaminate our waters, causing serious water quality problems.

EPA encountered a similar situation while sampling a commercial fishing vessel in New Bedford, Massachusetts. The samples from the fish hold exceeded water quality criteria for enterococci (127 MPN/ 100 ml) and fecal coliform (125,000 CFU/ 100 ml). However, this vessel was sampled immediately adjacent to an SSO that contained raw fish waste and human sewage: the ambient water had enterococci concentrations of 4,342 MPN/ 100 ml and fecal coliform concentrations of 6,500 CFU/ 100 ml. This vessel also used ambient water to hose off its deck, introducing the pathogenic bacteria to the fish hold. Note that for fecal coliform, this latter vessel's fish hold effluent did appear to add to the high fecal coliform count in the sample.

None of the concentrations of the three pathogens exceeded the most stringent NRWQC set for the pathogens in cases where the ambient concentrations were also below the stringent NRWQC. Although the results were based on this limited number of samples, EPA believes it is unlikely that there is an onboard source of these pathogenic bacteria in the fish hold.

EPA was able to test the effluent from three separate fish holds from three vessels while they were being cleaned (see Table 3.4.6, lower half of table). Two of the fish hold cleaning effluent samples were from those vessels discussed above, where ambient water pathogen concentrations were impacted by the discharge from a CSO and an SSO. The third sample was from a vessel sampled in Sitka, Alaska. Similar to the fish hold effluent results from Massachusetts, EPA found that the concentrations of the effluent from the fish hold cleaning exceeded the NRWQC in one out of the three samples for *E. coli*, two out of the three samples for enterococci, and two out of three samples for fecal coliform. All the samples exceeding the most stringent screening benchmarks for the pathogens were from the vessels located in Massachusetts. Pathogen concentrations were below the detection limit for all three pathogens for the fish hold cleaning effluent from the vessel in Sitka. In all cases, background concentrations in the ambient water exceeded the fish hold cleaning effluent. Similar to what EPA observed with the fish hold effluent data, pathogen contamination in fish hold cleaning effluent from fishing vessels is not a likely source of pathogen contamination to receiving waters. Instead, EPA suspects that the pathogen contamination in these effluents might come from the vessel pumping ambient water with high levels of bacteria onboard.

Table 3.4.6. Results of Fish Hold and Fish Hold Cleaning Effluent Sample Analyses for Pathogen Indicators[1]

Analyte[2]	Units[3]	No. samples	No. detected	Detected Proportion (%)	Average Conc.	Median Conc.	Minimum Conc.	10%	25%	75%	90%	Maximum Conc.	Screening BM[4]
Fish Hold													
E. coli by MPN	MPN/100 ml	7	6	86	83	41			10	110	310	310	130
Enterococci by MPN	MPN/100 ml	7	5	71	380	41				250	2200	2200	33
Fecal Coliform by MF	CFU/100 ml	11	6	55	11000	10				270	100000	130000	14
Fish Hold Cleaning													
E. Coli by MPN	MPN/100 ml	3	2	67	200	52				550	550	550	130
Enterococci by MPN	MPN/100 ml	3	2	67	1000	150				2800	2800	2800	33
Fecal Coliform by MF	CFU/100 ml	3	2	67	1900	250				5300	5300	5300	14

Notes:

(1) Nondetect (censored) concentrations were replaced with ½ of the reporting limit for calculating average concentrations. The remaining statistics in this table were only calculated when analytes were detected at a sufficient frequency. For example, if an analyte was detected in fewer than 50% of samples, then a median concentration was not calculated. A blank cell reflects a situation when a median or percentile could not be computed based on detected concentrations. The percentiles are the concentrations of each analyte below which at least that percentage of the values fall. So the 10th percentile is the concentration below which at least 10% of the observations were found.

(2) MPN = Most Probable Number; MF = Membrane Filtration.

(3) CFU = Colony Forming Units.

(4) Screening BM represents the screening benchmark referred to in Section 3.1.3, and is the most stringent 2006 NRWQC or other conservative benchmark used to calculate PHQs.

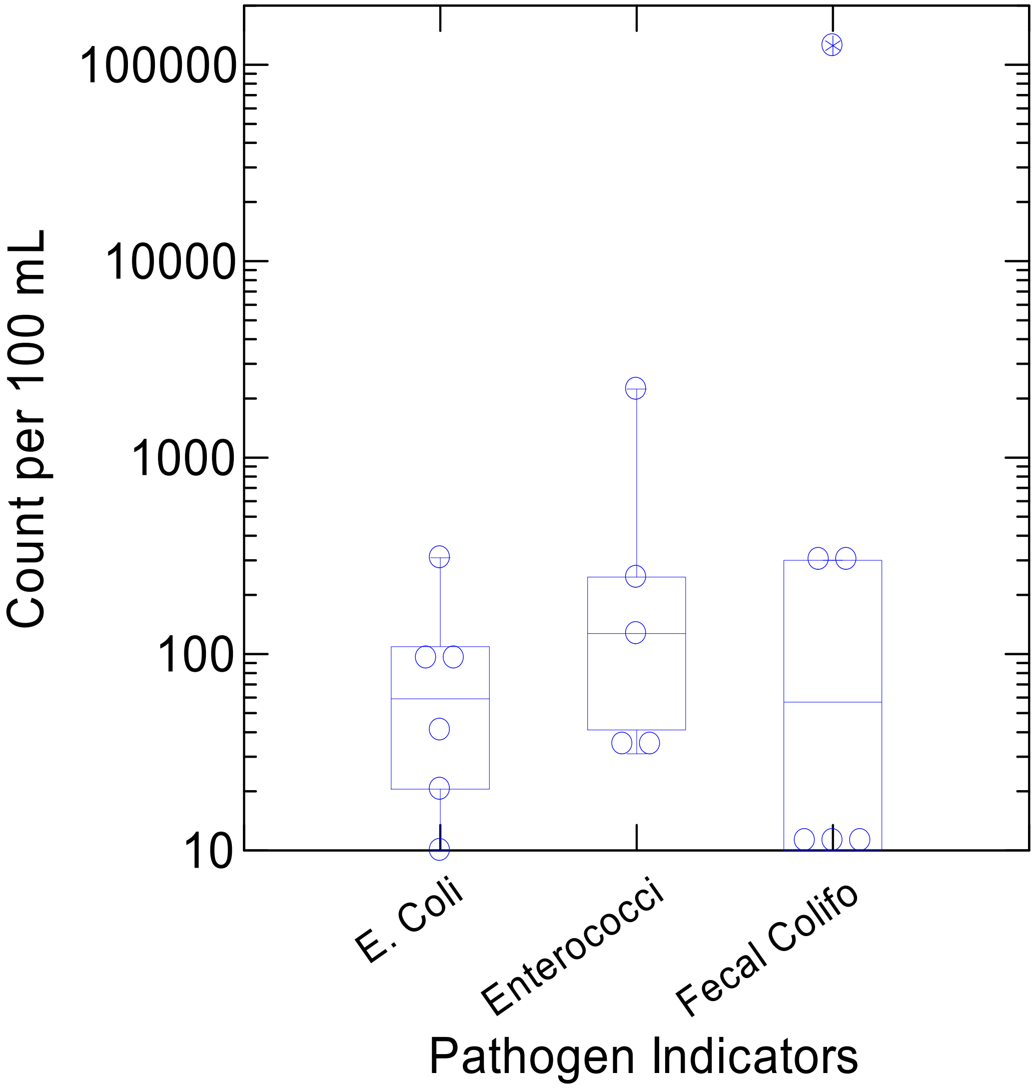


Figure 3.4.12. Box and Dot Density Plot of Measured Pathogen Concentrations in Samples of Fish Hold Effluent

(Note: All values were subtantially influenced by background concentrations in the ambient water, and of the 25 sample results presented (seven results for *E. coli*, seven for enterococci, and 11 for fecal coliform), only two of the samples exceeded their background concentrations by more than 20 CFU/MPN 100 ml).

3.2.4.4 Nutrients

Samples of fish hold effluent and fish hold cleaning were analyzed for four nutrients or nutrient-related parameters: ammonia nitrogen, nitrate/nitrite, TKN, and total phosphorus (see Table 3.4.7). The corresponding nutrient concentrations detected in fish hold and fish hold cleaning effluent samples are shown in Figures 3.4.13 and 3.4.14, respectively.

Concentrations of total ammonia nitrogen (NH3-N), nitrate/nitrite nitrogen (NO3/NO2-N), TKN, and total phosphorus roughly compare to values of untreated raw sewage (see values in Table 3.4.8). The fish hold effluent had average ammonia concentrations of approximately 12 mg/L and the fish hold cleaning effluent had average concentrations of 16 mg/L, which compares roughly to weak sewage as reported by Metcalf and Eddy (1979) (see Table 3.4.8). However, there were several discharges in which the ammonia concentration substantially exceeded these concentrations, and these discharges could potentially result in acute toxic effects in the receiving water at and near the point of discharge (see Figure 3.4.13). These high values increase the average considerably (the median values for fish hold and fish hold cleaning effluent are 2.1 and 4.8 mg/L, respectively). Most of the ammonia concentrations in samples collected from both fish hold and fish hold cleaning effluent exceed the PHQ screening benchmark of 1.2 mg/L based on the freshwater chronic aquatic life criterion of 1.2 mg N/L, with the highest concentration resulting in a PHQ value of over 130.

In contrast, average nitrate concentrations were near zero for both fish hold effluent (maximum concentration of 0.39 mg/L) and fish hold cleaning effluent (maximum concentration of max 0.53 mg/L). These concentrations are similar to those expected in raw sewage effluent no matter the strength of the sewage effluent (see Table 3.4.8). However, the average total phosphorus concentrations of 13 mg/L for the fish hold effluent and 8.5 mg/L for fish hold cleaning effluent were similar to concentrations in medium to strong raw sewage (see Tables 3.4.7 and 3.4.8).

TKN values averaged 110 mg/L for fish hold effluent and 59 mg/L for fish hold cleaning effluent. These TKN results[31] can be roughly compared with total nitrogen results from Metcalf and Eddy (1979), showing that the nitrogen discharges are roughly equivalent to strong sewage.

Protein, free amino acids, and nucleotides from fish and fish by-products are all potential sources of nitrogen. Inorganic phosphorus in the form of phosphate is a key

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[31] TKN includes ammonia (NH3) and ammonium (NH4+), and organic nitrogen values. Total nitrogen includes ammonia (NH3) and ammonium (NH4+), organic nitrogen, and nitrate and nitrite values. Raw sewage tends to have very low nitrate and nitrite values.

element in DNA, RNA, and adenosine triphosphate (ATP) – key components present in the tissue and blood of any animal.

As shown in Figures 3.4.14 and 3.4.15, there is considerable variation exceeding two orders of magnitude in the concentrations of three of the four nutrient and nutrient-related parameters. EPA observed that nutrient concentrations showed some relationship to the geographical location where the vessels operated. As shown in Figure 3.4.15, concentrations of ammonia, TKN, and TP from the Gulf Coast shrimp boats and the New England ground fishery trawlers appear to be higher than those from the fishing vessels sampled in Alaska or the New England lobster tank. In addition, compared to the lobster tank, whose water source is primarily flow-through water, all fishing vessel platforms appear to add nutrients to the effluent.

Table 3.4.7. Results of Fish Hold (upper half) and Fish Hold Cleaning Effluent (lower half) Sample Analyses for Nutrients[1]

Analyte	Units	No. samples	No. detected	Detected Proportion (%)	Average Conc.	Median Conc.	Minimum Conc.	10%	25%	75%	90%	Maximum Conc.	Screening BM[2]
Fish Hold													
Ammonia As Nitrogen (NH3-N)	mg/L	26	25	96	12	2.1		0.64	1.1	6.7	32	160	1.2
Nitrate/Nitrite (NO3/NO2-N)	mg/L	26	18	69	0.10	0.092				0.11	0.27	0.39	NA
Total Kjeldahl Nitrogen (TKN)	mg/L	26	25	96	110	75		3.5	19	160	340	540	NA
Total Phosphorus	mg/L	26	25	96	13	9.7		0.43	3.2	17	28	76	0.10
Fish Hold Cleaning													
Ammonia As Nitrogen (NH3-N)	mg/L	9	7	78	16	4.8			0.034	18	97	97	1.2
Nitrate/Nitrite (NO3/NO2-N)	mg/L	9	8	89	0.24	0.27			0.070	0.35	0.53	0.53	NA
Total Kjeldahl Nitrogen (TKN)	mg/L	9	6	67	59	40				140	170	170	NA
Total Phosphorus	mg/L	9	7	78	8.5	11			0.025	17	20	20	0.10

Notes:

(1) Nondetect (censored) concentrations were replaced with ½ of the reporting limit for calculating average concentrations. The remaining statistics in this table were only calculated when analytes were detected at a sufficient frequency. For example, if an analyte was detected in fewer than 50% of samples, then a median concentration was not calculated. A blank cell reflects a situation when a median or percentile could not be computed based on detected concentrations. The percentiles are the concentrations of each analyte below which at least that percentage of the values fall. So the 10th percentile is the concentration below which at least 10% of the observations were found.

(2) Screening BM represents the screening benchmark referred to in Section 3.1.3, and is the most stringent 2006 NRWQC or other conservative benchmark used to calculate PHQs.

Table 3.4.8. Raw Sewage Concentrations of Nutrients

Constituent	Concentration (expressed as mg/L)		
	Strong Sewage	Medium Sewage	Weak Sewage
Ammonia as N	50	25	12
Nitrate as N	0	0	0
Total Nitrogen	85	40	20
Total Phosphorus	15	8	4

Source: Metcalf and Eddy, 1979.

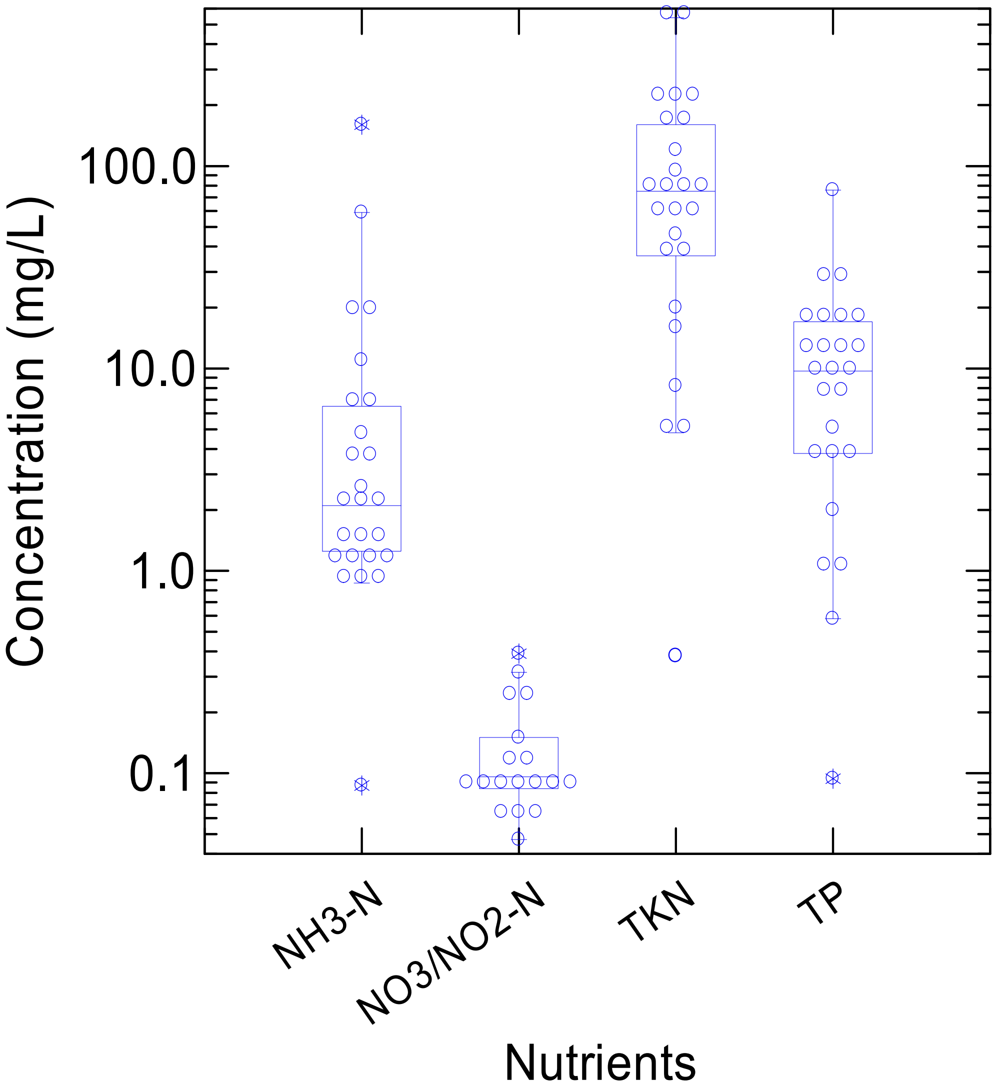

Figure 3.4.13. Box and Dot Density Plot of Nutrient Concentrations Measured in Samples of Fish Hold Effluent
(Note: High maximum concentrations for certain samples for ammonia (160 mg N/L), total phosphorus (76 mg/L), and TKN (338 mg/L) are evident).

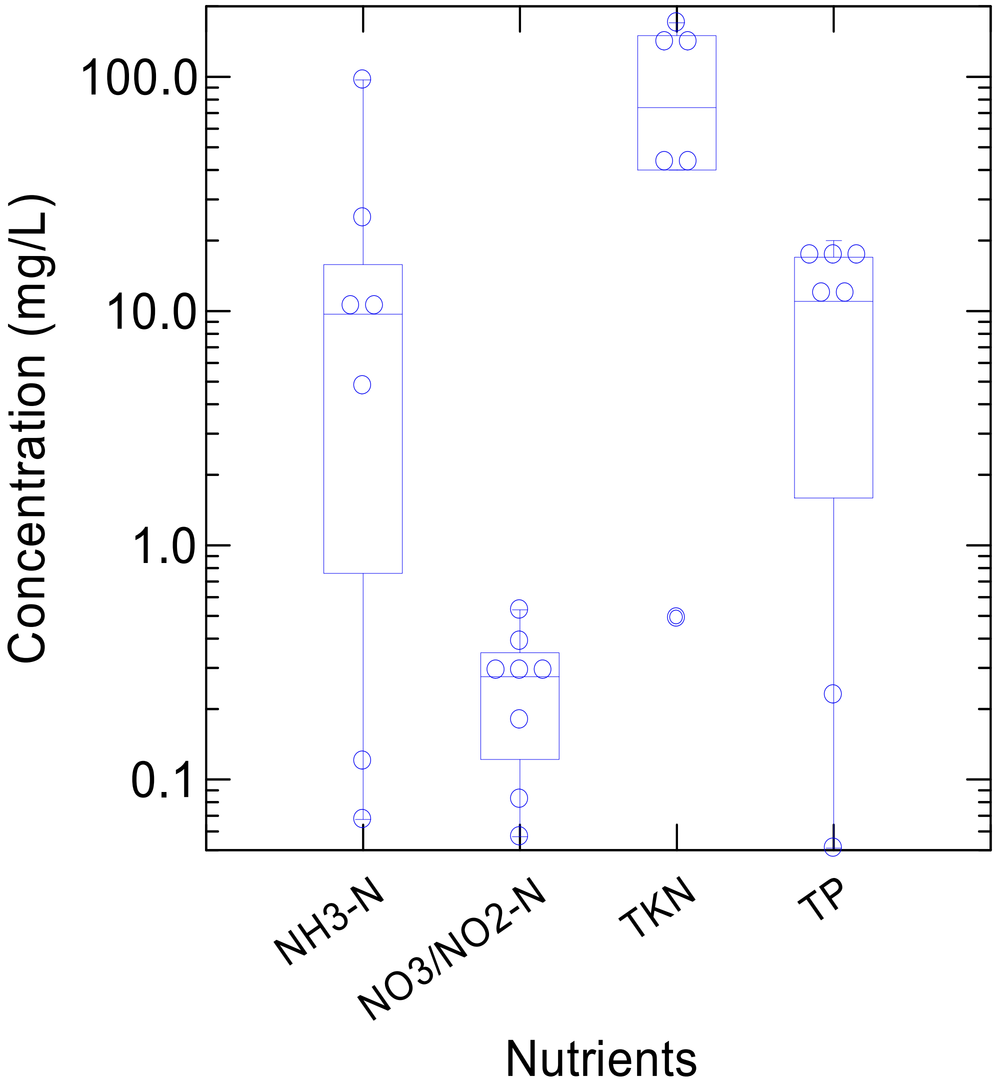

Figure 3.4.14. Box and Dot Density Plot of Nutrient Concentrations Measured in Samples of Fish Hold Cleaning Effluent
(Note: For all parameters except ammonia, nutrient concentrations tend to be lower for fish hold cleaning effluent).

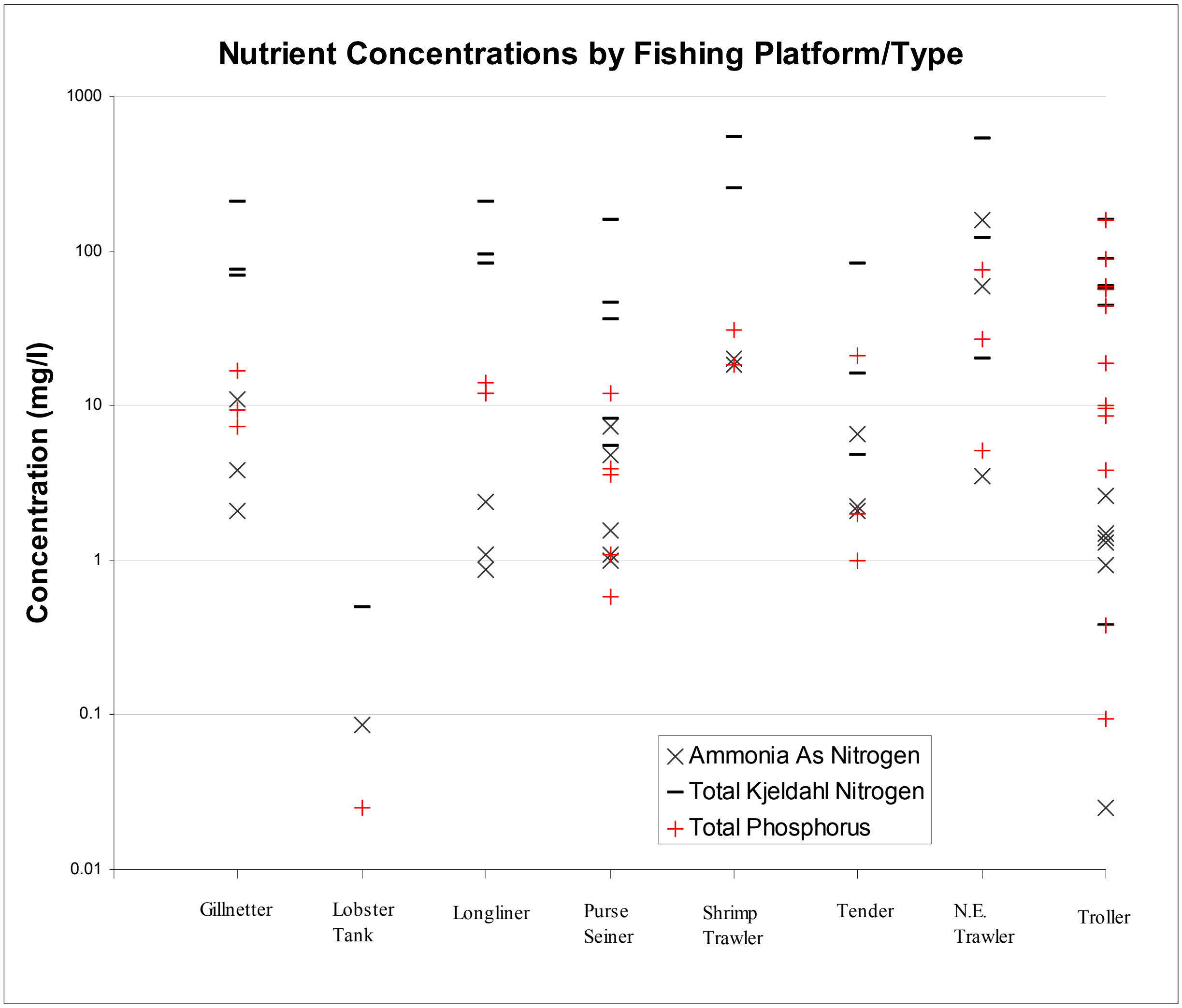

Figure 3.4.15. Comparison of Concentrations of Ammonia, TKN, and Total Phosphorus in Different Fishing Vessel Platforms to those in the Lobster Tank (which has a live catch and continuously circulating water)

3.2.4.5 Nonylphenols

EPA analyzed three fish hold samples for nonylphenols. Short-chain nonylphenol ethoxylates (e.g., NP2EO, NP1EO) and NP were not detected in any of these samples. EPA expected this result because detergents should not be present when seafood catch is stored in the vessel's fish hold compartment except for residual amounts from poor rinsing after cleaning.

As expected, several long chain nonylphenol and octylphenol ethoxylates (NPEOs and OPEOs, respectively)) were detected in the fish hold cleaning samples collected from eight vessels (see Table 3.4.9). As with deck washdown water, the NPEOs with the longest ethoxylate chains were detected in approximately a third of the vessels, with concentrations increasing as ethoxylate chain is reduced (i.e., concentrations increasing from NP18EO to NP10EO). Of the vessels where long ethoxalate chain NPEOs were detected, only one of the three vessels had detectable concentrations of NPEOs representing the shortest chains (NP3EO through NP5EO); measured concentrations were low in the range of 12 to 32 µg/L, respectively. The OPEO with the longest ethoxylate chain (OP12EO) was detected in only one vessel, as were the lower ethoxylate chain OPEOs. For OPEOs, the concentrations showed the same general trend as the NPEOs with concentrations increasing as ethoxylate chain is reduced, although the concentrations of the shorter chain OPEOs were much lower than the shorter chain NPEOs.

Total NPEO concentrations (from samples containing all 16 NPEO isomers) could be calculated for only two of the eight vessels whose fish hold cleaning effluent was sampled. The concentrations of total NPEOs ranged from 56 (a ground fishery trawler in Massachusetts) to 4,540 µg/L (another ground fishery trawler in Massachusetts). These results are shown graphically in Figure 3.4.16.

While there is no NRWQC for the sum of NPEOs or OPEOs, as indicated in previous subsections, these compounds can degrade to NP in fresh and salt water (the saltwater chronic aquatic life criterion for NP is only 1.7 µg/L). EPA did not collect samples of background levels for analysis of total NPEOs, OPEOs, and NP from ambient or source water.

Table 3.4.9. Results of Fish Hold Cleaning Effluent Sample Analyses for Long-chain Nonylphenols[1]

Analyte	Units	No. samples	No. detected	Detected Proportion (%)	Average Conc.	Median Conc.	Minimum Conc.	10%	25%	75%	90%	Maximum Conc.	Screening BM[2]
Total Nonylphenol Polyethoxylates	µg/L	8	2	25	620					42	4500	4500	NA
Nonylphenol octodecaethoxylate (NP18EO)	µg/L	8	4	50	1.6	0.15				0.27	12	12	NA
Nonylphenol heptadecaethoxylate (NP17EO)	µg/L	8	3	38	3.1					0.49	23	23	NA
Nonylphenol hexadecaethoxylate (NP16EO)	µg/L	8	3	38	6.9					1.1	51	51	NA
Nonylphenol pendecaethoxylate (NP15EO)	µg/L	8	3	38	14					2.1	100	100	NA
Nonylphenol tetradecaethoxylate (NP14EO)	µg/L	8	2	25	25					2.9	180	180	NA
Nonylphenol tridecaethoxylate (NP13EO)	µg/L	8	2	25	39					3.9	290	290	NA
Nonylphenol dodecaethoxylate (NP12EO)	µg/L	8	2	25	56					5.5	420	420	NA
Nonylphenol undecaethoxylate (NP11EO)	µg/L	8	2	25	75					6.4	560	560	NA
Nonylphenol decaethoxylate (NP10EO)	µg/L	8	2	25	75					5.9	550	550	NA
Nonylphenol nonaethoxylate (NP9EO)	µg/L	8	2	25	73					4.7	530	530	NA
Nonylphenol octaethoxylate (NP8EO)	µg/L	8	2	25	74					4.3	540	540	NA
Nonylphenol heptaethoxylate (NP7EO)	µg/L	8	2	25	66					3.1	470	470	NA
Nonylphenol hexaethoxylate (NP6EO)	µg/L	8	2	25	51					1.9	360	360	NA
Nonylphenol pentaethoxylate (NP5EO)	µg/L	8	1	13	32						220	220	NA
Nonylphenol tetraethoxylate (NP4EO)	µg/L	8	1	13	21						140	140	NA
Nonylphenol triethoxylate (NP3EO)	µg/L	8	1	13	12						79	79	NA
Octylphenol dodecaethoxylate (OP12EO)	µg/L	8	1	13	2.8						11	11	NA
Octylphenol undecaethoxylate (OP11EO)	µg/L	8	1	13	2.7						15	15	NA
Octylphenol decaethoxylate (OP10EO)	µg/L	8	1	13	4.5						20	20	NA
Octylphenol nonaethoxylate (OP9EO)	µg/L	8	1	13	4.9						23	23	NA

Notes:

(1) Nondetect (censored) concentrations were replaced with ½ of the reporting limit for calculating average concentrations. The remaining statistics in this table were only calculated when analytes were detected at a sufficient frequency. For example, if an analyte was detected in fewer than 50% of samples, then a median concentration was not calculated. A blank cell reflects a situation when a median or percentile could not be computed based on detected concentrations. The percentiles are the concentrations of each analyte below which at least that percentage of the values fall. So the 10th percentile is the concentration below which at least 10% of the observations were found.

(2) Screening BM represents the screening benchmark referred to in Section 3.1.3, and is the most stringent 2006 NRWQC or other conservative benchmark used to calculate PHQs.

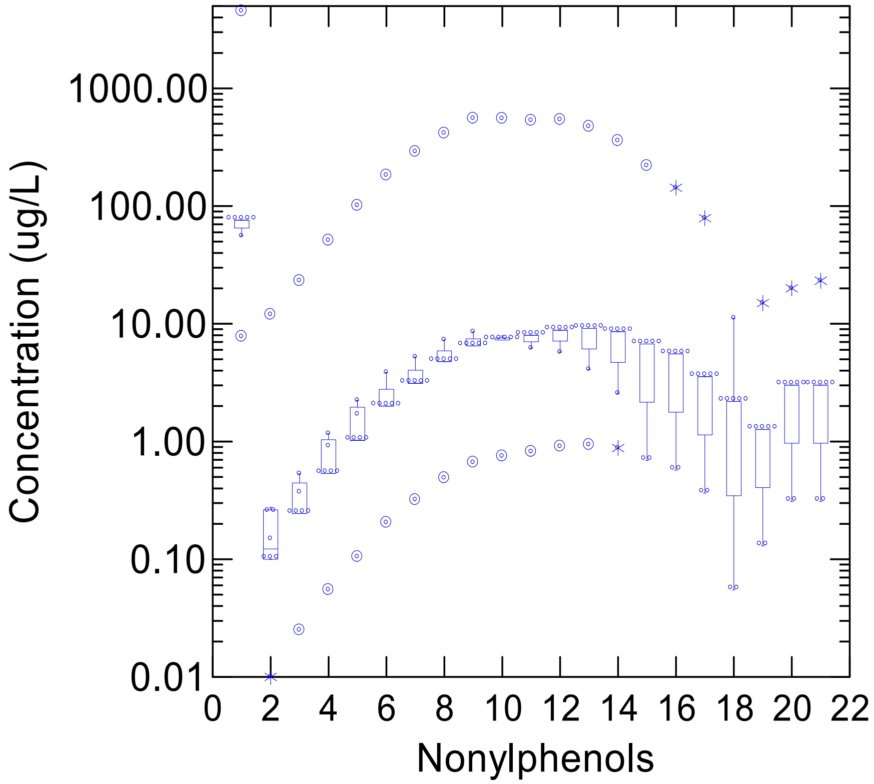

Figure 3.4.16. Box and Dot Density Plot of Nonylphenol Concentrations Measured in Samples of Fish Hold Cleaning Effluent

Nonylphenol parameters are identified as follows (nonylphenol and octylphenol ethoxylates in fish hold effluent were not detected):

(1) Total Nonylphenol Polyethoxylates
(2) Nonylphenol octodecaethoxylate (NP18EO)
(3) Nonylphenol heptadecaethoxylate (NP17EO)
(4) Nonylphenol hexadecaethoxylate (NP16EO)
(5) Nonylphenol pendecaethoxylate (NP15EO)
(6) Nonylphenol tetradecaethoxylate (NP14EO)
(7) Nonylphenol tridecaethoxylate (NP13EO),
(8) Nonylphenol dodecaethoxylate (NP12EO)
(9) Nonylphenol undecaethoxylate (NP11EO)
(10) Nonylphenol decaethoxylate (NP10EO)
(11) Nonylphenol nonaethoxylate (NP9EO)
(12) Nonylphenol octaethoxylate (NP8EO)
(13) Nonylphenol heptaethoxylate (NP7EO)
(14) Nonylphenol hexaethoxylate (NP6EO)
(15) Nonylphenol pentaethoxylate (NP5EO)
(16) Nonylphenol tetraethoxylate (NP4EO)
(17) Nonylphenol triethoxylate (NP3EO)
(18) Octylphenol dodecaethoxylate (OP12EO)
(19) Octylphenol undecaethoxylate (OP11EO)
(20) Octylphenol decaethoxylate (OP10EO)
(21) Octylphenol nonaethoxylate (OP9EO)

3.2.4.6 Regional variation in Fish Hold Effluent Discharges

Based on public comments received on EPA's draft version of this report, EPA conducted a regional analysis of vessel fish hold discharges. EPA was able to conduct this analysis because there were 26 different hold discharges sampled. However, of the 26 fish hold discharges sampled, twenty were from Alaska, four were from New England, and only two were from the Gulf. A sample size of two is the absolute minimum number that can be used for any statistical comparisons, and caution must be exercised before drawing any general conclusions on the effects of fish hold discharge for an entire geographic region based on only two samples. Additionally, there is limited variation in the platforms sampled at New England and Gulf Coast locations. EPA cautions these results must be considered preliminary in nature and cannot be considered conclusive. The limitations of this analysis are also discussed in the following paragraphs.

The potential regional differences in concentrations of fish hold discharges were examined for seven analytes (Total Copper, Total Zinc, Total Arsenic, Ammonia, Total Kjeldahl Nitrogen, Total Phosphorus, and Biological Oxygen Demand). Concentrations of each of these analytes were compared for the three regions in which vessels with fish hold discharge were sampled (Alaska, Gulf Coast, and New England). Mean analyte concentrations with corresponding standard deviations are shown for each of the regions in Table 3.4.10. Based on this preliminary analysis, mean concentrations of all seven analytes were lower in the fish hold discharges from fishing vessels in Alaska compared to the concentrations discharged from fishing vessels in the Gulf Coast and New England. A preliminary statistical analysis (Welch's t-tests accounting for unequal variance and unequal sample sizes – see accompanying text box for details) comparing each of these

Regional Comparison of Fish Hold Discharge Concentrations

A preliminary analysis was performed to assess the effects of geographic region on seven selected analytes listed in Table 3.4.10. Vessels were grouped into three broad geographic regions, and concentration differences between groups were evaluated using Welch's t-tests accounting for unequal sample size and uneven variance. Prior to analysis, all concentrations were log transformed to stabilize sample variance. EPA performed t-test analyses with and without subtracting background analyte concentrations. The results were fundamentally similar. For each analyte, three comparisons were made (Alaska-Gulf, Alaska-New England, Gulf-New England), at a Bonferroni adjusted significance level of .017 (.05/3), to account for the effect of multiple comparisons.

Two additional analyses were performed to examine whether the observed regional differences could be explained by differences in fishing method (nets vs. no nets), or fish hold cooling method (ice vs. refrigerated seawater vs. both). These analyses also consisted of Welch's t-tests for unequal sample size and unequal sample variance, and were conducted using log transformed concentrations after subtracting ambient concentration with appropriate Bonferroni adjusted significance levels to account for the effect of multiple comparisons.

groups suggests that regional differences in the fish hold discharge concentrations for these seven analytes might be present, as concentrations from the two Gulf Coast vessels (shrimpers) were statistically significantly higher than concentrations from the twenty Alaska vessels for six of the seven analytes tested. The one exception was total arsenic, which did not differ significantly between any of the three regions.

Although these results suggest the possibility of regional differences, they may also simply be a statistical artifact of: 1) a population of vessels that were both small in number and highly unevenly distributed across regions, 2) vessel type, 3) fish hold cooling method, 4) fishery type, or 5) some combination of the above. Both of the Gulf Coast vessels were shrimp trawlers, and three of the four New England vessels were ground fishery trawlers. Trawling vessels may also fish closer to the bottom of the water column, and could be expected to accumulate more organic matter along with their catch, which could potentially explain the higher concentrations of the analytes examined in this analysis. A fourth New England sample was taken from a lobster tank which consistently circulated ambient water. The twenty Alaska vessels consisted of five purse seiners, three gillnetters, three longliners, three tender vessels, and six trollers. The purse seiners and gillnetters spread nets, which may tend to pull fish or other material from closer to the bottom of the water column (though this is less likely in many deep waters off of Alaska). A second analysis was performed to determine whether the regional differences observed were an artifact of the distribution of vessel type; specifically, whether the vessel fishing method employed nets (trawlers, purse seiners, gillnetters), or some other method (lobster vessel, longliners, trollers). When the vessels were analyzed in two groups, those that do not use nets versus those that use nets, concentrations of total ammonia were statistically significantly higher, and concentrations of total arsenic and total copper were marginally ($0.10<P<0.05$) statistically significantly higher in vessels that use nets, perhaps because these vessels tend to fish closer to the bottom of the water column. It should be noted that both of the Gulf vessels and three of the four New England vessels were vessel types that employed nets, which may have influenced the results. When the same analysis was performed using only the Alaska vessels, only ammonia was marginally statistically significantly higher in the vessels that fish with nets, while zinc concentrations were statistically significantly higher in vessels that fish without nets. Again, small sample caveats apply to these and all other analyses described in this section.

Finally, the effects of fish hold cooling method on fish hold discharge concentrations were examined. Of the twenty six vessels sampled, thirteen vessels used ice, ten used refrigerated water, two used both ice and refrigerated seawater, and one used recirculating ambient water. When vessels were examined as a function of cooling method, there were no statistically significant differences between any of the groups. This analysis was repeated for the subset of vessels from Alaska, and aside from ($0.1<P<0.05$) statistically significantly higher ammonia concentrations in Alaska vessels that chilled fish holds using refrigeration versus those that used ice, there were no statistically significant differences in fish hold discharges that could be explained by fish hold cooling method. However, this result cannot be separated from the effects of fishing method (nets vs. no nets), as seven of seven vessels that cooled fish holds with refrigerated seawater also fished with nets, while nine of ten vessels that cooled with ice used fishing methods that did not involve nets.

Although results of this analysis suggest differences in fish hold discharge concentrations are more pronounced between regions than between fishing method or fish hold cooling method, these results should be considered preliminary, and additional information will be required to draw any substantive conclusions regarding inter-region differences. Both the Gulf Coast and New England regions are represented by a small number of sample vessels. Not only is the Gulf Coast region represented by the minimum number of vessels with which to perform any statistical comparisons, the two vessels are similar with regard to vessel type and fish hold cooling method; therefore it cannot be assumed that the two sampled discharges are representative of the entire Gulf Coast fishery. While these analyses suggest the possibility of regional differences, the presence of true regional differences would require the sampling of a larger number of vessels from the Gulf and New England regions encompassing a broader, more evenly distributed number of vessels to account for the effects of vessel and discharge (ice or refrigerated water) type, as well as additional sampling of ambient receiving waters.

Table 3.4.10. Means (and Standard Deviations) for Selected Analyte Concentrations, by Geographic Region. Units for All Analytes Expressed as µg/L, Except for BOD (mg/L).

Region	Mean Analyte Concentration Above Ambient (1 s.d.)							Vessel Type (no.)
	Total Cu	Total Zn	Total As	Ammonia	TKN	Total P	BOD	
Alaska	53.7	253	4.79	2.72	75.4	8.40	416	Gillnetter (3)
	(69.0)	(223)	(3.69)	(2.74)	(64.4)	(6.35)	(336)	Longliner (3)
								Purse Seiner (5)
								Tender Vessel (3)
								Troller (6)
Gulf Coast	1640	446	186	19.0	397	24.7	3250	Shrimp Trawler (2)
	(30.7)	(75.5)	(233)	(1.39)	(201)	(8.73)	(499)	
New England	112	706	132	55.2	165	26.0	1720	Lobster Tank (1)
	(146)	(773)	(170)	(74.2)	(245)	(33.7)	(2370)	Ground Fishery Trawler (3)

*As discussed in the text above, there are substantial limitations to this regional analysis which mean these results are preliminary in nature. Additional information is needed before making firm conclusions.

3.2.4.7 Summary of the Characterization of Fish Hold Effluent and Fish Hold Cleaning Effluent

Table 3.4.11 summarizes the specific analytes within fish hold and fish hold cleaning effluent water that may have the potential to pose risk to human health or the environment. EPA's interpretation of a realized risk likely posed by these analytes, relative to pollutant loadings, background ambient and source water contaminant levels and characteristics, and other relevant information useful for this assessment, is presented in Chapter 5.

Total iron was sampled for in only two vessels, but PHQs were between 5 and 10. Concentrations of dissolved copper exceeded NRWQC standards in all effluents sampled, with PHQs>10 in four of the vessels sampled.

The concentrations of certain total and dissolved metals, as well as many of the other pollutants, measured in fish hold and fish hold cleaning effluent were elevated. Concentrations of total arsenic were detected in 16 of 26 samples, and when detected were measured at levels greatly exceeding its respective screening benchmark (i.e., NRWQC), resulting in PHQs of well over 100. Likewise, total copper concentrations, while only exceeding the NRWQC for human health of 1,300 µg/L in a few samples, were high in these few instances and might pose potential acute toxicity risk to aquatic life[32]. To a large degree, total aluminum, iron, and manganese concentrations could be explained by the respective metal concentrations in the surrounding waters. Arsenic and copper, however, most likely originated from the fish hold effluent. Concentrations of dissolved copper exceeded NRWQC standards in all effluents sampled, with PHQs well above 10 in four of the vessels sampled. Samples with concentrations of dissolved arsenic resulting in PHQs above 10 were limited to just two fishing vessels (a shrimper[33] and a ground fishing trawler) with a third vessel having a PHQ of approximately 2. Approximately 2/3 of the concentrations of dissolved zinc in fish hold effluent exceeded NRWQC benchmarks, but no concentrations of dissolved zinc exceeded a PHQ of 10, and most concentrations were below a PHQ of 3. Dissolved selenium was measured above reporting limits in only six discharges with PHQs>1 in all samples, and PHQs between 5 and 10 for two samples (including a shrimping vessel[33]). Total and dissolved metals concentrations were qualitatively similar in fish hold cleaning effluents, but, in general, concentrations in cleaning effluent were lower than in corresponding fish hold effluents.

Several classical pollutants found in fish hold and fish hold cleaning effluent may have the potential to pose risk. A classical pollutant found in fish hold and fish hold cleaning effluent

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[32] As discussed earlier in this chapter, total copper concentrations could pose potential risk to the aquatic environment because the human health criteria of 1,300 µg/L is significantly higher than the 3.1 µg/L benchmark used for dissolved copper based on the saltwater chronic ambient water quality criterion for the protection of aquatic life. When high levels of particulate copper are discharged, some of the particulate copper will likely convert to dissolved copper and be made bioavailable to aquatic life.

[33] See discussion in footnotes 29 and 30 and Section 3.2.4.1.

that poses one of the greatest potential risks to receiving waters is BOD, which was found at elevated concentrations in all sampled vessels and, in many instances, was higher than concentrations found in raw sewage (see Fig. 3.4.12). Concentrations of COD and TOC correlated with BOD concentrations and were similarly elevated in all fishing vessels. The high BOD in these samples likely contributed to the pervasively low dissolved oxygen levels in these samples. TSS and turbidity in fish hold and fish hold cleaning effluent are also equivalent to levels found in raw sewage, and concentrations of sulfide, particularly in samples from the New England ground fishery trawlers, exceeded the low PHQ screening benchmark (0.002 mg/L) for this classical pollutant.

The other pollutants of potential concern in fish hold and fish hold cleaning effluent were the nutrient and nutrient-related parameters, particularly NH3-N, TKN, and TP, all of which were measured at concentrations similar to comparable concentrations typically measured in strong (raw) sewage samples. Again, mean concentrations of BOD, COD, TOC, NH3-N, TKN, and TP were highest in shrimping and trawling vessels.

Aside from a select few samples, the high pathogen concentrations found in fish hold and fish hold cleaning samples likely did not stem from the effluent itself, but rather, from the excessively high concentrations measured in ambient background water contaminating the fish holds from the deck washdown process.

Table 3.4.11. Characterization of Fish Hold Effluent and Fish Hold Cleaning Effluent and Summary of Analytes that May Have the Potential to Pose Risk

Vessel Type (no. vessels)	**Analytes that May Have the Potential to Pose Risk in Fish Hold and Fish Hold Cleaning Effluent[1]**												
	Microbiologicals	**Volatile Organic Compounds**	**Semivolatile Organic Compounds**	**Metals (dissolved)**	**Metals (total)**	**Oil and Grease**	**Sulfide**	**Short-Chain Alkylphenol Ethoxylates and NP**	**Long-Chain Alkylphenol Ethoxylates**	**Nutrients**	**BOD, COD, and TOC**	**Total Suspended Solids**	**Other Physical/Chemical Parameters**
Fishing Vessels (31)	**enterococci,** **Fecal coliform**			As,**Cu**, Zn	Al**,As,** **(**Cu)^{2},Fe		**x**			**NH3-N** **TKN** **TP**	**BOD** **COD** TOC	**x**	**DO**, TRC, turbidity

(1) Analytes are generally **bolded** when a large proportion of the samples have concentrations exceeding the NRWQC (e.g., 25 to 50 percent), when several of the samples have PHQs > 10 (e.g., two or three of five), when a few samples result in PHQs greatly exceeding the screening benchmark (i.e., 100s to 1,000s), in the case of oil and grease and for nonylphenol, when one or more samples exceed an existing regulatory limit by more than a factor of 2, or when concentrations of analytes are sufficiently high that they may have the potential to pose risks to local water bodies. See text in Section 3.1.3 for a definition of PHQs and Table 3.1 for screening benchmarks used to calculate these values.

(2) Only a few PHQs near or slightly exceeding 1, but concentrations (in excess of 1,000 µg/L) potentially acutely toxic to aquatic life, particularly to organisms living in the benthos.

3.2.5 Graywater

EPA sampled graywater from eight vessels: five tugboats, a shrimper, a water taxi and a recreational powerboat. The samples included graywater from sinks, dishwashers, and showers, as well as graywater samples from several mixed or unspecified sources. Graywater samples were analyzed for a range of pollutants including pathogen indicators, classical pollutants, nonylphenols, metals, and nutrients. The analytical results were intended to provide representative graywater pollutant concentrations over the range of normal vessel operations.

Graywater volumes vary considerably depending on the class of vessel and its intended use, vessel size, the number of crew and passengers onboard, and the types of graywater-generating activities onboard (e.g., galleys, sinks, showers, wash machines). Based on observations made during the sampling program and from discussions with crew members, EPA estimated that tugboats, some of which provide living quarters for three to five crew members, generate approximately 130 gpd of graywater. Water taxis, which carry a significantly larger number of crew and passengers, but with fewer graywater-generating activities, generate approximately 75 gpd of graywater. Graywater generation on commercial fishing boats might range from a few gpd to hundreds of gpd, depending on the length of the trip and the size of the crew. Due to the highly variable graywater generation volumes possible within vessel classes, EPA was unable to further define graywater generation rates.

The Sink and Shower Facilities of a Tugboat

3.2.5.1 Pathogen Indicators (Microbiologicals)

Graywater is generated from personal bathing, food preparation, and dish and clothes washing, so EPA expected that this vessel discharge category could contain high levels of pathogens. The analytical data for the pathogen indicator bacteria *E. coli*, enterococci and fecal coliform confirm this expectation as the levels of pathogens measured in graywater were by far the highest values measured in any of the vessel discharges. However, it should also be noted that for each of the pathogen indicators, a wide range of values were measured in the graywater samples. EPA also noted that source water (generally municipal water transferred onto the vessel (service water)) does not appear to account for any of the pathogen concentrations.

The analytical results for pathogen indicators in the eight graywater samples are summarized in Table 3.5.1 and displayed in Figure 3.5.1. For each of these parameters, the highest levels (660,000 MPN/100 mL for *E. coli*, 240,000 MPN/100 mL for enterococci, and 570,000 CFU/100 mL for fecal coliform) were measured in the mixed graywater sample from a tugboat. For comparison, EPA measured average levels of 292,000 MPN/100 mL for *E. coli*, 8,920 MPN/100 mL for enterococci, and 36,000,000 CFU/100 mL for fecal coliform in untreated graywater, as reported in the 2008 Cruise Ship Discharge Assessment Report (USEPA, 2008). Typical fecal coliform concentrations in untreated domestic wastewater are 10,000 to 100,000 MPN/100 mL[34]. The second highest concentration, of *E. coli,* was measured in a mixed (dish/shower) graywater sample, while the second highest concentrations, for enterococci and fecal coliform, were measured in a dishwashing sample. Samples of graywater from sinks and showers tended to have lower levels of the pathogen indicators. Pathogen indicators were not detected in graywater samples from the sink of one vessel, a water taxi.

Figure 3.5.2 presents in box/scatter plots the PHQs for the three pathogen indicators in graywater. As this figure shows, the majority of the values measured for each of the pathogen indicators exceeded the water quality screening benchmarks, by up to four orders of magnitude (or more, in the case of fecal coliform).

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[34] Note, as indicated above in Table 3.1 and elsewhere, units of MPN/100 ml for fecal coliform approximate similar units of CFU/100 ml; therefore, the two units of expression are appropriate for comparison here.

Table 3.5.1. Results of Graywater Sample Analyses for Pathogen Indicators[1]

Analyte	Units[2]	No. samples	No. detected	Detected Proportion (%)	Average Conc.	Median Conc.	Minimum Conc.	10%	25%	75%	90%	Maximum Conc.	Screening BM[3]
E. Coli	MPN/100 ml	8	7	88	110000	16000			180	120000	660000	660000	130
Enterococci	MPN/100 ml	8	7	88	40000	500			70	57000	240000	240000	33
Fecal Coliform	CFU/100 ml	8	7	88	200000	270000			74	450000	570000	570000	14

Notes:

(1) Nondetect (censored) concentrations were replaced with ½ of the reporting limit for calculating average concentrations. The remaining statistics in this table were only calculated when analytes were detected at a sufficient frequency. For example, if an analyte was detected in fewer than 50% of samples, then a median concentration was not calculated. A blank cell reflects a situation when a median or percentile could not be computed based on detected concentrations. The percentiles are the concentrations of each analyte below which at least that percentage of the values fall. So the 10th percentile is the concentration below which at least 10% of the observations were found.

(2) MPN = Most Probable Number; CFU = Colony Forming Units.

(3) Screening BM represents the screening benchmark referred to in Section 3.1.3, and is the most stringent 2006 NRWQC or other conservative benchmark used to calculate PHQs.

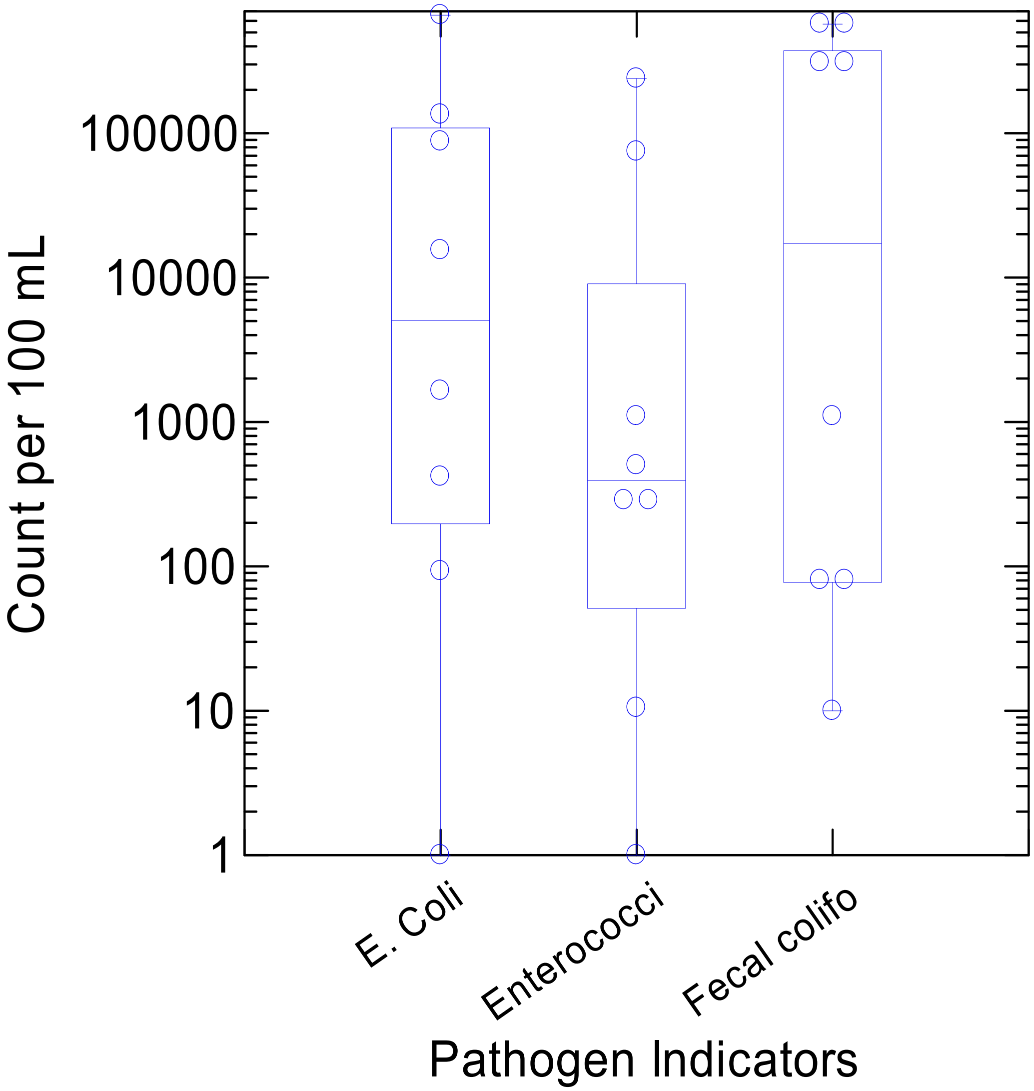

Figure 3.5.1. Box and Dot Density Plot of Pathogen Indicator Values Measured in Samples of Graywater

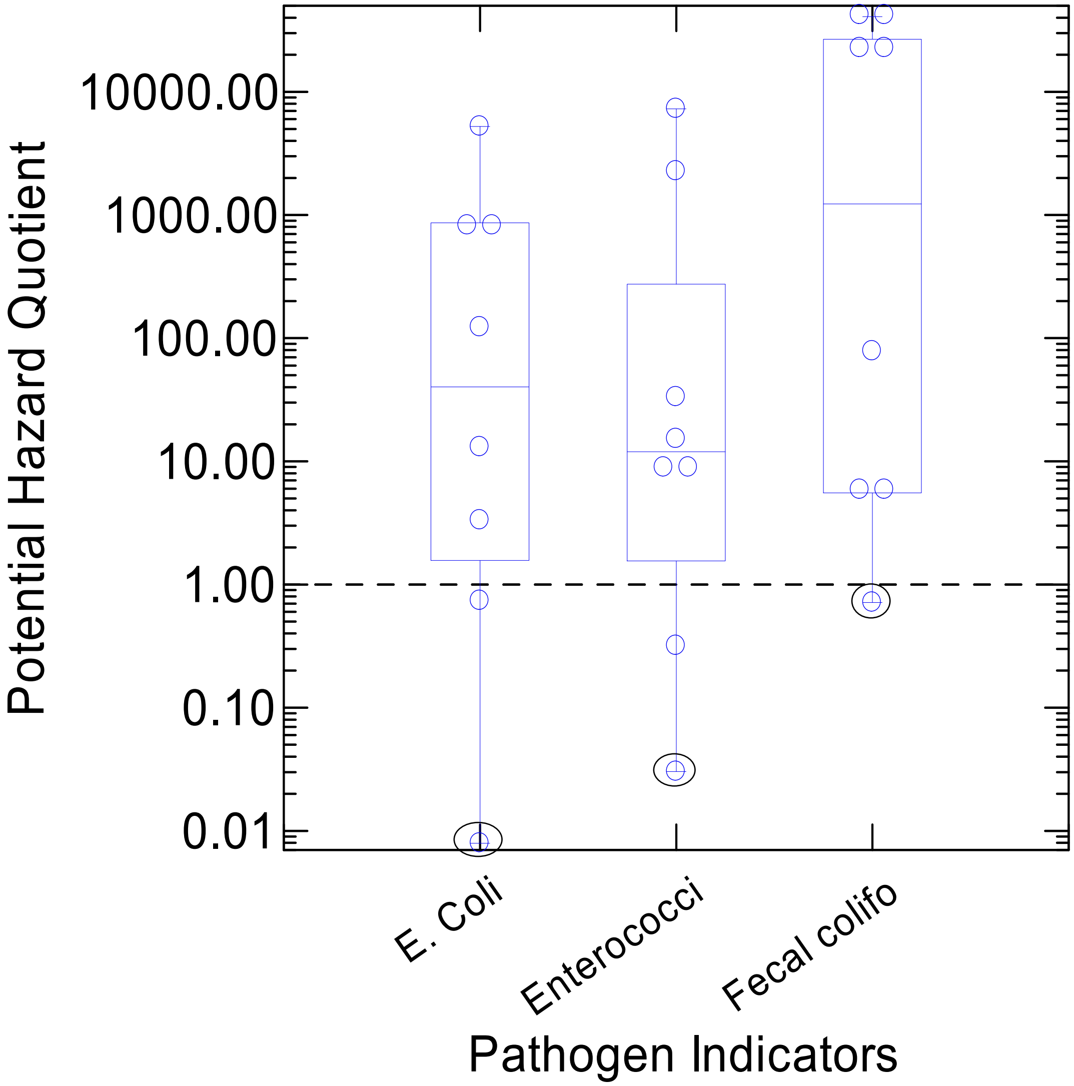

Figure 3.5.2. Box and Dot Density Plot of Potential Hazard Quotients for Pathogen Indicators Measured in Samples of Graywater
(Note: Replacement values for non-detects are circled).

3.2.5.2 Classical Pollutants

Graywater samples were analyzed for 14 classical pollutants (see Table 3.5.2). Figure 3.5.3 illustrates the variability of the concentrations/values measured for the classical pollutants in graywater. There was no one vessel or graywater source that tended to have the highest level of a majority of the classical pollutants, unlike the case for the pathogen indicators. The highest concentrations of oil and grease (100 mg/L HEM and 35.3 mg/L SGT-HEM) were measured in the sample of mixed dish/shower graywater on one tugboat; EPA speculates that the source of the oil and grease are primarily oils from cooking and other food sources discharged with the sink water. The highest levels of TSS (99 mg/L) and turbidity (128 NTU) were measured in the dishwashing graywater from a second tugboat. The highest sulfide concentration (1.45 mg/L) was measured in a shower graywater sample from a third tugboat. The highest measured concentrations of BOD (1200 mg/L), COD (4,040 mg/L), and TOC (440 mg/L) were measured in the sample of shower graywater from the recreational powerboat.

Many of the classical pollutants that were elevated in the graywater samples likely reflect the washing and bathing activities that generate graywater discharges. For example, sulfide[35] is a parameter that is commonly elevated in water distribution systems, especially on the hot water side. Sulfur-reducing bacteria, which use sulfur as an energy source, are the primary producers of large quantities of hydrogen sulfide. Sulfur-reducing bacteria can live in plumbing systems and hot water heaters. A second example is the high concentration of BOD measured in graywater samples (mentioned above), which reflects the BOD generated onboard the vessels sampled and not from the service water used by that vessel.

Figure 3.5.4 presents the PHQs for classical pollutants in graywater in box/scatter plots. As this figure shows, the PHQ threshold of 1 was exceeded for sulfide, TRC (detected in only one sample (0.11 mg/L) above the reporting limit of 0.0075 mg/L for a PHQ of 15), BOD, oil and grease (measured as HEM), and TSS. The highest PHQs were calculated for sulfide at 367 and BOD at 40. All of the graywater samples exceeded the 30 mg/L benchmark for BOD, and all five of the detected concentrations of sulfide exceeded the 0.002 mg/L benchmark.

The source of water used on the sampled vessels was, in all cases, potable freshwater bunkered in port (service water). Therefore, EPA did not consider it appropriate to compare the

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[35] Although sulfide (S^{2-}) is the analyte, hydrogen sulfide (H_2S) is the nonpriority pollutant for which a NRWQC has been established. Sulfides are commonly found as either hydrogen sulfide or hydrosulfide (HS^-). EPA conservatively assumes that all of the sulfide is in the form of hydrogen sulfide (H_2S) is the form that is toxic to fish. However, the proportion of each depends on the pH of the water. At pH 9 about 99 percent of the sulfide is in the form of HS^-; at pH 7 the sulfide is equally divided between HS^- and H_2S; and at pH 5 about 99 percent of the sulfide is present as H_2S. Unless heavily polluted, freshwater rivers typically tend to have a pH which ranges from about 4.5 to about 7, marine environments have an average pH of around 8.1 (seawater is more basic freshwater), while estuaries may have a pH between that of freshwater and seawater (approximately 5 to 8) dependent upon salinity and other factors. Hence, the use of sulfide (S^{2-}) as the analyte to detect for the presence of hydrogen sulfide (H_2S) is more conservative in marine and estuarine environments than in freshwater ones, but is a reasonable analyte to use due to variation found in different aquatic ecosystems.

concentrations of classical pollutants in graywater to ambient water body concentrations; rather, EPA compared the concentrations of classical pollutants to those found in the service water. None of the conventional parameters discussed here were consistently detected in service water.

Table 3.5.2. Results of Graywater Sample Analyses for Classical Pollutants[1]

Analyte	Units	No. samples	No. detected	Detected proportion (%)	Average Conc.	Median Conc.	Minimum Conc.	10%	25%	75%	90%	Maximum Conc.	Screening BM[2]
Biochemical Oxygen Demand (BOD)	mg/L	8	8	100	430	260	99	99	110	850	1200	1200	30
Chemical Oxygen Demand (COD)	mg/L	8	8	100	1000	440	180	180	270	1700	4000	4000	NA
Conductivity	mS/cm	7	7	100	0.43	0.41	0.22	0.22	0.30	0.50	0.79	0.79	NA
Dissolved Oxygen	mg/L	7	7	100	7.4	7.1	6.0	6.0	6.3	8.3	10	10	NA
Hexane Extractable Material (HEM)	mg/L	8	8	100	39	29	9.4	9.4	14	68	100	100	15
pH	SU	8	8	100	7.4	7.2	6.1	6.1	6.7	8.5	8.7	8.7	NA
Salinity	ppt	6	6	100	0.25	0.20	0.10	0.10	0.18	0.40	0.40	0.40	NA
Silica Gel Treated HEM (SGT-HEM)	mg/L	8	6	75	8.1	1.5			0.33	9.4	35	35	15
Sulfide	mg/L	8	5	63	0.11	0.017			0.0	0.035	0.73	0.73	0.0020
Temperature	C	8	8	100	27	27	21	21	24	29	36	36	NA
Total Organic Carbon (TOC)	mg/L	7	7	100	140	83	27	27	66	160	440	440	NA
Total Residual Chlorine	mg/L	8	6	75	0.12	0.020					0.11	0.11	0.0075
Total Suspended Solids (TSS)	mg/L	8	8	100	52	58	14	14	37	69	81	81	30
Turbidity	NTU	8	8	100	74	89	40	40	45	110	110	110	NA

Notes:

(1) Nondetect (censored) concentrations were replaced with ½ of the reporting limit for calculating average concentrations. The remaining statistics in this table were only calculated when analytes were detected at a sufficient frequency. For example, if an analyte was detected in fewer than 50% of samples, then a median concentration was not calculated. A blank cell reflects a situation when a median or percentile could not be computed based on detected concentrations. The percentiles are the concentrations of each analyte below which at least that percentage of the values fall. So the 10th percentile is the concentration below which at least 10% of the observations were found.

(2) Screening BM represents the screening benchmark referred to in Section 3.1.3, and is the most stringent 2006 NRWQC or other conservative benchmark used to calculate PHQs.

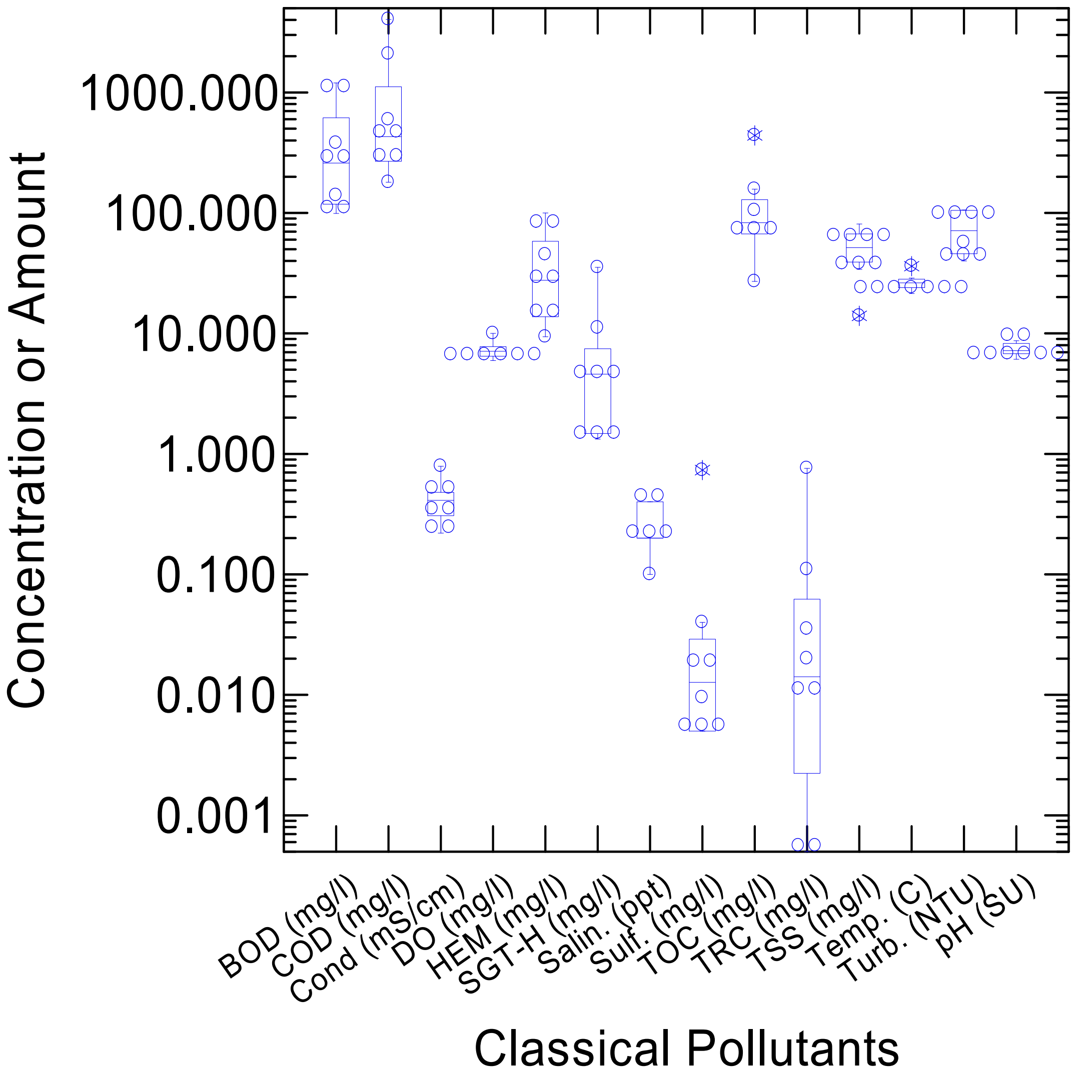

Figure 3.5.3. Box and Dot Density Plot of Classical Pollutant Concentrations/Values Measured in Samples of Graywater

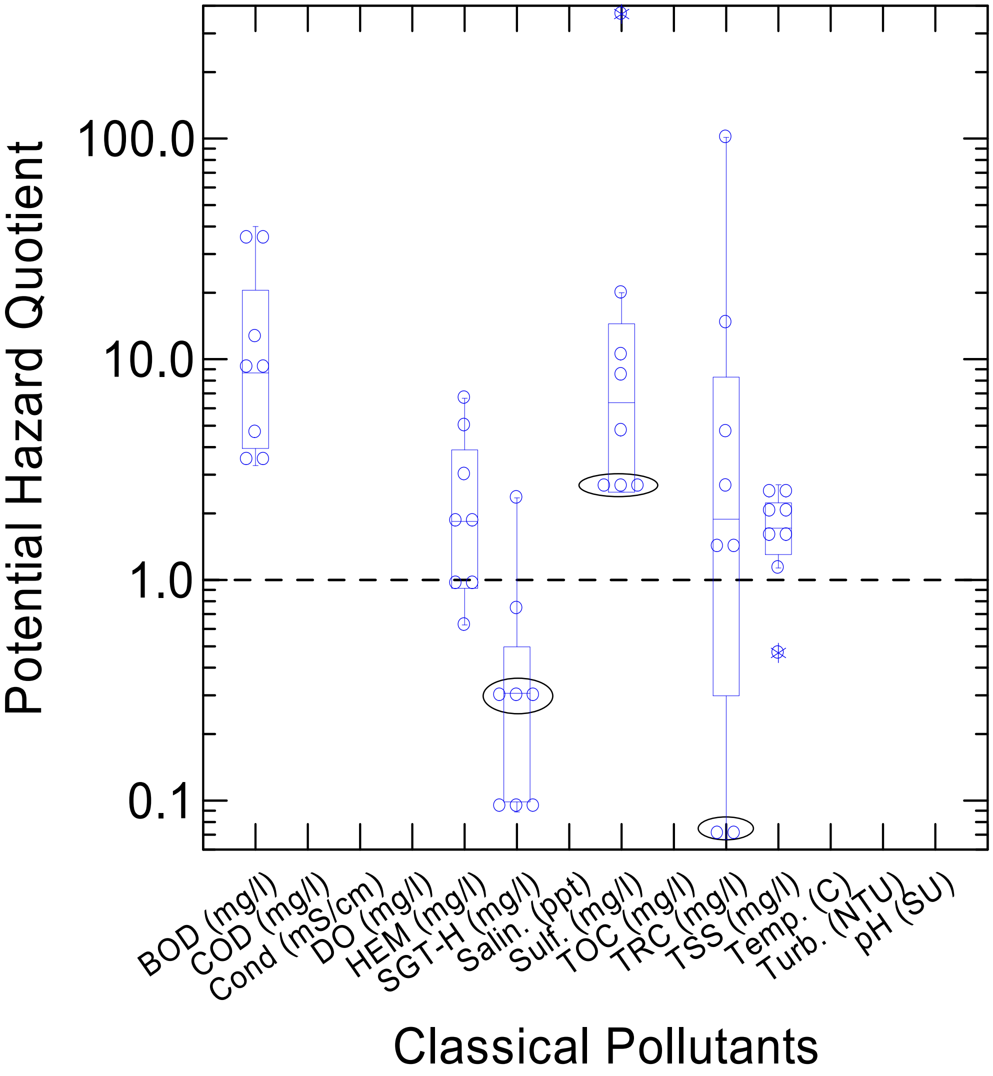

Figure 3.5.4. Box and Dot Density Plot of Potential Hazard Quotients for Classical Pollutants in Samples of Graywater
(Note: Replacement values for non-detects are circled).

3.2.5.3 Nonylphenols

Long- and short-chain nonylphenol and octylphenol ethoxylates and NP were expected in graywater discharges given their use in soaps for hand and body washing and in liquid detergents for dish washing. EPA anticipated that the long-chain alkylphenol ethoxylates would be present in all graywater samples where detergents were used for cleaning, while the short-chain ethoxylates (and possibly NP) would be present if detergents were used for cleaning and there was a graywater holding tank that provided the additional residence time necessary for biological activity to degrade the NPEOs and OPEOs.

Graywater samples were analyzed for 34 long- and short-chain nonylphenol and octylphenol ethoxylates, including 28 NPEOs and OPEOs, bisphenol A, and total nonylphenol (NP). Of these parameters, 25 were detected in one or more samples (see Table 3.5.3). Average concentrations for NP18EO-NP3EO and OP12EO-OP6EO ranged from approximately 0.1 to 10 µg/L. The average concentrations of total nonylphenol polyethoxylates (sum of NPEO isomers) and total octylphenol polyethoxylates (sum of OPEO isomers) were 66 and 63 µg/L, respectively. All of the NPEOs were detected in the graywater sample from the sink of one of the tugboats and the graywater sampled from the shower on the recreational powerboat. All of the OPEOs were detected in the graywater sampled from the shower on the recreational powerboat. NPEOs and OPEOs were also occasionally detected in graywater samples from three of the other vessels.

EPA did not calculate any PHQs for the nonylphenol parameters measured in graywater. The only screening benchmark available was the saltwater chronic NRWQC for NP (1.7 µg/L). There were no analytical results for NP to compare to this screening benchmark, and no NRWQC exist for the other nonylphenol parameters (individual or total long- and short-chain NPEOs and OPEOs). None of the long- or short-chain nonylphenol or octylphenol ethoxylates or NP were detected in the ambient water surrounding these vessels.

Table 3.5.3. Results of Graywater Sample Analyses for Nonylphenols (only long-chain NPEOs and OPEOs were detected) [1]

Analyte	Units	No. samples	No. detected	Detected Proportion (%)	Average Conc.	Median Conc.	Minimum Conc.	10%	25%	75%	90%	Maximum Conc.	Screening BM[2]
Total Nonylphenol Polyethoxylates	µg/L	8	2	25	66					15	53	53	NA
Nonylphenol octodecaethoxylate (NP18EO)	µg/L	8	2	25	0.084					0.023	0.041	0.041	NA
Nonylphenol heptadecaethoxylate (NP17EO)	µg/L	8	3	38	0.31					0.12	1.0	1.0	NA
Nonylphenol hexadecaethoxylate (NP16EO)	µg/L	8	3	38	0.59					0.23	1.6	1.6	NA
Nonylphenol pendecaethoxylate (NP15EO)	µg/L	8	3	38	1.1					0.49	2.4	2.4	NA
Nonylphenol tetradecaethoxylate (NP14EO)	µg/L	8	3	38	2.2					0.95	5.8	5.8	NA
Nonylphenol tridecaethoxylate (NP13EO)	µg/L	8	3	38	3.5					1.9	9.3	9.3	NA
Nonylphenol dodecaethoxylate (NP12EO)	µg/L	8	3	38	5.4					3.2	14	14	NA
Nonylphenol undecaethoxylate (NP11EO)	µg/L	8	3	38	7.0					4.7	16	16	NA
Nonylphenol decaethoxylate (NP10EO)	µg/L	8	2	25	6.7					2.0	6.9	6.9	NA
Nonylphenol nonaethoxylate (NP9EO)	µg/L	8	2	25	7.3					2.5	7.3	7.3	NA
Nonylphenol octaethoxylate (NP8EO)	µg/L	8	2	25	7.9					1.5	7.6	7.6	NA
Nonylphenol heptaethoxylate (NP7EO)	µg/L	8	1	13	7.8						6.5	6.5	NA
Nonylphenol hexaethoxylate (NP6EO)	µg/L	8	1	13	7.3						5.5	5.5	NA
Nonylphenol pentaethoxylate (NP5EO)	µg/L	8	2	25	5.8					1.6	3.7	3.7	NA
Nonylphenol tetraethoxylate (NP4EO)	µg/L	8	2	25	4.7					1.1	2.7	2.7	NA
Nonylphenol triethoxylate (NP3EO)	µg/L	8	1	13	2.8						0.99	0.99	NA
Total Octylphenol Polyethoxylates	µg/L	8	1	13	63						37	37	NA
Octylphenol dodecaethoxylate (OP12EO)	µg/L	8	4	50	1.5	0.22				3.3	3.5	3.5	NA
Octylphenol undecaethoxylate (OP11EO)	µg/L	8	2	25	2.0					3.1	5.2	5.2	NA
Octylphenol decaethoxylate (OP10EO)	µg/L	8	2	25	3.5					4.1	7.2	7.2	NA
Octylphenol nonaethoxylate (OP9EO)	µg/L	8	1	13	3.3						7.8	7.8	NA
Octylphenol octaethoxylate (OP8EO)	µg/L	8	1	13	7.6						7.3	7.3	NA
Octylphenol heptaethoxylate (OP7EO)	µg/L	8	1	13	10						6.3	6.3	NA
Octylphenol hexaethoxylate (OP6EO)	µg/L	8	1	13	10						4.1	4.1	NA

Notes:
(1) Nondetect (censored) concentrations were replaced with ½ of the reporting limit for calculating average concentrations. The remaining statistics in this table were only calculated when analytes were detected at a sufficient frequency. For example, if an analyte was detected in fewer than 50% of samples, then a median concentration was not calculated. A blank cell reflects a situation when a median or percentile could not be computed based on detected concentrations. The percentiles are the concentrations of each analyte below which at least that percentage of the values fall. So the 10th percentile is the concentration below which at least 10% of the observations were found.
(2) Screening BM represents the screening benchmark referred to in Section 3.1.3, and is the most stringent 2006 NRWQC or other conservative benchmark used to calculate PHQs.

3.2.5.4 Metals

Graywater samples were analyzed for dissolved (filtered) and total concentrations of metals. The analytical results are summarized in Table 3.5.4 for the dissolved metals and Table 3.5.5 for the total metals that were detected in at least one graywater sample. The following metals were detected in all of the graywater samples:

- Dissolved and total aluminum
- Total barium
- Dissolved and total calcium
- Dissolved and total copper
- Dissolved and total manganese
- Dissolved and total potassium
- Dissolved and total sodium
- Dissolved and total zinc.

Concentrations of other metals were measured in 50 percent or more of the graywater samples:

- Dissolved barium
- Total chromium
- Total iron
- Total lead
- Dissolved and total magnesium
- Dissolved and total nickel
- Dissolved and total selenium
- Total vanadium.

Figures 3.5.5 and 3.5.6 present the ranges of concentrations measured for dissolved and total metals in the graywater samples. The plots show that dissolved and total metals concentrations range over five orders of magnitude. Calcium, magnesium, potassium and sodium, which are the major cations present in seawater, were the dissolved metals measured at the highest concentrations. Dissolved aluminum, copper, and zinc were also measured at relatively high concentrations (greater than 100 µg/L) in most graywater samples. For these dissolved metals, service water samples contained up to 80 percent of the graywater concentration for aluminum, up to 100 percent for copper, and up to 170 percent for zinc. Although the comparison of service water and graywater concentrations suggests that service water might be the source of these metals in some of the graywater samples, this was not always the case. In fact, service water concentrations tended to be low in the samples that corresponded to the highest metals concentrations in graywater.

Total concentrations for each metal were generally similar to or somewhat higher than the dissolved concentrations. Aside from the major seawater cations, concentrations of total metals in the graywater samples were highest for aluminum (912 µg/L), copper (440 µg/L), iron (458 µg/L), and zinc (3,470 µg/L). For these total metals, EPA found that service water samples contained up to 74 percent of the graywater concentration for aluminum, up to 115 percent for copper, up to 175 percent for iron, and up to 32 percent for zinc. As was the case for dissolved metals, comparing the service water and graywater concentrations suggests that service water might be the source of these total metals in some, but not all, of the graywater samples.

To quantify the relationship between dissolved and total metals concentrations, EPA calculated the average dissolved fraction (f_d) of each metal in the graywater samples. The metals in graywater discharges with the highest average dissolved fractions (f_d > 90 percent) included arsenic, calcium, magnesium, nickel, potassium, and sodium. For all of the other metals where dissolved fractions could be calculated (aluminum, barium, chromium, copper, iron, lead, manganese, selenium, vanadium, and zinc), the average values were in the intermediate (90 percent > f_d > 50 percent) range.

The plots in Figures 3.5.7 and 3.5.8 display the distribution of PHQs based on the screening benchmark for each of the dissolved and total metals. For dissolved metals, copper and zinc concentrations consistently exceed the screening benchmarks; the maximum PHQs for copper and zinc were 90 and 18.5, respectively. For total metals, the measured concentrations of aluminum consistently exceeded the screening benchmarks. PHQs for total aluminum varied from 0.6 to 10.5. The PHQs based on measured concentrations of total arsenic were 160 and 110 (arsenic was detected in only two of eight graywater samples, one of which may have an elevated measured concentration due to positive interference(see discussion on page 74 for more information); these high values reflect the very low NRWQC (0.018 µg/L; human health for the consumption of water + organism) for this carcinogen.

Table 3.5.4. Results of Graywater Sample Analyses for Dissolved Metals[1]

Analyte	Units	No. samples	No. detected	Detected Proportion (%)	Average Conc.	Median Conc.	Minimum Conc.	10%	25%	75%	90%	Maximum Conc.	Screening BM[2]
Heavy and Other Metals													
Aluminum	µg/L	7	7	100	190	160	24	24	86	300	460	460	NA
Arsenic	µg/L	8	2	25	1.9					1.1	4.5	4.5	36
Barium	µg/L	3	2	67	26	27				45	45	45	NA
Chromium	µg/L	8	2	25	1.4					1.4	2.2	2.2	11
Copper	µg/L	8	8	100	55	17	5.3	5.3	7.6	60	280	280	3.1
Iron	µg/L	3	1	33	83					150	150	150	NA
Lead	µg/L	8	4	50	2.5	1.1				4.2	6.0	6.0	2.5
Manganese	µg/L	8	8	100	17	8.8	4.7	4.7	6.4	35	42	42	NA
Nickel	µg/L	8	4	50	5.5	2.1				70	9.8	9.8	8.2
Selenium	µg/L	8	1	13	3.5						1.4	1.4	5.0
Thallium	µg/L	3	1	33	0.80					1.4	1.4	1.4	NA
Vanadium	µg/L	3	1	33	0.73					1.2	1.2	1.2	NA
Zinc	µg/L	8	8	100	400	240	70	70	80	610	1500	1500	81
Cationic Metals													
Calcium	µg/L	8	8	100	34000	33000	1800	1800	25000	36000	81000	81000	NA
Magnesium	µg/L	8	7	88	9400	11000			6600	13000	18000	18000	NA
Potassium	µg/L	3	3	100	5500	5700	4100	4100	4100	6700	6700	6700	NA
Sodium	µg/L	3	3	100	79000	48000	31000	31000	31000	160000	160000	160000	NA

Notes:

(1) Nondetect (censored) concentrations were replaced with ½ of the reporting limit for calculating average concentrations. The remaining statistics in this table were only calculated when analytes were detected at a sufficient frequency. For example, if an analyte was detected in fewer than 50% of samples, then a median concentration was not calculated. A blank cell reflects a situation when a median or percentile could not be computed based on detected concentrations. The percentiles are the concentrations of each analyte below which at least that percentage of the values fall. So the 10th percentile is the concentration below which at least 10% of the observations were found.

(2) Screening BM represents the screening benchmark referred to in Section 3.1.3, and is the most stringent 2006 NRWQC or other conservative benchmark used to calculate PHQs.

Table 3.5.5. Results of Graywater Sample Analyses for Total Metals[1]

Analyte	Units	No. samples	No. detected	Detected Proportion (%)	Average Conc.	Median Conc.	Minimum Conc.	10%	25%	75%	90%	Maximum Conc.	Screening BM[2]
Heavy and Other Metals													
Aluminum	µg/L	8	8	100	380	420	50	50	190	540	910	910	87
Arsenic	µg/L	8	2	25	2.0					1.5	2.9[3]	2.9	0.018
Barium	µg/L	3	3	100	29	28	7.4	7.4	7.4	51	51	51	1000
Cadmium	µg/L	8	1	13	0.82						2.0	2.0	NA
Chromium	µg/L	8	4	50	2.5	2.2				4.2	4.9	4.9	NA
Copper	µg/L	8	8	100	100	71	10	10	14	140	440	440	1300
Iron	µg/L	3	2	67	220	150				460	460	460	300
Lead	µg/L	8	5	63	7.6	1.7				5.8	43	43	NA
Manganese	µg/L	8	8	100	22	13	7.3	7.3	8.9	41	51	51	100
Nickel	µg/L	8	4	50	5.9	2.6				8.6	10	10	610
Selenium	µg/L	8	1	13	3.8						1.7	1.7	170
Vanadium	µg/L	3	2	67	1.7	1.9				2.6	2.6	2.6	NA
Zinc	µg/L	8	8	100	890	270	54	54	130	2000	3500	3500	7400
Cationic Metals													
Calcium	µg/L	8	8	100	35000	36000	1900	1900	26000	37000	82000	82000	NA
Magnesium	µg/L	8	7	88	9700	11000			6500	13000	18000	18000	NA
Potassium	µg/L	3	3	100	5500	6400	3400	3400	340	6600	6600	6600	NA
Sodium	µg/L	3	3	100	81000	47000	36000	36000	36000	160000	160000	160000	NA

Notes:

(1) Nondetect (censored) concentrations were replaced with ½ of the reporting limit for calculating average concentrations. The remaining statistics in this table were only calculated when analytes were detected at a sufficient frequency. For example, if an analyte was detected in fewer than 50% of samples, then a median concentration was not calculated. A blank cell reflects a situation when a median or percentile could not be computed based on detected concentrations. The percentiles are the concentrations of each analyte below which at least that percentage of the values fall. So the 10th percentile is the concentration below which at least 10% of the observations were found.

(2) Screening BM represents the screening benchmark referred to in Section 3.1.3, and is the most stringent 2006 NRWQC or other conservative benchmark used to calculate PHQs.

(3) EPA suspects that this measured concentration may be elevated due to positive interference, see Section 3.1.3.

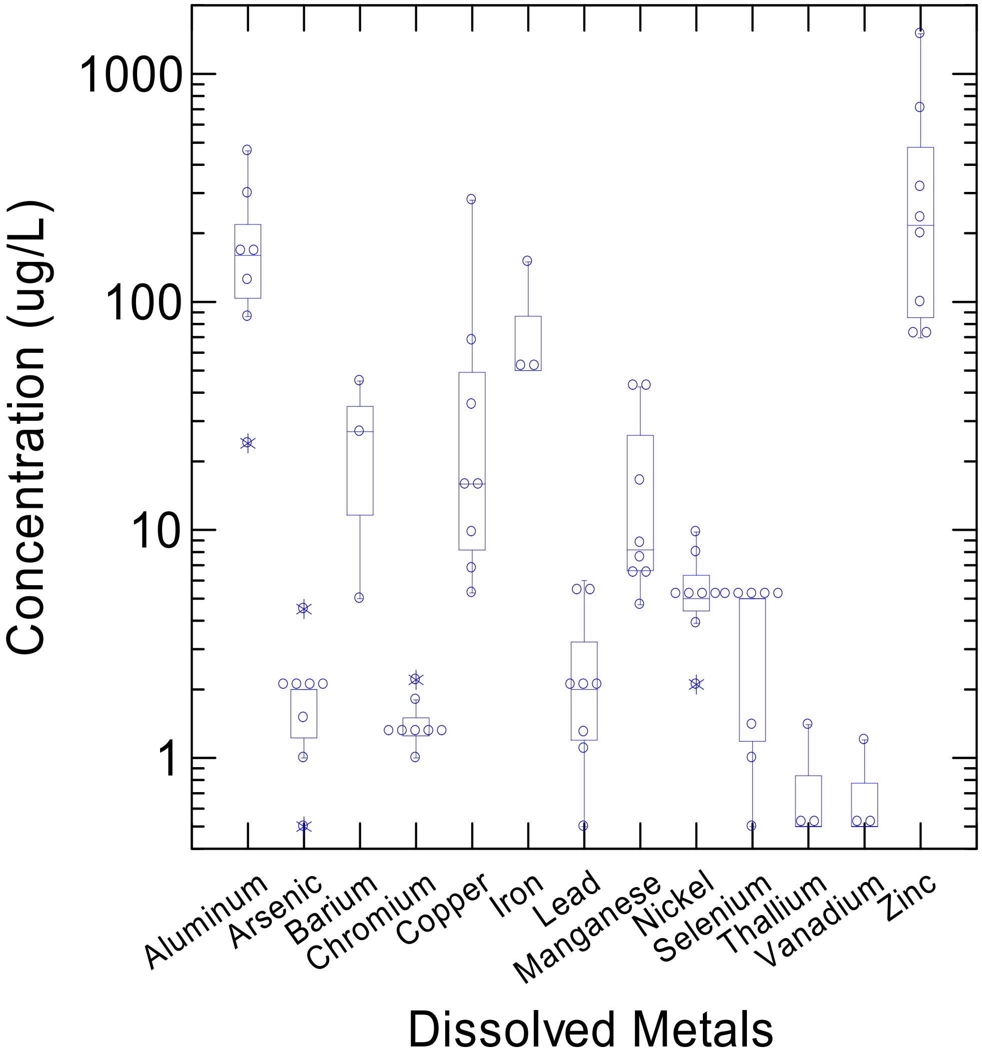

Figure 3.5.5. Box and Dot Density Plot of Dissolved Metals Concentrations Measured in Samples of Graywater

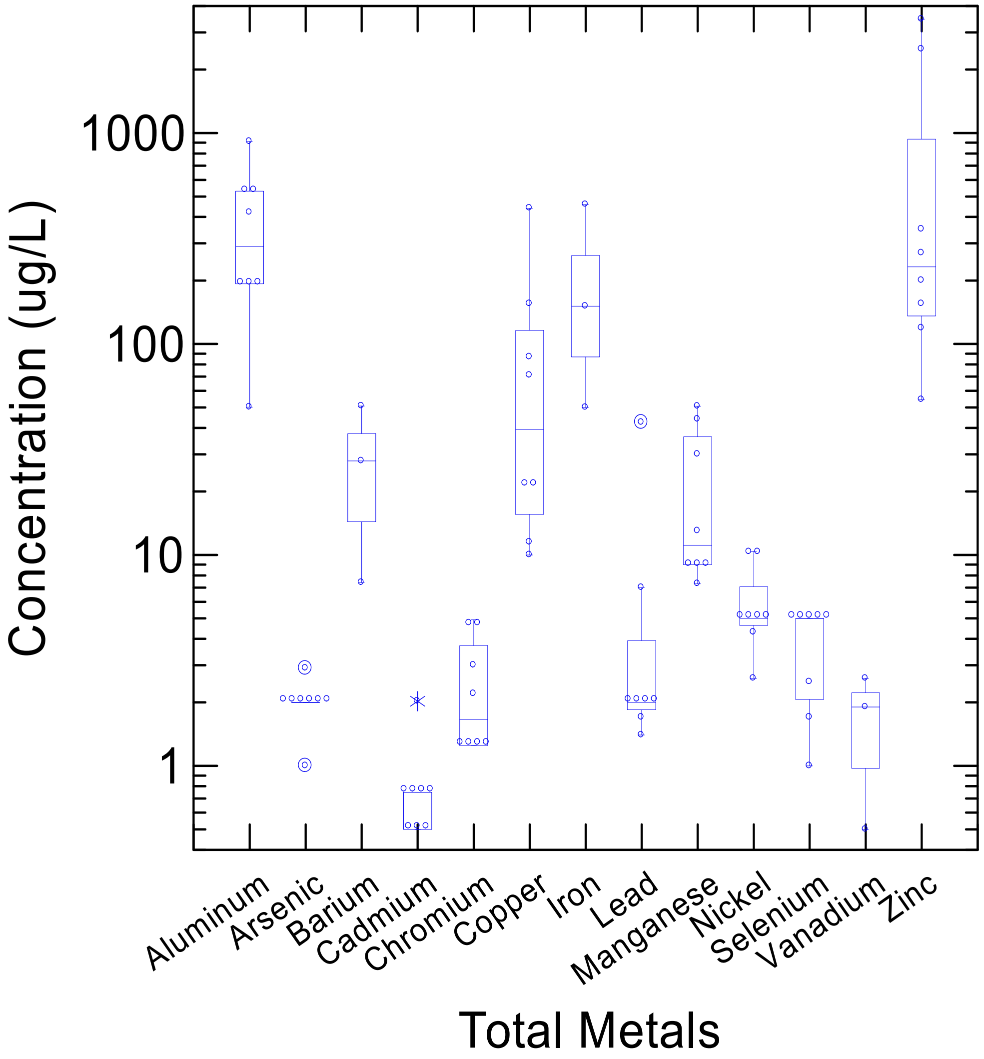

Figure 3.5.6. Box and Dot Density Plot of Total Metals Concentrations Measured in Samples of Graywater

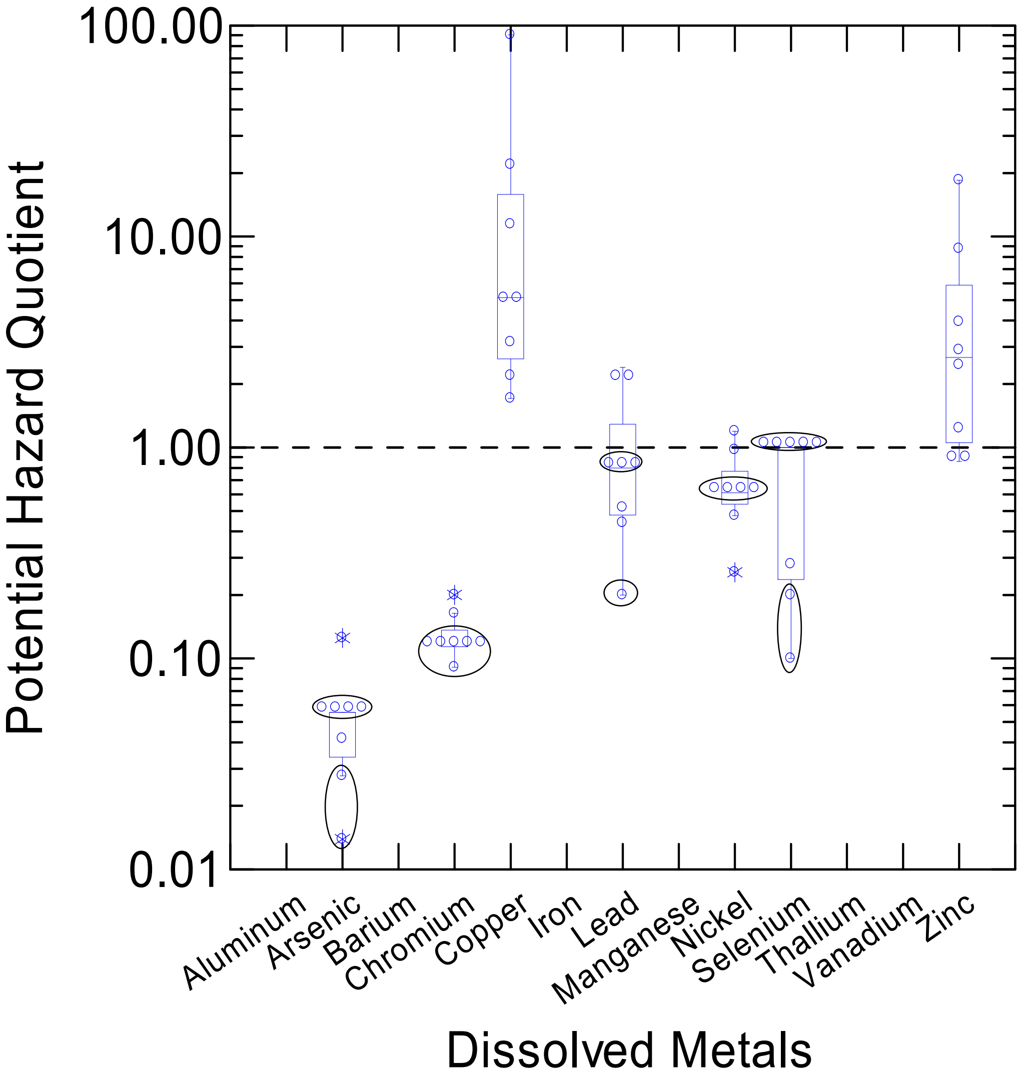

Figure 3.5.7. Box and Dot Density Plot of Potential Hazard Quotients for Dissolved Metals in Samples of Graywater

(Note: Replacement values for non-detects are circled).

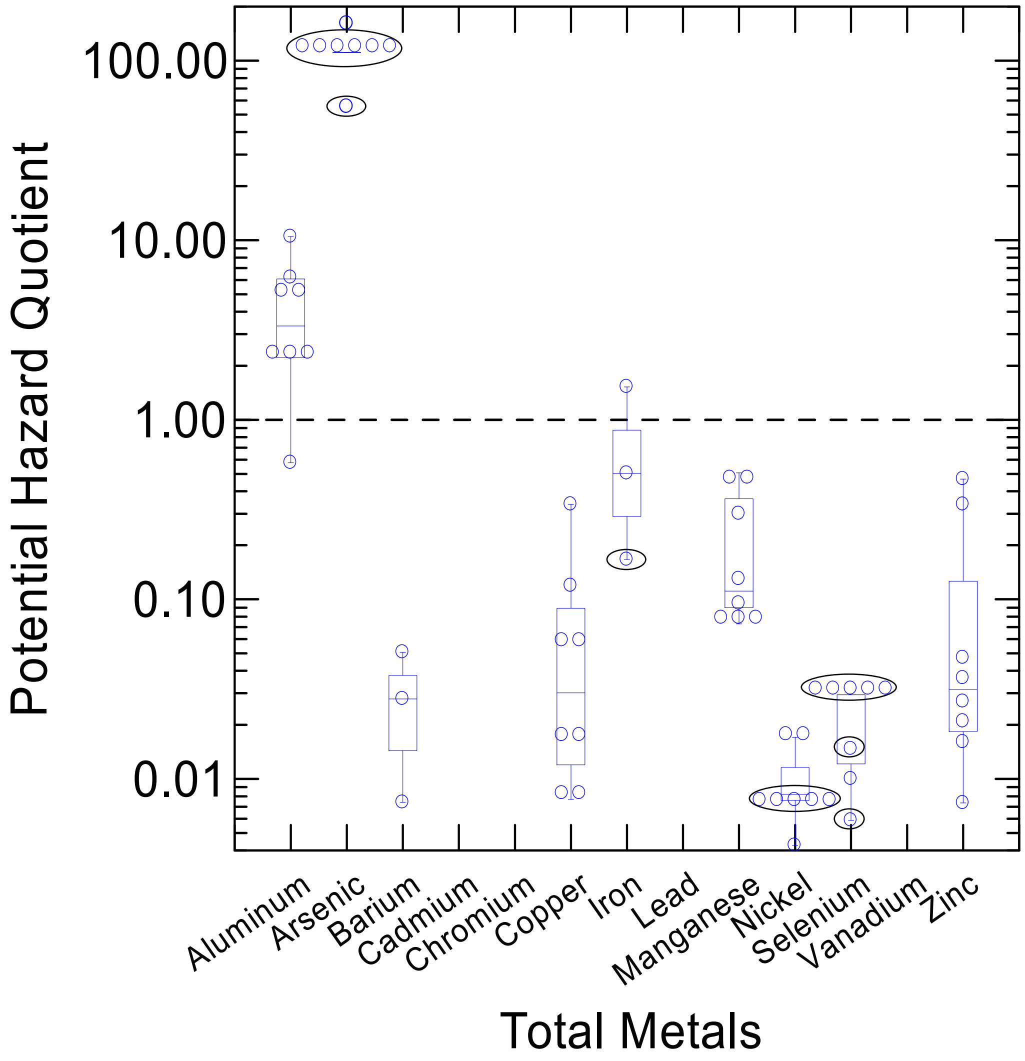

Figure 3.5.8. Box and Dot Density Plot of Potential Hazard Quotients for Total Metals in Samples of Graywater
(Note: Replacement values for non-detects are circled).

3.2.5.5 Nutrients

Graywater samples were analyzed for four nutrient and nutrient-related parameters: ammonia nitrogen, nitrate/nitrite, TKN, and total phosphorus (see Table 3.5.6). The nutrient concentrations measured in graywater samples are displayed in Figure 3.5.9. The highest nutrient concentrations measured in graywater were: 4.5 mg/L (ammonia nitrogen), 2.4 mg/L (nitrate/nitrite), 45 mg/L (TKN), and 3.4 mg/L (total phosphorus); all of these values were measured in a single sample of shower graywater from a tugboat. A likely source of the phosphorus in graywater could be phosphate detergents, although both phosphorus and nitrogen parameters also reflect food and possibly other wastes. Of these maximum nutrient concentrations, only TKN was high enough to fall within the range of concentrations typical of untreated domestic wastewater (20 to 85 mg/L; Metcalf and Eddy, 1979). Although each of these nutrients was occasionally detected in service water, only nitrate/nitrite was present in service water at concentrations high enough to be comparable with those in graywater.

Figure 3.5.10 presents the PHQs calculated for the nutrients. As shown in this figure, total phosphorus PHQs ranged from 4.2 to 34 because concentrations in graywater consistently exceeded the screening benchmark. Graywater samples from three tugboats also had PHQs of greater than 1 because the concentrations for ammonia nitrogen exceeded the screening benchmark.

Table 3.5.6. Results of Graywater Sample Analyses for Nutrients[1]

Analyte	Units	No. samples	No. detected	Detected Proportion (%)	Average Conc.	Median Conc.	Minimum Conc.	10%	25%	75%	90%	Maximum Conc.	Screening BM[2]
Ammonia As Nitrogen (NH3-N)	mg/L	8	8	100	1.3	0.75	0.19	0.19	0.22	1.8	4.5	4.5	1.2
Nitrate/Nitrite (NO3/NO2-N)	mg/L	8	7	88	1.6	1.9			0.90	2.3	2.4	2.4	NA
Total Kjeldahl Nitrogen (TKN)	mg/L	8	8	100	10	6.7	2.2	2.2	3.8	7.7	45	45	NA
Total Phosphorus	mg/L	8	8	100	1.4	1.2	0.42	0.42	0.62	2.2	3.4	3.4	0.10

Notes:

(1) Nondetect (censored) concentrations were replaced with ½ of the reporting limit for calculating average concentrations. The remaining statistics in this table were only calculated when analytes were detected at a sufficient frequency. For example, if an analyte was detected in fewer than 50% of samples, then a median concentration was not calculated. A blank cell reflects a situation when a median or percentile could not be computed based on detected concentrations. The percentiles are the concentrations of each analyte below which at least that percentage of the values fall. So the 10th percentile is the concentration below which at least 10% of the observations were found.

(2) Screening BM represents the screening benchmark referred to in Section 3.1.3, and is the most stringent 2006 NRWQC or other conservative benchmark used to calculate PHQs.

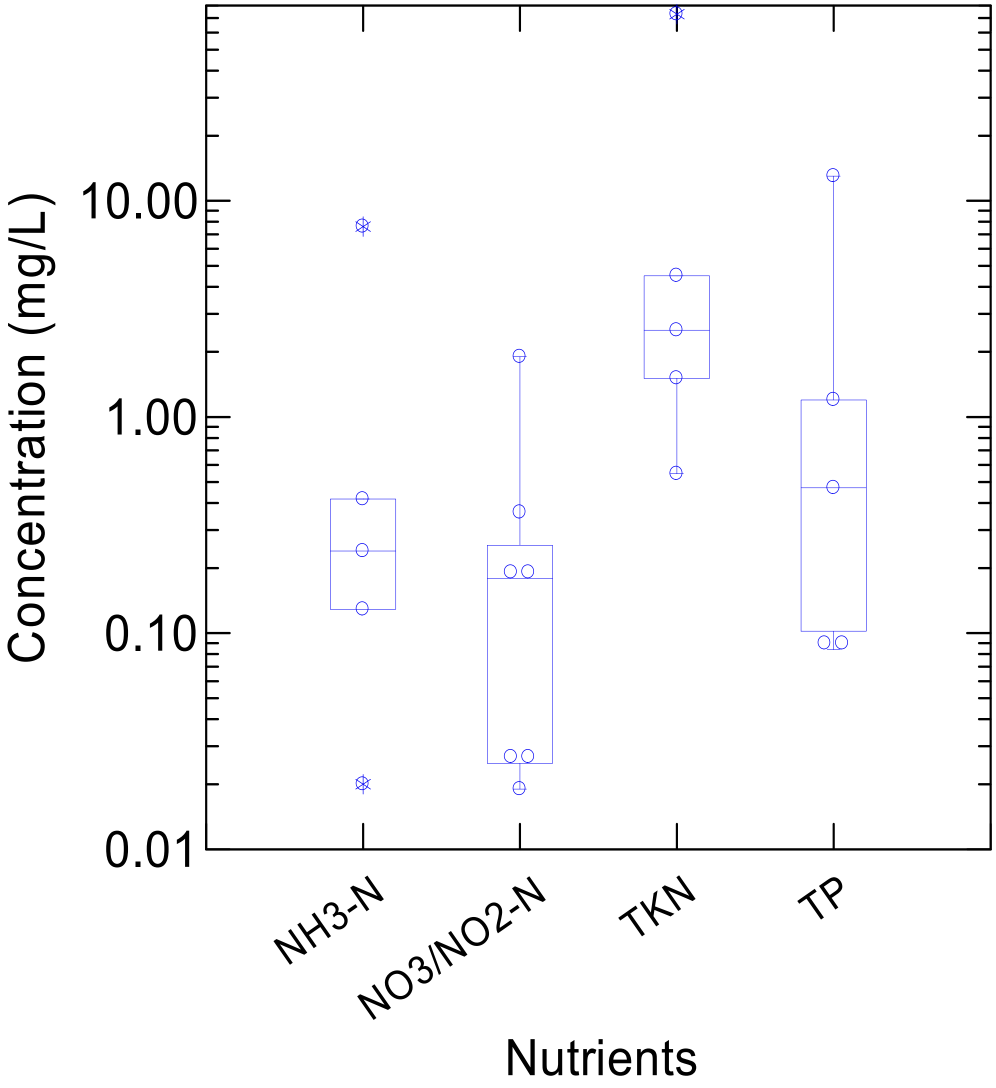

Figure 3.5.9. Box and Dot Density Plot of Nutrient Concentrations Measured in Samples of Graywater

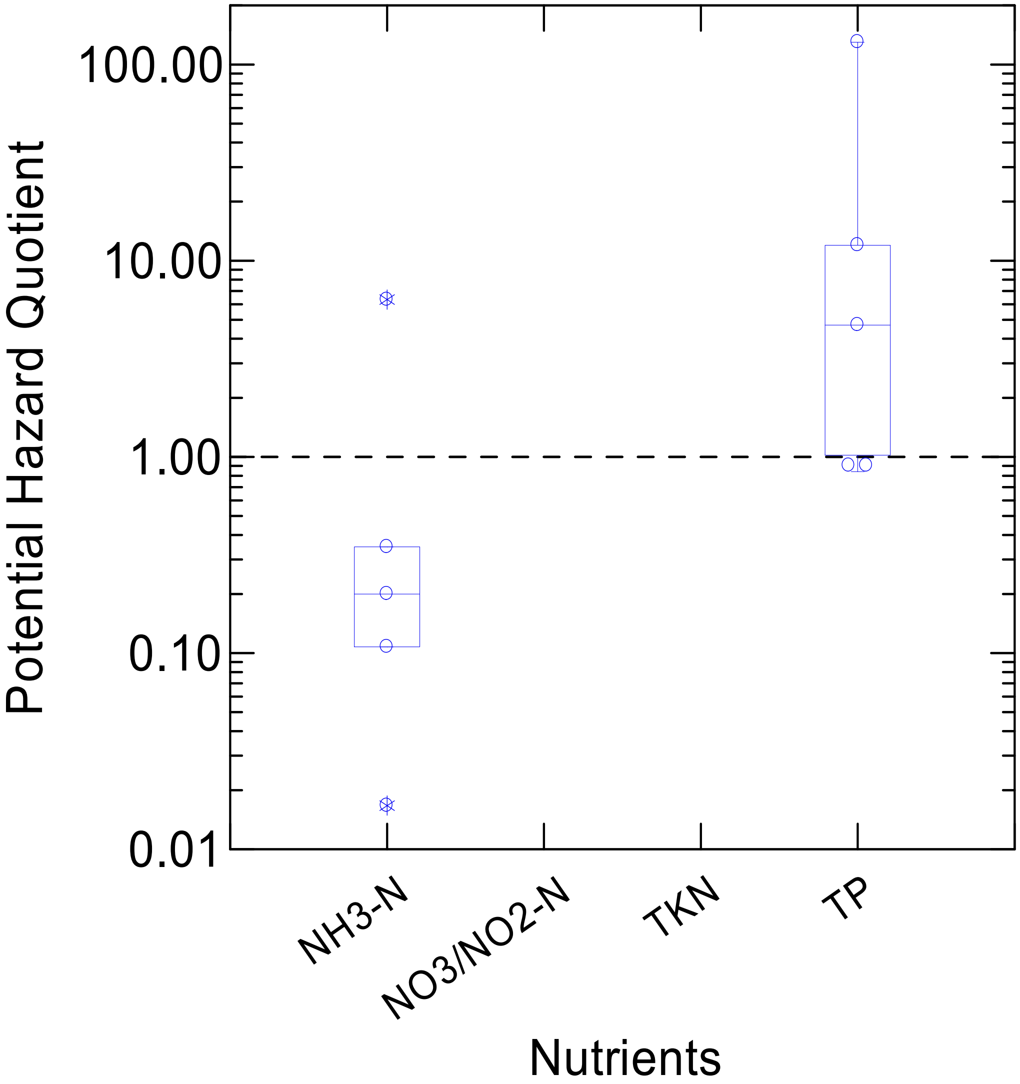

Figure 3.5.10. Box and Dot Density Plot of Potential Hazard Quotients for Nutrients in Samples of Graywater

3.2.5.6 Summary of the Characterization of Graywater Effluent Analyses

Table 3.5.7 summarizes the specific analytes in graywater effluent that may have the potential to pose risk to human health or the environment. EPA's interpretation of the realized risk that may be posed by these analytes, relative to pollutant loadings, background ambient and source water contaminant levels and characteristics, and other relevant information useful for this assessment, is presented in Chapter 5.

Pathogens were found at higher concentrations in graywater effluent than in any other type of pollutant. The highest concentrations of all three pathogen groups (fecal coliforms, enterococci*,* and *E. coli*) were found in the effluent of one of the five tugboats sampled, but were found at high concentrations in all five sampled tugboats. For all eight vessels sampled, the majority of PHQs for all three pathogen groups were greater than 1 (PHQs for all fecal coliform samples were greater than 10), and, in many cases, were between 100 and 10,000. The fecal coliform concentrations most often exceeded the water quality benchmarks, followed by *E. coli* and enterococci concentrations, in that order. Pathogens were not detected in the one water taxi.

BOD was the pollutant with the next highest concentrations that exceeded water quality benchmarks, with PHQs>1 in all eight vessels and PHQ values exceeding 9 for five of the vessels. The highest BOD concentrations were found from the recreational powerboat (PHQ = 40). Concentrations of COD and TOC were positively correlated to BOD concentrations and were found at high levels in all eight vessels. Sulfide was detected in five of the eight vessels and exceeded benchmark concentrations in all five instances (PHQs of up to 367). Sulfides were detected in graywater from all vessels sampled, and elevated in the five tugboat discharges, with PHQs ranging from 5-367. TSS and oil and grease (measured as HEM) concentrations were also slightly elevated, particularly in tugboats. The highest HEM concentration (100 mg/L) was observed in the graywater discharge from a tugboat. SGT-HEM was detected in six of eight vessels, but only one sample had a PHQ greater than 2.

Total nonylphenol polyethoxylates (sum of isomers from NP3EO to NP18EO) were notable only in one tugboat and the recreational boat. Total NPEOs was highest in the graywater sample collected from the recreational powerboat. No short-chain alkylphenol ethoxylates (NP1EO,NP2EO or OP1EO or OP2EO) or bisphenol A were detected in any of the graywater samples. Likewise, no NP was detected, so no comparisons could be made to the screening benchmark.

Among the nutrients sampled, total phosphorus concentrations exceeded the benchmark of 0.10 mg/L in all vessels sampled, with PHQs ranging from 4.2 to 34.

Concentrations of dissolved copper and zinc regularly exceeded NRWQC benchmarks, with a maximum PHQ of 90 for dissolved copper and 18 for dissolved zinc. The median concentration for dissolved aluminum was 160 µg/L, though no benchmark exists. Service water concentrations of dissolved aluminum, copper, and zinc were moderately influential, but only in the graywater samples with the lowest measured concentrations. Total arsenic was detected in the shrimping[36] and recreational vessel where concentrations exceeded NRWQC benchmarks (PHQ values were 111 and 161, respectively). Total aluminum concentrations exceeded NRWQC benchmarks in seven of the eight vessels, with one vessel exceeding a PHQ of 10.

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[36] See Section 3.2.5.4and footnote 3 in Table 3.5.5.

Table 3.5.7. Characterization of Graywater Effluent and Summary of Analytes that May Have the Potential to Pose Risk

Vessel Type (no. vessels)	Analytes that May Have the Potential to Pose Risk in Graywater Effluent and Vessel Sources[1,2]												
	Microbiologicals	Volatile Organic Compounds	Semivolatile Organic Compounds	Metals (dissolved)	Metals (total)	Oil and Grease	Sulfide	Short-Chain Alkylphenol Ethoxylates or NPs	Long-Chain Alkylphenol Ethoxylates	Nutrients	BOD, COD, and TOC	Total Suspended Solids	Other Physical/Chemical Parameters
Tugboat (5)	**fecal coliform** **enterococci** ***E. coli***			Al, **Cu**, **Zn**	Al	**x**	**x**		x	**TP**, NH3-N	**BOD** **COD** TOC	x	
Shrimping Vessel (1)	fecal coliform enterococci *E. coli*			Cu, Zn	As, Al					TP	BOD COD TOC		
Water Taxi (1)				Cu, **Zn**	Al					TP	BOD COD TOC		TRC
Recreational (1)	**fecal coliform** **enterococci** ***E. coli***			Cu, Zn	As, Al	x			x	TP	**BOD** **COD** TOC		

(1) Analytes are generally **bolded** when a large proportion of the samples have concentrations exceeding the NRWQC (e.g., 25 to 50 percent), when several of the samples have PHQs > 10 (e.g., two or three of five), when a few samples result in PHQs greatly exceeding the screening benchmark (i.e., 100s to 1,000s), in the case of oil and grease and for nonylphenol, when one or more samples exceed an existing regulatory limit by more than a factor of 2, or when concentrations of analytes are sufficiently high that they may have the potential to pose risks to local water bodies. See text in Section 3.1.3 for a definition of PHQs and Table 3.1 for screening benchmarks used to calculate these values.

(2) EPA notes that the conclusion of potential risk is drawn from a small sample size, in some cases a single vessel, for certain discharges sampled from some vessel classes. EPA included these results in the tables to provide a concise summary of the data collected in the study, but strongly cautions the reader that these conclusions, where there are only a few samples from a given vessel class, should be considered preliminary and might not necessarily represent pollutant concentrations from these discharges from other vessels in this class.

3.2.6 Engine Effluent

Vessel engines are primarily used for two purposes: propulsion and electrical generation. Engines used for vessel propulsion can be either outboard or inboard engines. Vessels that require significant lighting or have electrical equipment such as appliances and/or electric motors are likely equipped with engines used for electrical generation.

Engine cooling systems include direct cooling, indirect cooling, and keel cooling. Direct and indirect cooling systems discharge wastewater, while keel cooling systems are zero discharge. Some engines with direct and indirect cooling systems also use water to cool and quiet their exhaust, referred to as engine wet exhaust. These engines inject spent cooling water from the engine into the exhaust stream, so that the cooling water directly contacts the engine exhaust. Possible constituents of concern in engine effluent include the following: thermal loading; metals from the discharge contacting the exhaust system, from erosion of moving engine components (e.g., pistons), or from trace constituents of the fuel; and oil and grease and organic compounds as constituents of fuel or possible products of incomplete fuel combustion.

The volume of engine cooling water discharged depends on the type of engine and power level of operation. Vessels with outboard propulsion engines discharge between 1 and 2 gpm of raw cooling water per engine based on observations made during the sampling program. The cooling water discharge rate from inboard marine diesel engines varies based on power levels, but typically averages around 20 gpm when engines operate between 1,500 and 2,000 rpm (Sherwood Pumps, 2009). Marine diesel generator sets require 5 to 6 gpm of cooling water for smaller units (9.5 kW) (Cummins, 2008), and up to 20 and 25 gpm of cooling water for larger marine generator sets (80 kW) (Cummins, 2004). Daily discharge rates for these engines are a function of daily operating time.

Collecting the Engine Effluent of a Water Taxi at Idle

Collecting the Engine Effluent of a Tow and Salvage Vessel at Full Speed

For this study, EPA collected engine cooling water discharge samples from a variety of vessel classes with different engine types, as summarized in Table 3.6.1. Note that two of the sampled vessels are recreational vessels and are not study vessels. In addition, both of the sampled research vessels and four of the six sampled tow/salvage vessels (those with outboard propulsion engines) were manufactured for pleasure and therefore are also recreational vessels and not study vessels. EPA sampled engine effluent from these vessels because all of the sampled engines can be installed on either recreational or nonrecreational vessels and are representative of engines on study vessels.

Samples were analyzed for classical pollutants, metals (dissolved and total), SVOCs, and VOCs. Engine discharge samples were typically collected from the discharge port using a sample transfer jar attached to a pole. The contents of the sample transfer jar were poured into a lined utility bucket. If the engines were operated at multiple engine levels (e.g., idle, half power, full power), then equal portions of sample were collected from each power level and composited for a single laboratory analysis. Ten of the 13 sampled vessels with inboard propulsion engines and all six sampled vessels with outboard propulsion engines were operated at multiple power levels. Similarly, if a vessel operated more than one engine, then equal portions of sample were collected from each engine and composited for a single laboratory analysis. However, samples for analysis of oil and grease and VOCs are not appropriate to composite. For these analytes, samples were collected and analyzed separately for each engine power level or were collected from only one of the multiple engines.

Table 3.6.1. Sampled Engine Characteristics

Fuel Type	Cooling Type	Engine Wet Exhaust?	Number of Vessels Sampled	Vessel Types
Inboard Propulsion Engines				
Diesel	Direct	Yes	3	Water Taxi (2), Fishing
Diesel	Indirect	Yes	5	Tour Boat (2), Water Taxi, Tow/Salvage, Fire Boat
Diesel	Unknown	Yes	3	Tour Boat, Water Taxi, Recreational
Diesel	Unknown	Unknown	1	Fishing
Gasoline	Indirect	Yes	1	Recreational
Outboard Propulsion Engines				
Gasoline	Direct	Yes	5	Tow/Salvage (4), Research
Gasoline	Unknown	Yes	1	Research
Generator Engines				
Diesel	Direct	Yes	1	Tour Boat
Diesel	Indirect	Yes	1	Fire Boat
Diesel	Unknown	Unknown	2	Fishing, Tour Boat
Unknown	Indirect	Yes	1	Water Taxi

EPA also observed a number of vessels, particularly tug boats and larger commercial fishing vessels, that use keel-cooled propulsion and generator engines. The vessels were not sampled as these closed-loop cooling systems do not have a discharge. Approximately two-thirds of the 61 vessels visited had keel cooled engine systems.

An additional source of relevant engine effluent data is EPA's sampling program for the Uniform National Discharge Standards (UNDS) rulemaking. In 2006, EPA sampled propulsion engine wet exhaust discharges from two small Armed Forces vessels with inboard diesel engines with engine wet exhaust: a 36-foot landing craft personnel large (LCPL) and a 7-meter rigid inflatable boat (RIB) (USEPA, 2008b). This sampling program was specifically designed to characterize engine wet exhaust discharges by power level. While these Armed Forces vessels are not study vessels, the engines used on these vessels are comparable to those used on study vessels. Samples from both vessels were analyzed for eight classical pollutants and 92 volatile and semivolatile compounds. Samples from the LCPL were also analyzed for seven total metals. Grab samples of the engine discharge were collected from sample taps installed into the exhaust lines of the vessels. Three replicate engine discharge samples were collected at each of five different engine power levels: 0 percent (idle), 25 percent, 50 percent, 75 percent, and 100 percent (full power). Three replicate background seawater samples were also collected. Sampling was conducted in the open ocean.

3.2.6.1 Inboard Propulsion Engines

For this study, EPA collected cooling water discharge samples from inboard propulsion engines on 13 vessels: four water taxis, three tour boats, two fishing vessels, one tow/salvage vessel, one fire boat, and two recreational vessels (Table 3.6.1). These engines included both direct and indirect cooling discharges from both gasoline- and diesel-fueled engines. For the UNDS program, EPA sampled engine wet exhaust from inboard propulsion engines on two personnel craft. Results for each class of pollutant are presented and discussed in the following subsections.

The Inboard Propulsion Engine of a Fire Boat

3.2.6.1.1 Classical Pollutants

Table 3.6.2 presents analytical results for 11 classical pollutants detected in samples of discharges from inboard propulsion engines. All of the classical pollutants analyzed for were detected and the detected results are shown in Figure 3.6.1. Engine cooling water discharge differs from all other discharges in that the water used in the engines is drawn from surrounding waters and immediately discharged to the same waters. For this reason, EPA analyzed the sample results to determine which pollutant concentrations were contributed primarily by engine operations and which were contributed primarily by background ambient concentrations (see footnotes on Table 3.6.2 and Figure 3.6.1). The remainder of this subsection discusses those pollutants found to be contributed primarily by engine operations.

Temperature increases in engine effluent above background were generally less than 5°C. However, on three vessels operated at higher power levels (recreational vessel, tow/salvage vessel, and fire boat), temperature increases were greater than 20°C. EPA’s findings were similar for the UNDS sampling program, with temperature increases ranging from less than 3°C at idle to a maximum of 27°C at full power.

Oil and grease (measured as HEM) was detected in the majority of engine effluent samples; however, detected concentrations were low (most were less than 5 mg/L). All sample results were well below the 33 CFR § 151.10 and MARPOL prohibition of the discharge of oil and oily mixtures with an oil content greater than 15 ppm into seawater from vessels. HEM values exceeded 5 mg/L in only three grab samples, and all three were collected during engine operation at relatively high power levels. For the UNDS sampling program, HEM was not detected in any engine effluent samples, regardless of power level (≤ 4 mg/L).

Sulfide was detected in only two of 11 samples at concentrations of 0.013 and 0.016 mg/L. These measured concentrations are six to eight times greater than the most conservative PHQ screening benchmark of 0.002 mg/L. Sulfide might be present as a trace constituent in the fuel, as a product of incomplete combustion, or due to formation within the biofilm in the cooling system piping. For the UNDS sampling program, sulfide was not detected in any engine wet exhaust samples.

For this study, TSS concentrations in effluent discharge samples were contributed primarily by background ambient concentrations (i.e., sample concentrations ranged from <5 to 17 mg/L while ambient water concentrations ranged from 7.8 to 20 mg/L). For the UNDS sampling program, TSS was not detected in any of the samples from the LCPL; however, TSS was present in the RIB discharge samples at concentrations ranging from 6 to 14 mg/L, which were statistically greater than background for some power levels. UNDS TSS results correspond with the field observations for samples from the RIB at the highest power levels (i.e., the samples were observed to be cloudy and contained settleable materials (resembling soot)). In this study, EPA observed that some effluent engine samples were also cloudy and contained settleable materials at higher power levels.

TRC was detected in only one engine effluent sample collected from a fishing vessel at a concentration of 0.17 mg/L. Fish hold effluent from this vessel, containing TRC at a concentration of 0.27 mg/L, was discharged into the water surrounding the vessel just prior to collection of engine effluent samples; the propulsion engine on this vessel utilizes the ambient water for cooling. EPA believes that the TRC value for the engine effluent sample was likely influenced by the fish hold effluent discharge.

Table 3.6.2. Results of Inboard Propulsion Engine Sample Analyses for Classical Pollutants[1]

Analyte	Units	No. Samples	No. Detected	Detected Proportion (%)	Average Conc.	Median Conc.	Minimum Conc.	10%	25%	75%	90%	Maximum Conc.
Conductivity[2]	mS/cm	10	6	100	11	6.1	0.22	0.22	0.22	17	44	44
Dissolved Oxygen[3]	mg/L	10	6	100	6.8	7.4	1.7	2.0	4.0	9.3	13	14
Hexane Extractable Material (HEM)	mg/L	12	8	66	3.0	2.2				3.8	5.4	5.7
pH[2]	SU	13	13	100	6.9	6.6	6.2	6.2	6.4	7.4	7.9	8.0
Salinity[2]	ppt	10	10	100	6.9	3.3	0.10	0.10	0.10	9.9	28	28
Silica Gel Treated HEM (SGT-HEM)	mg/L	12	7	58	4.0	2.6				3.6	4.3	4.4
Sulfide	mg/L	11	2	18	0.0062						0.013	0.013
Temperature	C	13	13	100	22	21	6.5	9.9	17	26	36	39
Total Residual Chlorine[2]	mg/L	13	1	7.7	0.048						0.10	0.17
Total Suspended Solids (TSS)[3]	mg/L	11	8	73	11	13				16	17	17
Turbidity[3]	NTU	13	13	100	32	29	1.2	2.7	18	45	69	80

Notes:
(1) Nondetect (censored) concentrations were replaced with ½ of the reporting limit for calculating average concentrations. The remaining statistics in this table were only calculated when analytes were detected at a sufficient frequency. For example, if an analyte was detected in fewer than 50% of samples, then a median concentration was not calculated. A blank cell reflects a situation when a median or percentile could not be computed based on detected concentrations. The percentiles are the concentrations of each analyte below which at least that percentage of the values fall. So the 10th percentile is the concentration below which at least 10% of the observations were found.
(2) Sample concentrations were almost completely accounted for (≥ 90 percent) by background concentrations in ambient water.
(3) Sample concentrations were predominantly accounted for (≥ 50 percent and <90 percent) by background concentrations in ambient water.

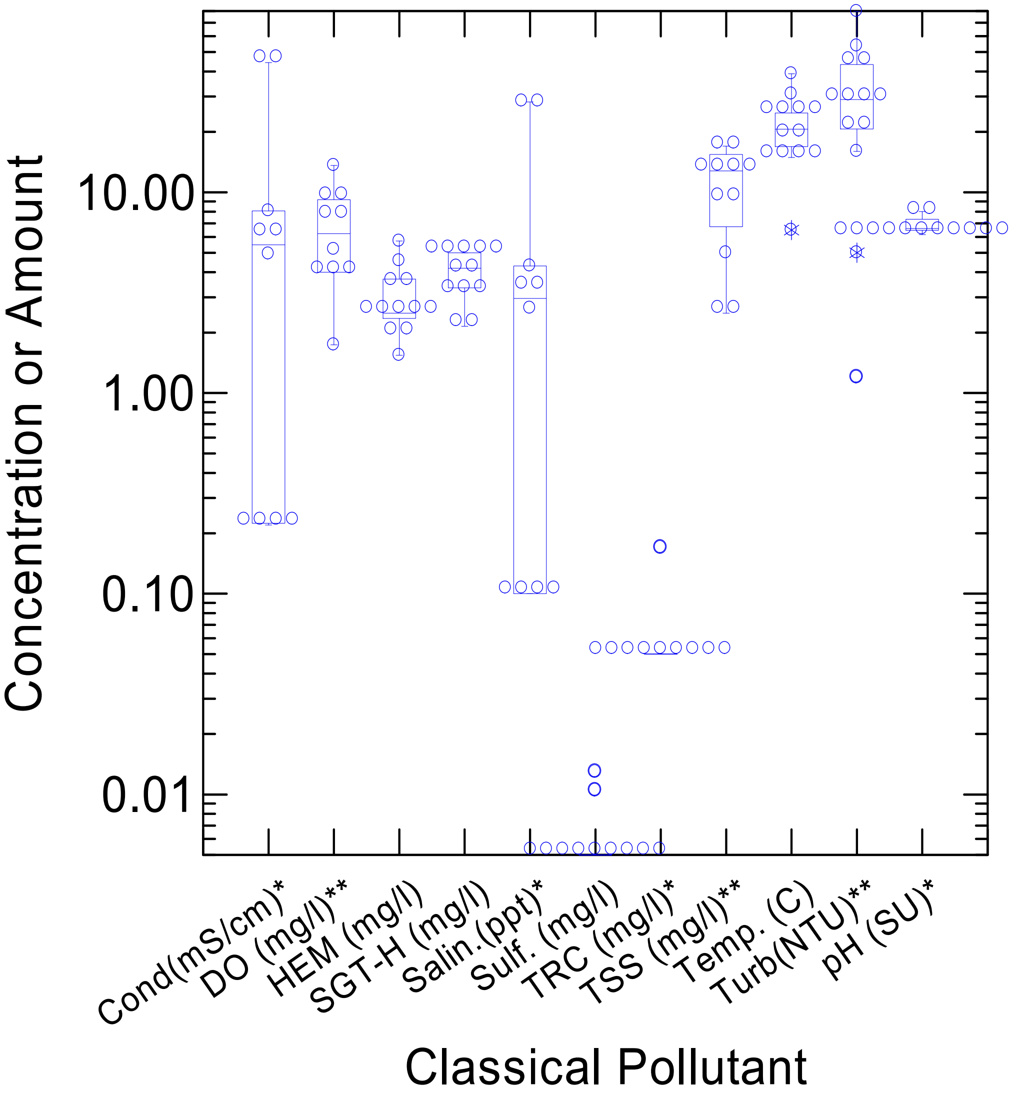

Figure 3.6.1. Box and Dot Density Plot of Classical Pollutant Values Measured in Samples of Inboard Propulsion Engine Effluent

* Sample concentrations were almost completely accounted for (≥ 90 percent) by background concentrations in ambient water.

** Sample concentrations were predominantly accounted for (≥ 50 percent and <90 percent) by background concentrations in ambient water.

3.2.6.1.2 Metals

Inboard propulsion engine effluent samples were analyzed for 22 dissolved and total metals. Table 3.6.3 presents analytical results for the 16 metals that were detected in one or more engine effluent samples. The detected results are also shown in Figures 3.6.2 and 3.6.3 for dissolved and total metals, respectively. Figures 3.6.4 and 3.6.5 display the distribution of PHQs based on the screening benchmark for each of the dissolved and total metals. EPA analyzed the sample results to determine which metals were contributed primarily by engine operations and which were contributed primarily by background ambient concentrations. The remainder of this subsection discusses those metals found to be contributed primarily by engine operations.

For most metals, concentrations for the dissolved and total forms were similar, indicating that engine operations contribute metals in dissolved rather that particulate form. Two exceptions were iron and lead. A comparison of dissolved and total iron concentrations indicates that almost all iron was present in particulate form. One possible source of particulate iron in engine effluent is rust. Lead was detected in engine effluent samples from only four of the 13 vessels sampled (three water taxis and a tow/salvage vessel). Total lead concentrations (maximum measured concentration = 9.6 μg/L) exceeded dissolved lead concentrations by three to four times.

Dissolved and total copper were detected in almost all engine effluent samples at concentrations ranging from 3 to 53 μg/L and 5 to 66 μg/L, respectively. Dissolved copper concentrations exceeded the PHQ screening benchmark of 3.1 μg/L (saltwater chronic criterion) by one to 17 times (see Figure 3.6.4). In contrast, none of the total copper concentrations exceeded the PHQ screening benchmark of 1,300 μg/L (human heath for consumption of water and aquatic organisms (see Figure 3.6.5)).

Dissolved and total zinc were also detected in a majority of engine effluent samples. Detected concentrations ranged from 12 to 120 μg/L and 11 to 95 μg/L for dissolved and total zinc, respectively (see Figures 3.6.2 and 3.6.3). However, only the two highest detected dissolved zinc concentrations (83 and 120 μg/L) exceeded the PHQ screening benchmark of 81 μg/L (saltwater chronic criterion). None of the detected total zinc concentrations exceeded the PHQ screening benchmark of 7,400 μg/L (human heath for consumption of water and aquatic organisms).

Dissolved and total nickel were detected in approximately half of the engine effluent samples, and dissolved and total chromium and lead were each detected in fewer than half of the engine effluent samples. Detected concentrations were generally within five times the reporting limit and none exceeded the screening benchmarks for these analytes (see Figures 3.6.4 and 3.6.5). Note, however, that lead is a persistent bioaccumulative and toxic chemical (PBT) and the long-term mass loading is more important than the discharge concentrations.

Dissolved manganese was detected in 11 of 13 engine effluent samples. Manganese was predominantly in particulate form in background ambient water; therefore, EPA assumed dissolved manganese concentrations in engine effluent samples to be contributed by engine operations. NRWQCs or other PHQ screening benchmarks have not been determined for dissolved manganese.

Dissolved iron and dissolved and total vanadium were each detected in no more than three engine effluent samples at measured concentrations close to the reporting limit. NRWQCs or other PHQ screening benchmarks have not been determined for these analytes at this time.

Finally, the concentrations in engine effluent discharges that exceeded the PHQ screening benchmark concentrations for dissolved selenium, total aluminum, and total arsenic were caused by high background concentrations in ambient water (which exceeded benchmark concentrations) and not by engine operations. Moreover, in the case of dissolved and total arsenic and selenium, measured concentrations above their respective reporting limits (three different water taxis and the recreational vessel) may be substantially elevated due to positive interference (see Section 3.1.3). After subtracting the contribution of ambient water (also potentially elevated due to positive interference), none of the detected concentrations exceeded their PHQ screening benchmarks.

Comparing study sampling results with the metals data from the engine wet exhaust sampling conducted for the UNDS program affirms EPA's sampling results. For the UNDS program, EPA determined that five of the seven total metals analyzed for were present at concentrations statistically greater than background: cadmium, chromium, copper, lead, and nickel. Total mercury was not detected in any samples, and total arsenic concentrations did not exceed background concentrations. Table 3.6.4 compares the metals results from this study and the UNDS program.

EPA notes that there were some important differences between the UNDS sampling and the sampling conducted in this study to consider when comparing the results. The UNDS program used a different analytical method, as well as a different methodology to calculate mean concentrations. Also, background metals concentrations in harbors for this study are greater than those in the open ocean for the UNDS program.

Table 3.6.3. Results of Inboard Propulsion Engine Sample Analyses for Metals[1]

Analyte	Units	No. Samples	No. Detected	Detected Proportion (%)	Average Conc.	Median Conc.	Minimum Conc.	10%	25%	75%	90%	Maximum Conc.
Heavy and Other Metals												
Aluminum, Dissolved[2]	µg/L	13	12	92	200	100		3.8	23	180	880	940
Aluminum, Total[2]	µg/L	13	13	100	340	300	59	61	120	410	920	940
Arsenic, Dissolved[3,4]	µg/L	13	4	31	4.2					8.7	12	14
Arsenic, Total[3,4]	µg/L	13	6	46	4.5					8.7	13	15
Barium, Dissolved[2]	µg/L	7	7	100	35	32	23	23	29	34	63	63
Barium, Total[2]	µg/L	7	7	100	36	34	24	24	28	35	63	63
Chromium, Dissolved	µg/L	13	3	23	1.2					0.75	1.9	2.1
Chromium, Total	µg/L	13	3	23	1.3					0.95	2.4	2.6
Copper, Dissolved	µg/L	13	12	92	16	6.6		1.6	5.5	23	51	53
Copper, Total	µg/L	13	11	85	18	9.3			5.6	25	62	66
Iron, Dissolved	µg/L	7	1	14	64						150	150
Iron, Total[3]	µg/L	7	6	86	250	250			150	310	520	520
Lead, Dissolved	µg/L	13	3	23	1.5					0.60	2.1	2.3
Lead, Total	µg/L	13	4	31	3.0					4.1	8.5	9.6
Manganese, Dissolved	µg/L	13	11	85	43	44			30	55	82	91
Manganese, Total[2]	µg/L	13	11	85	55	53			40	74	95	100
Nickel, Dissolved	µg/L	13	7	54	4.4	2.5				4.3	4.9	5.3
Nickel, Total[2]	µg/L	13	7	54	4.6	3.1				4.3	5.5	5.6
Selenium, Dissolved[2,4]	µg/L	13	4	31	11					21	32	34
Selenium, Total[3,4]	µg/L	13	4	31	11					21	31	32
Vanadium, Dissolved	µg/L	7	3	43	0.90					1.4	1.7	1.7
Vanadium,Total	µg/L	7	2	29	1.4					1.1	1.6	1.6
Zinc, Dissolved	µg/L	13	9	69	38	23				74	110	120
Zinc, Total	µg/L	13	11	85	38	29			11	75	89	95
Cationic Metals												
Calcium, Dissolved[2]	µg/L	13	13	100	80000	37000	24000	24000	26000	62000	310000	310000

Table 3.6.3. Results of Inboard Propulsion Engine Sample Analyses for Metals[1]

Analyte	Units	No. Samples	No. Detected	Detected Proportion (%)	Average Conc.	Median Conc.	Minimum Conc.	10%	25%	75%	90%	Maximum Conc.
Calcium, Total[2]	µg/L	13	13	100	81000	37000	26000	26000	29000	62000	310000	310000
Magnesium, Dissolved[2]	µg/L	13	13	100	200000	12000	5200	5200	5900	160000	1000000	1100000
Magnesium, Total[2]	µg/L	13	13	100	200000	12000	5800	5900	6500	160000	1000000	1100000
Potassium, Dissolved[2]	µg/L	7	7	100	32000	39000	4000	4000	4100	58000	63000	63400
Potassium, Total[2]	µg/L	7	7	100	32000	39000	3700	3700	3800	58000	65000	65000
Sodium, Dissolved[3]	µg/L	7	7	100	770000	860000	36000	36000	40000	1600000	1600000	1600000
Sodium,Total[3]	µg/L	7	7	100	860000	860000	35000	35000	39000	1600000	2000000	2000000

Notes:

(1) Nondetect (censored) concentrations were replaced with ½ of the reporting limit for calculating average concentrations. The remaining statistics in this table were only calculated when analytes were detected at a sufficient frequency. For example, if an analyte was detected in fewer than 50% of samples, then a median concentration was not calculated. A blank cell reflects a situation when a median or percentile could not be computed based on detected concentrations. The percentiles are the concentrations of each analyte below which at least that percentage of the values fall. So the 10th percentile is the concentration below which at least 10% of the observations were found.

(2) Sample concentrations were almost completely accounted for (≥ 90 percent) by background concentrations in ambient water.

(3) Sample concentrations were predominantly accounted for (≥ 50 percent and <90 percent) by background concentrations in ambient water.

(4) Values well above their respective reporting limits are suspected of being elevated due to positive interference. (See discussion in Section 3.1.3).

Table 3.6.4. Comparison of Metals Results for EPA P.L. 110-299 and UNDS Engine Wet Exhaust Sampling

Metal	Mean Inboard Propulsion Engine Effluent Concentration (µg/L)	
	EPA P.L. 110-299 Sampling	UNDS Engine Wet Exhaust Sampling
Arsenic, Total	4.5	2.2
Cadmium, Total	Not Detected (Reporting Limit = 1)	0.024
Chromium, Total	1.3	0.33
Copper, Total	18	24
Lead, Total	3.0	0.2
Nickel, Total	4.6	6.8

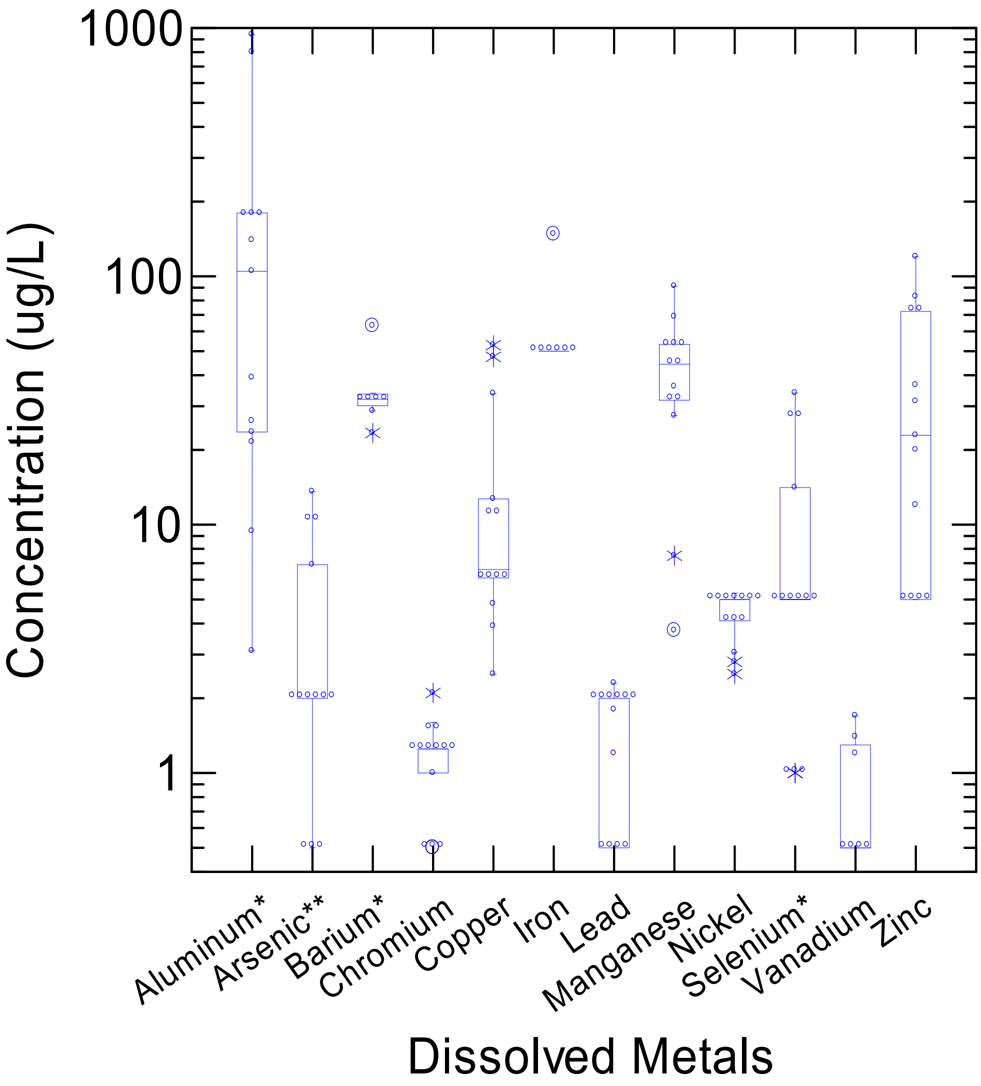

Figure 3.6.2. Box and Dot Density Plot of Dissolved Metals Concentrations Measured in Samples of Inboard Propulsion Engine Effluent

* Sample concentrations were almost completely accounted for (≥ 90 percent) by background concentrations in ambient water.

** Sample concentrations were predominantly accounted for (≥ 50 percent and <90 percent) by background concentrations in ambient water.

(Note: Values well above their respective reporting limits for dissolved arsenic and selenium are suspected of being elevated due to positive interference).

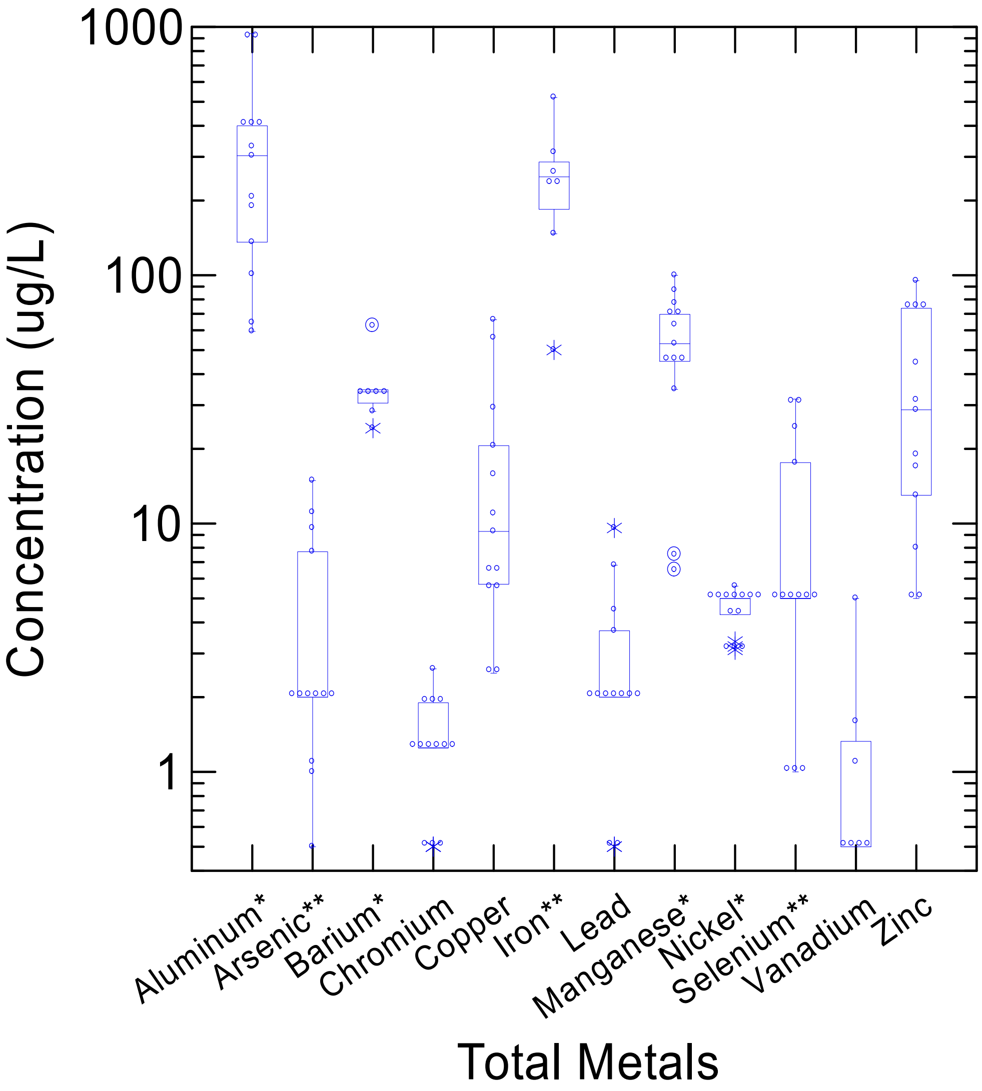

Figure 3.6.3. Box and Dot Density Plot of Total Metals Concentrations Measured in Samples of Inboard Propulsion Engine Effluent

* Sample concentrations were almost completely accounted for (≥ 90 percent) by background concentrations in ambient water.

** Sample concentrations were predominantly accounted for (≥ 50 percent and <90 percent) by background concentrations in ambient water.

(Note: Values well above their respective reporting limits for total arsenic and selenium are suspected of being substantially elevated due to positive interference).

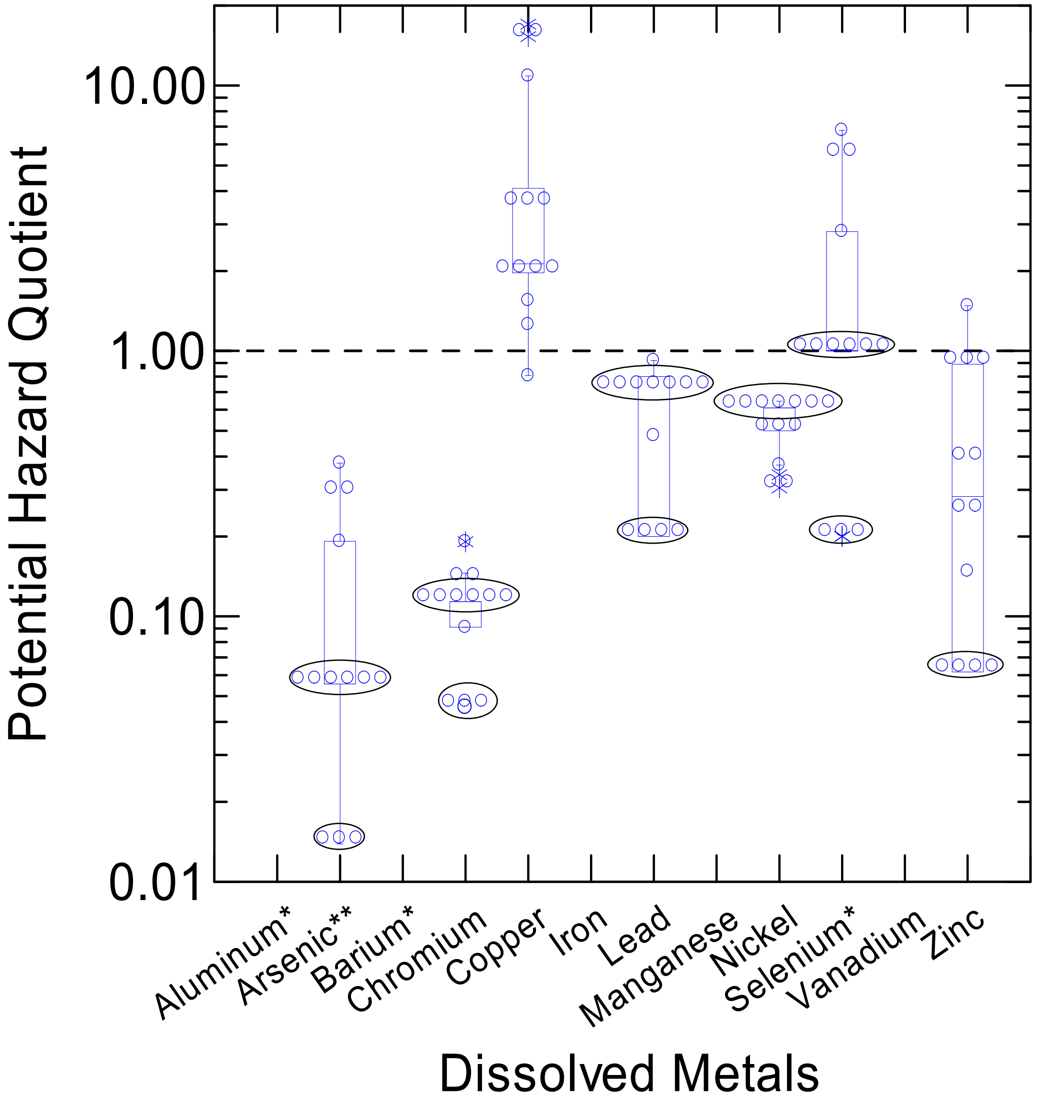

Figure 3.6.4. Box and Dot Density Plot of Potential Hazard Quotients for Dissolved Metals in Samples of Inboard Propulsion Engine Effluent

* Sample concentrations were almost completely accounted for (≥ 90 percent) by background concentrations in ambient water.

** Sample concentrations were predominantly accounted for (≥ 50 percent and <90 percent) by background concentrations in ambient water.

(Note: Replacement values for non-detects are circled. Also, values well above their respective reporting limits for dissolved arsenic and selenium are suspected of being elevated due to positive interference).

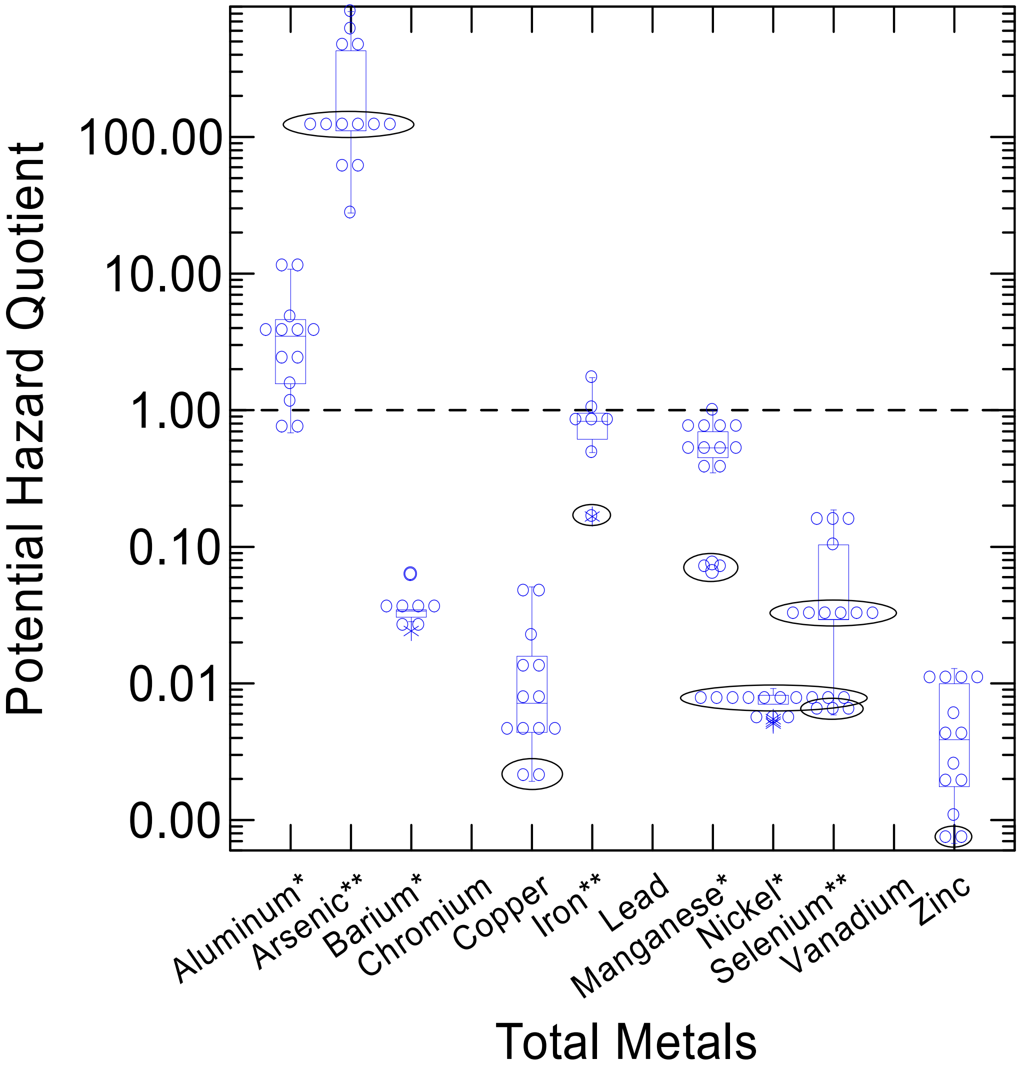

Figure 3.6.5. Box and Dot Density Plot of Potential Hazard Quotients for Total Metals in Samples of Inboard Propulsion Engine Effluent

* Sample concentrations were almost completely accounted for (≥ 90 percent) by background concentrations in ambient water.

** Sample concentrations were predominantly accounted for (≥ 50 percent and <90 percent) by background concentrations in ambient water.

(Note: Replacement values for non-detects are circled. Also, values well above their respective reporting limits for total arsenic and selenium are suspected of being elevated due to positive interference).

3.2.6.1.3 Semivolatile Organic Compounds

Inboard propulsion engine effluent samples were analyzed for 76 SVOCs for the sampling conducted as part of the P.L. 110-299 study. Table 3.6.5 presents analytical results for the 31 SVOCs that were detected in one or more engine effluent samples. The detected results are also shown in Figures 3.6.6 and 3.6.7 for analyte concentrations and for PHQs based on the lowest NRWQC or other PHQ screening benchmark where applicable, respectively. EPA analyzed the sample results to determine which SVOCs were contributed primarily by engine operations and which were contributed primarily by background ambient concentrations. All were found to be contributed primarily by engine operations.

Many of the detected SVOCs can be classified among the following pollutant classes: polycyclic aromatic hydrocarbons or PAHs (14 analytes), straight-chain hydrocarbons (five analytes), phenol and methyl phenols (five analytes), and phthalates (two analytes). These include all of the SVOCs detected most frequently and at the highest concentrations.

PAHs are present in fuel in small amounts and may be formed as products of incomplete combustion. EPA has identified seven PAHs as probable human carcinogens, six of which were detected in engine effluent collected from a recreational vessel with a gasoline engine dewinterized immediately prior to sampling (see details below): benzo(a)anthracene, benzo(b)fluoranthene, benzo(k)fluoranthene, benzo(a)pyrene, chrysene, and indeno(1,2,3-cd)pyrene. Most of these compounds exceed a PHQ of 1,000 as shown in Figure 3.6.7.

Phthalates are plasticizers (chemicals added to plastics to make them flexible) and are commonly detected in environmental samples (ATSDR, 2002). Bis(2-ethylhexyl) phthalate was detected at concentration just above the screening benchmark of 1.2 µg/L (human heath for consumption of water and aquatic organisms).

Phenol and methyl phenols are present in petroleum products and may also be generated as products of incomplete combustion. Discharges of phenol and methyl phenols are assumed to not cause any environmental impacts as detected concentrations did not exceed the PHQ screening benchmarks for these analytes. Straight-chain (alkane) hydrocarbons are also components of fuel; none of the straight-chain hydrocarbons detected in engine effluent have a NRWQC or other PHQ screening benchmark, and they are not PBT chemicals

It is important to note that 11 of the detected SVOCs were found only in one sample collected from a recreational vessel (recreational vessels are not study vessels). These included all six of the detected PAHs that are probable human carcinogens, as well as four additional PAHs. Engine effluent from this recreational vessel also contributed the maximum detected concentrations for six additional analytes, including several additional PAHs as well as four of the five detected phenol/methyl phenols. (Maximum sample concentrations for 2,4-dimethylphenol, straight-chain hydrocarbons, and phthalates were contributed by other vessels.)

This recreational vessel was the only sampled vessel that used gasoline as fuel rather than diesel; however, the lack of replication precludes any determination as to whether fuel type is a critical factor for engine effluent characteristics. In addition, the engines on this vessel were dewinterized immediately prior to sampling. The lack of engine operation for several months prior to sampling could have contributed to engine effluent characteristics.

Comparing study sampling results with the results from the engine wet exhaust sampling conducted for the UNDS program reveals some similarities. For the LCPL, phenol and bis(2-ethylhexyl)phthalate were the only detected SVOCs; however, the presence of bis(2-ethyhexyl) phthalate in LCPL effluent may be due to laboratory contamination and so data for the purpose of comparison are not shown in this report. For the RIB, phenol was the only detected SVOC. EPA determined that phenol was present at concentrations statistically greater than background. Table 3.6.6 compares the phenol results from this study to those from the UNDS program. Note that the UNDS program used a different methodology to calculate mean concentrations.

Table 3.6.5. Results of Inboard Propulsion Engine Sample Analyses for SVOCs[1]

Analyte	Units	No. Samples	No. Detected	Detected Proportion (%)	Average Conc.	Median Conc.	Minimum Conc.	10%	25%	75%	90%	Maximum Conc.
1,2-Diethyl-Cyclobutane	µg/L	1	1	100	10							
1,6-Dimethyl	µg/L	1	1	100	35							
1-Methylnaphthalene	µg/L	2	2	100	13	24	3.2	3.2	3.2	24	24	24
2,4-Dimethylphenol	µg/L	12	4	33	3.7					2.4	16	22
2-Methylnaphthalene	µg/L	8	6	75	17	13			0.90	36	46	46
Acenaphthene	µg/L	12	1	8.3	2.0						1.5	2.2
Acenaphthylene	µg/L	12	3	25	7.0					1.7	44	61
Anthracene	µg/L	12	1	8.3	3.3						12	18
Benzo(a)anthracene	µg/L	12	1	8.3	3.3						13	18
Benzo(a)pyrene	µg/L	12	1	8.3	3.2						11	16
Benzo(b)fluoranthene	µg/L	12	1	8.3	2.8						7.8	11
Benzo(g,h,i)perylene	µg/L	12	1	8.3	2.6						6.9	9.8
Benzo(k)fluoranthene	µg/L	12	1	8.3	3.1						11	15
Bis(2-ethylhexyl) phthalate	µg/L	12	4	33	1.7					1.2	1.8	20
Chrysene	µg/L	12	1	8.3	3.3						12	18
Di-n-butyl phthalate	µg/L	12	6	50	1.7	1.1				1.6	3.5	3.8
Eicosane	µg/L	2	2	100	19	28	10	10	10	28	28	28
Fluorene	µg/L	12	4	33	3.5					2.8	14	18
Heptadecane	µg/L	4	4	100	29	27	3.5	3.5	3.8	67	80	80
Indeno(1,2,3-cd)	µg/L	12	1	8.3	2.5						5.6	8.0
m-Cresol	µg/L	4	1	25	13					34	45	45
Naphthalene	µg/L	12	10	8.3	30	6.6			1.9	34	160	210
n-Hexadecane	µg/L	3	3	100	26	17	3.1	3.1	3.1	57	57	57
Nonadecane	µg/L	2	2	100	27	38	15	15	15	38	38	38
Nonanoic Acid	µg/L	1	1	100	11							
o-Cresol	µg/L	3	3	100	6.6	5.8	5.7	5.7	5.7	8.4	8.4	8.4

Table 3.6.5. Results of Inboard Propulsion Engine Sample Analyses for SVOCs[1]

Analyte	Units	No. Samples	No. Detected	Detected Proportion (%)	Average Conc.	Median Conc.	Minimum Conc.	10%	25%	75%	90%	Maximum Conc.
Octadecane	µg/L	2	2	100	10	17	3.1	3.1	3.1	17	17	17
p-Cresol	µg/L	7	5	71	26	17				24	110	110
Phenanthrene	µg/L	12	3	25	6.1					1.3	35	48
Phenol	µg/L	12	8	67	27	3.7				37	140	170
Pyrene	µg/L	12	1	8.3	6.6						40	57

Notes:

(1) Nondetect (censored) concentrations were replaced with ½ of the reporting limit for calculating average concentrations. The remaining statistics in this table were only calculated when analytes were detected at a sufficient frequency. For example, if an analyte was detected in fewer than 50% of samples, then a median concentration was not calculated. A blank cell reflects a situation when a median or percentile could not be computed based on detected concentrations. The percentiles are the concentrations of each analyte below which at least that percentage of the values fall. So the 10th percentile is the concentration below which at least 10% of the observations were found.

(2) Sample concentrations were almost completely accounted for (≥ 90 percent) by background concentrations in ambient water.

(3) Sample concentrations were predominantly accounted for (≥ 50 percent and <90 percent) by background concentrations in ambient water.

Table 3.6.6. Comparison of Phenol Results for EPA P.L. 110-299 and UNDS Engine Wet Exhaust Sampling

Analyte	Mean Inboard Propulsion Engine Effluent Concentration (µg/L)		
	EPA P.L. 110-299 Sampling	UNDS Small Boat Engine Wet Exhaust Sampling	
		LCPL	RIB
Phenol	27	13	14

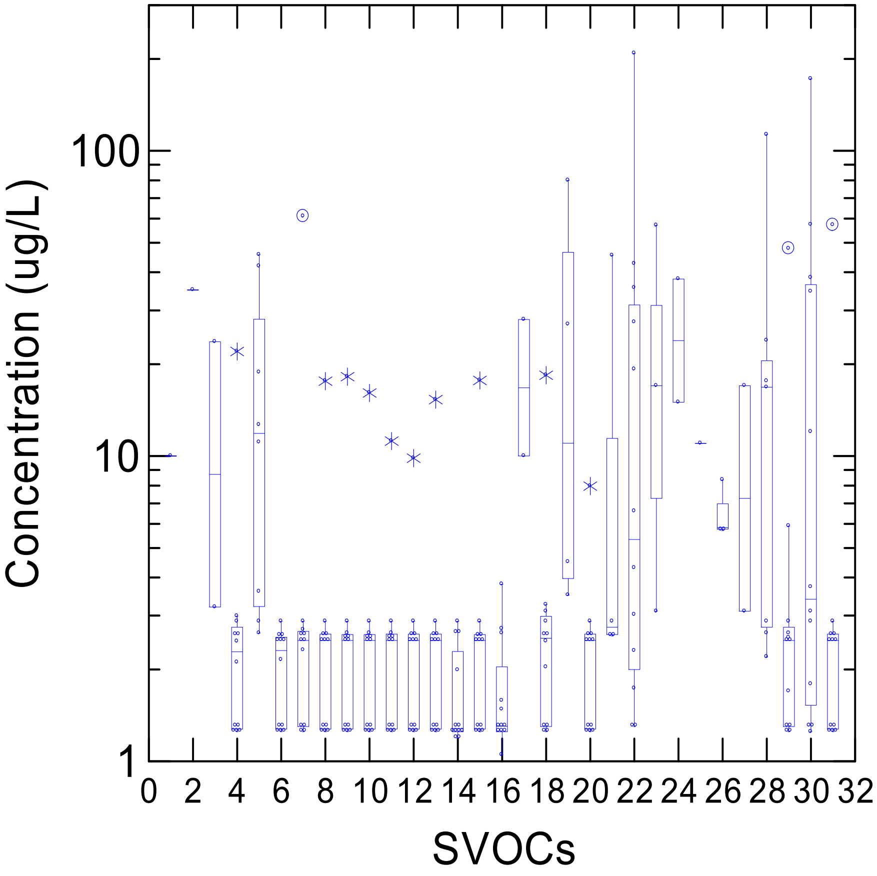

Figure 3.6.6. Box and Dot Density Plot of SVOC Concentrations Measured in P.L. 110-299 Study Samples of Inboard Propulsion Engine Effluent

SVOCs are identified as follows:

(1) 1,2-Diethyl-Cyclobutane
(2) 1,6-dimethylnaphthalene
(3) 1-methylnaphthalene
(4) 2,4-Dimethylphenol
(5) 2-Methylnaphthalene
(6) Acenaphthene
(7) Acenaphthylene
(8) Anthracene
(9) Benzo(a)anthracene
(10) Benzo(a)pyrene
(11) Benzo(b)fluoranthene
(12) Benzo(g,h,i)perylene
(13) Benzo(k)fluoranthene
(14) Bis(2-ethylhexyl) phthalate
(15) Chrysene
(16) Di-n-butyl phthalate
(17) Eicosane
(18) Fluorene
(19) Heptadecane
(20) Indeno(1,2,3-cd)pyrene
(21) m-Cresol
(22) Naphthalene
(23) n-Hexadecane
(24) Nonadecane
(25) Nonanoic Acid
(26) o-Cresol
(27) Octadecane
(28) p-Cresol
(29) Phenanthrene
(30) Phenol
(31) Pyrene

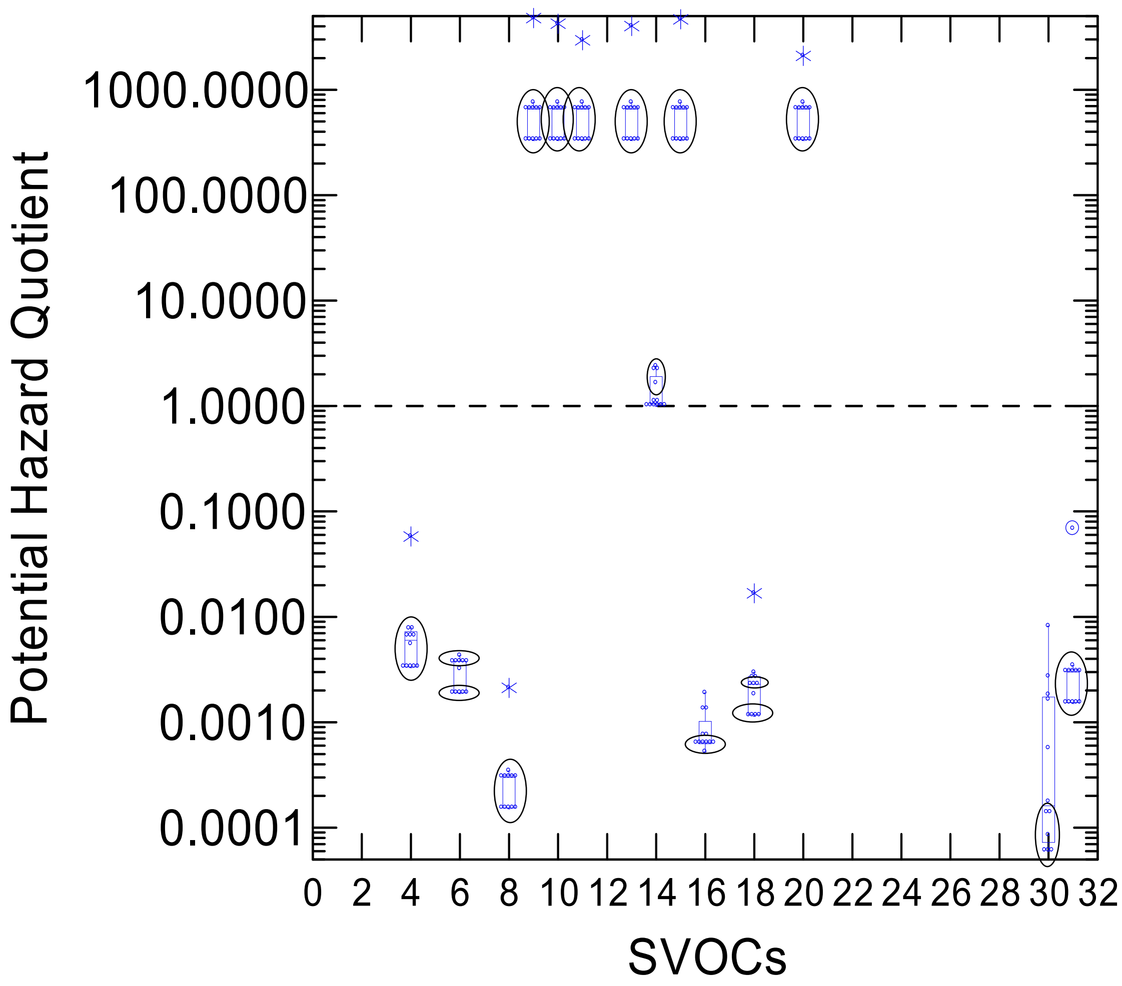

Figure 3.6.7. Box and Dot Density Plot of Potential Hazard Quotients for SVOCs in P.L. 110-299 Study Samples of Inboard Propulsion Engine Effluent

SVOCs are identified as follows (replacement values for non-detects are circled):

(1) 1,2-Diethyl-Cyclobutane
(2) 1,6-dimethylnaphthalene
(3) 1-methylnaphthalene
(4) 2,4-Dimethylphenol
(5) 2-Methylnaphthalene
(6) Acenaphthene
(7) Acenaphthylene
(8) Anthracene
(9) Benzo(a)anthracene
(10) Benzo(a)pyrene
(11) Benzo(b)fluoranthene
(12) Benzo(g,h,i)perylene
(13) Benzo(k)fluoranthene
(14) Bis(2-ethylhexyl) phthalate
(15) Chrysene
(16) Di-n-butyl phthalate
(17) Eicosane
(18) Fluorene
(19) Heptadecane
(20) Indeno(1,2,3-cd)pyrene
(21) m-Cresol
(22) Naphthalene
(23) n-Hexadecane
(24) Nonadecane
(25) Nonanoic Acid
(26) o-Cresol
(27) Octadecane
(28) p-Cresol
(29) Phenanthrene
(30) Phenol
(31) Pyrene

3.2.6.1.4 Volatile Organic Compounds

Inboard propulsion engine effluent samples were analyzed for 84 VOCs. Table 3.6.7 presents analytical results for the 38 VOCs that were detected in one or more engine effluent samples. The detected results are also shown in Figures 3.6.8 and 3.6.9 for analyte concentrations and for PHQs based on the lowest NRWQC or other PHQ screening benchmark where applicable, respectively. EPA analyzed the sample results to determine which VOCs were contributed primarily by engine operations and which were contributed primarily by background ambient concentrations. All were found to be contributed primarily by engine operations.

Approximately one-third of the detected VOCs were frequently detected in engine effluent (i.e., greater than half of the sampled vessels). Some of these compounds are volatile constituents of fuel, specifically benzene, toluene, ethylbenzene, and xylene. Others are trimethylbenzenes, which are naturally present in fuel, and ketones, which may be formed as products of incomplete combustion. Among these compounds, only benzene and toluene have an NRWQC. Approximately half of the detected benzene concentrations (from water taxis, tour boats and a recreational vessels) exceeded the PHQ screening benchmark of 2.2 µg/L (human heath for consumption of water and aquatic organisms), including discharges from one vessel that exceeded the benchmark by a factor of more than 50 (the next highest concentration that exceeded the benchmark was by less than a factor of 4) (see Figure 3.6.9). None of the detected toluene concentrations exceeded the PHQ screening benchmark of 1,300 µg/L (human health for consumption of water and aquatic organisms).

Approximately one-third of the detected VOCs were detected relatively infrequently (i.e., detected in fewer than half the sampled vessels). Among these compounds, only chloroform and methylene chloride have an NRWQC. However, none of the detected concentrations for these two analytes exceeded the PHQ screening benchmarks of 5.7 µg/L (human heath for consumption of water and aquatic organisms) and 1,300 µg/L (human heath for consumption of water and aquatic organisms), respectively.

The final third of detected VOCs were detected in engine effluent from only one or two vessels. None of these analytes have an NRWQC or are PBT chemicals, and are therefore not expected to have the potential to pose risk to human health or the environment.

It is important to note the maximum detected concentrations for 11 of the VOCs were found in samples collected from a recreational vessel (recreational vessels are not study vessels). These included benzene, toluene, ethylbenzene, xylene, and trimethylbenzenes (maximum sample concentrations for ketones were contributed by other vessels). As noted above, this recreational vessel was the only sampled vessel that used gasoline as fuel rather than diesel; however, this data set is too small to demonstrate whether fuel type is a critical factor for engine effluent characteristics. In addition, the engines on this vessel were dewinterized immediately prior to sampling. The lack of engine operation for several months prior to sampling could have contributed to engine effluent characteristics.

Comparing these sampling results with the results from the engine wet exhaust sampling conducted for the UNDS program reveals some similarities. For the LCPL, no VOCs were detected. For the RIB, 1,2,3-trimethylbenzene, and 1,3,5-trimethylbenzene were the detected VOCs. However, EPA determined that the trimethylbenzenes were not present at concentrations statistically greater than background.

Table 3.6.7. Results of Inboard Propulsion Engine Sample Analyses for VOCs [1]

Analyte	Units	No. Samples	No. Detected	Detected Proportion (%)	Average Conc. [2]	Median Conc.	Minimum Conc.	10%	25%	75%	90%	Maximum Conc. [2]
(2-Methyl-1-Propenyl)-Benzene	µg/L	1	1	1.00	3.2							
1,2,3,4-Tetrahydro-5-Methylnaphthalene	µg/L	1	1	1.00	24							
1,2,3,4-Tetrahydro-6-Methylnaphthalene	µg/L	2	2	1.00	19	33	4.6	4.6	4.6	33	33	33
1,2,3,4-Tetrahydro	µg/L	2	2	1.00	12	22	3.2	3.2	3.2	22	22	22
1,2,4-Trimethylbenzene	µg/L	7	7	1.00	6.1	1.8	0.12	0.12	0.30	3.8	32	32
1,3,5-Trimethylbenzene	µg/L	7	5	0.71	2.1	0.70				0.92	7.2	7.2
1,3-Methylnaphthalene	µg/L	1	1	1.00	4.2							
1,7-Methylnaphthalene	µg/L	1	1	1.00	19							
2,3-Dihydro-4-Methyl-1H-Indene	µg/L	1	1	1.00	53							
2,6-Dimethyl	µg/L	1	1	1.00	41							
2-Butanone	µg/L	7	7	1.00	17	7.8	2.6	2.6	3.0	32	40	40
2-Ethyl-1,3,5-Trimethyl-Benzene	µg/L	1	1	1.00	4.4							
2-Ethyl-1,4-Dimethyl-Benzene	µg/L	1	1	1.00	20							
2-Hexanone	µg/L	7	5	0.71	2.1	1.1				2.9	3.2	3.2
4-Isopropyltoluene	µg/L	7	3	0.43	1.8					1.3	1.4	1.4
4-Methyl-2-Pentanone	µg/L	7	3	0.43	1.9					0.80	1.6	1.6
Acetone	µg/L	8	8	1.00	58	34	6.0	6.0	15	110	150	150
Benzene	µg/L	12	9	0.75	12	2.3			0.17	5.4	84	120
Benzocycloheptatriene	µg/L	1	1	1.00	39							
Biphenyl	µg/L	8	6	0.75	4.1	3.0			0.27	4.5	12	12
Chloroform	µg/L	12	4	0.33	1.7					1.0	2.1	2.1
Dimethocxymethane	µg/L	1	1	1.00	89							
Ethylbenzene	µg/L	12	6	0.50	2.3	0.10				0.83	12	16
Isopropylbenzene	µg/L	7	3	0.43	1.9					1.4	1.5	1.5

Table 3.6.7. Results of Inboard Propulsion Engine Sample Analyses for VOCs [1]

Analyte	Units	No. Samples	No. Detected	Detected Proportion (%)	Average Conc. [2]	Median Conc.	Minimum Conc.	10%	25%	75%	90%	Maximum Conc. [2]
m-,p-Xylene (sum of isomers)	µg/L	7	7	1.00	11	1.8	0.30	0.30	0.90	2.0	70	70
Methyl acetate	µg/L	7	1	0.14	2.4						1.5	1.5
Methyl tertiary butyl ether (MTBE)	µg/L	7	1	0.14	2.4						1.9	1.9
Methylene chloride	µg/L	12	4	0.33	1.2					0.14	0.19	0.20
n-Butylbenzene	µg/L	7	3	0.43	1.8					1.0	1.1	1.1
n-Pentadecane	µg/L	2	2	100	24	31	16	16	16	31	31	31
n-Propylbenzene	µg/L	7	4	57	1.5	0.15				0.40	2.2	2.2
n-Tetradecane	µg/L	2	2	100	20	33	6.5	6.5	6.5	33	33	33
O-Xylene	µg/L	7	7	100	5.5	1.5	0.20	0.20	0.65	1.8	32	32
sec-Butylbenzene	µg/L	7	1	14	2.3						1.4	1.4
Styrene	µg/L	7	7	100	6.1	1.3	0.13	0.13	0.50	3.4	35	35
Toluene	µg/L	12	8	67	11	0.90				2.8	80	110
Trichlorofluoromethane	µg/L	12	1	8.3	2.1						1.9	2.7
Vinyl acetate	µg/L	7	1	14	2.4						1.9	1.9

Notes:

(1) Nondetect (censored) concentrations were replaced with ½ of the reporting limit for calculating average concentrations. The remaining statistics in this table were only calculated when analytes were detected at a sufficient frequency. For example, if an analyte was detected in fewer than 50% of samples, then a median concentration was not calculated. A blank cell reflects a situation when a median or percentile could not be computed based on detected concentrations. The percentiles are the concentrations of each analyte below which at least that percentage of the values fall. So the 10th percentile is the concentration below which at least 10% of the observations were found.

(2) In some cases, the detected concentration(s) for an analyte could be lower than the replacement value (½ of the reporting limit) for a concentration that was nondetected. In an extreme (but possible) case, this could result in an average concentration for an analyte that is greater than the maximum detected concentration.

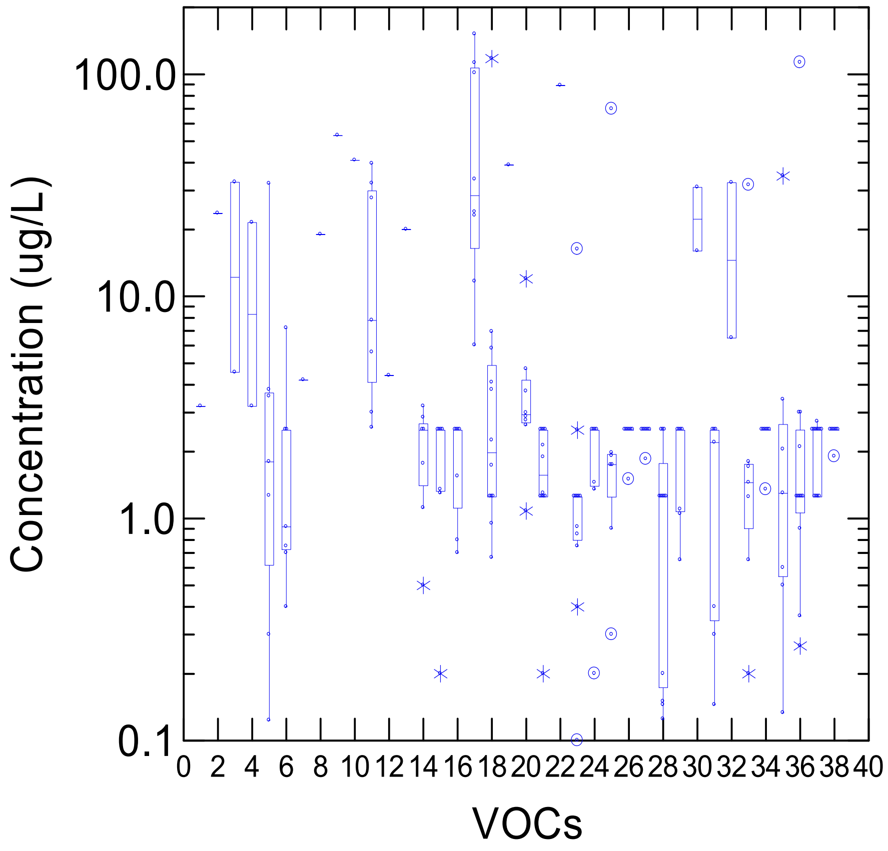

Figure 3.6.8. Box and Dot Density Plot of Volatile Organic Compounds Concentrations Measured in P.L. 110-299 Study Samples of Inboard Propulsion Engine Effluent

VOCs are identified as follows:

(1) (2-Methyl-1-Propenyl)-Benzene
(2) 1,2,3,4-Tetrahydro-5-Methylnaphthalene
(3) 1,2,3,4-Tetrahydro-6-Methylnaphthalene
(4) 1,2,3,4-Tetrahydronaphthalene
(5) 1,2,4-Trimethylbenzene
(6) 1,3,5-Trimethylbenzene
(7) 1,3-Methylnaphthalene
(8) 1,7-Methylnaphthalene
(9) 2,3-Dihydro-4-Methyl-1H-Indene
(10) 2,6-dimethylnaphthalene
(11) 2-Butanone
(12) 2-Ethyl-1,3,5-Trimethyl-Benzene
(13) 2-Ethyl-1,4-Dimethyl-Benzene
(14) 2-Hexanone,
(15) 4-Isopropyltoluene
(16) 4-Methyl-2-Pentanone
(17) Acetone
(18) Benzene
(19) Benzocycloheptatriene
(20) Biphenyl
(21) Chloroform
(22) Dimethoxymethane
(23) Ethylbenzene
(24) Isopropylbenzene
(25) m-,p-Xylene (sum of isomers)
(26) Methyl acetate
(27) Methyl tertiary butyl ether (MTBE)
(28) Methylene chloride
(29) n-Butylbenzene,
(30) n-Pentadecane
(31) n-Propylbenzene
(32) n-Tetradecane
(33) O-Xylene
(34) sec-Butylbenzene
(35) Styrene
(36) Toluene
(37) Trichlorofluoromethane
(38) Vinyl acetate

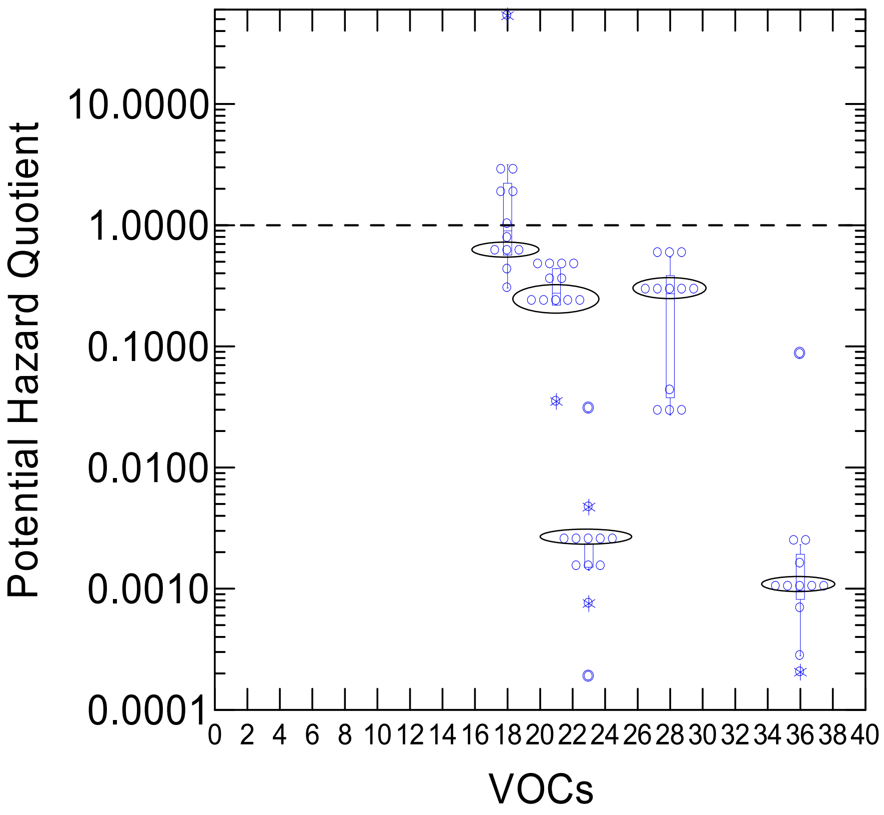

Figure 3.6.9. Box and Dot Density Plot of Potential Hazard Quotients for Volatile Organic Compounds in P.L. 110-299 Study Samples of Inboard Propulsion Engine Effluent

VOCs are identified as follows (replacement values for non-detects are circled):

(1) (2-Methyl-1-Propenyl)-Benzene
(2) 1,2,3,4-Tetrahydro-5-Methylnaphthalene
(3) 1,2,3,4-Tetrahydro-6-Methylnaphthalene
(4) 1,2,3,4-Tetrahydronaphthalene
(5) 1,2,4-Trimethylbenzene
(6) 1,3,5-Trimethylbenzene
(7) 1,3-Methylnaphthalene
(8) 1,7-Methylnaphthalene
(9) 2,3-Dihydro-4-Methyl-1H-Indene
(10) 2,6-dimethylnaphthalene
(11) 2-Butanone
(12) 2-Ethyl-1,3,5-Trimethyl-Benzene
(13) 2-Ethyl-1,4-Dimethyl-Benzene
(14) 2-Hexanone
(15) 4-Isopropyltoluene
(16) 4-Methyl-2-Pentanone
(17) Acetone
(18) Benzene
(19) Benzocycloheptatriene
(20) Biphenyl
(21) Chloroform
(22) Dimethoxymethane
(23) Ethylbenzene
(24) Isopropylbenzene
(25) m-,p-Xylene (sum of isomers)
(26) Methyl acetate
(27) Methyl tertiary butyl ether (MTBE)
(28) Methylene chloride
(29) n-Butylbenzene
(30) n-Pentadecane
(31) n-Propylbenzene
(32) n-Tetradecane
(33) O-Xylene
(34) sec-Butylbenzene
(35) Styrene
(36) Toluene
(37) Trichlorofluoromethane
(38) Vinyl acetate

3.2.6.2 Outboard Propulsion Engines

For this study, EPA collected samples of discharges from outboard propulsion engines on six vessels: four tow/salvage vessels and two research vessels (see Table 3.6.1 above). It is important to note that all six of these vessels were confirmed by the vessel owners/operators to be manufactured for pleasure. Vessels manufactured for pleasure are defined as recreational vessels under P.L. 110-288 and are not study vessels. Nonetheless, EPA has included the results here assuming they are representative of vessels with outboard propulsion engines, some of which may be study vessels. EPA also collected these results so that the Agency could later compare results between study vessels and recreational vessels if appropriate.

The Outboard Engine of a Tow and Salvage Vessel

3.2.6.2.1 Classical Pollutants

Outboard propulsion engine effluent samples were analyzed for 11 classical pollutants. Table 3.6.8 presents analytical results for the eight classical pollutants that were detected in one or more engine effluent samples. The detected results are also shown in Figure 3.6.10. EPA analyzed the sample results to determine which pollutants concentrations were contributed primarily by engine operations and which were contributed primarily by background ambient concentrations (see footnotes on table and figure). The remainder of this subsection discusses those pollutants found to be contributed primarily by engine operations.

Temperature increases in engine effluent above background were less than 5°C for all vessels. Engine effluent temperatures were only slightly higher (approximately 1°C) when vessels were operated at higher power levels as compared to idling.

Oil and grease (measured as HEM) was not detected in any of the engine effluent samples. SGT-HEM was detected in only two of 16 grab samples at concentrations significantly less than the reporting limit (sample concentrations of 0.86 mg/L and 0.94 mg/L, compared to reporting limit of 10 mg/L).

Table 3.6.8. Results of Outboard Propulsion Engine Sample Analyses for Classical Pollutants[1]

Analyte	Units	No. Samples	No. Detected	Detected Proportion (%)	Average Conc.	Median Conc.	Minimum Conc.	10%	25%	75%	90%	Maximum Conc.
Conductivity[3]	mS/cm	5	5	100	167	17	7.3	7.3	9.2	22	25	25
Dissolved Oxygen[2]	mg/L	5	5	100	6.2	6.3	5.7	5.7	5.9	6.4	6.4	6.4
pH[2]	SU	6	6	100	7.4	7.3	7.0	7.0	7.1	7.7	7.9	7.9
Salinity[3]	ppt	5	5	100	11	12	3.9	3.9	7.3	14	16	16
Silica Gel Treated HEM (SGT-HEM)	mg/L	6	2	33	4.5					3.6	3.6	3.6
Temperature	C	6	6	100	28	31	14	14	25	31	32	32
Total Suspended Solids (TSS) [3]	mg/L	6	2	33	8.1					13	17	17
Turbidity[2]	NTU	6	6	100	13	10	6.5	6.5	8.0	21	25	25

Notes:

(1) Nondetect (censored) concentrations were replaced with ½ of the reporting limit for calculating average concentrations. The remaining statistics in this table were only calculated when analytes were detected at a sufficient frequency. For example, if an analyte was detected in fewer than 50% of samples, then a median concentration was not calculated. A blank cell reflects a situation when a median or percentile could not be computed based on detected concentrations. The percentiles are the concentrations of each analyte below which at least that percentage of the values fall. So the 10th percentile is the concentration below which at least 10% of the observations were found.

(2) Sample concentrations were almost completely accounted for (≥ 90 percent) by background concentrations in ambient water.

(3) Sample concentrations were predominantly accounted for (≥ 50 percent and <90 percent) by background concentrations in ambient water.

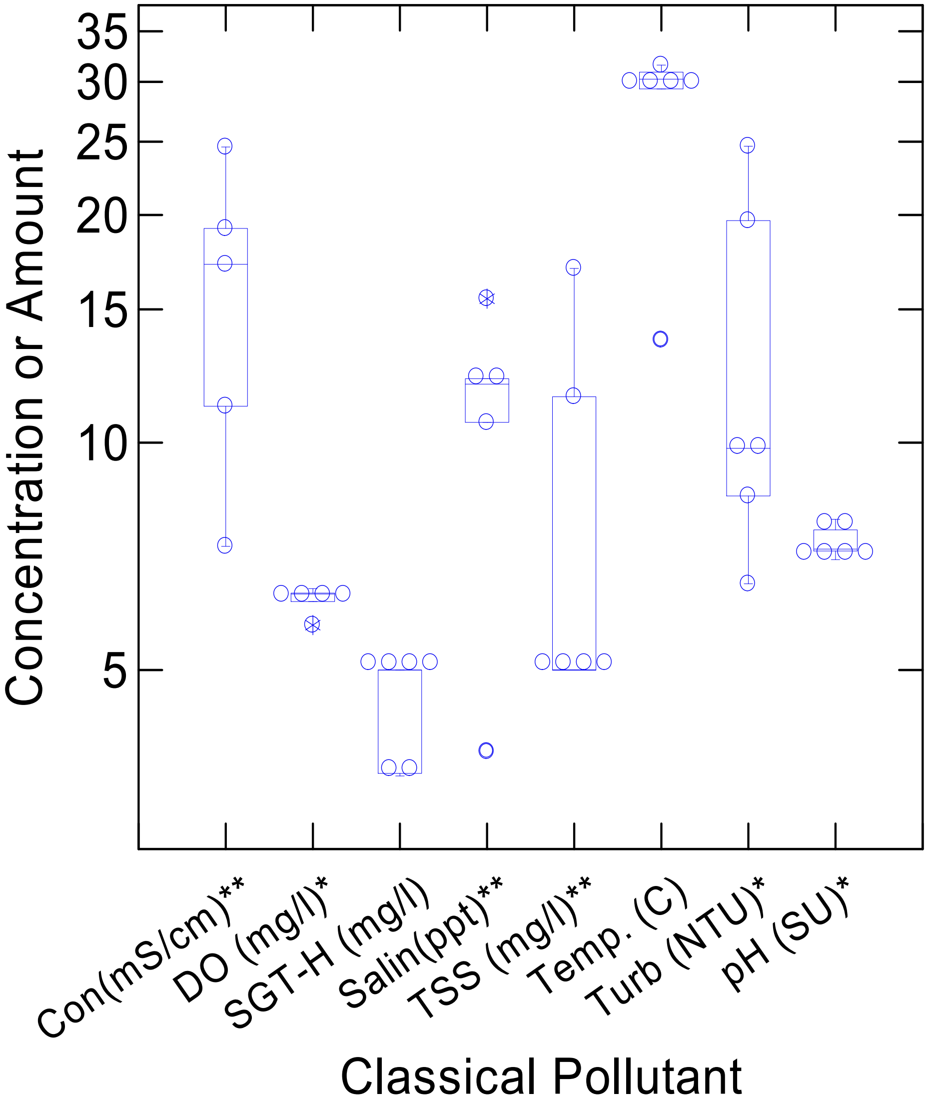

Figure 3.6.10. Box and Dot Density Plot of Classical Pollutant Values Measured in Samples of Outboard Propulsion Engine Effluent

* Sample concentrations were almost completely accounted for (≥ 90 percent) by background concentrations in ambient water.

** Sample concentrations were predominantly accounted for (≥ 50 percent and <90 percent) by background concentrations in ambient water.

3.2.6.2.2 Metals

Outboard propulsion engine effluent samples were analyzed for dissolved and total concentrations of 22 metals. Table 3.6.9 presents analytical results for the 14 metals that were detected in one or more engine effluent samples. The detected results are also shown in Figures 3.6.11 and 3.6.12 for dissolved and total metals, respectively. Figures 3.6.13 and 3.6.14 display the distribution of PHQs based on the screening benchmark for each of the dissolved and total metals. EPA analyzed the sample results to determine which metals were contributed primarily by engine operations and which were contributed primarily by background ambient concentrations (see footnotes on table and figures). The remainder of this subsection discusses those metals found to be contributed primarily by engine operations.

Dissolved and total concentrations for both vanadium and zinc are similar, which indicates that engine operations contribute these metals in dissolved rather that particulate form. Dissolved zinc was detected in all engine effluent samples at concentrations two to five times the reporting limit; none of the concentrations exceed the PHQ screening benchmark (a value of 81 µg/L based on the chronic saltwater criterion for aquatic life). Dissolved vanadium was detected in engine effluent from four of the six sampled vessels at concentrations close to the reporting limit (<2 times reporting limit of 1 µg/L). Dissolved vanadium does not have an NRWQC or other PHQ screening benchmark.

Total arsenic was detected in engine effluent from five of the six sampled vessels at concentrations two to five times the reporting limit (reporting limit = 8 µg/L), however, EPA suspects the measured concentrations of total (and dissolved) arsenic are elevated due to positive interference. Likewise, dissolved selenium was detected in all engine effluent samples at concentrations ranging from 2.4 to 100 µg/L; however, EPA suspects the measured concentrations of dissolved (and total) selenium are elevated due to positive interference.

Finally, concentrations in engine effluent discharges for dissolved copper, total aluminum, total iron, and total manganese that exceed benchmark concentrations appear to be caused by background concentrations in ambient water and not by engine operations.

Table 3.6.9. Results of Outboard Propulsion Engine Sample Analyses for Metals[1]

Analyte	Units	No. Samples	No. Detected	Detected Proportion (%)	Average Conc.	Median Conc.	Minimum Conc.	10%	25%	75%	90%	Maximum Conc.
Heavy and Other Metals												
Aluminum, Dissolved[2]	µg/L	6	5	83	7.4	8.2			5.1	9.7	10	10
Aluminum, Total[2]	µg/L	6	6	100	160	58	34	34	38	320	570	570
Arsenic, Dissolved[3,4]	µg/L	6	5	83	25	32			8.6	37	41	41
Arsenic, Total[3,4]	µg/L	6	5	83	24	30			9.9	34	41	41
Barium, Dissolved[2]	µg/L	6	6	100	25	15	13	13	14	41	57	57
Barium, Total[2]	µg/L	6	6	100	27	16	14	14	14	43	65	65
Copper, Dissolved[3]	µg/L	6	6	100	3.3	3.4	2.8	2.8	3.1	3.5	3.5	3.5
Copper, Total[3]	µg/L	6	5	83	3.6	3.4			2.4	3.8	3.9	3.9
Iron, Total[3]	µg/L	6	2	33	200					460	560	560
Manganese, Dissolved[2]	µg/L	6	6	100	6.0	5.4	1.0	1.0	1.2	10	18	18
Manganese, Total[3]	µg/L	6	6	100	57	35	29	29	29	91	140	140
Nickel, Dissolved[3]	µg/L	6	6	100	5.6	6.6	3.2	3.2	3.6	7.1	7.4	7.4
Nickel, Total[3]	µg/L	6	6	100	11	7.7	3.3	3.3	5.6	14	33	33
Selenium, Dissolved[3,4]	µg/L	6	6	100	76	97	2.4	2.4	24	110	130	130
Selenium, Total[3,4]	µg/L	6	6	100	72	94	1.5	1.5	22	100	120	120
Vanadium, Dissolved	µg/L	6	2	33	0.87					1.5	1.8	1.8
Vanadium,Total	µg/L	6	3	50	1.7	1.2				1.4	1.5	1.5
Zinc, Dissolved[3]	µg/L	6	6	100	11	11	3.5	3.5	7.1	14	19	19
Zinc, Total	µg/L	6	6	100	11	8.3	3.5	3.5	6.4	14	28	28
Cationic Metals												
Calcium, Dissolved[3]	µg/L	6	6	100	130000	160000	43000	43000	50000	170000	200000	200000
Calcium, Total[3]	µg/L	6	6	100	130000	160000	43000	43000	51000	170000	190000	190000
Magnesium, Dissolved[3]	µg/L	6	6	100	380000	480000	31000	31000	120000	520000	630000	630000

Table 3.6.9. Results of Outboard Propulsion Engine Sample Analyses for Metals[1]

Analyte	Units	No. Samples	No. Detected	Detected Proportion (%)	Average Conc.	Median Conc.	Minimum Conc.	10%	25%	75%	90%	Maximum Conc.
Magnesium, Total[3]	µg/L	6	6	100	370000	480000	31000	31000	120000	520000	600000	600000
Potassium, Dissolved[3]	µg/L	6	6	100	130000	160000	11000	11000	48000	190000	220000	220000
Potassium, Total[3]	µg/L	6	6	100	130000	160000	11000	11000	48000	180000	210000	210000
Sodium, Dissolved[3]	µg/L	6	6	100	2900000	3800000	220000	220000	1000000	4100000	4700000	4700000
Sodium,Total[3]	µg/L	6	6	100	2900000	3700000	220000	220000	1100000	4000000	4700000	4700000

Notes:

(1) Nondetect (censored) concentrations were replaced with ½ of the reporting limit for calculating average concentrations. The remaining statistics in this table were only calculated when analytes were detected at a sufficient frequency. For example, if an analyte was detected in fewer than 50% of samples, then a median concentration was not calculated. A blank cell reflects a situation when a median or percentile could not be computed based on detected concentrations. The percentiles are the concentrations of each analyte below which at least that percentage of the values fall. So the 10th percentile is the concentration below which at least 10% of the observations were found.

(2) Sample concentrations were almost completely accounted for (≥ 90 percent) by background concentrations in ambient water.

(3) Sample concentrations were predominantly accounted for (≥ 50 percent and <90 percent) by background concentrations in ambient water.

(4) Measured concentrations well above their respective reporting limits, are suspected of being elevated due to positive interference (See section 3.1.3).

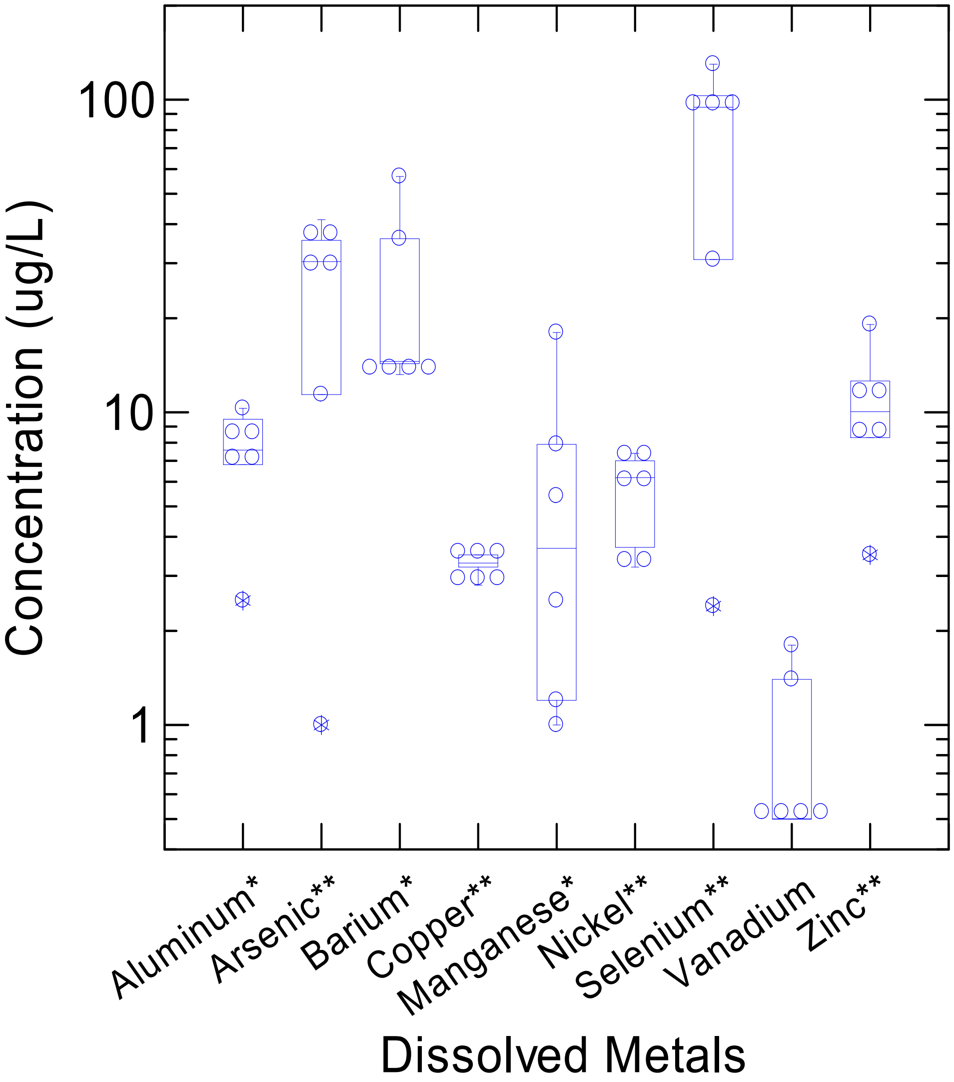

Figure 3.6.11. Box and Dot Density Plot of Dissolved Metals Concentrations Measured in Samples of Outboard Propulsion Engine Effluent

* Sample concentrations were almost completely accounted for (≥ 90 percent) by background concentrations in ambient water.

** Sample concentrations were predominantly accounted for (≥ 50 percent and <90 percent) by background concentrations in ambient water.

(Note: Measured concentrations well above their respective reporting limits for dissolved arsenic and selenium are suspected of being elevated due to positive interference).

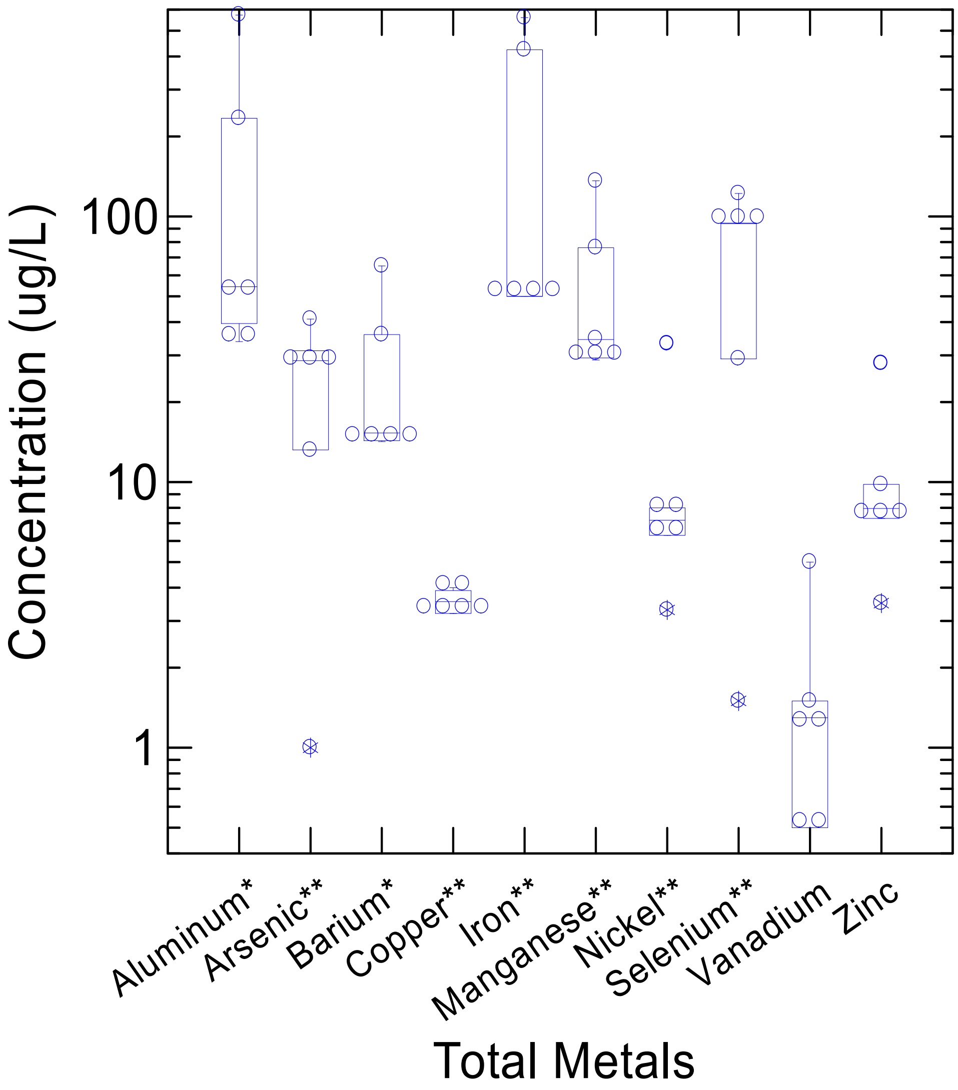

Figure 3.6.12. Box and Dot Density Plot of Total Metals Concentrations Measured in Samples of Outboard Propulsion Engine Effluent

* Sample concentrations were almost completely accounted for (≥ 90 percent) by background concentrations in ambient water.

** Sample concentrations were predominantly accounted for (≥ 50 percent and <90 percent) by background concentrations in ambient water.

(Note: Measured concentrations well above their respective reporting limits for total arsenic and selenium are suspected of being elevated due to positive interference).

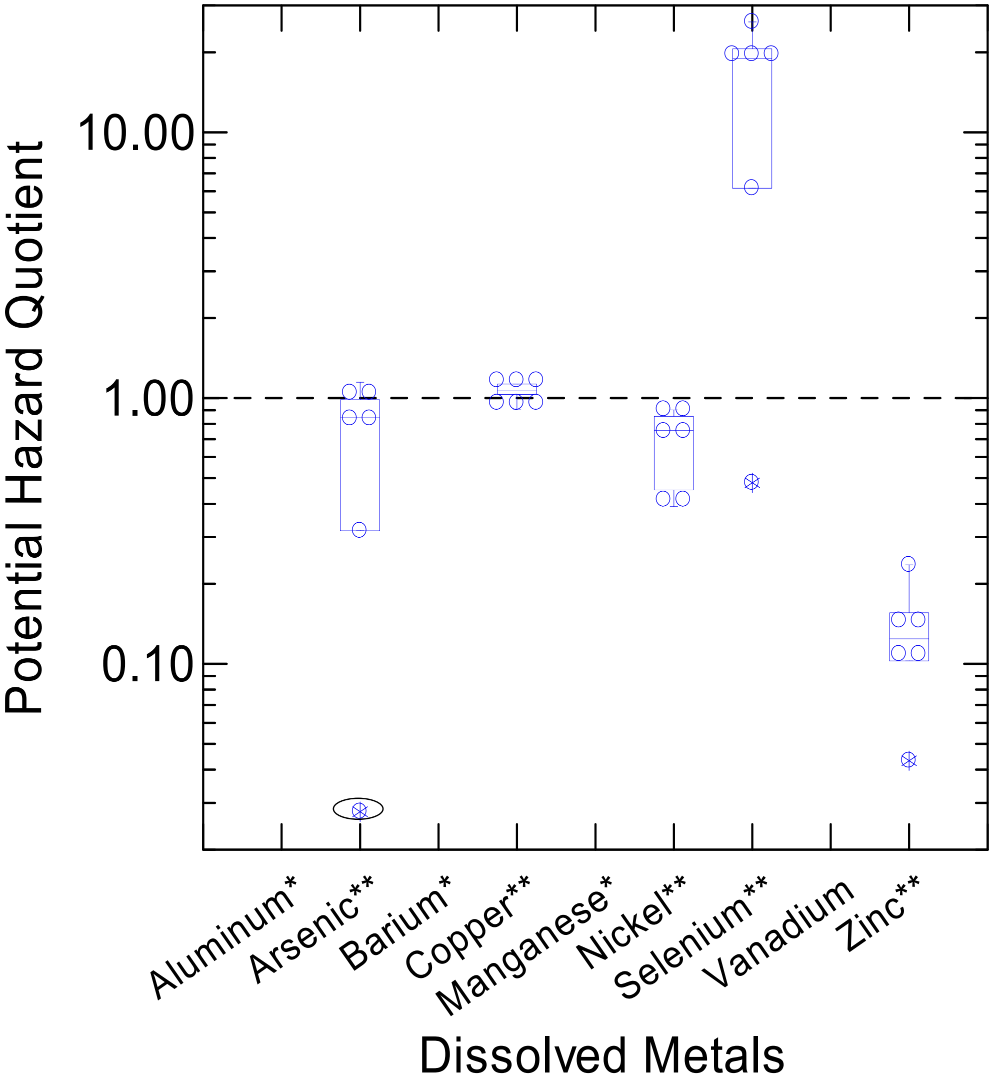

Figure 3.6.13. Box and Dot Density Plot of Potential Hazard Quotients for Dissolved Metals in Samples of Outboard Propulsion Engine Effluent

* Sample concentrations were almost completely accounted for (≥ 90 percent) by background concentrations in ambient water.

** Sample concentrations were predominantly accounted for (≥ 50 percent and <90 percent) by background concentrations in ambient water.

(Note: Replacement values for non-detects are circled. Also, measured concentrations well above their respective reporting limits for dissolved arsenic and selenium are suspected of being elevated due to positive interference).

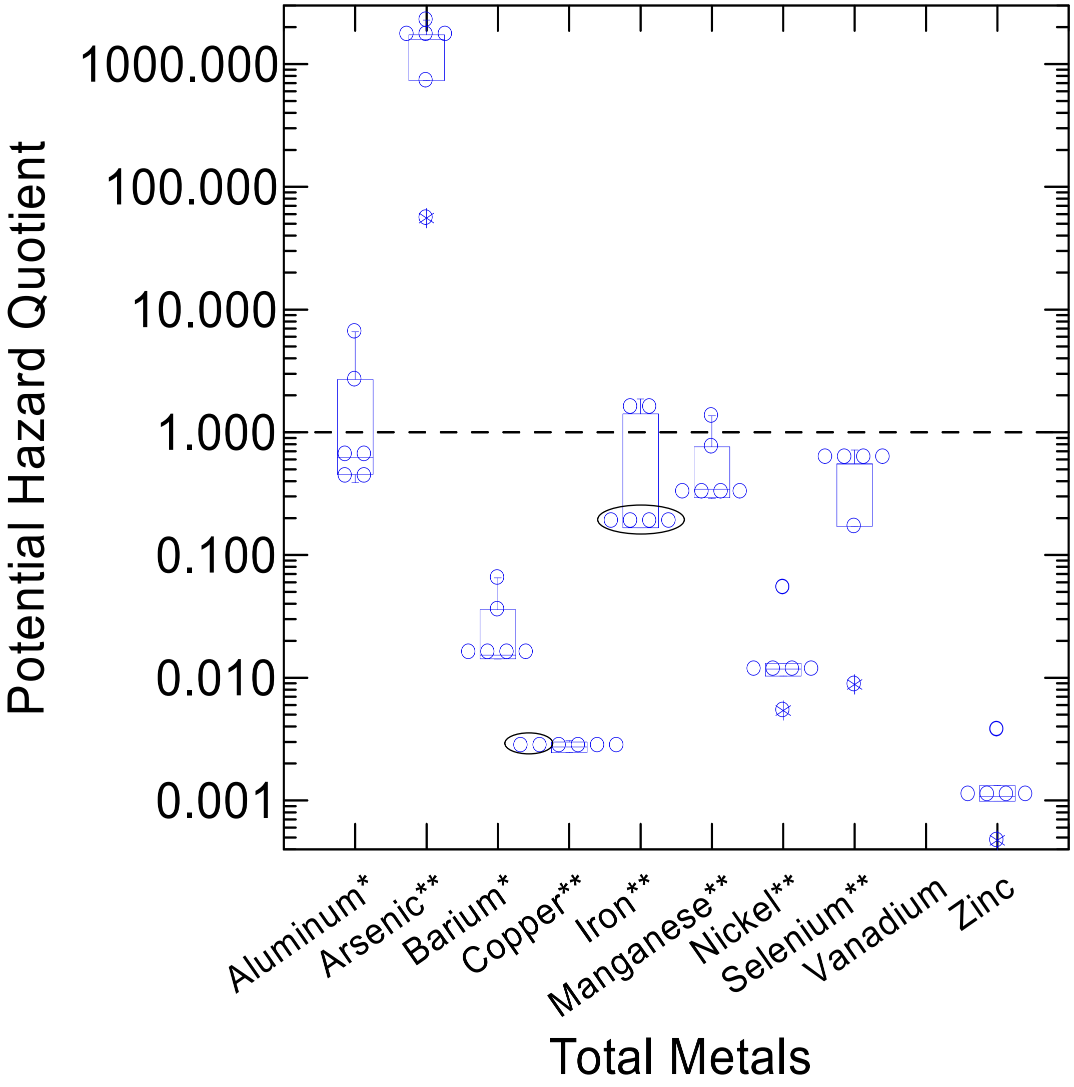

Figure 3.6.14. Box and Dot Density Plot of Potential Hazard Quotients for Total Metals in Samples of Outboard Propulsion Engine Effluent

* Sample concentrations were almost completely accounted for (≥ 90 percent) by background concentrations in ambient water.

** Sample concentrations were predominantly accounted for (≥ 50 percent and <90 percent) by background concentrations in ambient water.

(Note: Replacement values for non-detects are circled. Also, measured concentrations well above their respective reporting limits for total arsenic and selenium are suspected of being elevated due to positive interference).

3.2.6.2.3 Semivolatile Organic Compounds

Outboard propulsion engine effluent samples were analyzed for 62 SVOCs. Table 3.6.10 presents analytical results for the seven SVOCs that were detected in one or more engine effluent samples. The detected results are also shown in Figure 3.6.15. EPA analyzed the sample results to determine which SVOCs were contributed primarily by engine operations and which were contributed primarily by background ambient concentrations. All were found to be contributed primarily by engine operations.

The detected SVOCs can be classified among the following pollutant classes: polycyclic aromatic hydrocarbons (PAHs) (one analyte), phenol and methyl phenols (four analytes), phthalates (one analyte), and methylnaphthalenes (one analyte). All of these SVOCs were frequently detected in engine effluent (i.e., more than half of the sampled vessels). However, all of the detected SVOC concentrations are well below any applicable PHQ screening benchmarks. For example, the maximum PHQ for any of the detected SVOCs was 2,4-dimethylphenol with a PHQ of approximately 0.005. Therefore, SVOCs in engine effluent are highly unlikely to have the potential to pose risk to human health or the environment.

Table 3.6.10. Results of Outboard Propulsion Engine Sample Analyses for SVOCs [1]

Analyte	Units	No. Samples	No. Detected	Detected Proportion (%)	Average Conc.	Median Conc.	Minimum Conc.	10%	25%	75%	90%	Maximum Conc.
2,4-Dimethylphenol	µg/L	6	1	17	2.5					0.49	2.0	2.0
2-Methylnaphthalene	µg/L	6	2	33	2.4					1.5	2.8	2.8
Di-n-butyl phthalate	µg/L	6	3	50	2.4	1.2				2.3	3.5	3.5
m-Cresol	µg/L	6	2	33	2.6					1.9	4.2	4.2
Naphthalene	µg/L	6	5	83	7.8	2.0			1.4	12	35	35
p-Cresol	µg/L	6	2	33	3.7					3.9	9.8	9.8
Phenol	µg/L	6	2	33	4.6					5.9	14	14

Notes:

(1) Nondetect (censored) concentrations were replaced with ½ of the reporting limit for calculating average concentrations. The remaining statistics in this table were only calculated when analytes were detected at a sufficient frequency. For example, if an analyte was detected in fewer than 50% of samples, then a median concentration was not calculated. A blank cell reflects a situation when a median or percentile could not be computed based on detected concentrations. The percentiles are the concentrations of each analyte below which at least that percentage of the values fall. So the 10th percentile is the concentration below which at least 10% of the observations were found.

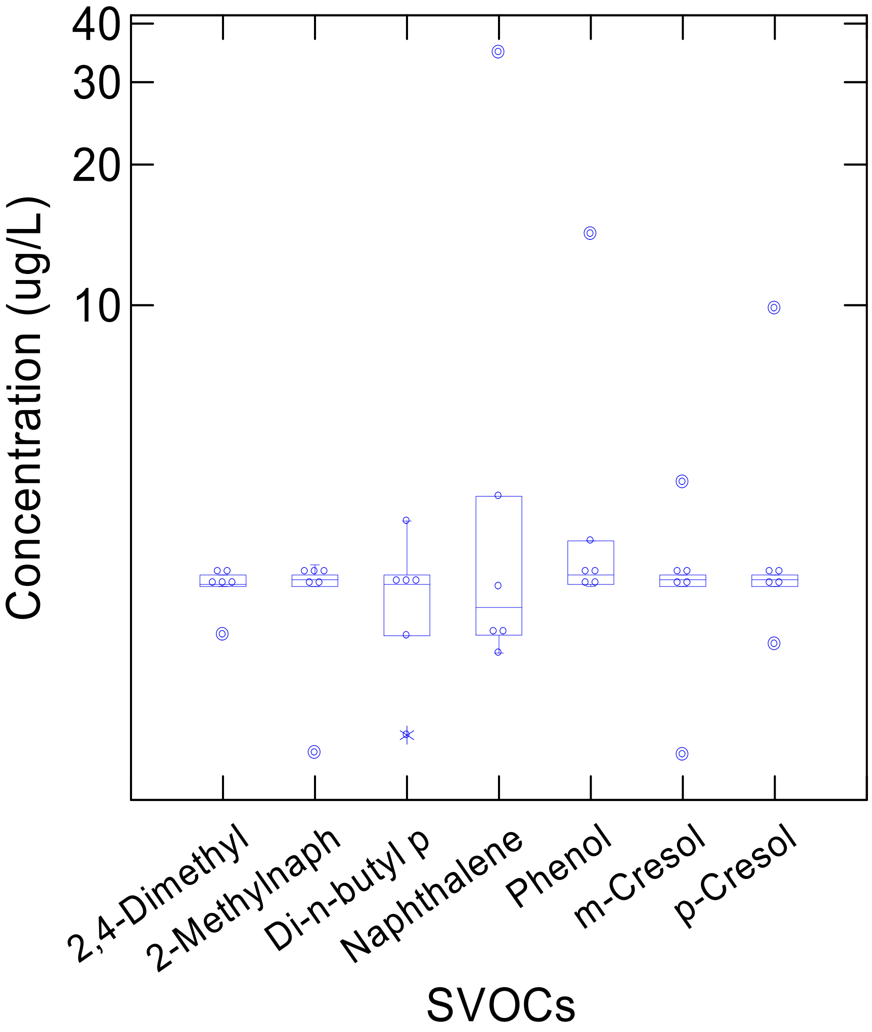

Figure 3.6.15. Box and Dot Density Plot of SVOC Concentrations Measured in Samples of Outboard Propulsion Engine Effluent

(Note: two analyte names were truncated: 2-Methylnaphalene and Di-n-butyl phthalate).

3.2.6.2.4 Volatile Organic Compounds

Outboard propulsion engine effluent samples were analyzed for 70 VOCs. Table 3.6.11 presents analytical results for the 18 VOCs that were detected in one or more engine effluent samples. The detected results are also shown in Figures 3.6.16 and 3.6.17 for analyte concentrations and for PHQs based on the lowest NRWQC or other PHQ screening benchmark where applicable, respectively. EPA analyzed the sample results to determine which VOCs were contributed primarily by engine operations and which were contributed primarily by background ambient concentrations. All were found to be contributed primarily by engine operations. Some of these compounds are volatile constituents of fuel, specifically benzene, toluene, ethylbenzene, and xylene. Others are trimethylbenzenes, which are naturally present in fuel, and one is a ketone, which may be formed as a product of incomplete combustion. Among these compounds, benzene, ethylbenzene, and toluene have an NRWQC. Most of the detected benzene concentrations exceeded the PHQ screening benchmark of 2.2 µg/L (human heath for consumption of water and aquatic organisms), including discharges from the two research vessels that exceed the benchmark by factors of five and 28. None of the detected ethylbenzene and toluene concentrations exceeded the PHQ screening benchmarks.

The final one-third of the detected VOCs were detected relatively infrequently (i.e., detected in fewer than half the sampled vessels). Among these compounds, only methylene chloride has an NRWQC. However, none of the detected methylene chlorine concentrations exceeded the screening benchmark.

Table 3.6.11. Results of Outboard Propulsion Engine Sample Analyses for VOCs [1]

Analyte	Units	No. Samples	No. Detected	Detected Proportion (%)	Average Conc. [2]	Median Conc.	Minimum Conc.	10%	25%	75%	90%	Maximum Conc. [2]
1,2,4-Trimethylbenzene	µg/L	6	6	100	13	2.3	0.30	0.30	0.53	24	63	63
1,3,5-Trimethylbenzene	µg/L	6	5	83	4.6	1.9			0.75	6.5	18	18
2-Butanone	µg/L	6	2	33	3.8					3.8	12	12
2-Hexanone	µg/L	6	1	17	2.5					0.56	2.3	2.3
4-Methyl-2-Pentanone	µg/L	6	1	17	2.3					0.35	1.4	1.4
Acetone	µg/L	6	5	83	7.8	2.5			1.4	11	34	34
Benzene	µg/L	6	6	100	13	2.4	0.13	0.13	0.76	24	62	62
Cyclohexane	µg/L	6	1	17	2.4					0.41	1.7	1.7
Ethylbenzene	µg/L	6	6	100	8.2	2.1	0.90	0.90	0.92	14	38	38
Isopropylbenzene	µg/L	6	2	33	2.4					1.3	3.8	3.8
m-,p-Xylene (sum of isomers)	µg/L	6	6	100	28	3.4	0.33	0.33	0.43	52	140	140
Methyl tertiary butyl ether (MTBE)	µg/L	6	1	17	2.3					0.34	1.4	1.4
Methylcyclohexane	µg/L	6	1	17	2.3					0.36	1.5	1.5
Methylene chloride	µg/L	6	5	83	0.58	0.20			0.15	0.20	0.20	0.20
n-Propylbenzene	µg/L	6	4	67	3.2	1.7				3.6	9.4	9.4
O-Xylene	µg/L	6	6	100	15	4.0	0.17	0.17	0.43	26	70	70
Styrene	µg/L	6	5	83	4.9	3.4			0.22	6.6	16	16
Toluene	µg/L	6	6	100	52	3.8	0.40	0.40	0.75	98	260	260

Notes:

(1) Nondetect (censored) concentrations were replaced with ½ of the reporting limit for calculating average concentrations. The remaining statistics in this table were only calculated when analytes were detected at a sufficient frequency. For example, if an analyte was detected in fewer than 50% of samples, then a median concentration was not calculated. A blank cell reflects a situation when a median or percentile could not be computed based on detected concentrations. The percentiles are the concentrations of each analyte below which at least that percentage of the values fall. So the 10th percentile is the concentration below which at least 10% of the observations were found.

(2) In some cases, the detected concentration(s) for an analyte could be lower than the replacement value (½ of the reporting limit) for a concentration that was nondetected. In an extreme (but possible) case, this could result in an average concentration for an analyte that is greater than the maximum detected concentration.

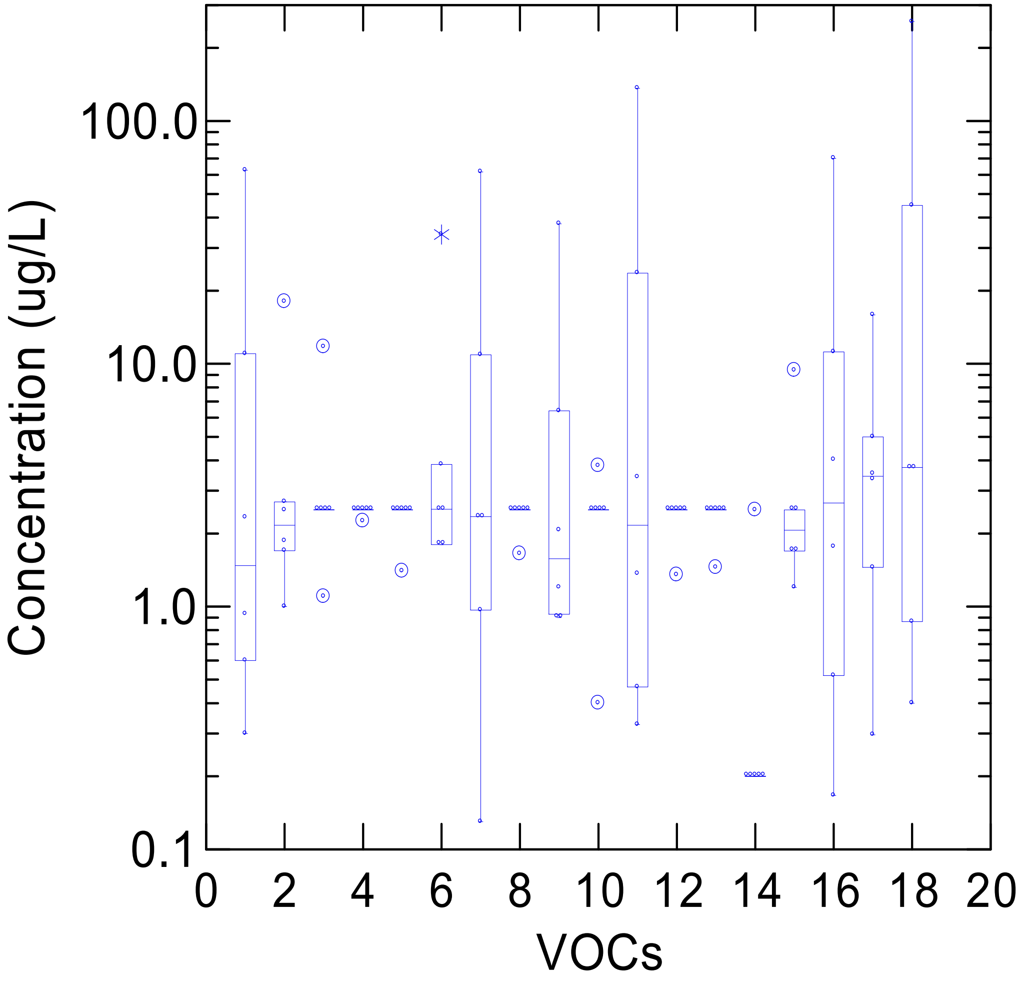

Figure 3.6.16. Box and Dot Density Plot of Volatile Organic Compounds Concentrations Measured in Samples of Outboard Propulsion Engine Effluent

VOCs are identified as follows:

(1) 1,2,4-Trimethylbenzene
(2) 1,3,5-Trimethylbenzene
(3) 2-Butanone
(4) 2-Hexanone
(5) 4-Methyl-2-Pentanone
(6) Acetone
(7) Benzene
(8) Cyclohexane
(9) Ethylbenzene
(10) Isopropylbenzene
(11) m-,p-Xylene (sum of isomers)
(12) Methyl tertiary butyl ether (MTBE)
(13) Methylcyclohexane
(14) Methylene chloride
(15) n-Propylbenzene
(16) O-Xylene
(17) Styrene
(18) Toluene

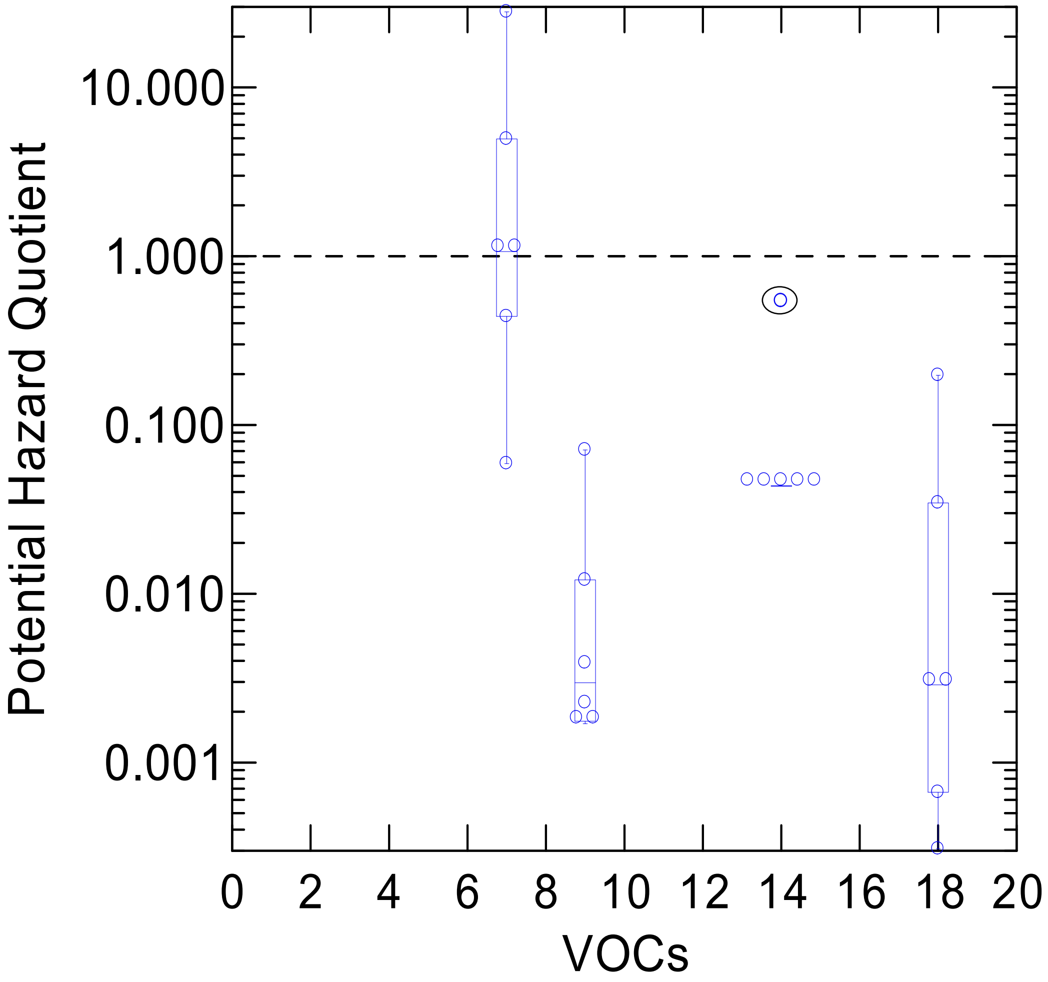

Figure 3.6.17. Box and Dot Density Plot of Potential Hazard Quotients for Volatile Organic Compounds in Samples of Outboard Propulsion Engine Effluent

VOCs are identified as follows (replacement values for non-detects are circled):

(1) 1,2,4-Trimethylbenzene
(2) 1,3,5-Trimethylbenzene
(3) 2-Butanone
(4) 2-Hexanone
(5) 4-Methyl-2-Pentanone
(6) Acetone
(7) Benzene
(8) Cyclohexane
(9) Ethylbenzene
(10) Isopropylbenzene
(11) m-,p-Xylene (sum of isomers)
(12) Methyl tertiary butyl ether (MTBE)
(13) Methylcyclohexane
(14) Methylene chloride
(15) n-Propylbenzene
(16) O-Xylene
(17) Styrene
(18) Toluene

3.2.6.3 Generator Engines

For this study, EPA collected cooling water discharge samples from engines on generator sets onboard five vessels: a fishing vessel, a fire boat, two tour boats, and a water taxi (Table 3.6.1). These engines included both direct and indirect cooling discharges from both gasoline- and diesel-fueled engines.

The Generator on a Fire Boat

3.2.6.3.1 Classical Pollutants

Table 3.6.12 presents analytical results for 11 classical pollutants detected in samples of discharges from generator engines (all classical pollutants analyzed for were detected). The detected results are also shown in Figure 3.6.18. EPA analyzed the sample results to determine which pollutant concentrations were contributed primarily by generator engine operations and which were contributed primarily by background ambient concentrations (see footnotes on table and figure). The remainder of this subsection discusses those classical pollutants found to be contributed primarily by generator engine operations.

Temperature increases in generator engine effluent above background were approximately 5°C for the fishing vessel, fire boat, and water taxi. For the two tour boats, temperature increases were 9 and 13°C.

Oil and grease (measured as HEM) was detected in engine effluent from three of the five sampled generators; however, detected concentrations were low, ranging from less than the reporting limit to just above the reporting limit (reporting limit = 5 mg/L). All sample results were well below the 33 CFR Part 151.10 prohibition of the discharge of oil and oily mixtures with an oil content greater than 15 ppm into seawater from vessels.

Sulfide was detected in only one of five samples at a concentration of 0.012 mg/L, which is slightly above the reporting limit of 0.01 mg/L. This concentration is six times greater than the most conservative PHQ screening benchmark – a 2006 NRWQC value of 0.002 mg/L for the protection of aquatic life. Sulfide could be present due to entrainment in fuel, as a product of incomplete combustion, or due to formation within the biofilm in the cooling system piping.

TRC was detected in only one generator engine effluent sample collected from a water taxi at a concentration of 0.15 mg/L. This detected concentration is 20 times greater than the PHQ screening benchmark of 0.0075 mg/L. There is no known source of TRC for this vessel as background concentration of the ambient water at this location was below detection and the generator did not use service water that might contain TRC.

Table 3.6.12. Results of Generator Engine Sample Analyses for Classical Pollutants[1]

Analyte	Units	No. Samples	No. Detected	Detected Proportion (%)	Average Conc. [4]	Median Conc.	Minimum Conc.	10%	25%	75%	90%	Maximum Conc. [4]
Conductivity[2]	mS/cm	4	4	100	11	0.31	0.23	0.23	0.23	32	43	43
Dissolved Oxygen[2]	mg/L	4	4	100	5.3	6.2	1.9	1.9	2.6	7.7	8.2	8.2
Hexane Extractable Material (HEM)	mg/L	5	3	60	2.9	1.1				4.3	5.8	5.8
pH[2]	SU	5	5	100	6.5	6.6	5.7	5. 7	5.9	7.0	7.0	7.0
Salinity[3]	ppt	4	4	100	6.5	0.20	0.10	0.10	0.10	19	25	25
Silica Gel Treated HEM (SGT-HEM)	mg/L	5	1	20	4.2					0.55	1.1	1.1
Sulfide	mg/L	4	1	25	0.0068					0.0090	0.012	0.012
Temperature	C	5	5	100	21	20	18	18	19	24	26	26
Total Residual Chlorine	mg/L	5	1	20	0.060					0.075	0.15	0.15
Total Suspended Solids (TSS)[3]	mg/L	4	3	75	9.0	12			2.1	13	13	13
Turbidity[2]	NTU	5	5	100	27	33	1.3	1.3	14	38	39	39

Notes:

(1) Nondetect (censored) concentrations were replaced with ½ of the reporting limit for calculating average concentrations. The remaining statistics in this table were only calculated when analytes were detected at a sufficient frequency. For example, if an analyte was detected in fewer than 50% of samples, then a median concentration was not calculated. A blank cell reflects a situation when a median or percentile could not be computed based on detected concentrations. The percentiles are the concentrations of each analyte below which at least that percentage of the values fall. So the 10th percentile is the concentration below which at least 10% of the observations were found.

(2) Sample concentrations were almost completely accounted for (≥ 90 percent) by background concentrations in ambient water.

(3) Sample concentrations were predominantly accounted for (≥ 50 percent and <90 percent) by background concentrations in ambient water.

(4) In some cases, the detected concentration(s) for an analyte could be lower than the replacement value (½ of the reporting limit) for a concentration that was nondetected. In an extreme (but possible) case, this could result in an average concentration for an analyte that is greater than the maximum detected concentration.

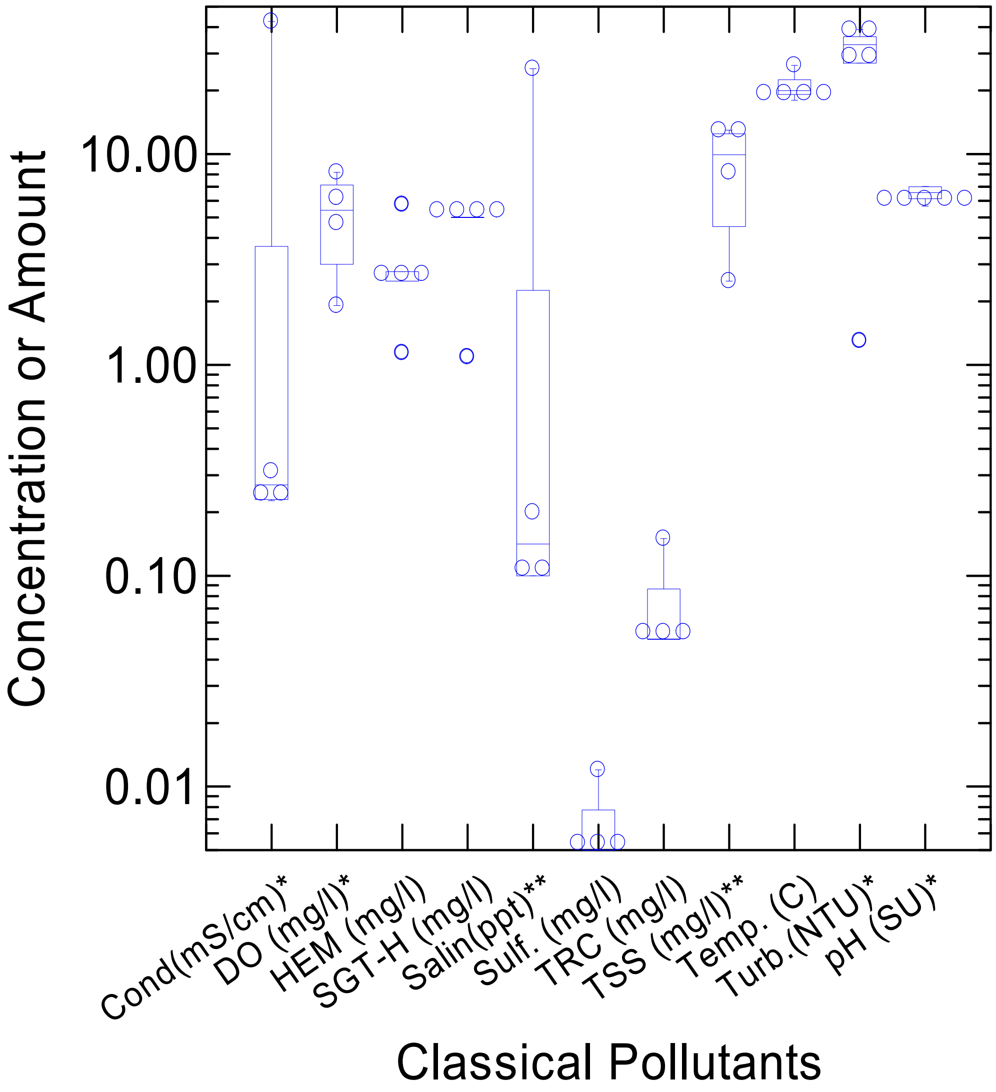

Figure 3.6.18. Box and Dot Density Plot of Classical Pollutant Values Measured in Samples of Generator Engine Effluent

* Sample concentrations were almost completely accounted for (≥ 90 percent) by background concentrations in ambient water.

** Sample concentrations were predominantly accounted for (≥ 50 percent and <90 percent) by background concentrations in ambient water.

3.2.6.3.2 Metals

Generator engine effluent samples were analyzed for dissolved and total concentrations of 22 metals. Table 3.6.13 presents analytical results for the 11 metals that were detected. The detected results are also shown in Figures 3.6.19 and 3.6.20 for dissolved and total metals, respectively. Figures 3.6.21 and 3.6.22 display the distribution of PHQs based on the screening benchmark for each of the dissolved and total metals. EPA analyzed the sample results to determine which metals were contributed primarily by generator engine operations and which were contributed primarily by background ambient concentrations (see footnotes on table and figures). The remainder of this subsection discusses those metals found to be contributed primarily by generator engine operations.

Dissolved and total metals concentrations are similar, which indicates that engine operations contribute metals in dissolved rather that particulate form. Dissolved copper was detected in all five generator effluent samples at concentrations ranging from 2.4 to 13 µg/L. Total copper was detected in two of the five samples at concentrations of 2.4 and 11 µg/L (reporting limit = 5 µg/L). Dissolved copper concentrations exceeded the PHQ screening benchmark of 3.1 µg/L (2006 NRWQC saltwater chronic aquatic life criterion) by as much as five times. In contrast, none of the total copper concentrations exceeded the PHQ screening benchmark of 1,300 µg/L (human health criterion based on consumption of water and aquatic organisms).

Dissolved manganese was detected in four of the five generator engine effluent samples. Manganese was predominantly in particulate form in background ambient water; therefore, dissolved manganese concentrations in engine effluent samples are assumed to be contributed by engine operations. NRWQCs or other PHQ screening benchmarks have not been determined for dissolved manganese.

Dissolved zinc was detected in two of the five generator engine effluent samples. Detected concentrations were 21 to 29 µg/L, which are substantially lower than the screening benchmark of 81 µg/L (2006 NRWQC saltwater chronic aquatic life criterion).

Finally, concentrations in generator engine effluent discharges that exceed benchmark concentrations for total aluminum are likely caused or heavily influenced by higher concentrations in ambient water (which exceeded benchmark concentrations).

Table 3.6.13. Results of Generator Engine Sample Analyses for Metals[1]

Analyte	Units	No. Samples	No. Detected	Detected Proportion (%)	Average Conc. [4]	Median Conc.	Minimum Conc.	10%	25%	75%	90%	Maximum Conc. [4]
Heavy and Other Metals												
Aluminum, Dissolved[2]	µg/L	5	5	100	280	160	11	11	86	540	870	870
Aluminum, Total[2]	µg/L	5	5	100	420	390	120	120	220	640	890	890
Barium, Dissolved[2]	µg/L	1	1	100	37							
Barium, Total[2]	µg/L	1	1	100	37							
Copper, Dissolved	µg/L	5	5	100	6.5	5.6	2.4	2.4	3.9	9.5	13	13
Copper, Total	µg/L	5	2	40	4.2					6.7	11	11
Iron, Total[2]	µg/L	1	1	100	200							
Manganese, Dissolved	µg/L	5	4	80	33	36			16	49	53	53
Manganese, Total[3]	µg/L	5	4	80	40	43			17	59	63	63
Nickel, Dissolved[3]	µg/L	5	1	20	4.5					1.4	2.7	2.7
Nickel, Total[3]	µg/L	5	1	20	3.5					1.4	2.7	2.7
Zinc, Dissolved	µg/L	5	2	40	13					25	29	29
Zinc, Total[3]	µg/L	5	3	60	11	12				15	19	19
Cationic Metals												
Calcium, Dissolved[2]	µg/L	5	5	100	80000	26000	23000	23000	24000	160000	290000	290000
Calcium, Total[2]	µg/L	5	5	100	82000	28000	27000	27000	27000	160000	290000	290000
Magnesium, Dissolved[2]	µg/L	5	5	100	180000	5900	5200	5200	5200	440000	870000	870000
Magnesium, Total[2]	µg/L	5	5	100	180000	6600	5900	5900	5950	450000	890000	890000
Potassium, Dissolved[2]	µg/L	1	1	100	4000							
Potassium, Total[2]	µg/L	1	1	100	3600							
Sodium, Dissolved[2]	µg/L	1	1	100	37000							
Sodium,Total[2]	µg/L	1	1	100	36000							

Notes:

(1) Nondetect (censored) concentrations were replaced with ½ of the reporting limit for calculating average concentrations. The remaining statistics in this table were only calculated when analytes were detected at a sufficient frequency. For example, if an analyte was detected in fewer than 50% of samples, then a median concentration was not calculated. A blank cell reflects a situation when a median or percentile could not be computed based on detected concentrations. The percentiles are the concentrations of each analyte below which at least that percentage of the values fall. So the 10th percentile is the concentration below which at least 10% of the observations were found.

(2) Sample concentrations were almost completely accounted for (≥ 90 percent) by background concentrations in ambient water.

(3) Sample concentrations were predominantly accounted for (≥ 50 percent and <90 percent) by background concentrations in ambient water.

(4) In some cases, the detected concentration(s) for an analyte could be lower than the replacement value (½ of the reporting limit) for a concentration that was nondetected. In an extreme (but possible) case, this could result in an average concentration for an analyte that is greater than the maximum detected concentration.

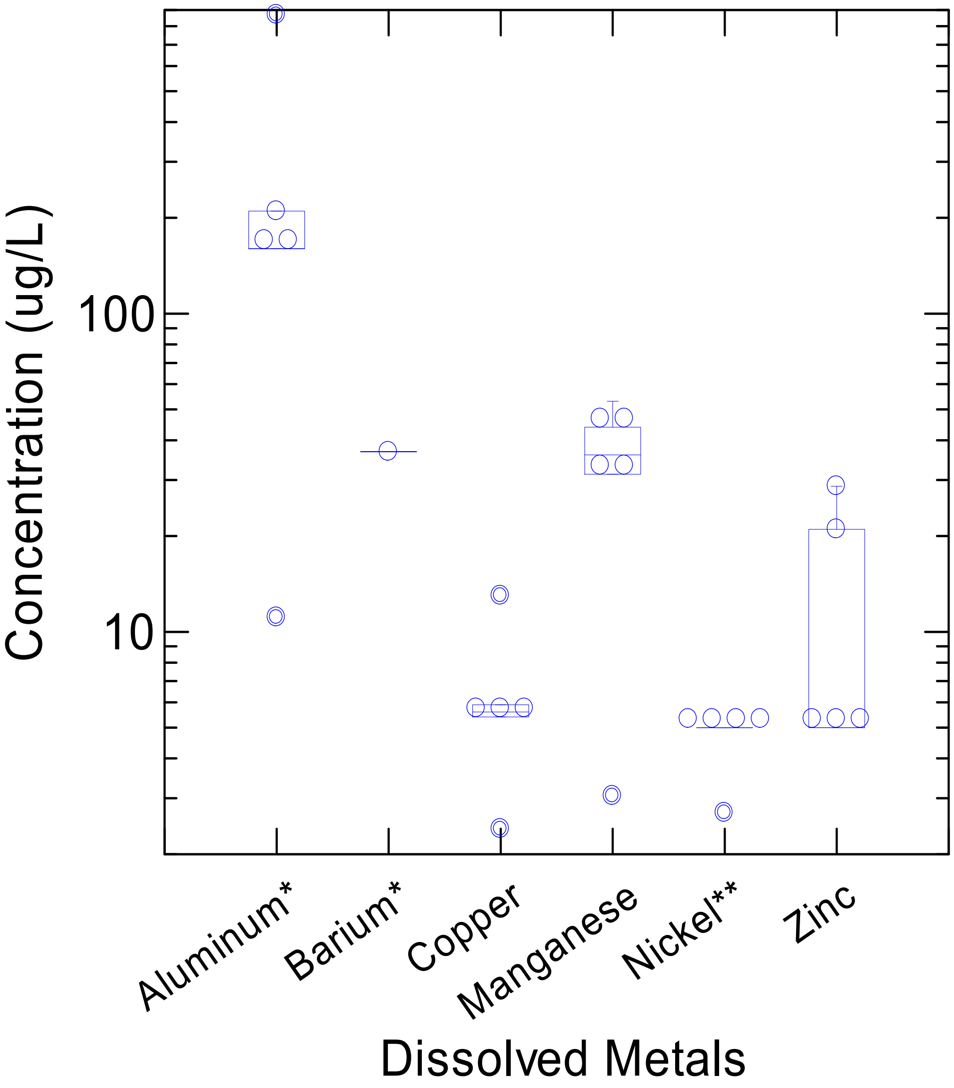

Figure 3.6.19. Box and Dot Density Plot of Dissolved Metals Concentrations Measured in Samples of Generator Engine Effluent

* Sample concentrations were almost completely accounted for (≥ 90 percent) by background concentrations in ambient water.

** Sample concentrations were predominantly accounted for (≥ 50 percent and <90 percent) by background concentrations in ambient water.

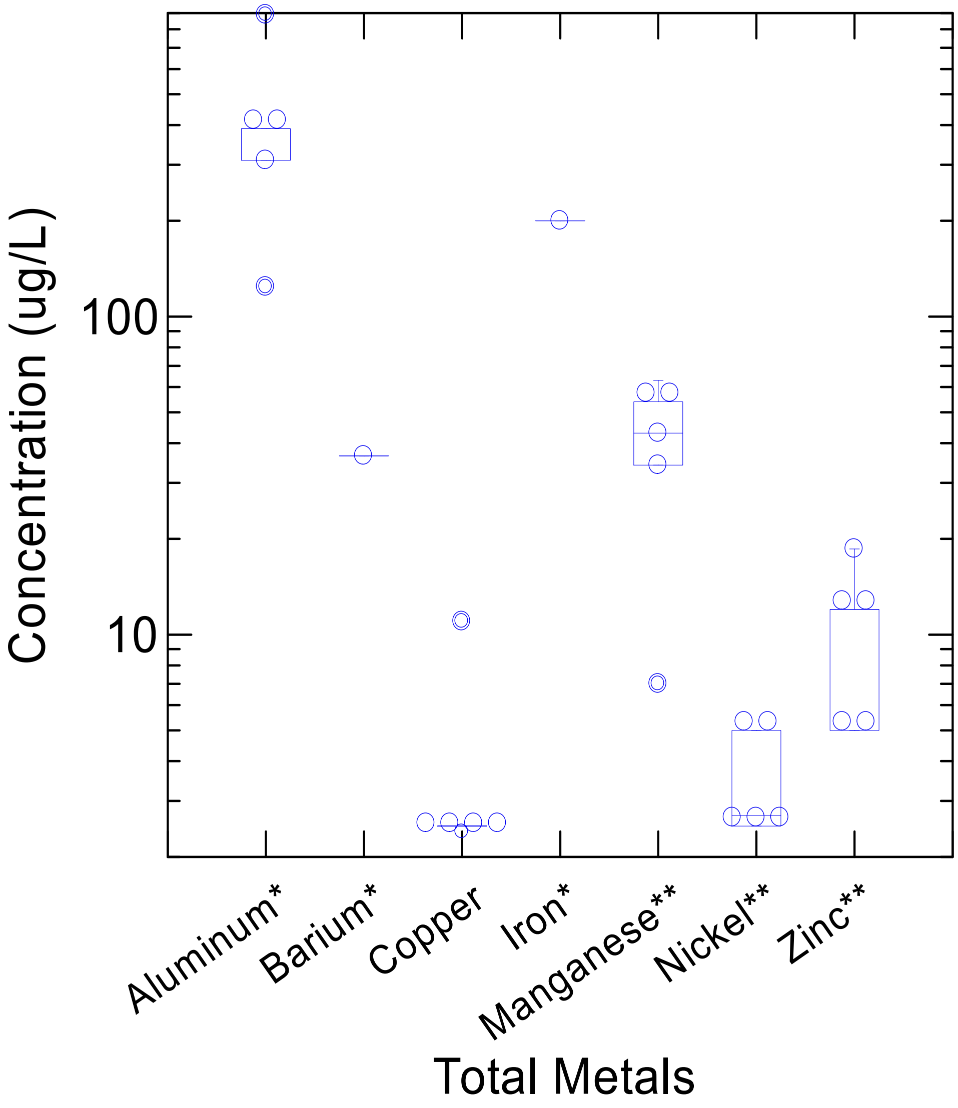

Figure 3.6.20. Box and Dot Density Plot of Total Metals Concentrations Measured in Samples of Generator Engine Effluent

* Sample concentrations were almost completely accounted for (≥ 90 percent) by background concentrations in ambient water.

** Sample concentrations were predominantly accounted for (≥ 50 percent and <90 percent) by background concentrations in ambient water.

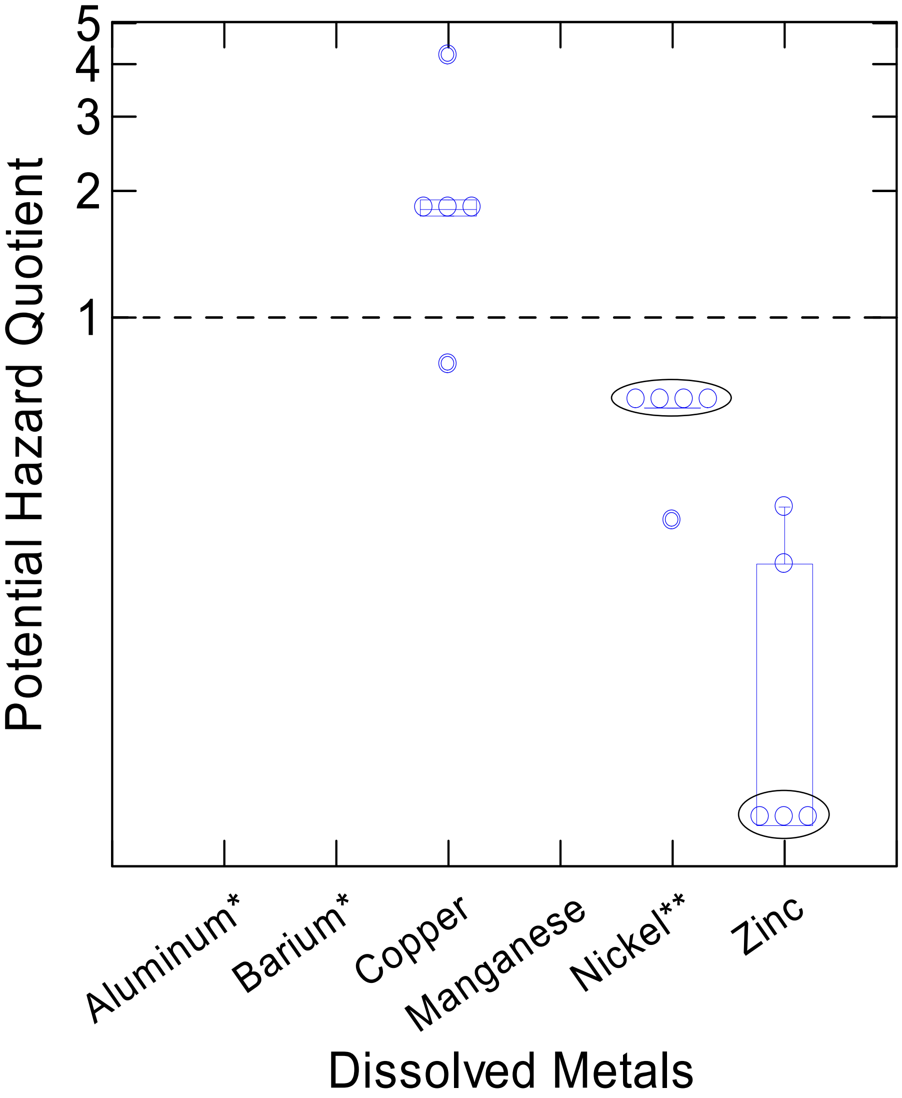

Figure 3.6.21. Box and Dot Density Plot of Potential Hazard Quotients for Dissolved Metals in Samples of Generator Engine Effluent

* Sample concentrations were almost completely accounted for (≥ 90 percent) by background concentrations in ambient water.

** Sample concentrations were predominantly accounted for (≥ 50 percent and <90 percent) by background concentrations in ambient water.

(Note: Replacement values for non-detects are circled).

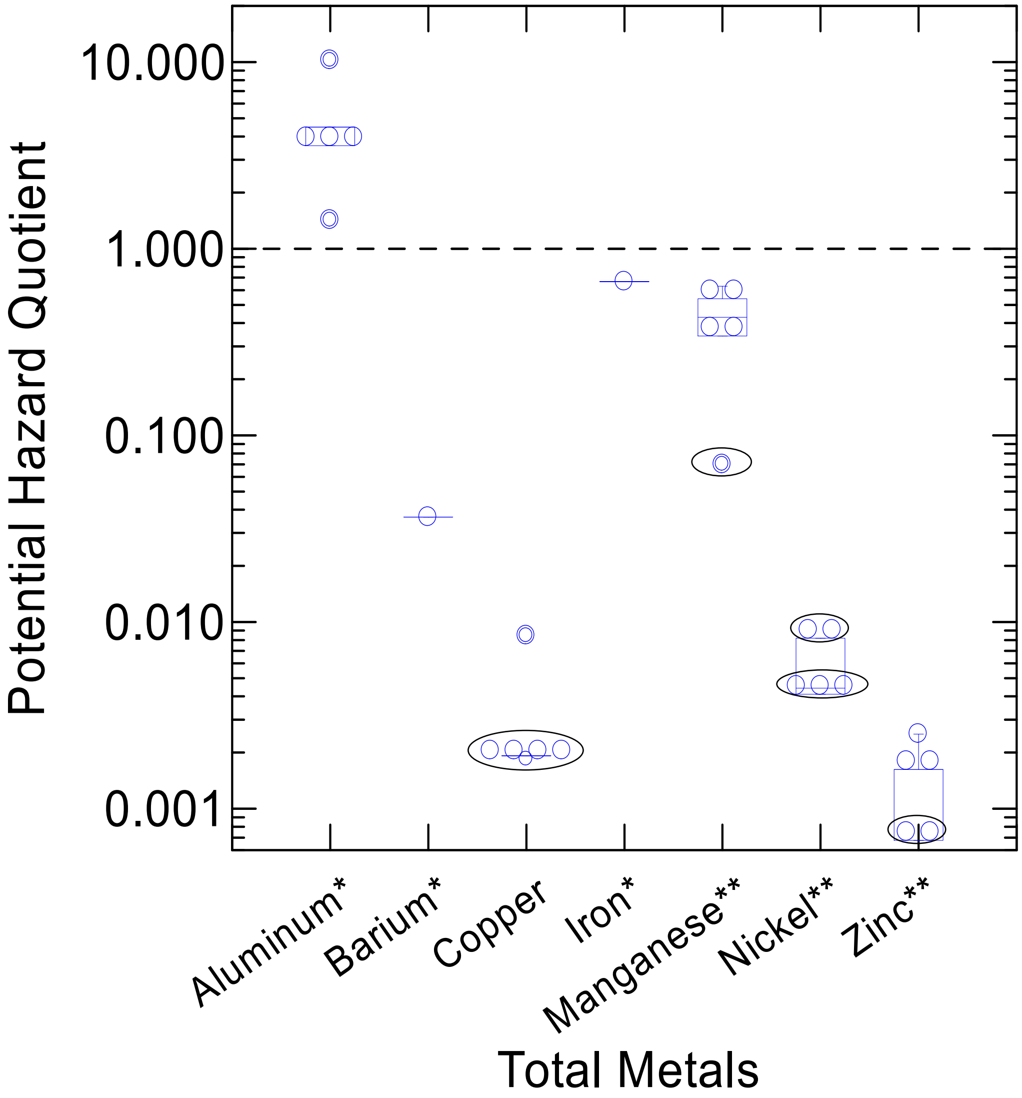

Figure 3.6.22. Box and Dot Density Plot of Potential Hazard Quotients for Total Metals in Samples of Generator Engine Effluent

* Sample concentrations were almost completely accounted for (≥ 90 percent) by background concentrations in ambient water.

** Sample concentrations were predominantly accounted for (≥ 50 percent and <90 percent) by background concentrations in ambient water.

(Note: Replacement values for non-detects are circled).

3.2.6.3.3 Semivolatile Organic Compounds

Generator engine effluent samples were analyzed for 79 SVOCs. Table 3.6.14 presents analytical results for the 26 SVOCs that were detected in one or more engine effluent samples (14 of the detected SVOCs were analyzed for and detected in only one generator effluent sample). The detected results are shown in Figures 3.6.23 and 3.6.24 for analyte concentrations and PHQs based on the lowest applicable NRWQC or other PHQ screening benchmark. EPA analyzed the sample results to determine which SVOCs were contributed primarily by generator engine operations and which were contributed primarily by background ambient concentrations. All were found to be contributed primarily by generator engine operations.

Many of the detected SVOCs can be classified among the following pollutant classes: PAHs (five analytes), straight-chain hydrocarbons (six analytes), phenol and methyl phenols (five analytes), and phthalates (two analytes). These include all of the SVOCs analyzed for and detected most frequently and at the highest concentrations.

PAHs are present in fuels in small amounts and may be formed as products of incomplete combustion. However, none of the detected PAH concentrations exceeded the screening benchmarks for these analytes, indicating that they are unlikely to have the potential to pose risk to human health or the environment.

Straight-chain (alkane) hydrocarbons are also components of fuel. None of these analytes has an NRWQC or other PHQ screening benchmark, and they are not PBT chemicals. Therefore, the straight-chain hydrocarbons detected in engine effluent are unlikely to have the potential to pose risk to human health or the environment.

Phenol and methyl phenols are also present in petroleum products and may also be generated as products of incomplete combustion. Discharges of phenol and methyl phenols are assumed not to result in any environmental impacts as detected concentrations did not exceed the screening benchmarks for these analytes.

Phthalates are plasticizers (chemicals added to plastics to make them flexible) and are commonly detected in environmental samples (ATSDR, 2002). Bis(2-ethylhexyl) phthalate was detected at concentration just above the screening benchmark of 1.2 μg/L (human heath for consumption of water and aquatic organisms).

The generator engine effluent sample from the fire boat contained the maximum concentration of 12 of the detected SVOCs. These include all five of the detected PAHs, four of the five detected phenols and methyl phenols, and both of the detected phthalates. The generator effluent sample from a tour boat contained the maximum concentration of all six of the detected straight-chain hydrocarbons.

Table 3.6.14. Results of Generator Engine Sample Analyses for SVOCs[1]

Analyte	Units	No. Samples	No. Detected	Detected Proportion (%)	Average Conc.[2]	Median Conc.	Minimum Conc.	10%	25%	75%	90%	Maximum Conc.[2]
1-methylnaphthalene	µg/L	3	3	100	6.7	5.4	3.8	3.8	3.8	11	11	11
2,4-Dimethylphenol	µg/L	5	1	20	2.6					4.0	7.9	7.9
2-Cyclopenten1-one	µg/L	2	2	100	8.5	13	3.9	3.9	3.9	13	13	13
2-Hydroxy-Benzaldehyde	µg/L	2	2	100	11	17	4.3	4.3	4.3	17	17	17
2-Methylnaphthalene	µg/L	4	4	100	16	10	4.6	4.6	5.5	32	40	40
2-Naphthalene	µg/L	2	2	100	18	20	16	16	16	20	20	20
3-Methyl-Benzaldehyde	µg/L	1	1	100	18							
3-Methylphenol	µg/L	1	1	100	12							
3-Phenyl-2-Propenal	µg/L	1	1	100	8.1							
Acenaphthylene	µg/L	5	1	20	1.8					1.9	3.8	3.8
Acetophenone	µg/L	1	1	100	11							
Bis(2-ethylhexyl) phthalate	µg/L	5	1	20	1.3					0.63	1.3	1.3
Di-n-butyl phthalate	µg/L	5	1	20	1.3					0.59	1.2	1.2
Eicosane	µg/L	1	1	100	32							
Fluorene	µg/L	5	1	20	2.0					2.4	4.9	4.9
Heneicosane	µg/L	1	1	100	22							
Heptadecane	µg/L	3	3	100	30	8.9	4.1	4.1	4.1	76	76	76
m-Cresol	µg/L	1	1	100	18							
Naphthalene	µg/L	5	4	80	17	7.3			2.3	36	61	61
n-Hexadecane	µg/L	1	1	100	46							
Nonadecane	µg/L	1	1	100	40							
Octadecane	µg/L	1	1	100	44							
p-Cresol	µg/L	1	1	100	43							

Table 3.6.14. Results of Generator Engine Sample Analyses for SVOCs [1]

Analyte	Units	No. Samples	No. Detected	Detected Proportion (%)	Average Conc. [2]	Median Conc.	Minimum Conc.	10%	25%	75%	90%	Maximum Conc. [2]
Phenanthrene	µg/L	5	3	60	3.9	3.2				6.8	9.7	9.7
Phenol	µg/L	5	4	80	23	13			2.1	48	75	75
Pyrene	µg/L	5	1	20	1.4					0.90	1.8	1.8

Notes:
(1) Nondetect (censored) concentrations were replaced with ½ of the reporting limit for calculating average concentrations. The remaining statistics in this table were only calculated when analytes were detected at a sufficient frequency. For example, if an analyte was detected in fewer than 50% of samples, then a median concentration was not calculated. A blank cell reflects a situation when a median or percentile could not be computed based on detected concentrations. The percentiles are the concentrations of each analyte below which at least that percentage of the values fall. So the 10th percentile is the concentration below which at least 10% of the observations were found.
(2) In some cases, the detected concentration(s) for an analyte could be lower than the replacement value (½ of the reporting limit) for a concentration that was nondetected. In an extreme (but possible) case, this could result in an average concentration for an analyte that is greater than the maximum detected concentration.

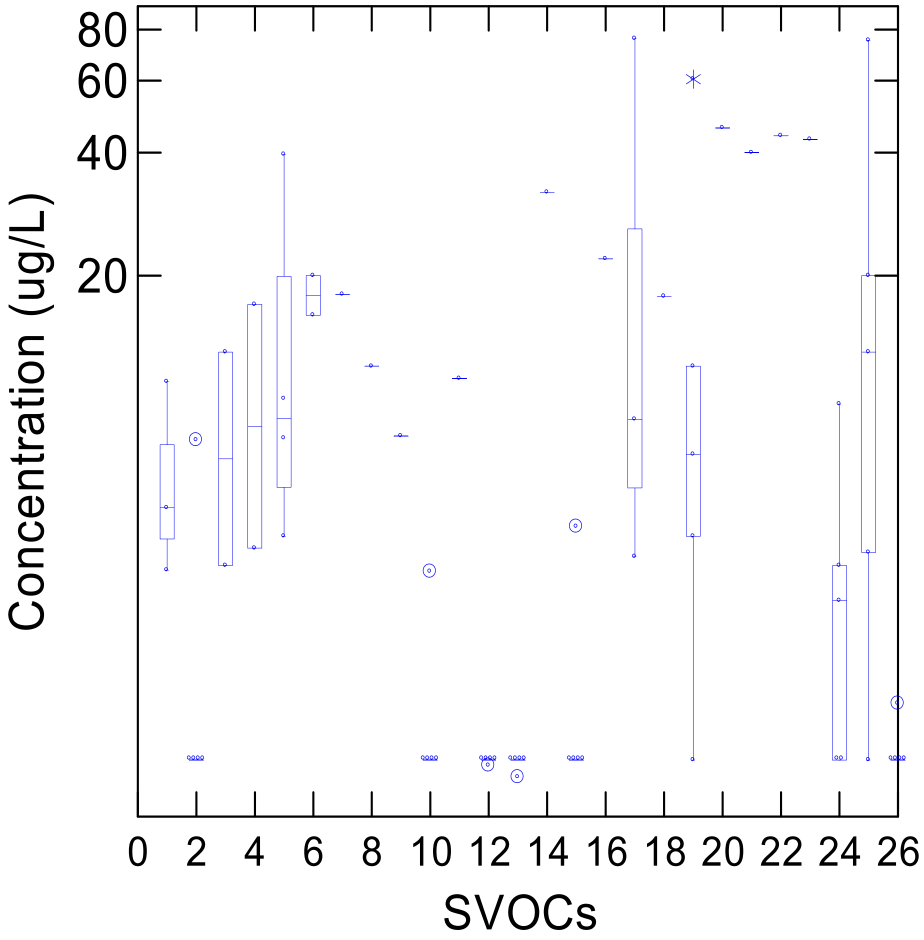

Figure 3.6.23. Box and Dot Density Plot of SVOC Concentrations Measured in Samples of Generator Engine Effluent

SVOCs are identified as follows:

(1) 1-methylnaphthalene
(2) 2,4-Dimethylphenol
(3) 2-Cyclopenten1-one
(4) 2-Hydroxy-Benzaldehyde
(5) 2-Methylnaphthalene
(6) 2-Naphthalenecarboxaldehyde
(7) 3-Methyl-Benzaldehyde
(8) 3-Methylphenol
(9) 3-Phenyl-2-Propenal
(10) Acenaphthylene
(11) Acetophenone
(12) Bis(2-ethylhexyl) phthalate
(13) Di-n-butyl phthalate
(14) Eicosane
(15) Fluorene
(16) Heneicosane
(17) Heptadecane
(18) m-Cresol
(19) Naphthalene
(20) n-Hexadecane
(21) Nonadecane
(22) Octadecane
(23) p-Cresol
(24) Phenanthrene
(25) Phenol
(26) Pyrene

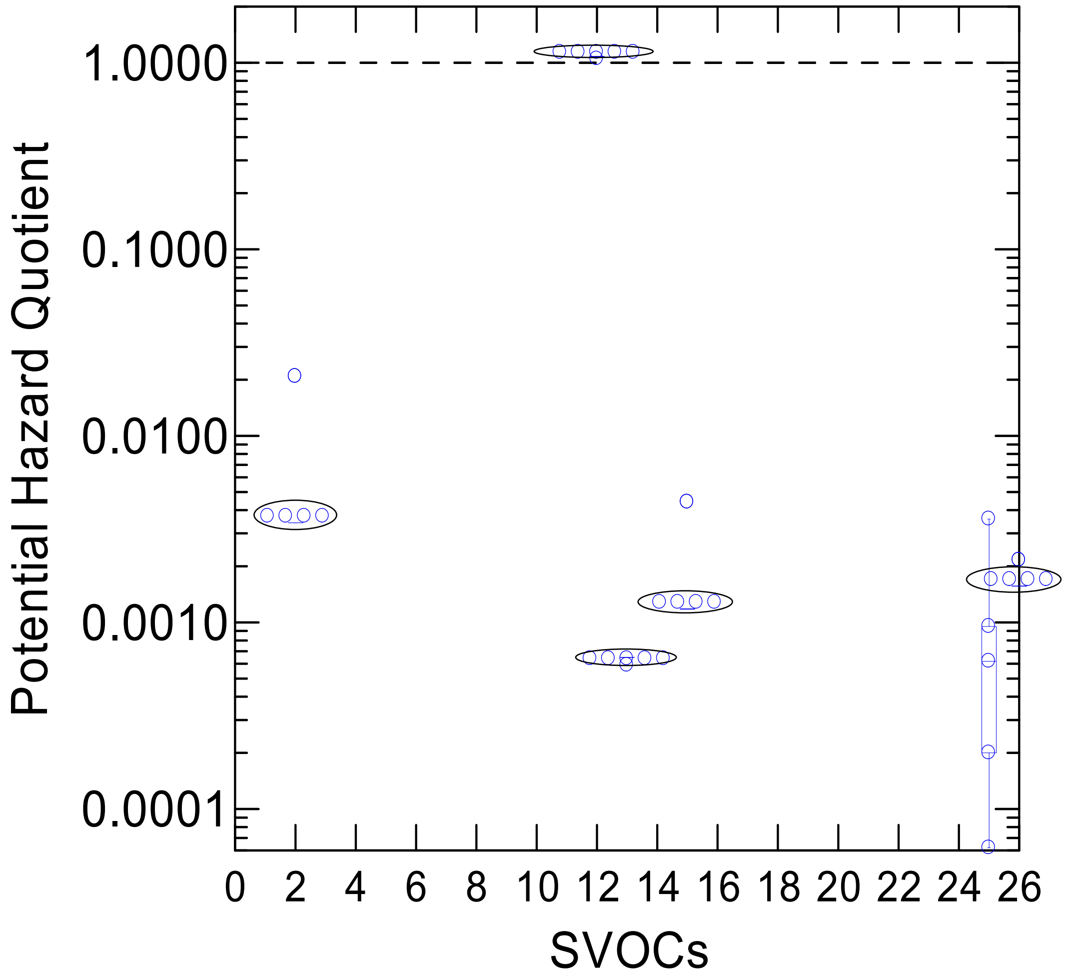

Figure 3.6.24. Box and Dot Density Plot of Potential Hazard Quotients for SVOCs in Samples of Generator Engine Effluent

SVOCs are identified as follows (replacement values for non-detects are circled):

(1) 1-methylnaphthalene
(2) 2,4-Dimethylphenol
(3) 2-Cyclopenten1-one
(4) 2-Hydroxy-Benzaldehyde
(5) 2-Methylnaphthalene
(6) 2-Naphthalenecarboxaldehyde
(7) 3-Methyl-Benzaldehyde
(8) 3-Methylphenol
(9) 3-Phenyl-2-Propenal
(10) Acenaphthylene
(11) Acetophenone
(12) Bis(2-ethylhexyl) phthalate
(13) Di-n-butyl phthalate
(14) Eicosane
(15) Fluorene
(16) Heneicosane
(17) Heptadecane
(18) m-Cresol
(19) Naphthalene
(20) n-Hexadecane
(21) Nonadecane
(22) Octadecane
(23) p-Cresol
(24) Phenanthrene
(25) Phenol
(26) Pyrene

3.2.6.3.4 Volatile Organic Compounds

Generator engine effluent samples were analyzed for 80 VOCs. Table 3.6.15 presents analytical results for the 28 VOCs that were detected. The detected results are also shown in Figures 3.6.25 and 3.6.26 for analyte concentrations and for PHQs based on the lowest NRWQC or other PHQ screening benchmark, where applicable, respectively. EPA analyzed the sample results to determine which VOCs were contributed primarily by generator engine operations and which were contributed primarily by background ambient concentrations. All were found to be contributed primarily by generator engine operations.

Twenty-two of the detected VOCs were analyzed for in only one sample. None of these compounds has an NRWQC or are PBT chemicals. Of the seven detected VOCs that were analyzed for in more than one sample, three have an NRWQC: benzene, ethylbenzene, and toluene. All of the detected benzene concentrations (from three of the five samples) exceeded the PHQ screening benchmark of 2.2 µg/L by factors ranging from one to nine. The single detected concentration for each of ethylenebenzene and toluene did not exceed their respective PHQ screening benchmarks.

Note that the generator effluent sample from the fire boat contained the maximum concentration of 19 of the detected VOCs. These include benzene, toluene, ethylbenzene, xylene, trimethylbenzenes, and ketones.

Table 3.6.15. Results of Generator Engine Sample Analyses for VOCs[1]

Analyte	Units	No. Samples	No. Detected	Detected Proportion (%)	Average Conc.	Median Conc.	Minimum Conc.	10%	25%	75%	90%	Maximum Conc.
(E)-2-Butenal	µg/L	1	1	100	12							
1,2,3,4-Tetrahydro-5-Methylnaphthalene	µg/L	1	1	100	5.9							
1,2,3,4-Tetrahydro-6-Methylnaphthalene	µg/L	1	1	100	7.2							
1,2,4-Trimethylbenzene	µg/L	1	1	100	8.0							
1,3,5-Trimethylbenzene	µg/L	1	1	100	1.6							
2,6-Dimethyl	µg/L	1	1	100	5.5							
2-Butanone	µg/L	1	1	100	83							
2-Butenal	µg/L	1	1	100	19							
2-Ethyl-1,4-Dimethyl-Benzene	µg/L	1	1	100	5.7							
4-Isopropyltoluene	µg/L	1	1	100	0.40							
4-Methyl-2-Pentanone	µg/L	1	1	100	1.7							
Acetone	µg/L	2	2	100	120	220	22	22	22	220	220	220
Benzaldehyde	µg/L	1	1	100	4.2							
Benzene	µg/L	5	3	60	5.9	3.1				12	21	21
Benzofuran	µg/L	1	1	100	6.9							
Biphenyl	µg/L	1	1	100	12							
Ethylbenzene	µg/L	5	1	20	1.4					1.0	2.0	2.0
Isopropylbenzene	µg/L	1	1	100	0.50							
m-,p-Xylene (sum of isomers)	µg/L	1	1	100	5.3							
Methyl acetate	µg/L	1	1	100	0.80							
n-Pentadecane	µg/L	1	1	100	40							
n-Propylbenzene	µg/L	1	1	100	0.90							
n-Tetradecane	µg/L	1	1	100	20							
O-Xylene	µg/L	1	1	100	3.4							
sec-Butylbenzene	µg/L	1	1	100	0.50							

Table 3.6.15. Results of Generator Engine Sample Analyses for VOCs[1]

Analyte	Units	No. Samples	No. Detected	Detected Proportion (%)	Average Conc.	Median Conc.	Minimum Conc.	10%	25%	75%	90%	Maximum Conc.
Styrene	µg/L	1	1	100	8.9							
Toluene	µg/L	5	1	20	3.5					6.2	12	12
Vinyl acetate	µg/L	1	1	100	1.5							

Notes:
(1) Nondetect (censored) concentrations were replaced with ½ of the reporting limit for calculating average concentrations. The remaining statistics in this table were only calculated when analytes were detected at a sufficient frequency. For example, if an analyte was detected in fewer than 50% of samples, then a median concentration was not calculated. A blank cell reflects a situation when a median or percentile could not be computed based on detected concentrations. The percentiles are the concentrations of each analyte below which at least that percentage of the values fall. So the 10th percentile is the concentration below which at least 10% of the observations were found.

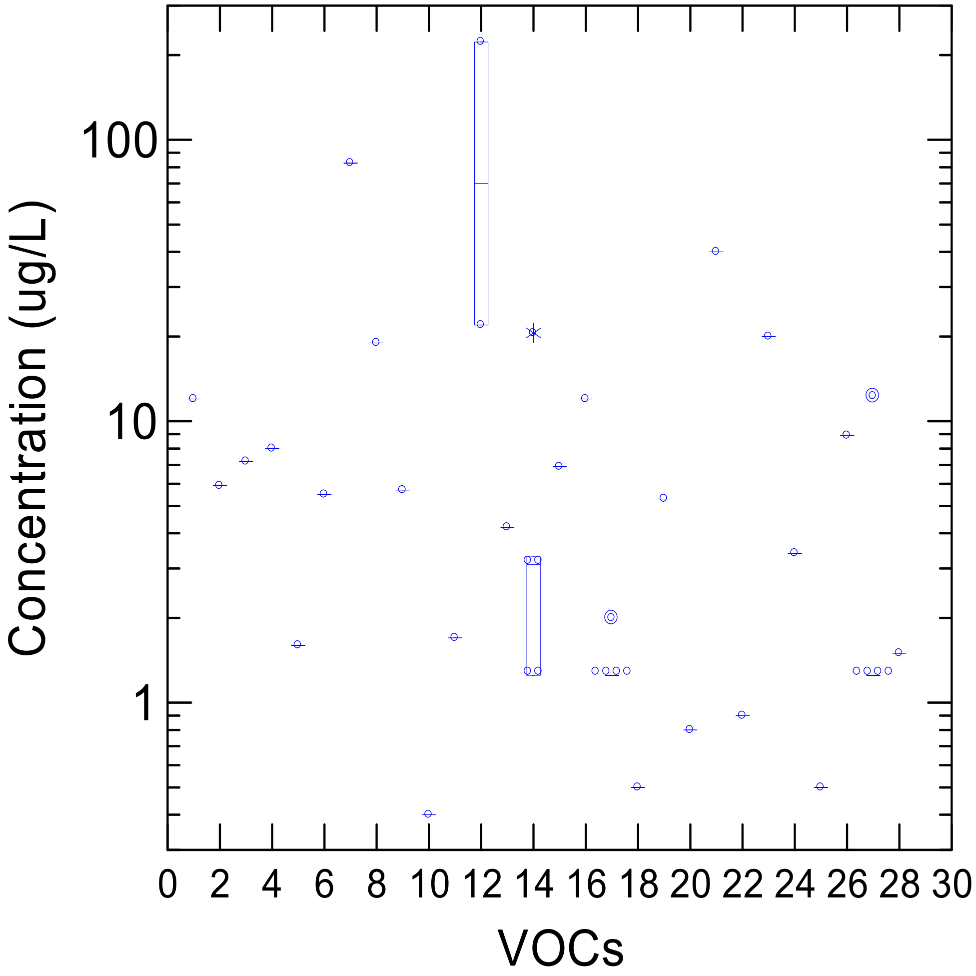

Figure 3.6.25. Box and Dot Density Plot of VOC Concentrations Measured in Samples of Generator Engine Effluent

VOCs are identified as follows:

(1) (E)-2-Butenal
(2) 1,2,3,4-Tetrahydro-5-Methylnaphthalene
(3) 1,2,3,4-Tetrahydro-6-Methylnaphthalene
(4) 1,2,4-Trimethylbenzene
(5) 1,3,5-Trimethylbenzene
(6) 2,6-dimethylnaphthalene
(7) 2-Butanone
(8) 2-Butenal
(9) 2-Ethyl-1,4-Dimethyl-Benzene
(10) 4-Isopropyltoluene
(11) 4-Methyl-2-Pentanone
(12) Acetone
(13) Benzaldehyde
(14) Benzene
(15) Benzofuran
(16) Biphenyl
(17) Ethylbenzene
(18) Isopropylbenzene
(19) m-,p-Xylene (sum of isomers)
(20) Methyl acetate
(21) n-Pentadecane
(22) n-Propylbenzene
(23) n-Tetradecane
(24) o-Xylene
(25) sec-Butylbenzene
(26) Styrene
(27) Toluene
(28) Vinyl acetate

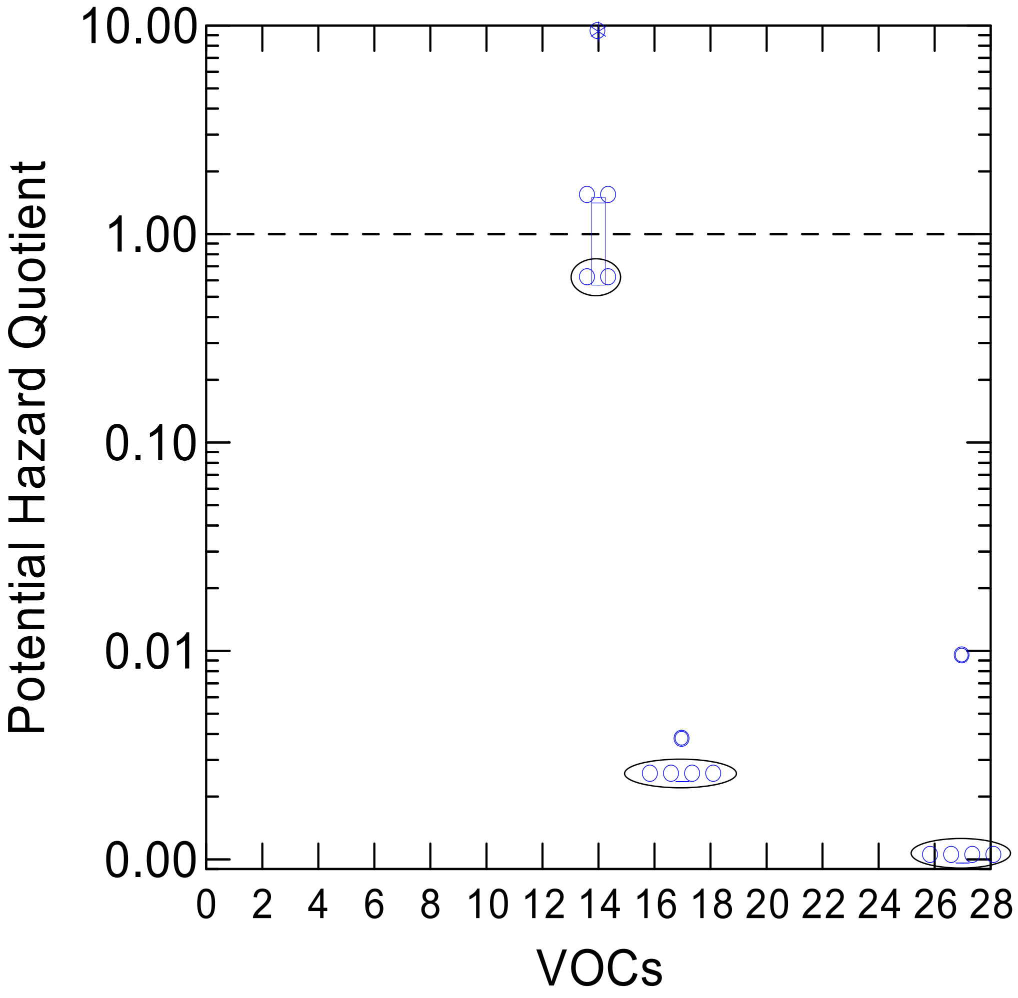

Figure 3.6.26. Box and Dot Density Plot of Potential Hazard Quotients for VOCs in Samples of Generator Engine Effluent

VOCs are identified as follows (replacement values for non-detects are circled):

(1) (E)-2-Butenal
(2) 1,2,3,4-Tetrahydro-5-Methylnaphthalene
(3) 1,2,3,4-Tetrahydro-6-Methylnaphthalene
(4) 1,2,4-Trimethylbenzene
(5) 1,3,5-Trimethylbenzene
(6) 2,6-dimethylnaphthalene
(7) 2-Butanone
(8) 2-Butenal
(9) 2-Ethyl-1,4-Dimethyl-Benzene
(10) 4-Isopropyltoluene
(11) 4-Methyl-2-Pentanone
(12) Acetone
(13) Benzaldehyde
(14) Benzene
(15) Benzofuran
(16) Biphenyl
(17) Ethylbenzene
(18) Isopropylbenzene
(19) m-,p-Xylene (sum of isomers)
(20) Methyl acetate
(21) n-Pentadecane
(22) n-Propylbenzene
(23) n-Tetradecane
(25) sec-Butylbenzene
(26) Styrene
(27) Toluene
(28) Vinyl acetate

3.2.6.4 Comparison of Effluent Generated at Different Propulsion Engine Power Levels

Although inboard and outboard propulsion engines were often sampled during operation at different power levels (e.g., idle, half power, full power), these samples were generally composited for a single analysis. Exceptions include samples for analysis of HEM/SGT-HEM and VOCs, which were collected and analyzed separately for each power level of engine operation (composite samples for these analytes are not appropriate). EPA reviewed the HEM/SGT-HEM and VOC data to determine whether there were any trends in the resulting data based on engine power level of operation.

HEM was detected in the majority of inboard engine effluent samples; however, detected concentrations were low (the majority were less than the reporting limit of 5 mg/L). Of the eight vessels with inboard engines with detected HEM concentrations that were sampled at different power levels, engine effluent samples from six had higher HEM concentrations at higher engine levels than at idle. Data for the remaining two vessels were inconclusive. Note, however, that differences in HEM concentrations among power levels were small, ranging from 0.1 to 5 mg/L. For outboard engines, HEM was not detected in any of the engine effluent samples.

Regarding VOC results for inboard engines, EPA reviewed benzene, toluene, ethylbenzene, and xylene concentrations as these compounds were the most frequently detected. Of the eight vessels with inboard engines with detected benzene concentrations that were sampled at different power levels, engine effluent samples from five contained higher benzene concentrations at higher engine levels than at idle. Data for the remaining three vessels showed the opposite pattern, with higher benzene concentrations at idle than at higher engine levels. For seven of these sampled vessels, differences in benzene concentrations among the power levels were small, ranging from 0.1 to 4.7 μg/L. In contrast, for the remaining vessel (a recreational vessel), the difference in benzene concentrations from idle to three-quarter speed was 89 μg/L, with the higher concentration detected at idle. As discussed previously, this recreational vessel was the only sampled vessel that used gasoline as fuel rather than diesel. In addition, the engines on this vessel were dewinterized immediately prior to sampling.

The differential among detected concentrations of ethylbenzene, xylene, and toluene at different power levels is too small to draw any conclusions, except for the engine effluent data for the recreational vessel. Differences in detected concentrations between idle and three-quarter power were 18 μg/L for ethylbenzene, 73 μg/L for m-,p-xylene, 31 μg/L for o-xylene, and 84 μg/L for toluene. The higher concentrations were found at idle for all four analytes.

The UNDS sampling program provides a useful comparison for this study as it was specifically designed to evaluate engine wet exhaust characteristics among power levels, including the separate collection and analysis of three replicate samples at each of five different power levels. Tables 3.6.16 and 3.6.17 present sample results from the UNDS study by power level for the LCPL and RIB, respectively.

EPA made several conclusions for the LCPL based on a review of the engine effluent results. Chromium, copper, lead, and nickel were all detected at concentrations significantly greater than background concentrations for all five power levels. For copper and nickel, concentrations were highest at idle, second highest at 100 percent power, and then generally decreased with decreasing power levels (decreasing engine RPM). Chromium concentrations were highest at 100 percent power and then also decreased with decreasing power levels, with the lowest chromium concentrations found at idle. Lead concentrations were not significantly different at the various power levels. For TOC and phenol, only idle concentrations were significantly greater than background concentrations.

For the RIB, only TOC concentrations were significantly greater than background concentrations for all five power levels. TOC concentrations were highest at 100 power and then generally decreased with decreasing power levels; TOC concentrations were lowest at idle.

Table 3.6.16. Mean Concentration Results, UNDS Engine Wet Exhaust Discharge and Background Samples for the LCPL[1]

Analyte	Mode 1 RPM 2050 (100% Power)	Mode 2 RPM 1850 (75% Power)	Mode 3 RPM 1650 (50% Power)	Mode 4 RPM 1300 (25% Power)	Mode 5 RPM 750 (0% Power)	Background Water	Units
	Mean	Mean	Mean	Mean	Mean	Mean	
Classical Parameters							
Nitrate/Nitrite ($NO_2 + NO_3$-N)	ND (0.010)	0.011	0.011	ND (0.010)	0.012	ND (0.010)	mg/L
Total Organic Carbon (TOC)	1.15	1.03	0.933	0.858	1.73	0.992	mg/L
Metals							
Arsenic, Total	2.22	1.98	1.92	2.38	2.21	2.29	µg/L
Cadmium, Total	0.032	0.028	0.024	0.022	0.022	0.020	µg/L
Chromium, Total	0.574	0.431	0.313	0.310	0.260	ND (0.100)	µg/L
Copper, Total	21.7	26.0	17.2	13.5	40.1	0.780	µg/L
Lead, Total	0.369	0.188	0.145	0.118	0.127	0.030	µg/L
Nickel, Total	4.12	4.79	3.04	2.81	14.8	0.477	µg/L
SVOCs							
Bis(2-ethylhexyl)phthalate	ND (10.0)	ND (10.0)	ND (10.18)	ND (10.0)	20.4	ND (10.0)	µg/L
Phenol	ND (10.0)	ND (10.0)	ND (10.18)	ND (10.0)	19.7	ND (10.0)	µg/L

Source: USEPA, 2008b.

(1) Mean values were estimated based on the replicate concentrations for each mode or background sample using a lognormal or modified-delta lognormal distribution.

ND – Not detected (number in parentheses is reporting limit).

Table 3.6.17. Mean Concentration Results, UNDS Engine Wet Exhaust Discharge and Background Samples for the RIB[1]

Analyte	Mode 1 RPM 2450 (100% Power)	Mode 2 RPM 2270 (75% Power)	Mode 3 RPM 1720 (50% Power)	Mode 4 RPM 1290 (25% Power)	Mode 5 RPM 400 (0% Power)	Background Water	Units
	Mean	Mean	Mean	Mean	Mean	Mean	
Classical Parameters							
Biochemical Oxygen Demand (BOD)	ND (2.00)	ND (2.00)	ND (2.00)	4.8	3.3	3.3	mg/L
Nitrate/Nitrite (NO_2 + NO_3-N)	0.017	ND (0.010)	0.015	0.012	0.013	ND (0.010)	mg/L
Total Organic Carbon (TOC)	1.67	1.55	1.27	1.15	1.29	0.832	mg/L
Total Suspended Solids (TSS)	11.9	12.4	ND (5.00)	5.3	ND (5.00)	ND (5.00)	mg/L
SVOCs							
Phenol	32.4	24.6	ND (10.0)	ND (10.0)	ND (10.0)	ND (10.0)	µg/L
VOCs							
1,2,3-Trimethylbenzene	12.3	ND (10.0)	ND (10.0)	ND (10.0)	12.6	ND (10.0)	µg/L
1,3,5-Trimethylbenzene	12.3	ND (10.0)	ND (10.0)	ND (10.0)	12.6	ND (10.0)	µg/L

Source: USEPA, 2008b.

(1) Mean values were estimated based on the replicate concentrations for each mode or background sample using a lognormal or modified-delta lognormal distribution.

ND – Not detected (number in parentheses is reporting limit).

3.2.6.5 Engine Dewinterizing Effluent

Marine engines used in cold climates typically require maintenance prior to winter storage to prevent engine damage caused by freezing or corrosion. The indirect cooling systems in inboard engines are typically winterized by draining the water from the ambient water cooling system and refilling the system with approximately 5 gallons of antifreeze. Marine engine antifreeze contains propylene glycol[37], corrosion inhibitors, and other additives. In spring, the 5 gallons of antifreeze is emptied by starting the engine, which discharges the glycol solution and replaces it with ambient water. EPA sampled dewinterizing effluent from an inboard engine on a recreational vessel as it was converted from winter storage. This sample was collected in the same manner as that used for sampling other engine effluents. The sample was analyzed for select classical pollutants and metals.

Table 3.6.18 presents the collected dewinterizing effluent data, together with the mean inboard propulsion engine effluent concentrations from Tables 3.6.2 and 3.6.3. The source of the biochemical oxygen demand concentrations is the propylene glycol in the antifreeze. Elevated metals concentrations in dewinterizing effluent compared to those in inboard engine effluent could have been due to prolonged contact of the antifreeze with the engine cooling system and associated piping.

Outboard engines are winterized by spraying an oily aerosol, commonly referred to as “fog,” into the combustion air intake while the motor is running. Therefore, the engine dewinterizing effluent sample results in this subsection are not applicable to outboard engines.

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[37] Ethylene glycol is not used for marine applications due to its higher toxicity as compared to propylene glycol.

Table 3.6.18. Comparison of Dewinterizing Effluent with Propulsion Effluent

Analyte	Units	Dewinterizing Effluent	Inboard Propulsion Engine Mean Concentration from Tables 3.6.2 and 3.6.3
Classical Parameters			
Biochemical Oxygen Demand (BOD)	mg/L	11	Not analyzed
Total Residual Chlorine	mg/L	2.8	0.048[1]
Turbidity	NTU	350	32[2]
Metals			
Aluminum, Dissolved	µg/L	560	200[1]
Aluminum, Total	µg/L	3,700	340[1]
Antimony, Dissolved	µg/L	2.1	Not detected
Antimony, Total	µg/L	2.4	Not detected
Arsenic, Dissolved	µg/L	24	4.2[2,4]
Arsenic, Total	µg/L	32	4.5[2,4]
Barium, Dissolved	µg/L	43	35[1]
Barium, Total	µg/L	59	36[1]
Calcium, Dissolved	µg/L	21,000	80,000[1]
Calcium, Total	µg/L	25,000	81,000[1]
Chromium, Dissolved	µg/L	820	1.2
Chromium, Total	µg/L	720	1.3
Cobalt, Dissolved	µg/L	8.7	Not detected
Cobalt, Total	µg/L	12	Not detected
Copper, Dissolved	µg/L	370	16
Copper, Total	µg/L	820	18
Iron, Dissolved	µg/L	3,300	64
Iron, Total	µg/L	20,000	250[2]
Lead, Dissolved	µg/L	19	1.5
Lead, Total	µg/L	64	3.0
Magnesium, Dissolved	µg/L	5,200	200,000[1]
Magnesium, Total	µg/L	6,400	200,000[1]
Manganese, Dissolved	µg/L	160	43
Manganese, Total	µg/L	400	55[1]
Nickel, Dissolved	µg/L	7.2	4.4
Nickel, Total	µg/L	18	4.6[1]
Potassium, Dissolved	µg/L	23,000	32,000[1]
Potassium, Total	µg/L	23,000	32,000[1]
Selenium, Dissolved	µg/L	45	11[1,4]
Selenium, Total	µg/L	54	11[2,4]
Sodium, Dissolved	µg/L	690,000	770,000[2]
Sodium, Total	µg/L	630,000	860,000[2]
Vanadium, Dissolved	µg/L	230	Not detected
Vanadium, Total	µg/L	190	Not detected
Zinc, Dissolved	µg/L	570	38
Zinc, Total	µg/L	900	38

(1) Sample concentrations were almost completely accounted for (≥90 percent) by background concentrations in ambient water.

(2) Sample concentrations were predominantly accounted for (≥50 percent and <90 percent) by background concentrations in ambient water.

(3) Measured concentrations well above their respective reporting limits for dissolved arsenic and selenium are suspected of being elevated due to positive interference

3.2.6.6 Summary of the Characterization of Engine Effluent Analyses

Tables 3.6.19 and 3.6.20, and Table 3.6.21 at the end of this subsection, compare effluent characteristics for inboard and outboard propulsion engines and generator engines. Specifically, Table 3.6.19 compares the number of analytes detected in effluent from these engines, while Table 3.6.20 compares engine effluent analyte concentrations for those pollutants that may have the potential to lead to environmental impacts. Finally, Table 3.6.21 summarizes the specific analytes within each engine effluent type with the potential to pose risk to human health or the environment. The Table 3.6.21 is presented here to help interpret a realized risk likely posed by these analytes in engine effluent as summarized in Chapter 5.

Table 3.6.19. Comparison of Number of Detected Analytes in Engine Effluent

Analyte Class	Number of Analytes Detected in Engine Effluent		
	Inboard Propulsion	Outboard Propulsion	Generator
Classical Parameters	11	11	11
Metals	16	14	11
SVOCs	31	7	26
VOCs	38	18	28
Total	**96**	**50**	**76**

Table 3.6.20. Comparison of Results for Selected Analytes in Engine Effluent

Analyte	Units	Mean Concentration		
		Inboard Propulsion	Outboard Propulsion	Generator
Temperature Differential	°C	5 (low power levels) 20 (high power levels)	<5	<5 to 13
Oil and Grease (HEM)	mg/L	3.0	Not detected	2.9
Arsenic, Total	µg/L	4.5[1]	24[1]	Not detected
Copper, Dissolved	µg/L	16	3.3	6.5
Lead, Dissolved	µg/L	1.5	Not detected	Not detected
Lead, Total	µg/L	3.0	Not detected	Not detected
Selenium, Dissolved	µg/L	11[1]	76[1]	Not detected
Zinc, Dissolved	µg/L	38	11	13
PAHs	µg/L	14 total detected 6 carcinogens	1 detected 0 carcinogens	5 detected 0 carcinogens
Benzene	µg/L	12	13	5.9

(1) Measured concentrations well above their respective reporting limits for dissolved arsenic and selenium are suspected of being elevated due to positive interference.

Among all engine types, the SVOCs and VOCs were the most frequently detected pollutants (Table 3.6.19). Concentrations of PAHs were potentially high in inboard engine effluent. Fourteen PAHs were detected, including six of the seven PAHs classified as known carcinogens (Table 3.6.20), but these were only detected in a single inboard engine effluent from a gasoline engine of a recreational vessel (not a study vessel) dewinterized immediately prior to sampling. PAH concentrations in this sample were several hundred to over 1,000 times greater than their associated benchmarks. PAHs were also detected in outboard engine and generator effluents, but at concentrations lower than their associated benchmarks. Furthermore, none of the probable human carcinogens were detected in generator or outboard propulsion engine effluent samples.

The plasticizer bis(2-ethylhexyl) phthalate was found in the effluents of all engine types, PHQs were just above 1; however, the measured concentrations appear to be largely reflective of ambient concentrations. The VOC benzene was also found at concentrations above the PHQ screening benchmarks in all engine effluents. Trimethylbenzenes and ketones (VOCs) were frequently detected in the effluents of inboard engines, but no screening benchmarks exist for these compounds. Despite the high frequency of concentrations of benzene that exceeded screening benchmarks in engine effluent of all types, rarely were PHQs in excess of 5.

Among the classical pollutants, inboard propulsion engines increase cooling water temperatures by moderate amounts (<5°C) at low power levels, but by as much as 20°C at higher power levels. In contrast, outboard propulsion engines increase cooling water temperatures by <5°C, regardless of engine level. Most of the generator engine effluent samples increased cooling water temperature by <5°C; however, two of the generator engine effluent samples had greater temperature differentials.

Oil and grease was not detected in effluent from outboard propulsion engines, but was detected at concentrations just above reporting limits in effluent from inboard propulsion and generator engines. Such concentrations were well below PHQ screening benchmarks for saltwater discharge. However, EPA did occasionally observe a sheen in receiving waters where marine engines were operating.

Table 3.6.21 lists those metals that were found to be contributed primarily by engine operations (elevated above ambient water concentrations) and were detected at concentrations that exceed a NRWQC, indicating that they may have the potential to cause environmental impacts. After accounting for background concentrations, dissolved concentrations of copper exceeded NRWQC in most inboard engine and generator effluents. The highest PHQ for dissolved copper was 17. Several effluents from inboard and outboard engines had dissolved selenium at concentrations approximately two to seven times higher than NRWQC benchmarks; however, these measured concententrations are suspected of being elevated due to positive interference. Among the total metals, PHQs for arsenic were much greater than 1 in both inboard and outboard engines. However, as in case of dissolved selenium, all of the arsenic values measured above reporting limits are suspected of being elevated due to positive interference. Total arsenic was not detected in generator effluents.

Table 3.6.21. Characterization of Engine Effluent and Summary of Analytes that May Have the Potential to Pose Risk

Vessel Type (no. vessels)	**Analytes that May Have the Potential to Pose Risk in Engine Effluent Discharge and Vessel Sources**[1,2]												
	Microbiologicals	**Volatile Organic Compounds**	**Semivolatile Organic Compounds**	**Metals (dissolved)**	**Metals (total)**	**Oil and Grease**	**Sulfide**	**Short-Chain Alkylphenol Ethoxylates or NP**	**Long-Chain Alkylphenol Ethoxylates**	**Nutrients**	**BOD, COD, and TOC**	**Total Suspended Solids**	**Other Physical/Chemical Parameters**
Inboard Engines													
Water Taxis (4)		Benzene	Bis(2-ethylhexyl) phthalate	**Cu**									**Temp**[3]
Tour Boats(3)		Benzene		Cu									**Temp**[3]
Fishing Vessels (2)				Cu									**Temp**[3]
Tow/Salvage Vessel (1)				Cu									**Temp**[3]
Fire Boat (1)			Bis(2-ethylhexyl) phthalate	Cu									**Temp**[3]
Recreational Vessel (2)[4]		**Benzene**	**PAHs**[5]	Cu			x						**Temp**[3]
Outboard Engines													
Tow/Salvage Vessel (4)		Benzene											
Research (2)		**Benzene**											

Table 3.6.21. Characterization of Engine Effluent and Summary of Analytes that May Have the Potential to Pose Risk

	Analytes that May Have the Potential to Pose Risk in Engine Effluent Discharge and Vessel Sources[1,2]												
Generator Engines (5)		Benzene	Bis(2-ethylhexyl) phthalate	Cu			x						Temp, TRC

Notes:

(1) Analytes are generally **bolded** when a large proportion of the samples have concentrations exceeding the NRWQC (e.g., 25 to 50 percent), when several of the samples have PHQs > 10 (e.g., two or three of five), when a few samples result in PHQs greatly exceeding the screening benchmark (i.e., 100s to 1,000s), or, in the case of oil and grease and for nonylphenol, when one or more samples exceed an existing regulatory limit by more than a factor of 2. See text in Section 3.1.3 for a definition of PHQs and Table 3.1 for screening benchmarks used to calculate these values.

(2) EPA notes that the conclusion of potential risk is drawn from a small sample size, in some cases a single vessel, for certain discharges sampled from some vessel classes. EPA included these results in the tables to provide a concise summary of the data collected in the study, but strongly cautions the reader that these conclusions, where there are only a few samples from a given vessel class, should be considered preliminary and might not necessarily represent pollutant concentrations from these discharges from other vessels in this class.

(3) At full (100%) power.

(4) For inboard engine effluent, higher measured concentrations and concentrations that exceeded the screening benchmarks were consistently from the recreational vessel, which was de-winterized immediately prior to sampling (see text). The recreational vessel was the only vessel sampled that used gasoline instead of diesel fuel. PHQs for the majority of samples were less than 5.

(5) All PAHs detected (6 of which are probable human carcinogens) were from one sample collected from a recreational vessel with a gasoline engine dewinterized immediately prior to sampling and after a winter of non-use.

3.2.7 Firemain Discharges

The primary purpose of the firemain system is to supply water for fire fighting, although this system can also be used for other secondary purposes (deck washing, various maintenance and training activities, anchor chain washdown, or to create bypass flow from the firemain pumps to cool auxiliary machinery equipment) onboard the vessels of interest in this study. The firemain systems (see Section 1.5) sampled by EPA on three tour boats, two tug boats, and the single fire boat for this study are generally only used during emergencies and during biweekly testing. The firemain system intake water sampled on the vessels selected in this study was taken from the surrounding (ambient) water without addition of foam-forming agents such as aqueous film-forming foam (AFFF) or other chemical additions.

The Firemain Hose on a Tour Boat

It should be noted that AFFF agents could potentially be used on the vessels of interest in this study, although none of the vessels were outfitted with systems that used AFFF. AFFF agents are used for fire suppression and are a combination of fluoro-chemical surfactants, hydrocarbon surfactants, and solvents that are injected into the water stream of a fire hose. These film-forming agents can form water solution films on the surface of flammable liquids, separating the fuel from the air (oxygen).

EPA focused on analyzing the samples of firemain discharge water for metals, VOCs, and SVOCs. Metals were selected for analysis because water in the “wet type” firemain system passes through a significant amount of metal pipe onboard most vessels. EPA initially selected

VOCs and SVOCs to characterize the AFFF, which, as noted, none of the vessels sampled in the study used while testing their firemain systems. Despite the lack of AFFF use while testing firemain systems, EPA decided to analyze for VOCs and SVOCs in firemain system discharge water anyway.

3.2.7.1 Metals

Only half the total number of metals analyzed for in water samples from firemain systems were detected in the six vessels sampled.

Figure 3.7.1 presents the concentration ranges for dissolved metals detected in firemain water samples. The figure shows that dissolved metals concentrations span two orders of magnitude. Average dissolved concentrations of aluminum and zinc were highest, followed, in order of decreasing concentration, by barium, copper, manganese, nickel, and lead.

Figure 3.7.2 presents the concentration ranges of total metals detected in firemain water samples. Except for barium (dissolved:total metal ratio, or f_d, of 0.96), total metal concentrations were much higher than their corresponding dissolved metal concentrations, particularly for lead and copper. For the other total metal concentrations detected at higher levels, a disproportionate amount of the metals in ambient water is in the particulate form (i.e., aluminum, manganese and probably iron).

Arsenic, cadmium, selenium, antimony, beryllium, cobalt, silver, thallium, and vanadium were not detected in the firemain discharges.

Dissolved and total aluminum and total manganese were detected in the firemain effluent of all six of the vessels sampled. These metal concentrations are moderately to strongly influenced by ambient water concentrations. Dissolved zinc, also moderately influenced by ambient water, was detected in five of the samples. Dissolved and total copper, as well as dissolved manganese, were detected in four of the samples and were generally not affected by ambient water concentrations. Total lead was detected in three of the samples, and only one of the firemain systems had dissolved lead and chromium at detectable levels. Dissolved and total barium and total iron were also detected in one sample from a firemain system.

Disparities between dissolved:total metal concentrations sampled in firemain water versus ambient water suggest chromium, lead, and iron detected in firemain samples at least partially originated from the network of pipes within the firemain system. The dissolved:total metal ratio for copper was lower in the firemain water samples than in the ambient water samples (f_ds of 0.79), suggesting the possibility that some of the total copper detected in firemain samples originated from the network of pipes within the vessels that support the firemain system - most likely due to corrosion. Dissolved:total concentrations in firemain samples for the remaining metals (aluminum, barium, zinc, manganese, nickel) were similar to corresponding ambient dissolved:total concentration ratios, suggesting most of these metals detected in firemain samples originated from the ambient water. Ambient harbor water data are not shown.

Figures 3.7.3 and 3.7.4 display the distribution of PHQs based on the most conservative (most protective) screening benchmark for each of the dissolved and total metals. PHQs for only one of the dissolved metals (copper) include a value of greater than 10 (one dissolved copper concentration from the firemain system analyzed from a tour boat resulted in a PHQ of 24). PHQs with values of slightly higher than 1 were found for two other dissolved metals (lead and zinc) when using the most conservative (most stringent 2006 NRWQC) screening benchmark. In contrast, all of the concentrations for total aluminum and the concentrations for the single detected total iron value exceeded the most stringent 2006 NRWQC; however, none of these PHQs exceeded 11.

In summary, the concentration of metals in firemain water was generally lower than some other discharges (e.g. bilgewater, deck washdown water). The water used in the vessel firemain systems analyzed in this study was ambient water, and the concentrations of most of the dissolved and total metals in firemain water reflect these surrounding ambient concentrations. Aluminum, manganese, and iron had high concentrations in the ambient water from which the firemain withdrew water and were generally higher or the same as other discharges. Dissolved and total copper, dissolved and total lead, and to a lesser degree, nickel and zinc, were found in concentrations higher than the ambient water. Of these metals, dissolved copper is the only metal also found at concentrations consistently above the most conservative screening benchmarks, albeit only with PHQ values in the 1 to 11 range, which is considerably lower than values found in most other discharge types discussed in this report.

Table 3.7.1. Results of Firemain System Sample Analyses for Metals[1]

Analyte	Units	No. samples	No. detected	Detected Proportion (%)	Average Conc. [5]	Median Conc.	Minimum Conc.	10%	25%	75%	90%	Maximum Conc. [5]	Screening BM[2]
Heavy and Other Metals													
Aluminum, Dissolved[3]	µg/L	6	6	100	110	140	15	15	72	150	160	160	NA
Aluminum, Total[4]	µg/L	6	6	100	330	360	180	180	200	440	650	650	87
Barium, Dissolved[3]	µg/L	1	1	100	36								NA
Barium, Total[3]	µg/L	1	1	100	37								1000
Chromium, Total[4]	µg/L	6	1	17	1.7					1.2	4.9	4.9	NA
Copper, Dissolved	µg/L	6	4	67	23	15				40	74	74	3.1
Copper, Total	µg/L	6	4	67	150	70				290	580	580	1300
Iron, Total	µg/L	1	1	100	3800								300
Lead, Dissolved	µg/L	6	1	17	2.1					1.1	4.3	4.3	2.5
Lead, Total	µg/L	6	3	50	50	7.6				81	270	270	NA
Manganese, Dissolved[4]	µg/L	6	4	67	17	16				31	47	47	NA
Manganese, Total[4]	µg/L	6	6	100	86	98	49	49	59	120	120	120	100
Nickel, Dissolved[4]	µg/L	6	1	17	4.9					1.1	4.4	4.4	8.2
Nickel, Total[4]	µg/L	6	2	033	7.0					11	11	11	610
Zinc, Dissolved[4]	µg/L	6	5	83	120	58			5.3	270	370	370	81
Zinc, Total	µg/L	6	6	100	490	280	20	20	26	1200	1600	1600	7400
Cationic Metals													
Calcium, Dissolved[3]	µg/L	6	6	100	27000	25000	23000	23000	24000	29000	37000	37000	NA
Calcium, Total[3]	µg/L	6	6	100	30000	29000	23000	23000	23000	38000	40000	40000	NA
Magnesium, Dissolved[3]	µg/L	6	6	100	6500	6500	5200	5200	5700	7200	9000	9000	NA
Magnesium, Total[3]	µg/L	6	6	100	7300	6600	5500	5500	6200	9200	9800	9800	NA
Sodium, Dissolved[3]	µg/L	1	1	100	38000								NA
Sodium,Total[3]	µg/L	1	1	100	37000								NA
Potassium, Dissolved[3]	µg/L	1	1	100	3800								NA
Potassium, Total[3]	µg/L	1	1	100	3600								NA

Notes:

(1) Nondetect (censored) concentrations were replaced with ½ of the reporting limit for calculating average concentrations. The remaining statistics in this table were only calculated when analytes were detected at a sufficient frequency. For example, if an analyte was detected in fewer than 50% of samples, then a median concentration was not calculated. A blank cell reflects a situation when a median or percentile could not be computed based on detected concentrations. The percentiles are the concentrations of each analyte below which at least that percentage of the values fall. So the 10th percentile is the concentration below which at least 10% of the observations were found.

(2) Screening BM represents the screening benchmark referred to in Section 3.1.3, and is the most stringent 2006 NRWQC or other conservative benchmark used to calculate PHQs.

(3) Sample concentrations were strongly influenced by background concentrations in ambient water, accounting for greater than 90% of sample concentrations in the majority of samples.

(4) Sample concentrations were moderately influenced by background concentrations in ambient water, accounting for between 50 and 90% of sample concentrations in the majority of samples.

(5) In some cases, the detected concentration(s) for an analyte could be lower than the replacement value (½ of the reporting limit) for a concentration that was nondetected. In an extreme (but possible) case, this could result in an average concentration for an analyte that is greater than the maximum detected concentration.

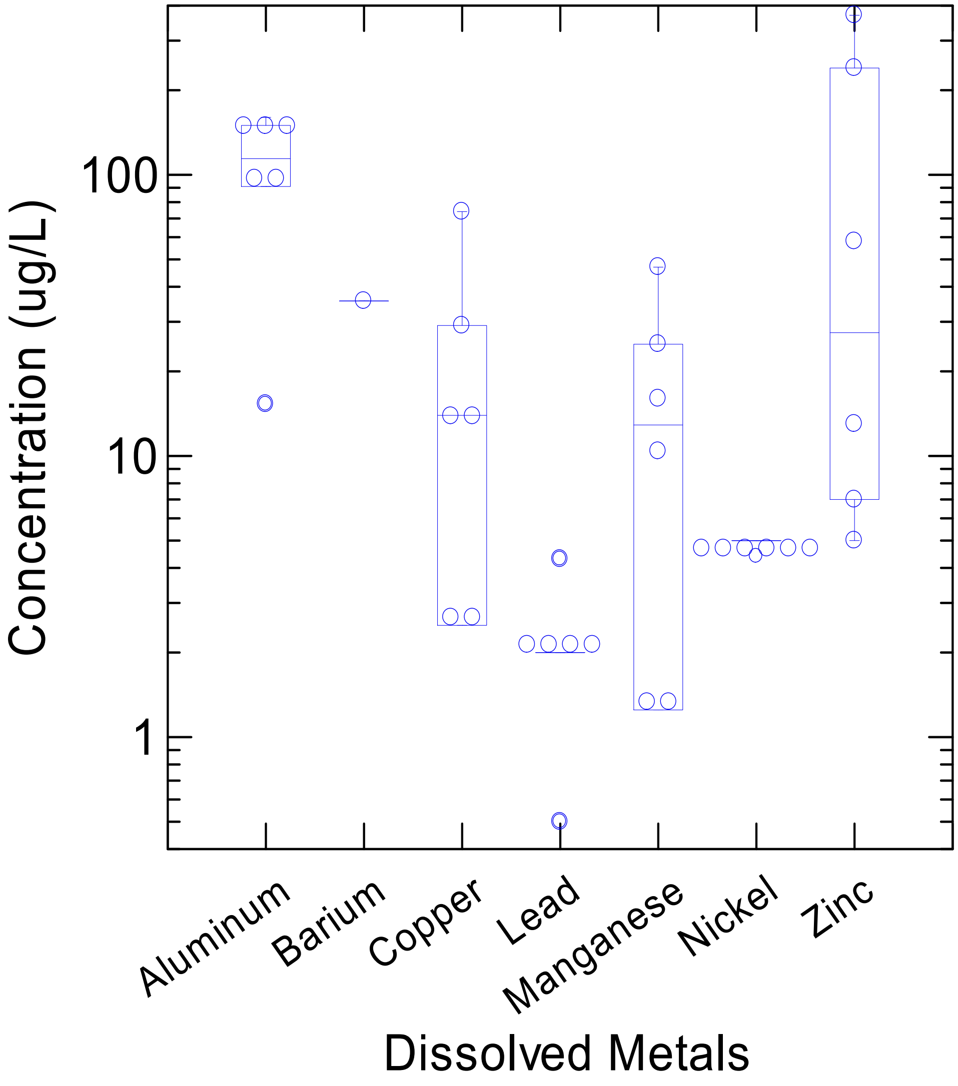

Figure 3.7.1. Box and Dot Density Plot of Dissolved Metals Concentrations Measured in Samples of Firemain Water

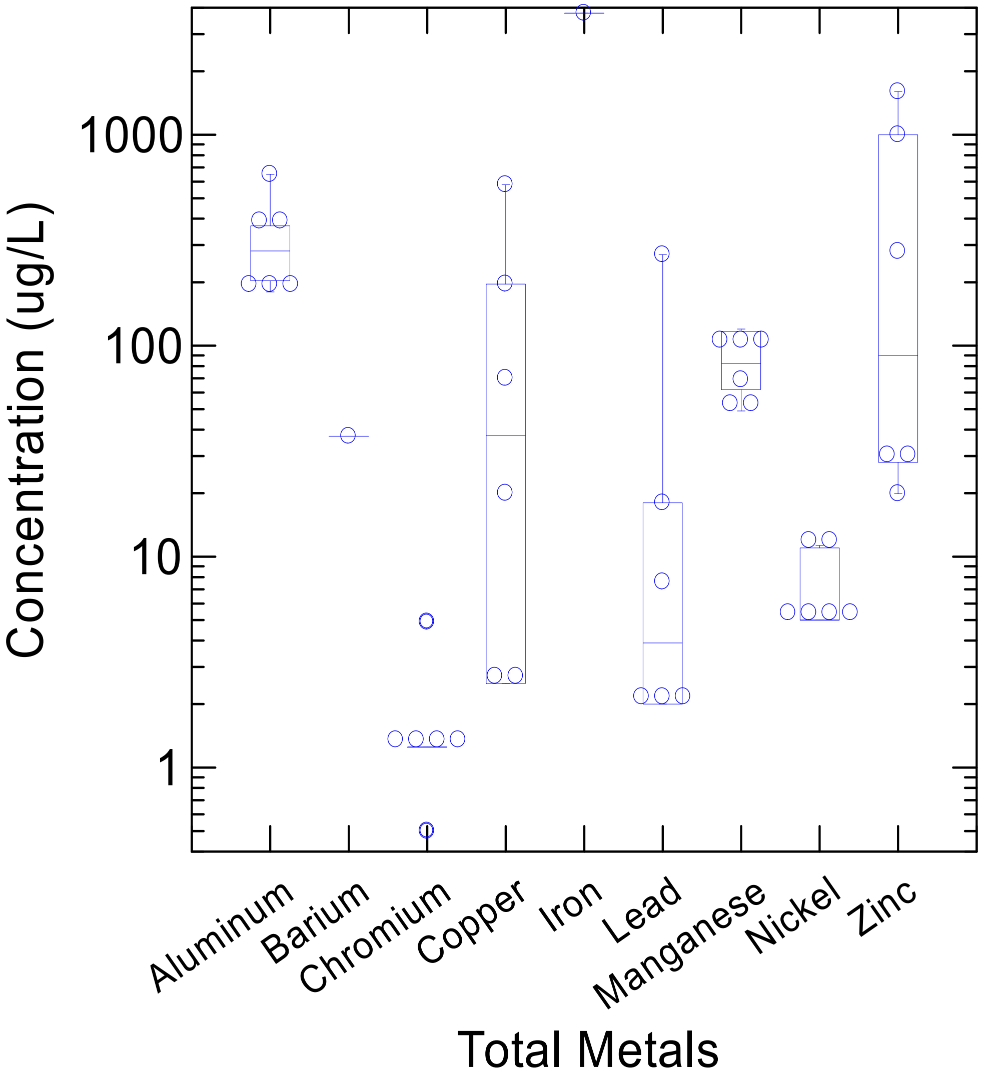

Figure 3.7.2. Box and Dot Density Plot of Total Metals Concentrations Measured in Samples of Firemain Water

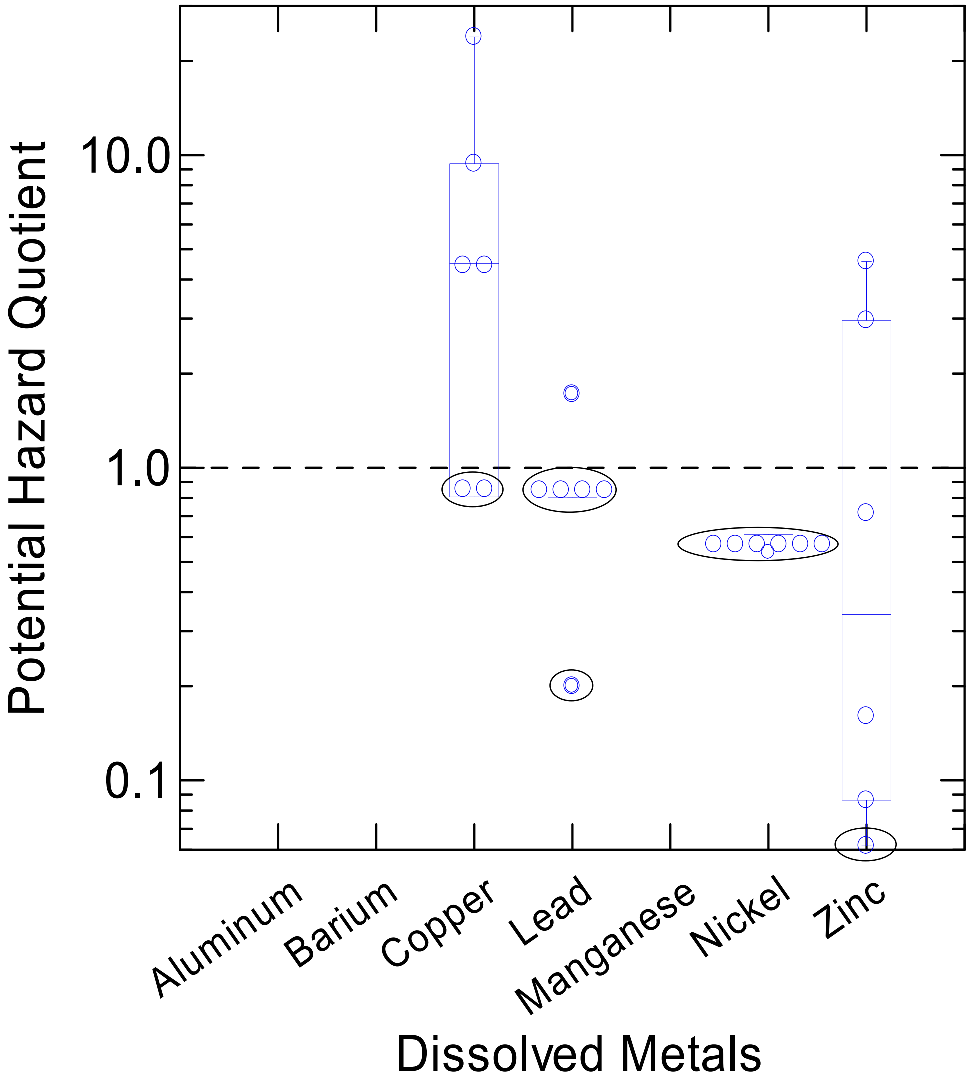

Figure 3.7.3. Box and Dot Density Plot of Potential Hazard Quotients for Dissolved Metals in Samples of Firemain Water

(Note: Replacement values for non-detects are circled).

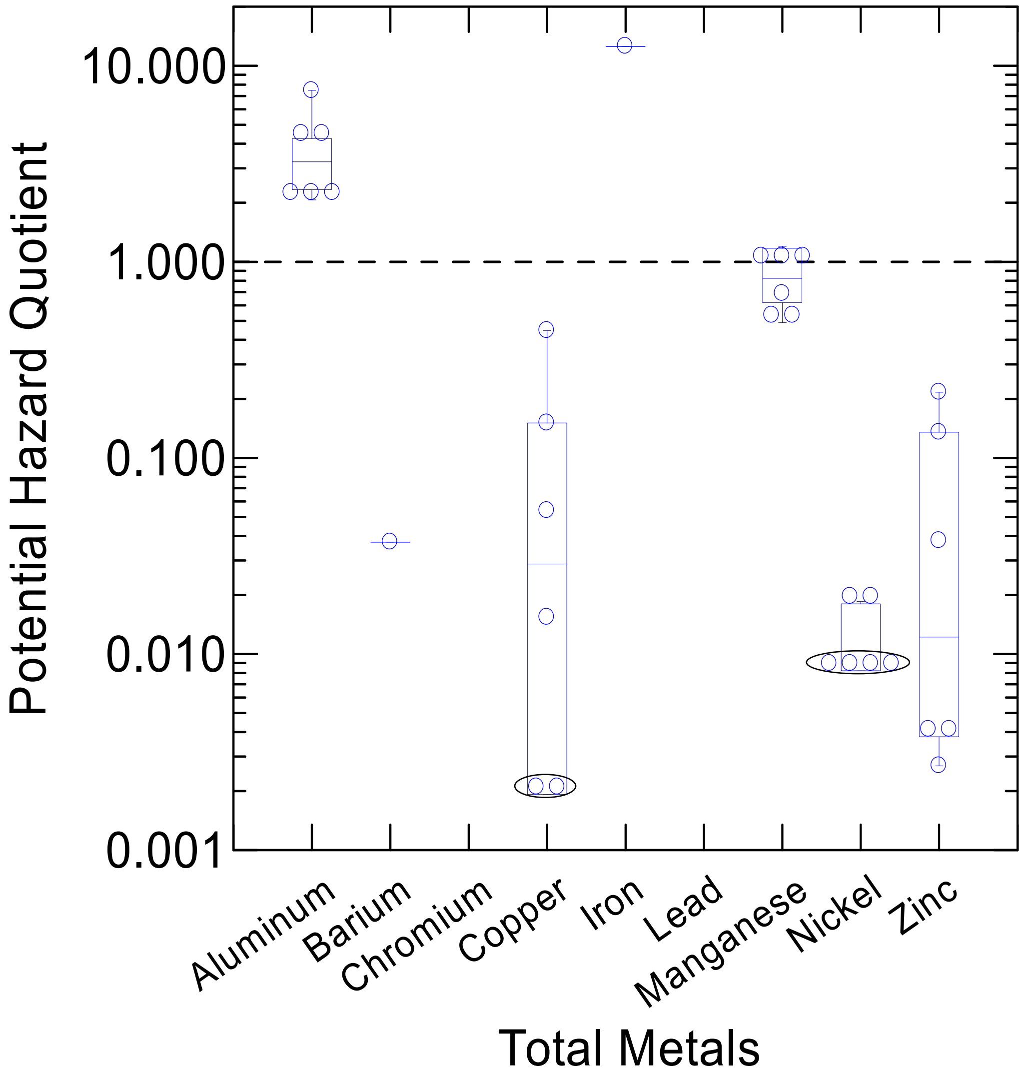

Figure 3.7.4. Box and Dot Density Plot of Potential Hazard Quotients for Total Metals in Samples of Firemain Water
(Note: Replacement values for non-detects are circled).

3.2.7.2 Classical pollutants

The firemain system water samples were analyzed for 10 classical pollutants (BOD, COD, TOC, and sulfide were not analyzed for as they were not expected in firemain system discharge (see Table 2.2). Of the 10 classical pollutants analyzed for, oil and grease (measured as HEM and SGT-HEM) were not detected in any samples (Table 3.7.2). The concentrations of all other pollutants, with the possible exception of turbidity, were not elevated.

The conductivity, pH, and low salinity (ranging from 0.01 to 0.2 parts per thousand) in the firemain water samples are consistent with freshwater ambient water (all firemain samples were taken from vessels operating in fresh water). The pH of these waters was between 7 and 8, and turbidity and TSS was low, under 90 NTU and 20 mg/L, respectively. The firemain system effluent was sampled in the spring, and the temperature was in a seasonal range of 14 to 22^{o}C and varied according to geographic location (warmer water samples in southern United States and colder in mid-Atlantic and northern states). Dissolved oxygen in firemain system water ranged from a low of 4.1 mg/L (slightly less then 50 percent saturation) to a high of 13 mg/L (super-saturated). All of these values were, to a large degree, consistent with concentrations of these parameters found in respective ambient water.

Figure 3.7.5 illustrates the variability of the values measured for the classical pollutants in firemain system water, which is relatively low given the relative similarities in ambient water quality (freshwater harbors sampled during springtime) for the three locations where vessels were sampled. The only other parameters detected in this category were TRC and turbidity. TRC was only detected in one of the six samples collected (measured at the reporting limit = 0.10 mg/L; PHQ = 13). All of the other TRC concentrations were below the reporting limit of 0.10 mg/L, which, when reported at half the reporting limit or 0.05 mg/L, still exceeds the most stringent 2006 NRWQC for TRC of 0.0075 mg/L. In contrast, turbidity ranged from a low of 4.6 to a high of 89 NTU, concentrations similar to the range of turbities (3 to 180 NTU) observed in estuaries. In contrast, turbidity in raw sewage can be several hundred NTUs or more. There is no screening benchmark for turbidity from which to assess potential to cause or contribute to adverse effects on water quality.

To summarize, the concentrations of classical pollutants in firemain system water samples are within the normally expected ranges for the given season and geographical location where vessels were sampled. It appears that the classical pollutant concentrations primarily reflect concentrations found in the ambient water.

Table 3.7.2. Results of Firemain System Water Sample Analyses for Classical Pollutants[1]

Analyte	Units	No. samples	No. detected	Detected Proportion (%)	Average Conc.	Median Conc.	Minimum Conc.	10%	25%	75%	90%	Maximum Conc.	Screening BM[2]
Conductivity	mS/cm	5	5	100	0.32	0.24	0.23	0.23	0.24	0.43	0.47	0.47	NA
Dissolved Oxygen	mg/L	5	5	100	7.7	6.8	4.1	4.1	4.9	11	13	13	NA
pH	SU	6	6	100	7.4	7.4	6.9	6.9	7.0	7.8	7.9	7.9	NA
Salinity	ppt	5	5	100	0.12	0.10	0.010	0.010	0.055	0.20	0.20	0.20	NA
Temperature	C	5	5	100	18	19	14	14	15	21	22	22	NA
Total Residual Chlorine	mg/L	6	1	17	0.05					0.025	0.10	0.10	0.0075
Total Suspended Solids (TSS)	mg/L	1	1	100	16								30
Turbidity	NTU	6	6	100	33	27	4.6	4.6	16	48	89	89	NA

Notes:

(1) Nondetect (censored) concentrations were replaced with ½ of the reporting limit for calculating average concentrations. The remaining statistics in this table were only calculated when analytes were detected at a sufficient frequency. For example, if an analyte was detected in fewer than 50% of samples, then a median concentration was not calculated. A blank cell reflects a situation when a median or percentile could not be computed based on detected concentrations. The percentiles are the concentrations of each analyte below which at least that percentage of the values fall. So the 10th percentile is the concentration below which at least 10% of the observations were found.

(2) Screening BM represents the screening benchmark referred to in Section 3.1.3, and is the most stringent 2006 NRWQC or other conservative benchmark used to calculate PHQs.

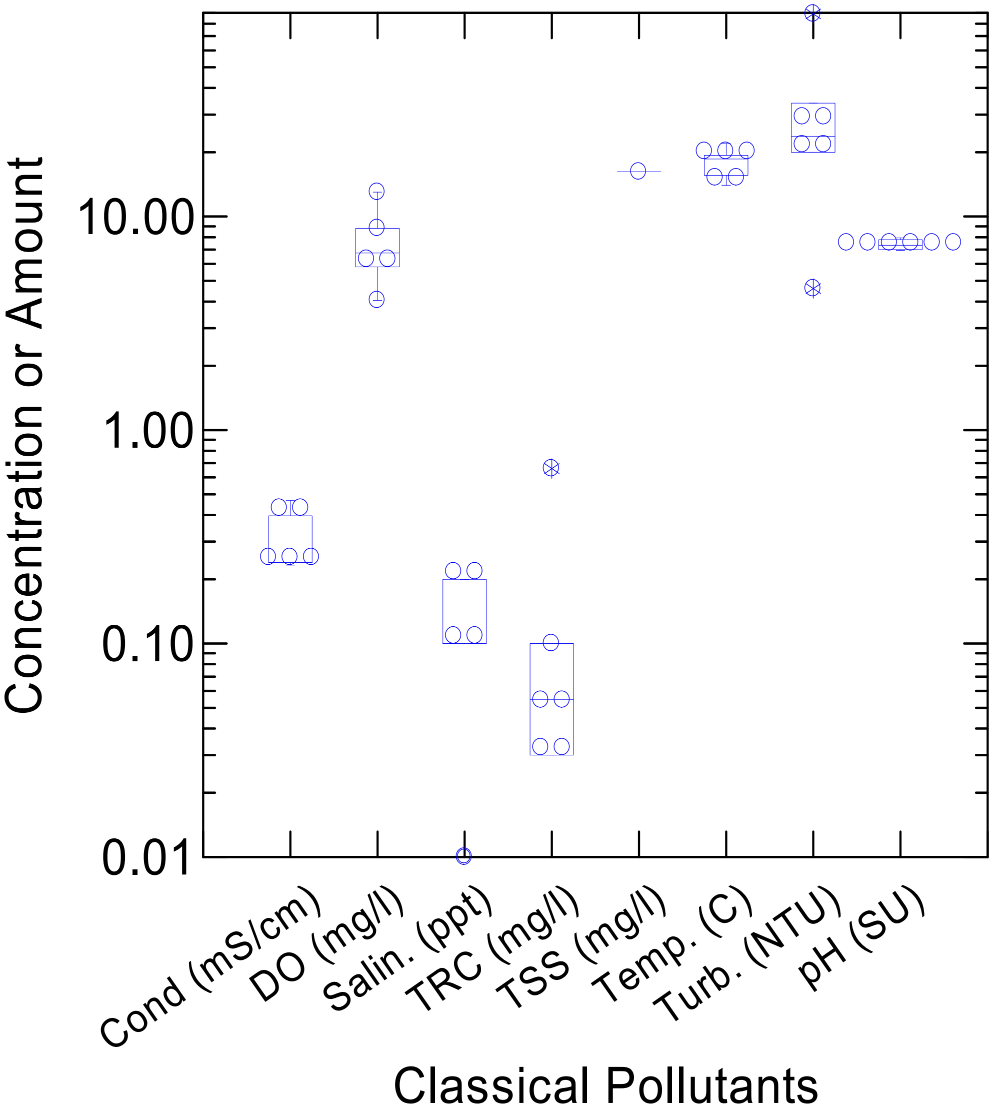

Figure 3.7.5. Box and Dot Density Plot of Classical Pollutants Measured in Samples of Firemain Water

(Note: Concentrations reflect ambient water concentrations and values because ambient water was used as the source of water for all fireman systems in the vessels sampled in the study program).

3.2.7.3 Volatile and Semivolatile Organic Chemicals

VOC and SVOCs were targeted in firemain systems for this program because of the expectation that AFFF agents might be injected into the water stream of a fire hose to practice potential fire suppression scenarios. AFFF was not used, however, by any of the vessels sampled for this study.

Of the 57 SVOCs that were analyzed for in the six firemain system water samples, only six were detected, none of which were detected in more than one sample (Table 3.7.3 and Figure 3.7.6). Similarly, of 37 VOCs analyzed for, only five were detected, and as with the SVOCs, none were detected in more than one sample (Table 3.7.3). When SVOC and VOC concentrations were above detection levels, concentrations were relatively low. Of these, only bis(2-ethylhexyl) phthalate was measured at a sufficiently high concentration of 4.6 µg/L that exceeded the associated PHQ of 3.8, based on the most conservative screening benchmark of 1.2 µg/L (human health criterion). Bis(2-ethylhexyl) phthalate was also the only SVOC or VOC detected in ambient water, but interestingly, at a slightly higher concentration of 13 µg/L.

Table 3.7.3. Results of Firemain Water Sample Analyses for SVOCs [1]

Analyte	Units	No. samples	No. detected	Detected Proportion (%)	Average Conc.[1]	Median Conc.	Minimum Conc.	10%	25%	75%	90%	Maximum Conc.	Screening BM[2]
SVOCs													
2,6,10,14-Tetramethyl Pentadecane	µg/L	1	1	100	9.9								NA
2-Mercaptobenzothiazole	µg/L	1	1	100	4.1								NA
Benzothiazole	µg/L	1	1	100	7.2								NA
Bicyclo[2.2.1]heptane,1,7,7-Trimethyl-	µg/L	1	1	100	14								NA
Bis(2-ethylhexyl) phthalate	µg/L	4	1	25	2.1					3.4	4.6	4.6	1.2
Isopropylbenzene-4,methyl-1	µg/L	1	1	100	9.9								NA
VOCs													
1-Methyl-2-(1-Methylethyl)-Benzene	µg/L	1	1	100	97								NA
1-Methyl-4-(1-Methylidene)-Cyclohexane	µg/L	1	1	100	6.8								NA
Limonene	µg/L	1	1	100	9.5								NA
n-Pentadecane	µg/L	1	1	100	3.8								NA
n-Tetradecane	µg/L	1	1	100	3.5								NA

Notes:

(1) Nondetect (censored) concentrations were replaced with ½ of the reporting limit for calculating average concentrations. The remaining statistics in this table were only calculated when analytes were detected at a sufficient frequency. For example, if an analyte was detected in fewer than 50% of samples, then a median concentration was not calculated. A blank cell reflects a situation when a median or percentile could not be computed based on detected concentrations. The percentiles are the concentrations of each analyte below which at least that percentage of the values fall. So the 10th percentile is the concentration below which at least 10% of the observations were found.

(2) Screening BM represents the screening benchmark referred to in Section 3.1.3, and is the most stringent 2006 NRWQC or other conservative benchmark used to calculate PHQs.

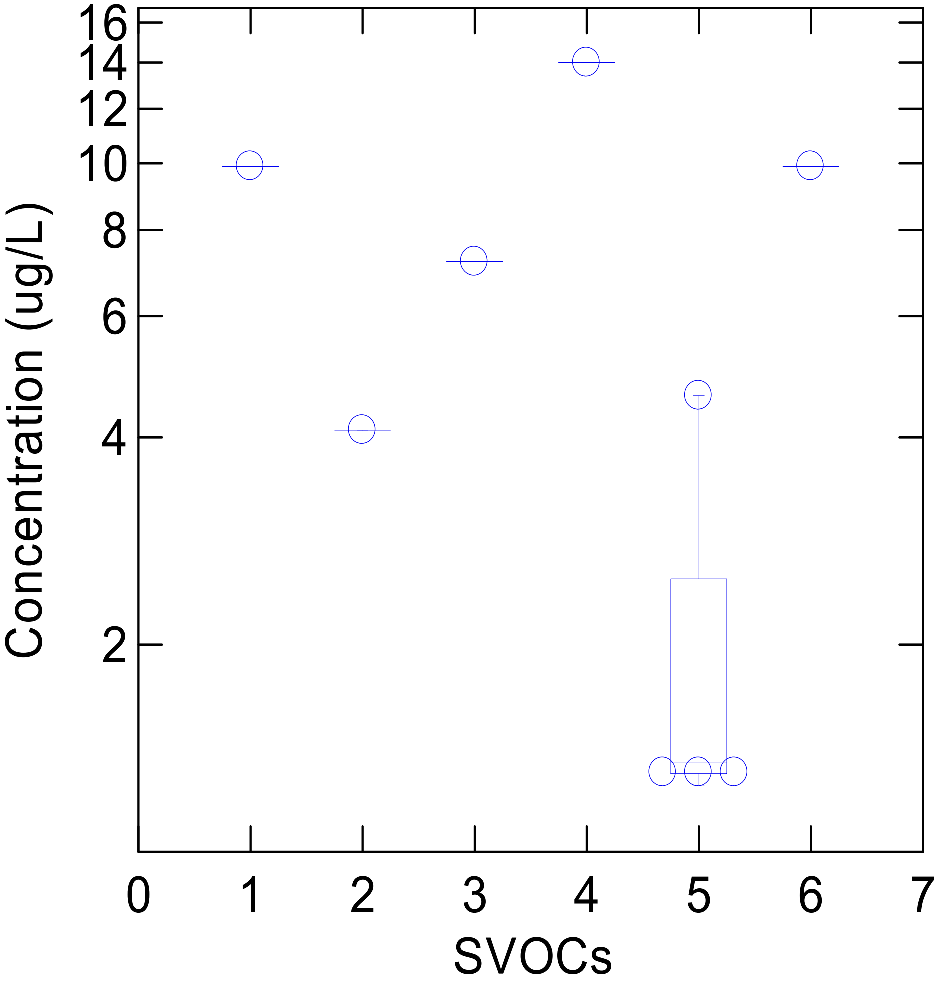

Figure 3.7.6. Box and Dot Density Plot of SVOC Concentrations Measured in Samples of Firemain Water

SVOCs are identified as follows:
(1) 2,6,10,14-Tetramethyl Pentadecane,
(2) 2-Mercaptobenzothiazole,
(3) Benzothiazole,
(4) Bicyclo[2.2.1]Heptane,1,7,7-Trimethyl-,
(5) Bis(2-Ethylhexyl) Phthalate,
(6) Isopropylbenzene-4, Methyl-1

3.2.7.4 Summary of the Characterization of Firemain System Water Analyses

Table 3.7.4 summarizes the specific analytes in firemain system effluent that may have the potential to pose risk to human health or the environment. EPA's interpretation of a realized risk likely posed by these analytes, relative to pollutant loadings, background ambient and source water contaminant levels and characteristics, and other relevant information useful for this assessment, is presented in Chapter 5.

The proportion of dissolved to total metals for firemain system discharge was low overall, relative to other discharge types. Among the dissolved metals, copper was detected in the highest concentrations and exceeded the NRWQC in the largest number of samples (four of six samples). The corresponding PHQs for dissolved copper ranged from approximately 4 to over 20. Dissolved lead and zinc had concentrations that exceeded the most conservative NRWQC in one and three samples, respectively, but none of the PHQs were above 10. Total aluminum and iron concentrations exceeded NRWQC benchmarks in all samples, with PHQs ranging from 1-5 (aluminum) and of approximatley 13 (iron; single sample from a fire boat). However, most of the aluminum in firemain discharge can be attributed to aluminum in the ambient waters. Overall, the concentrations of metals in firemain discharge were low compared to other discharge types.

Among the classical pollutants, TRC was the only pollutant of potential concern. However, TRC was detected right at the reporting limit of 0.10 mg/L in only one of six samples and the concentration likely reflects an elevated TRC concentration in the ambient water.

Finally, the concentration of bis(2-ethylhexyl) phthalate (an SVOC) exceeded the NRWQC (PHQ = 3.8) in one discharge sample; however, most SVOCs and VOCs sampled for were below detection limits, and when they were detected, occurred at very low concentrations. It is noteworthy to reiterate that bis(2-ethylhexyl) phthalate was also the only SVOC or VOC detected in ambient water, and at a slightly higher concentration (13 µg/L) than in the one firemain water sample.

Table 3.7.4. Characterization of Firemain Discharge and Summary of Analytes that May Have the Potential to Pose Risk

Vessel Type (no. vessels)	**Analytes that May Have the Potential to Pose Risk in Firemain Discharge and Probable Source[1, 2]**											
	Microbiologicals	**Volatile Organic Compounds**	**Semivolatile Organic Compounds**	**Metals (total and dissolved)**	**Oil and Grease**	**Sulfide**	**Short-Chain Alkylphenol Ethoxylates and NP**	**Long-Chain Alkylphenol Ethoxylates**	**Nutrients**	**BOD, COD, and TOC**	**Total Suspended Solids**	**Other Physical/Chemical Parameters**
Tour (3)			Bis(2-ethylhexyl) phthalate	**Cu(dissolved)**; Fe (total)								TRC
Tug (2)												
Fireboat (1)				Cu (dissolved)								

Notes:

(1) EPA notes that the conclusion of potential risk is drawn from a small sample size, in some cases a single vessel, for certain discharges sampled from some vessel classes. EPA included these results in the tables to provide a concise summary of the data collected in the study, but strongly cautions the reader that these conclusions, where there are only a few samples from a given vessel class, should be considered preliminary and might not necessarily represent pollutant concentrations from these discharges from other vessels in this class.

(2) Analytes are generally bolded when a large proportion of the samples have concentrations exceeding the NRWQC (e.g., 25 to 50 percent), when several of the samples have PHQs > 10 (e.g., two or three of five), when a few samples result in PHQs greatly exceeding the screening benchmark (i.e., 100s to 1,000s), or, in the case of oil and grease and for nonylphenol, when one or more samples exceed an existing regulatory limit by more than a factor of 2. See text in Section 3.1.3 for a definition of PHQs and Table 3.1 for screening benchmarks used to calculate these values.

3.2.8 Antifouling Hull Coatings

Antifouling hull systems (AFSs) are specialized paints and other coatings intended to retard the growth of algae, weeds, and encrusting organisms such as barnacles and zebra mussels on the underwater portion of vessel hulls. These organisms may foul hulls and other underwater parts, increasing corrosion and drag, reducing safety and maneuverability, decreasing fuel efficiency and economy, and lengthening transit times (WHOI, 1952). Vessel hull fouling is often significant as vessels can move between a diverse range of aquatic environments and remain in the photic zone that is the most productive region of the water body (Chambers et al., 2006). Exposed to a variety of organisms, vessel hulls can transfer the organisms into other water bodies, where they can become invasive species[38].

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Figure 3.8.1. Encrusting organisms (left) and weeds (right) growing on vessel hulls (figures from the Naval Surface Warfare Center's Carderock Division, West Bethesda, Maryland, and the Boating Industry Association of Victoria, South Melbourne, Australia[39]).

What is a Biocide?
A **biocide** is a chemical substance capable of killing living organisms, usually in a selective way.

The development of AFSs has a long history, as mariners have tried for centuries to keep vessel bottoms free of barnacles and other fouling growth (Yebra et al., 2004; Readman, 2006). Ancient civilizations of the Greeks and the Romans coated their vessels with lead sheathing secured by

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[38] For this report, EPA did not evaluate the relationship between Anti Foulant Systems, fouled vessel hulls and the transport/spread of invasive species   Other studies have shown that fouled vessel hulls contribute to the spread of invasive species and increase fuel consumption, thereby increasing greenhouse gas emissions and vessel operator cost. Though it is beyond the scope of this study, preventing vessel hull fouling provides important environmental and economic benefits, however, as discussed in this section, biocidal anti-foulant paints can also contribute to environmental degradation.

[39] See http://www.dt.navy.mil/sur-str-mat/fun-mat/pai-pro-bra/fou-con-tec/images/fouling.jpg and http://www.biavic.com.au/files/weedunderhull.jpg, respectively, for access to figures.

copper nails. These heavy metals were early examples of using biocides to control fouling. Columbus' ships are thought to have been coated with pitch and tallow. In the United Kingdom, lead sheathing was abandoned by the Navy in the late 1600s, and antifouling paints containing tar, grease, sulphur pitch and brimstone were developed (Carberry, 2006). One hundred years later, copper sheathing was used that prevented fouling through dissolution of the toxic metal ions (Readman, 2006). With the introduction of iron ships in the mid-1800s, different antifouling paints were needed because the copper sheathing reacted with the hull material to hasten corrosion of the iron. New paints were developed by adding toxic biocides such as copper oxide, arsenic, and mercury oxide to resin binders. Following the Second World War, the introduction of petroleum-based resins and health and safety concerns relating to arsenic- and mercury-containing paints meant that copper-based paints became most popular (Readman, 2006).

In the late 1950s and early 1960s, new antifouling paint formulations using tributyltin (TBT) proved to be excellent in preventing hull fouling. TBT, especially in "self-polishing" formulations, proved very efficient, and the application of TBT-based paints rapidly expanded. TBT was frequently formulated together with cuprous oxide to control a broader range of organisms. Not only was antifouling performance improved, but tin-based formulas (without copper components) are noncorrosive to aluminum, which was being used more in the construction of vessel hulls and propulsion systems. Unfortunately, the use of TBT also had severe and unexpected environmental consequences (Carberry, 2006). As the popularity of TBT grew, oyster producers in France reported shell malformations caused by paint leachate containing TBT that rendered their harvest worthless. Wild populations of other mollusc species were also affected at very low concentrations of TBT in the water and sediment (Evans et al., 1994). For example, female dog whelks (*Nucella* sp.) developed male characteristics (termed imposex) at these levels (Bryan et al., 1986). This masculinization of female gastropods was also reported in the open North Sea (Ten Hallers-Tjabbes et al., 1994). TBT use on small vessels was phased out in the late 1980s, when EPA and other regulatory agencies (including those in Canada, Australia, and many in Europe) restricted use of TBT-based AFSs to ships longer than 25 meters (see Section 6.2.3 of this report for further discussion about regulatory elimination of TBT).

Restrictions on the use of TBT-based AFSs opened the market for paint manufacturers and chemical companies developing new biocides for new antifouling paints to be used on vessels. Other metallic species, such as copper (copper hydroxide, copper thiocyanate) and zinc (zinc pyrithione), are currently used as substitutes for TBT. Copper oxide (in formulations without TBT) is by far the most common of the metallic biocides, used in more than 90 percent of the approximately 180 AFS products registered in California (Singhasemanon, 2008). A single AFS product might actually contain multiple biocides, with "booster biocides" incorporated to increase the duration and functionality of copper-based AFSs (Chambers et al., 2006). Irgarol is currently the organic biocide booster most frequently formulated into AFS products. As was the case for TBT, the biocides used in AFSs today can be toxic to a range of aquatic organisms, not just fouling organisms. In the subsections below, EPA discusses the literature on studies of adverse effects of these AFS biocides to aquatic resources as well as alternatives to using biocidal AFSs.

EPA did not sample antifouling systems as part of this study because of lack of time and resources available for this study. Assessing AFS discharge involves isolating a commercial vessel within a confined body of water (a “boat bag” or slip liner), and measuring the release, discharge, or leaching of the AFS biocide(s) over a period of time (weeks or months); the amount of time needed for the study would impose economic hardship on the vessel’s owners and operators. Rather, EPA elected to rely on the significant secondary data on anitifouling systems available in the literature.

3.2.8.1 Copper Biocides

Copper is typically the biocide added to antifouling paints to prevent biofouling organisms from attaching to the hull. The most common form of copper used in AFSs is cuprous oxide, which acts as a preventative biocide by leaching into the water body. Cuprous oxide concentrations in marine antifouling paints range from 26 to 76 percent by weight, with most paints in the 40- to 70-percent range. Since cuprous oxide is 89 percent copper by weight, typical cuprous oxide marine antifouling paints are 36 to 62 percent copper by weight (TDC Environmental, 2004). Two additional copper biocides are occasionally used in AFSs: copper thiocyanate and copper hydroxide. These formulations are not as common, although copper thiocyanate has the advantage of being compatible with aluminum. The contribution of copper from these paints to receiving water is small relative to AFSs containing cuprous oxide (TDC Environmental, 2004).

Conventional copper-based AFSs fall into several general categories: copolymer or ablative paints and hard contact leaching paints (Conway and Locke, 1994). Copolymer paints release biocide at a constant rate, ablating (wearing away) much like a bar of soap, which is intended to reduce the need for cleaning. Hard contact leaching paints are usually modified epoxy paints that leach biocide upon contact with water, and, over time, the biocide is released at a decreasing rate. Each of these coating formulations can benefit from periodic hull cleaning to remove fouling growth, maintain a smooth surface, and improve the copper release on vessel hulls, but underwater hull cleaning can be a source of pollution or introduce non-native species if not done carefully. Cleaning frequencies and methods vary by paint type, area of vessel operation, frequency and conditions of operation, and vessel operator’s needs. Techniques that capture removed fouling growth and paint residue reduce negative impacts on the environment.

Passive leaching rates from antifouling paint, including those that are copper-based, depend on a number of factors, including the paint matrix (e.g., vinyl, epoxy), copper content, age of the paint, time since last hull cleaning, and frequency of painting. Leaching rates also vary with environmental conditions such as pH, temperature, salinity, and the existing slime "biofilm" layer (CRWQCB, 2005).

Rates of passive leaching of dissolved copper from AFSs on seven recreational vessels painted with epoxy copper antifouling paints were investigated in studies conducted in Southern California by the U.S. Navy, under test conditions intended to represent realistic vessel conditions. Copper release rates were found to range from 2 to 14 µg/cm^2/day, with an average leaching rate of 8.2 µg/cm^2/day[40]. In another study of copper-based AFSs on recreational vessels, researchers with the Southern California Coastal Water Research Project (SCCWRP) measured the mass emissions of dissolved copper from both passive leaching and underwater hull cleaning (Schiff et al., 2003). Fiberglass panels were painted with copper-based antifouling paints and immersed in seawater in a harbor environment. SCCWRP researchers determined the average flux rates for epoxy and hard vinyl copper antifouling paints to be approximately 4.3 and 3.7 µg/cm^2/day over the course of a month, respectively. In the SCCWRP study, the authors also discussed the comparability of the results between the U.S. Navy and SCCWRP studies. According to the authors, the range of passive leaching measurements from the U.S. Navy study was within the range of measurements obtained in the SCCWRP study. By combining the results from the two studies, an average passive leaching rate for vessels at the Shelter Island Yacht Club (SIYB) was determined to be 6.5 µg/cm^2/day (CRWQCB, 2005). In the United Kingdom, Thomas et al. (1999) found higher copper leaching rates for ablative copper antifouling paint ranging from 18.6 to 21.6 µg/cm^2/day in 17 day experiments (Schiff et al., 2003). Table 3.8.1 summarizes the passive leaching rates for vessel AFSs found in the literature. The copper leaching rates summarized in this table were measured in experiments designed to simulate environmentally relevant conditions. However, more recently developed types of AFSs may leach at different rates, and the actual rates of copper leaching from many vessels and real-world environmental conditions may differ from those in Table 3.8.1[41].

Estimates of copper released from AFS leaching and underwater hull cleaning were calculated based upon the 6.5 µg/cm^2/day average flux rate cited above, which was extrapolated to vessels using the underwater surface area of the hull[42], and then to marinas (or harbors) based on the number of vessels in the marinas. Despite the caveats and limitations discussed above, EPA uses these estimates in Chapter 4 to calculate loadings from vessel hull AFSs to attempt to

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[40] EPA notes that a calculated average for release rates will not reflect real-world conditions for many vessels and environmental conditions.

[41] Additional test data for copper AFC leaching rates were provided to EPA by the Antifouling Coatings Work Group (AFWG) of the American Coatings Assoc iation (ACA) during the public comment period. These data substantially agree with EPA's best estimate of copper AFC leaching rate (6.5 µg/cm^2/day) used for water quality modeling in Chapter 4.

[42] Hull surface area can be estimated using the following equation: Hull Surface Area = VesselLength*Beam*0.85 (Interlux, 1999).

understand the impacts of this source of copper discharge from certain vessels on large water bodies.

Even when an effective AFS is used, the biofouling could accumulate over time to unacceptable levels. If the AFS is still viable, this accumulated growth can be removed from vessel hulls by a number of methods, most frequently by underwater hull cleaning. Several studies have investigated the release of copper from copper-based AFSs into water bodies during underwater hull cleaning. The amount of copper released depends on cleaning frequency, method of cleaning, type of paint, and frequency of painting (SWRCB, 1996). Valkirs et al. (1994) found that underwater hull cleaning resulted in elevated total copper concentrations near the vicinity of the operation as dissolved copper was released during and shortly after hull cleaning. Smaller amounts of dissolved copper also leached from debris and sediments after cleaning. The particulate form of copper was rapidly incorporated into the bottom sediment, likely rendering it unavailable to aquatic organisms. The biologically active species of copper complexed rapidly, and dissolved copper levels returned to precleaning conditions within minutes to hours after the hull cleaning. Valkirs et al. (1994) concluded that potential adverse effects of hull cleaning on aquatic organisms from the increased dissolved copper concentrations were relatively short-term and pulsed in nature, while the potential adverse effects of increased particulate copper were probably long-term in nature, and dependent on resuspension or sediment uptake from benthic organisms.

McPherson and Peters (1995) also studied the effects of underwater hull cleaning on water body copper concentrations and toxicity to aquatic life. In the study, an underwater hull cleaning operation was performed in Shelter Island Yacht Basin using Best Management Practices (BMPs) that used less abrasive techniques to remove fouling growth (e.g., hand-wiping with a soft cloth). Most of the copper released during the cleaning was in the dissolved form. Researchers found that the plume of copper released by cleaning moved with the current, and that the degree of plume contamination depended on fouling extent and exertion by the diver. McPherson and Peters (1995) concluded that underwater hull cleaning elevates concentrations in the vicinity of the operation, which return to background levels within minutes. The researchers did not identify the type of antifouling paint (ablative or contact leaching paint), the age of the antifouling paint on the vessel, or the time since last hull cleaning. While the study provided important information regarding impacts of underwater hull cleaning on water quality, it did not provide copper emission rates associated with hull cleaning.

Schiff et al. also estimated dissolved copper emissions rates associated with underwater hull cleaning. Fiberglass panels were painted with copper antifoulants to simulate the hulls of recreational vessels. The study objective was to estimate the flux rates of dissolved copper from underwater hull cleaning of vessels painted with two commonly used types of copper-based antifouling paints in San Diego Bay. Schiff found that hull cleaning released between 3.8 to 17.4 $\mu g/cm^2$ per event (see Table 3.8.2), with an average release of 8.6 $\mu g/cm^2$/event. The researchers concluded that underwater hull cleaning results in a greater daily load of copper to the environment than passive leaching. In terms of mass loading, the authors concluded that approximately 95 percent of dissolved copper from antifouling paint enters the environment via passive leaching (CRWQCB, 2005). EPA notes, however, that this does not include loading rates from particulate copper, which may also impair the environment in the benthos due to biogeochemical cycling.

AFSs that are applied to vessel hulls are one of the most commonly identified major sources for copper in marinas. A number of studies have been carried out to estimate the loading of copper from vessel AFSs. EPA estimated that copper loading from AFS use in California's Lower Newport Bay (LNB) area, which harbors approximately 10,000 boats, contributed more than 62,000 pounds of copper (via passive leaching and underwater hull cleaning) into LNB waters annually (USEPA, 2002). EPA believed that this load could account for as much as 80 percent of all copper input into LNB.

The U.S. Navy and private researchers conducted two copper source loading studies for the San Diego Bay in the late 1990s (Johnson et al., 1998; PRC, 1997). Both studies concluded that AFSs accounted for the majority of dissolved copper loading to the bay. The San Diego Regional Water Quality Control Board (SDRWQCB) estimated that passive leaching and underwater hull cleaning of the 2,400 boats berthed in the SIYB marina combine to contribute 98 percent of the copper load to the basin (Singhasemanon et al., 2009). Of the approximately 1.8 pounds of copper estimated released per boat per year (TDC Environmental, 2004), about 95 percent is believed to leach from AFS while boats are moored at the dock; the remaining 5 percent is believed to be released during monthly underwater hull cleaning activities.

The constant input of copper by leaching from the AFSs applied to pleasure, commercial, and military vessels has been cited as a likely primary source of copper in San Diego Bay. Sediment concentrations measured at the SIYB were relatively high (from 133 to 212 mg/kg) compared to other areas in San Diego Bay (Valkirs et al., 1994). Elevated copper concentrations (108 to 270 mg/kg) were found throughout San Diego Bay, with small boat harbors, commercial shipping berths, and military berths most affected. This distribution pattern is expected, considering the historical use of copper-based antifouling paints in the area.

Marinas in general tend to have elevated levels of pollutants in the water and sediments, including copper, as explained later in this subsection. For example, monitoring in the Southern California Bight demonstrated that sediment from marinas throughout southern California had consistently elevated copper levels compared to surrounding waters (Bay et al., 2000). The National Oceanic and Atmospheric Administration (NOAA , 1991) found the highest sediment concentrations, reaching over 104 mg copper/dry kg, in marinas, compared to other areas throughout the Southern California Bight. Sediment quality surveys around the United States routinely find high copper concentrations in marinas and harbors (USEPA, 1996; NOAA, 1994).

A recent study of AFS biocides in California marinas found dissolved copper concentrations ranging from 0.1–18.4 µg/L (Singhasemanon, 2008) in the water. Concentrations were significantly higher in salt- and brackish water marinas than in freshwater marinas. Dissolved copper concentrations in many of the salt- and brackish water marinas exceeded established water quality standards. Thus, there are ecological risks due to copper in many salt and brackish water marinas (Singhasemanon, 2008).

Copper contamination from vessel hulls is a water quality problem that is not unique to California. Within the United States, other areas of current concern to regulators include Chesapeake Bay, Maryland; Port Canaveral and Indian River Lagoon, Florida; and various harbors in the state of Washington (Carson et al, 2009).

Elevated copper levels in marinas may be attributable to a number of factors. Marinas are home to high concentrations of recreational and commercial vessels. Since recreational vessels spend much of their time moored in marinas, most of the biocide from the antifouling paints on the vessel hulls is released in the marinas. Moreover, marinas are purposefully constructed to shelter boats from currents and waves, so they are not flushed well. Elevated trace metal concentrations in marinas are partly the result of the lack of mixing and dispersion. Thus, AFS pollution at these locations would represent some of the worst-case scenarios with regard to water quality (Singhasemanon et al., 2009; CRWQCB, 2005).

The biocides leached from AFSs can accumulate in the water of poorly flushed boat basins to levels that might harm marine life, especially mollusks, crustaceans, and echinoderms (Johnson and Gonzalez, 2006). At relatively low concentrations, copper is toxic to a wide range of aquatic organisms, not just fouling organisms (CRWQCB, 2005). Concentrations as low as 5 to 25 µg/L can be lethal for marine invertebrates (Chambers et al., 2006). Elevated copper levels affect growth, development, feeding, reproduction, and survival at various life stages of fish, mussels, oysters, scallops, crustaceans, and sea urchins. High copper levels also change the types of phytoplankton that thrive in boat basins (Calabrese et al., 1984). Low levels of dissolved copper affect the olfactory capabilities in juvenile Coho salmon, which is critical for homing, foraging, and predator avoidance (Baldwin et al., 2004). The effect of copper on olfaction of juvenile salmonids suggests that copper might affect other fish species, too. Most effects on fish are sublethal (e.g., they may hinder metabolic processes, reproduction, development, activity levels and behavior). Thus, the damage is chronic and less noticeable than, for example, fish kills caused by sudden oxygen depletion (Evans et al., 1994).

In the California marina study, significant toxicity was measured in eight of 47 water samples; seven of the toxic samples came from Marina del Rey (MdR) in Los Angeles (Singhasemanon et al., 2009). The authors concluded that copper was the most likely cause of the toxicity in these samples. Two models of copper bioavailability and toxicity to aquatic organisms, the Biotic Ligand Model (BLM) and dissolved organic carbon (DOC) model, were used to confirm these findings. The BLM and DOC model predictions agreed favorably with the actual toxicity data, although both models tended to slightly overpredict toxicity, especially when close to the toxic effect concentration (i.e., EC_{50}) (Singhasemanon, 2008).

Rivera-Duarte et al. (2003) also investigated the bioavailability and toxicity of copper in San Diego Bay and found that toxicity was based on chemical speciation and followed the free ion activity model. The EC_{50} for mussel larval development was observed near 10^{-11} molar (i.e., 0.64 ng/L) free copper ion. The toxic threshold concentration of free copper ion was independent of spatial and temporal effects, indicating the need to study chemical speciation of copper released from antifouling paints in order to determine its environmental effects (Rivera-Duarte et al., 2003).

Table 3.8.1. Rates of Passive Copper Leaching from Vessel AFSs

Study	Test Method	AFS	Leaching Rate ($\mu g/cm^2/day$)
UK (Thomas et al., 1999)	Not reported	Ablative copper antifouling paint	18.6 – 21.6
U.S. Navy (Zirino and Seligman, 2002)	Not reported	Ablative copper antifouling paint	Average = 3.9
U.S. Navy (Valkirs et al., 2003)	7 recreational vessels in recirculating dome system	Epoxy copper antifouling paint	2 - 14 (average = 8.2)
SCCWRP (Schiff et al., 2003)	Fiberglass panels in recirculating dome system	Epoxy copper antifouling paint	4.3
		Hard vinyl/Teflon copper antifouling paint	3.7
		Biocide-free coating	0.24

Table 3.8.2. Dissolved Copper Release from Vessel AFSs During an Underwater Hull Cleaning "Event"

AFS	Cleaning Method	Copper Release ($\mu g/cm^2$/event)
Epoxy copper antifouling paint	Less abrasive management practices	8.6
	No management practices	17.4
Hard vinyl/Teflon copper antifouling paint	Less abrasive management practices	3.8
	No management practices	4.2
Biocide-free coating	Less abrasive management practices	0.03
	No management practices	0.05

Source: Schiff et al., 2003

Table 3.8.3. Estimated Dissolved Copper Mass Emissions from a 9.1m (30ft) Powerboat

Source	Dissolved Copper Emission (grams/month)		
	Epoxy Copper Antifouling Paint	Hard Vinyl/Teflon Copper Antifouling Paint	Biocide-Free Coating
Passive leaching (min-max)	24.9 (23.3-27.8)	21.4 (15.7-24.5)	1.4 (0.9-1.8)
Underwater hull cleaning with BMPs (min-max)	1.8 (1.7-2.0)	0.8 (0.5-1.2)	<0.01 (0-0.01)
Total emissions (min-max)	26.7 (20.5-33.6)	22.2 (15.0-31.5)	1.4 (0.9-1.8)

Source: Schiff et al., 2003

3.2.8.2 Irgarol and Other Organic Biocide Boosters

Irgarol (Irgarol 1051, *N*-tert-butyl-*N′*-cyclopropyl-6-methylthio- 1,3,5-triazine-2,4-diamine) is a highly effective biocide used in AFSs to prevent the growth of autotrophic (e.g., plants and algae) organisms on vessel hulls. After the ban of tributyltin (TBT) on vessels shorter than 25 meters, the use of TBT-free paints containing copper compounds and organic booster biocides such as Irgarol increased considerably and became more widespread (Mohr et al., 2009). Other organic biocides, including Diuron (3-(3,4-dichlorophenyl)-1,1-dimethylurea), dichlorofluanid (1,1-dichloro-N-(dimethylamino)sulfonyl)-1-fluoro-N-phenylmethanesulfenamide), and Sea-Nine (4,5-dichloro-2-n-octyl-4-isothiazolino-3-one) are also added to AFS preparations to boost performance (Thomas et al., 2001). The use of biocide boosters is in part a response to concerns about performance, environmental impacts, and, according to Chambers et al., (2006), a reported increasing tolerance of some macrophytes and algae to copper. Freshwater locations such as the Great Lakes are plagued primarily by algae (West Marine, 2008), and booster biocides such as Irgarol are used to restrict the growth of algae by blocking photosynthesis near the water surface. To date, however, most studies on Irgarol have focused on marine areas and toxicity tests with marine organisms (Mohr et al., 2009).

Irgarol has been detected with increasing frequency at ecologically sensitive levels in coastal waters worldwide, as reviewed by Konstantinou and Albanis (2004). In ports and marinas in coastal waters, it has been detected in relevant effect concentrations of up to 4.2 µg/L (Basheer et al., 2002). Levels of up to 1.4 and 2.4 µg/L have been reported from UK marinas and freshwater sites (Thomas et al., 2002). In the United States, Irgarol and its major metabolite M1 have been detected in the Chesapeake Bay and Florida (Hall and Gardinali, 2004). In the California marina study, Irgarol and M1 were detected in all 45 marina samples (Singhasemanon et al., 2009); Irgarol concentrations ranged from 12 to 712 ng/L, and M1 concentrations ranged from 1.6 to 217.1 ng/L. Higher concentrations of irgarol and M1 were found in salt water marinas.

Although Irgarol was predicted to easily dissipate under natural conditions (Hall et al., 2005), it is the most frequently detected antifouling biocide worldwide (Konstantinou and Albanis, 2004). Published values of the half-life of Irgarol in water are between 24 and 200 days (Mohr et al., 2009).

EPA has expressed concern over the potential toxic effects of Irgarol on aquatic plants and algae (USEPA, 2003a). Compared to other triazines like atrazine and simazine, Irgarol is a more potent inhibitor of algal photosynthesis, and is therefore highly toxic to macrophytes, phytoplankton, and periphyton (Mohr et al., 2008). Irgarol is likely to be much less toxic to animals than flora (Mohr et al., 2009). The main metabolite M1 is also toxic to aquatic plants and algae, but in many cases much more than 10 times less toxic than Irgarol.

Although Irgarol is formulated in AFSs to control periphyton on vessel hulls, the range of environmental concentrations measured in freshwater can be toxic to nontarget macrophytes. The results of the Mohr et al. (2009) study indicate that Irgarol is likely to have serious impacts on natural macrophyte communities at environmentally relevant concentrations. The fact that Irgarol accumulates in macrophytes, especially at lower concentrations, suggests the expected toxicity of Irgarol may be underestimated (Mohr et al., 2009).

What are Macrophytes, Phytoplankton, and Periphyton?

A **macrophyte** is an aquatic plant that grows in or near water and is either emergent, submergent, or floating.

Phytoplankton are planktonic algae that live in water bodies.

Periphyton is a complex mixture of algae, cyanobacteria, heterotrophic microbes, and detritus that is attached to submerged surfaces in most aquatic ecosystems.

Irgarol concentrations at many of the marinas in the California study were high enough to be toxic to some phytoplankton and aquatic plants (Singhasemanon et al., 2009). For example, the range of observed Irgarol concentrations (12 to 712 ng/L) exceed aquatic benchmark values that are protective of 90 percent of aquatic plant species. The Irgarol metabolite M1 never exceeded the aquatic benchmark value (Singhasemanon, 2008).

3.2.8.3 Zinc Biocides

In recent years, there has been an increase in the registration of AFS products with zinc pyrithione (bis(N-oxopyridine-2-thionato)zinc(II)), also commonly known as zinc omadine, as the primary biocide (Singhasemanon et al., 2009).

In a California marina study, dissolved zinc concentrations from paints containing zinc omadine ranged from 1.0–66.6 µg/L with a concentration distribution that was similar to dissolved copper (Singhasemanon, 2008). Dissolved zinc concentrations were much higher in saltwater marinas than brackish and freshwater marinas. Zinc concentrations did not exceed California Toxics Rule (CTR) fresh- and saltwater standards. If zinc pyrithione becomes more popular as an AFS biocide in the future (e.g., as a replacement for copper AFSs), the contributions of zinc AFSs to the marina zinc load will increase and potentially lead to zinc-related toxicity (Singhasemanon et al., 2009).

3.2.8.4 Emerging Biocides

As mentioned in the introduction to this subsection, AFSs using copper-containing biocides are the most common substitutes for TBT. However, paint manufacturers continue to search for new antifouling biocides. One promising development is ECONEA, a metal-free biocide developed by a pharmaceutical company. According to the paint manufacturers, ECONEA is rapidly biodegradable and does not accumulate in the marine environment, and is reported by the manufacturer to very effectively control a wide range of invertebrate fouling organisms in significantly less amounts compared to conventional biocides. However, AFSs formulated with ECONEA have not entered the market, and independent testing data are not currently available.

3.2.8.5 Biocide-Free (Nonbiocidal) AFSs

In recent years, biocide-free coatings designed to prevent fouling growth from adhering to boat hulls have entered the market. Biocide-free coatings are designed to produce a slick surface that prevents fouling organisms from firmly adhering to the hull. Currently available nonbiocidal bottom coatings may be silicone-based, epoxy-based, water (urethane)-based, or polymer-based. They do not include biocidal components. Epoxy coatings are durable, and are expected to last for many years, but require frequent and aggressive cleaning (Johnson and Miller, 2002). The most commonly used nonbiocidal coatings are silicone elastomeric coatings, which are rubbery and are more easily nicked or abraded than epoxy, although recent advances have improved their durability. They are sometimes called “fouling release” coatings, because fouling growth is sheared off the hull once the vessel exceeds a certain speed (e.g., 20 knots). Movement of a foul-release-coated vessel through the water dislodges organisms that do adhere. The utility of these coatings depends on vessel speeds and the proportion of time the vessel is underway (rather than at dock). Foul-release coatings are typically more expensive than biocidal AFSs. Because of their expense and operational requirements, foul-release systems generally are not used on recreational vessels at this time.

To date, nontoxic AFS alternatives have not been widely accepted in the boating industry, due to concerns about practicality and cost. If adopted, these alternatives would eliminate the leaching of biocides from marine antifouling paint, as well as biocide release during underwater hull cleaning.

A number of projects are underway to develop new biocide-free AFSs. The European Commission is collaborating with industry with the goal of developing a nonbiocidal antifouling coating that relies on nanostructuring to impede the adhesion of fouling organisms (Ambio, 2008). The U.S. Navy is sponsoring research by University of Florida engineers to develop a biocide-free hull coating based on the geometry of shark skin scales. Chambers et al. (2006) provide a review of these and other biomimetic approaches to environmentally effective AFSs.

Because nonbiocidal coatings do not affect fouling growth, they may need more frequent cleaning than biocide-based AFSs, and can be more effective when used with other practices designed to increase the amount of shearing and decrease exposure to fouling organisms during times of inactivity: using the vessel more often and/or operating it at higher speeds; storing it on land or on a hoist at the slip when not in use; and, surrounding the vessel with a slip liner and adding 10 to 15 percent fresh water to reduce salinity (Johnson and Gonzalez, 2006).

3.2.8.6 BMPs

The most effective way to reduce biocide emissions from AFSs on recreational vessels is by carefully selecting the AFS. The owner/operator should match antifouling performance with how the vessel typically operates. Choosing a nonbiocidal AFS can eliminate emissions from vessels that, for example, operate at high speeds when they are underway. Slow-release formulations or formulations with lower biocide content may also reduce the release of biocides into the aquatic environment. As noted previously, passive leaching accounts for most of the biocide release from recreational vessels, but biocide also could leach into the water body during underwater hull cleaning and AFS application and removal.

In addition to AFS selection, other BMPs may be used to limit emissions of toxic components from AFSs. These BMPs include specifications for capturing and treating materials removed during underwater hull cleaning, properly managing wastes from AFS application processes, and capturing and appropriately disposing of old hull coating residue prior to repainting. When nonbiocidal coatings are used, companion strategies can be used to reduce fouling including slip liners, boat lifts, and frequent hull cleaning (Johnson and Gonzalez, 2006).

BMPs for underwater hull cleaning must also address the potential introduction of aquatic nuisance species (ANS). EPA notes that small vessels are strongly suspected of contributing to the spread of numerous invasive species including zebra and quagga mussels. Prohibitions on biocide-containing AFSs could potentially exacerbate the spread of ANS as the toxicity of vessel hull coatings declines and as water quality improves as a result.

Pollutants from passive leaching and hull cleaning can be reduced by implementing other BMPs, such as using nontoxic (or less toxic) antifouling paints to replace copper-based paints. Switching to nontoxic and less toxic antifouling paints will reduce the loading from both passive leaching and underwater hull cleaning. For example, if all new boats entering the Shelter Island Yacht Basin use nontoxic or less toxic coatings and existing boats replace copper coatings with nontoxic or less toxic coatings at the next routine hull-stripping (as assumed in their total maximum daily load), the basin's water quality is expected to dramatically improve (CRWQCB, 2005). Additionally, nontoxic or less toxic coatings will require companion strategies such as slip liners, boat lifts, and frequent hull cleaning to control fouling (Johnson and Gonzalez, 2006).

3.2.8.7 Conclusion

Antifouling systems currently used on the majority of recreational and commercial vessels are paints that prevent and retard fouling growth by leaching biocides, most frequently cuprous oxide, onto the hull. Biocides can enter a water body through passive leaching, underwater hull cleaning, hull painting, and AFS removal processes. Biocides leached from vessel AFSs can accumulate in the water of poorly flushed boat basins to levels that could harm marine life. Copper from vessel hulls in particular is a water quality concern in many near-coastal waters of the United States, including the waters of Southern California, the Chesapeake Bay, Port Canaveral and Indian River Lagoon in Florida, and in various harbors in the state of Washington. Copper leaching from vessel hulls has also been reported as a problem in several European countries, including Sweden, the Netherlands, and Denmark.

Concerns about impacts to aquatic ecosystems from both TBT and copper have led to the development of AFSs that use alternative biocides or are biocide-free. At this time, these alternatives are relatively costly and have not been widely accepted by boaters. Releases of biocidal components of AFS can be reduced by implementing BMPs, including the use of nontoxic (or less toxic) antifouling paints to replace copper-based paints.

CHAPTER 4

POTENTIAL LARGE-SCALE IMPACTS OF STUDY VESSELS' INCIDENTAL DISCHARGES TO HUMAN HEALTH AND THE ENVIRONMENT

In Chapter 3, EPA described the variety of vessel discharges and the scope and magnitude of pollutants discharged by 'study vessels.' EPA discussed whether these discharges of pollutants exceeded a National Recommended Water Quality Criteria (NRWQC) at end-of-pipe or contained persistent bioaccumulative toxic (PBT) chemicals which could indicate a potential for environmental effects. Public Law (P.L.) 110-299 tasks EPA with assessing the potential for discharges incidental to the normal operation of vessels to pose a risk to human health, welfare, or the environment from all sizes of commercial fishing vessels and other nonrecreational vessels less than 79 feet in length. As part of this assessment, EPA used a screening-level model as a tool to evaluate the cumulative effects of discharges from a population of such vessels operating in a large receiving water body.

EPA developed the screening-level water quality model to assess the impacts of vessel discharges on a hypothetical harbor environment[1]. For purposes of the model, EPA developed several vessel population scenarios that included multiple vessels from numerous vessel classes, such as fishing vessels, tour boats, water taxis, and tugboats discharging various waste streams (e.g., antifouling leachate, bilgewater, engine effluent, graywater). EPA then modeled numerous scenarios combining the different vessel populations in different hypothetical harbors to represent a range of environmental conditions potentially observed in harbors across the United States.

Due to the limitations of this screening-level model, EPA assumed that the background concentration for all analytes in the harbor water was zero. Although this assumption is likely unrealistic, removing other loading considerations from model calculations allowed EPA to evaluate whether incidental discharges from study vessels alone have the potential to exceed National Recommended Water Quality Criteria (NRWQC) in receiving waters without any additional sources of pollution. Vessel discharges may have a potential to contribute to water body impairment when vessel discharge pollutant concentrations exceed the NRWQC at end-of-pipe, depending on the quantity of pollutant in the discharge, what other potential sources of pollution are present, and the characteristics of the waters in which the vessel is operating. For example, if a group of vessels contributes a significant quantity of a given pollutant via a

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[1] For this analysis, the "harbor environment" refers to a large body of water that could potentially have 175 to 300 commercial vessels simultaneously discharging. EPA assumed that the harbor area extended beyond the defined vessel docking area to include the surrounding water body with an estimated surface area ranging from one to three square miles.

discharge into a water body, the impact of the vessel discharge is more likely to contribute to a water quality exceedance. If a group of vessels contributes only a very small quantity of a given pollutant via a discharge, the impact of the vessel discharge is less likely to contribute meaningfully to a water quality exceedance. EPA believes that assessing the potential for vessel discharges to contribute to water-body impairment is best conducted on a site-specific basis and is beyond the scope of this screening-level analysis.

Based on this assessment, EPA determined that incidental discharges from study vessels do not solely cause any NRWQC to be exceeded in the modeled hypothetical large estuaries and harbors. This determination suggests that these discharges alone are unlikely to cause impairments to relatively large water bodies. However, if a large water body already contains select pollutants, then vessels that contribute significant quantities of these pollutants might contribute to such an NRWQC exceedance. Furthermore, as discussed in Chapter 3, many pollutants detected in the vessel discharges were present at concentrations that exceed an NRWQC at the end of pipe, and therefore have the potential to negatively impact the receiving water on a more localized scale. Because the screening model assumes instantaneous and universal dilution in a large hypothetical harbor, the model is not designed to examine impacts on a local scale, in small water bodies with many vessels, or in water bodies with little to no flushing (i.e. dilution). These discharges may cause environmental concerns in areas such as small side embayments or marinas where flushing rates are low (see discussion in Section 4.6). As discussed above, EPA further notes that this model does not take into account any loadings from vessels that are not study vessels or other point/nonpoint sources that discharge pollutants that contribute to the loadings in the water body.

For the purpose of this study, EPA selected a simple screening-level model to provide a coarse "big picture" assessment of the overall potential for discharges from study vessels to cause or contribute to an impact on human health, welfare, or the environment. Although a screening-level model has several limitations, it identifies any major water quality issues, provides valuable information on pollutants of concern, identifies data gaps, and serves as a starting point for any future site-specific studies that are beyond the scope and objectives of this study.

The remainder of this chapter details EPA's cumulative effects assessment and is organized as follows:

- Section 4.1: Model Selection - Presents EPA's rationale for selecting the Fraction of Freshwater Screening-Level Model for the analysis.

- Section 4.2: Fraction of Freshwater Model - Describes the "fraction of freshwater model" and presents the equations and input parameters required for the screening-level analysis.

- Section 4.3: Vessel Discharge Loading Rates - Describes the methodology for developing the input parameters required to calculate the total analyte-specific loading rates for each vessel population scenario.

- Section 4.4: Hypothetical Harbor - Describes the methodology for developing hypothetical harbor input parameters.

- Section 4.5: Model Scenarios - Presents the 24 model scenarios represented in the model.

- Section 4.6: Model Results - Presents the results from the "fraction of freshwater model."

- Section 4.7: Conclusions - Presents EPA's conclusions on the potential for vessel discharges from study vessels to solely impact large-scale harbors or estuaries (e.g., to solely pose a risk to human health, welfare, and the environment).

4.1 MODEL SELECTION

Study vessels discharge into coastal harbors throughout the United States. Estuarine models, which are commonly used to assess harbor water quality, consist of two primary components: hydrodynamics (i.e., water transport processes) and water quality. Estuarine models are generally classified into the following four levels according to the temporal and spatial complexity of the hydrodynamic component of the model:

- Level I - Desktop screening models that calculate seasonal or annual mean concentrations based on steady-state conditions and simplified flushing time estimates.

- Level II - Computerized steady-state or tidally averaged quasi-dynamic simulation models, which generally use a box or compartment-type network.

- Level III - Computerized one-dimensional (i.e., estuary is well-mixed vertically and laterally) and quasi-two-dimensional (i.e., a link-node system describes estuary longitudinal and lateral mixing) dynamic simulation models.

- Level IV - Computerized two-dimensional (i.e., represents estuary longitudinal and lateral mixing) and three-dimensional (i.e., represents estuary longitudinal, lateral, and vertical mixing) dynamic simulation models (EPA 2001).

The sheer number of different coastal harbor environments potentially impacted by these vessels precludes using the more complex and data-intensive Level II, III, and IV models for the cumulative impacts analysis. For these reasons, EPA selected a Level I screening-level model, the "fraction of freshwater model," for the environmental assessment of vessel discharges from study vessels.

In addition to coastal harbors, study vessels also discharge to freshwater environments such as the Great Lakes and major river systems (e.g., Mississippi River). The "fraction of freshwater model" is applicable to only estuarine or saltwater-influenced environments; therefore, the modeling approach presented in this chapter does not address the potential environmental impact of vessel discharges in completely freshwater environments. Additional screening-level modeling approaches would be required to assess possible impacts of vessel discharges in these environments. EPA assumes that discharges to freshwater systems represent a smaller percentage of the total load from study vessels based on hailing port information provided in the Marine Information for Safety and Law Enforcement (MISLE) database maintained by the U.S. Coast Guard. Based on these data, commercial fishing vessels are almost exclusively located along U.S. coastal waters, and only about a third of other nonrecreational vessels less than 79 feet in length cite an inland waterway as their hailing port.

4.2 FRACTION OF FRESHWATER MODEL

The "fraction of freshwater model" is a series of equations that represent the harbor environment in zero dimensions and at a steady state (USEPA, 2001). These calculations are zero-dimensional in that they estimate concentrations at a given point in a water body within a specified, spatially homogenous volume. For example, the calculations assume instantaneous and homogeneous mixing of vessel discharges within the defined volume of a given harbor. It does not account for gradients of concentrations that would occur with distance from discharge source(s) such as plumes from vessels and other sources[2]. Specifying plumes and accounting for locations of numerous discharge sources would require a two- or three-dimensional model, which is beyond this Level I screening-level analysis.

Steady state means that the calculations provide an instantaneous estimate of the concentration under the assumption of chemical and physical equilibrium. Chemical equilibrium means that the water body salinity and the vessel discharge analyte concentrations do not change over time, while physical equilibrium means that the volume of water in the water body, tides, currents, and vessel discharge flow rates do not change over time. The assumption is that every process occurs instantaneously; therefore, temporal variability is not a factor. Accounting for changes in tides, currents, river flow, vessel discharge flow rates, and discharge concentrations over time would require a dynamic model, which is beyond this Level I screening-level model. This aspect of the model may cause it to underestimate localized environmental impacts,

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[2] Discharge plumes can be highly structured, especially in low-flushing environments; therefore, the development of a worst-case scenario using a screening-level model is not entirely conservative due to the assumptions of instantaneous and homogenous mixing within the entire volume of the harbor. A true worst-case scenario would likely include the concentration of pollutants within a small area of the harbor due to minimal dispersion of discharge plumes across the harbor. It would also include background concentrations and take other pollutant loadings into account (e.g., sewage treatment facilities, recreational vessels and other large vessels, stormwater, agricultural runoff).

especially in areas with inadequate flushing. However, in estimating quantities of pollutants discharged from the various discharge types, EPA has tended to use conservative parameter estimates (i.e., estimates that may overstate the average value) for variables such as flow and pollutant concentration.

The "fraction of freshwater model" calculates the analyte concentration in a harbor resulting from vessel discharges using the following four steps:

- Step 1: Calculate vessel discharge analyte loading rates (Equations 4-1 and 4-2)
- Step 2: Calculate the fraction of freshwater in the harbor (Equation 4-3)
- Step 3: Calculate the harbor flushing time (Equation 4-4)
- Step 4: Calculate the harbor analyte concentration (Equation 4-5)

The following subsections describe the input requirements, assumptions, and calculations for each step in the "fraction of freshwater model."

4.2.1 Step 1: Calculate Vessel Discharge Analyte Loading Rates

Analyte-specific total discharge loading rates (W_e) are required as input values in the "fraction of freshwater model" to calculate the instantaneous analyte concentrations in the harbor (C_x). In this analysis, analyte loading rates were based on the following four input parameters:

- Average analyte concentrations for each vessel class discharge type;
- Estimated flow rate for each discharge type within a vessel class;
- Number of vessels per vessel class present in the harbor; and
- Percentage of vessels per vessel class discharging each discharge type in the harbor (Equation 4-1).

$$W_{e,z} = \Sigma(C_{e,y,z} * Q_{y,z} * N_{,z} * P_{y,z}) \qquad \text{Equation 4-1}$$

Where:

$W_{e,z}$ = Discharge loading rate for analyte *e* from vessel class *z* (mass/time)
$C_{e,y,z}$ = Average concentration of analyte *e* in discharge *y* from vessel class *z* (mass/volume)
$Q_{y,z}$ = Flow rate for discharge *y* from vessel class *z* (volume/time)
$N_{,z}$ = Number of vessels in vessel class *z* present in the harbor
$P_{y,z}$ = Percentage of vessels in vessel class *z* discharging discharge *y*

EPA calculated the analyte-specific total discharge loading rate by summing the discharge loading rates for that analyte from each vessel class (Equation 4-2). Section 4.3 describes EPA's methodology for calculating this loading rate in more detail.

$$W_e = \Sigma(W_{e,z}) \qquad \text{Equation 4-2}$$

Where:

W_e = Total discharge loading rate for analyte e from study vessel discharges (mass/time)
$W_{e,z}$ = Discharge loading rate for analyte e from vessel class z (mass/time)

4.2.2 Step 2: Calculate the Fraction of Freshwater in the Harbor

The "fraction of freshwater model" estimates analyte concentrations in one dimension using information on freshwater inflow and by comparing salinity in the harbor with salinity in the seawater at the mouth of the harbor (USEPA, 2001). The fraction of freshwater (f_x) at any location in the estuary is calculated as:

$$f_x = (S_s - S_x)/S_s \qquad \text{Equation 4-3}$$

Where:

f_x = Fraction of freshwater at location x in the model harbor (unit-less)
S_s = Seaward boundary salinity at the mouth of model harbor (PSU)
S_x = Salinity at location x in model harbor (PSU)

EPA states that this ratio (f_x) "…can be viewed as the degree of dilution of the freshwater inflow (as well as pollutants) by seawater" from tidal influx in the harbor (USEPA, 2001).

4.2.3 Step 3: Calculate the Harbor Flushing Time

Harbor flushing time is defined as the amount of time required to replace the freshwater volume of the harbor by the river freshwater input. The flushing time (t) of the model harbor is calculated using Equation 4-4:

$$t = (\mathrm{V} * f_x)/\mathrm{Q}_{\mathrm{fw}} \qquad \text{Equation 4-4}$$

Where:

t = Model harbor flushing time
V = Volume of model harbor
f_x = Fraction of freshwater at location x in model harbor (unit-less)
Q_{fw} = Inflow of freshwater to model harbor from the model river (volume/time)

4.2.4 Step 4: Calculate the Harbor Analyte Concentration

The concentration of an analyte at location x (C_x) is the analyte-specific total loading rate (W_e in mass/time) divided by the flow rate away from location x, described by the volume of the harbor (V) divided by the flushing time (t) (USEPA 2001):

$$C_x = W_e/(V/t) \qquad \text{Equation 4-5}$$

Where:

C_x = Instantaneous analyte concentration at location x in model harbor (mass/volume)
W_e = Analyte-specific loading rate (mass/time) as calculated under Step 1
V = Volume of the model harbor as defined in Step 3
t = Model harbor flushing time as calculated in Step 3

4.3 VESSEL DISCHARGE LOADING RATES

Step 1 in the "fraction of freshwater model" calculates a range of analyte-specific total loading rates (W_e in mass/time) from fishing and nonrecreational vessels less than 79 feet based on the analyte concentration in a given discharge, the estimated flow rate for a given discharge, and assumptions on the number of vessels present in a harbor and percentage of vessels discharging each discharge type in the harbor. The following subsections present EPA's methodology for developing the modeling input parameters to calculate the analyte-specific total discharge loading rate.

4.3.1 Calculate the Average Analyte Concentrations

As described in Chapter 2, EPA collected wastewater characterization data for nine vessel discharges sampled from a total of 61 vessels (See Table 2.1). The objective of EPA's sampling program was to provide information on the nature, type, and composition of discharges from representative single study vessels and study vessel classes. EPA calculated vessel-class-specific analyte concentrations by averaging all of the discharge effluent sampling data by discharge type and by analyte. Replicate samples from a single vessel were averaged together prior to calculating a vessel-class-specific average. Certain analytes were not detected above the sample reporting limit in some wastewater samples. To fully represent the variability of pollutant concentrations in vessel discharges, EPA included both nondetected and detected results in calculating average vessel-class-specific analyte concentrations. For nondetected results, EPA assumed the analyte concentration was equal to one-half the sample reporting limit for that analyte. EPA based this assumption on the expectation that the analyte was present in wastewater, albeit at a concentration less than the sample reporting limit.

4.3.2 Discharge Flow Rate Assumptions

EPA calculated discharge-specific flow rates for each of the 59[3] study vessels sampled based on the following information for each discharge type:

- Known or estimated flow rates for the pump or mechanism controlling the discharge
- Assumptions on the frequency of discharge
- Assumptions on the duration of the discharge

EPA estimated vessel-specific discharge flow rates based on data and field observations from EPA's vessel sampling program, as well as information from secondary data sources. EPA developed frequency and duration assumptions based on interview responses from the vessel crew or observations from EPA's vessel sampling team. For example, EPA reviewed interview responses from a tow/salvage vessel operator to estimate bilge discharges based on the observation that the bilge pump discharges 60 gallons per minute for an approximate duration of five seconds per pump-out with an average frequency of one pump out every 10-minutes. As another example, the frequency at which fishing vessels discharge fish hold water into a harbor is generally dictated by how often the vessel offloads its catch. EPA used vessel sampling team field observations to develop the discharge frequency for each fishing vessel subclass (Table 4.3.1).

In addition, many of the study vessel classes discharge different amounts in different seasons. For example, fishing vessels operate during certain times of the year to coincide with different peak fishing seasons. As a conservative estimate, to account for the seasonal nature of these discharge loadings, EPA developed vessel flows to represent the loading rate that would typically occur during peak vessel activity for each vessel class. Specifically, EPA calculated the loading rates to represent the summer (or peak) season for all vessels, which is the time of greatest fishing activity in the major harbors across the United States and is generally the peak of recreational and tourist activity. [4]

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[3] As previously discussed, EPA excluded the sampling data from the two recreational vessels in the model because these vessels are not study vessels.

[4] Vessel flow rates presented in the screening-level analysis are not intended to be used to estimate annual loads. Additional seasonal considerations, such as the length of different fishing seasons, are required to calculate annual loads, which is beyond the scope of the screening-level analysis.

Table 4.3.1. Offload Frequency by Fishing Vessel Subtype

Fishing Vessel Subclass	Frequency of Offloads[1]
Purse Seiners	Daily
Trollers	Daily
Gillnetters	Daily
Tenders	Once every 2 days
Longliners	Once every 2 days
Shrimpers	Once every 3 days
Trawlers	Once every 3 days

(1) Based on sampling team observation in the field.

Table 4.3.2 provides examples of the known or estimated field data parameters and assumptions used to calculate the vessel-specific discharge flow rates for each discharge type. Where data parameter information were unknown, EPA used information from a similar vessel discharge type or used best professional judgment to estimate the required information. Appendix G provides a detailed description of the data and assumptions used to calculate the discharge-specific flows for each of these 59 sampled vessels. EPA averaged the vessel-specific discharge flows presented in Appendix G by vessel class and discharge type to calculate the vessel class-specific flow rates ($Q_{y,z}$) used in the model (Table 4.3.3).

Table 4.3.2. Examples of Field Data and Assumptions for Flow Rate Calculations by Discharge

Discharge Type	Example Data Parameters	Example Assumptions	Example Discharge Flow Calculation
Bilgewater	- Flow rate of bilge pump - Frequency of bilge pump out - Duration of a single pump out	- 12 volt bilge pump at 20 gpm[1] - Discharged all year - 5 min to pump bilge - 2 pumpouts per day	- 5 min to pump bilge - 1 pump per week - Discharged 365 days a year - 12 volt bilge pump at 20 gpm 20 gal per min X 5 min X 1 pump/7 days = 14.3 gal/day (0.05 m^3/day)
Deck Wash	- Volume of water used during deck wash down - Frequency of deck washes - Duration of deck washes - Flow rate of garden hose or high-pressure sprayers used to wash decks	- Garden hose flow rate is 11.67 gpm[2] - 1 wash every 2 weeks - 15 minutes per deck wash	- Cleaned with hose - 15 minute per deck wash - Garden hose flow rate is 11.67 gpm - 1 wash every 2 weeks 11.67 gal per min X 15 min X 1 wash/14 days = 7.21 gal/day (0.03 m^3/day)
Fish Hold	- Volume of holding tanks - Volume of fish - Whether the tanks hold fish in water or ice - Amount of ice - Frequency of offloads - Length of fishing season	- Density of fish is 0.9 kg/liter - Holding tank is 70% shrimp, 30% water[3] - Ice tank holds 50% fish, 35% ice, 15% air[4]	- 5,000-gallon tank - 75% full at offload - Holding tank is 70%shrimp, 30% water - 1 offload every 3 days 5000 gal X 30% X 3/4 full X 1offload/3 days = 375 gal/day (1.42 m^3/day)
Fish Hold Clean	- Frequency of tank cleanings - Length of fishing season - Washed with garden hose	- 30-minute wash for tenders and purse seiners - 15-minute wash for all other fishing vessels - Wash done after each offload - Garden hose flow rate is 11.67 gpm	- 15-minute hose down after each offload - 1 offload every 3 days - Garden hose flow rate is 11.67 gpm 11.67 gal per min X 15 min X 1 wash/ 3 day = 33.66 gal/day (0.13 m^3/day)
Graywater	- Number of crew onboard - Types of graywater generated - Frequency of laundry washed - Frequency of showers	- Laundry – front-load washer uses 25 gal/load - Laundry - standard washer uses 40 gal/load - Shower - 17.2 gal per shower[5] - Shower - 0.8 showers per person per day[5] - Sink - 30 min of sink use per crew per week - Sink - 2.2 gal per min in standard sink	- 3 crew - 17.2 gal per shower - 0.8 showers per person per day 3 crew X 17.2 gal per shower X 0.8 showers per person per day = 41.28 gal/day (0.16 m3/day)

Table 4.3.2. Examples of Field Data and Assumptions for Flow Rate Calculations by Discharge

Discharge Type	Example Data Parameters	Example Assumptions	Example Discharge Flow Calculation
Generator Engine	- Engine type - Cooling system type - Hours of use per year	- 2 gpm cooling flow for a standard generator[6]	- 17,000 hours over 15 years - 2 gpm cooling flow 2 gal/min X 60 min/hr X 17000hrs/15 years/365 days = 372.6 gal/day (1.41 m3/day)
Propulsion Engine	- Engine type - Cooling system type - Hours of use per year - Number of engines onboard	- 1 gpm cooling water flow rate for outboard engine - 20 gpm cooling water flow rate for inboard engine[6]	- Cummins inboard 380hp diesel engine - 463 hours in last 2 years - 20 gpm cooling water flow rate 20 gal per min X 231.5 hours/year = 761.1 gal/day (2.88 m^3/day)
Shaft Water	- Duration of boat operation	- 10 mL/min constant drip (3.8 gal/day drip)[4]	- operates 5 days/week - 10 mL/min constant drip (3.8 gal/day drip) 3.8 gal per day X 5 days/week = 2.71 gal/day (0.01 m^3/day)

(1) Estimate based on commonly used 12-volt bilge pumps. Flow rates ranged from 5 gpm to 30 gpm via Google.
(2) EPA used http://www.uiweb.uidaho.edu/extension/lawn/Files/Garden_Hose.htm to calculate the average flow rate of a garden hose (i.e., 11.67 gpm). EPA calculated the flow rate as the average flow for all three sizes of standard garden hose (1/2, 5/8, and 3/4 inches in diameter), assuming a water pressure of 40 PSI and a hose length of 100 feet.
(3) Based on data from one of the sampled vessels: 2,700 cubic feet per tank, 3 tanks (229,461.75 liters of tanks space), holds 325,000 lbs of salmon (163,798 liters of fish assuming density of fish is 0.9 kg/L). 163,798 liters of fish/229,461.75 liters of tanks space = 70% of fish. Assume remaining is hold water.
(4) Based on sampling team observation in the field.
(5) WaterSense Showerhead Factoids, Draft Date 7/27/09.

Table 4.3.3. Vessel Flow Rates

Vessel Class	Vessel Subclass	Discharge	Flow Discharged to Harbor per Vessel (m^3/day) [1]
Fire Boat	NA	Deck Wash	0.0100
Fire Boat	NA	Engine Effluent	36.3
Fire Boat	NA	Fire Main Effluent	0.00 [2]
Fire Boat	NA	Generator Effluent	1.80
Fishing	Gillnetter	Engine Effluent	14.9
Fishing	Gillnetter	Fish Hold Effluent	0.800
Fishing	Lobster Boat	Fish Hold Effluent	2.83
Fishing	Longliner	Bilgewater	0.450
Fishing	Longliner	Fish Hold Effluent	2.83
Fishing	Longliner	Fish Hold Cleaning Effluent	0.00 [2]
Fishing	Purse Seiner	Engine Effluent	16.6
Fishing	Purse Seiner	Fish Hold Effluent	16.3
Fishing	Purse Seiner	Fish Hold Cleaning Effluent	1.07
Fishing	Purse Seiner	Generator Effluent	1.41
Fishing	Shrimper	Bilgewater	2.84
Fishing	Shrimper	Deck Wash	0.344
Fishing	Shrimper	Fish Hold Effluent	1.25
Fishing	Shrimper	Graywater	0.00 [2]
Fishing	Tender Vessel	Fish Hold Effluent	19.3
Fishing	Tender Vessel	Fish Hold Cleaning Effluent	0.660
Fishing	Trawler	Deck Wash	0.344
Fishing	Trawler	Fish Hold Effluent	1.25
Fishing	Trawler	Fish Hold Clean	0.220
Fishing	Troller	Deck Wash	0.470
Fishing	Troller	Fish Hold Effluent	3.04
Fishing	Troller	Fish Hold Cleaning Effluent	0.660
Research	NA	Engine Effluent	0.0900
Supply Boat	NA	Deck Wash	0.0300
Tour Boat	NA	Bilgewater	0.0400
Tour Boat	NA	Deck Wash	0.140
Tour Boat	NA	Engine Effluent	42.2
Tour Boat	NA	Fire Main Effluent	0.00 [2]
Tour Boat	NA	Generator Effluent	3.82
Tow/Salvage	NA	Bilgewater	1.39
Tow/Salvage	NA	Deck Wash	0.0240
Tow/Salvage	NA	Engine Effluent	0.952
Tugboat	NA	Deck Wash	0.0978
Tugboat	NA	Fire Main Effluent	0.00 [2]
Tugboat	NA	Graywater	0.478
Tugboat	NA	Shaft Water	0.0100

Table 4.3.3. Vessel Flow Rates

Vessel Class	Vessel Subclass	Discharge	Flow Discharged to Harbor per Vessel (m^3/day) 1
Water Taxi	NA	Bilgewater	0.130
Water Taxi	NA	Deck Wash	0.0650
Water Taxi	NA	Engine Effluent	39.8
Water Taxi	NA	Generator Effluent	9.08
Water Taxi	NA	Graywater	0.280

NA – Not applicable.
(1) EPA estimated discharge flow rates for each vessel class based on data and field observations from EPA's vessel sampling program, as well as information from secondary data sources. EPA assumes that discharges not listed for a given vessel class are either not generated by a given vessel class or are discharged outside of the hypothetical harbor area.
(2) These waste streams are all discharged in the harbor; however, the relatively small volume and infrequency of the discharge results in an insignificant daily discharge volume.

4.3.3 Number of Vessels Present in the Harbor

The total number of vessels present in any given harbor and the distribution of vessels among the different vessel classes operating in that harbor vary significantly across the United States. The number and distribution of vessels among the different classes depend on factors such as the regional economic base (e.g., fishing versus recreation), size of the city supporting the harbor, and geographic location (e.g., Alaska versus Gulf of Mexico). To represent the variety of vessel combinations potentially present in a harbor, EPA developed the following three vessel population scenarios for the model:

- Scenario 1: Fishing Harbor - A harbor where fishing is the primary economic driver in the region, and fishing vessels represent the majority of vessels present in the harbor[5].

- Scenario 2: Large Metropolitan Harbor - A harbor where there are nonrecreational study vessels associated with a large metropolitan city that would require a greater number of support vessels such as supply boats, tow/salvage vessels, and tugboats. In addition, EPA assumed that there would be a higher level of vessel activity within the hypothetical harbor compared to the activity assumed for Scenarios 1 and 3. Note that this screening analysis does not include large non study vessels such as container ships, tankers, bulk carriers, or other larger vessels, which would be present in almost any large port[6].

- Scenario 3: Recreational Harbor – A harbor where the primary economic driver is the tourist or recreation industry. Although recreational vessels are not study vessels, EPA assumed that a recreational harbor would have a high concentration of nonrecreational support vessels such as tow/salvage, tour boats, and water taxis associated with the regional recreational and tourist industry. However, as noted previously, this analysis does not consider discharges from non study vessels and other sources.

EPA used data from the MISLE database maintained by the U.S. Coast Guard to develop the number of vessels present in the hypothetical harbors for the three scenarios and the distribution among the different vessel classes. The MISLE database includes a wide range of information regarding vessel and facility characteristics, accidents, marine pollution incidents, and other pertinent information tracked by the U.S. Coast Guard from investigation and

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[5] Charter fishing vessels are not modeled as part of this analysis. Charter fishing vessels are generally either manufactured or used primarily for pleasure, or leased, rented, or chartered to a person for the pleasure of that person. Many are not inspected by the US Coast Guard. These vessels are exempted from NPDES permitting requirements by the Clean Boating Act (P.L. 110-288). Other charter fishing vessels are inspected by the US Coast Guard. These inspected, non-recreational vessels are not exempted from NPDES by the Clean Boating Act, and are study vessels only if they are less than 79 feet. As a general matter, therefore, EPA anticipates that a significant portion of charter fishing vessels are not study vessels.

[6] Due to time and resource constraints, EPA did not sample these large vessels for this study. Therefore, EPA did not calculate loadings from these larger vessels for this screening analysis.

inspection activity. While MISLE represents the most comprehensive national dataset currently available, it may not capture the entire universe of study vessels that operate in U.S. waters (see Chapter 1 of this report for further discussion about the vessel universe in this study and the MISLE database).

EPA identified and compiled hailing port and vessel class distribution data on the top 20 hailing ports cited in the MISLE database. Based on the identified harbors, EPA selected representative harbors for each vessel population scenario to develop the vessel distributions in the model (see Table 4.3.4).

Table 4.3.4. Vessel Population Scenario Representative Harbors Based on the Top 20 Hailing Ports Cited in the MISLE Database

Top 20 Hailing Ports Cited in MISLE	Vessel Population Scenario 1 Fishing Harbor	Vessel Population Scenario 2 Large Metropolitan Harbor	Vessel Population Scenario 3 Recreational Harbor
Boston, MA		X	
Cordova, AK	X		
Gloucester, MA	X		
Homer, AK	X		
Houma, LA			X
Houston, TX	X		X
Juneau, AK	X		
Ketchikan, AK	X		
Key West, FL			X
Kodiak, AK	X		
Miami, FL		X	X
New Orleans, LA	X	X	X
New York, NY		X	X
Norfolk, VA			X
Petersburg, AK	X		
Portland, OR	X		X
San Diego, CA		X	X
San Francisco, CA			X
Seattle, WA	X		X
Sitka, AK	X		

For each representative harbor, EPA calculated the percentages of fishing vessels and non-fishing study vessels reported in the MISLE database (see Table 4.3.5, Table 4.3.6, and Table 4.3.7). EPA averaged the percentages of fishing and non-fishing vessels to develop the overall proportion of these vessel types for each vessel population scenario.

Table 4.3.5. Percentage of Study Vessels Present in Representative Fishing Harbor

Hailing Port	Percentage of Fishing Vessels	Percentage of Non-fishing Study vessels
New Orleans, LA	26%	74%
Seattle, WA	69%	31%
Houston, TX	56%	44%
Juneau, AK	82%	18%
Houma, LA	39%	61%
Cordova, AK	94%	6%
Homer, AK	82%	18%
Sitka, AK	76%	24%
Kodiak, AK	91%	9%
Portland, OR	51%	49%
Ketchikan, AK	62%	38%
Gloucester, MA	84%	16%
Petersburg, AK	93%	7%
Average	**70%**	**30%**

Source: MISLE database.

Table 4.3.6. Percentage of Study Vessels Present in Representative Large Metropolitan Harbor

Hailing Port	Percentage of Fishing Vessels	Percentage of Non-fishing Study vessels
New Orleans, LA	26%	74%
New York, NY	21%	79%
Miami, FL	43%	57%
Boston, MA	55%	45%
San Diego, CA	37%	63%
Average	**36%**	**64%**

Source: MISLE database.

Table 4.3.7. Percent of Study Vessels Present in Representative Recreational Harbor

Hailing Port	Percent of Fishing Vessels	Percent of Non-fishing Study vessels
New Orleans, LA	26%	74%
Seattle, WA	69%	31%
New York, NY	21%	79%
Houston, TX	56%	44%
San Francisco, CA	64%	36%
Miami, FL	43%	57%
Norfolk, VA	28%	72%
Houma, LA	39%	61%
San Diego, CA	37%	63%
Portland, OR	51%	49%
Key West, FL	47%	53%
Average	**44%**	**56%**

Source: MISLE database.

EPA established the total number of vessels present in each vessel population scenario based on:

- Field observations from EPA's vessel sampling program.
- Total vessel population data for the top 20 hailing ports as reported in the MISLE database.
- An assumption that the hypothetical harbor is representative of up to 10 miles of shoreline.
- An assumption that the vessel distributions reflect vessel populations during peak activity for each scenario (i.e., summer season during peak fishing, recreational, and tourist activity).

Based on these assumptions, EPA selected a total vessel population of 175 vessels for Scenarios 1 and 3 and 300 vessels for Scenario 2 (see Table 4.3.8). Table 4.3.8 presents the distribution of vessels among the different vessel classes for each vessel population scenario developed using the vessel ratios discussed above, assumptions on the total vessel population, field observations, and best professional judgment.

Table 4.3.8. Vessel Population Scenarios

Vessel Class	Vessel Subclass	Vessel Population Scenario 1 Fishing Harbor	Vessel Population Scenario 2 Metropolitan Harbor	Vessel Population Scenario 3 Recreational Harbor
Fire Boat	NA	1	5	1
Fishing	Gillnetter	12	10	9
Fishing	Lobster Boat	12	10	9
Fishing	Longliner	24	16	15
Fishing	Purse Seiner	12	10	9
Fishing	Shrimper	10	8	5
Fishing	Tender Vessel	20	10	9
Fishing	Trawler	20	16	13
Fishing	Troller	12	10	9
Research	NA	2	10	8
Supply Boat	NA	12	55	10
Tour Boat	NA	10	20	24
Tow/Salvage	NA	6	40	20
Tugboat	NA	12	60	10
Water Taxi	NA	10	20	24
Total Number of Vessels		**175** [1]	**300** [2]	**175** [3]

NA – Not applicable.

(1) Fishing harbor - percentage of fishing vessels is 70%, percentage of non-fishing vessels is 30%.

(2) Large metropolitan harbor - percentage of fishing vessels is 30%, percentage of non-fishing vessels is 70%.

(3) Recreational harbor - percentage of fishing vessels is 45%, percentage of non-fishing vessels is 55%.

4.3.4 Percentage of Vessels Discharging in the Harbor

In addition to the number of vessels present in the harbor, EPA also established the percentage of vessels within each vessel class and discharge type that discharge into the harbor. The purpose of this is to account for the fact that not all vessels within a vessel class discharge all waste streams. EPA developed and selected the percentage of vessels discharging to the harbor (see Table 4.3.9) based on interview responses and data collected during EPA's vessel sampling program. EPA assumed all sampled vessels generate all discharges unless otherwise noted by the vessel operators as follows:

- Vessel does not have the system or process responsible for the discharge (e.g., the vessel does not generate graywater as it does not have sinks, showers, or washing machines).
- System has no discharge (e.g., vessel propulsion and generator engines are keel-cooled).
- Vessel typically discharges outside U.S. waters (e.g., fishing vessel washes decks after each catch at fishing grounds greater than 12 nautical miles from shore).

Based on these criteria, EPA calculated the percentage of vessels ($P_{y,z}$) in each vessel class that discharge each discharge type into the harbor using the following equation:

$P_{y,z} = Sample\ N_{y,z} / Sample\ N_z$ Equation 4-6

Where:

$P_{y,z}$ = Percentage of vessels in vessel class z discharging discharge y

$Sample\ N_{y,z}$ = Number of vessels in vessel class z discharging discharge y from EPA's vessel sampling program

$Sample\ N_z$ = Number of vessels from vessel class z from EPA's vessel sampling program

Appendix G includes the field data and assumptions used to develop the percentage of vessels input parameter ($P_{y,z}$) for each vessel class and discharge stream.

Table 4.3.9. Percentage of Vessels Discharging in the Harbor

Vessel Class	Vessel Subclass	Discharge	Percentage of Vessels Discharging Flow in Harbor [1]
Fire Boat	NA	Deck Wash	100%
Fire Boat	NA	Engine Effluent	100%
Fire Boat	NA	Fire Main Effluent	100%
Fire Boat	NA	Generator Effluent	100%
Fishing	Gillnetter	Engine Effluent	80%
Fishing	Gillnetter	Fish Hold Effluent	80%
Fishing	Lobster Boat	Fish Hold Effluent	100%
Fishing	Longliner	Bilgewater	33%
Fishing	Longliner	Fish Hold Effluent	100%
Fishing	Longliner	Fish Hold Cleaning Effluent	100%
Fishing	Purse Seiner	Engine Effluent	40%
Fishing	Purse Seiner	Fish Hold Effluent	100%
Fishing	Purse Seiner	Fish Hold Cleaning Effluent	100%
Fishing	Purse Seiner	Generator Effluent	40%
Fishing	Shrimper	Bilgewater	50%
Fishing	Shrimper	Deck Wash	80%
Fishing	Shrimper	Fish Hold Effluent	80%
Fishing	Shrimper	Graywater	100%
Fishing	Tender Vessel	Fish Hold Effluent	100%
Fishing	Tender Vessel	Fish Hold Cleaning Effluent	67%
Fishing	Trawler	Deck Wash	80%
Fishing	Trawler	Fish Hold Effluent	80%
Fishing	Trawler	Fish Hold Clean Effluent	40%
Fishing	Troller	Deck Wash	17%
Fishing	Troller	Fish Hold Effluent	100%
Fishing	Troller	Fish Hold Cleaning Effluent	33%

Table 4.3.9. Percentage of Vessels Discharging in the Harbor

Vessel Class	Vessel Subclass	Discharge	Percentage of Vessels Discharging Flow in Harbor [1]
Research	NA	Engine Effluent	100%
Supply Boat	NA	Deck Wash	100%
Tour Boat	NA	Bilgewater	67%
Tour Boat	NA	Deck Wash	67%
Tour Boat	NA	Engine Effluent	100%
Tour Boat	NA	Fire Main Effluent	100%
Tour Boat	NA	Generator Effluent	67%
Tow/Salvage	NA	Bilgewater	33%
Tow/Salvage	NA	Deck Wash	100%
Tow/Salvage	NA	Engine Effluent	83%
Tugboat	NA	Deck Wash	100%
Tugboat	NA	Fire Main Effluent	100%
Tugboat	NA	Graywater	67%
Tugboat	NA	Shaft Water	89%
Water Taxi	NA	Bilgewater	75%
Water Taxi	NA	Deck Wash	100%
Water Taxi	NA	Engine Effluent	100%
Water Taxi	NA	Generator Effluent	25%
Water Taxi	NA	Graywater	25%

NA – Not applicable.

(1) The percentages of vessels discharging to the harbor were determined based on field observations of sampled vessels. As a conservative estimate, it was assumed that 100% of vessels in sampled vessel classes with no information available discharge in the harbor.

4.3.5 Vessel Discharge Loading Rates

EPA calculated the vessel class-specific loading rates for each analyte ($W_{e,z}$) using Equation 4-1 for each of the three vessel population scenarios described in Section 4.3.3. EPA then calculated the total analyte-specific load rates (W_e) for each vessel population scenario using Equation 4-2. Appendix G presents the total analyte-specific loading rates for each of the three vessel population scenarios represented in the model (i.e., fishing harbor, large metropolitan harbor, and recreational harbor).

4.3.6 Dissolved Copper Loading Rates from Antifouling Paints

In addition to the loading rates calculated based on EPA's vessel sampling program data, EPA also considered the additional dissolved copper load to receiving waters associated with antifouling paints used on vessel hulls. As described in Chapter 3, antifouling systems (AFSs) are designed to release biocide over time to retard growth and maintain a smooth underwater surface (Schiff et al., 2003). Copper oxide is the most common biocide added to AFSs to prevent biofouling organisms from attaching to the hull. Numerous studies have investigated the leaching rate of copper from both passive leaching and underwater hull cleaning (Thomas et al., 1999; Zirino and Seligman, 2002; Valkirs et al., 2003; Schiff et al., 2003). Based on estimates produced in these studies, EPA selected a dissolved copper leaching rate of 8.2 $\mu g/cm^2/day$ to estimate the additional dissolved copper load to the harbor from vessel AFSs. EPA estimated the average vessel length for each vessel class based on information available in the MISLE database and field observations from EPA's vessel sampling program (Table 4.3.10). EPA assumed that the beam of the vessel beam (i.e., width) was equal to approximately one-third its length and used Equation 4-7 (Interlux, 1999) to estimate the hull surface area for each vessel class:

$$A_z = L_z * (L_z/3) * 0.85 \qquad \text{Equation 4-7}$$

Where:

A_z = Hull surface area for individual vessels in vessel class z (area)
L_z = Average length of vessels in vessel class z (distance)

Table 4.3.10. Estimated Average Vessel Length by Vessel Class

Vessel Class	Vessel Subclass	Vessel Length (feet) [1]
Fire Boat	NA	50
Fishing	Gillnetter	35
Fishing	Lobster Boat	35
Fishing	Longliner	35
Fishing	Purse Seiner	50
Fishing	Shrimper	50
Fishing	Tender Vessel	100
Fishing	Trawler	50
Fishing	Troller	35
Research	NA	40
Supply Boat	NA	50
Tour Boat	NA	50
Tow/Salvage	NA	40
Tugboat	NA	79
Water Taxi	NA	79

NA – Not applicable.
(1) - EPA estimated the average vessel length for each vessel class based on information available in the MISLE database and field observations during EPA's vessel sampling program.

EPA calculated the dissolved copper loading rate from AFSs for each vessel population scenario using Equation 4-8, and then added these loadings to the dissolved copper loading rates calculated in Section 4.3.5 for the other vessel discharges to determine the total dissolved copper load introduced into the harbor for each loading scenario[7]. EPA calculated that AFSs contribute approximately 2.79 lbs/day of dissolved copper under Vessel Population Scenario 1 (fishing harbor), 4.86 lbs/day under Vessel Population Scenario 2 (large metropolitan harbor), and 2.63 lbs/day under Vessel Population Scenario 3 (recreational harbor[8]). Appendix G presents the total dissolved copper loading rates represented in the model.

$$AFC\ W_{copper} = \Sigma\ N_z * A_z * 8.2\ \mu g/cm^2/day \qquad \text{Equation 4-8}$$

Where:

$AFS\ W_{copper}$ = AFS discharge loading rate for dissolved copper (mass/time)

N_z = Number of vessels in vessel class *z* present in the harbor

A_z = Hull surface area for individual vessels in vessel class *z* (area)

4.4 HYPOTHETICAL HARBOR

Given the wide variety of coastal harbor environments potentially impacted by study vessel discharges, EPA developed several hypothetical harbors for the vessel discharge environmental assessment to represent a range of environmental conditions that could potentially be impacted. To develop input values that represented realistic environmental conditions, EPA identified and collected environmental data on eight harbors (Table 4.4.1) that represented a geographically and environmentally diverse group of water bodies, had the potential for a high density of study vessels, and received freshwater inflow from a major river system.

Table 4.4.1. Harbors Selected for Model Input Parameter Development

Harbor Name	City Name	State	River Name
Cohasset Harbor	Boston	Massachusetts	Gulf River
Dorchester Bay	Boston	Massachusetts	Neponset River
Auke Bay	Juneau	Alaska	Mendenhall River
Biscayne Bay	Miami	Florida	Miami River
Mobile Bay	Mobile	Alabama	Tensaw, Blakeley, and Mobile River
Yaquina Bay	Newport	Oregon	Yaquina River
Craford Bay	Norfolk	Virginia	Eastern and Southern Branch Elizabeth River
Eastern Channel	Sitka	Alaska	Indian River

The "fraction of freshwater model" requires the following four input parameters to define the water body characteristics:

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[7] Note that some hull cleaning methods can release a plume of antifouling paint, which contains copper in particulate form, in the water. The particulate copper can settle into the sediments and over time reenter the water body in the dissolved form. EPA did not include the potential dissolved copper load from particulate copper resulting from hull cleaning.

[8] As noted above, these loading rates do not include the loading from nonstudy vessels.

- Seaward boundary salinity at the mouth of the harbor (S_s)
- Salinity at location x in the harbor (S_x)
- Volume of the harbor (V)
- Inflow of freshwater to the harbor (Q_{fw})

EPA collected data on the four input parameters for the harbors listed in Table 4.4.1 and calculated a flushing time using Equation 4-4 in Section 4.2.3. Appendix G presents the environmental data identified by EPA for each harbor listed in Table 4.4.1. EPA selected the input parameters for the hypothetical harbors' salinity, volume, and river flow based on the environmental data collected for the harbors with the minimum and maximum flushing times (Table 4.4.2). EPA assumed an average ocean salinity of 35 PSU for the salinity at the seaward boundary of the hypothetical harbor.

Table 4.4.2. Hypothetical Harbor Input Parameters

Model Parameter	Model Input Value	Units
Harbor Salinity (S_x) Minimum	26.1	PSU
Harbor Salinity (S_x) Maximum	31	PSU
Ocean Salinity (S_s)	35	PSU
Harbor Volume (V) Minimum	3,090,000	m^3
Harbor Volume (V) Maximum	38,500,000	m^3
River Flow (Q_{fw}) Minimum	352,000	m^3/day
River Flow (Q_{fw}) Maximum	2,900,000	m^3/day

Using the input parameters in Table 4.4.2, EPA developed eight hypothetical harbors for the vessel discharge environmental assessment (see Table 4.4.3). For each harbor scenario, EPA calculated the fraction of freshwater (f_x) and flushing time (t) using Equations 4-3 and 4-4 in Sections 4.2.2 and 4.2.3, respectively. Flushing times for the hypothetical harbors ranged from less than a day (0.122 days or 2.9 hours) to 27.8 days.

Table 4.4.3. Hypothetical Harbor Scenarios

Hypothetical Harbor Scenarios	Harbor Salinity (S_x)	Ocean Salinity (S_s)	Harbor Volume (V)	River Flow (Q_{fw})	f_x	Flushing Time (Days)
Harbor Scenario 1	26.1 PSU S_x Min	35 PSU	3,090,000 m^3 V Min	352,000 m^3/day Q_{fw} Min	0.254	2.23
Harbor Scenario 2	26.1 PSU S_x Min	35 PSU	3,090,000 m^3 V Min	2,900,000 m^3/day Q_{fw} Max	0.254	0.271
Harbor Scenario 3	26.1 PSU S_x Min	35 PSU	38,500,000 m^3 V Max	352,000 m^3/day Q_{fw} Min	0.254	27.8
Harbor Scenario 4	26.1 PSU S_x Min	35 PSU	38,500,000 m^3 V Max	2,900,000 m^3/day Q_{fw} Max	0.254	3.38
Harbor Scenario 5	31 PSU S_x Max	35 PSU	3,090,000 m^3 V Min	352,000 m^3/day Q_{fw} Min	0.114	1
Harbor Scenario 6	31 PSU S_x Max	35 PSU	3,090,000 m^3 V Min	2,900,000 m^3/day Q_{fw} Max	0.114	0.122
Harbor Scenario 7	31 PSU S_x Max	35 PSU	38,500,000 m^3 V Max	352,000 m^3/day Q_{fw} Min	0.114	12.5
Harbor Scenario 8	31 PSU S_x Max	35 PSU	38,500,000 m^3 V Max	2,900,000 m^3/day Q_{fw} Max	0.114	1.52

4.5 MODEL SCENARIOS

EPA developed a total of 24 model scenarios (see Table 4.5.1) for the screening-level analysis based on the three vessel population scenarios and the eight hypothetical harbors discussed in Sections 4.3.3 and 4.4, respectively. EPA calculated the estimated harbor dilution for each model scenario using the following equation:

$$D_x = (V/t)/\Sigma(Q_{y,z} * N_{y,z} * P_{y,z}) \quad \text{Equation 4-9}$$

Where:

D_x = Harbor dilution at location x

V = Volume of model harbor

t = Model harbor flushing time

$Q_{y,z}$ = Flow rate for discharge y from vessel class z (volume/time)

$N_{y,z}$ = Number of vessels in vessel class z discharging discharge y

$P_{y,z}$ = Percent of vessels in vessel class z discharging discharge y

Table 4.5.1. Fraction of Freshwater Model Scenarios

Model Scenario	Total Loading Rate (W_e) Scenario	Hypothetical Harbor Scenario	Dilution (D_x)
Model Scenario 1	Vessels Population Scenario 1 Fishing Harbor	Harbor Scenario 1	705
Model Scenario 2	Vessels Population Scenario 1 Fishing Harbor	Harbor Scenario 2	5,810
Model Scenario 3	Vessels Population Scenario 1 Fishing Harbor	Harbor Scenario 3	705
Model Scenario 4	Vessels Population Scenario 1 Fishing Harbor	Harbor Scenario 4	5,810
Model Scenario 5	Vessels Population Scenario 1 Fishing Harbor	Harbor Scenario 5	1,570
Model Scenario 6	Vessels Population Scenario 1 Fishing Harbor	Harbor Scenario 6	12,900
Model Scenario 7	Vessels Population Scenario 1 Fishing Harbor	Harbor Scenario 7	1,570
Model Scenario 8	Vessels Population Scenario 1 Fishing Harbor	Harbor Scenario 8	12,900
Model Scenario 9	Vessels Population Scenario 2 Metropolitan Harbor	Harbor Scenario 1	506
Model Scenario 10	Vessels Population Scenario 2 Metropolitan Harbor	Harbor Scenario 2	4,170
Model Scenario 11	Vessels Population Scenario 2 Metropolitan Harbor	Harbor Scenario 3	506
Model Scenario 12	Vessels Population Scenario 2 Metropolitan Harbor	Harbor Scenario 4	4,170
Model Scenario 13	Vessels Population Scenario 2 Metropolitan Harbor	Harbor Scenario 5	1,130
Model Scenario 14	Vessels Population Scenario 2 Metropolitan Harbor	Harbor Scenario 6	9,280
Model Scenario 15	Vessels Population Scenario 2 Metropolitan Harbor	Harbor Scenario 7	1,130
Model Scenario 16	Vessels Population Scenario 2 Metropolitan Harbor	Harbor Scenario 8	9,280
Model Scenario 17	Vessels Population Scenario 3 Recreational Harbor	Harbor Scenario 1	494
Model Scenario 18	Vessels Population Scenario 3 Recreational Harbor	Harbor Scenario 2	4,070
Model Scenario 19	Vessels Population Scenario 3 Recreational Harbor	Harbor Scenario 3	494
Model Scenario 20	Vessels Population Scenario 3 Recreational Harbor	Harbor Scenario 4	4,070
Model Scenario 21	Vessels Population Scenario 3 Recreational Harbor	Harbor Scenario 5	1,100
Model Scenario 22	Vessels Population Scenario 3 Recreational Harbor	Harbor Scenario 6	9,050
Model Scenario 23	Vessels Population Scenario 3 Recreational Harbor	Harbor Scenario 7	1,100
Model Scenario 24	Vessels Population Scenario 3 Recreational Harbor	Harbor Scenario 8	9,050

As shown in Table 4.5.1, there are duplicate dilution factor values for different model scenarios (e.g., Model Scenarios 1 and 3 both have a dilution factor of 705). Hence, there are effectively 12 unique model scenarios and not 24 presented in this screening-level analysis. The duplicate dilution factors are an artifact of EPA's decision to calculate dilution factors and instantaneous harbor concentrations using all combinations of the input parameters in Table 4.4.2. In calculating the dilution factor, the volume of the harbor (V) cancels out of the dilution equation (Equation 4-9) and is not a consideration (see below).

$$D_x = (V/t)/\Sigma(Q_{y,z} * N_{y,z} * P_{y,z})$$

Where:

(V/t) = $(V/(V*f_x/Q_{fw})$

$\Sigma(Q_{y,z} * N_{y,z} * P_{y,z})$ = Total discharge flow from all vessels

EPA used three total discharge flows ($\Sigma(Q_{y,z} * N_{y,z} * P_{y,z})$ (i.e., vessel flows in a fishing harbor, large metropolitan harbor, and recreational harbor) and four different volume-to-flushing-time (V/t) ratios (i.e., assumed two f_x values in the model and two Q_{fw} values) in the model. Section 4.6 discusses the results from the 12 unique model scenarios and presents the results of the duplicate scenarios as one result (i.e., harbor concentrations from Model Scenarios 1 and 3).

4.6 MODEL RESULTS

EPA calculated the instantaneous concentration (C_x) in the hypothetical harbor using Equation 4-5 presented in Section 4.2.4 for each of the 12 model scenarios defined in Table 4.5.1. Appendix G presents the concentrations for all model scenarios for each vessel population scenario. EPA compared the instantaneous concentrations in the hypothetical harbor with the NRWQC to evaluate the potential for the cumulative effect of study vessel incidental discharges to impact aquatic life or human health. EPA determined that none of the modeled concentrations in the hypothetical harbor for the 12 scenarios exceeded an aquatic life or human health NRWQC.

4.6.1 Dilution Factor Analysis

The model scenario dilutions factors calculated for the 12 unique scenarios ranged from 494 to 12,900. EPA performed a sensitivity analysis to determine the dilution factor at which point NRWQC would be exceeded. EPA calculated the "tipping point" dilution in the hypothetical harbor where the instantaneous concentration in the harbor would equal the most stringent NRWQC for aquatic life or human health using the three vessel population scenario loading rates discussed in Section 4.3.5. Table 4.6.1 presents the tipping point dilution factors for the top 10 analytes with the highest dilution factor requirements to avoid exceeding an NRWQC. Based on the results of the dilution analysis, a harbor dilution factor of greater than 358 is required to avoid exceeding any NRWQC for aquatic life or human health, which is below the range of calculated model scenario dilution factors (i.e., 494 to 12,900). This sensitivity analysis also demonstrates that dissolved copper and total arsenic represent the most significant environmental risk from study vessels incidental discharges. These two analytes have relatively stringent range of dilution requirements depending on the vessel population scenario selected to avoid exceeding a NRWQC (i.e., dilution factors of greater than 144 to 266 for dissolved copper and 284 to 358 for total arsenic) and represent the highest dilution requirements for all the analytes detected in vessel discharges. Following dissolved copper, the required dilution factors drop off significantly with a dilution of greater than 33.7 required to avoid exceeding all other NRWQC with most of the remaining dilution factors below one.

Table 4.6.1. "Tipping Point" Dilution Factors for Harbor Instantaneous Concentration to Equal the NRQWC Based on Vessel Population Scenario Loading Rates [1]

Class	Analyte	Vessel Scenario 1 Fishing Harbor Dilution (D_x)	Vessel Scenario 2 Metropolitan Harbor Dilution (D_x)	Vessel Scenario 3 Recreational Harbor Dilution (D_x)
Metals	Arsenic, Total [2]	358	331	284
Metals	Copper, Dissolved	214	266	144
Metals	Arsenic, Dissolved [2]	31.4	33.7	29.6
Classicals	Total Residual Chlorine	12.4	16.2	12.2
Metals	Aluminum, Total	6.77	5.15	4.83
Classicals	Sulfide	1.75	2.36	1.65
Metals	Selenium, Total [2]	1.13	1.46	1.52
VOC	Benzene	0.756	1.57	1.34
Metals	Manganese, Total	0.684	0.983	1.04

(1) Table includes only those analytes that required a dilution factor of greater than one to avoid exceeding a NRWQC.

(2) EPA suspects a limited number of the samples analyzed for selenium (and even fewer for arsenic) for bilgewater, packing gland effluent, propulsion engine effluent, graywater and deck washdown water may have elevated measured concentrations due to positive interference. Despite these limited instances of interference, EPA believes the fish hold concentrations reasonably represent true effluent concentrations for the discharge (see discussion in Sections 3.1.3 and 3.2.4.1 for further information). EPA considered these interferences when interpreting the potential for vessel discharges to pose a risk to human health, aquatic life, or the environment and determined that such cationic interference does not influence the major findings presented in the modeling analysis.

4.6.2 Supplemental Model Run in Response to Comments

In response to public comments submitted for the draft version of this report, EPA performed a supplemental model run using revised values based on information submitted by commenters to assess the impacts of these alternative values on the model results. EPA adjusted the model assumptions presented in Table 4.6.2 and recalculated the associated discharge flows and loads. EPA observed no significant change in model results based on the revised values. Table 4.6.3 presents the revised "tipping point" dilution factors for the supplemental model run.

Table 4.6.2. Revised Model Assumptions

Vessel Class	Vessel Subclass	Discharge	Old Assumption	New Assumption
Fishing	Gillnetter	Fish Hold	Offloads daily	Offloads once per five days
Fishing	Longliner	Fish Hold	Offloads once per two days	Offloads once per five days
Fishing	Toller	Fish Hold Clean	Offloads daily	Offloads once per seven days
Fishing	Toller	Fish Hold	Offloads daily	Offloads once per seven days
Fishing	Toller	Fish Hold	840 ft^3 fish hold	595 ft^3 fish hold
Fishing	Toller	Fish Hold	5.5 tons of ice per offload	2 tons of ice per offload
Fishing	Toller	Deck Wash	125 gallons per deck wash	50 gallons per deck wash
Fishing	Shrimping	Bilge Water	150 gallons per minute bilge pump rate	20 gallons per minute bilge pump rate
Tour Boat	NA	Bilge Water	14.3 gallons per day	5 gallons per day

Table 4.6.3. Supplemental Model Run "Tipping Point" Dilution Factors for Harbor Instantaneous Concentration to Equal the NRQWC Based on Vessel Population Scenario Loading Rates [1]

Class	Analyte	Vessel Scenario 1 Fishing Harbor Dilution (D_x)	Vessel Scenario 2 Metropolitan Harbor Dilution (D_x)	Vessel Scenario 3 Recreational Harbor Dilution (D_x)
Metals	Arsenic, Total [2]	349	325	279
Metals	Copper, Dissolved [3]	225	273	147
Metals	Arsenic, Dissolved [2]	31.1	33.6	29.5
Classicals	Total Residual Chlorine	12.4	16.2	12.1
Metals	Aluminum, Total	6.77	5.10	4.79
Classicals	Sulfide	1.68	2.33	1.60
Metals	Selenium, Total [2]	1.03	1.42	1.50
VOC	Benzene[3]	0.790	1.61	1.37
Metals	Manganese, Total [3]	0.696	0.997	1.05

(1) Table includes only those analytes that required a dilution factor of greater than one to avoid exceeding a NRWQC.

(2) EPA suspects a limited number of the samples analyzed for selenium (and even fewer for arsenic) for bilgewater, packing gland effluent, propulsion engine effluent, graywater and deck washdown water may have elevated measured concentrations due to positive interference. Despite these limited instances of interference, EPA believes the fish hold concentrations reasonably represent true effluent concentrations for the discharge (see discussion in Sections 3.1.3 and 3.2.4.1 for further information). EPA considered these interferences when interpreting the potential for vessel discharges to pose a risk to human health, aquatic life, or the environment and determined that such cationic interference does not influence the major findings presented in the modeling analysis.

(3) The revised model assumptions (see Table 4.6.2) did not significantly impact the total loads for this analyte; however, these assumptions lowered the total discharge volume from these vessels. Therefore, the dilution factors for the supplemental model run for this analyte are higher than the original model run due to the same mass loading rate being divided by a smaller total discharge flow.

4.6.3 Loading Rate Analysis

EPA compared the three analyte-specific loading rates used in the model with other known loading rates to provide perspective on their magnitude and on their relative contribution to the possible impairment of receiving waters (see Table 4.6.2 and Table 4.6.3). EPA selected the following loading sources for comparison:

- Loads From Publicly Owned Treatment Works (POTW)
- Dissolved copper loads discharged to the Shelter Island Yacht Basin
- Estimated metal loading rates from urban stormwater

EPA generated estimates for hypothetical medium-sized sewage treatment facilities with a discharge rate of 10 million gallons per day (MGD). These estimates were derived from the

National Research Council's 1993 report "Managing Wastewater in Urban Areas". EPA calculated loadings by multiplying an effluent volume of 10 MGD times the low and high effluent concentrations for selected parameters using four types of wastewater treatment (chemically-enhanced primary plus biological treatment, primary or chemically enhanced primary plus nutrient removal, primary or chemically enhanced primary plus nutrient removal plus gravity filtration, or primary or chemically enhanced primary plus nutrient removal plus high lime plus filtration)[9]. Values presented in Table 4.6.2 present the lowest and highest derived loadings for these medium systems. EPA determined that the nutrient loads from the 175 to 300 study vessels were comparable to the low end estimates for Ammonia as Nitrogen and total phosphorus, but notably lower than those from the high end treated effluent estimates from sewage treatment facilities. As noted above, the model nutrient loadings from study vessels do not include sewage discharges (which is likely a source of nutrients from these vessels)[10], whereas these data are from POTW effluent, which has a significant sewage component. Table 4.6.2 shows that a medium sewage treatment facility discharges a higher volume of metals than these 175 to 300 study vessels. Finally, these study vessels discharge comparable levels of BOD; though sewage treatment facilities are discharging a larger volume of effluent, they remove significant quantities of BOD from the effluent. On the other hand, study vessels' incidental discharges are untreated waste, some of which has notably high BOD concentrations (e.g., fish hold effluent).

EPA also obtained nutrient loading estimates from a sewage treatment facility with advanced nutrient removal capabilities to provide real world example nutrient loadings that may be associated with POTW discharges (Albert, 2007). This facility discharges approximately 40 to 50 MGD. EPA determined that the nutrient loads (i.e., ammonia as nitrogen, nitrate/nitrite as nitrogen, total Kjeldahl nitrogen, and total phosphorus) from the 175 to 300 study vessels used to establish the vessel loads in the screening-level analysis were notably lower than the nutrient loads from this sewage treatment facility. It is important to note that these model nutrient loads do not include nutrient contributions from vessel sewage discharges (possibly a significant source of nutrients), as sewage discharges are excluded from the scope of P.L. 110-299.

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[9] A number of systems exist which are both smaller and larger than 10 MGD; for example, the Blue Plains POTW in Washington DC is the largest advanced wastewater treatment system in the word and discharges an average of approximately 330 MGD. The wastewater treatment facilities in nearby Arlington County discharge less than 40 MGD. In comparison, the sewage treatment facility in Sitka, Alaska is designed to discharge only 1.8 MGD.

[10] Sewage from vessels within the meaning of CWA section 312, which includes graywater in the case of commercial vessels operating on the Great Lakes, is exempt from the CWA definition of "pollutant". 33 U.S.C. 1362(6); 33 U.S.C. 1322(a)(6). As a result, vessel sewage discharges are not subject to NPDES permitting. Instead, Congress enacted a separate non-permitting scheme – CWA section 312 – to regulate the discharge of sewage from vessels.

Under section 312 of the CWA, all vessels equipped with installed toilet facilities must also be equipped with an operable U.S. Coast Guard-certified marine sanitation device (MSD). 33 U.S.C. 1322(h). The provisions of section 312 are implemented jointly by EPA and the Coast Guard: EPA sets performance standards for MSDs, and the Coast Guard is responsible for developing regulations governing the design, construction, certification, installation and operation of MSDs, consistent with EPA's standards. 33 U. S.C. 1322(b). Current performance standards which apply to MSDs have standards for solids and fecal coliform. Generally speaking, most MSDs currently installed on study vessels are not designed to remove nutrients from sewage.

Therefore, these estimates are not a complete representation of vessel nutrient loadings; rather, they are merely an estimate of nutrient loadings from incidental discharges.

As described in Chapter, 3 dissolved copper concentrations resulting from study vessels' incidental discharges potentially pose a risk to aquatic life. A significant contribution of the dissolved copper load is from copper leaching from antifouling coatings on vessel hulls. In 2005, the California Regional Water Quality Control Board examined the dissolved copper loads to Shelter Island Yacht Basin from recreational vessel antifouling hull coatings and other source loads in support of a Total Maximum Daily Load (TMDL) analysis for the impaired water. EPA compared the dissolved copper loads from Shelter Island Yacht Basin TMDL to the vessel population scenario loading rates (Table 4.6.2). EPA determined that the estimated dissolved copper loads from 175 to 300 study vessels used in the model (i.e., 2.75 to 4.97 lb/day) were consistent with the combined dissolved copper loads from passive leaching and hull cleaning from 2,363 recreational vessels present in Shelter Island Yacht Basin (i.e., 12.7 lb/day). EPA also compared the model dissolved copper loads to the combined estimated contributions from urban runoff, background, and atmospheric deposition in Shelter Island Yacht Basin (i.e., 0.381 lb/day). The model dissolved copper loads from hull leaching and other discharge streams were significantly larger than the other source contributions present in Shelter Island Yacht Basin, suggesting that dissolved copper from study vessels incidental discharges can represent a significant portion of the dissolved copper load in a water body.

EPA also estimated metal loading rates for urban stormwater runoff based on reported loading rates from a 2001 literature study by Davis et al. and an assumed watershed area of approximately 17 square miles (watershed area determined from readily available information on watersheds' drainage areas for the water bodies discussed in Table 4.4.1). As shown in Table 4.6.2, EPA determined that urban stormwater likely represents a greater load of total copper, total lead, zinc, and cadmium to receiving waters than discharges from 175 to 300 study vessels. However, the model results indicate that dissolved copper loads from study vessels are significant.

Table 4.6.4. Comparison of Model Loading Rates with Other Potential Point Source Loading Rates

Analyte	Model Loading Rates from Vessel Population Scenarios [1]			POTW Loading Rates 10 mg/day[2] (lb/day)	POTW Loading Rates ~40 mg/day[3] (lb/day)	Shelter Island Yacht Basin Loading Rates [4,5,6]					Estimated Urban Runoff Loading Rates [7] (lb/day)
	Fishing Harbor (lb/day)	Large Metropolitan Harbor (lb/day)	Recreational Harbor (lb/day)			Passive Leaching (lb/day)	Hull Cleaning (lb/day)	Urban Runoff (lb/day)	Background (lb/day)	Atmospheric Deposition (lb/day)	
Ammonia as Nitrogen (NH3-N)	8.52	6.07	5.07	8.35-41.7	36.2	NA	NA	NA	NA	NA	NA
Biochemical Oxygen Demand (BOD)	635	481	392	250.4-751.1	NA	NA	NA	NA	NA	NA	NA
Nitrate/Nitrite (NO3 + NO2-N)	0.127	0.203	0.102	NA	1,320	NA	NA	NA	NA	NA	NA
Total Phosphorus	13.8	8.91	7.74	8.35-125.2	22.0	NA	NA	NA	NA	NA	NA
Total Kjeldahl Nitrogen (TKN)	97.8	68.5	59.0	NA	285	NA	NA	NA	NA	NA	NA
Arsenic, Total	0.0279	0.0359	0.0315	0.117-1.17	NA	NA	NA	NA	NA	NA	NA
Cadmium, Total	0.000749	0.000657	0.000551	0.117-0.609	NA	NA	NA	NA	NA	NA	0.032
Copper, Dissolved	2.88	4.97	2.75	NA	NA	12.1	0.604	0.181	0.181	0.0181	NA
Copper, Total	0.158	0.179	0.165	1.25-4.17	NA	NA	NA	NA	NA	NA	1.0
Lead, Total	0.0108	0.0154	0.0142	1.50-4.01	NA	NA	NA	NA	NA	NA	1.8
Zinc, Total	0.758	0.613	0.516	3.34-9.35	NA	NA	NA	NA	NA	NA	17

NA- Not available.

(1) Model loading rates do not include contributions from study vessel sewage waste streams as these discharges are not covered under P.L. 110-299.

(2) Estimated loadings from concentrations for medium sewage treatment facilities (~10 mg/d) derived from concentrations presented in National Research Council (1993).

(3) Estimated nutrient loads from an actual sewage treatment facility with advanced nutrient removal capabilities with an average of approximately 40 mgd discharge (Albert, 2007).

(4) Estimated point source loads to Shelter Island Yacht Basin (California Regional Water Quality Control Board, 2005).

(5) Passive leaching and hull cleaning loading rates were based on an assumption of 2,363 recreational vessels present in Shelter Island Yacht Basin.

(6) Urban runoff contributions were based on a watershed area of 0.84 mi2 draining to Shelter Island Yacht Basin, and the atmospheric deposition loads were based on a surface area of Shelter Island Yacht Basin of 0.27 mi2.

(7) Estimated urban stormwater loads were based on loading rates presented in Davis et al., 2001 and an assumed watershed area of 17 mi2 (MA DEP, 2006).

The loading rates presented are average annual daily loads.

4.7 CONCLUSIONS

This screening-level analysis evaluated the potential for discharges incidental to the normal operation of vessels to pose a risk to human health, welfare, or the environment in large water bodies. The analysis includes all sizes of commercial fishing vessels and other nonrecreational vessels less than 79 feet in length. EPA selected a Level I screening-level model (see Section 4.1) to help assess the potential impacts from study vessels' incidental discharges and modeled several scenarios combining different vessel assemblages and different hypothetical harbors to represent a range of environmental conditions potentially observed in harbors across the United States. The modeled constituent concentrations from the discharges into the hypothetical harbor for the 12 scenarios did not exceed an aquatic life or human health NRWQC solely from study vessel discharges; however, the model did not account for background loadings. Certain pollutants (e.g., arsenic and dissolved copper) are more likely to contribute to a water quality criterion being exceeded under real-world conditions. Furthermore, the model's capabilities do not allow for the evaluation of whether these discharges cause localized impacts (see Section 4.2), nor do they allow an analysis of issues such as bioaccumulation or persistent toxicity in water bodies or accumulation of pollutants in sediments.

As discussed in the introduction, EPA's fraction of freshwater analysis is only intended to evaluate environmental effects from vessel discharges at the water body or harbor scale and does not address the environmental effects that could potentially occur in localized areas such as small side embayments or marinas. As discussed in Section 4.1, the "fraction of freshwater model" does not describe concentration gradients within plumes from vessels. Accounting for spatial and temporal variability in a harbor would require a more data intensive dynamic model and is beyond a Level I screening-level model. EPA acknowledges that incidental discharges from study vessels may pose an environmental threat in confined areas with low receiving water flushing rates and a large population of vessels. In the dilution analysis discussed in Section 4.6, EPA determined that a "tipping point" dilution factor of greater than 358 would be required to avoid exceeding any NRWQC based on the estimated loading rates used in the model (see Table 4.6.1). These results suggest that the loading rates represented in the model may have the potential to cause a water quality criterion to be exceeded on a localized scale either before complete mixing is achieved in the receiving water (i.e., as the plume dissipates) or if the discharges are released in a receiving water with a dilution potential of lower than 358. The model further suggests that these vessels may be more likely to contribute to an NRWQC being exceeded (particularly where the diluting factor is high for a pollutant) where the ambient concentrations or other sources of pollutants are significant. On the other hand, EPA has tended to use conservative estimates of some parameters (e.g., flow and pollutant concentrations) in its modeling.

In the "fraction of freshwater model," EPA calculated the instantaneous concentration in the hypothetical harbor based solely on pollutant contributions from discharges from study vessels. Although the assumption that harbor background pollutant concentrations are zero for all analytes is likely unrealistic, removing other loading considerations from model calculations allows for the assessment of the potential for study vessel incidental discharges alone to cause an NRWQC to be exceeded. Although the "fraction of freshwater model" results suggest that study vessels' incidental discharges will not cause an environmental impact on their own, the fact that pollutants are present in the vessel discharges at concentrations that exceed the NRWQC at end-of-pipe may support a determination that some of these discharges have the potential to contribute to a water quality standard exceedence.

Based on the dilution results, the two pollutants that represent the greatest risk for contributing to an environmental effect or water body impairment are total arsenic and dissolved copper. EPA determined that the loading rates from the metropolitan harbor (i.e., Model Scenarios 9 and 11) were at the greatest risk of exceeding the NRWQC for these pollutants. However, the minimum dilution factors required to avoid exceeding the NRWQC for these pollutants (i.e., 284 for total arsenic and 144 for dissolved copper in the recreational harbor) are similar to the lowest dilution factor represented in the hypothetical harbor scenarios (i.e., 494). This suggests that study vessel's incidental discharges may be contributing a significant load of these two pollutants to the water body. Given the right environmental conditions (i.e., low flushing) or pollutant loadings from other point/nonpoint sources (e.g., recreational vessels, large commercial vessels, stormwater runoff, and industrial and municipal point sources), the concentrations of these pollutants may have a potential to cause or contribute to an exceedence of the NRWQC, regardless of vessel class distributions. These results are consistent with real-world observations that metals are frequently associated with vessel discharges in concentrations of potential environmental concern (see Chapter 3). In particular, environmental impacts from dissolved copper leaching from hull coatings has been well documented in low flushing environments such as Shelter Island Yacht Basin near San Diego, California, and Marina Del Rey Harbor in Los Angeles, California.

Nutrients from study vessels' incidental discharges represent another pollutant class with the potential to contribute to deleterious environmental effects. Nutrients differ from other pollutants present in vessel discharges in that the environmental effects are driven by site-specific environmental conditions (e.g., water temperature, types of algae present, limiting nutrient). For example, the estimated nutrient loads used in the modeling analysis may contribute to an environmental effect in one water body, but not another depending on a variety of factors that control eutrophication. EPA has not developed an NRWQC for nutrients; however, some states have established water-body-specific or state-wide standards for nutrients based on site-specific evaluations.

CHAPTER 5
SUMMARY OF FINDINGS

This chapter summarizes the major findings of EPA's detailed analyses described in Chapters 1, 3, and 4. It describes findings on vessel classes that are covered by this study. It summarizes major findings from the characterization of select discharges from the study vessels, including EPA's interpretation of these findings in the context of the level of potential risk from these pollutant loadings. Additionally, it discusses major findings of EPA's assessment of the predicted impacts of these discharges to a hypothetical harbor. This chapter also briefly summarizes possible benefits to human health, welfare, and the environment from reducing, eliminating, controlling, or mitigating discharges from study vessels.

5.1 SUMMARY OF CLASSES OF VESSELS COVERED BY THIS STUDY

EPA estimates there is a population of approximately 140,000 study vessels. According to the U.S. Coast Guard's Marine Information for Safety and Law Enforcement (MISLE) database, there are approximately 70,000 commercial fishing vessels operating in the United States. These vessels represent the largest category of study vessels. Passenger vessels comprise the second highest number of vessels within the study population, with approximately 21,000 vessels. These vessels are further classified by subtypes according to the types of activities in which they are involved, such as diving vessels, charter fishing vessels, ferries, harbor cruise vessels, and sailing vessels. The study population also includes over 11,000 utility vessels, including tugs/towing vessels, school ships, research vessels/ships, mobile offshore drilling units, offshore vessels, offshore supply vessels, oil recovery vessels, and industrial vessels. Other vessel categories such as freight barges (approximately 8,000 vessels), tank barges (approximately 900 vessels), freight ships (approximately 800 vessels), unclassified public vessels (approximately 600 vessels), and tank ships (approximately 200 vessels) account for the remainder of other non-recreational study vessels. An additional 27,375 vessels in the MISLE database are also believed to be study vessels; however, the database does not indicate their type of service. See Chapter 1 for additional discussions of the study vessel and recreational vessel populations.

5.2 SUMMARY OF EFFLUENT CHARACTERIZATION OF SELECT DISCHARGES FROM THE STUDY VESSELS

The major findings of EPA's analysis of the vessel discharge characterization data for study vessels are summarized below. For this study, EPA sampled 61 vessels in nine states generating over 22,000 data points. EPA tested for 301 analytes and detected 154 of these analytes in at least one sample; therefore, 158 of the tested analytes were never found in the discharges. Section 5.2.1 discusses the estimated volumes of the discharges and Section 5.2.2 discusses the detected pollutants that may have the potential to pose a risk to human health or the environment. See chapters 3 and 4 for more technical, in-depth discussions of these results.

5.2.1 Estimated Volumes of Select Discharges from the Study Vessels

EPA estimated volumes for each discharge from the study vessels based on data and field observations from EPA's vessel sampling efforts, as well as information from secondary data sources. Discharge volumes are important to both characterize the discharge and to analyze the potential risk of the pollutant concentrations discharged from vessels. EPA also used these discharge volumes to calculate flow rates for the modeling of pollutant loadings to a hypothetical harbor in Chapter 4.

Bilgewater generation rates are highly variable. EPA observed as little as 2 gallons of bilgewater discharged from a tow/salvage vessel following a tow activity to as much as 750 gallons of bilgewater discharged during the daily bilge pump-out from a 62-foot shrimp boat from the Gulf of Mexico. In general, based on observations from dozens of vessel operations, EPA estimates that small (less than 79 feet), nonrecreational vessels typically generate between 10 and 15 gallons per day (gpd) of bilgewater.

Stern tube packing gland effluent is by nature limited to the small amount of water needed to provide cooling and lubrication to the gland around the drive shaft. The range in estimated discharge for stern tube packing gland effluent is approximately 4 to 8 gpd.

For deckwash water from tour boats, water taxis, and tow boats, EPA estimates a discharge volume of between 20 and 30 gpd. Fishing boats are estimated to generate more deckwash water and the volumes generated vary with the type of boat. Trollers, trawlers, gillnetters, and purse seiners may wash their decks three to four times per day while fishing, producing as much as an estimated 750 to 900 gpd of deckwash water.

The volume of fish hold effluent generated by a fishing vessel depends on the size of the vessel and the method used to keep the product fresh. Smaller fishing vessels such as small salmon trollers or long-liners may discharge an estimated fish hold volume ranging from 70 to 200 gpd. Mid-size fishing vessels, such as gill netters and purse seiners found in Alaska and shrimp boats in the Gulf of Mexico may discharge approximately 333 to 1,000 gpd. Larger fishing vessels such as off-shore trawlers found in New England and tenders found in Alaska, however, can have refrigerated seawater holding tanks or ice hold tanks as large as 15,000 gallons. These vessels are expected to offload seafood and discharge the fish hold effluent every three to five days, resulting in an estimated flow rate ranging from 900 to 2,000 gpd. EPA estimates the volume of fish hold cleaning effluent discharged by certain fishing vessels to be anywhere from 300 to 400 gallons per cleaning, which occur typically every three to five days when the fish holds are emptied (discharge volumes range from an estimated 60 to 200 gpd depending on frequency of offloading).

Fisherman unloading their catch to the dock from a trawler (dragger) in Massachusetts.

Graywater volumes also vary considerably depending on the class of vessel and its use, size, number of crew and passengers onboard, and types of graywater-generating activities onboard (e.g., galleys, sinks, showers, and washing machines). For example, EPA estimated that tugboats, some of which provide living quarters for three to five crew members, generate approximately 130 gpd of graywater. Water taxis typically have considerably more people onboard, but less graywater is generated per person because the discharge is typically limited to bathroom sinks with an estimated 75-gpd discharge. Graywater generation on commercial fishing boats might range from a few to hundreds of gpd, depending on the length of the trip and the size of the crew.

Finally, the volume of engine effluent discharged depends on the type of engine and power level of operation. Vessels with outboard propulsion engines are estimated to discharge between 1 to 2 gallons per minute (gpm) of raw cooling water per engine. The cooling water discharge rate from inboard marine diesel engines varies based on power levels, but typically averages around 20 gpm for the study vessels. Marine diesel generator sets require approximately 5 to 6 gpm of cooling water for smaller units, and up to 20 to 25 gpm of cooling water for larger marine generator sets. Daily discharge rates for these engines are a function of the daily operating time.

5.2.2 Analytes of Potential Risk in Select Discharges from Study Vessels

EPA compared the measured concentration of any given analyte to its most stringent benchmark[1] (Table 3-1) as one means to identify pollutants in vessel discharges that may have a potential to pose a risk to human health or aquatic life. EPA divided the concentration of an analyte by its corresponding benchmark to calculate a potential hazard quotient (PHQ). If a PHQ is less than 1, there is less of a concern that the pollutant in the discharge will have impacts to human health or aquatic life. An exception to this determination is when the pollutant is persistent and/or bioaccumulative and may increase in concentration within the ecosystem food chain to harmful levels. If a PHQ is equal to or greater than 1, then there is more of a concern. However, PHQs of greater than 1 do not provide conclusive evidence of risk to human health or the environment for the following reasons:

1. Samples were collected at the "end of pipe" as the vessels discharged into larger waters (e.g., harbors, rivers). However, the discharge is typically diluted in the water body. Therefore, accounting for possible dilution in the receiving water could result in ambient PHQ of less than 1 (except possibly small harbors or marinas with limited or no flushing or where the receiving water PHQ is already above 1 due to other factors).

2. The benchmarks used to evaluate the potential for risk were always the most protective, even if it was not the most commonly applicable screening benchmark for that particular analyte. Given this, the potential for risk might be over-stated.

3. The surrounding ambient water or source water (vessel service[2] or city water supply) used in the vessel systems that generated these discharges (e.g., engine cooling water drawn from ambient water or potable water used for deck cleaning) may already contain high concentrations of some of these analytes. In these instances, a high analyte concentration measured at the "end of pipe" may not originate from vessel activities, but rather from the water used in these operations.

EPA made the following general observations based on its review of the vessel discharge data (see Chapter 3 for EPA's detailed analysis of the data):

- Dissolved copper was the analyte detected in vessel discharges at concentrations that consistently posed the greatest potential risk for local impacts and for contributing to exceedances of water quality standards in larger water bodies. Copper is a heavy metal that can restrict the growth and reproduction of plants and algae and can produce both acute (short-term) and chronic (long-term) toxic effects on reproduction, growth, and

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[1] To provide a context for the level of contaminant concentrations presented, EPA used National Recommended Water Quality Criteria (NRWQC) and several other benchmarks as a preliminary screen for all discharge data with the potential to cause or contribute to the nonattainment of a water quality standard in a given receiving water body.

[2] Service water here means the vessel potable water supply. For study vessels, vessel service water generally originates from municipal water supply rather than produced on board.

survival in fish and shellfish. Prolonged exposure to elevated copper concentrations can lead to long-term liver and kidney damage in humans. Concentrations of dissolved copper exceeding the most protective screening benchmark were found in at least some samples for every sampled discharge type, except for outboard engine and generator engine effluents.

Dissolved copper was detected at the highest concentrations in the deck washdown, graywater, fish hold, and bilgewater discharges from most vessel classes, particularly utility vessels (e.g., towboats, supply boats). PHQs for mean dissolved copper concentrations ranged from a low of 1.1 in graywater discharges to a high of approximately 200 in fish hold effluent. Based on concentration and average discharge volume, deck washdown and fish hold discharges contribute the most dissolved copper.

Copper is released (leached) from antifouling hull coatings used on certain vessels to prevent buildup of organisms such as barnacles and algae. Copper can also be released via underwater hull cleaning, hull coating removal operations, and paint application. Although copper antifouling discharges were not measured, previous studies have shown it can be a major contributor to copper concentrations in harbors, especially marinas with large vessel populations (see Section 3.2.8.1).

Average ambient dissolved copper concentrations in the harbors sampled in this study were also slightly higher than the most protective benchmark (mean PHQ of 1.6). However, discharge concentrations still exceeded the benchmark even after subtracting the potential contribution of copper from ambient waters.

- Total arsenic[3] concentrations in vessel discharges were also notably higher than the most protective screening benchmark. In samples where arsenic was detected, PHQs for mean total arsenic concentrations ranged from a low of 110 in graywater discharge to a high of 2,900 in bilgewater discharge. Arsenic is a metalloid (a nonmetallic element with some metal properties) that is easily absorbed by aquatic plants, algae, fish, and shellfish. Arsenic can cause a variety of acute and chronic toxic effects in aquatic organisms, as well as in humans who ingest arsenic via drinking water and contaminated seafood. Arsenic is a known carcinogen, and prolonged high exposures via ingestion can cause cancer, skin irritation, kidney and liver damage, and neurological damage.

  Despite the high potential toxicity of total arsenic, the risk posed to aquatic life is lower than what is suggested by this analysis for two reasons. First, the screening benchmark for total arsenic is a human health criterion to prevent cancer-causing agents in drinking water and is over 100 times lower than that of any other metal in this study. The high

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[3] See discussion in Section 3.1.3 regarding potential positive interference which may have resulted in elevated measured concentrations of arsenic for a subset of samples.

total arsenic PHQs in vessel discharges are the result of this low benchmark for human health, which is 2,000 times lower than the dissolved arsenic benchmark that is based on chronic, long-term toxicity to saltwater aquatic life. Many of the waters where many study vessels operate, particularly for certain vessel types such as commercial fishing vessels, are not typically used as drinking water sources (i.e., ocean and coastal waters). However, some waters where study vessels operate (e.g., the Mississippi River) do serve as drinking water sources and high arsenic loadings in these waters could contribute to human health concerns.

Second, between 20 to 100 percent of the total arsenic measured in the various vessel discharges can be attributed to ambient water that is used as source water for vessel systems. Vessel discharges most influenced by ambient total arsenic concentrations include those from stern tube packing glands, outboard engines, and firemain systems. However, less than half of the total arsenic measured in bilgewater, deckwash, and fish hold discharges appears to be contributed by concentrations in ambient water, indicating that these discharges potentially contribute to arsenic toxicity in receiving waters. Based on concentration and average discharge volume, deck washdown and fish hold discharges appear to contribute the most total arsenic.

- Total aluminum concentrations exceeded benchmark concentrations in at least some samples for all discharge types; however, some of the aluminum concentrations in the discharge may be due to background concentrations (e.g., not added to the discharge by the vessel). Average PHQs for total aluminum ranged from a high of 39 in deck washdown discharge to a low of 1.8 in outboard engine effluent. The metalloid aluminum is most toxic to aquatic organisms in acidic conditions (i.e., waters with a pH < 7). When pH is neutral (7) or higher, aluminum can still inhibit growth of aquatic organisms but to a lesser extent. The pH measured in the vessel discharges and ambient water sampled in this study was generally 7 or higher. Chronic exposure to high concentrations can cause aluminum to accumulate in bones of fish (and humans) and lead to loss of kidney function.

  Indications are that the potential risk from total aluminum is greatest in deck washdown discharges, followed by fish hold discharges, and then stern tube packing gland discharges. For deck washdown, there is an elevated risk because of the high aluminum concentrations (possibly from the leaching of the abundant amount of aluminum found on the surfaces of many vessels), as well as the potentially large discharge volume (up to 900 gpd). Fish hold discharge also contains high total aluminum concentrations with discharges up to 1,000 gpd. Although concentrations in the stern tube packing gland discharge are nearly as high as those in fish hold effluent, potential for risk from stern tube packing gland effluent is lower due to the lower volume of the discharge.

Ambient concentrations of total aluminum were high (ranging from 29 to 3,950 µg/L – see Appendix E) in all of the sampled harbors for this study. The average concentration of total aluminum in ambient water is higher than the average concentration of total aluminum for all discharge types except for deck washdown, fish hold effluent, and stern tube/packing gland effluent. For fish hold[4] and stern tube packing gland discharges, it appears half of the measured total aluminum likely originates from the ambient water. Deck washdown discharge from vessels that use ambient water to clean decks have an estimated 20 percent of the measured total aluminum concentrations contributed by ambient water. In contrast, only 2 percent of the measured total aluminum concentrations were attributable to background concentrations for vessels that used service water to clean their decks (primarily tugboats/utility vessels).

- Concentrations of other metals such as total iron and manganese and dissolved cadmium, lead and zinc above their respective screening benchmarks were measured in some samples of deck washdown effluents (PHQs ranging from 1 to 11). These heavy metals are all known to produce acute and chronic toxic effects in aquatic organisms and humans, in the following order: cadmium is more toxic than lead, which is more toxic than zinc, which is more toxic than iron. These elevated concentrations were particularly prevalent in the deck washdown discharges from utility vessels. However, decks of utility vessels (tugboats) are washed less frequently than fishing vessel decks, so overall metal loads from the two types of vessels are more comparable than concentrations alone might suggest. Although background concentrations of these metals in the ambient and service waters used to wash decks were generally low (except for dissolved zinc in some background samples), average PHQs of all these metals in vessel discharges were not significantly greater than 1, indicating that these metals likely pose minimal potential risk to the environment.

- Total phosphorus concentrations were elevated in some samples of bilgewater, deck washdown, fish hold, and graywater discharges. Average PHQs for total phosphorus in these discharge categories ranged from a high of 130 in fish hold effluent to a low of 14 in graywater. Total phosphorus in some vessel discharges comes from detergents and soaps. Other total phosphorus loadings come from decaying seafood (in fish hold) or leftover food (graywater). Based on concentration and average discharge volume, fish hold effluent contributes the most total phosphorus.

  Phosphorus is an important macronutrient limiting reproduction and growth of plant material and algae (so called "primary production"). Elevated levels of phosphorus can

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[4] The assertion that background concentrations contribute approximately half of aluminum concentrations for fish hold effluent assumes that vessels either took in the original fish hold water from the surrounding harbor waters, or that the fishing grounds where the vessel took in the fish hold water share similar characteristics with surrounding harbor waters.

contribute to nuisance algal blooms, eutrophication (nutrient enrichment), and low dissolved oxygen levels in the water column (hypoxia). Ambient concentrations of total phosphorus, averaged across all sampled harbors, were twice the concentration of the PHQ screening benchmark.

- The concentrations of reactive nitrogen compounds (e.g., nitrate, nitrite, ammonia) and the parameter TKN were generally not significantly elevated; except for in fish hold and fish hold cleaning effluents. Concentrations of ammonia exceed the most stringent recommended acute aquatic life criterion. Concentrations of TKN also exceeded the most stringent screening value. TKN in fish hold and fish hold cleaning effluent were also typical of concentrated raw sewage.

- Biochemical oxygen demand (BOD) and chemical oxygen demand (COD) were elevated in bilgewater, deck washdown, fish hold, and graywater discharges. BOD and COD are measures of oxygen-demanding substances present in the discharges (e.g., organic matter) that can contribute to hypoxia (low dissolved oxygen) in receiving waters. Average BOD concentrations were highest in fish hold effluents (as high as 25 times the concentrations in raw sewage), followed by graywater and then bilgewater and deck washdown water. The BOD levels in fish hold effluent and graywater are comparable to BOD concentrations in raw sewage. Fish hold effluent also has a relatively high discharge volume, so this discharge can contribute a significant BOD/COD loading to receiving waters, particularly when multiple vessels discharge at the sample location (e.g., pierside at a fish processing facility). Hence, depending upon receiving water characteristics, BOD and COD from fish hold effluent may significantly impact the local environment and contribute to water quality exceedances in receiving waters.

- Pathogen indicators, *E. coli*, enterococci, and fecal coliforms, were also found in elevated concentrations in some samples of bilgewater and deck washdown (fishing vessels only), fish hold, and graywater discharges. These three types of bacteria are all found in animal digestive tracts. Epidemiological studies suggest a link between high concentrations of *E. coli* and enterococci in ambient waters and incidents of gastrointestinal illnesses associated with swimming. Accordingly, they are used as indicators of the possible presence of intestinal pathogens. The highest concentrations by far of all three pathogen indicators were found in graywater, with PHQs of around 1,000 for all three bacteria. The estimated discharge volume of graywater from study vessels, however, is relatively small (130 gpd maximum). Larger vessels with additional crew or passengers are expected to generate considerably more graywater (see EPA's Cruise Ship Discharge Assessment Report, USEPA, 2008c). Fish hold effluent contained the second highest concentrations of these pathogen indicators and may pose a potential level of risk considering the relatively high volume of this discharge and possible discharge by multiple vessels in the same location. However, EPA notes that most of the pathogen concentrations in fish hold effluent were well below or similar to ambient water concentrations, and this study is inconclusive as to whether fish hold effluent results in additional discharge of pathogen indicators[5].

- The semivolatile organic compound bis(2-ethylhexyl) phthalate was found in elevated concentrations in some samples of bilgewater, stern tube packing gland, deck washdown, firemain, and inboard engine and engine generator discharges. The highest PHQ of 59 for bis(2-ethylhexyl) phthalate was found in a bilgewater discharge sample. Even though bis(2-ethylhexyl) phthalate was found at elevated concentrations in multiple discharges, the overall frequency of detection was low and generally detected at concentrations just slightly above the benchmark. This compound is a plasticizer that is added to an ever-increasing variety of plastics to provide flexibility and is the most common phthalate in the environment. Although no conclusive evidence exists demonstrating bis(2-ethylhexyl) phthalate affects humans, high concentrations have been shown to feminize males of other species. Bis(2-ethylhexyl) phthalate was not analyzed for in fish hold or graywater discharge samples.

- Benzene was the only volatile organic compound found with any frequency at concentrations above, but generally close to, the PHQ benchmark. Benzene is a known carcinogen that is a common constituent of fuel. Benzene can also be formed as a product of incomplete combustion of fuel. Elevated concentrations of benzene were detected in a bilgewater sample and in samples from both outboard engine and generator engine discharges.

- Long- or short-chain nonylphenol and octylphenol ethoxylates (two distinct subsets of alkylphenol ethoxylates) were detected in some samples of bilgewater, stern tube/packing gland, deck washdown, and graywater discharges, and total nonylphenol was detected in one sample from bilgewater. Nonylphenols were not analyzed for in samples of the remaining discharge types.

  Nonylphenols (a term used generally here to identify a specific group of alkylphenols of potential human and environmental concern which also includes the octylphenols) are manmade organic compounds that are used in a wide variety of applications, such as the manufacturing of detergents, because of their surfactant properties. Nonylphenols are synthetic estrogens, which means they can mimic the natural vertebrate hormone estrogen

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[5] Fish hold water may also serve as a potential pathway for the spread of aquatic nuisance species (ANS). This might occur where fish and water are taken onboard in one place and then transported significant distances for sale or unloading and the water is discharged. Organisms discharged with the water may include parasites and commensals taken in with fish, as well as organisms taken in with water used for refrigerated seawater. EPA did not study the potential for these discharges to transport ANS; however, the Agency is identifying this as a potential area of concern that may warrant further research.

and evoke an estrogen-like response. An example of such a response is the disruption of male sexual development, causing female characteristics to emerge.

Commercial nonylphenol is most accurately described by CAS number 84852-15-3 (phenol, 4-nonyl-branched), but CAS numbers 104-40-5 (phenol, 4-nonyl-) and 25154-52-3 (phenol, nonyl) have also been used to describe these compounds. The commercial nonylphenol mixtures tested that correspond with EPA's criteria are those with CAS numbers 84852-15-3 and 25154-52-3. The analyte category named "total nonylphenol" in the database generated for this study is directly equivalent to the commercial mixture of nonylphenol isomers specified under CAS Number 84852-15-3, and thus is directly comparable to the NRWQC.

Total nonlyphenol (or NP) was not detected, except in one bilgewater sample with a PHQ of 4. Long-chain nonylphenol and octylphenol ethoxylates were detected with far greater frequency, but these longer chain compounds are more water soluble and less toxic than NP. The long-chain nonylphenol and octylphenol ethoxylates will all degrade into NP over time; however, research is ongoing with regard to proportion and duration of the conversion.

Table 5.1 summarizes the major findings discussed above.

Table 5.1. Analytes of Potential Risk by Discharge[1]

Discharge Type (Volume/vessel)	**Analyte Group**								
	Microbiologicals	**Volatile and Semivolatile Organic Compounds**	**Metals (dissolved)**	**Metals (total)**	**Oil and Grease**	**Classical Pollutants**	**Nutrients**	**Nonylphenols[32]**	**Comments**
Bilgewater (2 to hundreds of gpd; average between 10 and 15 gpd)	**enterococci** (detected in only sample collected – shrimping boat; PHQ=124)	**Benzene** (Detected in 4 of 7 samples – highest PHQ = 187; towboat) **Bis(2-ethylhexyl) phthalate** (detected in 4 of 7 samples – non-fishing vessels only; PHQs up to 59)	**Copper** (detected in all of 7 samples; PHQ up to 113 - tour boat) **Cadmium** (detected in only 1 sample; PHQ value of 40 – tour boat).	**Arsenic** (detected in all of 7 samples; PHQs 72 to 1,790)	**HEM** (detected in all of 7 samples; only one sample where PHQ exceeds factor of 2 – conc. = 44 mg/L; towboat)	**Sulfide** (detected in only 2 samples; PHQ as high as 210 from a fishing boat) **TRC** (highest conc. 0.16 mg/L, tour boat; PHQ = 21) **BOD/COD** (elevated in 3 of 5 samples; conc. roughly equivalent to raw sewage)	**Total phosphorus** (elevated in 3 of 5 samples; highest PHQ=130 – longliner fishing boat)	**Long- and short-chain** (NP in single sample-shrimping boat; PHQ = 4)	Tour and tow/salvage boats (utility boats) tended to have highest concentrations of metals and VOCs/SVOCs
Stern tube packing gland effluent (from 4 to 8 gpd)	NA	**Bis(2-ethylhexyl) phthalate** (detected in 3 of 9 samples – max. conc. = 24 µg/L; PHQ = 20)	**Nickel** (detected in 6 of 9 samples; PHQs in 4 samples from 13 to 126) **Copper** (detected in 4 of 9 samples; PHQs from 5 to 30)	**Arsenic** (detected in 3 of 9 samples; PHQs possibly exceed 250)		**TSS** (detected in all of 9 samples – max conc. = 270 mg/L; PHQ = 9)			HEM detected at a max conc. = 67 mg/L; max SGT HEM = 56 mg/L – PHQs approx. 4, respectively. No nonylphenol poly ethoxylates (NPEOs) detected, only longer chain octylphenol polyethoxylates (OPEOs) indicative of contamination from lubricants.

Table 5.1. Analytes of Potential Risk by Discharge[1]

Discharge Type (Volume/vessel)	**Analyte Group**								
	Microbiologicals	**Volatile and Semivolatile Organic Compounds**	**Metals (dissolved)**	**Metals (total)**	**Oil and Grease**	**Classical Pollutants**	**Nutrients**	**Nonylphenols**[32]	**Comments**
Deck washdown and/or runoff (from 20 to 30 gpd utility; 750 to 900 gpd fishing)	**Fecal coliform, enterococci *E. coli*** (detected in all 5 samples collected - fishing vessels only. Concentrations of fecal coliform highest in samples; PHQs as high as 40)		**Copper** (detected in 29 of 31 samples - PHQs from 2 to 65; highest for utility vessels) **Zinc** (detected in all of 31 samples – 67% of PHQs between 1 and 10. Max. conc. of 1,200 µg/L in tugboat; PHQ = 14) **Lead** (detected in 15 of 31 samples – PHQs in 2 samples from 10 to 21) **Cadmium** (detected in 2 of 31 samples – max. conc. = 22 µg/L in tow boat; PHQ = 90)	**Arsenic** (detected in 23 of 31 samples; conc. from 4 to 83 µg/L – PHQs from 200 to 4,000 because very low NRWQC) **Aluminum** (detected in 30 of 31 samples – PHQs between 7.5 and 150. Max. conc. of 13,000 µg/L in tugboat) **Iron** (detected in 18 of 19 samples – PHQs between 3.1 and 48. Max. conc. of 14,500 µg/L in tugboat) **Manganese** (detected only in tugboats and water taxi – PHQs between 1.2 and 13. Max. conc. of 12,800 µg/L in water taxi)2	**HEM** (detected in 26 of 29 samples – only 3 samples with PHQ > 2. Range of concentrations 1.1 to a max of 133 mg/L in a tugboat) **SGT HEM** (detected in 22 of 29 samples – only 1 sample with PHQ > 2. Range of concentration 0.91 to a max of 84 mg/L in a tugboat)	**BOD and COD** (detected in 29 of 31 BOD samples- all COD samples; concentrations roughly equivalent to raw sewage- all vessel types) **TSS** (detected in all of 32 samples – PHQs between 1 and 17; max. concentrations in tugboats) **TRC** (detected in 7 of 31 samples - PHQs between 23 and 100. Max. conc. of 0.8 mg/L in fish trolling boat	**Total phosphorus** (detected in all of 31 samples; PHQ as high as 220 in a tugboat)		Concentrations of many dissolved metals in so-called “utility” or non-fishing vessels statistically higher compared with fishing vessels. Elevated concentrations of total arsenic, aluminum and iron strongly influenced by surrounding ambient water concentrations. TOC detected in all of 25 samples at concentrations from a low of 3.5 to a very high 350 mg/L (tugboat). Bis(2-ethylhexyl)-phthalate detected in only 1 sample (PHQ = 5.6). Only 3 of 29 vessels sampled had detectable concentrations of NPEOs of the shortest chain (NP3EO) indicative of detergents; concentrations ranging from 0.80 to 29 µg/L.

Table 5.1. Analytes of Potential Risk by Discharge[1]

Discharge Type (Volume/vessel)	**Analyte Group**								
	Microbiologicals	**Volatile and Semivolatile Organic Compounds**	**Metals (dissolved)**	**Metals (total)**	**Oil and Grease**	**Classical Pollutants**	**Nutrients**	**Nonylphenols**[32]	**Comments**
Fish hold/ Fish hold cleaning effluent - Fishing vessels only (tens to several hundred or a few thousand gpd (or gallons per several days dependent upon offloading frequency) based on fishing vessel type and platform)	**Fecal coliform, enterococci** (detected in only 1 sample well above ambient concentrations; PHQs of 8,900 and 68 respectively)	NA	**Copper** (detected in 23 of 26 samples - PHQs from 1 to 300. Max. conc. of 921 µg/L in shrimper)	**Arsenic** (detected in 16 of 26 samples; conc. from 3.1 to 380 µg/L – PHQs from 170 to potentially 21,000 because very low NRWQC)		**BOD and COD** (detected in 24 of 26 BOD samples- all COD samples; median concentrations of BOD and COD were 440 and 940 mg/L with max of 5,100 and 8,700 mg/L equivalent to sewage sludge) **Sulfide** (detected in 7 of 25 samples – PHQs between 5 and 80; max. concentrations = 0.16 mg/L in fish trawler) **TSS** (detected in all of 26 samples – PHQs of 4 samples between 17 and 37) **DO** (hypoxic, i.e., ≤ 2.0 mg/L in 3 of 26 samples – all purse seiners)	**Ammonia** (detected in 25 of 26 samples; conc. from 0.087 to 160 µg/L – PHQ at max conc. = 133) **TKN** (detected in 25 of 26 samples; values indicative of strong sewage) **Total phosphorus** (detected in 25 of 26 samples - all but 3 samples resulting in PHQs above 10; highest PHQ=760)	NA	Level of detection of all analytes similar in fish hold cleaning effluent, although concentrations somewhat reduced. HEM detected at a max conc. = 16 mg/L; PHQ = 1.

Table 5.1. Analytes of Potential Risk by Discharge[1]

Discharge Type (Volume/vessel)	**Analyte Group**								
	Microbiologicals	**Volatile and Semivolatile Organic Compounds**	**Metals (dissolved)**	**Metals (total)**	**Oil and Grease**	**Classical Pollutants**	**Nutrients**	**Nonylphenols**[32]	**Comments**
Graywater (tugs – 130 gpd; taxis – 75 gpd; fishing – a few to few hundred gpd)	***E. coli,* Fecal coliform, enterococci** (detected in 7 of 8 samples collected - concentrations of fecal coliform generally highest in mixed shower/sink samples; PHQs as high as 1,000)	NA	**Copper** (detected in all of 8 samples - PHQs from 1.7 to 90. Max. conc. of 280 µg/L in tugboat) **Zinc** (detected in all of 8 samples - max. conc. = 1,500 µg/L in sink water from a water taxi; PHQ = 19)		**HEM** (detected in all of 8 samples - 4 samples with PHQ 2 or more. Concentrations from 9.4 to a max of 100 mg/L in tugboats) **SGT HEM** (detected in 6 of 8 samples – only 1 sample with PHQ >2. Range of concentration 1.3 to a max of 35 mg/L from a tugboat)	**Sulfide** (detected in 5 of 8 samples – PHQs between 4.8 and 370; max. concentration = 0.73 mg/L in tugboat) **BOD and COD** (detected in all of 8 samples; median concentration of BOD and COD were 260 and 440 mg/L, respectively with max of 1,200 and 4,000 mg/L indicative of strong sewage)	**Total phosphorus** (detected in 8 of 8 samples – all but 3 PHQs above 10; highest PHQ=34 in tugboat)		Only 1 of 8 vessels sampled had detectable concentrations of NPEOs of the shortest chain (NP3EO) indicative of detergents; concentration of 0.99 µg/L.

Table 5.1. Analytes of Potential Risk by Discharge[1]

Discharge Type (Volume/vessel)	**Analyte Group**								
	Microbiologicals	**Volatile and Semivolatile Organic Compounds**	**Metals (dissolved)**	**Metals (total)**	**Oil and Grease**	**Classical Pollutants**	**Nutrients**	**Nonylphenols**[32]	**Comments**
Propulsion Engine Effluent – inboard (20 gpm – high power)	NA	**PAHs** (6 probable carcinogenic PAHs detected in sample from a recreational vessel with a gasoline engine. Measured concentrations result in PHQs from 2,100 to 4,800)	**Copper** (detected in 12 of 13 samples - PHQs from 3 samples from 11 to 17. Max. conc. of 53 µg/L in sample from water taxi at idle)			**Temperature** (high idle only; temperature increases of up to 20°C)	NA	NA	Note: Though the recreational vessel with the gasoline engine is not a “study vessel”, it represents EPA’s only samples from a gasoline engine. EPA assumes gasoline engines from similarly designed study vessels would have similar characteristics.
Propulsion Engine Effluent – outboard (1 to 2 gpm)	NA	**Benzene** (detected in 6 of 6 samples – only one sample with a PHQ above 10; value of 28 based on a max. conc. of 62 µg/L in sample from research vessel averaged from variable speeds)					NA	NA	

Table 5.1. Analytes of Potential Risk by Discharge[1]

Discharge Type (Volume/vessel)	**Analyte Group**								
	Microbiologicals	**Volatile and Semivolatile Organic Compounds**	**Metals (dissolved)**	**Metals (total)**	**Oil and Grease**	**Classical Pollutants**	**Nutrients**	**Nonylphenols[32]**	**Comments**
Engine Effluent - Generator (5 to 25 gpm)	NA	**Benzene** (detected in 3 of 5 samples – only one sample with a PHQ approaching 10; value of 9 based on a max. conc. of 21 µg/L in sample from a fire boat)					NA	NA	
Firemain Systems (no volume estimated- used infrequently)	NA		**Copper** (detected in 4 of 6 samples - PHQs from 3.8 to 23; highest for a tour boat)				NA	NA	

Notes:

(1) Generally includes analytes when a large proportion of the samples have concentrations exceeding the NRWQC, when several of the samples have PHQs > 10, when a few samples result in PHQs greatly exceeding the screening benchmark (i.e., 100s to 1,000s), or, in the case of oil and grease and for nonylphenol, when one or more samples exceed an existing regulatory limit by more than a factor of 2. See text above and in Section 3.1.3 for a definition of PHQs and Table 3.1 for screening benchmarks used to calculate these values.

(2) Longer chain nonylphenol and octylphenol ethoxylates degrade to shorter chained ethoxylates under aerobic conditions. In general, the shorter the chain, the more hydrophobic, persistent, and toxic the substance becomes. 4-Nonylphenol (NP) is a shorter-chain nonylphenol that has been found in surface water and is toxic to aquatic life. NP is formed from the longer chain nonylphenol and octylphenol ethoxylates as they break down. The time span from time of use on the vessel to time of sampling of the discharge was probably not long enough for this to occur, except for discharges of bilgewater.

gpm = gallons per minute

gpd = gallons per day

NA - Not applicable; discharge not analyzed for this analyte group.

5.3 SUMMARY OF PREDICTED IMPACTS FROM SELECT POLLUTANTS IN STUDY VESSEL DISCHARGES

5.3.1 Potential Watershed-Wide Impacts from Study Vessels

Using estimated discharge volumes and average pollutant concentrations, EPA evaluated the potential for cumulative effects of the discharges from an assemblage of study vessels on a large hypothetical harbor. The evaluation used a screening-level water quality model to estimate the pollutant concentration into several hypothetical harbors based on different scenarios of vessel groups. Model assumptions included instantaneous and universal dilution of vessel discharges in the harbor and a background concentration of zero for all analytes in the harbor environment (i.e., the model is not able to evaluate whether vessel discharges are likely to cause environmental or human health impacts in the immediate vicinity of the vessel discharges or in small water bodies). Instead, the model can only analyze potential vessel loadings to and impacts on hypothetical large water bodies. Furthermore, the model is not able to analyze parameters that do not have numeric aquatic life or human health based criteria such as BOD or nutrients.

The model did not predict that discharges from the study vessels solely exceeded aquatic life or human health NRWQC for any of the hypothetical harbor scenarios evaluated. This is primarily due to the large dilution predicted in these large harbors (even with low flushing). However, some of these pollutants from these vessels could reasonably have more significant local impacts (although determining this is outside the scope of the model used in this study). In smaller water bodies with many vessels or in more confined areas of a harbor with little to no flushing, EPA believes study vessel discharges have the potential to cause or contribute to exceedances of NRWQC in receiving waters.

Under the low-dilution scenarios, dissolved copper and total arsenic discharges represent the greatest environmental concern and are more likely than other pollutants to contribute to exceedances of water quality standards, particularly if there are other sources of these pollutants (e.g., stormwater runoff) present. These results are summarized below.

Dissolved Copper

EPA determined that the loading rates of dissolved copper from a metropolitan harbor likely posed the greatest potential risk to human health and aquatic life from study vessels on a large scale. Compared to other types of harbors, a metropolitan harbor has a higher level of activity from its vessel population and has more support utility vessels such as supply boats, tow/salvage vessels, and tugboats. The model predicted that discharges from study vessels have the reasonable potential to contribute a significant load of dissolved copper to a water body. Furthermore, when considering the loadings of dissolved copper from other sources (e.g., recreational vessels, large commercial vessels, stormwater runoff, and industrial and municipal point sources), the model results suggest a reasonable potential for the concentrations of dissolved copper to exceed the NRWQC in this type of harbor.

The results of this study are consistent with real-world observations that metals are frequently associated with vessel discharges in concentrations of potential environmental concern. Environmental impacts from dissolved copper leaching from antifouling hull coatings have been well documented in low-flushing environments in harbors with large numbers of recreational vessels, such as the Shelter Island Yacht Basin near San Diego, California, and Marina Del Rey Harbor in Los Angeles, California (see Section 3.3.8.1 of this report). The impacts from the high levels of dissolved copper include reduced primary production and productivity; accumulation of copper in sediments, reducing sediment quality; and chronic low-level toxicity to aquatic organisms, especially sensitive mollusks, crustaceans, and echinoderms.

Total Arsenic

EPA determined that the loading rates of total arsenic (and to a certain extent, dissolved arsenic) may pose a potential risk to human health and the environment in low-dilution or low-flushing environments. Arsenic was found to be ubiquitous in this study, both in vessel discharges and in ambient water[6]. Although arsenic concentrations in ambient water can be quite high in select harbors, certain discharges from study vessels contribute to the overall arsenic load. While the source of total arsenic in vessel discharges is unknown, EPA suspects that atmospheric deposition contributes to total arsenic concentrations in deck washdown and possibly in bilgewater. Total arsenic in fish hold discharges may be biological in origin (from seafood catch) or from sediment entrained in the catch. The biological contribution of arsenic may be significant in that total arsenic concentrations are substantially greater in seawater organisms than in freshwater organisms (Francesconi and Kuehnelt, 2002; USEPA 2003b).

The greatest impact of high total arsenic in harbors is primarily via the food chain and subsequent bioaccumulation to high levels in seafood consumed by humans. Arsenic exposure through drinking water is also of concern where receiving water is used as a source for drinking water. Arsenic is strongly linked to cancer in humans and a potent inhibitor of certain enzymes in vertebrates.

5.3.2 Potential Localized or Near-Field Impacts of Vessel Discharges to Receiving Waters

EPA found that some study vessel incidental discharges may pose an environmental threat in confined water bodies with low flushing rates and a large population of vessels, in water bodies that are hypoxic or hypereutrophic, and/or where the background concentrations or other

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[6] See discussion in Section 3.1.3 regarding potential positive interference which may have resulted in elevated measured concentrations of arsenic for a subset of samples.

sources of these pollutants are significant. In addition to the parameters (copper and arsenic) discussed in Section 5.3.1, the following classical pollutants may likely exhibit near-field effects.

BOD and COD

In general, oxygen-demanding compounds in vessels discharges (measured as BOD and COD) are expected to pose little risk to the environment due to the relatively low volume of vessel discharges that contain these pollutants. However, the frequency and magnitude of BOD and COD in certain discharges (as much as 25 times the concentrations found in raw sewage) warrant additional discussion.

Specifically, the relatively high BOD and COD concentrations in fish hold and fish hold cleaning effluent could pose a localized water quality impact in areas such as small side embayments where flushing rates are low or where portions of the water body are already low in dissolved oxygen. The high levels of BOD result from the degradation of organic material and its by-products in the fish hold. Higher volume discharges with high BOD concentrations (e.g., certain fish hold effluent) may contribute to localized hypoxic conditions in receiving waters, depending on the volume of effluent discharged, the number of vessels discharging in confined areas, and other factors such as season and water temperature.

Pathogen Indicators

Bacteria such as *E. coli*, enterococci, and fecal coliforms are generally of limited concern for most discharges where the pathogens were present (i.e., bilgewater, deck washdown, and fish hold discharges). However, high levels of pathogens in graywater (and potentially other discharge types) may pose some risk to human health and larger vessels with additional crew or passengers are expected to generate considerably more graywater than smaller vessels. However, looked at on a relative basis, the risk from pathogens in graywater is substantially lower than risks from other sources that cause very high concentrations of pathogen indicators in surrounding ambient water. For example, during sampling for this study in Massachusetts that took place in wet weather, a sanitary sewer overflow and a combined sewer overflow caused extremely high pathogen indicator counts in two different harbors, relative to what would be expected from graywater discharges from study vessels.

Total Phosphorus

Nutrients in vessel discharges are generally expected to pose little risk to the environment. However, the frequency and magnitude of total phosphorus in certain discharges warrants some additional discussion.

The environmental effects of nutrients are driven by site-specific environmental conditions (e.g., receiving water temperature, types of algae present, and limiting nutrient conditions). For example, nutrients in vessel discharges may contribute to an environmental effect in one water body, but not another depending on a variety of environmental conditions that control eutrophication (excess productivity in a water body). While EPA has not developed NRWQC for total phosphorus and other nutrients in coastal waters, some states have established water-body-specific or state-wide standards for nutrients based on site-specific evaluations.

As mentioned above, the water quality impact of concern for total phosphorus is eutrophication. The first indications of potential problems are the increased ambient levels of total phosphorus, often followed by an immediate increase in the density (biomass) of the planktonic algal community. This increased algal biomass usually blocks light and reduces water clarity and may contribute to nuisance algal blooms and declining dissolved oxygen. Of note in this study was that the mean total phosphorus concentration in the 15 ambient water samples collected was two times the screening benchmark, suggesting that the incremental effect of discharges from study vessels may be small.

5.4 POSSIBLE BENEFITS TO HUMAN HEALTH, WELFARE, AND THE ENVIRONMENT FROM REDUCING, ELIMINATING, CONTROLLING, OR MITIGATING ONE OR MORE OF THE DISCHARGES FROM THE STUDY VESSELS

Some vessel discharges from commercial fishing vessels and commercial vessels less than 79 feet in length may have the potential to impact the aquatic environment and/or human health. As noted above, using the results obtained in this study, EPA modeled a hypothetical large harbor to evaluate the potential water quality impacts caused by the nine vessel discharge types EPA sampled. Based on this evaluation, EPA determined that the incidental discharges from study vessels to a relatively large water body are not likely to solely cause an exceedance of any NRWQC (i.e., these discharges are unlikely to pose acute or chronic excursions of the NRWQC across an entire large water body). However, many of the pollutants in the vessel discharges were at end-of-pipe concentrations that exceeded an NRWQC, and therefore have the potential to contribute to an exceedance of water quality standards at a more localized scale. The study results indicate that total arsenic and dissolved copper are the most significant water quality concern for the study vessels as a whole. These pollutants are more likely than other pollutants to contribute to exceedances of water quality standards, particularly if there are other sources of pollutants or the receiving water already has high background concentrations.

Gloucester Harbor faces many environmental stressors including Combined Sewer Overflows and Urban Stormwater Runoff. For most pollutants, the impact of these sources may be more significant than from study vessels. However, some pollutants, such as copper or BOD are discharged in notable quantities from certain study vessel discharges.

Like an individual house in an urban watershed, most individual vessels have only a minimal environmental impact. However, the impacts caused by these vessels is potentially significant where there are high vessel concentrations, low circulation in waters, additional environmental stressors, or pollutant loadings from other sources (e.g., recreational vessels, large commercial vessels, stormwater runoff, and industrial and municipal point sources). Reducing certain discharges or certain pollutants in discharges from these vessels in sensitive waters may result in significant environmental benefits to those waters; however, EPA did not analyze the feasibility or cost of managing these discharges as part of this study.

CHAPTER 6

ANALYSIS OF THE EXTENT TO WHICH INCIDENTAL DISCHARGES ARE CURRENTLY SUBJECT TO REGULATION UNDER FEDERAL LAW OR A BINDING INTERNATIONAL OBLIGATION OF THE UNITED STATES

As discussed in Chapter 1, Congress directed EPA, in consultation with the U.S. Coast Guard and other interested federal agencies, to conduct a study of discharges incidental to the normal operation of all fishing vessels and nonrecreational vessels less than 79 feet in length (study vessels). Among other things, the study's charge directed EPA to include an "analysis of the extent to which the discharges are currently subject to regulation under federal law or a binding international obligation of the United States" (Public Law (P.L.) 110-299 § 3(b)(6)). This chapter and accompanying tables present that analysis. Note, however, that as discussed in Chapter 1, this chapter includes some discussion of treaties and statutes that pertain to nonstudy vessels for information purposes. In accordance with P.L. 110-299, this study does not include significant discussion about discharges of sewage or ballast water.[1]

This chapter is organized into four sections. Section 6.1 offers brief overviews of the international obligations addressing vessel discharges, while Section 6.2 summarizes applicable federal statutes and regulations. Section 6.3 includes a brief overview of other international and federal laws that do not directly regulate discharges incidental to the normal operation of a vessel, but which the Agency felt merited some discussion. Finally, Section 6.4 provides tables identifying which applicable laws apply to specific incidental discharges.

6.1 INTERNATIONAL AGREEMENTS

6.1.1 <u>The International Convention for the Prevention of Pollution from Ships (MARPOL 73/78)</u>

The International Convention for the Prevention of Pollution from Ships, 1973, as modified by the Protocol of 1978 (MARPOL 73/78), is the primary international instrument for regulating and preventing pollution from vessels. A total of 150 countries are Parties to

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[1] As of the writing of this report, ballast water discharges are regulated by the U.S. Coast Guard under the National Invasive Species Act of 1996 (NISA), by EPA under Section 402 of the Clean Water Act, and by several states under state law. NISA is discussed briefly in this analysis to the extent that it addresses invasive species from sources other than ballast water. Furthermore, the International Convention for the Control and Management of Ships' Ballast Water and Sediments (BWM Convention), adopted by the International Maritime Organization (IMO) in 2004, establishes ballast water discharge standards. The Convention has not yet attracted the requisite number of Parties necessary for its entry into force. For further discussion, see Standards for Living Organisms in Ships' Ballast Water Discharged in U.S. Waters (74 FR 44,631 (Aug. 28, 2009)).

MARPOL. MARPOL includes six annexes, covering six categories of vessel discharges: oil (Annex I), noxious liquid substances (Annex II), harmful packaged substances (Annex III), sewage (Annex IV), garbage (Annex V), and air emissions (Annex VI).

Before entering into force, the Convention required ratification by 15 member states, with a combined merchant fleet of not less than 50 percent of the total world shipping fleet, measured by gross tonnage. To ratify the convention, member states are required to ratify only Annexes I and II; the remaining annexes are optional. The United States has ratified Annexes I, II, III, V, and VI (the United States has not ratified Annex IV, which regulates sewage discharges from ships; the United States regulates sewage under Section 312 of the Clean Water Act, which is discussed in Section 6.2, Federal Laws).

In the United States, MARPOL is primarily implemented through the Act to Prevent Pollution from Ships (APPS), 33 U.S.C. §§ 1901–1915. APPS implements Annexes I, II, V, and VI. Annex III of MARPOL is implemented through the Hazardous Materials Transportation Act, 49 U.S.C. § 5101 *et seq*. These implementing statutes are discussed in depth in Section 6.2, Federal Laws.

6.1.1.1 MARPOL Annex I: Prevention of Pollution by Oil

MARPOL Annex I establishes requirements for the control of oil pollution from vessels. As previously discussed in this report, small to large amounts of oil can be found in numerous vessel discharges, including bilgewater, deck runoff, and engine effluent. The requirements of this Annex apply to all ships operating in the marine environment, unless expressly provided otherwise.

Every oil tanker of 150 gt and above and every other ship of 400 gt and above is required to undergo a series of surveys to ensure that the ship's structure, equipment, systems, fittings, arrangements, and material are in full compliance with all applicable Annex I requirements and do not pose "an unreasonable threat of harm to the marine environment" (Annex I, Regulations 6.1 and 6.4.1). The surveys are required before the ship is put in service (or before an International Oil Pollution Prevention Certificate [IOPP Certificate], explained below, is issued for the first time); for IOPP Certificate renewal purposes; at certain intervals surrounding the anniversary date of the ship's IOPP Certificate; and after certain repairs or renewals are completed (Annex I, Regulation 6).

Oil tankers of 150 gt and above and ships of 400 gt and above that travel to ports or offshore terminals under the jurisdiction of other Parties to Annex I are required to have an IOPP Certificate, which indicates completion of and compliance with Annex I's inspection requirements. These certificates are issued or endorsed by the government of the state, or any persons or organizations authorized by it, under whose authority the ship is operating (Annex I, Regulation 7). The IOPP Certificate shall not be issued for a time period exceeding five years, subject to various survey provisions contained in the Annex (Annex I, Regulation 10).

Annex I prohibits the discharge of oil or oily mixtures into the sea, except under the following circumstances:

- Ships of 400 gt and above, whether inside or outside a special area where:
    - The ship is proceeding *en route*.
    - The oily mixture is processed through area-appropriate oil filtering equipment (under Regulation 14).
    - The oil content of the effluent without dilution does not exceed 15 parts per million (ppm).
    - The oily mixture does not originate from cargo pump-room bilges on oil tankers.
    - The oily mixture, in case of oil tankers, is not mixed with oil cargo residues.

- Ships of less than 400 gt, whether inside or outside a special area where:
    - The ship is proceeding *en route*.
    - The ship has in operation equipment of a design approved by the government under whose authority the ship is operating, that ensures that the oil content of the effluent without dilution does not exceed 15 ppm.
    - The oily mixture does not originate from cargo pump-room bilges on oil tankers.
    - The oily mixture, in the case of oil tankers, is not mixed with oil cargo residues (Annex 1, Regulation 15).

- Discharges of oil or oily mixtures from cargo areas of oil tankers outside special areas where:
    - The tanker is more than 50 nautical miles from the nearest land.
    - The tanker is proceeding *en route*.
    - The instantaneous rate of discharge of oil content does not exceed 30 liters per nautical mile.
    - For tankers delivered on or before December 31, 1979, the total quantity of oil discharged into the sea does not exceed 1/15,000 of the total quantity of the particular cargo of which the residue formed a part, or for tankers delivered after December 31, 1979, 1/30,000 of the total quantity of the particular cargo of which the residue formed a part.
    - The tanker has in operation an oil discharge monitoring and control system and a slop tank arrangement (under Regulations 29 and 31). (Annex 1, Regulation 34).

Discharges of oil or oily mixtures from the cargo area of an oil tanker while in a special area are prohibited (Annex 1, Regulation 34).

Discharging oil or oily mixtures from any ship in the Antarctic area is expressly prohibited. No discharge into the sea may contain substances in quantities or concentrations that are hazardous to the marine environment or substances introduced for the purpose of circumventing the conditions of discharge specified in Annex 1 (Annex 1, Regulation 15).

The prohibition against the discharge of oil and oily mixtures does not apply where the discharge is necessary for the purpose of securing the safety of a ship or saving life at sea. The prohibition also does not apply where the discharge resulted from damage to the ship or its equipment, provided that all reasonable precautions were taken after the occurrence of the damage or discovery of the discharge and the damage was not caused intentionally or recklessly with knowledge that damage would probably result. Ships may discharge substances containing oil when those substances are being used to combat specific pollution incidents in an effort to minimize damage from the pollution, subject to relevant governments' approvals (Annex I, Regulation 4).

Every oil tanker of 150 gt and above and every other ship of 400 gt and above must maintain an Oil Record Book Part I.[2] The Oil Record Book Part I must be completed whenever any of the following machinery-space events occur: ballasting or cleaning of oil fuel tanks; discharge of dirty ballast water or cleaning water from oil fuel tanks; collection and disposal of oil residues; discharge overboard or disposal otherwise of bilgewater that has accumulated in machinery spaces; bunkering of fuel or bulk lubricating oil; accidental or other exceptional discharge of oil; and failure of oil filtering equipment. The Oil Record Book Part I must be readily available for inspection. A Party to Annex I may request inspection of the Oil Record Book Part I while any ship to which this Annex applies is in its port or offshore terminal and require the master of the ship to certify that any copies made of the Oil Record Book Part I are true. (Annex I, Regulation 17).

Oil tankers of 150 gt and above and all other ships of 400 gt and above must carry onboard a shipboard oil pollution emergency plan approved by the government under whose authority the tanker is operating. The plan must include the procedures for ship operators to follow to report an oil pollution incident, the list of authorities or people to be contacted in the event of an oil pollution incident, a detailed description of the actions to be taken immediately to reduce the discharges of oil following an incident, and a contact onboard responsible for coordinating with authorities to combat the pollution. This plan may be combined with the emergency response plan required by MARPOL Annex II (discussed below). Oil tankers of 5,000 tons deadweight or more must have prompt access to computerized damage stability and residual structural strength calculation programs (Annex I, Regulation 37).

Governments of Parties to Annex I must ensure that there are adequate reception facilities for discharging oil and oily residues and comply with various requirements related thereto, including capacity and location requirements (Annex I, Regulation 38).

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[2] Oil tankers must also maintain an Oil Record Book Part II (Annex I, Regulation 36).

Although ballast water falls outside the scope of P.L. 110-299, the Agency notes that Annex I includes regulations governing ballast water. These regulations establish when ships must have segregated ballast tanks and under what circumstances ballast water may be carried in oil fuel tanks or cargo tanks (Annex I, Regulations 16 and 18).

In addition to the requirements discussed above, Annex I includes a number of requirements applicable to oil tankers alone. Since oil tankers would not generally be expected to be study vessels, EPA has omitted an in-depth discussion of these requirements, which include:

1. New-build protective cargo tank arrangements (including double-hull/double-bottom requirements) for certain tankers (Annex I, Regulations 19–20).
2. Double-bottom pump-room requirements for oil tankers of 5,000 tons deadweight and above constructed on or after January 1, 2007 (Annex I, Regulation 22).
3. Requirement that oil tankers delivered on or after January 1, 2010, be built in such a way that if they are damaged, oil will not spill from them at a rate greater than MARPOL allows (Annex I, Regulations 23-25).
4. Limitations on the size and arrangement of cargo tanks for oil tankers of 150 gt and above, depending on delivery date (Annex I, Regulation 26).
5. Subdivision, damage stability, and intact stability criteria (Annex I, Regulations 27–28).
6. Cargo tank cleaning requirements, including requirements relating to slop tanks (Annex I, Regulation 29).
7. Pumping, piping, and discharge arrangement regulations governing the discharge of dirty ballast water or oil-contaminated water (Annex I, Regulation 30).
8. Oil discharge monitoring and control system requirements, including requirements for effective government-approved oil/water interface detectors (Annex I, Regulations 31–32).

Also outside the scope of this study, but worth noting, is that Annex I includes requirements applicable to fixed or floating platforms. Specifically, fixed or floating platforms must comply with the requirements of the Annex applicable to ships of 400 gt and above, other than oil tankers, except that they shall be equipped only to the extent practicable relating to tanks for oily residue and oil filtering equipment. Records involving oil or oily mixture discharges must be kept in a form approved by the government under whose authority the vessel is operating, and the discharge of oil or oily mixtures to the sea is prohibited except when the oil content of the discharge without dilution does not exceed 15 ppm (Annex I, Regulation 39).

6.1.1.2 MARPOL Annex II: Control of Pollution by Noxious Liquid Substances in Bulk

MARPOL Annex II addresses pollution caused by “noxious liquid substances” (NLS) carried in bulk. Substances regulated as NLS under MARPOL are categorized into four categories[3] based on their potential to cause harm:

- Category X: Substances that, if discharged into the sea from tank cleaning or deballasting operations, present a major hazard to either marine resources or human health and therefore justify the prohibition of the discharge into the marine environment.
- Category Y: Substances that, if discharged into the sea from tank cleaning or deballasting operations, present a hazard to either marine resources or human health or cause harm to amenities or other legitimate uses of the sea and therefore justify a limitation on the quality and quantity of the discharge into the marine environment.
- Category Z: Substances that, if discharged into the sea from tank cleaning or deballasting operations, will present a minor hazard to either marine resources or human health and therefore justify less stringent restrictions on the quality and quantity of the discharge into the marine environment.
- Other Substances: Substances that fall outside of categories X, Y, or Z because they are considered to present no harm to marine resources, human health, amenities, or other legitimate uses of the sea when discharged into the sea from tank cleaning or deballasting operations. The discharge of bilge or ballast water or other residues or mixtures containing these substances are not subject to any requirements under MARPOL Annex II. (Annex II, Regulation 6).

All ships certified to carry one or more of these substances in bulk must follow the requirements established in Annex II unless the discharge is necessary for the purpose of securing the safety of a ship or saving life at sea (Annex II, Regulations 2–3). The Annex’s requirements also do not apply where the discharge resulted from damage to the ship or its equipment, provided that reasonable precautions were taken after the occurrence of the damage or discovery of the discharge, and the damage was not caused intentionally or recklessly with knowledge that damage would probably result. Discharges of other substances may also be exempted from Annex II’s requirements if they are government-approved (by both the government under whose authority the ship is operating and any government in whose

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[3] This categorization scheme was developed when Annex II was revised; it entered into force in January 2007. The United States Coast Guard’s implementing regulations, discussed below, have not yet been revised to reflect this new scheme.

jurisdiction the discharge will occur) and being used to combat specific pollution incidents in an effort to minimize damage from the pollution (Annex II, Regulation 3). Regulation 4 of Annex II provides for a number of other specific exemptions to the Annex's requirements.

Ships intending to carry NLS in bulk to other Parties to MARPOL must obtain an International Pollution Prevention Certificate for the Carriage of Noxious Liquid Substances in Bulk ("Certificate"). The Certificate records the results of the various inspections to which NLS-carrying ships are subject. The government under which the ship is registered is typically responsible for issuing the Certificate, using a form provided in Appendix 3 to Annex II (Annex II, Regulation 9). Certificates are issued for a period of time not to exceed five years (Annex II, Regulation 10).

Prior to and at periodic intervals after a ship is issued a Certificate, it is subject to a complete inspection of its structure, equipment, systems, fittings, arrangements, and materials to ensure compliance with Annex II. The government of the country under whose authority a ship is operating is responsible for having these inspections conducted. If a ship or its equipment is found to not correspond substantially with the particulars of the Certificate, corrective action must be taken. If corrective action is not taken, the ship's Certificate should be withdrawn. Conformity with these MARPOL requirements is necessary to ensure that the ship does not pose an unreasonable threat of harm to the marine environment (Annex II, Regulation 8).

Ships that are certified to carry NLS in bulk that are identified in chapter 17 of the International Bulk Chemical Code must generally ensure that their design, construction, equipment, and operation are in conformance with the requirements of that Code (Annex II, Regulation 11).

Ships constructed prior to July 1, 1986, must have a pumping and piping arrangement ensuring that each tank certified to carry substances in Category X or Y does not retain more than 300 liters of residue in the tank and its associated piping. Each tank certified to carry substances in Category Z must not retain more than 900 liters in the tank and its associated piping (Annex II, Regulation 12(1)). Ships constructed on or after July 1, 1986, but before January 1, 2007, must not retain residue greater than 100 liters for Category X or Y substances or 300 liters for Category Z substances in the tank and its associated piping (Annex II, Regulation 12(2)). Ships constructed after January 1, 2007, must not retain residue in a quantity greater than 75 liters in the tank or its associated piping for Category X, Y, or Z (Annex II, Regulation 12(3)).

Ships certified to carry Category X, Y, or Z substances, except ships constructed before January 1, 2007, and certified to carry Category Z substances, must have at least one underwater discharge outlet, which must be located within the cargo area in the vicinity of the turn of the bilge and arranged to avoid the re-intake of residue/water mixtures by the ship's seawater intakes. The residue/water mixture discharged into the sea must not pass through the ship's boundary layer (Annex II, Regulation 12 (6)-(9)).

Ships are prohibited from discharging into the sea residues of Category X, Y, or Z substances or ballast water, tank washings, or other mixtures containing these substances unless the discharges fully comply with the applicable operational requirements of Annex II. Specifically, 1) the ship must be proceeding en route at a speed of at least 7 knots in the case of self-propelled ships or at least 4 knots for other ships, 2) the discharge must be made below the waterline through the underwater discharge outlets at a rate not to exceed what the outlet was designed for, and 3) the discharge must be made no less than 12 nautical miles from the nearest land and in water not less that 25 meters deep (Annex II, Regulation 13(1)-(2)). For Category Z substances on ships not required to have an underwater discharge outlet, the requirement that discharges occur below the waterline does not apply. Annex II also sets out requirements for the discharge of NLS residues (Annex II, Regulation 13(6)–(7)). Any discharge of NLS or mixtures into the Antarctic area is prohibited (Annex II, Regulation 13(8)).

Every ship certified to carry Category X, Y, or Z substances must have a government approved Manual onboard. The Manual is meant to inform the ship's officers of the physical arrangements and operational procedures necessary to comply with Annex II (Annex II, Regulation 14). Ships must also carry with them a Cargo Record Book to record where NLS substances were loaded and unloaded and the circumstances of the loading and unloading. If any accidental or emergency discharges occur, those must also be recorded in the Cargo Record Book (Annex II, Regulation 15).

Ships certified to carry NLS in bulk that weigh 150 gt or above must carry onboard a marine pollution emergency plan for NLS. The plan must be government approved and must include the procedures for ship operators to follow to report an NLS pollution incident, the list of authorities and people to be contacted in the event of an NLS pollution incident, a detailed description of the actions to be taken immediately to reduce the discharges of NLS following an incident, and a contact onboard responsible for coordinating with authorities to combat the pollution (Annex II, Regulation 17).

The Government of each Party to MARPOL must ensure that its ports and terminals have adequate NLS reception facilities for the ships utilizing those ports and terminals to meet the requirements of Annex II (Annex II, Regulation 18).

6.1.1.3 MARPOL Annex III: Prevention of Pollution by Harmful Substances Carried by Sea in Packaged Form

MARPOL Annex III establishes requirements for preventing pollution caused by harmful substances that are carried in packaged form. "Harmful substances" are defined as those substances that are identified as marine pollutants in the International Maritime Dangerous Goods Code (IMDG Code). "Packaged form" is defined as the forms of containment specified for harmful substances in the IMDG Code (Annex III, Regulation 1(1)). Although the requirements of this Annex do not directly regulate discharges incidental to the normal operation of a vessel, they play a critical role in preventing harmful substances from entering into such discharge streams.

Annex III prohibits the carriage of harmful substances from all ships unless the requirements of the Annex are followed (Annex III, Regulation 1(2)). Empty packages that were previously used to carry harmful substances and contain harmful residue are themselves considered harmful substances and must be treated as such (Annex III, Regulation 1(4)). Additionally, the Government of each Party to MARPOL is required to issue detailed requirements on packing, marking, labeling, documentation, stowage, quantity limitations, and exceptions for preventing or minimizing pollution of the marine environment by harmful substances (Annex III, Regulation 1(3)).

The Annex requires that packages containing harmful substances be adequate to minimize the hazard to the marine environment, having regard to their specific contents (Annex III, Regulation 2). They must be durably marked with the correct technical name (trade names alone are prohibited), must indicate that the substance is a marine pollutant, and should be supplemented where possible by other means (e.g., use of the relevant United Nations number). The durability of both the package and the markings must be considered because the Annex requires that the markings be able to withstand at least three months immersed in the sea (Annex III, Regulation 3).

In all documents relating to the carriage of harmful substances at sea, the correct technical name of each substance must be used, and the substance must be identified with the words “MARINE POLLUTANT.” The shipping documents provided by the shipper must be accompanied by a signed certificate declaring that the shipment is properly packaged and marked and in proper condition for carriage to minimize the hazard to the marine environment. Every ship must keep, both onboard and onshore, a list or manifest detailing the harmful substances onboard and where they are stowed (Annex III, Regulation 4).

Packages containing harmful substances must be stowed and secured so as to minimize the hazards to the marine environment, without impairing the safety of the ship and the people onboard (Annex III, Regulation 5). Some harmful substances may face restrictions, for sound scientific and technical reasons, as to the quantity that can be carried onboard, and in some cases, carrying them might be prohibited altogether. These determinations will take into account the size, construction, and equipment of the ship, as well as the packaging and nature of the substance (Annex III, Regulation 6).

Except where necessary to protect the ship or saving life at sea, the jettisoning of harmful substances carried in packaged form is prohibited (Annex III, Regulation 7).

6.1.1.4 MARPOL Annex IV: Prevention of Pollution by Sewage from Ships

Annex IV of MARPOL establishes requirements for the prevention of pollution caused by sewage from ships. The discussion of discharges of sewage from vessels was specifically excluded from the scope of this study; therefore, the summary of this section is omitted. See P.L. 110–299, § 3(c)(2). It should also be noted that, as mentioned above, the United States is not a party to Annex IV and is therefore not obligated to follow its requirements.

6.1.1.5 MARPOL Annex V: Prevention of Pollution by Garbage from Ships

Annex V of MARPOL regulates garbage pollution from ships. Under the Annex, "Garbage" is defined as all kinds of victual, domestic, and operational waste (excluding fresh fish and fish parts) generated during the normal operation of the ship and liable to be disposed of continuously or periodically (Annex V, Regulation 1(1)). Although the requirements of this Annex do not directly regulate discharges subject to this report ("garbage" is not subject to the former NPDES permit exclusion at 40 CFR 122.3(a)), they play a critical role in preventing garbage from entering into and contaminating discharge streams subject to this report.

The Annex establishes different disposal requirements depending on the type of garbage being disposed of. Disposal into the sea of dunnage—lining and packing materials that will float—is prohibited if the ship is closer than 25 nautical miles from the nearest land. The disposal of food wastes and all other garbage, including paper products, rags, glass, metal, bottles, crockery, and similar refuse is prohibited less than 12 nautical miles from the nearest land; however, it may be permitted if it has passed through a comminuter or grinder, is small enough that it can pass through a screen with openings no greater than 25 mm, and is disposed of as far as practicable from the nearest land (but no closer than 3 nautical miles). The disposal of plastics, including but not limited to synthetic ropes, synthetic fishing nets, and plastic garbage bags, is prohibited. Where garbage is mixed, the more stringent requirements will apply (Annex V, Regulation 3). Additional special requirements are in place for discharges into certain defined areas.[4]

None of the disposal regulations described above apply where: 1) the disposal was necessary for the purpose of securing the safety of the ship or those onboard or saving life at sea; 2) the garbage escaped as the result of damage to the ship (provided all reasonable precautions were taken before and after the incident to prevent or minimize the escape); or 3) disposal was the result of an accidental loss of synthetic fishing nets (provided that all reasonable precautions were taken to prevent the loss) (Annex V, Regulation 6).

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[4] For the purposes of Annex V, the special areas are the Mediterranean Sea area; the Baltic Sea area; the Black Sea area; the Red Sea area; the "Gulfs" area; the North Sea area: the Antarctic area; and the wider Caribbean region, including the Gulf of Mexico and the Caribbean Sea (although the rules have not entered into force with respect to all of these areas yet). For the specific requirements, see Annex V, Regulation 5.

The Parties to the Annex must ensure that ports and terminals have adequate facilities for the reception of garbage (Annex V, Regulation 7).

Each ship 12 meters or more in length must display placards that notify those onboard of the various disposal requirements. The placards must be written in the working language of the ship's personnel and, for ships engaged in voyages to ports or offshore terminals under the jurisdiction of other Parties to the Convention, shall also be in English, French, or Spanish (Annex V, Regulation 9(1)).

Every ship 400 gt and above and every ship certified to carry 15 or more people must carry a garbage management plan for the crew to follow. The plan must describe procedures for collecting, storing, processing, and disposing of garbage, including the use of equipment onboard. It must be written in the working language of the crew and identify the person in charge of carrying out the plan (Annex V, Regulation 9(2)). Ships of this size or certification that travel to ports or offshore terminals under the jurisdiction of other countries party to MARPOL, and every fixed and floating platform engaged in exploration and exploitation of the seabed, must also carry a Garbage Record Book onboard. The Garbage Record Book must include a record of every discharge operation or incineration, including the date and time of the discharge, the position of the ship, a description of the garbage, and the estimated amount discharged or incinerated. Any escapes or accidental losses must also be noted in the Garbage Record Book, along with a description of the circumstances of the loss (Annex V, Regulation 9(3)).

6.1.1.6 MARPOL Annex VI: Prevention of Air Pollution from Ships

Annex VI of MARPOL regulates air emissions from ships. Air emissions are outside the scope of this study, therefore, the summary of this Annex has been omitted.

6.1.1.7 MARPOL Summary

The earlier chapters of this study describe a number of pollutants detected by EPA in incidental vessel discharges that have the potential to pose a risk to human health or the environment. Of these pollutants of concern, it appears that oil and grease are the only pollutants found in incidental discharges that would be directly regulated by MARPOL, through Annex I. However, MARPOL may indirectly regulate other pollutants found in incidental discharges, such as metals, to the extent that they are found in any of the noxious liquid substances categorized under Annex II or garbage under Annex V and prevented from entering incidental discharge streams . In all cases, the requirements of MARPOL only apply to those vessels that are large enough to meet the size thresholds established in the treaty.

6.1.2 <u>The International Convention on the Control of Harmful Anti-Fouling Systems on Ships</u>

The International Convention on the Control of Harmful Anti-Fouling Systems on Ships was adopted by the IMO on October 5, 2001, and entered into force on September 17, 2008. The

U.S. Senate gave its consent to ratify the Convention on September 26, 2008; however, the United States will not deposit its instrument of ratification with the IMO until Congress adopts the necessary implementing legislation. Implementing legislation was introduced on September, 24, 2009. See Clean Hull Act of 2009, H.R. 3618, 111th Congress (1st Session 2009). If passed, this new legislation would replace the Organotin Anti-Fouling Paint Control Act of 1988 (OAPC), discussed below.

Parties to the Convention are required to take steps to reduce or eliminate adverse effects on the marine environment and human health caused by antifouling systems. Under the Convention, an "antifouling system" is any coating, paint, surface treatment, surface, or device used on a ship to control or prevent the attachment of unwanted organisms (Article 2(2)).

The Convention applies to any ship entitled to fly the flag of a Party; ships not entitled to fly the flag of a Party but that operate under the authority of that Party; and ships that enter a port, shipyard, or offshore terminal of a Party but do not fall under one of the earlier categories. Warships, naval auxiliary, or other ships owned or operated by a Party are exempted when used only for noncommercial government service. However, each Party must ensure that these exempted ships operate in a manner consistent with the Convention, where reasonable and practicable. Parties must also ensure that favorable treatment is not given to ships registered to countries that are not Parties to the Convention (Article 3).

Under the Convention, Parties must prohibit and/or restrict the application, re-application, installation, or use of environmentally harmful antifouling systems on ships registered under them, as well as on ships that enter its ports, shipyards, or offshore terminals (Article 4). As of January 1, 2008, ships are prohibited from having any organotin compounds on their hulls that act as biocides, unless the compounds have been sealed so that no leaching occurs (Annex I).

Parties to the Convention must take measures to require that wastes generated by the application or removal of an antifouling system are collected, handled, treated, and disposed of in a safe and environmentally sound manner (Article 5). In the United States., this provision would be implemented through the Solid Waste Disposal Act, 33 U.S.C. §§ 6901–6992, and the Clean Water Act, 33 U.S.C. §§ 1251–1387.

Any Party can propose an amendment to the Convention, including proposals to prohibit antifouling systems other than organotins. The process for proposing an amendment, and subsequently considering and adopting it, is described in Articles 6, 7, and 16.

Parties must take appropriate measures to promote and facilitate scientific and technical research on the effects of antifouling systems, as well as monitoring these effects. The research should include observation, measurement, sampling, evaluation, and analysis of the effects of antifouling systems. Parties should share the information learned in these studies with other Parties to the Convention when requested (Article 8).

The Convention requires Parties to report to the IMO a list of all surveyors and organizations that are authorized to act on behalf of that Party in administration of matters relating to the control of anti-fouling systems. Parties must also annually report information regarding any antifouling systems that were approved, restricted, or prohibited under domestic law. For antifouling systems that were approved, registered, or licensed by a Party, that Party must provide to other Parties upon request relevant information on which that decision was made (alternatively, a Party could require the manufacturers of approved, registered, or licensed antifouling systems to provide this information) (Article 9).

A Party must ensure that ships entitled to fly under its flag or operate under its authority are surveyed and certified in accordance with the requirements of Annex 4 (Article 10). Annex 4 requires that ships of 400 gt and above that are engaged in international voyages be surveyed before the ship is put into service and whenever the antifouling systems are changed or replaced. The survey is intended to ensure the ship's antifouling system fully complies with the Convention (Annex 4, Regulation 1). At the conclusion of the survey, the ship will be issued an International Anti-Fouling System Certificate (Annex 4, Regulation 2). Ships less than 400 gt and 24 meters or more in length and that are engaged in international voyages must carry a Declaration, signed by the owner or his agent, declaring that the antifouling system used on the ship complies with the requirements of the Convention (Annex 4, Regulation 5).

Ships to which the Convention applies may be inspected in any port, shipyard, or offshore terminal of a Party. Unless there are clear grounds for believing that a ship is in violation of the Convention, the inspection is limited to: 1) verifying that, where required, there is a valid International Anti-Fouling System Certificate or Declaration onboard; and/or 2) a brief sampling of the ship's antifouling system, taking into account IMO guidelines. If there are clear grounds to believe that a ship is in violation of the Convention, a more thorough inspection is permitted, taking into account IMO guidelines. Additionally, a Party may take steps to warn, detain, dismiss, or exclude from its ports any ship that is found to be in violation but must immediately notify the country under whose flag the ship is registered (Article 11).

Parties must, through domestic laws, prohibit violations of the Convention and establish sanctions severe enough to discourage violations.[5] If a violation occurs within the jurisdiction of a Party, that Party must either cause proceedings to be taken in accordance with its domestic laws or furnish any information or evidence it has showing a violation has occurred to the government under whose authority the ship concerned is operating. If that government finds the

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[5] For vessels larger than 79 feet, EPA has prohibited the discharge of tributyltin and other organotins under the Agency's Vessel General Permit (see Section 6.2.3).

evidence sufficient to enable proceedings to be brought, it must do so as soon as possible, in accordance with its laws, and notify both the IMO and the reporting Party that it has done so. If the government does not take action within one year after receiving the information, it must so inform the Party that reported the alleged violation (Article 12).

Parties must make every effort to avoid unduly detaining or delaying ships while conducting inspections or investigating potential violations. If a ship is unduly detained or delayed, it is entitled to compensation for any loss or damage suffered (Article 13).

The Convention does not prejudice the rights or obligations of any country under customary international law as reflected in the United Nations Convention on the Law of the Sea (Article 15).

Presently, the International Convention on the Control of Harmful Anti-Fouling Systems on Ships only regulates the use of organotin tributyling (TBT) in antifouling coatings. Effective January 2003, new applications of antifouling coatings containing TBT were prohibited by the treaty, and as of January 2008, all vessels with an existing TBT antifouling coating on their hulls are required to apply a protective coating over the TBT to prevent leaching.

Since the use of TBT has been prohibited, vessel operators have turned to anti-fouling systems that contain other potentially harmful pollutants, such as copper. Copper is not currently regulated under the International Convention on the Control of Harmful Anti-Fouling Systems on Ships; however, the treaty provides a system whereby Parties may propose that a specific anti-fouling system be regulated under the treaty. Through this mechanism, copper may one day be regulated under the treaty if parties to the treaty determine it is necessary.

6.1.3 International Convention for the Safety of Life at Sea (SOLAS)

The International Convention for the Safety of Life at Sea (SOLAS) is considered the most important international treaty concerning the safety of merchant ships. The first version was adopted in 1914 in response to the *Titantic* disaster and has been amended many times since then, most recently in 1974. The primary objective of SOLAS is to establish minimum standards for the construction, equipment, and operation of ships, in consideration of their safety. The responsibility for ensuring compliance rests with the individual flag states, although contracting governments do have limited authority to inspect ships of other contracting governments if there are clear grounds for believing the SOLAS requirements are not being met. For additional information on SOLAS, please see the IMO's discussion of the Convention at www.imo.org

While SOLAS does not directly regulate vessel discharges, it does provide environmental benefits through its regulations and through adoption of the International Safety Management (ISM) Code, all of which assist in preventing spills and other accidental discharges. The ISM Code provides an international standard for safely managing and operating ships and for preventing pollution. In addition to other requirements, under the Code, companies or individuals responsible for operating vessels must establish a safety and environmental-protection policy and ensure that the policy is implemented and maintained at all levels of the organization, both ship-based and shore-based. These operators must also create a safety management system, which is a structured and documented system that enables company personnel to effectively implement the company's safety and environmental protection policy (ISM Code, Part A).

SOLAS could be used to address any of the pollutants of potential concern identified by EPA though this study, to the extent that the individual policies adopted by vessel operators address specific pollutants found in incidental discharges.

6.1.4 Boundary Waters Treaty

The Boundary Waters Treaty is an agreement the United States and Canada entered into in 1919 to govern the management of boundary waters. Among other things, the treaty provides that "boundary waters" – defined as "waters from main shore to main shore of the lakes and rivers and connecting waterways, or the portion thereof, along with the international boundary" between the U.S. and Canada - "and waters flowing across the boundary shall not be polluted on either side to the injury of health or property on the other" (Preliminary Article and Article IV.2).

The Treaty established the International Joint Commission (IJC), composed of three commissioners from each country, to assist in the resolution of boundary water issues (Article III). Since 1919, the IJC has addressed a variety of water-use and water-quality issues. The Treaty is a foundational backdrop for other bilateral agreements between the United States and Canada, such as the Great Lakes Water Quality Agreement.

As a foundational agreement, the Boundary Waters Treaty does not directly regulate specific pollutants, which means it does not directly regulate specific pollutants in incidental discharges.

6.1.5 Great Lakes Water Quality Agreement

The Great Lakes Water Quality Agreement, first signed in 1972, and revised in 1978 and 1987, expresses the commitment of both the United States and Canada to restore and maintain the chemical, physical, and biological integrity of the waters of Great Lakes Basin Ecosystem. It also reaffirms the rights and obligations of both countries under the Boundary Waters Treaty. The Great Lakes Water Quality Agreement is primarily implemented through Section 118 of the Clean Water Act.

One of the stated policies in the Agreement is the prohibition of discharges of toxic substances in toxic amounts and the virtual elimination of discharges containing any or all persistent toxic substances (Article II). The general objectives of the agreement are to ensure that the waters in the Great Lakes System are free from pollutants resulting from human activity, such as substances that will settle to form sludge deposits or harm aquatic life or waterfowl; floating materials (e.g., debris, oil, scum, other immiscible substances); materials or heat that produce color, odor, taste, or other conditions that will interfere with beneficial uses or are toxic or harmful to human health or the environment; and nutrients that create growths of aquatic life that interfere with beneficial uses (Article III).

Vessel discharges are directly addressed through Annexes 4 (discharges of oil and hazardous polluting substances from vessels), 5 (discharges of vessel wastes), and 6 (review of pollution from shipping sources) of the Agreement. In all of these annexes, "vessel" is defined as "any ship, barge or other floating craft, whether or not self-propelled" (Annex 4(1)(e), Annex 5(1)(e)).

Annex 4 addresses discharges of oil and hazardous polluting substances from vessels. Within this annex, the term "discharge" includes, but is not limited to, any spilling, leaking, pumping, pouring, emitting, or dumping; it does not include unavoidable direct discharges of oil from a properly functioning vessel engine (Annex 4(1)(a)). The annex requires that each country adopt regulations to prevent discharges of harmful quantities of oil and hazardous substances from vessels into the Great Lakes System. Specifically:

- Discharges of harmful quantities of oil or hazardous substances, including those contained in ballast water, must be prohibited and made subject to appropriate penalties.
- As soon as any person in charge, including a vessel owner/operator, becomes aware of a discharge, or probable discharge, of harmful quantities of oil or hazardous substances, he/she must immediately notify the appropriate agency in the jurisdiction where the discharge occurred. Failure to give this notice must be subject to appropriate penalties (Annex 4(2)).

A "harmful quantity of oil" is defined as "any quantity of oil that, if discharged from a ship that is stationary into clear calm water on a clear day, would produce a film or a sheen upon, or discoloration of, the surface of the water or adjoining shoreline, or would cause a sludge or emission to be deposited beneath the surface of the water or upon the adjoining shoreline" (Annex 4(1)).

Annex 4 also requires both countries to adopt regulations for the design, construction, and operation of vessels, as well as programs to ensure that merchant vessel personnel are trained in the use, handling, and stowage of oil and abatement of oil pollution, thereby preventing the discharge of harmful quantities of oil or hazardous polluting substances. For oil, the regulations must ensure that each vessel has a suitable means for containing spills of oil and oily wastes and retaining those wastes onboard for off-load at a reception facility. Oil loading, unloading, and bunkering systems must be suitably designed to minimize the possibility of failure (Annex 4(3)).

For hazardous polluting substances, each country must adopt programs and measures to prevent discharges of harmful quantities of hazardous polluting substances carried as cargo. Such regulations include ensuring that all vessels have a suitable means of containing onboard spills caused by loading or unloading operations and have the capability of retaining onboard wastes accumulated during vessel operation for off-loading to a reception facility. The regulations must also provide for the identification of vessels carrying cargos of hazardous substances and for the identification in vessel manifests of all the hazardous substances those vessels are carrying (Annex 4(4)). A list of hazardous polluting substances and potential hazardous polluting substances can be found in Appendices 1 and 2 to Annex 10.

Additionally, under Annex 4, both countries must ensure that there are adequate facilities for the reception, treatment, and subsequent disposal of oil and hazardous polluting substances from all vessels (Annex 4(5)).

Annex 5 addresses discharges of vessel wastes, including garbage, sewage, and waste water. "Garbage" is defined as "all kinds of victual, domestic, and operational wastes, excluding fresh fish and parts thereof generated during the normal operation of the ship and liable to be disposed of continually or periodically." "Wastewater" encompasses any water combined with other substances, "including ballast water and water used for washing cargo hold, but excluding water in combination with oil, hazardous polluting substances, or sewage" (Annex 5(1)).

The agreement requires both countries to adopt regulations that will:

- Prohibit the discharge of garbage from vessels and make such discharges subject to appropriate penalties.
- Prohibit the discharge of wastewater in harmful amounts or concentrations and make such discharges subject to appropriate penalties.
- Ensure that each vessel operating in boundary waters, and that has toilet facilities, is equipped with a device to contain, incinerate, or treat sewage to an adequate degree. Appropriate penalties must be provided for failure to comply (Annex 5(2)).

Within the Great Lakes System, certain critical use areas may be designated where the discharge of wastewater or sewage will be limited or prohibited (Annex 5(3)). Both countries must take measures to ensure there are adequate facilities for the reception, treatment, and subsequent disposal of garbage, wastewater, and sewage from vessels (Annex 5(5)).

Annex 6 calls on both the Canadian and U.S. Coast Guards to review "services, systems, programs, recommendations, standards, and regulations relating to shipping activities for the purpose of maintaining or improving Great Lakes water quality" (Annex 6(1)). The two Coast Guards must meet at least annually to consult on implementing the Agreement (Annex 6(2)).

Of the pollutants of potential concern identified by EPA earlier in this study, oil and grease are the pollutants most directly addressed under the Great Lakes Water Quality

Agreement. The Agreement also addresses wastewater, which may include some incidental discharges. Under the Clean Water Act, the Great Lakes National Program Office is tasked with developing and implementing specific action plans to carry out the responsibilities of the U.S. under the Great Lakes Water Quality Agreement. (33 U.S.C. § 1268(c)(1)(A)). EPA might be able to address incidental discharges through these action plans to the extent those discharges are "wastewater" as that term is defined in the Agreement.

Annex I lists a number of chemicals and pollutants that are specific objectives of the agreement, including metals such as arsenic, cadmium, chromium, copper, and nickel, among others. Annex I also provides standards for the concentration of total dissolved solids, hydrogen sulfide, phosphorus, and other pollutants in the Great Lakes.

6.1.6 St. Lawrence Seaway Regulations

In 1954, the United States statutorily created the Saint Lawrence Seaway Development Corporation to construct, operate, and maintain the section of the St. Lawrence Seaway between the Port of Montreal and Lake Erie that falls within the territorial limits of the United States (33 U.S.C. § 981). The mission of the wholly government-owned corporation, which is under the direction and supervision of the Department of Transportation, is to improve the operation and maintenance of a deep-draft waterway in cooperation with a Canadian counterpart.[6]

The Department of Transportation's regulations governing the Seaway can be found at 33 CFR Part 401. The regulations define the St. Lawrence Seaway as the "the deep waterway between the Port of Montreal and Lake Erie and includ[ing] all locks, canals and connecting and contiguous waters that are part of the deep waterway, and all other canals and works, wherever located, the management, administration and control of which have been entrusted to the Corporation or the Manager" (33 CFR § 401.2(j)).

While the regulations are primarily geared toward maintaining and using the Seaway, they do include provisions designed to lessen the impacts of vessel pollution to the Great Lakes, including a provision that prohibits the discharge of garbage, ashes, ordure, litter, or other materials into the Seaway (33 CFR § 401.59(d)). The regulations also prohibit any vessel from emitting sparks or excessive smoke, or from blowing boiler tubes (33 CFR § 401.59(a)). In addition, the regulations contain a blanket requirement that no discharge is allowed that is not in

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[6] In addition to the authorities under its enabling statute, 33 U.S.C. § 981 et seq., the St. Lawrence Seaway Development Corporation has authority to "operate, maintain, improve or expand vessel traffic services consisting of measures for controlling or supervising vessel traffic or for protecting navigation and the marine environment" pursuant to the Ports and Waterways Safety Act of 1978, at 33 U.S.C. 1223–1225, 1229. The U.S. Coast Guard has this authority in all other navigable waters of the United States, except for the area under the jurisdiction of the Corporation.

conformity with all applicable U.S. and Canadian regulations, except within certain areas of the Welland Canal, where no discharges are allowed at all (33 CFR § 401.59(b)).

Although ballast water is not a focus of this study, it should be noted that the St. Lawrence Seawater Regulations also include provisions relating to ballast water, including a recently passed regulation requiring all oceangoing vessels entering the Seaway to conduct saltwater flushing (Seaway Regulations and Rules: Periodic Update, Various Categories, 73 FR 9950 (February 25, 2008)).

The St. Lawrence Seaway Regulations only regulate specific pollutants to the extent they are found in ballast water.

6.2 FEDERAL LAWS

6.2.1 Act to Prevent Pollution from Ships (APPS)

The Act to Prevent Pollution from Ships (APPS) is the United States law implementing Annexes I, II, V, and VI of MARPOL (Annex III is implemented through the Hazardous Materials Transportation Act). The U.S. Coast Guard has the primary authority to implement and enforce the majority of provisions within APPS. EPA was also given specific authorities in certain sections of APPS, the most extensive of which relate to MARPOL Annex VI. The Coast Guard's implementing regulations, found at 33 CFR Part 151, are addressed below.

APPS applies to U.S.-registered ships regardless of where in the world they are operating. With respect to the implementation of Annexes I and II, APPS additionally applies to all foreign-flagged ships operating in navigable U.S. waters. The implementation of Annex V applies to all U.S.-registered ships, as well as all foreign-flagged ships in navigable U.S. waters or the exclusive economic zone of the United States (33 U.S.C. § 1902(a)). Warship, naval auxiliary, and ships owned by the United States that are engaged in noncommercial service are exempted from the requirements of APPS, except for certain provisions implementing Annex V.[7] Ships that are specifically exempted from MARPOL, or the Antarctic Protocol, are also exempted from the requirements of APPS.

In addition to implementing the requirements of MARPOL, described above, APPS establishes a number of administrative requirements regarding inspections, penalties for violations, procedures for legal actions, and public education requirements (33 U.S.C. §§ 1907, 1908, 1910, and 1915).

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[7] However, all surface ships and submersibles owned or operated by the Department of the Navy are required to comply with the special area requirements of Annex V. Unique vessels that cannot fully comply with the requirements of Annex V are permitted to discharge some types of garbage without regard to the requirements of Annex V. See 33 U.S.C. § 1902(d)(2).

6.2.1.1 U.S. Coast Guard Implementing Regulations

The U.S. Coast Guard implements APPS through its regulations at 33 CFR Part 151. These regulations apply to every ship required to comply with Annex I, II, or V of MARPOL (33 CFR § 151.03).[8]

6.2.1.1.1 Annex I Implementation—Prevention of Oil Pollution

The requirements of Annex I of MARPOL, pertaining to the prevention of oil pollution from ships, are implemented by the U.S. Coast Guard though its regulations at 33 CFR §§ 151.09–151.29. This section of the regulations, with the exception of the oil pollution emergency plan requirements,[9] is applicable to ships that are operated under the authority of the United States and that engage in international voyages, are certificated for ocean service, are certificated for coastwise service beyond three nautical miles from land, or are operated at any time seaward of the outmost boundary of the territorial seas of the United States. The regulations also apply to ships operated under the authority of another country while in the navigable waters of the United States or while at a port or terminal under U.S. jurisdiction (33 CFR § 151.09(a)). The regulations do not apply to warships, naval auxiliary, or other ships owned or operated by a country when engaged in noncommercial service; Canadian or U.S. ships operating exclusively on the Great Lakes or their connecting tributary waters or on any internal waters of the United States or Canada; or any ships specifically excluded by MARPOL.

The Coast Guard's requirements for oil discharges from ships other than oil tankers[10] are very similar to Annex I's requirements. The Coast Guard's regulations apply to the same size ships regulated under MARPOL; however, the Coast Guard also distinguishes vessels depending on how far off shore they are operating:

- When more than 12 nautical miles from the nearest land, any discharge of oil or oily mixtures must meet the following conditions:
    - The discharge must not originate from cargo pump room bilges.
    - The discharge must not be mixed with oil cargo residues.
    - The ship must not be within a special area.

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[8] On December 18, 2009, EPA finalized regulations to implement the air emission requirements of APPS (which themselves implement MARPOL Annex VI). The final rule is not scheduled to appear in the Federal Register until the end of February 2010. To see a pre-publication copy of the rule, please visit EPA's website at http://www.epa.gov/OMS/oceanvessels.htm#regs.

[9] The shipboard oil pollution emergency plan requirements at 33 CFR §§ 151.26-151.29 apply to all U.S.- and foreign-operated oil tankers of 150 gt and above and all other ships of 400 gt and above. The same exceptions described in the text apply, with the additional exception that barges or other ships constructed or operated in such a manner that no oil in any form can be carried aboard are also exempted from the requirements (33 CFR § 151.09(c)–(d)).

[10] The requirements for oil tankers are found in a separate section of the regulations (33 CFR Part 157).

  - The ship must be proceeding *en route*.[11]
  - The oil content of the effluent without dilution must be less than 15 ppm.
  - The ship must be operating oily-water separating equipment, a bilge monitor, a bilge alarm, or a combination of the three (33 CFR § 151.10(a)).

- When within 12 nautical miles from the nearest land, any discharge of oil or oily mixtures must meet all of the above requirements, with the additional requirement that the oily-water separating equipment be equipped with a U.S. government- or IMO-approved 15 ppm bilge alarm (33 CFR § 151.10(b)).

Ships of 400 gt or above and oil tankers are prohibited from discharging oil or oily mixtures while operating in a special area, as defined in 33 CFR § 151.13(a). However, if the discharge is of processed bilgewater from machinery space bilges, ships of this size may discharge in special areas if all of the above requirements are met and the ship is equipped with an automatic shut-off device that will engage when the oil content of the effluent exceeds 15 ppm (33 CFR § 151.13). Ships of 400 gt or less, other than oil tankers, may discharge in special areas only if the undiluted oil content of their effluent is 15 ppm or less. If a ship cannot meet the discharge requirements, the oily mixtures must be retained onboard or discharged to a reception facility (33 CFR § 151.10(f)).

As with MARPOL, these discharge requirements do not apply where the discharge is necessary to secure the safety of the ship or save life at sea, or if the discharge results from damage to the ship (provided reasonable precautions were taken after the occurrence of the damage or discovery of the discharge to prevent or minimize the discharge, and the owner or master of the ship did not act with intent to cause damage, or recklessly and with knowledge that damage would probably result) (33 CFR § 151.11).

The regulations also implement the reporting, survey, certification, inspection and enforcement, recordkeeping, and planning requirements of Annex I, described above (33 U.S.C. §§ 151.15, 151.17, 151.19, 151.23, 151.25–151.28).

6.2.1.1.2 Annex II Implementation—Prevention of Pollution from Noxious Liquid Substances

The requirements of Annex II of MARPOL, pertaining to the discharges of noxious liquid substances from ships, are implemented by the U.S. Coast Guard primarily through its regulations at 33 CFR §§ 151.30–151.49, although some requirements are also at 46 CFR Parts

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[11] A ship not traveling *en route* may discharge oil and oily mixtures, provided it is equipped with a U.S. government-or IMO-approved 15 ppm bilge alarm and complies with other requirements of 33 CFR § 151.10. 33 CFR § 151.10(d).

151 and 153.[12] Which regulations are applicable to a particular vessel depends on the specific substance(s) the ship is carrying (33 CFR § 151.31).

The primary regulations at 33 CFR §§ 151.30–151.49 are applicable to the same ships subject to the implementing regulations for Annex I (i.e., all ships operated under the authority of the United States that are engaged in international voyages, certificated for ocean service, certificated for coastwise service beyond 3 nautical miles from land, or operated seaward of the outermost boundary of the territorial sea of the United States). These requirements also apply to ships operated under the authority of another country while in U.S. waters or while at a port or terminal under U.S. jurisdiction (33 CFR § 151.30(a)). The same exemptions that apply to Annex I's implementing regulations also apply here, with an added exemption for tank barges whose certificates are endorsed by the Coast Guard for a limited short protected coastwise route if the barge is constructed and certificated primarily for service on inland routes (33 CFR § 151.30(b)).

U.S. oceangoing ships are prohibited from carrying certain Category C and D NLS, identified at 33 CFR §§ 151.47–151.49, in cargo tanks unless those tanks have been endorsed through a Certificate of Inspection to carry those substances. Foreign ships and ships traveling to foreign destinations must meet additional certification requirements (33 CFR §§ 151.33–151.35). Ships carrying Category C or D oil-like substances must also meet additional operating requirements, such as having monitoring and control equipment installed and meeting damage stability requirements (33 CFR § 151.37).

To discharge NLS residue to the sea, the ship must be at least 12 nautical miles from the nearest land. Additional depth restrictions and maximum rates of discharge also apply for particular types of residue (46 CFR § 153.1128). Discharges of NLS residue from slop tanks are also subject to additional restrictions (46 CFR § 153.1126). If a ship cannot meet these discharge requirements, the NLS residue must be retained onboard or discharged to a reception facility. If the NLS cargo or residue is being transferred at a port or terminal of the United States, the operator of the ship must notify the port or terminal at least 24 hours in advance of the name of the ship and the name, category, and volume of the NLS cargo that will be unloaded (33 CFR § 151.43).

6.2.1.1.3 Annex V Implementation – Prevention of Garbage Pollution from Ships

The requirements of Annex V of MARPOL, pertaining to garbage pollution from ships, are implemented by the Coast Guard through regulations found at 33 CFR §§ 151.51–151.77. These regulations apply to all ships of U.S. registry or nationality, all ships operated under the authority of the United States (including recreational and uninspected vessels), and all ships

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[12] Coast Guard regulations currently implement a prior version of Annex II. Parts 151 and 153 are currently under revision to implement revised Annex II, dated November 1, 2004. Navigation and Vessel Inspection Circular No. 03-06 contains guidance on the Coast Guard's implementation of revised Annex II.

operating in the navigable waters or the Exclusive Economic Zone of the United States. They do not apply to warships, naval auxiliary, other ships owned or operated by the United States when engaged in noncommercial service, or any ship specifically excluded by MARPOL (33 CFR § 151.51).

The regulations prohibit the discharge of garbage into the navigable waters of the United States by any person onboard any ship unless the requirements of MARPOL are followed. Commercial ships are permitted to discharge bulk dry cargo residues into the Great Lakes provided certain requirements are met (33 CFR § 151.66). As with Annex V, the discharge of plastic or garbage mixed with plastic into the sea or navigable waters of the United States is flatly prohibited (33 CFR § 151.67).

The Coast Guard's regulations also implement the recordkeeping, waste management plan, placard, inspection for compliance and enforcement, and reporting requirements of MARPOL (33 CFR §§ 151.55, 151.57, 151.59, 151.61, and 151.65).

As with MARPOL, oil and grease are pollutants of potential concern found in incidental discharges that would be directly regulated by APPS and the relevant implementing regulations. Like MARPOL, APPS and its relevant implementing regulations may indirectly regulate other pollutants found in incidental vessel discharges, such as metals, to the extent that they are found in any of the noxious liquid substances or garbage categorized under Annex II and Annex V or the Coast Guard's implementing regulations and are prevented from entering incidental discharge streams. As with MARPOL, APPS and the relevant implementing regulations only apply to those vessels that meet the size thresholds established in MARPOL.

6.2.2 Clean Water Act (CWA) §§ 311, 312/Oil Pollution Control Act

6.2.2.1 CWA § 311, Oil and Hazardous Substances

Clean Water Act (CWA) § 311 (Oil and Hazardous Substances Liability) states that it is U.S. policy that there should be no discharges of oil or hazardous substances into waters of the U.S., adjoining shorelines, into or upon the waters of the contiguous zone, and in certain other specified instances, except where permitted under MARPOL/APPS or where in quantities the president has, by regulation, determined not to be harmful (33 U.S.C. §§ 1321(b)(1)–(b)(3)). The term "discharge" excludes discharges in compliance with a National Pollutant Discharge Elimination System (NPDES) permit under CWA § 402; discharges anticipated in the NPDES permitting process; and discharges incidental to mechanical removal authorized by the president to remove or mitigate a discharge (33 U.S.C. § 1321(a)(2)). A list of hazardous substances EPA has designated under the CWA can be found at 40 CFR § 116.1.[13]

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[13] EPA's regulations implementing § 311 are located at 40 CFR § 110–117.

Any person in charge of a vessel or onshore facility must immediately notify the appropriate federal agency upon discovering any harmful discharge of oil or hazardous substance from the vessel or facility under their control. The federal agency will then notify appropriate state agencies. Any person in charge of a vessel or onshore facility who discharges in violation of the CWA and fails to provide immediate notification to the appropriate federal agency shall, upon conviction, be fined or imprisoned, or both (33 U.S.C. § 1321 (b)(5)). Owners or operators must respond immediately to any discharge or threat of discharge of oil (33 U.S.C. § 1321 (c)(5)).

This section of the CWA also requires the president to prepare and publish a National Contingency Plan (NCP) for the removal of oil and hazardous substances (33 U.S.C. § 1321(d)(1)). The NCP must include:

- an assignment of duties and responsibilities among federal departments and agencies;
- identification, procurement, maintenance, and storage of equipment and supplies;
- establishment of Coast Guard strike teams; a system of surveillance and notice;
- establishment of a national center to provide coordination and direction for operations in carrying out the plan;
- procedures and techniques to be employed in identifying, containing, dispersing, and removing oil and hazardous substances;
- a schedule of which chemicals and dispersants may be used in which waters to mitigate any spills;
- a system for states affected by a discharge to act to remove the discharge; establishment of criteria and procedures to ensure immediate and effective federal identification of and response to discharges or threats of discharges that will endanger public health;
- establishment of procedures and standards for removing a worst case discharge of oil;
- designation of federal officials to act as on-scene coordinators; establishment of procedures for the coordination of activities; and a fish and wildlife response plan (33 U.S.C. § 1321(d)(2)). The full text of the NCP can be found at 40 CFR Part 300.

6.2.2.2 Oil Pollution Control Act

The Oil Pollution Control Act of 1990 (OPA), 33 U.S.C. §§ 2701–2762, was passed as an almost immediate response to the *Exxon Valdez* tanker accident, which caused more than 11 million gallons of crude oil to spill into Alaska’s Price William Sound. The OPA expanded the federal government's authority to respond to oil spills, provided the money and resources necessary for the government to exercise its authority, and required revisions to the National Oil and Hazardous Substances Pollution Contingency Plan to broaden coordination and preparedness planning requirements. The OPA also increased penalties for regulatory noncompliance, broadened the response and enforcement authorities of the federal government, and preserved state authority to establish laws governing oil spill prevention and response. Additionally, the OPA created the Oil Spill Liability Trust Fund to help fund some of the cleanup costs and repair damage resulting from oil discharges (discussion on the exact requirements of the Fund has been omitted). The requirements of the OPA apply to all vessels, onshore facilities, offshore facilities, deepwater ports, and pipelines.

The OPA is implemented by both EPA and the U.S. Coast Guard. EPA regulations on oil spill prevention and response are found in 40 CFR Parts 112 and 300. U.S. Coast Guard regulations regarding oil spill prevention and response plans are located at 33 CFR §§ 155.1010–155.2230 and 49 CFR §§ 130.1–130.33.

6.2.2.3 CWA § 312, Marine Sanitation Devices

The CWA also requires EPA, in consultation with the Coast Guard, to promulgate federal performance standards for marine sanitation devices. These standards must be designed to prevent the discharge of untreated or inadequately treated sewage into or upon the navigable waters from vessels (33 U.S.C. § 1322(b)). Both the EPA and Coast Guard have promulgated regulations implementing this provision. The Coast Guard's regulations can be found at 33 CFR Part 159, while EPA's can be found at 40 CFR Part 140.

Because discharges of sewage were exempted by Congress from this study, as such discharges are not incidental to the normal operation of a vessel, an in-depth discussion of this provision and its implementing regulations has been omitted.

6.2.3 Organotin Antifouling Paint Control Act

The Organotin Antifouling Paint Control Act of 1988, 33 U.S.C. §§ 2401–2410, prohibits the use of antifouling paints containing organotin such as tributyltin (TBT) on vessels that are 25 meters or less in length, unless the vessel hull is aluminum or the paint is applied to an outboard motor (33 U.S.C. § 2403(b)). The term vessel is defined to include "every description of watercraft or other artificial contrivance used, or capable of being used, as a means of transportation on water" (33 U.S.C. § 2402(11)).

The Act also prohibits the sale, purchase, and application of antifouling paint containing organotin unless the paint has been approved by EPA as being a qualified antifouling paint. Under the Act, "antifouling paint" includes any "coating, paint, or treatment that is applied to a vessel to control fresh water or marine fouling organisms" (33 U.S.C. § 2402(2)). A qualified antifouling paint is one that has a release rate of not more than 4.0 micrograms per square centimeter per day (33 U.S.C. § 2402(6)).

As noted in Section 6.1.2, in September 2008 the United States Senate gave its advice and consented to ratification of the International Convention on the Control of Harmful Anti-Fouling Systems on Ships. However, the United States will not deposit its instrument of ratification with the IMO until Congress adopts the necessary implementing legislation. Implementing legislation is pending. See Clean Hull Act of 2009, H.R. 3618, 111th Congress (1st Session 2009). EPA has already canceled all U.S. FIFRA registrations for TBT antifouling paints. The last cancellation became effective December 31, 2005. Any current use of these products is dwindling because there are very limited or no stocks of the products remaining on the market. Also, the International Convention has made it difficult and undesirable for vessel owners/operators to use TBT antifouling paints.

Additionally, as discussed above, EPA has prohibited the use of TBT or other organotins as biocides on any vessel covered by the Vessel General Permit.

The Organotin Antifouling Paint Control Act only regulates the use of organotin, it does not extend to other pollutants of potential risk that may be present in antifouling hull coatings. Although the Act banned new applications of antifouling hull coatings containing organotin, organotin may still be present in residual quantities on older vessels.

6.2.4 National Invasive Species Act

The primary purpose of the National Invasive Species Act of 1996 (NISA), which reauthorized and amended the Non-Indigenous Aquatic Nuisance Prevention and Control Act of 1990, is to prevent, monitor, and control the unintentional introduction and dispersal of nonindigenous species into waters of the United States through ballast water and other pathways (16 U.S.C. § 4701(b)). The voluntary guidelines and mandatory regulations required by NISA apply, with only few exceptions, to all vessels equipped with ballast water tanks that operate in waters of the United States.[14]

Because ballast water was specifically exempted from this study by P.L. 110–299, an in-depth discussion of the ballast water requirements of NISA has been omitted.[15] In addition to ballast water guidelines, however, NISA requires the development of guidelines to prevent the spread of nonindigenous species from other vessel operations, such as hull fouling.

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[14] The Act requires that the Coast Guard and the Department of Defense implement ballast water management programs for seagoing vessels under their control (16 U.S.C. § 4713).

[15] For the ballast water requirements, see the text of the Act at 16 U.S.C. §§ 4701–4751 as well as the Coast Guard's regulations at 33 CFR Part 151, subparts C and D.

For example, the Coast Guard's regulations require that all vessels equipped with ballast water tanks that operate in the waters of the U.S. have fouling organisms removed from their hulls, piping, and tanks on a regular basis, and that any removed substances be disposed of in accordance with local, state, and other federal regulations (33 CFR § 151.2035(a)(6)).

The National Invasive Species Act does not directly regulate any of the pollutants of potential concern discussed in this study; the Act is focused solely on preventing the spread of nonindigenous species.

6.2.5 Hazardous Materials Transportation Act

The Hazardous Materials Transportation Act, 49 U.S.C. §§ 5101 *et seq.*, regulates the transportation of hazardous material in interstate, intrastate, and foreign commerce. The Act, which implements MARPOL Annex III, includes registration, reporting, and recordkeeping requirements and applies to any vessel involved in transporting hazardous material in commerce.

The Act, and its implementing Hazardous Materials Regulations (HMR), 49 C.F.R. parts 171-180, apply to anyone who transports hazardous material in commerce, causes hazardous material to be transported in commerce, is involved in any way in the design and manufacture of containers used to transport hazardous material, prepares or accepts hazardous material for transport in commerce, is responsible for the safety of transporting hazardous material in commerce, or certifies compliance with any requirement under the Act (49 U.S.C. § 5103(b)).

Anyone transporting a hazardous material (including a hazardous waste) by vessel must file a registration statement with the Department of Transportation (49 U.S.C. § 5108), and must also follow requirements addressing personnel and personnel training, inspections, equipment, and safety procedures (49 U.S.C. § 5106).

The Hazardous Materials Transportation Act does not directly regulate the discharge of any pollutants of potential concern. Instead, the requirements of the Act ensure that hazardous materials are transported safely and securely, thereby lessening the likelihood that hazardous pollutants will contaminate incidental vessel discharges.

6.2.6 National Marine Sanctuaries Act

The National Marine Sanctuaries Act, 16 U.S.C. § 1431 et seq., authorizes the Secretary of Commerce to designate and protect areas of the marine environment that are of special national significance because of their conservation, recreational, ecological, historical, scientific, educational, cultural, archeological, or esthetic qualities (16 U.S.C. § 1431(a)). The Act is implemented by the National Oceanic and Atmospheric Administration (NOAA) through its regulations at 15 CFR Part 922.

The National Marine Sanctuary Program currently consists of 13 national marine sanctuaries and one marine national monument: Thunder Bay (Great Lakes), Stellwagen Bank (Massachusetts), *Monitor* (an archeological site off the coast of Virginia), Gray's Reef (Georgia), the Florida Keys, Flower Garden Banks (Gulf of Mexico), Fagatele Bay (American Samoa), Hawaiian Islands/Humpback Whale, Papahānaumokuākea National Monument, Channel Islands, Monterey Bay (California), Gulf of the Farallones (California), Cordell Bank (California), and the Olympic Coast (Washington).

Additional restrictions and requirements may be imposed on vessel owners/operators who operate in or around these areas. For example, NOAA's regulations pertaining to the Hawaiian Islands/Humpback Whale National Marine Sanctuary prohibit the discharge or deposition of any material or other matter in the sanctuary, or outside the sanctuary if the discharge or deposit will subsequently enter and injure a humpback whale or humpback whale habitat, unless that discharge or deposition is carried out according to the terms or conditions of a federal or state permit (15 CFR § 922.184(a)(5)). Vessels operating in this area must also avoid coming within 100 yards of any humpback whale (except when authorized under the Marine Mammal Protection Act and Endangered Species Act) (15 CFR § 922.184(a)(1)).

The National Marine Sanctuaries Act does not directly regulate by name the discharge of any of pollutants of potential concern. However, the additional restrictions and requirements developed for many of the specific sanctuaries include direct prohibitions on the discharge of certain materials. For example, the regulations specific to the Channel Islands National Marine Sanctuary prohibit the discharge or deposition of "any material or other matter" except fish or fish parts, and water and "other biodegradable effluents incidental to vessel use." (15 CFR § 922.72(a)(2)). The regulations governing the Gulf of the Farallones National Marine Sanctuary prohibit the discharge "from within or into the Sanctuary, other than from a cruise ship, any water or other matter except: … clean vessel deck wash down, clean vessel engine cooling water, clean vessel generator cooling water, clean bilge water, or anchor wash." (15 CFR § 922.82(a)(2)(iii)).

6.2.7 Resource Conservation and Recovery Act

The Resource Conservation and Recovery Act (RCRA), 42 U.S.C. § 6901–6992k, was enacted in 1976 to amend the Solid Waste Disposal Act of 1965. RCRA was designed to minimize the hazards of waste disposal; conserve resources through waste recycling, recovery, and reduction; and ensure that waste management practices are protective of human health and the environment. The RCRA requirements apply to vessels to the extent that they create, carry, or dispose of solid or hazardous wastes.

By regulation, a "hazardous waste" under RCRA is one that falls on any number of lists EPA has created, or one that exhibits at least one of the following characteristics: ignitibility, corrosivity, reactivity, or toxicity (40 CFR § 261.3). A "solid waste" is any material that has been discarded; including any material that has been abandoned or recycled or is inherently waste-like (40 CFR § 261.2).

Subtitle C of RCRA establishes a "cradle-to-grave" system that addresses hazardous waste management from the moment of generation through ultimate disposal. The provisions of Subtitle C apply to all generators and transporters of hazardous waste (42 U.S.C. §§ 6921–6939). A "generator" is someone "whose act or process produces hazardous waste…or whose act first causes a hazardous waste to become subject to regulation" (40 CFR § 260.10). A "transporter" is anyone "engaged in the offsite transportation of hazardous waste by air, rail, highway, or water" (40 CFR § 260.10). A generator of a hazardous waste is subject to the requirements of subtitle C on packaging, labeling, marking, placarding, storage, recordkeeping, and inspection (40 C.F.R. part 262, subpart C). Additionally, both generators and transporters are required to use a manifest system to ensure that all hazardous waste subject to transport arrives at the designated treatment, storage, or disposal facility (42 U.S.C. §§ 6922(a)(5), 6923(a)(3)).

Hazardous waste generated on public vessels (i.e., those vessels owned or chartered by the United States and engaged in noncommercial service) is not subject to the storage, manifest, inspection, or recordkeeping requirements of RCRA until the waste is transferred to a shore facility, unless the waste is stored on the vessel for more than 90 days after the vessel is no longer in service or the waste is transferred to another public vessel within the territorial waters of the United States and is stored on that vessel for more than 90 days after the date of transfer (42 U.S.C. § 6939d). In addition, any "industrial discharges which are point sources subject to [NPDES[permits" are excluded from the definition of solid waste under RCRA (42 U.S.C. § 6903(27)).

RCRA's primary effect on study vessel discharges is indirect; RCRA's extensive requirements concerning the handling of any hazardous waste generated, stored or transported onboard the vessel ensure that such wastes do not make their way into the study discharges. However, because study vessel discharges are not subject to NPDES permitting, they would not qualify for the "industrial point source discharge exclusion" and, thus, could be subject to applicable RCRA requirements.

6.2.8 Federal Insecticide, Fungicide, and Rodenticide Act

The Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA), 7 U.S.C. § 136–136y, provides the basis for the regulation, sale, distribution, and use of pesticides in the United States. FIFRA authorizes EPA to review and register pesticides for specified uses, as well as suspend or cancel the registration of a pesticide if subsequent information shows that continued use would pose unreasonable risks.

One of FIFRA's primary requirements is that pesticides be registered by EPA before they may be sold or distributed in the United States. To obtain a registration, a pesticide manufacturer must submit a registration application to EPA that includes a proposed label containing specific directions for use of the pesticide. The application must also include or cite scientific data sufficient to support an EPA finding that the pesticide, when used according to label directions, will not cause unreasonable adverse effects on the environment (a risk benefit standard that takes into account the social, economic, and environmental costs and benefits associated with use of the pesticide). It is a violation of FIFRA to use a pesticide in a manner inconsistent with its label.

Pesticides may be registered as either general use or restricted use. A general use pesticide may be applied by anyone, while a restricted use pesticide may only be applied by certified applicators (applicators specifically certified by EPA or a state to apply restricted use pesticides) or persons working under the direct supervision of a certified applicator.

Vessels that use FIFRA-registered products onboard or as antifouling compounds must follow all FIFRA labeling requirements.

FIFRA governs the use of pesticides, including those applied aboard vessels in the United States. Although FIFRA does not directly regulate vessel discharges, the requirements of FIFRA require that pesticides are used in accordance with their label instructions, which may indirectly limit the quantity of pesticide related pollutants that end up in incidental vessel discharges.

6.3 ADDITIONAL INTERNATIONAL AND FEDERAL LAWS

EPA has identified a number of international and federal laws that fall outside the scope of this study, but which merit mentioning for information purposes.

6.3.1 International Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter

The International Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter, commonly referred to as the London Convention, entered into force in 1975. The London Convention prohibits the dumping of certain hazardous material and requires a permit for other identified materials and wastes. In 1996, the IMO adopted a more stringent protocol, which took effect in 2006. The United States is a party to the original London Convention but has not ratified the 1996 protocol. The United States implements the original London Convention through the Marine Protection, Research and Sanctuaries Act, 33 U.S.C. §§ 1401–1445. The London Convention and Protocol do no apply, however, to the disposal into the sea of matter incidental to or derived from the normal operation of vessels.

6.3.2 International Convention on Oil Pollution, Preparedness, Response and Cooperation

To emphasize the importance of effective preparation for combating oil spills, in 1990 the IMO adopted the International Convention on Oil Pollution, Preparedness, Response and Cooperation (OPRC). The OPRC, which entered into force in 1995 and has been ratified by the United States, establishes a global framework for international cooperation in responding to oil pollution. OPRC includes requirements such as onboard oil pollution emergency plans, the reporting and prompt investigation of spills, and coordinated response actions.

6.3.3 International Convention Relating to Intervention on the High Seas in Cases of Oil Pollution Casualties

The International Convention Relating to Intervention on the High Seas in Cases of Oil Pollution Causalities was adopted by the IMO in 1969. The Convention entered into force in 1975 and has been ratified by the United States. The purpose of the Convention is to affirm the right of coastal states to take such measures on the high seas as may be necessary to prevent, mitigate, or eliminate danger to their coastlines or related interests from spills of oil and other substances following marine accidents.

6.3.3.1 Intervention on the High Seas Act

The Intervention on the High Seas Act, 33 U.S.C. §§ 1471–1487, authorizes the Coast Guard to intervene whenever there is a ship collision, stranding, or other incident or occurrence that creates a grave and imminent danger to the coastline or related interests of the United States. This Act implements the International Convention Relating to Intervention on the High Seas in Cases of Oil Pollution Casualties.

6.3.4 Comprehensive Environmental Response, Compensation, and Liability Act

The Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), 42 U.S.C. §§ 9601–9675, regulates the release or substantial threat of release of hazardous substances (or those dangerous to public health or welfare) into the environment. The liability provisions of CERCLA are expressly applicable to releases from vessels. Additionally, CERCLA requires any person in charge of a vessel to immediately notify the National Response Center as soon as he has knowledge of any release of a hazardous substance from that vessel in a quantity equal to or greater than a reportable quantity (42 U.S.C. §§ 9602, 9603(a)).

6.3.5 CWA § 402, National Pollutant Discharge Elimination System (NPDES)

In December 2008, EPA issued an NPDES general permit, pursuant to CWA § 402, that is applicable to all vessels operating in a capacity as a means of transportation (except recreational vessels as defined in CWA § 502[25] and study vessels (except for their ballast water discharges) that have discharges incidental to their normal operations into waters of the United States. The permit establishes technology-based effluent limits for 26 different types of vessel discharges in the form of best management practices (BMPs), as well as water quality-based effluent limitations. The permit also includes inspection, monitoring, reporting, and recordkeeping requirements.

For study vessels, coverage under the general permit is limited to ballast water discharges. For that reason, a lengthy discussion of the permit falls outside the scope of P.L. 110–229. For more information about this permit, please visit: www.epa.gov/npdes/vessels.

6.3.6 Title XIV of the Consolidated Appropriations Act, 2001—Certain Alaskan Cruise Ship Operations

Title XIV sets standards for sewage and graywater discharges from large cruise ships (those authorized to carry 500 passengers or more for hire) while operating within certain waters in Alaska. The law prohibits these large cruise ships from discharging untreated sewage while operating in particular waters, but allows the discharge of treated sewage and graywater if certain conditions are met.

6.3.7 Toxic Substances Control Act

The Toxic Substances Control Act (TSCA), 15 U.S.C. §§ 2601–2695, was enacted in 1976 to provide EPA authority to collect information regarding chemical substances and to regulate unreasonable risks from the manufacture, import, processing, distribution in commerce, or use or disposal of chemical substances in the United States. EPA implements TSCA through its regulations at 40 CFR Parts 700–766.

TSCA addresses the production, importation, distribution in commerce, use, and disposal of chemical substances and mixtures of chemical substances generally, and also specifically regulates the following chemical substances: polychlorinated biphenyls (PCBs), asbestos, radon, lead, and mercury. TSCA requires EPA to maintain an inventory of each chemical substance manufactured or processed in the United States. Chemical substances as defined under TSCA do not include substances regulated under other specified laws, such as food additives, pesticides, drugs, cosmetics, tobacco, nuclear material, and munitions. Chemical substances listed on the inventory are considered “existing,” and those not listed are considered “new.” Existing substances are subject to any regulations or orders the Agency has issued for those substances.

New substances are subject to premanufacture notice requirements, described in Section 5 of TSCA.

EPA can collect information on chemical substances and chemical mixtures under TSCA, and EPA has the authority to regulate the use or disposal of chemicals or chemical mixtures if EPA finds that activity presents an unreasonable risk of injury to health or the environment. TSCA would allow EPA to regulate chemicals contained in incidental discharges were the Agency to find it meets this standard.

6.4 APPLICATION OF LEGAL AUTHORITIES TO DISCHARGES INCIDENTAL TO THE NORMAL OPERATION OF STUDY VESSELS

The preceding subsections discussed a number of international treaties and domestic laws that have been adopted to address the environmental impacts of vessel discharges. These subsections also include a summary of how each of the described treaties, statutes, and regulations would regulate specific incidental vessel discharges and specific vessels. The following tables provide additional information, in greater specificity, regarding the applicability of each of the international treaties and domestic laws to incidental vessel discharges.

Table 6-1 shows which international treaties and federal laws apply to the types of incidental discharges that might occur on study vessels. The purpose of this table is to summarize the preceding discussion and make clear which incidental discharges are regulated or potentially regulated by existing international and domestic laws.[16]

Table 6-2 shows which treaties, statutes, and regulations apply to certain size vessels. This table is not meant to imply that each class of vessel shown is covered by a particular statute/treaty in all instances. Whether a particular law/treaty applies to a particular vessel depends on vessel-specific circumstances, such as the vessel's size and class, as well as where that vessel is operating and what it is discharging. In many instances the treaties/laws shown classify vessels by weight rather than length. For the purposes of this table, EPA estimated the length that would correspond with a given vessel weight.

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[16] Note that for many of the authorities listed, application may depend on vessel- or discharge-specific circumstances (e.g., at what concentration certain substances are present in the discharge).

Table 6. 1. International Treaties and Federal Laws Applicable to Discharges Incidental to the Normal Operation of Vessels

	Deck Washdown and Runoff & Above Water Line Hull Cleaning	**Bilgewater**	**Shaft Packing Gland Effluent**	**Ballast Water[1]**	**Antifouling Leachate from Antifouling Hull Coatings**	**Aqueous Film-Forming Foam (AFFF)**	**Boiler /Economizer Blowdown**	**Cathodic Protection**	**Chain Locker Effluent**	**Controllable Pitch Propeller and Thruster Hydraulic Fluid and Other Oil to Sea Interfaces**	**Distillation and Reverse Osmosis Brine**	**Elevator Pit Effluent**	**Firemain Systems**	**Fresh-Water Layup**	**Gas Turbine Water Wash**	**Graywater**	**Motor Gasoline and Compensating Discharge**	**Non-Oily Washwater**	**Refrigeration and Air Condensate Discharge**	**Seawater Cooling Overboard Discharge**	**Seawater Piping Biofouling Prevention**	**Boat Engine Wet Exhaust**	**Sonar Dome Discharge**	**Underwater Ship Husbandry Discharges**	**Welldeck Discharges**	**Graywater Mixed with Sewage**	**Exhaust Gas Scrubber Washwater Discharge**	**Fish Hold Refrigerated Seawater Cooling Systems and/or Ice Slurry Discharges**
International Convention for the Prevention of Pollution from Ships (MARPOL)	b, c, d	b, c	b, c	b			b		b	b		b, c			B	b	b	c		b		b	b		b, c	b, h	b	b
International Convention on the Control of Harmful Anti-Fouling Systems on Ships	e				e																e							
International Convention for the Safety of Life at Sea (SOLAS)*																												

(*) SOLAS includes the ISM Code, which calls for a management system to minimize pollutants in vessel discharges. The specifics of each management system vary by vessel.

Table 6.1. International Treaties and Federal Laws Applicable to Discharges Incidental to the Normal Operation of Vessels

Boundary Waters Treaty / Great Lakes Water Quality Agreement [†]																												
St. Lawrence Seaway Regulations	d																											
Act to Prevent Pollution from Ships (APPS)	b, c, d	b, c	b, c	b			b		b	b		b, c			B	b	b			b		b	b		b, c	b	b	b
CWA § 311: Oil & Hazardous Substances / Oil Pollution Control Act	b	b	b	b			b		b	b		b		b	B	b	b			b		b	b		b	b	b	b
Organotin Antifouling Paint Control Act	e				a, e																a, e							
Hazardous Materials Transportation Act	f	f	f						f			f						f							f			
National Marine Sanctuaries Act	g	g	g	g	g	g	g	g	g	g	g	g	g	g	G	g	g	g	g	g	g	g	g	g	g	g	g	g
Resource Conservation and Recovery Act (RCRA)	f	f	f	f		f			f	f	f	f		f	F		f	f	f	f	f	f	f	f	f			
Toxic Substances Control Act (TSCA)	f	f	f	f		f			f	f	f	f		f	F		f	f	f	f	f	f	f	f	f			
Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA)					a				a												a							

Key for Table 6.1:

a = regulates pesticide constituents that may be found in discharge
b = discharge regulated by law/treaty to the extent that it contains oil
c = discharge regulated by law/treaty to the extent that it prevents contamination by noxious liquid substances
d = discharge regulated by law/treaty to the extent that it prevents contamination from garbage
e = regulates antifouling constituents that may be found in discharge
f = regulates toxic substances that may be found in discharge
g = application of law/treaty dependent on requirements specific to the vessel's location
h = the discharge is regulated by this treaty, but the United States has not ratified the relevant annex

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[†] The Boundary Waters Treaty protects the boundary waters of the United States and Canada from pollution generally.

Table 6.2. International Treaties and Federal Laws Applicable to Vessels (by Length)

	Study Vessels Less Than 79 Feet in Length	**Study Vessels Greater Than 79 Feet in Length**	**Nonstudy Vessels Greater Than 79 Feet in Length**
International Convention for the Prevention of Pollution from Ships (MARPOL 73/78)*			
Annex I	Xx	x*	x
Annex II	Xx	x	x
Annex III	X	x	x
Annex V	Xx	x	x
International Convention on the Control of Harmful Anti-Fouling Systems on Ships	X	x	x
International Convention for the Safety of Life at Sea (SOLAS)			
Boundary Waters Treaty / Great Lakes Water Quality Agreement	X	x	x
St. Lawrence Seaway Regulations	X	x	x
Act to Prevent Pollution from Ships (APPS)	Xx	x	x
CWA § 311: Oil & Hazardous Substances	X	x	x
CWA § 312: Marine Sanitation Devices	X	x	x
Oil Pollution Control Act (OPA)	Xx	x	x
Organotin Antifouling Paint Control Act	X		
Hazardous Materials Transportation Act	X	x	x
National Marine Sanctuaries Act	X	x	x
Resource Conservation and Recovery Act (RCRA)	X	x	x
Toxic Substances Control Act (TSCA)	X	x	x
Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA)	X	x	x

Key for Table 6.2:
x = law/treaty applicable to this vessel size
xx = law/treaty applicable, but generally fewer requirements than for larger vessels

* MARPOL treats oil tankers separately—those of 150 gt and above are subject to all of the requirements of the treaty, while those smaller than 150 gt have less stringent requirements. About half of the tankers weighing 150 gt are larger than 79 feet.

CHAPTER 7
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Appendix A
List of Acronyms

AC	Air conditioning
AFC	Antifouling coating
AFFF	Aqueous film forming foam
AFS	Antifouling hull systems
AIS	Aquatic Invasive Species
ANOVA	Analysis of Variance
ASTM	American Society for Testing and Materials
ATSDR	Agency for Toxic Substances and Disease Registry
AWT	Advanced Wastewater Treatment
BOD	Biochemical oxygen demand
BLM	Biotic Ligand Model
BM	Benchmark
BMP	Best management practice
BTEX	Benzene, toluene, ethylbenzene, xylene
C	Celsius
CCC	Criteria Continuous Concentration
CFR	Code of Federal Register
CFU	Colony Forming Units
CMC	Criteria Maximum Concentration
C-PORT	Conference of Professional Operators for Response Towing
CRWQCB	California Regional Water Quality Control Board
CSO	Combined sewer overflow
CSV	Comma-separated value
COC	Chain of custody
COD	Chemical oxygen demand
CTR	California Toxics Rule
CWA	Clean Water Act
DBP	Di-n-butyl phthalate

DC	Direct current
DEHP	Bis(2-ethylhexyl) phthalate
DO	Dissolved oxygen
DOC	Dissolved organic carbon
DOD	Department of Defense
EDD	Electronic data deliverable
EPA	Environmental Protection Agency
F	Fahrenheit
f_d	Average dissolved fraction
FW	Fresh water
gpd	Gallons per day
gpm	Gallons per minute
GRT	Gross register ton
HEM	N-hexane extractable materials
HH	Human health
HPLC	High performance liquid chromatography
HQ	Hazard quotient
ICCP	Impressed current cathodic protection
IDL	Interactive Data Language
IQR	Interquartile range
kw	Kilowatt
LCDR	Lieutenant Commander
LCPL	Landing craft personnel large
LNB	Lower Newport Bay
MA DEP	Massachusetts Department of Environmental Protection
MARPOL	International Convention for the Prevention of Pollution from Ships
MDL	Maximum daily load
MdR	Marina del Rey
MF	Membrane filtration
MISLE	Marine Information for Safety and Law Enforcement

MPN	Most Probable Number
MS	Microsoft
MSD	Marine Sanitation Device
MSIS	Marine Safety Information System
MTBE	Methyl tertiary butyl ether
ND	Not detected
NH3-N	Ammonia (total, as nitrogen)
NMMA	National Marine Manufacturers Association
NO3/NO2-N	Nitrate/Nitrite (as nitrogen)
NOAA	National Oceanic and Atmospheric Administration
NP	Nonylphenol
NPEC	Nonylphenol polyethoxy carboxylate
NPEO	Nonylphenol polyethoxylate
NRWQC	National Recommended Water Quality Criteria
NTU	Nephelometric Turbidity Units
O&G	Oil and grease
OCPD	Oceans and Coastal Protection Division
OPEO	Octylphenol polyethoxylate
OWOW	Office of Wetlands, Oceans, and Watersheds
PAH	Polycyclic aromatic hydrocarbon
PBT	Persistent, bioaccumulative, and toxic chemical
PHQ	Potential hazard quotient
P.L.	Public Law
POTW	Publicly owned treatment works
PPCP	Pharmaceuticals and personal care product
ppt	Part(s) per thousand
PSU	Practical salinity unit
P:T	Power to tonnage ratio
QA/QC	Quality assurance/quality control
QAPP	Quality Assurance Project Plan
QCW	Quality Criteria for Water

RIB	Rigid inflatable boat
RL	Reporting limit
RPD	Relative percent difference
RPM	Rotations per minute
RSW	Refrigerated seawater
SCCWRP	Southern California Coastal Water Research Project
SDRWQCB	San Diego Regional Water Quality Control Board
SGT-HEM	Silica Gel Treated n-hexane extractable materials
SH	Shellfish harvesting
SIYB	Shelter Island Yacht Basin
SWRCB	State Water Resources Control Board
SSO	Sanitary sewer overflow
SVOC	Semivolatile organic compound
SW	Salt water
TBT	Tributyltin
TIC	Tentatively identified compound
TIE	Toxicity identification and evaluation
TKN	Total Kjeldahl Nitrogen
TMDL	Total maximum daily load
TOC	Total organic carbon
TP	Total phosphorus
TRC	Total residual chlorine
TSS	Total suspended solids
UK	United Kingdom
UNDS	Uniform National Discharge Standards
U.S.	United States
U.S.C	United States Code
USCG	United States Coast Guard
USGS	United States Geological Survey
VGP	Vessel General Permit
VESDOC	Merchant Vessels of the United States

VOC	Volatile organic compound
W+O	Water Quality Criteria for Human Health based on Water and Organism Consumption
WHO	World Health Organization
WHOI	Woods Hole Oceanographic Institute
WOD05	World Ocean Database 2005
WTLUS	Waterborne Transportation Lines of the United States

Appendix B
Additional Characteristics of the P.L. 110 – 299 Vessel Population

This appendix provides additional details regarding study vessels. These details include additional information on vessel subcategories, general information about vessels' areas of operation (based upon their hailing port), and additional details regarding vessels' age and areas of operation. The discussion is based on data from the 139,814 vessels in the MISLE database identified as being within the study vessel population. These data have limitations as discussed in section B.6.

B.1 Vessel Subcategories

Table B.1 presents the top five subcategories by each general vessel service to provide insight into the various types of vessels included the categories. Except for utility vessels (for which the top five vessel classes are listed), vessel types are displayed for all other vessel service categories. Vessel class generally relates to the vessel construction or design whereas the type is a more detailed explanation of the vessels purpose and capabilities.[1] As shown in Table B.1, fish catching vessels – which are the focus of the definition of commercial fishing vessels included by reference in P.L. 110-299 – account for the vast majority of commercial fishing vessels recorded in MISLE.

Table B.1: Top Five Vessel Subcategories by Vessel Service[ab]

Vessel Service	Vessel Type/Class[c]	Number of Vessels
Commercial Fishing Vessel	Fish Catching Vessel	68,343
	Fishing Catching/Processing Vessel	178
	General	174
	Motor Propelled Vessels	155
	Fishing Support Vessel	116
Other non-recreational vessels (less than 79 feet in length)		
Freight Barge	General	6,954
	Dry Cargo Barge	411
	Deck Barge	295
	Lash / Seabee Barge	36
	Container Barge	8
Freight Ship	General	533
	Fishing Support Vessel	23
	Fish Catching Vessel	21
	Container Ship	14
	Ro-Ro/Container	4
Passenger Vessel	General	12,559
	Charter Fishing Vessel	2,053
	Excursion/Tour Vessel	1,233
	Diving Vessel (Recreational)	305
	Water Taxi	298

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[1] In addition, although not shown in *Table B.1*, a more detailed category exists in the database, *vessel subtype*. This field further breaks out the vessel types. For example, subtype fields that exist for fish catching vessels include trawlers, shrimpers, and whalers.

Vessel Service	Vessel Type/Class[c]	Number of Vessels
Public Vessel, Unclassified	General	145
	Law Enforcement (Non-military) Vessel	47
	Buoy/Lighthouse Tender	16
	Search and Rescue Vessel	14
	Patrol Ship	10
Tank Barge	Bulk Liquid Cargo (Tank) Barge	838
	Bulk Liquefied Gas Barge	10
	Dry Cargo Barge	7
	General	7
	Integrated Tug and Barge (Barge)	4
Tank Ship	General	102
	Petroleum Oil Tank Ship	22
	Gas Carrier	20
	Chemical Tank Ship	14
	Bulk Liquid Cargo (Tank) Barge	1
Utility Vessel	Towing Vessel	7,372
	Offshore	650
	Research Ship	488
	Barge	396
	School Ship	60

a This table is based on operational, U.S. flagged commercial fishing vessels (all lengths) and other non-recreational vessel less than 79 feet, including vessels that have an unspecified length (zero or null).
b "Unspecified" or "Miscellaneous Vessel" subcategories were not included among the top five vessel subcategories.
c Vessel *types* are displayed for all vessel service categories except for utility vessels; the top five vessel *classes* are listed for utility vessels.
Source:U.S. Coast Guard MISLE database, 2009

B.1.1 Population of Vessels undergoing Discharge Analysis

Table B.2 summarizes the population of specific vessel sub-types that were investigated and sampled by EPA: commercial fishing vessels, water taxis/ferries, tour vessels, towing vessels, emergency boats, and vessels classified as recreational vessels that operate as non-recreational vessels[2]. The vessel counts presented in the table provide rough estimates of the number of vessels that may be represented by each category of sampled vessels.[3]

EPA generally used the vessel service or current usage to categorize study vessels, however, the MISLE vessel classification generally refers to the category of vessel based on its original construction. The MISLE vessel type field provides the more detailed explanation of the vessels' purpose and current use. A more detailed vessel *subtype* category also exists in the MISLE database to further break out the vessel *types*. For example, MISLE has subtype entries for trawlers, shrimpers, and whalers within the fish catching vessel type, allowing for the population of vessels within these specific subtypes to be estimated.

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[2] EPA discusses the vessels sampled for this report in greater detail in Chapter 2 of this report.

[3] EPA considers these estimates to be only approximate counts due to the potential misclassification of vessels in MISLE as well as some of the dataset's ambiguous vessel classifications (e.g. categorizing a vessel as "general").

Table B.2: Total Number of Vessels in a Given Subtype which EPA Subsampled

Vessel Service	Vessel Type	Number of Vessels[a]	Percent of Vessel Type within Vessel Service
Commercial Fishing Vessel		69,944	100.0%
	All Commercial Fishing Vessel	*69,944*	*100.0%*
Passenger Vessels[b]		20,953	100.0%
	Water Taxi	*298*	*1.4%*
	Ferry	*272*	*1.3%*
	Excursion/Tour Vessel	*1,233*	*5.9%*
Utility Vessel		11,034	100.0%
	Towing Vessel (includes Tugboats)	*7,751*	*70.2%*
Non-Recreational Vessel		69,870	100.0%
	Classified as Recreational (on the basis of vessel type)	*1,624*	*2.3%*

a Number of vessels accounts for all vessels less than 79 feet in length, including vessels of unspecified length (zero or null)

b Most passenger vessels are listed as "general" passenger vessels: out of the approximately 21,000 passenger vessels, nearly 13,000 are listed as "general" passenger vessels.

Source: U. S. Coast Guard, MISLE database, 2009

In addition to the specific vessel types listed above, EPA sampled recreational vessels used in non-recreational service, in part to determine whether characteristics of their discharges differ from those of other types of vessels used in similar applications. The Clean Boating Act of 2008 covers vessels manufactured for recreational uses, unless they are inspected vessels used commercially.

Table B.3 provides examples of the most common vessels classified as recreational vessels in MISLE but that are identified as operating in a non-recreational capacity. Because the analysis presented throughout this section generally defines the population of moratorium vessels on the basis of the vessel service rather than original manufacture purpose, the vessel population estimate of generated for this report may overestimates the number of vessels to which the moratorium in P.L. 110-299 applies. Most vessels manufactured primarily for pleasure are permanently excluded from NPDES requirements by the Clean Boating Act[4] rather than the shorter-term moratorium in P.L. 110-299 as long those vessels meet the definition of a recreational vessel under the Clean Boating Act.

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[4] The Clean Boating Act, P.L. 110-288 defines the term 'recreational vessel' to mean any vessel that is— ''(i) manufactured or used primarily for pleasure; or (ii) leased, rented, or chartered to a person for the pleasure of that person." However, the term recreational vessel excludes any vessel "that is subject to Coast Guard inspection and that is (i) engaged in commercial use or (ii) carries paying passengers.".

Table B.3: Examples of Study Vessels in a Non-Recreational Vessel Service, Classified as Recreational Vessels

Vessel Class	Vessel Service	Vessel Type	Number of Vessels
Recreational	Passenger Vessel	Passenger (Uninspected)	767
Recreational	Commercial Fishing Vessel	Commercial Fishing Vessel	232
Recreational	Utility Vessel	Research Vessel	22

Source: U. S. Coast Guard, MISLE database, 2009

B.2 Vessel Geographical Area of Operation

EPA used MISLE data on hailing port of individual vessel records to characterize the geographical area of operation of vessels in the selected population. Although the hailing port does not account for the detailed traffic patterns of a vessel or for the amount of time a given vessel spends in the listed port, it nevertheless can provide information on a vessel's general area of operation. This may be particularly true of vessels that may have a fairly limited range of operation by virtue of their smaller size or the nature of activities they engage in (e.g., tug boat that operates within a given port area). Out of the 139,814 vessels in the study vessel population, 76,956 MISLE vessel records had sufficiently detailed information to determine their hailing state and general region of operation.[5]

Of the approximately 77,000 vessels records having sufficiently detailed information to determine their state and general region of operation, 20,000 vessels provided one of the hailing ports listed in Figure B.1. As evidenced by the figure, certain port cities, such as Seattle, WA and Juneau, AK are predominantly commercial fishing centers, while New Orleans, LA and New York, NY are predominantly listed by other non-recreational vessels. New Orleans, LA, is the most frequently cited hailing port with approximately 1,300 commercial fishing vessels and 3,800 other non-recreational vessels less than 79 feet. These hailing port distributions were used to inform estimates of vessels in a given water body for EPA's screening level modeling in Chapter 4 of this report.

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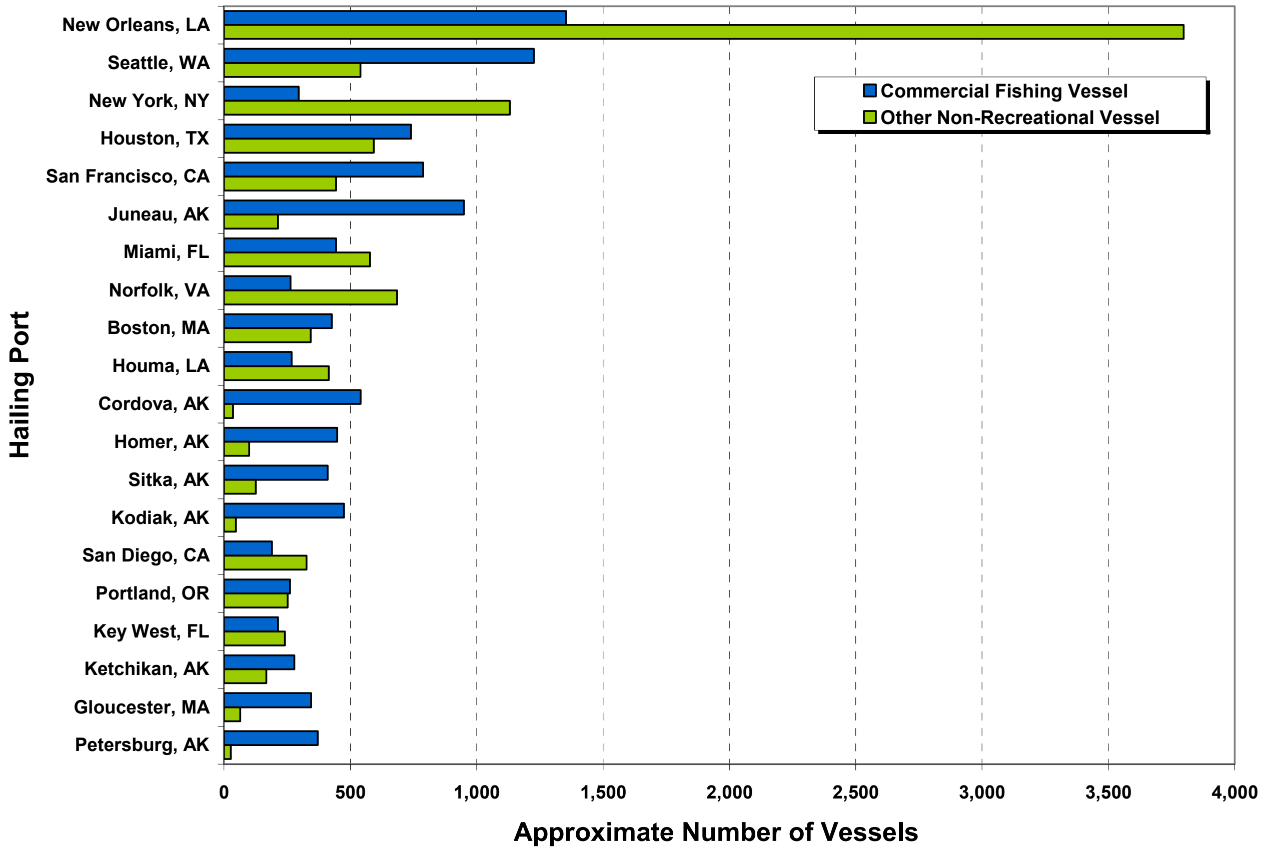
[5] For the remaining vessels, the hailing port information was either missing or too incomplete to be used in the analysis (e.g., only city name is provided).

Figure B.1: Approximate Number of Study Vessels for Hailing Ports Frequently Cited in MISLE



Note: This table is based on 76,956 operational, U.S. flagged commercial fishing vessels and other non-recreational vessel less than 79 feet for which hailing port information is provided in MISLE. EPA notes that the hailing port information is only available for about half of the "study vessels" listed in the MISLE database.

Source: U. S. Coast Guard, MISLE database, 2009

Table B.4 presents the number of vessels by vessel service and the nine census divisions, as displayed in *Figure B.2* below.[6] The divisions are defined by the U.S. Census Bureau as standard geographical units for reporting data for aggregated states. Although not specifically designed for this purpose, the divisions tend to follow the major maritime trade axes and waterways (e.g., coastwise, inland, Great Lakes, Pacific and Atlantic Oceans, Mississippi River, Gulf of Mexico) and therefore provide useful groupings for reporting vessel population estimates. The majority of approximately 70,000 vessels within the scope of P.L. 110-299 for which MISLE provides a U.S. hailing port operate within the Pacific and South Atlantic divisions (28 and 25 percent of vessels, respectively). This regional distribution is driven in part by the large concentration of commercial fishing vessels in the two regions primarily in Alaska with 6,560 vessels and Florida with 3,804 vessels.

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[6] In addition, separate vessel counts are provided for U.S. territories (Puerto Rico, US Virgin Islands, American Samoa, and Guam), Canadian provinces (Newfoundland and Labrador, New Brunswick, Quebec, Nova Scotia, Ontario, Alberta, and British Columbia), and for vessels that listed either another foreign hailing port or did not list a hailing port.

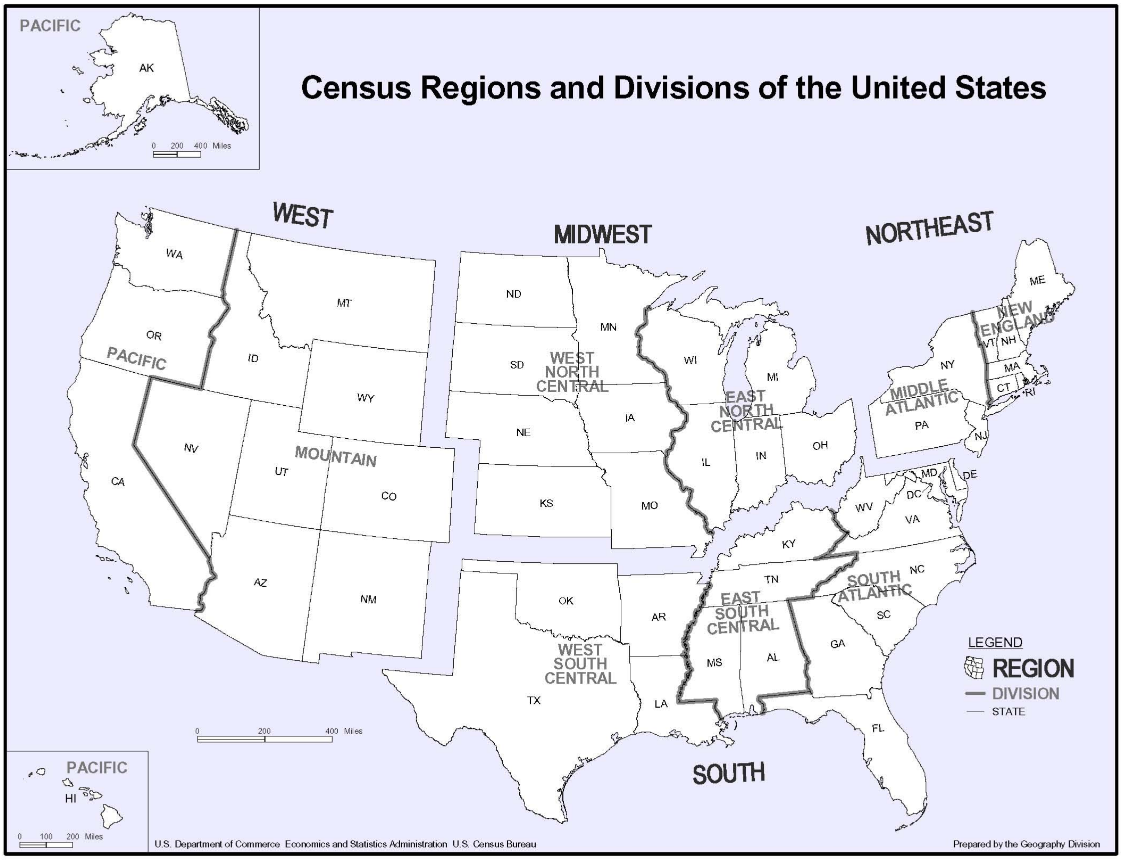
Table B.4: Number of Study Vessels by Vessel Service and Census Division, based on Hailing Port Information Provided in MISLE.

Census Division	Commercial Fishing Vessel	Freight Barge	Freight Ship	Passenger Vessel	Public Vessel, Unclassified	Tank Barge	Tank Ship	Utility Vessel	Unspecified
New England	7,173	41	39	1,158	14	12	6	302	939
Middle Atlantic	1,585	466	27	1,414	4	8	7	645	1,016
East North Central	414	53	20	1,274	2	28		487	1,467
West North Central	45	181	7	175		4	1	538	172
South Atlantic	9,400	440	83	4,821	15	39	18	1,347	3,062
East South Central	1,606	21	2	378	3	1		479	261
West South Central	6,386	2,238	22	1,107	5	65	4	2,732	924
Mountain	59	11	1	142				24	81
Pacific	14,482	129	133	3,187	19	64	5	1,155	2,281
National Total	**41,150**	**3,580**	**334**	**13,656**	**62**	**221**	**41**	**7,709**	**10,203**
U.S. Territories	*230*	*8*	*1*	*353*	*3*	*8*		*46*	*129*
Canadian Province	*3*			*2*					
Unknown / Other	*28,561*	*4,428*	*433*	*6,942*	*557*	*694*	*138*	*3,279*	*17,043*

This table is based on operational, U.S. flagged commercial fishing vessels and other non-recreational vessel less than 79 feet (including vessels of unspecified length) for which MISLE provides sufficiently detailed hailing port information.

Source: U. S. Coast Guard, MISLE database, 2009

Figure B.2: Geographical Definitions of U.S. Census Divisions

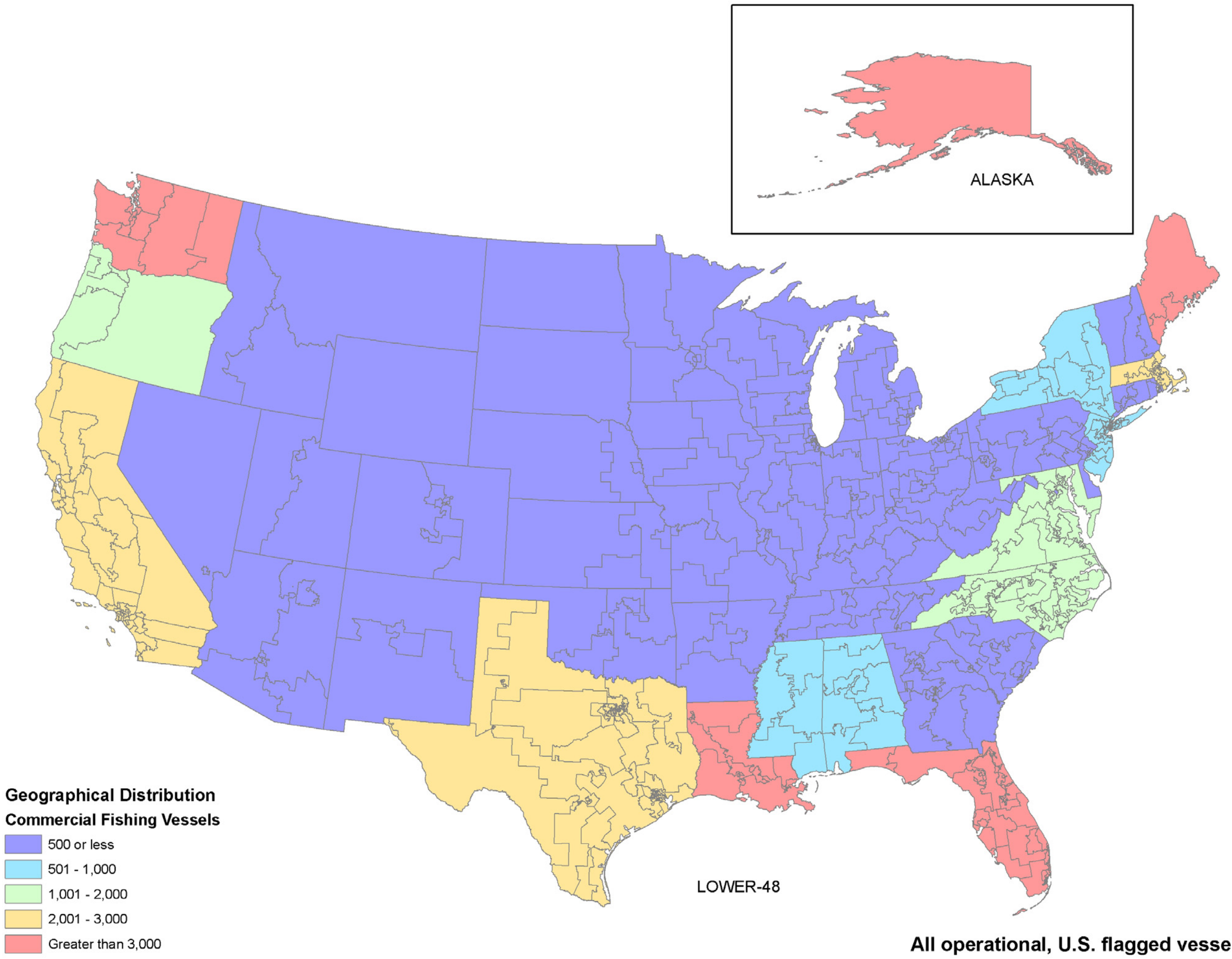


U.S. Department of Commerce Economics and Statistics Administration U.S. Census Bureau

Prepared by the Geography Division

The geographical distribution of commercial fishing vessels and other non-recreational vessels less than 79 feet is illustrated in the maps of Figure B.3 and Figure B.4, respectively. Commercial fishing vessels tend to cluster exclusively along the coastlines. Non-recreational vessels less than 79 feet tend to be found on the major U.S. shipping waterways such as the Mississippi river and the Great Lakes.

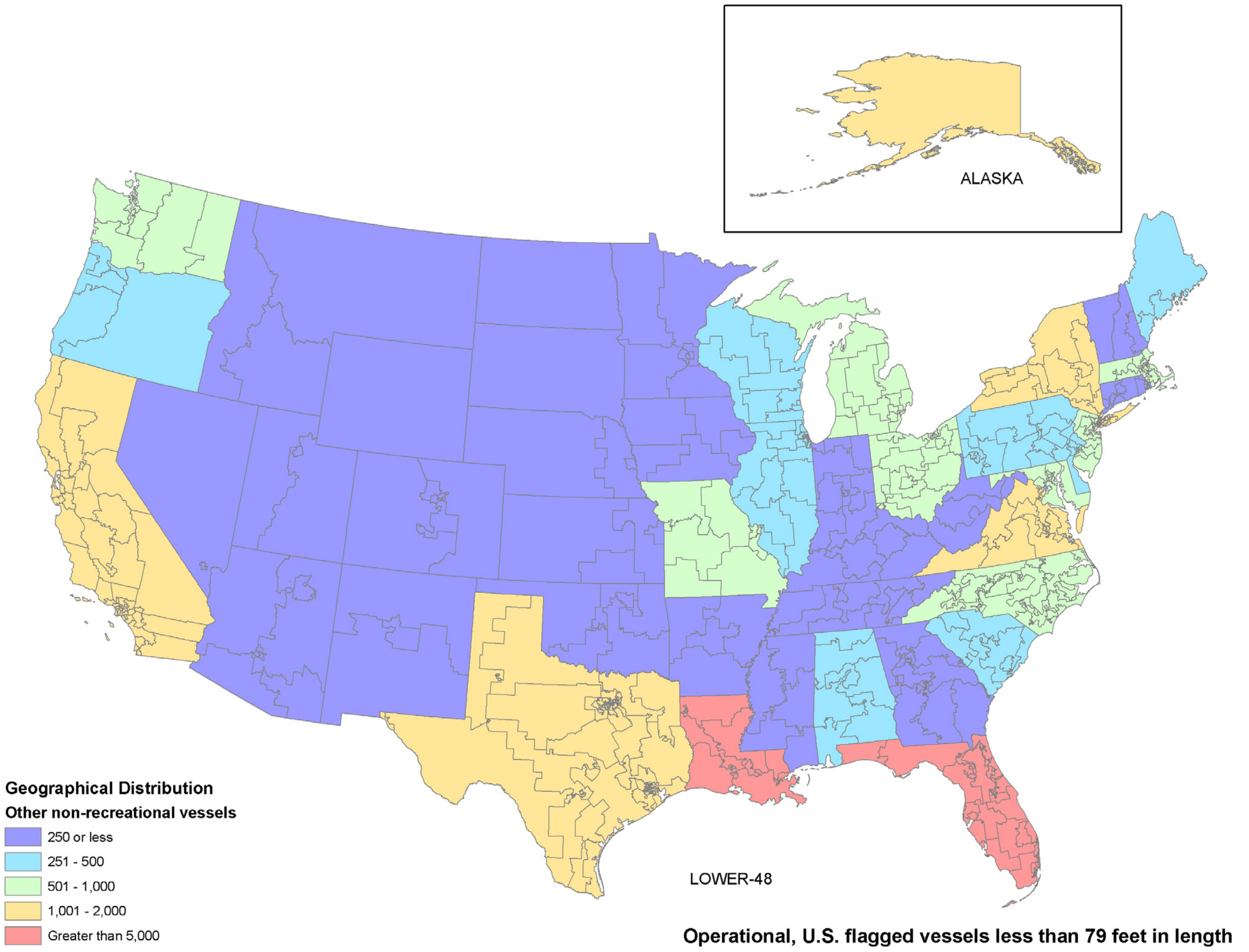
Figure B.3: Geographical Distribution of Commercial Fishing Vessels by Hailing Port State



All operational, U.S. flagged vessels

Source: U. S. Coast Guard, MISLE database, 2009; based on subset of operational, U.S. flagged commercial fishing vessels for which MISLE provides a hailing port.

Figure B.4: Geographical Distribution of Study Vessels (excluding Commercial Fishing Vessels) by Hailing Port State



Source: U. S. Coast Guard, MISLE database, 2009; based on subset of operational, U.S. flagged other non-recreational vessels less than 79 feet in length (including vessels of unspecified length) for which MISLE provides a hailing port.

Alaska and Florida both report a high number of commercial fishing vessels. These states have long coastal shorelines and the vessel density by miles of tidal shorelines is lower than in other states such as Mississippi, New Hampshire, and Massachusetts that have comparatively fewer miles of shoreline but access to large fishing grounds. According to National Marine Fisheries Service data, for example, Massachusetts alone accounted for over half of fish landings recorded in New England states in 2007, by pound.[7] Figure B.5 illustrates these differences by showing the density of commercial fishing vessels by miles of tidal shorelines. The states represented in Figure B.5 account for 99 percent of commercial fishing vessels recorded in MISLE that report a hailing port.

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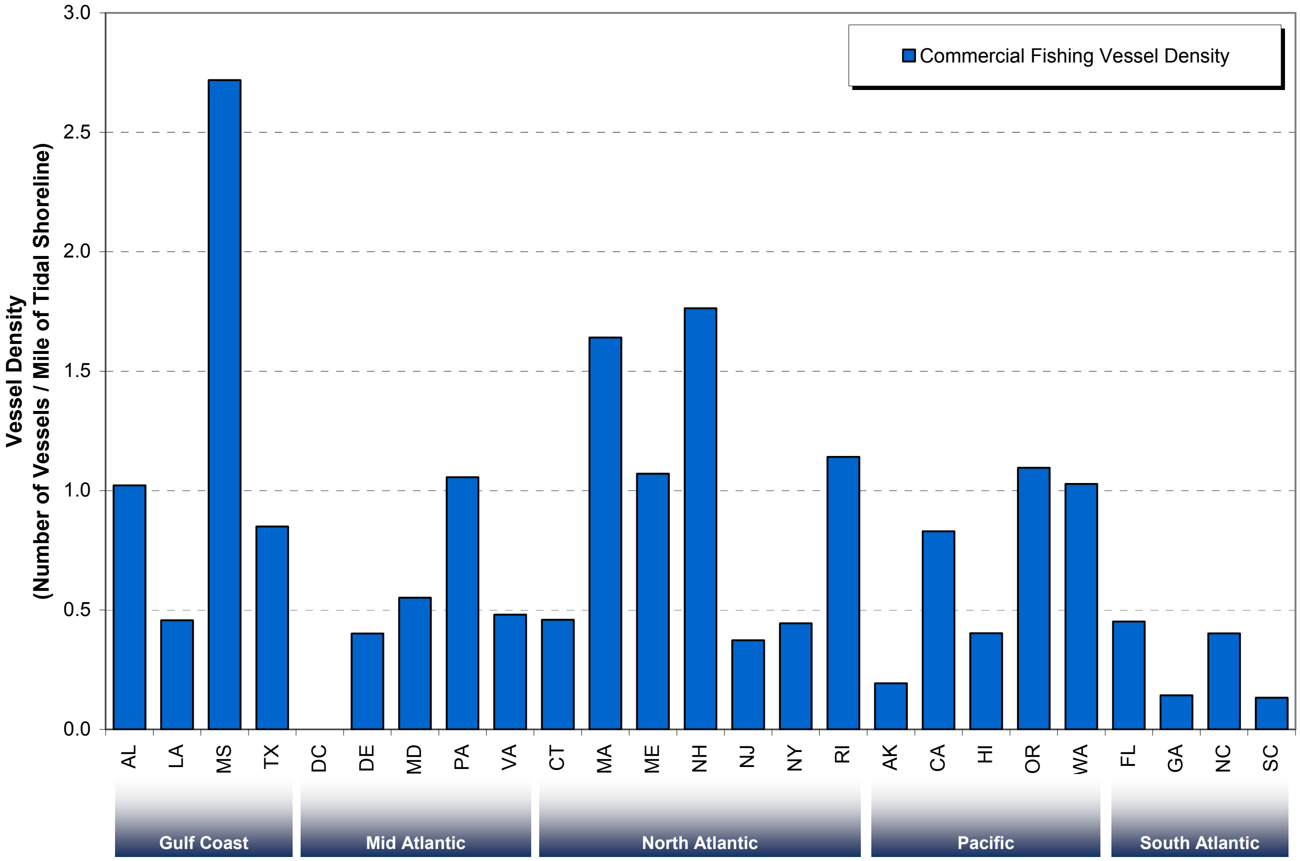
[7] *Annual Commercial Landing Statistics* database (http://www.st.nmfs.noaa.gov/st1/commercial/landings/annual_landings.html), Accessed May 26, 2009.

Figure B.5: Density of Commercial Fishing Vessels in Coastal States, by Mile of Tidal Shoreline

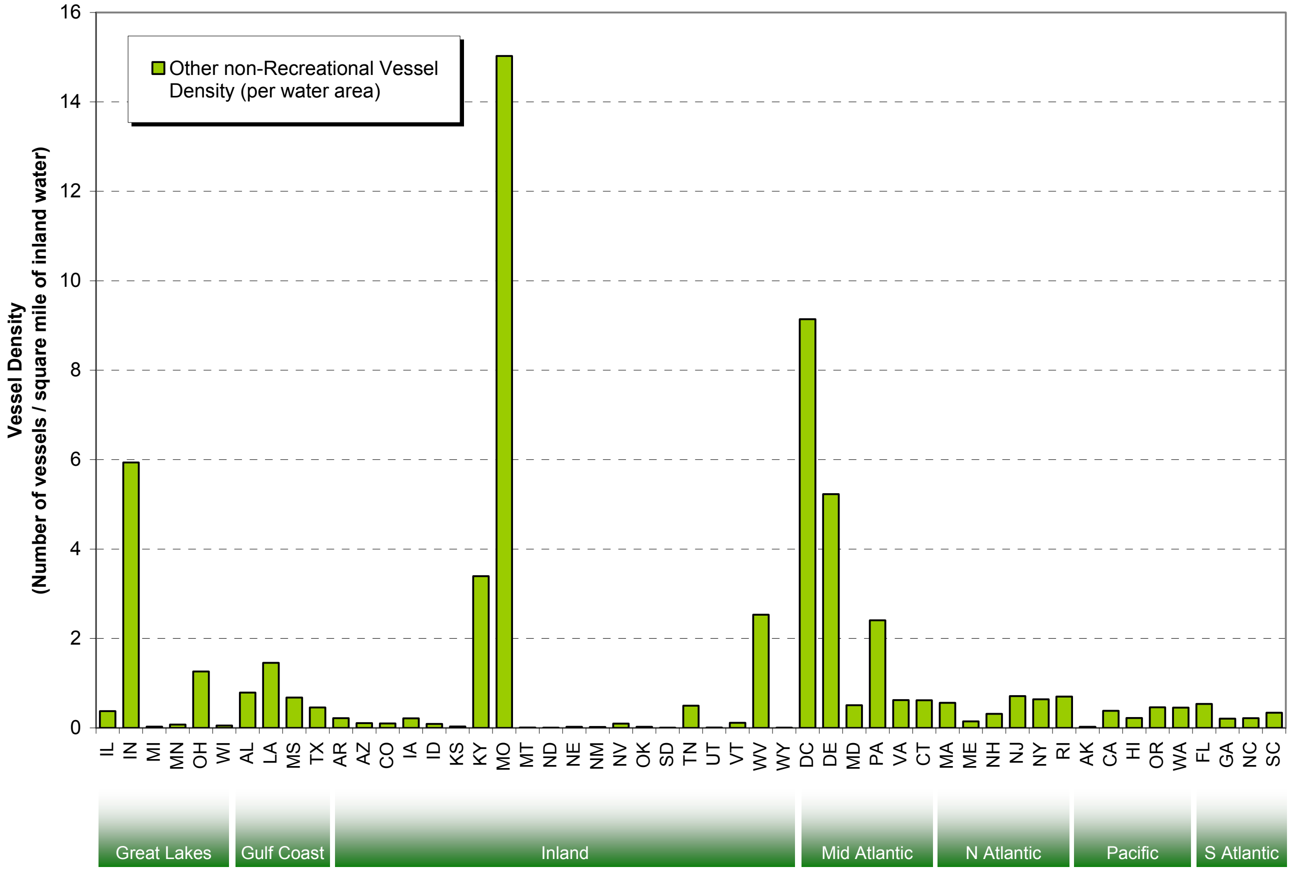


Coastal states included above account for 99 percent of commercial fishing vessels recorded in MISLE,

Sources: U. S. Coast Guard, MISLE database, 2009; based on subset of operational, U.S. flagged commercial fishing vessels for which MISLE provides a U.S. hailing port. Miles of tidal shoreline from U.S. Geological Survey and National Oceanic Atmospheric Administration, National Atlas of the United States, Coastline and Shoreline. Miles include shoreline of the outer coast, offshore islands, sounds, and bays, as well as the tidal portion of rivers and creeks.

In contrast to commercial fishing vessels, which are found almost exclusively along U.S. coasts, about a third of other non-recreational vessels less than 79 feet in length for which MISLE provides hailing port information have a hailing port located along inland waterways. Figure B.6 shows the density of these vessels by state, based on inland water area. Several inland and Great Lakes states (e.g., Missouri, Indiana, and Kentucky) exhibit a high vessel density in relation to their inland water areas, reflecting these states' adjacency to key navigable waterways such as the Mississippi or Missouri Rivers. However, though a vessel lists a city or state as its hailing port, it is unlikely that all vessel operations are confined exclusively to those states waters for many vessels. Additionally, as most vessel traffic may take place on only a small set of navigable waterways, vessel density in these navigable waters is likely to be even greater than implied by the state-wide numbers shown in Figure B.6. Hence, these are relative densities which likely depict which state waters have higher vessel activity.

Figure B.6: Density Study Vessels (excluding Commercial Fishing Vessels) by State, by Water Area



Sources: U. S. Coast Guard, MISLE database, 2009; based on subset of operational, U.S. flagged other non-recreational vessels less than 79 feet in length (including vessels of unspecified length) for which MISLE provides a U.S. hailing port. State statistics on square miles of water obtained from U.S. Census, Statistical Abstract of the United States, 2008. The area includes inland, coastal, Great Lakes, and territorial waters.

B.3 Other Vessel Characteristics: Construction and Propulsion

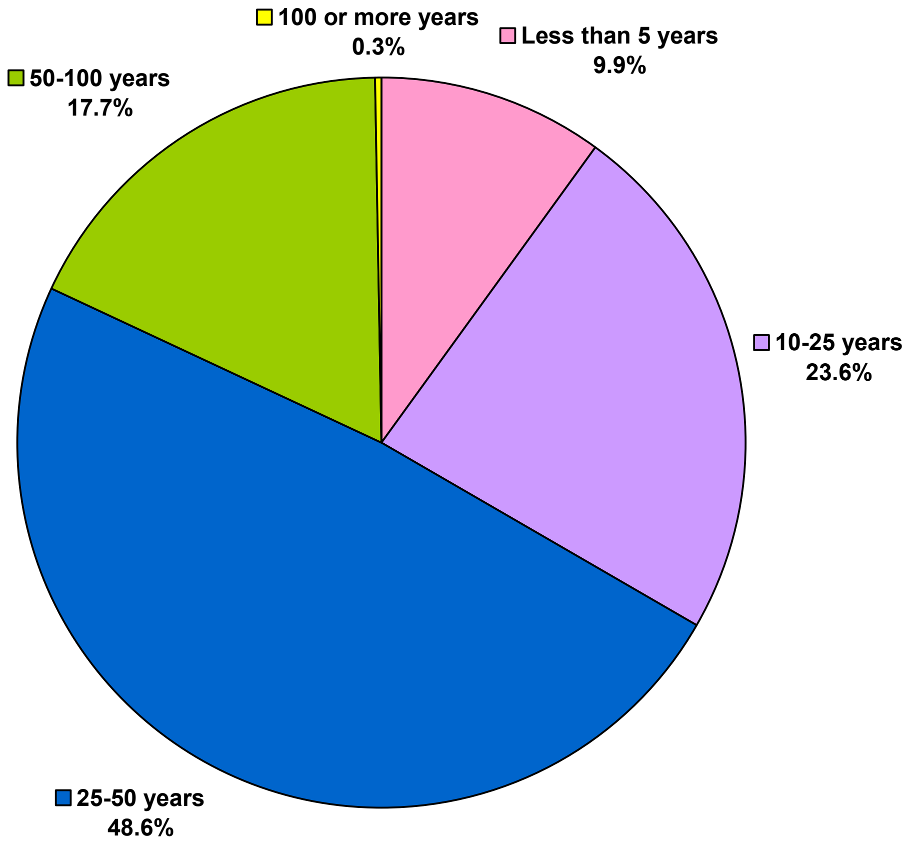
This section presents information on other various characteristics of study vessels that not only influence how vessels are used (e.g., for towing or icebreaking purposes vs. lighter service), but may also affect the characteristics of discharges incidental to vessel operations. In particular, the section provides statistics on the age of the vessels (Section B.3.1), hull material (Section B.3.2), propulsion method and fuel type (Section B.3.3), and, for self-propelled vessels, engine power rating (Section B.3.4). As for other vessel statistics presented in this report, the data are obtained from the USCG's MISLE database.

B.3.1 Vessel Age

Figure B.7 and Figure B.8 present the distribution of study vessels by vessel construction date or age. Figure B.7 summarizes the information across the entire selected population whereas details for each vessel service category are provided in Figure B.8. As seen from both figures, nearly half of the vessels fall within the age range of 25 to 50 years. The average age of vessels across all service categories is 33 years.

Vessel age is one of the factors that generally determines the type and performance of equipment used onboard vessels and the characteristics of discharges from the equipment. However, EPA recognizes that older vessels often have equipment which is rebuilt or replaced. For example, if an older vessel replaces its engine, the engine effluent will be influenced by the type and performance of the engine, not by the vessel's age. Freight ships and tank ships tend to have been in service longer than passenger vessels and generally have a greater level of rebuilding and replacement of original equipment.

Figure B.7: Distribution of Study Vessels by Age, in Years

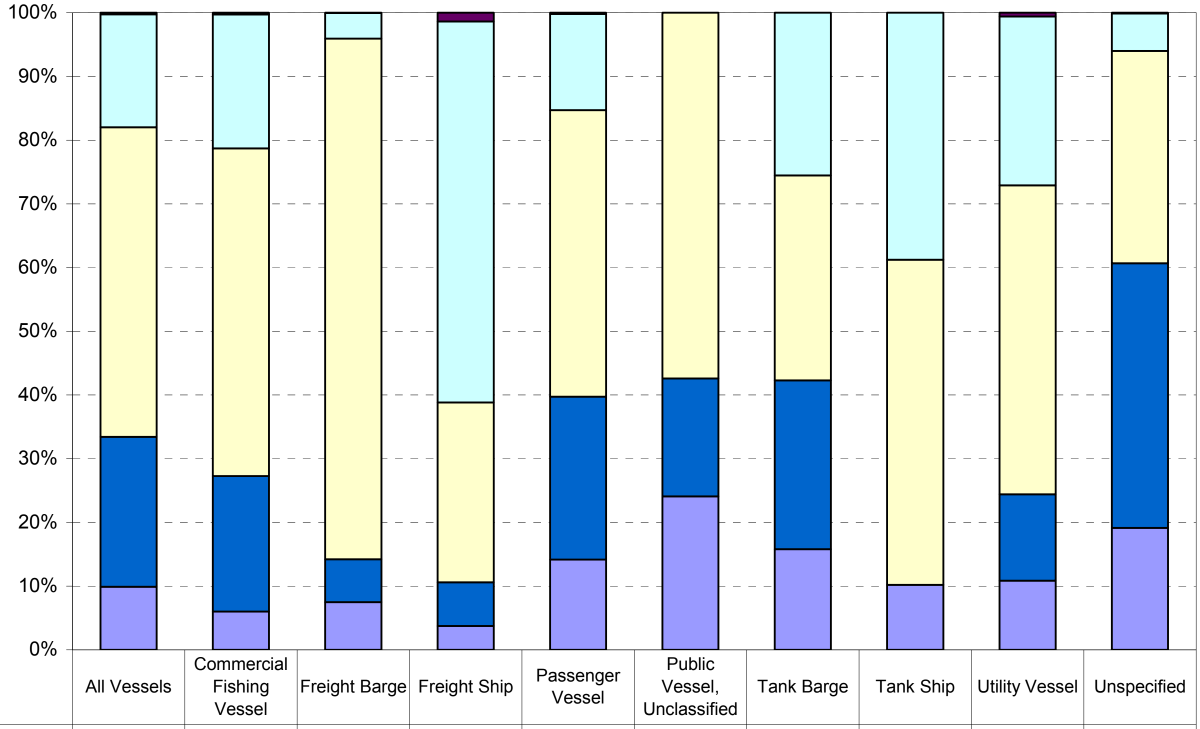


Note: This table is based on operational, U.S. flagged commercial fishing vessels and other non-recreational vessel less than 79 feet (including vessels of unspecified length).

Vessel age was either not reported or an invalid age (i.e. less than zero) was reported for approximately 43,000 vessels.

Source: U. S. Coast Guard, MISLE database, 2009

Figure B.8: Distribution of Study Vessels by Age and Vessel Service



	All Vessels	Commercial Fishing Vessel	Freight Barge	Freight Ship	Passenger Vessel	Public Vessel, Unclassified	Tank Barge	Tank Ship	Utility Vessel	Unspecified
■ 100 or more years	256	146	2	7	36				50	15
□ 50-100 years	17,231	10,921	173	305	2,669		81	19	2,246	817
□ 25-50 years	47,208	26,715	3,514	144	7,954	31	102	25	4,111	4,612
■ 10-25 years	22,892	11,049	290	35	4,525	10	84		1,148	5,751
□ Less than 5 years	9,603	3,125	321	19	2,502	13	50	5	920	2,648

Note: This table is based on operational, U.S. flagged commercial fishing vessels and other non-recreational vessel less than 79 feet (including vessels of unspecified length).

Vessel age was either not reported or an invalid age (i.e. less than zero) was reported for approximately 43,000 vessels.

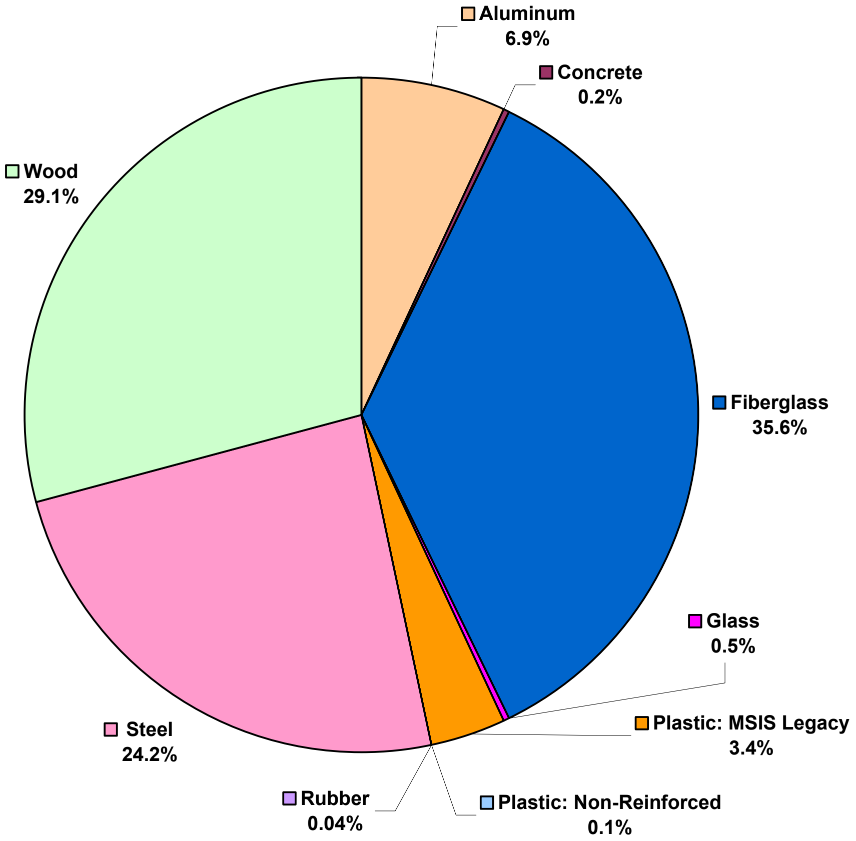
Source: U. S. Coast Guard, MISLE database, 2009

B.3.2 Hull Material Type

Figure B.9 and Figure B.10 present the distribution of vessels by type of hull material type. Figure B.9 provides a summary across all vessel service categories whereas Figure B.10 presents the information disaggregated by each category of vessel service.

The three most common hull material types are fiberglass, wood, and steel in order of most common usage. Commercial fishing vessels with wood hulls account for over three quarters of the total number of wood hulled vessels, although wood is also used in the hulls of a significant share of freight ships and passenger vessels less than 79 feet in length. The type of hull material affects the type of anti-foulant coatings that are applied and has implications on vessel discharges and receiving water quality. For example, steel hulls often have an anti-corrosive as well as anti-foulant hull coatings. The type of hull material may also affect the frequency with which certain maintenance procedures such as hull inspections are conducted.

Figure B.9: Number of Study Vessels by Hull Material Type

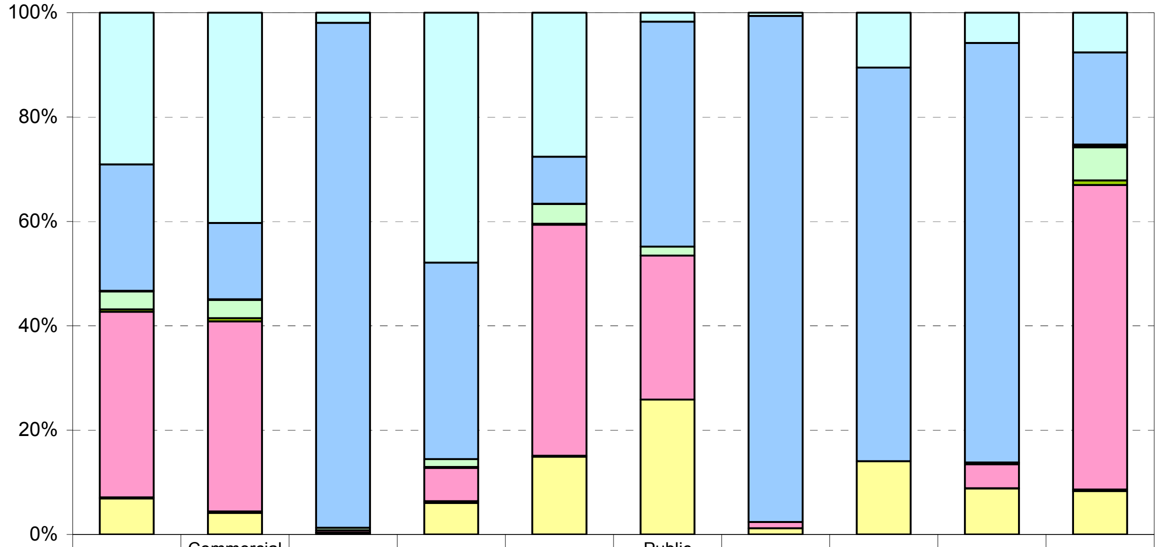


Note: This table is based on operational, U.S. flagged commercial fishing vessels and other non-recreational vessel less than 79 feet (including vessels of unspecified length).

Hull material type was not reported for approximately 43,000 vessels.

Source: U. S. Coast Guard, MISLE database, 2009

Figure B.10: Distribution of Study Vessels by Hull Material and Vessel Service



	All Vessels	Commercial Fishing Vessel	Freight Barge	Freight Ship	Passenger Vessel	Public Vessel, Unclassified	Tank Barge	Tank Ship	Utility Vessel	Unspecified
■ Wood	28,226	21,474	87	285	5,002	1	2	6	510	859
■ Steel	23,524	7,805	4,391	224	1,633	25	323	43	7,082	1,998
■ Rubber	34	1			10				2	21
■ Plastic: Non-Reinforced	98	58			2				2	36
■ Plastic: MSIS Legacy	3,318	1,875	22	9	684	1			10	717
■ Glass	463	310		1	33				16	103
■ Fiberglass	34,536	19,433	20	38	8,022	16	4		408	6,595
■ Concrete	213	137	2	2	36				1	35
■ Aluminum	6,704	2,211	15	36	2,698	15	4	8	778	939

Note: This table is based on operational, U.S. flagged commercial fishing vessels and other non-recreational vessel less than 79 feet (including vessels of unspecified length).

Approximately 43,000 vessels reported in MISLE do not have a hull material or have a material other than the primary materials listed above.

Source: U. S. Coast Guard, MISLE database, 2009

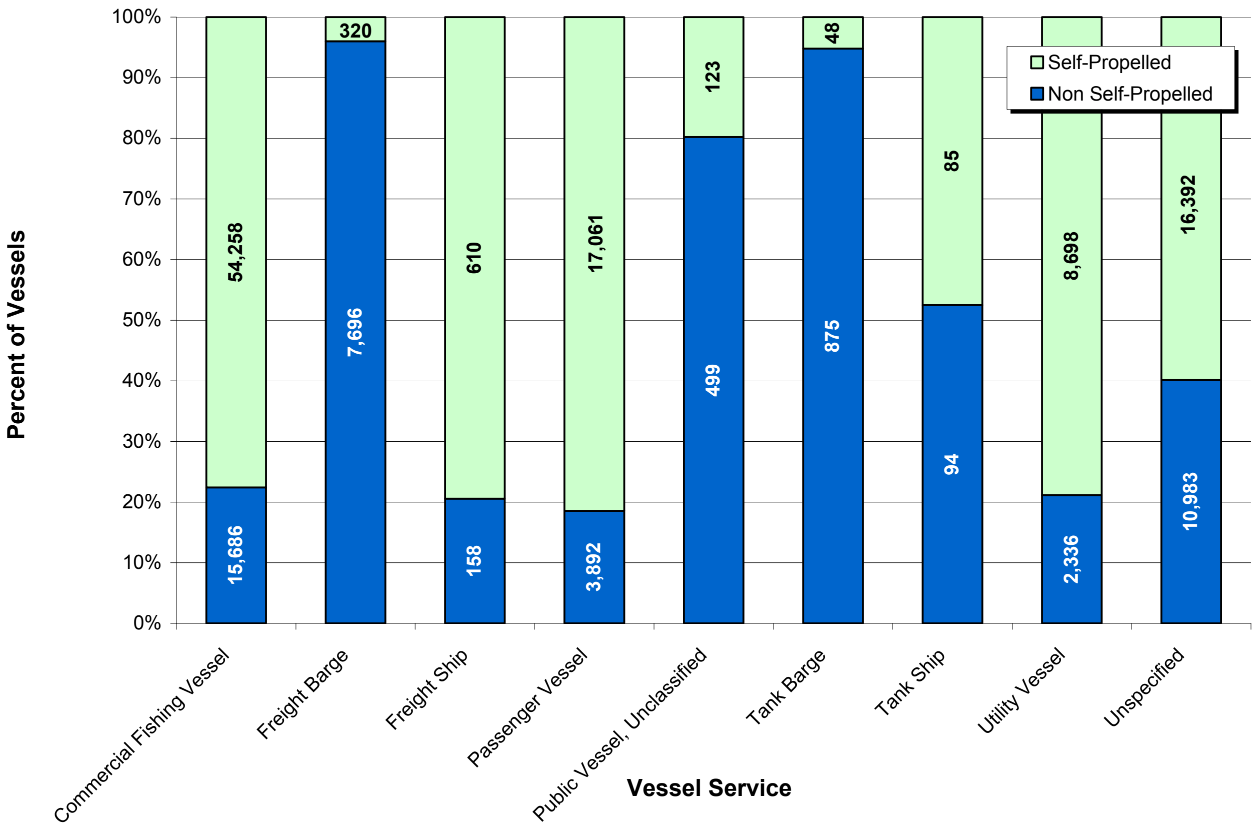
B.3.3 Propulsion Method and Type

Figure B.11 presents the number and percentage of vessels by vessel service and propulsion *method*. A vessel is characterized as *self-propelled* if the vessel uses self-contained engines and other machinery to propel the vessel (wind-driven vessels are also included in this category). *Non-self propelled* vessels are generally propelled by a separate towing vessel e.g. a barge or mobile offshore drilling unit is propelled by a tugboat.

Overall, within the selected subset of the study vessel population for which data are available in MISLE, 70 percent of vessels are self-propelled. The fraction of self-propelled vessels by service type varies from a low of 4 to 5 percent for freight barges and tank barges, to approximately 80 percent for commercial fishing vessels, freight ships, passenger vessels, and utility vessels. Most self-propelled vessels recorded in MISLE are propelled by either diesel motors (66.5 percent) or gasoline motors (26.9 percent).

Self-propelled vessels that use mechanical propulsion methods have certain types of equipment such as an engine, propeller shaft, and propulsion fuel tanks, which would affect the characteristics of discharges under normal operations. Discharges from these vessels may be more likely to have higher concentrations of oil, grease, organic compounds, and metals due to their use of lubricants, fuels and machinery.

Figure B.11: Distribution of Study Vessels by Propulsion Method



Note: This table is based on operational, U.S. flagged commercial fishing vessels and other non-recreational vessel less than 79 feet (including vessels of unspecified length).

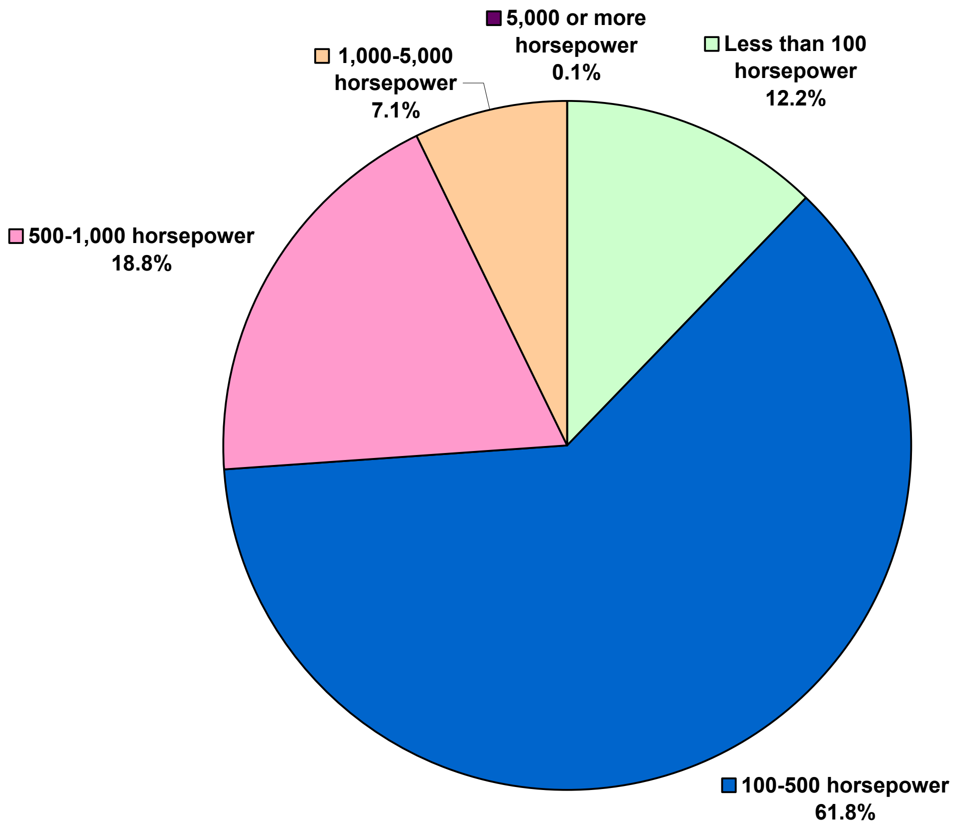
Source: U. S. Coast Guard, MISLE database, 2009

B.3.4 Horsepower Ahead

Figure B.12 and Figure B.13 display the distribution of study vessels by horsepower ahead. Horsepower ahead represents the rated power of a vessel's engine in forward motion (as opposed to horsepower astern) and is expressed as the work accomplished per unit of time (e.g., 1 hp = 550 foot-pounds of work per second). This power is transferred to the propulsion mode (e.g., jet or propeller) to create thrust and determines the vessel's speed at any given weight, or the weight that can be moved at any given speed. Figure B.12 summarizes the information across all vessels within the selected population whereas Figure B.13 presents the information by vessel service category. Vessel power rating may determine the amount and characteristics of discharges from operating vessels by affecting the size, type, and complexity of onboard propulsion equipment.

As evidenced by the two figures, nearly 62 percent of all vessels have a horsepower ahead ranging between 100 and 500. The average value across all vessels is 411 horsepower. The utility vessel and public vessel service categories have the highest proportion of vessels with a horsepower rating of 1,000 or greater. This is expected given the type of activities conducted by vessels in these service categories, e.g., towing and ice breaking. While not reflected in the figure, the MISLE data suggests a general relationship between vessel size and horsepower rating, within a given category of vessels.

Figure B.12: Distribution of Study Vessels by Horsepower Ahead

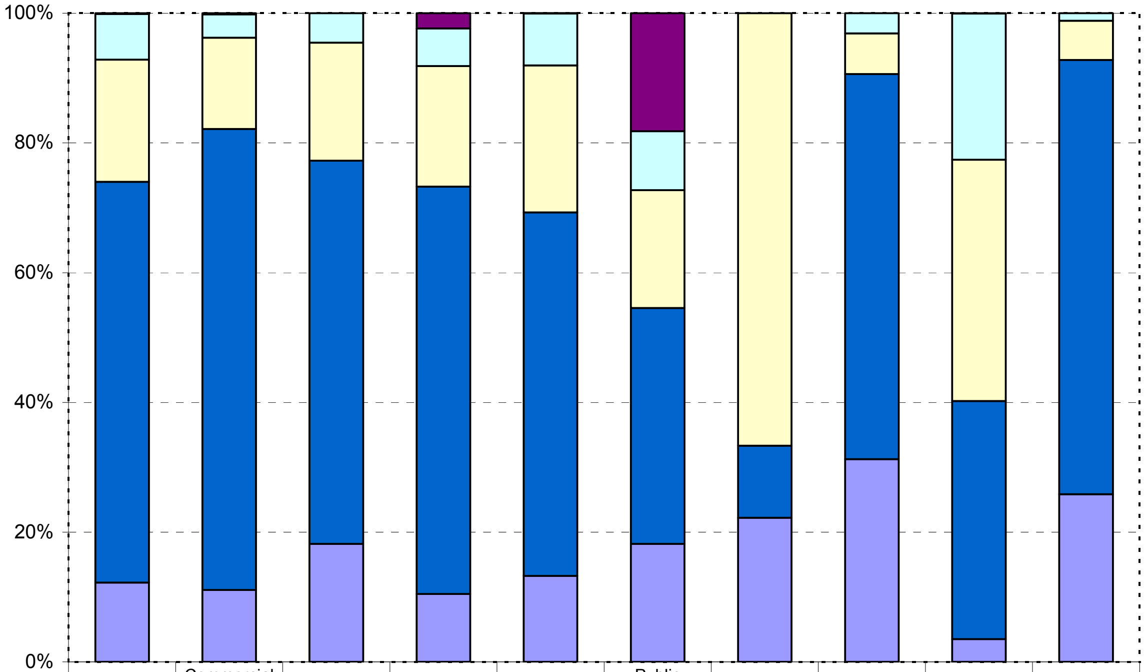


Note: This table is based on operational, U.S. flagged commercial fishing vessels and other non-recreational vessel less than 79 feet (including vessels of unspecified length).

MISLE does not report horsepower ahead for approximately 114,000 non-recreational study vessels.

Source: U. S. Coast Guard, MISLE database, 2009

Figure B.13: Distribution of Study vessels by Horsepower Ahead and Vessel Service



	All Vessels	Commercial Fishing Vessel	Freight Barge	Freight Ship	Passenger Vessel	Public Vessel, Unclassified	Tank Barge	Tank Ship	Utility Vessel	Unspecified
■ 5,000 or more horsepower	28	21		2	1	2			2	
□ 1,000-5,000 horsepower	1,831	443	1	5	642	1		1	711	27
□ 500-1,000 horsepower	4,886	1,732	4	16	1,808	2	6	2	1,174	142
■ 100-500 horsepower	16,041	8,748	13	54	4,473	4	1	19	1,159	1,570
■ Less than 100 horsepower	3,167	1,364	4	9	1,059	2	2	10	111	606

Note: This table is based on operational, U.S. flagged commercial fishing vessels and other non-recreational vessel less than 79 feet (including vessels of unspecified length).

Approximately 114,000 vessels reported in MISLE have no horsepower ahead value or a value of zero.

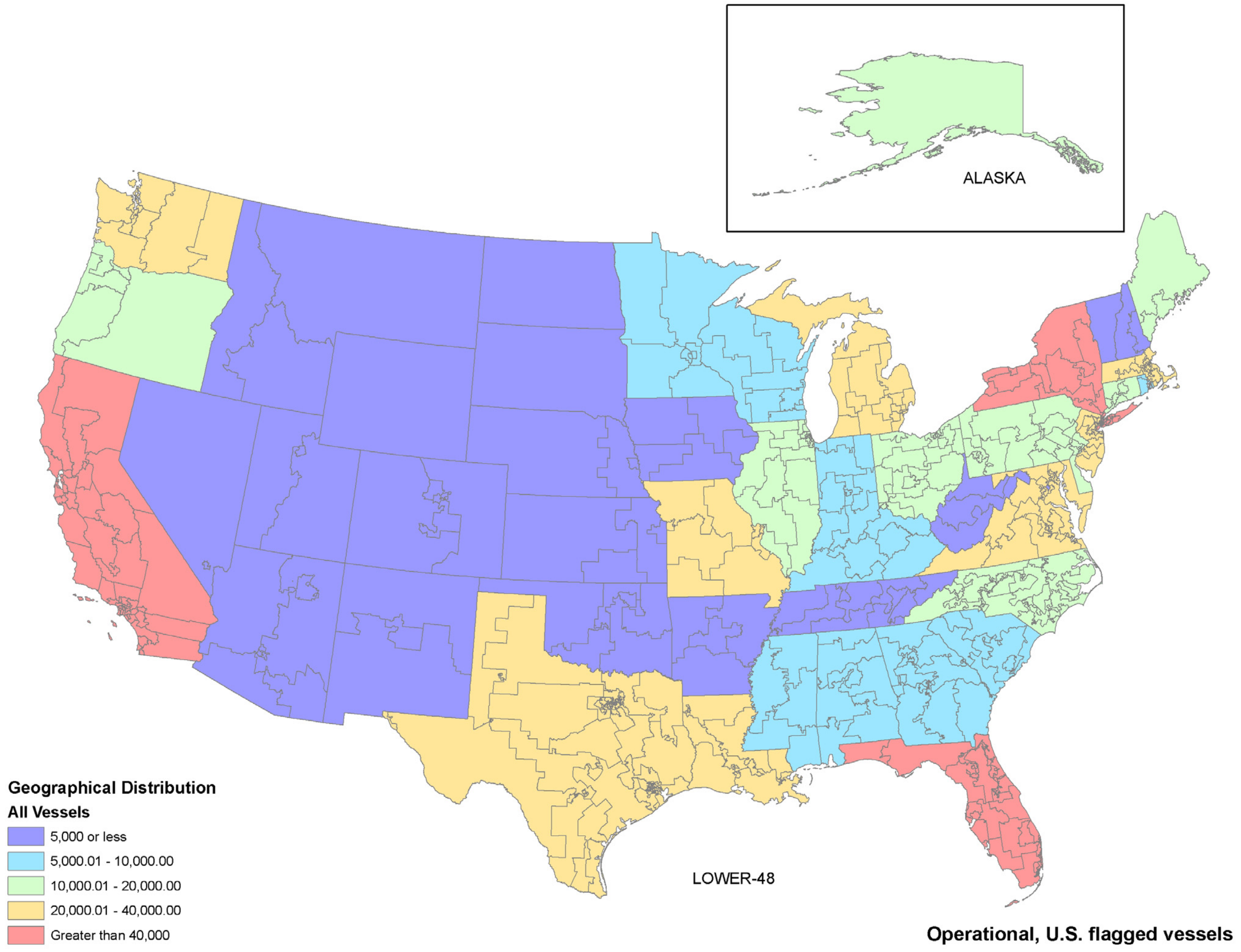
Source: U. S. Coast Guard, MISLE database, 2009

B.4 Distribution of the Study Vessel Universe versus the Recreational Vessel Universe

While the analysis presented in this section generally focuses on the subset of study vessels, a comparison of those vessels to the overall population is pertinent to understanding how discharges may differ between these vessels. At the same time, comparison of estimates provided in different sources also helps verify the population estimate derived from MISLE data. As discussed later in this section, the MISLE database appears to provide reasonably accurate data for larger recreational vessels; however, the database does not appear to provide accurate information for recreational vessels less than 25 feet.

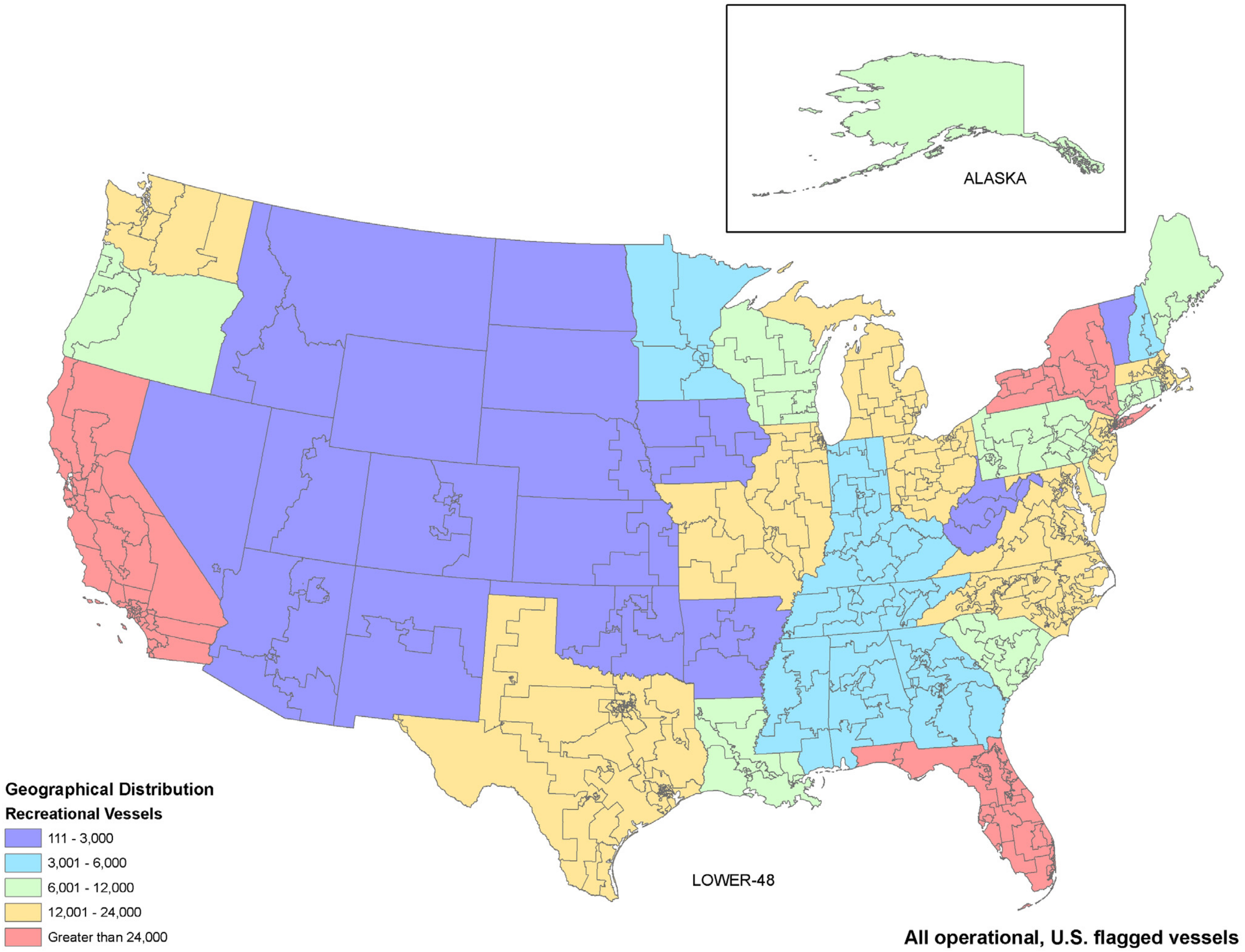
A comparison of the geographical distribution of the selected vessel population to that of the overall MISLE vessel universe (including all operational, U.S. flagged vessels) highlights some key differences. As discussed below in this section, recreational vessels less than 25 feet are not well represented in MLSE; hence, the values presented in these tables do not accurately reflect vessel numbers of these smaller vessels. As reflected in Figure B.14 below, several states that have hailing ports with a high percentage of the study vessel population account for a comparatively low percentage of the total universe of vessels. Conversely, States, such as California, with the largest number of vessels overall have comparatively fewer vessels in the population of commercial fishing vessels and non-recreational vessels less than 79 feet. The difference is generally attributable to the geographical distribution of recreational vessels (Figure B.15) as larger recreational vessels tend to be concentrated in certain states due to the states' longer coastlines, higher population or income, and/or a longer boating season. For these states, one can expect considerably greater numbers of recreational versus non-recreational vessels. The relative shares of non-recreational and recreation vessel categories are illustrated in Figure B.16 which summarizes the overall vessel universe by state and vessel service category, based on information provided in MISLE.

Figure B.14: Geographical Distribution of MISLE Vessel Universe by Hailing Port State



Source: U. S. Coast Guard, MISLE database, 2009; based on operational, U.S. flagged vessels for which MISLE provides a hailing port. Note that MLSE does not provide accurate estimates for smaller recreational vessels.

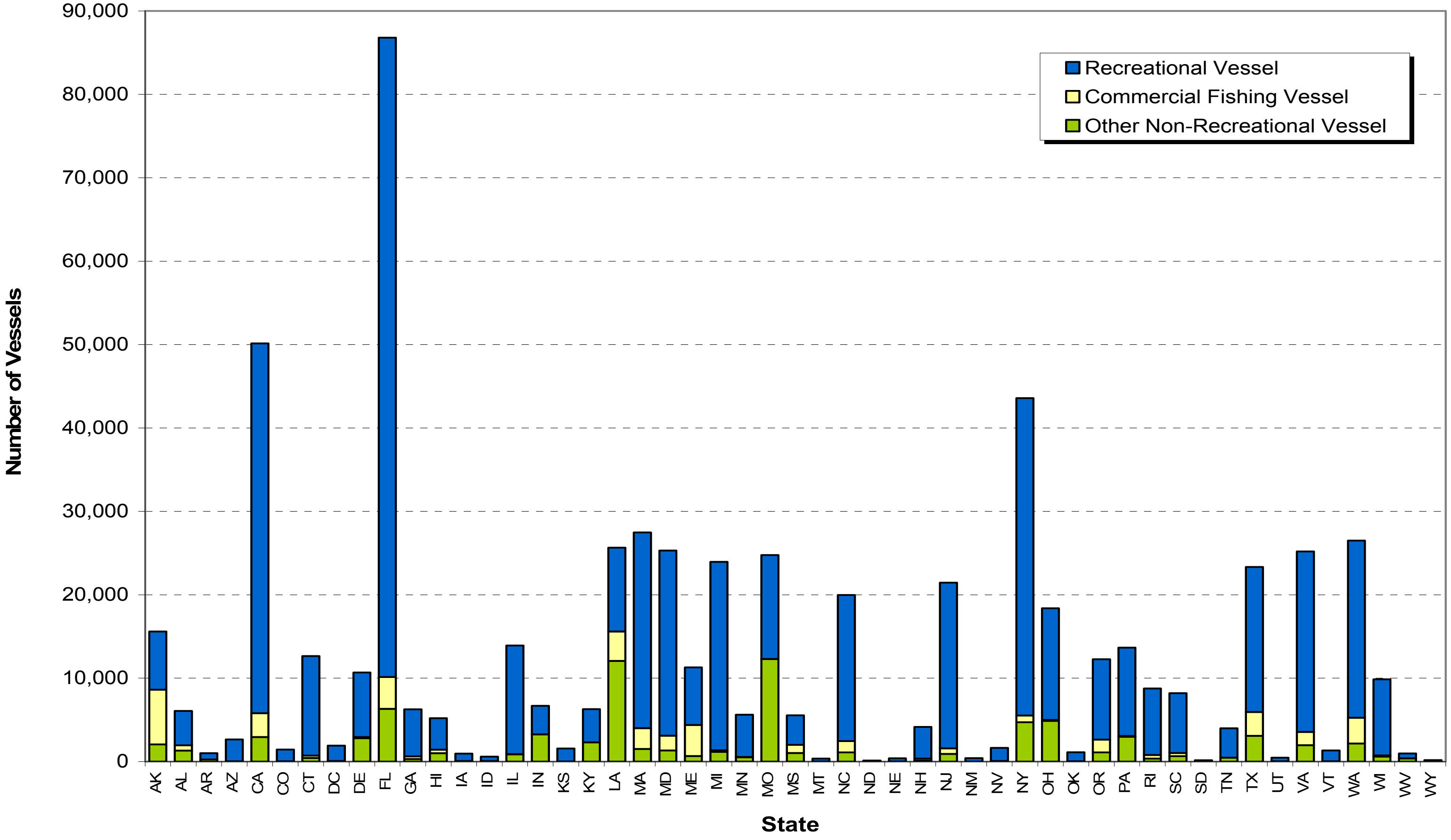
Figure B.15: Geographical Distribution of Recreational Vessels by Hailing Port State



All operational, U.S. flagged vessels

Source: U. S. Coast Guard, MISLE database, 2009. Note that MLSE does not provide accurate estimates for smaller recreational vessels.

Figure B.16 Comparison of the Number of MLSE recorded (Larger) Recreational vessels to Study Vessels by State



Note: The hailing port state was either not listed or a foreign port was listed for approximately 285,000 and 6,000 vessels, respectively. All vessels are included within each of the three vessel service categories, regardless of length.

The data likely only includes larger recreational vessels captured in MISLE and is therefore a gross underestimate of the total population of recreational vessels.

Source: U. S. Coast Guard, MISLE database, 2009

Study vessels represent a very small share of the total number of vessels operating on U.S. waters is evidenced by comparisons of the estimated number of study vessels (139,814 vessels) to the national statistics on recreational vessels. While the number of recreational vessels reported in MISLE is large (700,000 vessels), the actual number of recreational vessels found on U.S. waters is known to be significantly greater, or about 17 million. This is because industry estimates indicate a much larger number of recreational vessels than are captured in MISLE, particularly for smaller vessels less than 26 feet.

In its *2008 Recreational Boating Statistical Abstract*, the National Marine Manufacturers Association (NMMA) estimates that there are approximately 16.9 million recreational vessels in the U.S., including 13 million registered and/or documented boats and more than 4 million non-registered boats. This is a significantly greater estimate than the number of vessels documented in MISLE, which records the characteristics of 722,522 recreational vessels. The difference is accounted for by state-registered vessels that are not subject to documentation requirements[8], hence, they are captured by NMMA but not by MLSE. Figure B.17 illustrates the distribution of vessels by service and length, this time *including additional recreational vessels captured in industry estimates* (NMMA, 2009). Figure B.18 compares recreational vessels reported by MLSE and NMMA across the various census regions are covered in MISLE. As shown in these figures, there are a significantly greater number of small recreational vessels (less than 26 feet in length) than suggested by MISLE data alone. While MISLE grossly underestimates the number of recreational vessels below 26 feet, it appears to provide more reliable estimates for larger recreational vessel (MISLE over-represents the number of recreational vessels in the 40 to 65 feet length category, while it accounts for 55 percent and 73 percent of recreational vessels recorded by NMMA in the 26 to 40 feet and greater than 65 feet categories, respectively). Across all size categories with the exception of vessels greater than 65 feet, non-recreational vessels account for a relatively small fraction of the total universe of domestic vessels operating in U.S. waters.

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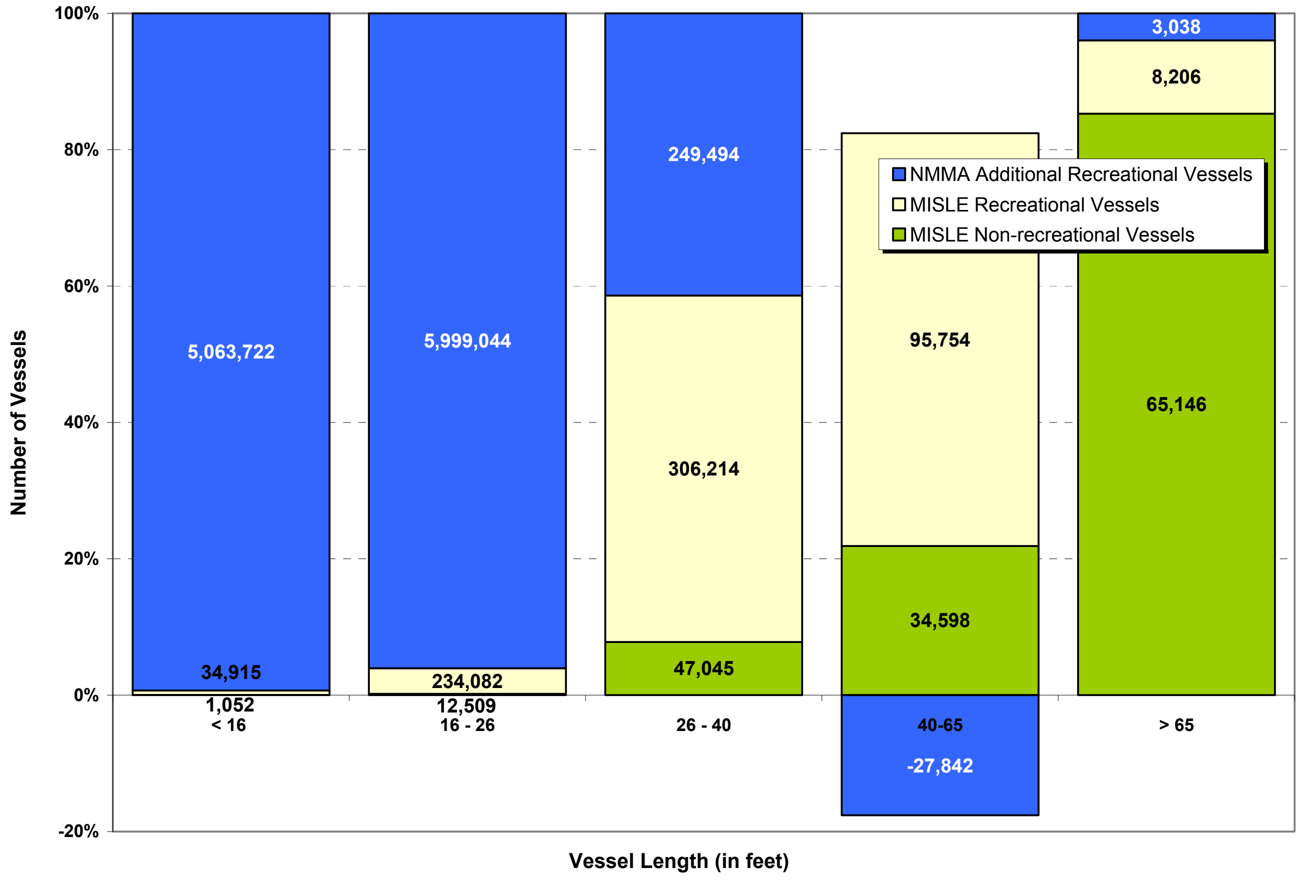
[8] Additional state boating regulations require that non-documented vessels, including smaller recreational vessels less than five tons, register with state authorities. While vessel registration requirements under State boating regulations vary, many states require that vessels of any size equipped with primary or secondary propulsion be registered; in some cases, non-motored vessels above 15 feet in length must also be registered. See additional discussion under Section B.5.

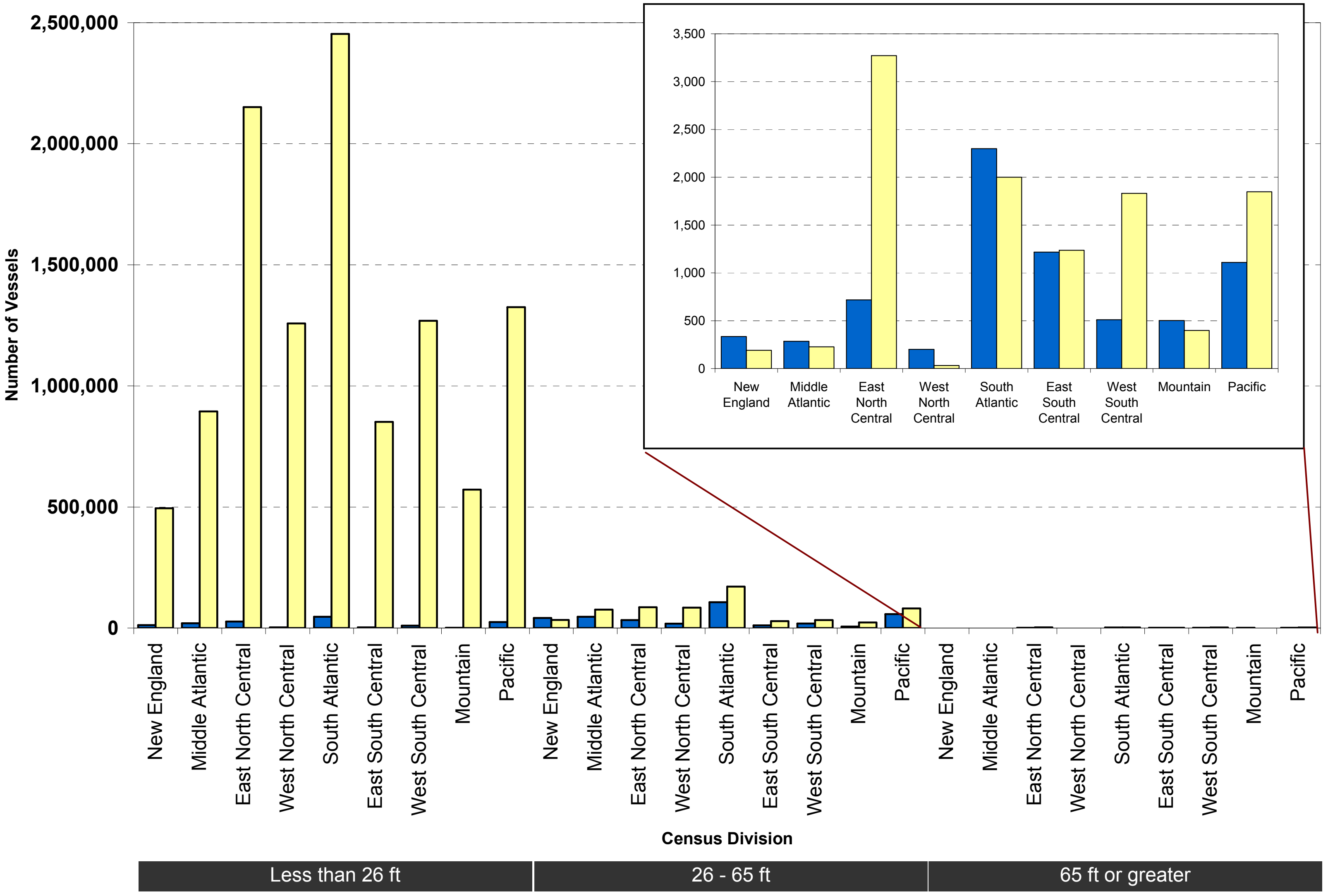
Figure B.17: Distribution of Vessels by Service Category and Length (in feet), Accounting for MISLE AND NMMA Estimates of Recreational Vessels



Source: U. S. Coast Guard, MISLE database, 2009 and NMMA 2007 Recreational Boating Statistical Abstract.

An additional 43,351 vessels are included in MISLE but do not have length information. These vessels are therefore excluded from the figure.

Figure B.18: Recreational Vessels as Reported in MISLE and as Estimated by NMMA



Yellow bars represent NMMA data while blue bars represent MISLE data

Source: U. S. Coast Guard, MISLE database, 2009 and NMMA 2007 Recreational Boating Statistical Abstract

B.5 Vessels Documented, Inspected, and/or State Registered

The MISLE database classifies vessels as documented, inspected, and/or state registered. These classifications are used to identify the types of requirements to which a given vessel is subject. According to a Coast Guard representative, generally only vessels that are not documented at the national level are state registered.[9] On the other hand, based on the MISLE dataset, nearly all (4,982) of the 5,259 inspected vessels are *also* either documented or state registered.

In order to be classified as a *documented* vessel, the vessel "must measure at least five tons and, with the exception of certain oil spill response vessels, must be wholly owned by a citizen of the U.S."[10] According to a Coast Guard representative, "*documentation* provides conclusive evidence of nationality for international purposes, provides for unhindered commerce between the states, and admits vessels to certain restricted trades, such as coastwise trade and the fisheries."

A vessel is listed as *inspected* in MISLE when the vessel is subject to inspection requirements under one of several U.S. Coast Guard regulations. According to a Coast Guard representative, certain U.S. vessels (e.g. passenger vessels that meet threshold size and passenger requirements) are required to undergo safety and security inspections, which includes inspections on a vessel's machinery, hull, safety equipment, and proper documents, before they can operate commercially in U.S. waters.[11]

A vessel is listed as *state registered* when the vessel is registered by a state authority. Only vessels that are not documented at the national level are state registered. Although each state sets its own registration requirements and therefore these requirements can vary from state to state, generally, any undocumented vessel that is self-propelled (meaning that machinery is used to propel the vessel) must be registered with the state.

Table B.5, below, presents the number of study vessels – by vessel service – classified as documented, inspected or state registered in MISLE. As seen within Table B.5, overall, approximately 36 percent of vessels reporting in MISLE are documented, 4 percent of vessels are inspected, and 26 percent of vessels are state registered, although the fractions of vessels in each class varies across the vessel service categories.

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[9] Approximately 1,200 vessels are listed as *both* documented and state-registered.

[10] Source: Personal email communication with Harold Krevait of the U.S. Coast Guard. April 22, 2009. Note, however that fishing vessels with only a "registry" endorsement on their certification of documentation do not have to be wholly owned by U.S. citizens but may be under majority control by U.S. interest (Personal communication with Division Chief, Fishing Vessel Safety Division (CG-5433), Fishing Vessel Safety Program, May 26, 2009).

[11] Source: Personal email communication with Harold Krevait of the U.S. Coast Guard. April 22, 2009.

Table B.5: Number of Study Vessels Documented, Inspected, and State Registered, by Vessel Service

	Total(1)	Documented(2)		Inspected(2)		State Registered	
Vessel Service	**Number**	**Number**	**Percent of Total**	**Number**	**Percent of Total**	**Number**	**Percent of Total**
Commercial Fishing Vessel	69,944(3)	27,770(3)	39.7%	3	0.0%	22,438(1)	32.1%
Freight Barge	8,016	811	10.1%	1	0.0%	48	0.6%
Freight Ship	768	211	27.5%	14	1.8%	40	5.2%
Passenger Vessel	20,953	10,613(4)	50.7%	4,968	23.7%	4,044	19.3%
Public Vessel, Unclassified	622	22	3.5%	3	0.5%	21	3.4%
Tank Barge	923	116	12.6%	49	5.3%	10	1.1%
Tank Ship	179	24	13.4%	15	8.4%	8	4.5%
Utility Vessel	11,034	6,008	54.4%	199	1.8%	1,020	9.2%
Unspecified	27,375	4,183	15.3%	7	0.0%	9,030	33.0%
All Vessels	*139,814*	*49,758*	*35.6%*	*5,259*	*3.8%*	*36,659*	*26.2%*

Note: This table is based on operational, U.S. flagged commercial fishing vessels and other non-recreational vessel less than 79 feet.

Source: U. S. Coast Guard, MISLE database, 2009

(1) Total number of other non-recreational vessels (other than commercial fishing vessels) includes all vessels less than 79 feet in length and vessels of unspecified length (zero or null).

(2) "Documented" and "Inspected" are not mutually exclusive categories. The number of documented vessel *includes* inspected vessels.

(3) The U.S. Coast Guard's Fishing Vessel Safety Program generally uses a figure of 80,000 as the approximate number of commercial fishing vessels, including about 20,000 documented vessels and 60,000 state-registered vessels. In 2007, the states reported a total of over 58,000 vessels that fish commercially and are registered in their jurisdictions.[12]

(4) 3,904 passenger vessels are both documented *and* inspected.

As described in Chapter 1, MISLE also includes additional vessels not subject to the documentation, inspection, or state registration requirements; information for these vessels was obtained through other Coast Guard activities such as non-mandatory inspections or incident investigations.

B.6 Uncertainty

The analysis presented in this section draws largely on national-level data collected by the U.S. Coast Guard. Several factors contribute to uncertainty in the estimates and findings presented:

- *Scope*. Some vessels may not be captured in the database due to the procedures by which vessels are identified and entered into the database. Data coverage is believed to be relatively good for vessels subject to documentation or inspection requirements (e.g., vessels engaged in coastwise trade or passenger vessels), but more incomplete for smaller vessels. The absence of information on the smaller, undocumented, uninspected vessels which were not manufactured or used for pleasure may lead EPA to under-estimate the size of the study vessels population. Conversely, categories used to classify vessels in MISLE may be broader than vessels that would otherwise be considered "in scope" for this study; for example, passenger vessels may include vessels that would meet the Clean Boating Act definition of recreational vessel, depending on their use.

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[12] Source: Personal communication with Division Chief, Fishing Vessel Safety Division (CG-5433), Fishing Vessel Safety Program, May 26, 2009.

- *Completeness*. Analyses of vessel characteristics were limited by the information provided for a vessel or the manner in which the information is entered. For example, the hailing port or horsepower ahead is provided for a only subset of vessels in the database. To the extent that the absence of the information is unevenly distributed among the vessel population, distributions drawn from the data may provide a biased understanding of the characteristics of the vessel population.

- *Accuracy*. Even when vessel data are populated, there may be issues with the accuracy of the information. For example, the status of vessels no longer operational (i.e., out of service) may not have been properly updated or vessel types may be misclassified. These errors are difficult to detect and may lead to inaccurate estimates of the actual population.

Uncertainty related to the scope of the data used in the analysis is discussed in greater detail below. Where possible, EPA compared findings drawn from the MISLE data to information from other sources, such as NMMA and NOAA, to ascertain and quantify the magnitude of the error on the population estimate. This review suggests that MISLE under-represents the population of recreational vessels smaller than about 25 feet in length and may similarly under-represent small non-recreational vessels. For larger recreational vessels, however, the number of vessels reported in MISLE is close, or for some size classes even greater than, the number estimated by NMMA. Based on this comparison, it is apparent that MISLE is significantly limited in terms of its characterization of the universe of small recreational vessels[13]. Since the analysis focuses more specifically on non-recreational vessels, however, EPA does not consider these limitations to be critical. In general, EPA believes that national vessel databases such as MISLE provide adequate coverage for the subset of study vessels, since a significant fraction of these vessels can be expected to be larger than about 25 feet in length, and useful data on the physical and operational characteristics of the study vessel population.

While MISLE constitutes the most comprehensive and readily available national-level data sets on vessels, it is important to note that the MISLE database covers a subset of vessels that are either required to be documented under federal regulations (e.g., at least five net tons) or vessels known to the U.S. Coast Guard through vessel inspections or incident investigations. Generally, the five ton tonnage threshold means that only those vessels more than about 25 feet in length are covered.

Unlike recreational vessels, there is no alternate national-level data source that would provide recent and comprehensive figures for the number of commercial fishing vessel by size category to allow EPA to assess MISLE coverage for these vessels. The MISLE database reports a total of 69,944 commercial fishing vessels nationally. This number does not include all state-registered vessels that commercially fish, but is generally comparable with industry totals reported in other sources. For example, Hoovers reports that 25,000 commercial fishing vessels have combined annual revenue of $4 billion. An additional 55,000 small, undecked vessels are also used to catch wild fish for economic gain, though the report notes that industry impact of these undecked vessels is "negligible." The total number of commercial fishing vessels reported in Hoovers would therefore be around 80,000. [14] Additionally, the U.S. Coast Guard's Fishing Vessel Safety Program generally uses a figure of 80,000 as the

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[13] EPA notes that MISLE is not designed or managed to provide accurate estimates of the small recreational vessel universe.

[14] (Source: http://www.hoovers.com/commercial-fishing, accessed 05/01/2009).

approximate number of commercial fishing vessels, including about 20,000 documented vessels and 60,000 state-registered vessels.[15]

No separate inventory of other non-recreational vessels less than 79 feet could be found to evaluate the coverage of these vessels in MISLE. It is therefore not possible to ascertain the extent to which MISLE under represent smaller utility vessels and other non-recreational vessels.

EPA also compared the number of commercial fishing vessels identified in MISLE with the number of vessels holding fishing permit licenses in New England, as obtained from NOAA's regional office, and with separate state-registered vessel estimates provided by the U.S. Coast Guard. Table B.6 presents the count of permitted fishing vessels within NOAA's New England division permitted vessel list and the count of commercial fishing vessels within MISLE that listed a New England hailing state. The table also provides estimates of the number of state-registered vessels used in commercial fisheries. As seen in the table, the MISLE dataset contains nearly double the number of commercial fishing vessels as permitted in NOAA's New England division. This difference may be due to the slightly different scopes of the NOAA and MISLE dataset. NOAA's dataset only includes permit holders of NOAA Fisheries Northeast Region[16] 2008 Vessel permits, whereas the MISLE dataset includes vessels that may not have fishery permits for that year (such as fishing *support* vessels) in addition to those that would hold permits. Additionally, as mentioned in the introduction to this section, it is possible that some of the commercial fishing vessels that Coast Guard considers to be operational were not actively engaged in fishing activities during 2008. With regards to numbers provided in MISLE as compared to state-registered vessel estimates, the MISLE data seem to slightly under-represent the vessels registered in New England states. Overall, however, comparison of commercial fishing vessel estimates across sources suggests that MISLE may adequately represent the population of these vessels despite the vessels' relatively small size and potentially higher probability of being excluded from the database scope.

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[15] Personal communication with Division Chief, Fishing Vessel Safety Division (CG-5433), Fishing Vessel Safety Program, May 26, 2009.

[16] Our table specifically compares the *New England* division data.

Table B.6: Comparison Among NOAA, State-registered and MISLE New England Region Commercial Fishing Vessel Populations

State	Number of Vessels		
	NOAA[a]	State-registered[b]	MISLE
CT	77	256	284
MA	1,514	2,006	2,492
ME	1,535	6,508	3,725
NH	196	0	231
RI	335	630	438
VT	0	0	3
New England Total	**3,657**	**9,400**	**7,173**

a Although NOAA's Northeast Region Vessel and Permit Listing documents 5,227 vessels, only 3,657 of these vessels list a principal hailing state in the New England region.

b. Some of the state registered fishing vessels reported by states for 2007 are also included in the reported MISLE numbers.[17]

Source: National Oceanic and Atmospheric Administration (NOAA) New England Commercial Fishing Permit Listing, 2009, U. S. Coast Guard, MISLE database, 2009, and Personal Communication with U.S. Coast Guard personnel, May 2009.

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[17] Personal communication with Division Chief, Fishing Vessel Safety Division (CG-5433), Fishing Vessel Safety Program, May 26, 2009.

Appendix C
Public Law 110-299 (S. 3298) and Public Law 110-288 (S. 2766)

Public Law 110-299 (S. 3298)

One Hundred Tenth Congress
of the
United States of America

AT THE SECOND SESSION

Begun and held at the City of Washington on Thursday,
the third day of January, two thousand and eight

An Act

To clarify the circumstances during which the Administrator of the Environmental Protection Agency and applicable States may require permits for discharges from certain vessels, and to require the Administrator to conduct a study of discharges incidental to the normal operation of vessels.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled,

SECTION 1. DEFINITIONS.

In this Act:

(1) ADMINISTRATOR.—The term “Administrator” means the Administrator of the Environmental Protection Agency.

(2) COVERED VESSEL.—The term “covered vessel” means a vessel that is—

(A) less than 79 feet in length; or

(B) a fishing vessel (as defined in section 2101 of title 46, United States Code), regardless of the length of the vessel.

(3) OTHER TERMS.—The terms “contiguous zone”, “discharge”, “ocean”, and “State” have the meanings given the terms in section 502 of the Federal Water Pollution Control Act (33 U.S.C. 1362).

SEC. 2. DISCHARGES INCIDENTAL TO NORMAL OPERATION OF VESSELS.

(a) NO PERMIT REQUIREMENT.—Except as provided in subsection (b), during the 2-year period beginning on the date of enactment of this Act, the Administrator, or a State in the case of a permit program approved under section 402 of the Federal Water Pollution Control Act (33 U.S.C. 1342), shall not require a permit under that section for a covered vessel for—

(1) any discharge of effluent from properly functioning marine engines;

(2) any discharge of laundry, shower, and galley sink wastes; or

(3) any other discharge incidental to the normal operation of a covered vessel.

(b) EXCEPTIONS.—Subsection (a) shall not apply with respect to—

(1) rubbish, trash, garbage, or other such materials discharged overboard;

(2) other discharges when the vessel is operating in a capacity other than as a means of transportation, such as when—

(A) used as an energy or mining facility;

(B) used as a storage facility or a seafood processing facility;
(C) secured to a storage facility or a seafood processing facility; or
(D) secured to the bed of the ocean, the contiguous zone, or waters of the United States for the purpose of mineral or oil exploration or development;
(3) any discharge of ballast water; or
(4) any discharge in a case in which the Administrator or State, as appropriate, determines that the discharge—
(A) contributes to a violation of a water quality standard; or
(B) poses an unacceptable risk to human health or the environment.

SEC. 3. STUDY OF DISCHARGES INCIDENTAL TO NORMAL OPERATION OF VESSELS.

(a) IN GENERAL.—The Administrator, in consultation with the Secretary of the department in which the Coast Guard is operating and the heads of other interested Federal agencies, shall conduct a study to evaluate the impacts of—
(1) any discharge of effluent from properly functioning marine engines;
(2) any discharge of laundry, shower, and galley sink wastes; and
(3) any other discharge incidental to the normal operation of a vessel.
(b) SCOPE OF STUDY.—The study under subsection (a) shall include—
(1) characterizations of the nature, type, and composition of discharges for—
(A) representative single vessels; and
(B) each class of vessels;
(2) determinations of the volumes of those discharges, including average volumes, for—
(A) representative single vessels; and
(B) each class of vessels;
(3) a description of the locations, including the more common locations, of the discharges;
(4) analyses and findings as to the nature and extent of the potential effects of the discharges, including determinations of whether the discharges pose a risk to human health, welfare, or the environment, and the nature of those risks;
(5) determinations of the benefits to human health, welfare, and the environment from reducing, eliminating, controlling, or mitigating the discharges; and
(6) analyses of the extent to which the discharges are currently subject to regulation under Federal law or a binding international obligation of the United States.
(c) EXCLUSION.—In carrying out the study under subsection (a), the Administrator shall exclude—
(1) discharges from a vessel of the Armed Forces (as defined in section 312(a) of the Federal Water Pollution Control Act (33 U.S.C. 1322(a));
(2) discharges of sewage (as defined in section 312(a) of the Federal Water Pollution Control Act (33 U.S.C. 1322(a)) from a vessel, other than the discharge of graywater from a vessel operating on the Great Lakes; and
(3) discharges of ballast water.
(d) PUBLIC COMMENT; REPORT.—The Administrator shall—
(1) publish in the Federal Register for public comment a draft of the study required under subsection (a);
(2) after taking into account any comments received during the public comment period, develop a final report with respect to the study; and
(3) not later than 15 months after the date of enactment of this Act, submit the final report to—
(A) the Committee on Transportation and Infrastructure of the House of Representatives; and
(B) the Committees on Environment and Public Works and Commerce, Science, and Transportation of the Senate.

Speaker of the House of Representatives.
Vice President of the United States and President of the Senate.

Public Law 110-288 (S. 2766)

One Hundred Tenth Congress of the United States of America

AT THE SECOND SESSION

Begun and held at the City of Washington on Thursday,
the third day of January, two thousand and eight

An Act

To amend the Federal Water Pollution Control Act to address certain discharges incidental to the normal operation of a recreational vessel.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled,

SECTION 1. SHORT TITLE.

This Act may be cited as the "Clean Boating Act of 2008".

SEC. 2. DISCHARGES INCIDENTAL TO THE NORMAL OPERATION OF RECREATIONAL VESSELS.

Section 402 of the Federal Water Pollution Control Act (33
U.S.C. 1342) is amended by adding at the end the following:
"(r) DISCHARGES INCIDENTAL TO THE NORMAL OPERATION OF RECREATIONAL VESSELS.—No permit shall be required under this Act by the Administrator (or a State, in the case of a permit program approved under subsection (b)) for the discharge of any graywater, bilge water, cooling water, weather deck runoff, oil water separator effluent, or effluent from properly functioning marine engines, or any other discharge that is incidental to the normal operation of a vessel, if the discharge is from a recreational vessel.".

SEC. 3. DEFINITION.

Section 502 of the Federal Water Pollution Control Act (33
U.S.C. 1362) is amended by adding at the end the following: "(25) RECREATIONAL VESSEL.— "(A) IN GENERAL.—The term 'recreational vessel' means any vessel that is—
"(i) manufactured or used primarily for pleasure; or
"(ii) leased, rented, or chartered to a person for the pleasure of that person. "(B) EXCLUSION.—The term 'recreational vessel' does not include a vessel that is subject to Coast Guard inspection and that— "(i) is engaged in commercial use; or "(ii) carries paying passengers.".

SEC. 4. MANAGEMENT PRACTICES FOR RECREATIONAL VESSELS.

Section 312 of the Federal Water Pollution Control Act (33
U.S.C. 1322) is amended by adding at the end the following: "(o) MANAGEMENT PRACTICES FOR RECREATIONAL VESSELS.—
"(1) APPLICABILITY.—This subsection applies to any discharge, other than a discharge of sewage, from a recreational vessel that is—
"(A) incidental to the normal operation of the vessel; and
"(B) exempt from permitting requirements under section 402(r). "(2) DETERMINATION OF DISCHARGES SUBJECT TO MANAGEMENT PRACTICES.— "(A) DETERMINATION.— "(i) IN GENERAL.—The Administrator, in

consultation with the Secretary of the department in which the Coast Guard is operating, the Secretary of Commerce, and interested States, shall determine the discharges incidental to the normal operation of a recreational vessel for which it is reasonable and practicable to develop management practices to mitigate adverse impacts on the waters of the United States. "(ii) PROMULGATION.—The Administrator shall promulgate the determinations under clause (i) in accordance with section 553 of title 5, United States Code. "(iii) MANAGEMENT PRACTICES.—The Administrator shall develop management practices for recreational vessels in any case in which the Administrator determines that the use of those practices is reasonable and practicable. "(B) CONSIDERATIONS.—In making a determination under subparagraph (A), the Administrator shall consider— "(i) the nature of the discharge; "(ii) the environmental effects of the discharge; "(iii) the practicability of using a management practice; "(iv) the effect that the use of a management practice would have on the operation, operational capability, or safety of the vessel; "(v) applicable Federal and State law; "(vi) applicable international standards; and "(vii) the economic costs of the use of the management practice. "(C) TIMING.—The Administrator shall— "(i) make the initial determinations under subparagraph (A) not later than 1 year after the date of enactment of this subsection; and "(ii) every 5 years thereafter— "(I) review the determinations; and "(II) if necessary, revise the determinations based on any new information available to the Administrator. "(3) PERFORMANCE STANDARDS FOR MANAGEMENT PRACTICES.—

"(A) IN GENERAL.—For each discharge for which a management practice is developed under paragraph (2), the Administrator, in consultation with the Secretary of the department in which the Coast Guard is operating, the Secretary of Commerce, other interested Federal agencies, and interested States, shall promulgate, in accordance with section 553 of title 5, United States Code, Federal standards of performance for each management practice required with respect to the discharge.

"(B) CONSIDERATIONS.—In promulgating standards under this paragraph, the Administrator shall take into account the considerations described in paragraph (2)(B).

"(C) CLASSES, TYPES, AND SIZES OF VESSELS.—The standards promulgated under this paragraph may— "(i) distinguish among classes, types, and sizes of vessels; "(ii) distinguish between new and existing vessels; and

"(iii) provide for a waiver of the applicability of the standards as necessary or appropriate to a particular class, type, age, or size of vessel. "(D) TIMING.—The Administrator shall—

"(i) promulgate standards of performance for a management practice under subparagraph (A) not later than 1 year after the date of a determination under paragraph (2) that the management practice is reasonable and practicable; and

"(ii) every 5 years thereafter— "(I) review the standards; and "(II) if necessary, revise the standards, in accordance with subparagraph (B) and based on any new information available to the Administrator.

"(4) REGULATIONS FOR THE USE OF MANAGEMENT PRACTICES.—

> "(A) IN GENERAL.—The Secretary of the department in which the Coast Guard is operating shall promulgate such regulations governing the design, construction, installation, and use of management practices for recreational vessels as are necessary to meet the standards of performance promulgated under paragraph (3).
>
> > "(B) REGULATIONS.—
> >
> > "(i) IN GENERAL.—The Secretary shall promulgate the regulations under this paragraph as soon as practicable after the Administrator promulgates standards with respect to the practice under paragraph (3), but not later than 1 year after the date on which the Administrator promulgates the standards.
> >
> > "(ii) EFFECTIVE DATE.—The regulations promulgated by the Secretary under this paragraph shall be effective upon promulgation unless another effective date is specified in the regulations.
> >
> > "(iii) CONSIDERATION OF TIME.—In determining the effective date of a regulation promulgated under this paragraph, the Secretary shall consider the period of time necessary to communicate the existence of the regulation to persons affected by the regulation.

“(5) EFFECT OF OTHER LAWS.—This subsection shall not affect the application of section 311 to discharges incidental to the normal operation of a recreational vessel.

“(6) PROHIBITION RELATING TO RECREATIONAL VESSELS.— After the effective date of the regulations promulgated by the Secretary of the department in which the Coast Guard is operating under paragraph (4), the owner or operator of a recreational vessel shall neither operate in nor discharge any discharge incidental to the normal operation of the vessel into, the waters of the United States or the waters of the contiguous zone, if the owner or operator of the vessel is not using any applicable management practice meeting standards established under this subsection.”.

Speaker of the House of Representatives.
Vice President of the United States and President of the Senate.

Appendix D
List of Target Analytes

Analytical Class	Analyte Name	Analytical Method	CAS Number
Pathogens	E. Coli by MF	EPA 1603	NA
Pathogens	E. Coli by MPN	IDEXX Colilert 18 Quanti-Tray or Multiple Tube Fermentation	NA
Pathogens	Enterococci by MF	EPA 1600	NA
Pathogens	Enterococci by MPN	IDEXX Enterolert Quanti-Tray or ASTM D6503-99	NA
Pathogens	Fecal Coliform by MF	MF-SM9222D	NA
Pathogens	Fecal Coliform by MPN	Multiple Tube Fermentation	NA
Classicals	Biochemical Oxygen Demand (BOD)	SM 5210 B 20th	NA
Classicals	Chemical Oxygen Demand (COD)	Chemical Oxygen Demand by HACH	NA
Classicals	Conductivity	A2510B	NA
Classicals	Dissolved Organic Carbon (DOC)	SM5310 B	NA
Classicals	Dissolved Oxygen	SM 4500-O G	NA
Classicals	Hexane Extractable Material (HEM)	USEPA-1664A	NA
Classicals	pH	SM 4500-H B	NA
Classicals	Salinity	SM 2520 A	NA
Classicals	Silica Gel Treated HEM (SGT-HEM)	USEPA-1664A	68334-30-5
Classicals	Sulfide	SM4500S2D	18496-25-8
Classicals	Temperature	SM 2550	NA
Classicals	Total Organic Carbon (TOC)	SM5310 B	NA
Classicals	Total Residual Chlorine	SM 4500-Cl G	NA
Classicals	Total Suspended Solids (TSS)	SM 2540 D 20th	NA
Classicals	Turbidity	EPA 180.1	NA
Metals	Aluminum, Dissolved	EPA200.7	7429-90-5
Metals	Aluminum, Dissolved	EPA200.8	7429-90-5
Metals	Aluminum, Total	EPA200.7	7429-90-5
Metals	Aluminum, Total	EPA200.8	7429-90-5
Metals	Antimony, Dissolved	EPA200.8	7440-36-0
Metals	Antimony, Total	EPA200.8	7440-36-0
Metals	Arsenic, Dissolved	EPA200.7	7440-38-2
Metals	Arsenic, Dissolved	EPA200.8	7440-38-2
Metals	Arsenic, Total	EPA200.7	7440-38-2
Metals	Arsenic, Total	EPA200.8	7440-38-2
Metals	Barium, Dissolved	EPA200.8	7440-39-3
Metals	Barium, Total	EPA200.7	7440-39-3
Metals	Barium, Total	EPA200.8	7440-39-3
Metals	Beryllium, Dissolved	EPA200.8	7440-41-7
Metals	Beryllium, Total	EPA200.8	7440-41-7
Metals	Cadmium, Dissolved	EPA200.7	7440-43-9
Metals	Cadmium, Dissolved	EPA200.8	7440-43-9
Metals	Cadmium, Total	EPA200.7	7440-43-9
Metals	Cadmium, Total	EPA200.8	7440-43-9
Metals	Calcium, Dissolved	EPA200.7	7440-70-2
Metals	Calcium, Total	EPA200.7	7440-70-2
Metals	Chromium, Dissolved	EPA200.7	7440-47-3
Metals	Chromium, Dissolved	EPA200.8	7440-47-3
Metals	Chromium, Total	EPA200.7	7440-47-3
Metals	Chromium, Total	EPA200.8	7440-47-3

Analytical Class	Analyte Name	Analytical Method	CAS Number
Metals	Cobalt, Dissolved	EPA200.8	7440-48-4
Metals	Cobalt, Total	EPA200.8	7440-48-4
Metals	Copper, Dissolved	EPA200.7	7440-50-8
Metals	Copper, Dissolved	EPA200.8	7440-50-8
Metals	Copper, Total	EPA200.7	7440-50-8
Metals	Copper, Total	EPA200.8	7440-50-8
Metals	Iron, Dissolved	EPA200.7	7439-89-6
Metals	Iron, Total	EPA200.7	7439-89-6
Metals	Lead, Dissolved	EPA200.7	7439-92-1
Metals	Lead, Dissolved	EPA200.8	7439-92-1
Metals	Lead, Total	EPA200.7	7439-92-1
Metals	Lead, Total	EPA200.8	7439-92-1
Metals	Magnesium, Dissolved	EPA200.7	7439-95-4
Metals	Magnesium, Total	EPA200.7	7439-95-4
Metals	Manganese, Dissolved	EPA200.7	7439-96-5
Metals	Manganese, Dissolved	EPA200.8	7439-96-5
Metals	Manganese, Total	EPA200.7	7439-96-5
Metals	Manganese, Total	EPA200.8	7439-96-5
Metals	Nickel, Dissolved	EPA200.7	7440-02-0
Metals	Nickel, Dissolved	EPA200.8	7440-02-0
Metals	Nickel, Total	EPA200.7	7440-02-0
Metals	Nickel, Total	EPA200.8	7440-02-0
Metals	Potassium, Dissolved	EPA200.7	2023695
Metals	Potassium, Total	EPA200.7	2023695
Metals	Selenium, Dissolved	EPA200.7	7782-49-2
Metals	Selenium, Dissolved	EPA200.8	7782-49-2
Metals	Selenium, Total	EPA200.7	7782-49-2
Metals	Selenium, Total	EPA200.8	7782-49-2
Metals	Silver, Dissolved	EPA200.8	7440-22-4
Metals	Silver, Total	EPA200.8	7440-22-4
Metals	Sodium, Dissolved	EPA200.7	7440-23-5
Metals	Sodium,Total	EPA200.7	7440-23-5
Metals	Thallium, Dissolved	EPA200.8	7440-28-0
Metals	Thallium, Total	EPA200.8	7440-28-0
Metals	Vanadium, Dissolved	EPA200.8	7440-62-2
Metals	Vanadium,Total	EPA200.8	7440-62-2
Metals	Zinc, Dissolved	EPA200.7	7440-66-6
Metals	Zinc, Dissolved	EPA200.8	7440-66-6
Metals	Zinc, Total	EPA200.7	7440-66-6
Metals	Zinc, Total	EPA200.8	7440-66-6
Nonylphenols	Bisphenol A	MS004	NA
Nonylphenols	Nonylphenol decaethoxylate (NP10EO)	MS006	NA
Nonylphenols	Nonylphenol diethoxylate (NP2EO)	MS004	NA
Nonylphenols	Nonylphenol dodecaethoxylate (NP12EO)	MS006	NA
Nonylphenols	Nonylphenol heptadecaethoxylate (NP17EO)	MS006	NA
Nonylphenols	Nonylphenol heptaethoxylate (NP7EO)	MS006	NA
Nonylphenols	Nonylphenol hexadecaethoxylate (NP16EO)	MS006	NA
Nonylphenols	Nonylphenol hexaethoxylate (NP6EO)	MS006	NA
Nonylphenols	Nonylphenol monoethoxylate	MS004	NA
Nonylphenols	Nonylphenol nonaethoxylate (NP9EO)	MS006	NA
Nonylphenols	Nonylphenol octaethoxylate (NP8EO)	MS006	NA
Nonylphenols	Nonylphenol octodecaethoxylate (NP18EO)	MS006	NA

Analytical Class	Analyte Name	Analytical Method	CAS Number
Nonylphenols	Nonylphenol pendecaethoxylate (NP15EO)	MS006	NA
Nonylphenols	Nonylphenol pentaethoxylate (NP5EO)	MS006	NA
Nonylphenols	Nonylphenol tetradecaethoxylate (NP14EO)	MS006	NA
Nonylphenols	Nonylphenol tetraethoxylate (NP4EO)	MS006	NA
Nonylphenols	Nonylphenol tridecaethoxylate (NP13EO)	MS006	NA
Nonylphenols	Nonylphenol triethoxylate (NP3EO)	MS006	NA
Nonylphenols	Nonylphenol undecaethoxylate (NP11EO)	MS006	NA
Nonylphenols	Octylphenol	MS004	NA
Nonylphenols	Octylphenol decaethoxylate (OP10EO)	MS006	NA
Nonylphenols	Octylphenol diethoxylate (OP2EO)	MS006	NA
Nonylphenols	Octylphenol dodecaethoxylate (OP12EO)	MS006	NA
Nonylphenols	Octylphenol heptaethoxylate (OP7EO)	MS006	NA
Nonylphenols	Octylphenol hexaethoxylate (OP6EO)	MS006	NA
Nonylphenols	Octylphenol nonaethoxylate (OP9EO)	MS006	NA
Nonylphenols	Octylphenol octaethoxylate (OP8EO)	MS006	NA
Nonylphenols	Octylphenol pentaethoxylate (OP5EO)	MS006	NA
Nonylphenols	Octylphenol tetraethoxylate (OP4EO)	MS006	NA
Nonylphenols	Octylphenol triethoxylate (OP3EO)	MS006	NA
Nonylphenols	Octylphenol undecaethoxylate (OP11EO)	MS006	NA
Nonylphenols	Total Nonylphenol Polyethoxylates	MS006	NA
Nonylphenols	Total Nonylphenols	MS004	NA
Nonylphenols	Total Octylphenol Polyethoxylates	MS006	NA
Nutrients	Ammonia As Nitrogen (NH3-N)	Ammonia by 4500-NH3	7664-41-7
Nutrients	Nitrate/Nitrite (NO3/NO2-N)	EPA353.2	NA
Nutrients	Total Kjeldahl Nitrogen (TKN)	EPA351.2	NA
Nutrients	Total Phosphorus	Total Phosphorus by 365.4	7723-14-0
SVOC	1,2-Diethyl-Cyclobutane	SVOCs by EPA 625	NA
SVOC	1,2-Diphenyl hydrazine	SVOCs by EPA 625	122-66-7
SVOC	1,6-dimethylnaphthalene	SVOCs by EPA 625	575-43-9
SVOC	1-methylnaphthalene	SVOCs by EPA 625	90-12-0
SVOC	2,4,5-Trichlorophenol	SVOCs by EPA 625	95-95-4
SVOC	2,4,6-Trichlorophenol	SVOCs by EPA 625	88-06-2
SVOC	2,4-Dichlorophenol	SVOCs by EPA 625	120-83-2
SVOC	2,4-Dimethylphenol	SVOCs by EPA 625	105-67-9
SVOC	2,4-Dinitrophenol	SVOCs by EPA 625	51-28-5
SVOC	2,4-Dinitrotoluene	SVOCs by EPA 625	121-14-2
SVOC	2,6,10,14-Tetramethyl Pentadecane	SVOCs by EPA 625	1921-70-6
SVOC	2,6-Dinitrotoluene	SVOCs by EPA 625	606-20-2
SVOC	2-Butoxy ethanol	SVOCs by EPA 625	NA
SVOC	2-Chloronaphthalene	SVOCs by EPA 625	91-58-7
SVOC	2-Chlorophenol	SVOCs by EPA 625	95-57-8
SVOC	2-Cyclopenten1-one	SVOCs by EPA 625	NA
SVOC	2-Hydroxy-Benzaldehyde	SVOCs by EPA 625	90-02-8
SVOC	2-Mercaptobenzothiazole	SVOCs by EPA 625	149-30-4
SVOC	2-Methylnaphthalene	SVOCs by EPA 625	91-57-6
SVOC	2-Naphthalenecarboxaldehyde	SVOCs by EPA 625	NA
SVOC	2-Nitroaniline	SVOCs by EPA 625	88-74-4
SVOC	2-Nitrophenol	SVOCs by EPA 625	88-75-5
SVOC	3,3'-Dichlorobenzidine	SVOCs by EPA 625	91-94-1
SVOC	3,6-Dimethylundecane	SVOCs by EPA 625	NA
SVOC	3-Methyl-2-Heptanone	SVOCs by EPA 625	NA
SVOC	3-Methyl-Benzaldehyde	SVOCs by EPA 625	620-23-5
SVOC	3-Methyl-Butanoic Acid	SVOCs by EPA 625	NA

Analytical Class	Analyte Name	Analytical Method	CAS Number
SVOC	3-Methylphenol	SVOCs by EPA 625	NA
SVOC	3-Nitroaniline	SVOCs by EPA 625	99-09-2
SVOC	3-Phenyl-2-Propenal	SVOCs by EPA 625	104-55-2
SVOC	4,6-Dinitro-2-Methylphenol	SVOCs by EPA 625	534-52-1
SVOC	4-Bromophenyl Phenyl Ether	SVOCs by EPA 625	101-55-3
SVOC	4-Chloro-3-Methylphenol	SVOCs by EPA 625	59-50-7
SVOC	4-Chloroaniline	SVOCs by EPA 625	106-47-8
SVOC	4-Chlorophenyl Phenyl Ether	SVOCs by EPA 625	7005-72-3
SVOC	4-Methyl-Pentanoic Acid	SVOCs by EPA 625	NA
SVOC	4-Nitrobenzenamine	SVOCs by EPA 625	100-01-6
SVOC	4-Nitrophenol	SVOCs by EPA 625	100-02-7
SVOC	5-Butyl-Hexadecane	SVOCs by EPA 625	NA
SVOC	Acenaphthene	SVOCs by EPA 625	83-32-9
SVOC	Acenaphthylene	SVOCs by EPA 625	208-96-8
SVOC	Acetophenone	SVOCs by EPA 625	98-86-2
SVOC	Anthracene	SVOCs by EPA 625	120-12-7
SVOC	Atrazine	SVOCs by EPA 625	1912-24-9
SVOC	Benzeneacetic Acid	SVOCs by EPA 625	NA
SVOC	Benzenepropanoic Acid	SVOCs by EPA 625	NA
SVOC	Benzidine	SVOCs by EPA 625	92-87-5
SVOC	Benzo(A)Anthracene	SVOCs by EPA 625	56-55-3
SVOC	Benzo(A)Pyrene	SVOCs by EPA 625	50-32-8
SVOC	Benzo(B)Fluoranthene	SVOCs by EPA 625	205-99-2
SVOC	Benzo(G,H,I)Perylene	SVOCs by EPA 625	191-24-2
SVOC	Benzo(K)Fluoranthene	SVOCs by EPA 625	207-08-9
SVOC	Benzothiazole	SVOCs by EPA 625	95-16-9
SVOC	Bicyclo[2.2.1]Heptane,1,7,7-Trimethyl-	SVOCs by EPA 625	NA
SVOC	Biphenyl[a]	SVOCs by EPA 625	92-52-4
SVOC	Bis (2-Chloroisopropyl)Ether	SVOCs by EPA 625	108-60-1
SVOC	Bis(2-Chloroethoxy)Methane	SVOCs by EPA 625	111-91-1
SVOC	Bis(2-Chloroethyl)Ether	SVOCs by EPA 625	111-44-4
SVOC	Bis(2-Chloroisopropyl) Ether	SVOCs by EPA 625	39638-32-9
SVOC	Bis(2-Ethylhexyl) Phthalate	SVOCs by EPA 625	117-81-7
SVOC	Butyl Benzyl Phthalate	SVOCs by EPA 625	85-68-7
SVOC	Caprolactam	SVOCs by EPA 625	105-60-2
SVOC	Carbazole	SVOCs by EPA 625	86-74-8
SVOC	Cholesterol	SVOCs by EPA 625	NA
SVOC	Chrysene	SVOCs by EPA 625	218-01-9
SVOC	Cyclohexadecane	SVOCs by EPA 625	NA
SVOC	Dibenz(A,H)Anthracene	SVOCs by EPA 625	53-70-3
SVOC	Dibenzofuran	SVOCs by EPA 625	132-64-9
SVOC	Diethyl Phthalate	SVOCs by EPA 625	84-66-2
SVOC	Dimethyl Phthalate	SVOCs by EPA 625	131-11-3
SVOC	Di-N-Butyl Phthalate	SVOCs by EPA 625	84-74-2
SVOC	Di-N-Octyl Phthalate	SVOCs by EPA 625	117-84-0
SVOC	Dodecane	SVOCs by EPA 625	
SVOC	Eicosane	SVOCs by EPA 625	112-95-8
SVOC	Fluoranthene	SVOCs by EPA 625	206-44-0
SVOC	Fluorene	SVOCs by EPA 625	86-73-7
SVOC	Heneicosane	SVOCs by EPA 625	629-94-7
SVOC	Heptadecane	SVOCs by EPA 625	629-78-7
SVOC	Hexachlorobenzene	SVOCs by EPA 625	118-74-1
SVOC	Hexachlorobutadiene[a]	SVOCs by EPA 625	87-68-3

Analytical Class	Analyte Name	Analytical Method	CAS Number
SVOC	Hexachlorocyclopentadiene	SVOCs by EPA 625	77-47-4
SVOC	Hexachloroethane	SVOCs by EPA 625	67-72-1
SVOC	Hexadecanoic Acid	SVOCs by EPA 625	NA
SVOC	Indeno(1,2,3-Cd)Pyrene	SVOCs by EPA 625	193-39-5
SVOC	Indole	SVOCs by EPA 625	NA
SVOC	Isophorone	SVOCs by EPA 625	78-59-1
SVOC	Isopropylbenzene-4,Methyl-1	SVOCs by EPA 625	99-87-6
SVOC	M-Cresol	SVOCs by EPA 625	108-39-4
SVOC	Naphthalene	SVOCs by EPA 625	91-20-3
SVOC	N-Hexadecane	SVOCs by EPA 625	544-76-3
SVOC	Nitrobenzene	SVOCs by EPA 625	98-95-3
SVOC	N-Nitroso Di-N-Propylamine	SVOCs by EPA 625	621-64-7
SVOC	N-Nitrosodimethylamine	SVOCs by EPA 625	62-75-9
SVOC	N-Nitrosodiphenylamine	SVOCs by EPA 625	86-30-6
SVOC	Nonadecane	SVOCs by EPA 625	629-92-5
SVOC	Nonanoic Acid	SVOCs by EPA 625	NA
SVOC	N-Pentadecane[a]	SVOCs by EPA 625	629-62-9
SVOC	N-Tetradecane[a]	SVOCs by EPA 625	629-59-4
SVOC	O-Cresol	SVOCs by EPA 625	95-48-7
SVOC	Octadecane	SVOCs by EPA 625	NA
SVOC	P-Cresol	SVOCs by EPA 625	106-44-5
SVOC	Pentachlorophenol	SVOCs by EPA 625	87-86-5
SVOC	Phenanthrene	SVOCs by EPA 625	85-01-8
SVOC	Phenol	SVOCs by EPA 625	108-95-2
SVOC	Pyrene	SVOCs by EPA 625	129-00-0
SVOC	Triethyl Phosphate	SVOCs by EPA 625	NA
VOC	(2-Methyl-1-Propenyl)-Benzene	VOCs by EPA 624	NA
VOC	(E)-2-Butenal	VOCs by EPA 624	NA
VOC	1,1,1,2-Tetrachloroethane	VOCs by EPA 624	630-20-6
VOC	1,1,1-Trichloroethane	VOCs by EPA 624	71-55-6
VOC	1,1,2,2-Tetrachloroethane	VOCs by EPA 624	79-34-5
VOC	1,1,2-Trichloroethane	VOCs by EPA 624	79-00-5
VOC	1,1-Dichloroethane	VOCs by EPA 624	75-34-3
VOC	1,1-Dichloroethene	VOCs by EPA 624	75-35-4
VOC	1,1-Dichloropropene	VOCs by EPA 624	563-58-6
VOC	1,2,3,4-Tetrahydro-5-Methylnaphthalene	VOCs by EPA 624	2809-64-5
VOC	1,2,3,4-Tetrahydro-6-Methylnaphthalene	VOCs by EPA 624	1680-51-9
VOC	1,2,3,4-Tetrahydronaphthalene	VOCs by EPA 624	119-64-2
VOC	1,2,3-Trichlorobenzene	VOCs by EPA 624	87-61-6
VOC	1,2,3-Trichloropropane	VOCs by EPA 624	96-18-4
VOC	1,2,4-Trichlorobenzene	VOCs by EPA 624	120-82-1
VOC	1,2,4-Trimethylbenzene	VOCs by EPA 624	95-63-6
VOC	1,2-Dibromo-3-Chloropropane	VOCs by EPA 624	96-12-8
VOC	1,2-Dibromoethane	VOCs by EPA 624	106-93-4
VOC	1,2-Dichlorobenzene	VOCs by EPA 624	95-50-1
VOC	1,2-Dichloroethane	VOCs by EPA 624	107-06-2
VOC	1,2-Dichloropropane	VOCs by EPA 624	78-87-5
VOC	1,3,5-Trimethylbenzene	VOCs by EPA 624	108-67-8
VOC	1,3-Dichlorobenzene	VOCs by EPA 624	541-73-1
VOC	1,3-Dichloropropane	VOCs by EPA 624	142-28-9
VOC	1,3-Methylnaphthalene	VOCs by EPA 624	NA
VOC	1,4-Dichlorobenzene	VOCs by EPA 624	106-46-7
VOC	1,7-Methylnaphthalene	VOCs by EPA 624	NA

Analytical Class	Analyte Name	Analytical Method	CAS Number
VOC	1-Ethyl-3-Methyl-Benzene	VOCs by EPA 624	NA
VOC	1-Methyl-2-(1-Methylethyl)-Benzene	VOCs by EPA 624	NA
VOC	1-Methyl-4-(1-Methylidene)-Cyclohexane	VOCs by EPA 624	NA
VOC	1-Methylnaphthalene[b]	VOCs by EPA 624	90-12-0
VOC	2- Heptanone	VOCs by EPA 624	NA
VOC	2,2-Dichloropropane	VOCs by EPA 624	594-20-7
VOC	2,3-Dihydro-4-Methyl-1h-Indene	VOCs by EPA 624	824-22-6
VOC	2,6-Dimethylnaphthalene	VOCs by EPA 624	581-42-0
VOC	2-Butanone	VOCs by EPA 624	78-93-3
VOC	2-Butenal	VOCs by EPA 624	NA
VOC	2-Ethyl-1,3,5-Trimethyl-Benzene	VOCs by EPA 624	NA
VOC	2-Ethyl-1,4-Dimethyl-Benzene	VOCs by EPA 624	2039-89-6
VOC	2-Ethyl-1-Hexanol	VOCs by EPA 624	104-76-7
VOC	2-Hexanone	VOCs by EPA 624	591-78-6
VOC	2-Methylnaphthalene[b]	VOCs by EPA 624	91-57-6
VOC	4-Chlorotoluene	VOCs by EPA 624	106-43-4
VOC	4-Isopropyltoluene	VOCs by EPA 624	99-87-6
VOC	4-Methyl-2-Pentanone	VOCs by EPA 624	108-10-1
VOC	Acetone	VOCs by EPA 624	67-64-1
VOC	Benzaldehyde	VOCs by EPA 624	100-52-7
VOC	Benzene	VOCs by EPA 624	71-43-2
VOC	Benzocycloheptatriene	VOCs by EPA 624	NA
VOC	Benzofuran	VOCs by EPA 624	271-89-6
VOC	Biphenyl	VOCs by EPA 624	92-52-4
VOC	Bromobenzene	VOCs by EPA 624	108-86-1
VOC	Bromochloromethane	VOCs by EPA 624	74-97-5
VOC	Bromodichloromethane	VOCs by EPA 624	75-27-4
VOC	Bromoform	VOCs by EPA 624	75-25-2
VOC	Bromomethane	VOCs by EPA 624	74-83-9
VOC	Carbon Disulfide	VOCs by EPA 624	75-15-0
VOC	Carbon Tetrachloride	VOCs by EPA 624	56-23-5
VOC	Chlorobenzene	VOCs by EPA 624	108-90-7
VOC	Chloroethane	VOCs by EPA 624	75-00-3
VOC	Chloroform	VOCs by EPA 624	67-66-3
VOC	Chloromethane	VOCs by EPA 624	74-87-3
VOC	Chlorotoluene	VOCs by EPA 624	25168-05-2
VOC	Cis-1,2-Dichloroethene	VOCs by EPA 624	156-59-2
VOC	Cis-1,3-Dichloropropene	VOCs by EPA 624	10061-01-5
VOC	Cyclohexane	VOCs by EPA 624	110-82-7
VOC	Dibromochloromethane	VOCs by EPA 624	124-48-1
VOC	Dibromomethane	VOCs by EPA 624	74-95-3
VOC	Dichlorodifluoromethane	VOCs by EPA 624	75-71-8
VOC	Dimethoxymethane	VOCs by EPA 624	NA
VOC	Ethylbenzene	VOCs by EPA 624	100-41-4
VOC	Fluorotrimethylsilane	VOCs by EPA 624	420-56-4
VOC	Hexachlorobutadiene	VOCs by EPA 624	87-68-3
VOC	Isopropylbenzene	VOCs by EPA 624	98-82-8
VOC	Limonene	VOCs by EPA 624	000138-86-3
VOC	M-,P-Xylene (Sum Of Isomers)	VOCs by EPA 624	NA
VOC	Methyl Acetate	VOCs by EPA 624	79-20-9
VOC	Methyl Tertiary Butyl Ether (MTBE)	VOCs by EPA 624	1634-04-4
VOC	Methylcyclohexane	VOCs by EPA 624	108-87-2
VOC	Methylene Chloride	VOCs by EPA 624	75-09-2

Analytical Class	Analyte Name	Analytical Method	CAS Number
VOC	Naphthalene[b]	VOCs by EPA 624	91-20-3
VOC	N-Butylbenzene	VOCs by EPA 624	104-51-8
VOC	Nonanal	VOCs by EPA 624	124-19-6
VOC	N-Pentadecane	VOCs by EPA 624	629-62-9
VOC	N-Propylbenzene	VOCs by EPA 624	103-65-1
VOC	N-Tetradecane	VOCs by EPA 624	629-59-4
VOC	O-Xylene	VOCs by EPA 624	95-47-6
VOC	Sec-Butylbenzene	VOCs by EPA 624	135-98-8
VOC	Styrene	VOCs by EPA 624	100-42-5
VOC	Sulfur Dioxide	VOCs by EPA 624	2025884
VOC	Tert-Butylbenzene	VOCs by EPA 624	98-06-6
VOC	Tetrachloroethene	VOCs by EPA 624	127-18-4
VOC	Tetrahydrofuran	VOCs by EPA 624	109-99-9
VOC	Toluene	VOCs by EPA 624	108-88-3
VOC	Trans-1,2-Dichloroethene	VOCs by EPA 624	156-60-5
VOC	Trans-1,3-Dichloropropene	VOCs by EPA 624	10061-02-6
VOC	Trichloroethene	VOCs by EPA 624	79-01-6
VOC	Trichlorofluoromethane	VOCs by EPA 624	75-69-4
VOC	Trichlorotrifluoroethane	VOCs by EPA 624	76-13-1
VOC	Trimethylsilanol	VOCs by EPA 624	1066-40-6
VOC	Vinyl Acetate	VOCs by EPA 624	108-05-4
VOC	Vinyl Chloride	VOCs by EPA 624	75-01-4

[a] Also measured analytically as a VOC using EPA Method 624. For the purposes of this report, this compound has been classified as a VOC to keep with other similar compounds.

[b] Also measured analytically as a SVOC using EPA Method 625. For the purposes of this report, this compound has been classified as an SVOC to keep with other PAHs.

NA = Not Applicable.

Appendix E

Analyte Concentrations and Summary Statistics from Ambient Water Samples

Analyte - Ambient Water[b,c]	#Waters	Min.	Mean	Median	Max.	Screening BM	Non Detects	Det. Limit(s)
Acetone	10	0.9	2.81	2.25	9.2	n/a	2	5
Aluminum, Dissolved	16	3.1	218.9	38.6	870	n/a	2	6.2
Aluminum, Total	16	29.2	653.9	357.5	3950	87	0	
Ammonia As Nitrogen (NH3-N)	15	0.02	0.15	0.066	0.93	1.2	6	0.04, 0.05
Arsenic, Dissolved	17	1	8.09	2	30	36	8	1, 4
Arsenic, Total	17	1	8.19	2.9	28.9	0.018	8	1, 4
Barium, Dissolved	10	14.2	39.04	34.55	65.2	n/a	0	
Barium, Total	10	13.3	45.96	33.9	96.3	1000	0	
Biochemical Oxygen Demand (BOD)	14	0.479	2.68	1.35	9.3	30	4	1, 4
Calcium, Dissolved	17	23000	104382	72100	310000	n/a	0	
Calcium, Total	17	23000	107876	71100	320000	n/a	0	
Chemical Oxygen Demand (COD)	15	10	298.3	72	1700	n/a	3	20
Conductivity	15	0.2215	10.49	7.18	38.2	n/a	0	
Copper, Dissolved	17	1.5	4.88	2.5	24.2	3.1[a]	7	5
Copper, Total	17	1.8	5.74	4	23.3	1300	7	5
Dissolved Organic Carbon (DOC)	17	1	4.66	4.4	8.5	n/a	1	3
Dissolved Oxygen	15	1	6.69	6.5	12.33	n/a	0	
E. Coli	9	5	3236	130	24196	130	1	10
Enterococci	9	5	1387	333	5099	33	1	10
Fecal Coliform	8	5	6452	220	44000	14	1	10
Iron, Total	10	50	812.2	382	4180	300	2	100
Magnesium, Dissolved	17	6000	304644	172000	1100000	n/a	0	
Magnesium, Total	17	6000	306001	168000	1100000	n/a	0	
Manganese, Dissolved	17	0.5	11.71	3.7	106	n/a	7	1, 2.5, 6.7, 17
Manganese, Total	17	1.25	60.54	43	165	100	2	2.5, 13
Nickel, Dissolved	17	2.3	4.60	5	7.2	8.2[a]	7	10
Nickel, Total	17	2.4	5.81	5	16.7	610	7	10
Nitrate/Nitrite (NO3/NO2-N)	15	0.025	0.36	0.097	1.5	n/a	6	0.05
pH	16	6.90	7.41	7.26	8.18	n/a	0	
Potassium, Dissolved	10	3600	72198	60700	175000	n/a	0	
Potassium, Total	10	3470	71119	59750	174000	n/a	0	
Salinity	14	0.1	6.06	3.85	22.4	n/a	0	
Selenium, Dissolved	17	1	22.51	5	100	5[a]	7	2, 10
Selenium, Total	17	1	22.71	5	93.9	170	10	2, 10
Sodium, Dissolved	10	17600	1446690	1009500	3630000	n/a	0	
Sodium,Total	10	17400	1459630	1160000	3680000	n/a	0	
Temperature	16	8.8	20.07	21.575	29.37	n/a	0	
Total Kjeldahl Nitrogen (TKN)	15	0.05	1.00	0.587	4.7	n/a	3	0.1
Total Organic Carbon (TOC)	13	2	6.12	5.1	19	n/a	0	
Total Phosphorus	15	0.0125	0.20	0.059	2	0.1	6	0.025, 0.05
Total Suspended Solids (TSS)	17	5	22.13	15	98	n/a	1	10
Turbidity	16	0.03	32.01	17.5	186	n/a	0	
Vanadium, Dissolved	10	0.5	0.94	0.5	2.3	n/a	6	
Vanadium,Total	10	0.5	2.90	1.6	9.3	n/a	5	1, 2.5, 10
Zinc, Dissolved	17	3.4	19.32	11.4	116	81	4	10
Zinc, Total	17	2.9	10.98	10.6	23.9	7400	4	10

Note:
(a) Screening benchmark (BM) is below detection limit(s)
(b) Analytes not listed in this table were not detected.
(c) Surrounding Ambient water (also used as service water on select vessels for deck washdown, firemain systems, or other services as specified in Chapter 3) was tested for the following classes of pollutants: pathogens, dissolved and total metals, the so-called ‘classical pollutants’, nutrient and nutrient related parameters, VOCs and SVOCs (see Appendix D).

Appendix F
Analyte Concentrations and Summary Statistics from Source Water Samples

Analyte - Source Water[b,c]	#Waters	Min.	Mean	Median	Max.	Screening BM	Non Detects	Det. Limit(s)
^{Alu}minum, Dissolved	11	6.3	64.94	17.1	310	n/a	1	50
Aluminum, Total	11	8.6	64.06	27.5	250	87	1	50
Ammonia As Nitrogen (NH3-N)	10	0.02	0.18	0.041	0.731	1.2	5	0.04,0.05
Barium, Dissolved	7	11.4	29.14	29	58.5	n/a	0	
Barium, Total	7	11.9	29.07	30.1	56.9	1000	0	
Bromodichloromethane	8	1.25	7.84	5.65	18	0.55[a]	2	2.5, 5
Calcium, Dissolved	11	1450	28496	29600	88000	n/a	0	
Calcium, Total	11	1280	28409	29700	88000	n/a	0	
Chemical Oxygen Demand (COD)	11	5	11.55	10	28.6	n/a	6	10, 20
Chloroform	8	0.05	18.56	16	57.2	5.7	0	
Conductivity	10	0.159	33.39	0.4075	330.4	n/a	0	
Copper, Dissolved	11	2.4	16.11	6.2	65	3.1[a]	2	5
Copper, Total	11	2.5	20.55	8.7	82	1300	2	5
Dibromochloromethane	8	0.9	3.38	2.45	10	0.4[a]	3	2.5, 5
Dissolved Oxygen	10	2.07	6.87	6.96	11.72	n/a	0	
Magnesium, Dissolved	11	250	6815	7100	19000	n/a	2	500, 1000
Magnesium, Total	11	350	6855	7300	19000	n/a	2	1000
Manganese, Dissolved	11	0.5	6.00	1.25	33	n/a	6	1, 2.5
Manganese, Total	11	1	9.30	5.4	37	100	1	2.5
Nitrate/Nitrite (NO3/NO2-N)	11	0.025	1.26	1.6	2.4	n/a	1	0.05
pH	11	6.61	7.37	7.08	8.45	n/a	0	
Potassium, Dissolved	7	1000	3077	3340	5220	n/a	2	2000, 3000
Potassium, Total	7	1000	3003	2840	5270	n/a	1	2000
Sodium, Dissolved	7	16100	56057	24300	140000	n/a	0	
Sodium,Total	7	11500	55143	24100	144000	n/a	0	
Temperature	10	5.47	20.42	21.16	31.16	n/a	0	
Total Kjeldahl Nitrogen (TKN)	10	0.05	0.66	0.401	1.8	n/a	1	0.1
Total Organic Carbon (TOC)	8	1.5	3.21	2.35	10.4	n/a	3	3
Total Phosphorus	10	0.025	0.30	0.363	0.52	0.1	2	0.05
Total Residual Chlorine	10	0.05	0.46	0.415	1.3	0.0075[a]	3	0.1
Turbidity	11	0.5	5.89	2	19.3	n/a	2	1
Zinc, Dissolved	11	4.1	154.8	25.3	1200	81	0	
Zinc, Total	11	4.1	145.3	25.1	1100	7400	0	

Note:
(a) Screening benchmark (BM) is below detection limit(s)
(b) Analytes not listed in this table were not detected.
(c) Source and service water was tested for the following classes of pollutants: pathogens, dissolved and total metals, the so-called ‘classical pollutants’, nutrient and nutrient related parameters, VOCs and SVOCs (see Appendix D).

Appendix G

SUPPORTING INFORMATION FOR EPA'S SCREENING-LEVEL WATER QUALITY MODEL

Appendix G.1: Vessel-Specific Flow Calculations by Discharge Type

Vessel Class (Vessel Subclass)	Discharge Type	Flow Rate (m^3/day)	Known Information	Assumptions	Calculations
Fire Boat	Deck Wash	0.01	1 deck wash per month 50 gallons per wash All deck washes done pier side		50 gal per month/30 days = 1.67 gal/day
Fire Boat	Generator Engine	1.82	1 generator Inboard diesel engine	2 gpm cooling water flow rate 4 hours operation when fire call 1 fire call per day	2 gal per minute X 240 min per day = 480 gal/day
Fire Boat	Propulsion Engine	36.34	2 propulsion engines 420 hp inboard engine	20 gpm cooling water flow 4 hours operation when fire call	20 gal per minute X 240 min per day X 2 engines = 9600 gal/day
Fishing (Gillnetter)	Fish Hold	1.52	1.5 tons of ice per offload 1 offload per day		1.5 tons of ice (or 1524 kg) X 1kg/L X 1 offload/day = 1524 liters/day
Fishing (Gillnetter)	Fish Hold	0.08	50 lbs (25.2 liters) if ice per offload offloads daily		75.6 liters/day
Fishing (Gillnetter)	Fish Hold	0.70	1.75 tons of ice per offload Offload daily	Ice tank holds 50% fish, 35% ice, 15% air (0.61tons of ice or 691.48 liters of ice)	691.47 liters/day
Fishing (Gillnetter)	Propulsion Engine	14.93		20 gpm cooling water flow rate 1200 hours per year in operation	20 gal/min X 60 min/hour X 1200 hours/365 days = 3945 gal/day

Appendix G.1: Vessel-Specific Flow Calculations by Discharge Type

Vessel Class (Vessel Subclass)	Discharge Type	Flow Rate (m^3/day)	Known Information	Assumptions	Calculations
Fishing (Gillnetter)	Propulsion Engine	14.93	1 Caterpillar 350hp	20 gpm cooling water flow rate 1200 hours per year in operation	20 gal/min X 60 min/hour X 1200 hours/365 days = 3945 gal/day
Fishing (Gillnetter)	Propulsion Engine	14.93		20 gpm cooling water flow rate 1200 hours per year in operation	20 gal/min X 60 min/hour X 1200 hours/365 days = 3945 gal/day
Fishing (Gillnetter)	Propulsion Engine	14.93		20 gpm cooling water flow rate 1200 hours per year in operation	20 gal/min X 60 min/hour X 1200 hours/365 days = 3945 gal/day
Fishing (Lobster Boat)	Fish Hold	2.83		Used average of known Longliner fish hold flow rates	
Fishing (Longliner)	Bilge Water	0.45	1 manual pump	12v bilge pump at 20 gpm 10 minutes per pump out 2 pump outs per day	20 gal per min X 10 min X 2 pump/day = 120 gal/day
Fishing (Longliner)	Fish Hold	4.06	8 tons of ice per offload Offload every 2 days	Tanks are full at offload	8 tons of ice (or 8128 kg) X 1kg/L X 1 offload/ 2 days = 4064 liters/day
Fishing (Longliner)	Fish Hold	1.59	Fish hold tank is 8X10X4 ft (9.06 m^3) Emptied at each offload	Ice tank holds 50% fish, 35% ice, 15% air (3.17 $m^3$of ice) Offloads 1 every 2 days	9.06 m^3 X 35% X 1 offload/2 days = 1.59 m^3/day
Fishing (Purse Seiner)	Fish Hold	31.71	Fish hold tank is 8X20X20 ft (90.6 m^3) Emptied at each offload	ice tank holds 50% fish, 35% ice, 15% air (3.17 m^3 of ice) offloads daily	90.6 m^3 X 35% = 31.71 m^3/day

Appendix G.1: Vessel-Specific Flow Calculations by Discharge Type

Vessel Class (Vessel Subclass)	Discharge Type	Flow Rate (m^3/day)	Known Information	Assumptions	Calculations
Fishing (Purse Seiner)	Fish Hold	15.66	fish hold tank A is 15X10X6 ft (25.5 m^3) fish hold tank A is 15X8X6 ft (20.4 m^3) holds 60,000 lbs of fish (27215 kg) emptied at each offload	density of fish is 0.9 kg/L offloads daily	27215 kg / 0.9kg/L = 30,239 L of fish (30.24 m^3 of fish) 45.9 m^3 tank - 30.24 m^3 of fish = 15.66 m^3 of hold water 15.66 m^3 of hold water X = 15.66 m^3/day
Fishing (Purse Seiner)	Fish Hold	18.36	tank holds about 85,000lbs of fish (42,840 liters of fish)	holding tank is 70% fish, 30% water offloads daily	42,840 liters of fish X 30 / 70 = 18,360 Liters/day
Fishing (Purse Seiner)	Fish Hold	10.20	fish hold tank is 1200 ft^3 (33.99 m^3) emptied at each offload	holding tank is 70% fish, 30% water offloads daily	33.99 m^3 X 30% = 10.2 m^3/day
Fishing (Purse Seiner)	Fish Hold	5.34	fish hold tank is 630 ft^3 (17.84 m^3) emptied at each offload	holding tank is 70% fish, 30% water offloads daily	17.84 m3 X 30% = 5.34 m^3/day
Fishing (Purse Seiner)	Fish Hold Clean	1.33		30 minute wash garden hose flow rate is 11.67 gpm	11.67 gal per min X 30 min X 1 wash/day = 350.1 gal/day
Fishing (Purse Seiner)	Fish Hold Clean	2.33		30 minute wash garden hose flow rate is 11.67 gpm	11.67 gal per min X 30 min X 1 wash/day = 350.1 gal/day
Fishing (Purse Seiner)	Fish Hold Clean	3.33		30 minute wash garden hose flow rate is 11.67 gpm	11.67 gal per min X 30 min X 1 wash/day = 350.1 gal/day
Fishing (Purse Seiner)	Fish Hold Clean	0.04	tanks are cleaned 1 per month	30 minute wash garden hose flow rate is 11.67 gpm	11.67 gal per min X 30 min X 1 wash/30 days = 11.67gal/day
Fishing (Purse Seiner)	Fish Hold Clean	3.33	4 month season	30 minute wash garden hose flow rate is 11.67 gpm	11.67 gal per min X 30 min X 1 wash/day = 350.1 gal/day
Fishing (Purse Seiner)	Generator Engine	1.41	17,000 hours over 15 years	2 gpm cooling flow	2 gal/min X 60 min/hr X 17000hrs/15 years/365 days = 372.6 gal/day

Appendix G.1: Vessel-Specific Flow Calculations by Discharge Type

Vessel Class (Vessel Subclass)	Discharge Type	Flow Rate (m^3/day)	Known Information	Assumptions	Calculations
Fishing (Purse Seiner)	Propulsion Engine	16.59	1 Cummin 350hp inboard diesel engine 4000 hours in 3 years	20 gpm cooling flow	20 gal/min X 60 min/hr X 4000hrs/3 years/365 days = 4383.6 gal/day
Research	Propulsion Engine	0.03	1 200hp gas outboard engine 5 years old 250 hours of use	1 gpm cooling water flow rate	1 gal per minute X 250 hours/ 5 years of use X 1 engines X 365 days/year = 8.22 gal/day
Research	Propulsion Engine	0.15	2 225 hp gas outboard engine 5 years old 600 hours of use	1 gpm cooling water flow rate	1 gal per minute X 600 hours/ 5 years of use X 2 engines X 365 days/year = 39.45 gal/day
Fishing (Shrimp Trawler)	Bilge Water	2.84	5 min per pump out 1 pump out every day 150 gal/min bilge pump rate	150gpm, 5 min per pump out, once a day: 750 gal/day	150 gal per min X 5 min per day = 750 gal/min
Fishing (Shrimp Trawler)	Deck Wash	0.66	1 deck wash per day 15 minute deck wash with garden hose	garden hose flow rate is 11.67 gpm	11.67 gal per min X 15 min X 1 wash/day = 175.05 gal/day
Fishing (Shrimp Trawler)	Deck Wash	0.76	200 gallons per day		200 gal/ day
Fishing (Shrimp Trawler)	Deck Wash	0.15	1 deck wash per offload 10 minute deck wash with garden hose	1 offload every 3 days Garden hose flow rate is 11.67 gpm	11.67 gal per min X 10 min X 1 wash/ 3 days = 38.9 gal/day
Fishing (Shrimp Trawler)	Fish Hold	0..22	Holding tank hold 3000lbs of shrimp	Density of fish is 0.9 kg/liter Holding tank is 70%shrimp, 30% water Offloads 1 every 3 days	1360 kg of fish / 0.9kg/L = 1512 liters of fish 1512 X 30%/70% = 648L of ice slurry 648L / 3 days = 216 L/day
Fishing (Shrimp Trawler)	Fish Hold	2.12	Holding tank is 1500 ft^3 Generally half full at offload	Holding tank is 70%shrimp, 30% water Offloads 1 every 3 days	1500 ft^3 X 30% X 1/2 full X 1offload/3 days = 75 ft^3/day

Appendix G.1: Vessel-Specific Flow Calculations by Discharge Type

Vessel Class (Vessel Subclass)	Discharge Type	Flow Rate (m^3/day)	Known Information	Assumptions	Calculations
Fishing (Shrimp Trawler)	Fish Hold Clean	0.13		15 minute hose down after each offload Offloads 1 every 3 days Garden hose flow rate is 11.67 gpm	11.67 gal per min X 15 min X 1 wash/ 3 day X = 33.66 gal/day
Fishing (Shrimp Trawler)	Fish Hold Clean	0.13		15 minute hose down after each offload Offloads 1 every 3 days Garden hose flow rate is 11.67 gpm	11.67 gal per min X 15 min X 1 wash/ 3 day X = 33.66 gal/day
Fishing (Shrimp Trawler)	Deck Wash	0.08	1 deck wash per offload 60 gallons per wash	1 offload every 3 days	60 gal every 3 days X year = 20 gal/day
Fishing (Shrimp Trawler)	Deck Wash	0.04	1 deck wash per offload 30 gallons per wash	2 offload every 3 days	30 gal every 3 days X year = 20 gal/day
Fishing (Shrimp Trawler)	Fish Hold	1.77		Used average of known trawler fish hold flow rates	
Fishing (Shrimp Trawler)	Fish Hold	1.42	5000 gallon tank 75% full at offload	Holding tank is 70%shrimp, 30% water Offloads 1 every 3 days	5000 gal X 30% X 3/4 full X 1offload/3 days = 375 gal /day
Fishing (Shrimp Trawler)	Fish Hold Clean	0.13		15 minute hose down after each offload Offloads 1 every 3 days Garden hose flow rate is 11.67 gpm	11.67 gal per min X 15 min X 1 wash/ 3 day X = 33.66 gal/day
Supply Boat	Deck Wash	0.05	Cleaned with hose 15 minute per deckwash	Garden hose flow rate is 11.67 gpm 1 wash every 2 weeks	11.67 gal per min X 15 min X 1 wash/14 days =12.5 gal/day

Appendix G.1: Vessel-Specific Flow Calculations by Discharge Type

Vessel Class (Vessel Subclass)	Discharge Type	Flow Rate (m^3/day)	Known Information	Assumptions	Calculations
Fishing (Tender Vessel)	Fish Hold	32.82	3 tanks of 2700 ft^3 each (229.4 m^3 total) holds 325,000 lbs of fish (147417 kg of fish) emptied at offload	density of fish is 0.9 kg/L offloads 1 every 2 days	147417 kg / 0.9kg/L = 163,797 L of fish (163.8 m^3 of fish) 229.4 m^3 tank - 163.8 m^3 of fish = 65.6 m^3 of hold water 65.6 m^3 of hold water X 1 offload/ 2 days =32.82 m^3/day
Fishing (Tender Vessel)	Fish Hold	18.43	holds 170,000 lbs of fish (77,110 kg of fish) emptied at offload	density of fish is 0.9 kg/L holding tank is 70% fish, 30% water offloads 1 every 2 days	77,110 kg / 0.9kg/L = 85678 L of fish (86 m^3 of fish) 86 m^3 of fish X 30% / 70% X 1 offload / 2 days = 18.43 m^3/day
Fishing (Tender Vessel)	Fish Hold	6.81	fish hold tank is 1600 ft^3 (45.3 m3)	holding tank is 70% fish, 30% water offloads 1 every 2 days (480ft^3),	45.3 m^3 X 30% X 1 every 2 days = 6.81m3/day
Fishing (Tender Vessel)	Fish Hold Clean	0.38		30 minute wash after each offload 1 offload every 2 days garden hose flow rate is 11.67 gpm after each offload, I offload/2days	11.67 gal per min X 30 min X 1 wash/2 days = 100.95gal/day
Fishing (Tender Vessel)	Fish Hold Clean	0.38		30 minute wash after each offload 1 offload every 2 days garden hose flow rate is 11.67 gpm after each offload, I offload/2days	11.67 gal per min X 30 min X 1 wash/2 days = 100.95gal/day
Tour Boat	Bilge Water	0.05	5 min to pump bilge 1 pump per week	12v bilge pump at 20 gpm	20 gal per min X 5 min X 1 pump/7 days = 14.3 gal/day
Tour Boat	Bilge Water	0.03	pumped very rarely	12v bilge pump at 20 gpm rarely defined as 1 pump every 2 weeks 5 min to pump bilge	20 gal per min X 5 min X 1 pump/14 days = 7.2 gal/day

Appendix G.1: Vessel-Specific Flow Calculations by Discharge Type

Vessel Class (Vessel Subclass)	Discharge Type	Flow Rate (m^3/day)	Known Information	Assumptions	Calculations
Tour Boat	Deck Wash	0.06	1 deck wash per week 10 minute deck wash with a garden hose	garden hose flow rate is 11.67 gpm	11.67 gal per min X 10 min X 1 wash/7 days = 16.67 gal/day
Tour Boat	Deck Wash	0.22	1 deck wash per day 5 minute deck wash with garden hose	garden hose flow rate is 11.67 gpm	11.67 gal per min X 5 min X 1 wash/1 days = 58.35 gal/day
Tour Boat	Generator Engine	5.40	2 45kw 76hp inboard diesel engine heat exchange system 6 hours per day of operation	2 gpm cooling flow	2 gal per minute X 360 min per day X 2 engines =1440 gal/day
Tour Boat	Generator Engine	2.20	2 27kw 46hp inboard diesel engines raw water cooled 4500 hours used in last 5 years	2 gpm cooling flow	2 gal per minute X 900 hours/year X 2 engines = 591.78 gal/day
Tour Boat	Propulsion Engine	27.25	1 catapillar 86hp diesel inboard engine 20 years old heat exchanger 6 hours per day of operation	20 gpm cooling flow	20 gal per min X 360 min per day X = 7200 gal/day
Tour Boat	Propulsion Engine	54.51	2 catapilar 275 diesel inboard engines heat exchange system 6 hours per day of operation	20 gpm cooling flow	20 gal per min X 360 min per day X 2 engines = 14400 gal/day
Tour Boat	Propulsion Engine	44.80	2 catapilar 275 diesel inboard engines raw water cooled 9000 hours operated in last 5 years	20 gpm cooling flow	20 gal per min X 1800 hours per year X 2 engines = 11836 gal/day
Tow/Salvage	Bilge Water	0.05	2 min per pump out 1 pump out every 3 days	12v bilge pump at 20 gpm	20 gal per min X 2 min X 1 pump/3 days = 13 gal/day

Appendix G.1: Vessel-Specific Flow Calculations by Discharge Type

Vessel Class (Vessel Subclass)	Discharge Type	Flow Rate (m^3/day)	Known Information	Assumptions	Calculations
Tow/Salvage	Bilge Water	2.73	60 gal per minute flow rate 5 second per pump out 1 pump out every 10 minutes		60 gal per minute X 12 min/day = 720 gal/day
Tow/Salvage	Deck Wash	0.03	1 deck wash per week 50 gallons per wash		50 gal per wash/7 days per week = 7.14 gal/day
Tow/Salvage	Deck Wash	0.03	1 deck wash per week 50 gallons per wash		50 gal per wash/7 days per week = 7.14 gal/day
Tow/Salvage	Deck Wash	0.01	25 gallons per wash	1 deck wash every 2 weeks	25 gal per wash/14 days = 1.79 gal/day
Tow/Salvage	Deck Wash	0.02	2 deck washes per week 20 gallons per wash		20 gal per wash/3.5 days = 5.7 gal/day
Tow/Salvage	Deck Wash	0.03	1 deck wash per week 50 gallons per wash		50 gal per wash/7 days per week = 7.14 gal/day
Tow/Salvage	Propulsion Engine	0.15	1 225 hp evinrude etech outboard 1 year old engine with 243 hours raw water cooled	1 gpm cooling water flow rate	1 gal per min X 243 hours/year = 39.95 gal/day
Tow/Salvage	Propulsion Engine	0.91	1 suzuki 225 hp outboard engine operates 4 hours per day	1 gpm cooling water flow rate	1 gal per min X 4 hours/day = 240 gal/day
Tow/Salvage	Propulsion Engine	0.56	2 suzuki 175hp gas outboard engines 1800 hours operated in last 4 years	1 gpm cooling water flow rate	1 gal per min X 450 hours/year X 2 engines = 147.95 gal/day
Tow/Salvage	Propulsion Engine	2.88	1 cummin inboard 380hp diesel engine 463 hours in last 2 years	20 gpm cooling water flow rate	20 gal per min X 231.5 hours/year = 761.1 gal/day
Tow/Salvage	Propulsion Engine	0.26	2 yamaha 150hp outboard gas engines 420 hours operated in last 2 years	1 gpm cooling water flow rate	1 gal per min X 210 hours/year X 2 engines = 69.04 gal/day

Appendix G.1: Vessel-Specific Flow Calculations by Discharge Type

Vessel Class (Vessel Subclass)	Discharge Type	Flow Rate (m^3/day)	Known Information	Assumptions	Calculations
Fishing (Trawler)	Bilge Water	2.84		used average of known shrimp trawler bilge flow rates	150 gal per min X 5 min per day = 750 gal/min
Fishing (Trawler)	Deck Wash	0.34		used average of known shrimp trawler deck wash flow rates	
Fishing (Trawler)	Fish Hold	1.77		used average of known shrimp trawler fish hold flow rates	
Fishing (Trawler)	Fish Hold Clean	0.13		15 minute hose down after each offload offloads 1 every 3 days garden hose flow rate is 11.67 gpm	11.67 gal per min X 15 min X 1 wash/ 3 day X = 33.66 gal/day
Fishing (Troller)	Deck Wash	0.47	125 gal per power wash	1 wash per day	125 gal/day
Fishing (Troller)	Fish Hold	4.16	fish hold tank is 12x10x7 ft^3 (23.8 m^3) emptied at each offload tank is offloaded at half full	ice tank holds 50% fish, 35% ice, 15% air offloads daily	23.8m^3 X 35% X 50% = 4.16 m^3/day
Fishing (Troller)	Fish Hold	0.79	600 gallon ice box emptied at each offload	ice tank holds 50% fish, 35% ice, 15% air offloads daily	600 gal X 35% = 210 gal/day
Fishing (Troller)	Fish Hold	1.58	160 ft^3 tank (4.53 m^3 tank)	ice tank holds 50% fish, 35% ice, 15% air offloads daily	4.53 m3 X 35% = 1.58 m^3/day
Fishing (Troller)	Fish Hold	5.59	5.5 tons of ice per offload 1 offload per day	tank holds 5.5 tons of ice (5588.3kg of ice or 6141 liters of ice) and 11,000 of fish, discharged at each offload, offloads daily,	5.5 tons of ice (5588.3 kg) X 1kg/L = 5588.29 L/day

Appendix G.1: Vessel-Specific Flow Calculations by Discharge Type

Vessel Class (Vessel Subclass)	Discharge Type	Flow Rate (m^3/day)	Known Information	Assumptions	Calculations
Fishing (Troller)	Fish Hold Clean	0.38		1 deck wash per offload 15 minute deck wash with garden hose 1 offload daily garden hose flow rate is 11.67 gpm	11.67 gal per min X 15 min = 100.95 gal/day
Fishing (Troller)	Fish Hold Clean	1.38		2 deck wash per offload 15 minute deck wash with garden hose 1 offload daily garden hose flow rate is 11.67 gpm	11.67 gal per min X 15 min = 100.95 gal/day
Tugboat	Deck Wash	0..38	1 deck wash per 2 weeks with garden hose 2 hours per deck wash	garden hose flow rate is 11.67 gpm	11.67 gal per min X 120 min X 1 wash/14 days = 100 gal/day
Tugboat	Deck Wash	0.14	1.5 deck washes per week 15 minutes per deck wash	garden hose flow rate is 11.67 gpm	11.67 gal per min X 22.5 min X 1 wash/7 days = 37.8 gal/day
Tugboat	Deck Wash	0.17	1.5 deck washes per week with garden hose 15-20 minutes per deck wash	garden hose flow rate is 11.67 gpm	11.67 gal per min X 17.5 min X 1.5 wash/7 days = 43.76 gal/day
Tugboat	Deck Wash	0.14	1 deck wash per 2 week with garden hose 45 minutes per deck wash	garden hose flow rate is 11.67 gpm	11.67 gal per min X 45 min X 1 wash/14 days = 37.51 gal/day
Tugboat	Deck Wash	0.14	1 deck wash per week with garden hose 15-30 minutes per deck wash	garden hose flow rate is 11.67 gpm	11.67 gal per min X 22.5 min X 1 wash/7 days = 37.51 gal/day
Tugboat	Deck Wash	0.19	2 deck washes per week with garden hose 15 minutes per deck wash	garden hose flow rate is 11.67 gpm	11.67 gal per min X 15 min X 2 washes/7 days = 50.01 gal/day

Appendix G.1: Vessel-Specific Flow Calculations by Discharge Type

Vessel Class (Vessel Subclass)	Discharge Type	Flow Rate (m^3/day)	Known Information	Assumptions	Calculations
Tugboat	Deck Wash	0.00	Uses pressure washer at 2 gallons per wash 1 wash every month		2 gal per wash X 1 wash every month = 0.067 gal/day
Tugboat	Deck Wash	0.05		garden hose flow rate is 11.67 gpm 1 deck washes per 2 weeks with garden hose 15 minutes per deck wash (use data of sister vessel)	11.67 gal per min X 15 min X 1 wash/14 days =12.5 gal/day
Tugboat	Deck Wash	0.05	1 deck washes per 2 weeks with garden hose 15 minutes per deck wash	garden hose flow rate is 11.67 gpm	11.67 gal per min X 15 min X 1 wash/14 days =12.5 gal/day
Tugboat	Graywater - Laundry	0.22	front load washer 16 loads per week	front load washer uses 25 gal/load	25 gal/load X 16 loads/week = 57.14 gal/day
Tugboat	Graywater - Laundry	0.22	front load washer 16 loads per week	front load washer uses 25 gal/load	25 gal/load X 16 loads/week = 57.14 gal/day
Tugboat	Graywater - Laundry	0.11	standard washer 5 loads per week	standard washer uses 40 gal/load	40 gal/load X 5 loads/week = 28.57 gal/day
Tugboat	Graywater - Laundry	0.22	front load washer 4 crew	front load washer uses 25 gal/load 4 loads of laundry per crew per week	25 gal/load X 16 loads/week = 57.14 gal/day
Tugboat	Graywater - Laundry	0.13	standard washer 6 loads per week	standard washer uses 40 gal/load	40 gal/load X 5 loads/week = 34.29 gal/day
Tugboat	Graywater - Laundry	0.02	1 load per week	has standard washer standard washer uses 40 gal/load	40 gal/load X 1 loads/week = 6.86 gal/day
Tugboat	Graywater - Shower	0.16	3 crew	17.2 gal per shower 0.8 showers per person per day	3 crew X 17.2 gal per shower X 0.8 showers per person per day = 41.28 gal/day
Tugboat	Graywater - Shower	0.16	3 crew	17.2 gal per shower 0.8 showers per person per day	3 crew X 17.2 gal per shower X 0.8 showers per person per day = 41.28 gal/day

Appendix G.1: Vessel-Specific Flow Calculations by Discharge Type

Vessel Class (Vessel Subclass)	Discharge Type	Flow Rate (m^3/day)	Known Information	Assumptions	Calculations
Tugboat	Graywater - Shower	0.26	5 crew	17.2 gal per shower 0.8 showers per person per day	5 crew X 17.2 gal per shower X 0.8 showers per person per day = 68.8 gal/day
Tugboat	Graywater - Shower	0.21	4 crew	17.2 gal per shower 0.8 showers per person per day	4 crew X 17.2 gal per shower X 0.8 showers per person per day = 55.04 gal/day
Tugboat	Graywater - Shower	0.21	4 crew	17.2 gal per shower 0.8 showers per person per day	4 crew X 17.2 gal per shower X 0.8 showers per person per day = 55.04 gal/day
Tugboat	Graywater - Shower	0.16	3 crew	17.2 gal per shower 0.8 showers per person per day	3 crew X 17.2 gal per shower X 0.8 showers per person per day = 41.28 gal/day
Tugboat	Graywater - Sink	0.11	3 crew	30 min of sink use per crew per week 2.2 gal per min in standard sink	2.2 gal per min X 3 crew X 30 min/7days = 28.29 gal/day
Tugboat	Graywater - Sink	0.11	3 crew	30 min of sink use per crew per week 2.2 gal per min in standard sink	2.2 gal per min X 3 crew X 30 min/7days = 28.29 gal/day
Tugboat	Graywater - Sink	0.18	5 crew	30 min of sink use per crew per week 2.2 gal per min in standard sink	2.2 gal per min X 5 crew X 30 min/7days = 47.14 gal/day
Tugboat	Graywater - Sink	0.14	4 crew	30 min of sink use per crew per week 2.2 gal per min in standard sink	2.2 gal per min X 4 crew X 30 min/7days = 37.71 gal/day
Tugboat	Graywater - Sink	0.14	4 crew	30 min of sink use per crew per week 2.2 gal per min in standard sink	2.2 gal per min X 4 crew X 30 min/7days = 37.71 gal/day

Appendix G.1: Vessel-Specific Flow Calculations by Discharge Type

Vessel Class (Vessel Subclass)	Discharge Type	Flow Rate (m^3/day)	Known Information	Assumptions	Calculations
Tugboat	Graywater - Sink	0.11	3 crew	30 min of sink use per crew per week 2.2 gal per min in standard sink	2.2 gal per min X 3 crew X 30 min/7days = 28.29 gal/day
Tugboat	Shaft Water	0.01	operates 5 days/week	10 mL/min constant drip (3.8 gal/day drip)	3.8 gal per day X 5 days/week = 2.71 gal/day
Tugboat	Shaft Water	0.01	operates 5 days/week	10 mL/min constant drip (3.8 gal/day drip)	3.8 gal per day X 5 days/week = 2.71 gal/day
Tugboat	Shaft Water	0.01	operates 5 days/week	10 mL/min constant drip (3.8 gal/day drip)	3.8 gal per day X 5 days/week = 2.71 gal/day
Tugboat	Shaft Water	0.01	operates 5 days/week	10 mL/min constant drip (3.8 gal/day drip)	3.8 gal per day X 5 days/week = 2.71 gal/day
Tugboat	Shaft Water	0.01	operates 5 days/week	10 mL/min constant drip (3.8 gal/day drip)	3.8 gal per day X 5 days/week = 2.71 gal/day
Tugboat	Shaft Water	0.01	operates 5 days/week	10 mL/min constant drip (3.8 gal/day drip)	3.8 gal per day X 5 days/week = 2.71 gal/day
Tugboat	Shaft Water	0.01	operates 5 days/week	10 mL/min constant drip (3.8 gal/day drip)	3.8 gal per day X 5 days/week = 2.71 gal/day
Tugboat	Shaft Water	0.01	operates 5 days/week	10 mL/min constant drip (3.8 gal/day drip)	3.8 gal per day X 5 days/week = 2.71 gal/day
Water Taxi	Bilge Water	0.13	2000 gal per hour pump 1 minute per pump out bilge pump operates when engine is turned on		33.33 gal per min X 1 min per pump out X 1 pump out/day =33.2 gal/day

Appendix G.1: Vessel-Specific Flow Calculations by Discharge Type

Vessel Class (Vessel Subclass)	Discharge Type	Flow Rate (m^3/day)	Known Information	Assumptions	Calculations
Water Taxi	Bilge Water	0.13	2000 gal per hour pump 1 minute per pump out bilge pump operates when engine is turned on		33.33 gal per min X 1 min per pump out X 1 pump out/day =33.2 gal/day
Water Taxi	Bilge Water	0.13	2000 gal per hour pump 1 minute per pump out bilge pump operates when engine is turned on		33.33 gal per min X 1 min per pump out X 1 pump out/day =33.2 gal/day
Water Taxi	Deck Wash	0.01	1 deck washes per month with garden hose 10 minutes per deck wash	garden hose flow rate is 11.67 gpm	11.67 gal per min X 10 min X 1 wash/30 days = 3.89 gal/day
Water Taxi	Deck Wash	0.01	1 deck washes per month with garden hose 10 minutes per deck wash	garden hose flow rate is 11.67 gpm	11.67 gal per min X 10 min X 1 wash/30 days = 3.89 gal/day
Water Taxi	Deck Wash	0.09	1 deck washes every week with garden hose 15 minutes per deck wash	garden hose flow rate is 11.67 gpm	11.67 gal per min X 15 min X 1 wash/7 = 25 gal/day
Water Taxi	Deck Wash	0.02	1 deck washes per month with garden hose 12.5 minutes per deck wash	garden hose flow rate is 11.67 gpm	11.67 gal per min X 12.5 min X 1 wash/30 days= 4.86 gal/day
Water Taxi	Generator Engine	9.08	2 21.5kw diesel generators heat exchange system operates 10 hours/day	2 gal per min cooling flow	2 gal per minute X 600 min per day X 2 engines = 2400 gal/day
Water Taxi	Graywater - Sink	0.28		100 passengers wash their hands/day faucet flow rate is 2.2 gal/min 20 seconds per wash	100 passengers/day X 20 second/wash X 2.2 gal/min = 73.34 gal/day

Appendix G.1: Vessel-Specific Flow Calculations by Discharge Type

Vessel Class (Vessel Subclass)	Discharge Type	Flow Rate (m^3/day)	Known Information	Assumptions	Calculations
Water Taxi	Propulsion Engine	33.18	2 95hp diesel inboard engines 20,000 hours of operation in 15 years	20 gal per min cooling flow	1200 gal per hour X 2 engines X 1,333 hours/year = 8765 gal/day
Water Taxi	Propulsion Engine	18.57	1 caterpillar 220hp diesel inboard 4475 hours of operation in 3 years	20 gal per min cooling flow	1200 gal per hour X 1,492 hours/year = 4905 gal/day
Water Taxi	Propulsion Engine	90.85	2 John Deer 25hp inboard diesel engines operates 10 hours/day	20 gal per min cooling flow	1200 gal per hour X 2 engines X 10 hrs/day = 24,000 gal/day
Water Taxi	Propulsion Engine	16.59	1 90hp diesel inboard engine 20,000 hours of operation in 15 years	20 gal per min cooling flow	1200 gal per hour X 1,333 hours/year = 4382 gal/day

Appendix G.2: Percent of Vessels by Vessel Class and Discharge Type Discharging in the Harbor

Vessel Class	Vessel Subclass	Discharge	Number of Sampled Vessels without Discharge System or Process (A)	Number of Sampled Vessels with a No Discharge System (B)	Number of Sampled Vessels that DischargedOutside U.S. Waters (C)	Number of Sampled Vessels that Discharge in the Harbor [1] (D)	Total Number of Sampled Vessels (E=A+B+C+D)	Percent of Vessels with Discharge (D/E)
Fire Boat	NA	Deck Wash	0	0	0	1	1	100%
Fire Boat	NA	Engine Effluent	0	0	0	1	1	100%
Fire Boat	NA	Fire Main	0	0	0	1	1	100%
Fire Boat	NA	Generator Effluent	0	0	0	1	1	100%
Fishing	Gillnetter	Deck Wash	0	0	5	0	5	0%
Fishing	Gillnetter	Engine Effluent	0	1	0	4	5	80%
Fishing	Gillnetter	Fish Hold	0	0	1	4	5	80%
Fishing	Lobster Boat	Fish Hold	0	0	0	1	1	100%
Fishing	Longliner	Bilge	0	1	1	1	3	33%
Fishing	Longliner	Fish Hold	0	0	0	3	3	100%
Fishing	Longliner	Fish Hold Clean	0	0	0	3	3	100%
Fishing	Purse Seiner	Engine Effluent	0	3	0	2	5	40%
Fishing	Purse Seiner	Fish Hold	0	0	0	5	5	100%
Fishing	Purse Seiner	Fish Hold Clean	0	0	0	5	5	100%
Fishing	Purse Seiner	Generator Effluent	1	2	0	2	5	40%
Fishing	Shrimping	Bilge	0	0	5	5	10	50%
Fishing	Shrimping	Deck Wash	0	0	2	8	10	80%
Fishing	Shrimping	Fish Hold	0	2	0	8	10	80%
Fishing	Shrimping	Graywater	0	0	0	10	10	100%
Fishing	Tender Vessel	Fish Hold	0	0	0	3	3	100%
Fishing	Tender Vessel	Fish Hold Clean	0	0	1	2	3	67%
Fishing	Trawler	Deck Wash	0	0	2	8	10	80%
Fishing	Trawler	Fish Hold	0	2	0	8	10	80%
Fishing	Trawler	Fish Hold Clean	0	3	2	4	10	40%
Fishing	Troller	Deck Wash	2	0	3	1	6	17%

Appendix G.2: Percent of Vessels by Vessel Class and Discharge Type Discharging in the Harbor

Vessel Class	Vessel Subclass	Discharge	Number of Sampled Vessels without Discharge System or Process (A)	Number of Sampled Vessels with a No Discharge System (B)	Number of Sampled Vessels that DischargedOutside U.S. Waters (C)	Number of Sampled Vessels that Discharge in the Harbor [1] (D)	Total Number of Sampled Vessels (E=A+B+C+D)	Percent of Vessels with Discharge (D/E)
Fishing	Troller	Fish Hold	0	0	0	6	6	100%
Fishing	Troller	Fish Hold Clean	4	0	0	2	6	33%
Research	NA	Engine Effluent	0	0	0	2	2	100%
Supply Boat	NA	Deck Wash	0	0	0	1	1	100%
Tour Boat	NA	Bilge	1	0	0	2	3	67%
Tour Boat	NA	Deck Wash	1	0	0	2	3	67%
Tour Boat	NA	Engine Effluent	0	0	0	3	3	100%
Tour Boat	NA	Fire Main	0	0	0	3	3	100%
Tour Boat	NA	Generator Effluent	1	0	0	2	3	67%
Tow/Salvage	NA	Bilge	1	3	0	2	6	33%
Tow/Salvage	NA	Deck Wash	0	0	0	6	6	100%
Tow/Salvage	NA	Engine Effluent	0	1	0	5	6	83%
Tugboat	NA	Deck Wash	0	0	0	9	9	100%
Tugboat	NA	Fire Main	0	0	0	9	9	100%
Tugboat	NA	Graywater	0	3	0	6	9	67%
Tugboat	NA	Shaft Water	0	1	0	8	9	89%
Water Taxi	NA	Bilge	0	1	0	3	4	75%
Water Taxi	NA	Deck Wash	0	0	0	4	4	100%
Water Taxi	NA	Engine Effluent	0	0	0	4	4	100%
Water Taxi	NA	Generator Effluent	3	0	0	1	4	25%
Water Taxi	NA	Graywater	3	0	0	1	4	25%

(1) - The percentage of vessels discharging to the harbor were determined based on field observations of sampled vessels. As a conservative estimate, sampled vessel classes with no information available were assumed to discharge in the harbor.

Appendix G.3: Vessel Scenario Total Analyte-Specific Loading Rates

Analyte Class	Analyte	Vessel Scenario 1 Total Loading Rate Fishing Harbor	Vessel Scenario 2 Total Loading Rate Large Metropolitan Harbor	Vessel Scenario 3 Total Loading Rate Recreational Harbor	Units
Bacteria	E. Coli by MF	8,860,000,000	44,300,000,000	7,380,000,000	CFU/day
Bacteria	E. Coli by MPN	3,570,000,000	16,000,000,000	2,880,000,000	MPN/day
Bacteria	Enterococci by MF	5,000,000,000	25,000,000,000	4,170,000,000	CFU/day
Bacteria	Enterococci by MPN	1,010,000,000	891,000,000	547,000,000	MPN/day
Bacteria	Fecal Coliform by MF	27,500,000,000	81,500,000,000	20,300,000,000	CFU/day
Bacteria	Fecal Coliform by MPN	10,000,000,000	50,000,000,000	8,330,000,000	MPN/day
Bacteria	Total Coliforms by MPN	42,900,000,000	214,000,000,000	35,800,000,000	MPN/day
Classicals	Biochemical Oxygen Demand (BOD)	635	481	392	lb/day
Classicals	Chemical Oxygen Demand (COD)	1,840	1,310	1,100	lb/day
Classicals	Dissolved Oxygen	25.6	37.4	41.3	lb/day
Classicals	Hexane Extractable Material (HEM)	11.4	19.1	17.5	lb/day
Classicals	Silica Gel Treated HEM (SGT-HEM)	13.2	20.7	20.8	lb/day
Classicals	Sulfide	0.0152	0.0285	0.0203	lb/day
Classicals	Total Organic Carbon (TOC)	239	185	147	lb/day
Classicals	Total Residual Chlorine	0.403	0.730	0.565	lb/day
Classicals	Total Suspended Solids (TSS)	231	207	186	lb/day
Nutrients	Ammonia As Nitrogen (NH3-N)	8.52	6.07	5.07	lb/day
Nutrients	Nitrate/Nitrite (NO3/NO2-N)	0.127	0.203	0.102	lb/day
Nutrients	Total Kjeldahl Nitrogen (TKN)	97.8	68.5	59.0	lb/day
Nutrients	Total Phosphorus	13.8	8.91	7.74	lb/day
Metals	Aluminum, Dissolved	2.01	1.70	1.64	lb/day
Metals	Aluminum, Total	2.55	2.70	2.60	lb/day
Metals	Antimony, Dissolved	0.0000217	0.000111	0.0000470	lb/day
Metals	Antimony, Total	0.0000711	0.000348	0.000137	lb/day
Metals	Arsenic, Dissolved [1]	0.0190	0.0285	0.0256	lb/day
Metals	Arsenic, Total [1]	0.0279	0.0359	0.0315	lb/day
Metals	Barium, Dissolved	0.0326	0.0747	0.0666	lb/day
Metals	Barium, Total	0.0368	0.0895	0.0709	lb/day
Metals	Cadmium, Dissolved	0.0000294	0.0000433	0.0000306	lb/day
Metals	Cadmium, Total	0.000749	0.000657	0.000551	lb/day
Metals	Calcium, Dissolved	653	561	528	lb/day
Metals	Calcium, Total	647	566	534	lb/day
Metals	Chromium, Dissolved	0.00195	0.00447	0.00424	lb/day
Metals	Chromium, Total	0.00514	0.00890	0.00713	lb/day

Appendix G.3: Vessel Scenario Total Analyte-Specific Loading Rates

Analyte Class	Analyte	Vessel Scenario 1 Total Loading Rate Fishing Harbor	Vessel Scenario 2 Total Loading Rate Large Metropolitan Harbor	Vessel Scenario 3 Total Loading Rate Recreational Harbor	Units
Metals	Cobalt, Dissolved	0.0000745	0.000184	0.0000776	lb/day
Metals	Cobalt, Total	0.000148	0.000262	0.000108	lb/day
Metals	Copper, Dissolved	2.88	4.97	2.75	lb/day
Metals	Copper, Total	0.158	0.179	0.165	lb/day
Metals	Iron, Dissolved	0.0161	0.0465	0.0145	lb/day
Metals	Iron, Total	0.376	0.819	0.600	lb/day
Metals	Lead, Dissolved	0.00176	0.00338	0.00340	lb/day
Metals	Lead, Total	0.0108	0.0154	0.0142	lb/day
Metals	Magnesium, Dissolved	1,980	1,500	1,390	lb/day
Metals	Magnesium, Total	1,910	1,470	1,360	lb/day
Metals	Manganese, Dissolved	0.120	0.230	0.255	lb/day
Metals	Manganese, Total	0.148	0.296	0.321	lb/day
Metals	Nickel, Dissolved	0.00854	0.0140	0.0133	lb/day
Metals	Nickel, Total	0.00987	0.0165	0.0145	lb/day
Metals	Potassium, Dissolved	56.0	105	113	lb/day
Metals	Potassium, Total	56.1	105	112	lb/day
Metals	Selenium, Dissolved [1]	0.0215	0.0412	0.0443	lb/day
Metals	Selenium, Total [1]	0.0244	0.0440	0.0471	lb/day
Metals	Silver, Dissolved	0.0000276	0.0000221	0.0000138	lb/day
Metals	Silver, Total	0.0000519	0.0000415	0.0000259	lb/day
Metals	Sodium, Dissolved	1,240	2,460	2,750	lb/day
Metals	Sodium,Total	1,440	2,880	3,260	lb/day
Metals	Thallium, Dissolved	0.0000144	0.0000710	0.0000120	lb/day
Metals	Thallium,Total	0.000000157	0.000000785	0.000000131	lb/day
Metals	Vanadium, Dissolved	0.00101	0.00201	0.00227	lb/day
Metals	Vanadium,Total	0.00130	0.00269	0.00254	lb/day
Metals	Zinc, Dissolved	0.310	0.295	0.259	lb/day
Metals	Zinc, Total	0.758	0.613	0.516	lb/day
Nonylphenols	Bisphenol A	0.00000886	0.0000177	0.0000213	lb/day
Nonylphenols	Nonylphenol decaethoxylate (NP10EO)	0.00191	0.00338	0.00314	lb/day
Nonylphenols	Nonylphenol dodecaethoxylate (NP12EO)	0.00152	0.00270	0.00255	lb/day
Nonylphenols	Nonylphenol heptadecaethoxylate (NP17EO)	0.0000955	0.000170	0.000167	lb/day
Nonylphenols	Nonylphenol heptaethoxylate (NP7EO)	0.00122	0.00210	0.00177	lb/day
Nonylphenols	Nonylphenol hexadecaethoxylate (NP16EO)	0.000209	0.000362	0.000357	lb/day
Nonylphenols	Nonylphenol hexaethoxylate (NP6EO)	0.000866	0.00147	0.00117	lb/day

Appendix G.3: Vessel Scenario Total Analyte-Specific Loading Rates

Analyte Class	Analyte	Vessel Scenario 1 Total Loading Rate Fishing Harbor	Vessel Scenario 2 Total Loading Rate Large Metropolitan Harbor	Vessel Scenario 3 Total Loading Rate Recreational Harbor	Units
Nonylphenols	Nonylphenol nonaethoxylate (NP9EO)	0.00173	0.00300	0.00276	lb/day
Nonylphenols	Nonylphenol octaethoxylate (NP8EO)	0.00159	0.00269	0.00239	lb/day
Nonylphenols	Nonylphenol octodecaethoxylate (NP18EO)	0.0000505	0.0000818	0.0000832	lb/day
Nonylphenols	Nonylphenol pendecaethoxylate (NP15EO)	0.000398	0.000684	0.000675	lb/day
Nonylphenols	Nonylphenol pentaethoxylate (NP5EO)	0.000525	0.000860	0.000596	lb/day
Nonylphenols	Nonylphenol tetradecaethoxylate (NP14EO)	0.000708	0.00124	0.00121	lb/day
Nonylphenols	Nonylphenol tetraethoxylate (NP4EO)	0.000233	0.000390	0.000173	lb/day
Nonylphenols	Nonylphenol tridecaethoxylate (NP13EO)	0.00109	0.00191	0.00184	lb/day
Nonylphenols	Nonylphenol triethoxylate (NP3EO)	0.000131	0.000226	0.0000944	lb/day
Nonylphenols	Nonylphenol undecaethoxylate (NP11EO)	0.00194	0.00343	0.00321	lb/day
Nonylphenols	Octylphenol decaethoxylate (OP10EO)	0.0000690	0.000254	0.0000836	lb/day
Nonylphenols	Octylphenol dodecaethoxylate (OP12EO)	0.0000413	0.000122	0.0000383	lb/day
Nonylphenols	Octylphenol heptaethoxylate (OP7EO)	0.00000302	0.0000151	0.00000251	lb/day
Nonylphenols	Octylphenol nonaethoxylate (OP9EO)	0.0000418	0.0000808	0.0000311	lb/day
Nonylphenols	Octylphenol octaethoxylate (OP8EO)	0.0000257	0.000129	0.0000214	lb/day
Nonylphenols	Octylphenol undecaethoxylate (OP11EO)	0.0000445	0.000151	0.0000503	lb/day
Nonylphenols	Total Nonylphenol Polyethoxylates	0.0136	0.0232	0.0215	lb/day
Nonylphenols	Total Nonylphenols	0.000153	0.000122	0.0000763	lb/day
VOC	(2-Methyl-1-Propenyl)-Benzene	0.00298	0.00595	0.00714	lb/day
VOC	(E)-1-Propenyl-Benzene	0.00000135	0.00000675	0.00000540	lb/day
VOC	(E)-2-Butenal	0.00544	0.0109	0.0131	lb/day
VOC	1,2,3,4-Tetrahydro-1-Methylnaphthalene	0.00342	0.00684	0.00821	lb/day
VOC	1,2,3,4-Tetrahydro-2-Methylnaphthalene	0.00316	0.00632	0.00758	lb/day

Appendix G.3: Vessel Scenario Total Analyte-Specific Loading Rates

Analyte Class	Analyte	Vessel Scenario 1 Total Loading Rate Fishing Harbor	Vessel Scenario 2 Total Loading Rate Large Metropolitan Harbor	Vessel Scenario 3 Total Loading Rate Recreational Harbor	Units
VOC	1,2,3,4-Tetrahydro-5-Methylnaphthalene	0.0277	0.0556	0.0664	lb/day
VOC	1,2,3,4-Tetrahydro-6-Ethylnaphthalene,	0.00298	0.00597	0.00716	lb/day
VOC	1,2,3,4-Tetrahydro-6-Methylnaphthalene	0.0253	0.0512	0.0603	lb/day
VOC	1,2,3,4-Tetrahydro-6-Methylnaphthalene (01)	0.00633	0.0127	0.0152	lb/day
VOC	1,2,3,4-Tetrahydro-6-Methylnaphthalene (02)	0.00530	0.0106	0.0127	lb/day
VOC	1,2,3,4-Tetrahydronaphthalene	0.0190	0.0382	0.0456	lb/day
VOC	1,2,3,4-Tetramethyl-Benzene	0.000643	0.00429	0.00214	lb/day
VOC	1,2,3,5-Tetramethyl-Benzene	0.000947	0.00631	0.00316	lb/day
VOC	1,2,3-Trimethylbenzene	0.00309	0.0206	0.0103	lb/day
VOC	1,2,4,5-Tetramethylbenzene	0.00144	0.00963	0.00481	lb/day
VOC	1,2,4-Trimethylbenzene	0.00616	0.0281	0.0176	lb/day
VOC	1,3,5-Trimethylbenzene	0.00166	0.00819	0.00474	lb/day
VOC	1,3-Methylnaphthalene	0.00391	0.00781	0.00938	lb/day
VOC	1,7-Methylnaphthalene	0.0177	0.0353	0.0424	lb/day
VOC	1-Ethyl-2,3-Dimethyl-Benzene (01)	0.00272	0.00955	0.00735	lb/day
VOC	1-Ethyl-2,3-Dimethyl-Benzene (02)	0.000393	0.00262	0.00131	lb/day
VOC	1-Ethyl-2,4-Dimethyl-Benzene	0.00153	0.0102	0.00510	lb/day
VOC	1-Ethyl-2-Methyl-Benzene	0.00000417	0.0000208	0.0000167	lb/day
VOC	1-Ethyl-3-Methyl-Benzene	0.00327	0.00663	0.00790	lb/day
VOC	1-Ethyl-4-Methyl-Benzene	0.00644	0.0429	0.0215	lb/day
VOC	1-Methyl-2-(1-Methylethyl)-Benzene	0.00	0.00	0.00	lb/day
VOC	1-Methyl-2-(1-Methylethyl)-Benzene (01)	0.00000337	0.0000169	0.0000135	lb/day
VOC	1-Methyl-2-(1-Methylethyl)-Benzene (02)	0.0000118	0.0000589	0.0000471	lb/day
VOC	1-Methyl-3-Propyl-Benzene	0.00126	0.00836	0.00419	lb/day
VOC	1-Methyl-4-(1-Methylidene)-Cyclohexane	0.00	0.00	0.00	lb/day
VOC	1-methyl-Indan	0.00792	0.0201	0.0199	lb/day
VOC	1-Propenyl-Benzene	0.00000155	0.00000774	0.00000619	lb/day
VOC	2- Heptanone	0.0000601	0.000400	0.000200	lb/day
VOC	2,3-Dihydro-1,2-Dimethyl-1H-Indene	0.000323	0.00216	0.00108	lb/day

Appendix G.3: Vessel Scenario Total Analyte-Specific Loading Rates

Analyte Class	Analyte	Vessel Scenario 1 Total Loading Rate Fishing Harbor	Vessel Scenario 2 Total Loading Rate Large Metropolitan Harbor	Vessel Scenario 3 Total Loading Rate Recreational Harbor	Units
VOC	2,3-Dihydro-1,6-Dimethyl-1H-Indene	0.00356	0.0103	0.00906	lb/day
VOC	2,3-Dihydro-1-Methylindene	0.00518	0.0104	0.0124	lb/day
VOC	2,3-Dihydro-1-methylindene (01)	0.00290	0.00579	0.00695	lb/day
VOC	2,3-Dihydro-1-methylindene (02)	0.00614	0.0123	0.0147	lb/day
VOC	2,3-Dihydro-4,7-Dimethyl-1H-Indene	0.0000409	0.000204	0.0000409	lb/day
VOC	2,3-Dihydro-4-Methyl-1H-Indene	0.0546	0.119	0.133	lb/day
VOC	2,3-Dihydro-4-Methyl-1H-Indene (01)	0.00000480	0.0000240	0.0000192	lb/day
VOC	2,3-Dihydro-4-Methyl-1H-Indene (02)	0.00000810	0.0000405	0.0000324	lb/day
VOC	2,3-Dihydro-5,6-dimethyl-1H-Indene	0.00281	0.00562	0.00674	lb/day
VOC	2,3-Dihydro-5-methyl-1H-Indene	0.00159	0.0106	0.00530	lb/day
VOC	2,6-Dimethylnaphthalene	0.0384	0.0769	0.0923	lb/day
VOC	2-Butanone	0.0297	0.0613	0.0706	lb/day
VOC	2-Butenal	0.00340	0.00679	0.00815	lb/day
VOC	2-Ethyl-1,3,5-Trimethyl-Benzene	0.00409	0.00819	0.00982	lb/day
VOC	2-Ethyl-1,4-Dimethyl-Benzene	0.0189	0.0378	0.0454	lb/day
VOC	2-Ethyl-1-Hexanol	0.00000111	0.00000741	0.00000370	lb/day
VOC	2-Ethyltoluene	0.00541	0.0209	0.0150	lb/day
VOC	2-Hexanone	0.00262	0.00562	0.00618	lb/day
VOC	2-Methyl-2-Propenal	0.00632	0.0130	0.0150	lb/day
VOC	2-Propenyl-Benzene	0.00471	0.0314	0.0157	lb/day
VOC	3-Buten-2-one	0.00578	0.0117	0.0138	lb/day
VOC	4-Ethyl-1,2-Dimethyl-Benzene	0.00000429	0.0000214	0.0000171	lb/day
VOC	4-Heptanone	0.0000795	0.000530	0.000265	lb/day
VOC	4-Isopropyltoluene	0.000864	0.00187	0.00210	lb/day
VOC	4-Methyl-2-Pentanone	0.000900	0.00182	0.00215	lb/day
VOC	Acetaldehyde	0.0183	0.0371	0.0436	lb/day
VOC	Acetone	0.133	0.271	0.316	lb/day
VOC	Acrolein	0.00764	0.0155	0.0183	lb/day
VOC	Benzaldehyde	0.000237	0.000474	0.000569	lb/day
VOC	Benzene	0.00719	0.0208	0.0182	lb/day
VOC	Benzocycloheptatriene	0.0363	0.0726	0.0871	lb/day

Appendix G.3: Vessel Scenario Total Analyte-Specific Loading Rates

Analyte Class	Analyte	Vessel Scenario 1 Total Loading Rate Fishing Harbor	Vessel Scenario 2 Total Loading Rate Large Metropolitan Harbor	Vessel Scenario 3 Total Loading Rate Recreational Harbor	Units
VOC	Benzofuran	0.00368	0.00736	0.00883	lb/day
VOC	Bromodichloromethane	0.00000416	0.0000277	0.0000139	lb/day
VOC	Butane	0.000521	0.00347	0.00174	lb/day
VOC	Butyraldehyde	0.00448	0.00917	0.0107	lb/day
VOC	Carbon disulfide	0.00000279	0.00000559	0.00000671	lb/day
VOC	Chloroform	0.00244	0.00488	0.00585	lb/day
VOC	cis-1,2-Dichloroethene	0.00000430	0.00000860	0.0000103	lb/day
VOC	Cyclohexane	0.0000660	0.000439	0.000221	lb/day
VOC	Dibromochloromethane	0.00000408	0.0000272	0.0000136	lb/day
VOC	Dimethocxymethane	0.0156	0.0130	0.0117	lb/day
VOC	Ethanol	0.0000212	0.000142	0.0000708	lb/day
VOC	Ethylbenzene	0.00230	0.0114	0.00667	lb/day
VOC	Indene	0.0000735	0.000368	0.0000941	lb/day
VOC	Isopropylbenzene	0.00132	0.00323	0.00327	lb/day
VOC	Limonene	0.00	0.00	0.00	lb/day
VOC	m,p-Xylene (Sum of Isomers)	0.00728	0.0414	0.0224	lb/day
VOC	Methyl acetate	0.00190	0.00382	0.00457	lb/day
VOC	Methyl tertiary butyl ether (MTBE)	0.00000865	0.0000564	0.0000293	lb/day
VOC	Methylcyclohexane	0.0000599	0.000398	0.000200	lb/day
VOC	Methylene chloride	0.000477	0.00104	0.00115	lb/day
VOC	n-Butylbenzene	0.000819	0.00164	0.00197	lb/day
VOC	nitro-Methane	0.00272	0.00544	0.00653	lb/day
VOC	Nonanal	0.00000183	0.00000366	0.00000440	lb/day
VOC	n-Propylbenzene	0.000644	0.00313	0.00191	lb/day
VOC	n-Valeraldehyde	0.00397	0.00819	0.00943	lb/day
VOC	O-Xylene	0.00481	0.0267	0.0145	lb/day
VOC	sec-Butylbenzene	0.00186	0.00372	0.00446	lb/day
VOC	Styrene	0.00138	0.00368	0.00340	lb/day
VOC	Sulfur dioxide	0.00739	0.0385	0.00964	lb/day
VOC	Tetrachloroethene	0.00000345	0.00000789	0.00000776	lb/day
VOC	Toluene	0.00857	0.0417	0.0254	lb/day
VOC	Trichloroethene	0.00000301	0.00000602	0.00000722	lb/day
VOC	Trichlorofluoromethane	0.00158	0.00316	0.00379	lb/day
VOC	Tridecane	0.00325	0.00649	0.00779	lb/day
VOC	Unknown VOC	0.00379	0.00907	0.00939	lb/day
VOC	Unknown VOC (01)	0.00288	0.00597	0.00681	lb/day
VOC	Unknown VOC (02)	0.00382	0.00777	0.00910	lb/day
VOC	Unknown VOC (03)	0.00347	0.00707	0.00826	lb/day
VOC	Unknown VOC (04)	0.00228	0.00483	0.00535	lb/day
VOC	Unknown VOC (05)	0.00208	0.00434	0.00490	lb/day

Appendix G.3: Vessel Scenario Total Analyte-Specific Loading Rates

Analyte Class	Analyte	Vessel Scenario 1 Total Loading Rate Fishing Harbor	Vessel Scenario 2 Total Loading Rate Large Metropolitan Harbor	Vessel Scenario 3 Total Loading Rate Recreational Harbor	Units
VOC	Vinyl acetate	0.00202	0.00407	0.00485	lb/day
SVOC	(E)-2-Tetradecene	0.000237	0.00118	0.000237	lb/day
SVOC	1,2,3,4-Tetrahydro-2,7-Dimethylnaphthalene	0.000169	0.00112	0.000562	lb/day
SVOC	1,2,3-Trichloro-(Z)-1-Propene	0.0000494	0.000330	0.000165	lb/day
SVOC	1,2,3-Trimethylbenzene (1)	0.000719	0.00479	0.00240	lb/day
SVOC	1,2,3-Trimethylbenzene (2)	0.000917	0.00611	0.00306	lb/day
SVOC	1,2,4,5-Tetramethylbenzene (1)	0.000101	0.000671	0.000336	lb/day
SVOC	1,2,4,5-Tetramethylbenzene (2)	0.0000934	0.000623	0.000311	lb/day
SVOC	1,2-Diethyl-Cyclobutane	0.00930	0.0186	0.0223	lb/day
SVOC	1,3-Dimethylnaphthalene	0.0000821	0.000411	0.0000821	lb/day
SVOC	1,3-Dimethylnaphthalene (01)	0.00527	0.0105	0.0127	lb/day
SVOC	1,4-Dimethyl-1,2,3,4-tetrahydronaphthalene	0.00780	0.0156	0.0187	lb/day
SVOC	1,4-Dimethylnaphthalene	0.00840	0.0185	0.0204	lb/day
SVOC	1,4-Dimethylnaphthalene (01)	0.00559	0.0112	0.0134	lb/day
SVOC	1,5-Dimethylnaphthalene	0.000737	0.00461	0.00203	lb/day
SVOC	1,6-Dimethylnaphthalene	0.0395	0.0792	0.0948	lb/day
SVOC	1,7,7-tri-(methyl)-bicyclo[2.2.1]heptane	0.00	0.00	0.00	lb/day
SVOC	1-Dodecanol	0.0000265	0.000177	0.0000884	lb/day
SVOC	1-Hexadecene	0.00000246	0.0000164	0.00000819	lb/day
SVOC	1-Methyl-2-Propyl-Benzene (01)	0.000758	0.00506	0.00253	lb/day
SVOC	1-Methyl-2-Propyl-Benzene (02)	0.000219	0.00146	0.000730	lb/day
SVOC	1-Methylnaphthalene	0.0358	0.0737	0.0857	lb/day
SVOC	1-Phenyl-1-Butene	0.00000119	0.00000595	0.00000476	lb/day
SVOC	2-(dodecyloxy)-Ethanol	0.0000331	0.000221	0.000110	lb/day
SVOC	2-(hexadecyloxy)-Ethanol	0.00000851	0.0000567	0.0000284	lb/day
SVOC	2-(tetradecyloxy)-Ethanol	0.0000246	0.000164	0.0000819	lb/day
SVOC	2,3-Dimethylnaphthalene	0.00688	0.0138	0.0165	lb/day
SVOC	2,4,6-Trichlorophenol	0.0000142	0.0000284	0.0000340	lb/day
SVOC	2,4-Dimethyl-Benzaldehyde	0.00000221	0.0000111	0.00000886	lb/day
SVOC	2,4-Dimethylphenol	0.00198	0.00405	0.00470	lb/day
SVOC	2,6,10,14-Tetramethyl Pentadecane	0.0124	0.0252	0.0294	lb/day
SVOC	2,6,10,14-Tetramethylhexadecae	0.00826	0.0165	0.0198	lb/day

Appendix G.3: Vessel Scenario Total Analyte-Specific Loading Rates

Analyte Class	Analyte	Vessel Scenario 1 Total Loading Rate Fishing Harbor	Vessel Scenario 2 Total Loading Rate Large Metropolitan Harbor	Vessel Scenario 3 Total Loading Rate Recreational Harbor	Units
SVOC	2,6,10,14-Tetramethylhexadecae (01)	0.000267	0.00178	0.000890	lb/day
SVOC	2,6-dimethyl-Heptadecane	0.0135	0.0270	0.0324	lb/day
SVOC	2,7-Dimethylnaphthalene	0.00967	0.0206	0.0229	lb/day
SVOC	2-Cyclopenten1-one	0.000929	0.00186	0.00223	lb/day
SVOC	2-Ethyl-Hexanoic acid	0.0947	0.631	0.316	lb/day
SVOC	2-Hydroxy-Benzaldehyde	0.0144	0.0292	0.0343	lb/day
SVOC	2-Mercaptobenzothiazole	0.00	0.00	0.00	lb/day
SVOC	2-Methyl Tridecane	0.000141	0.000942	0.000471	lb/day
SVOC	2-Methyl-Benzaldehyde	0.00607	0.0122	0.0146	lb/day
SVOC	2-Methyl-Dodecane	0.000117	0.000585	0.000117	lb/day
SVOC	2-Methylnaphthalene	0.0458	0.0957	0.110	lb/day
SVOC	2-Naphthalenecarboxaldehyde	0.00102	0.00203	0.00244	lb/day
SVOC	3,4-Dimethylphenol	0.00000104	0.00000520	0.00000416	lb/day
SVOC	3,5-Dimethyl-Benzaldehyde	0.00000135	0.00000673	0.00000538	lb/day
SVOC	3,6-Dimethylundecane	0.00000205	0.0000102	0.00000171	lb/day
SVOC	3-Methyl-Benzaldehyde	0.0129	0.0258	0.0310	lb/day
SVOC	3-Methyl-Benzaldehyde (01)	0.0145	0.0290	0.0347	lb/day
SVOC	3-Methyl-butanoic acid	0.000448	0.000299	0.000280	lb/day
SVOC	3-Methyl-Phenanthrene	0.00605	0.0121	0.0145	lb/day
SVOC	3-Methylphenol	0.000677	0.00135	0.00163	lb/day
SVOC	3-Phenyl-2-Propenal	0.000457	0.000914	0.00110	lb/day
SVOC	4,4-Dimethylbiphenyl	0.00629	0.0126	0.0151	lb/day
SVOC	4-Hydroxy-2-Butanone	0.00705	0.0141	0.0169	lb/day
SVOC	4-Methyl-1H-Benzotriazole	0.00000709	0.0000142	0.0000170	lb/day
SVOC	4-METHYL-PENTANOIC ACID	0.000299	0.000199	0.000187	lb/day
SVOC	5-Butyl-Hexadecane	0.00000158	0.00000789	0.00000131	lb/day
SVOC	5-Methyl-2-(1-methyl)-Cyclohexanol	0.00000694	0.0000462	0.0000231	lb/day
SVOC	9-Methyl-9H-Fluorene	0.00648	0.0130	0.0155	lb/day
SVOC	Acenaphthylene	0.00351	0.00707	0.00841	lb/day
SVOC	Acetophenone	0.0000444	0.000222	0.0000444	lb/day
SVOC	Benzeneacetic Acid	0.000228	0.000152	0.000142	lb/day
SVOC	Benzenepropanoic Acid	0.000251	0.000168	0.000157	lb/day
SVOC	Benzothiazole	0.0000293	0.0000712	0.0000728	lb/day
SVOC	Benzyl alcohol	0.0000464	0.000232	0.0000464	lb/day
SVOC	Biphenyl	0.00353	0.00767	0.00832	lb/day
SVOC	Bis(2-ethylhexyl) phthalate	0.00148	0.00362	0.00347	lb/day
SVOC	Caprolactam	0.0000250	0.000167	0.0000834	lb/day

Appendix G.3: Vessel Scenario Total Analyte-Specific Loading Rates

Analyte Class	Analyte	Vessel Scenario 1 Total Loading Rate Fishing Harbor	Vessel Scenario 2 Total Loading Rate Large Metropolitan Harbor	Vessel Scenario 3 Total Loading Rate Recreational Harbor	Units
SVOC	Cholesterol	0.000691	0.000461	0.000432	lb/day
SVOC	Cyclic octaatomic sulfur	0.0223	0.122	0.0366	lb/day
SVOC	Cyclodecane	0.000242	0.00121	0.000242	lb/day
SVOC	Cyclododecane	0.0000275	0.000182	0.0000903	lb/day
SVOC	Cyclotetradecane	0.0000145	0.0000967	0.0000484	lb/day
SVOC	Diethene Glycol Monododecyl Ether	0.0000273	0.000182	0.0000911	lb/day
SVOC	Dimethyl phthalate	0.0000827	0.000165	0.000199	lb/day
SVOC	Di-n-butyl phthalate	0.00182	0.00409	0.00424	lb/day
SVOC	Di-n-octyl phthalate	0.0000528	0.000344	0.000174	lb/day
SVOC	Disopropylene glycol	0.00000806	0.0000538	0.0000269	lb/day
SVOC	Dodecane	0.00000118	0.00000589	0.000000981	lb/day
SVOC	Dodecanoic acid	0.0000198	0.000132	0.0000661	lb/day
SVOC	Eicosane	0.0307	0.0638	0.0742	lb/day
SVOC	Ethanol, 2,2-oxybis-	0.000892	0.00595	0.00297	lb/day
SVOC	Ethanol, 2-Butoxy	0.00787	0.0157	0.0189	lb/day
SVOC	Fluorene	0.00374	0.00755	0.00896	lb/day
SVOC	Heneicosane	0.00918	0.0217	0.0227	lb/day
SVOC	Heptadecane	0.0548	0.111	0.131	lb/day
SVOC	Hexaethylene Glycol Monododecyl	0.0000166	0.000111	0.0000555	lb/day
SVOC	Hexaethylene Glycol Monododecyl (01)	0.00000667	0.0000444	0.0000222	lb/day
SVOC	Hexaethylene Glycol Monododecyl (02)	0.00000210	0.0000140	0.00000702	lb/day
SVOC	Hexagol	0.00000960	0.0000640	0.0000320	lb/day
SVOC	Indane	0.000785	0.00523	0.00262	lb/day
SVOC	Indole	0.00126	0.000838	0.000786	lb/day
SVOC	Isopropylbenzene-4,methyl-1	0.00	0.00	0.00	lb/day
SVOC	m-Cresol	0.0000717	0.000358	0.0000748	lb/day
SVOC	Naphthalene	0.0167	0.0395	0.0405	lb/day
SVOC	N-Butyl-Benzenesulfonamide	0.00000275	0.0000183	0.00000915	lb/day
SVOC	n-Hexadecane	0.0521	0.105	0.125	lb/day
SVOC	n-Hexadecanoic acid	0.0000140	0.0000935	0.0000468	lb/day
SVOC	Nonadecane	0.0421	0.0849	0.101	lb/day
SVOC	Nonadecane (01)	0.0130	0.0260	0.0312	lb/day
SVOC	Nonanoic Acid	0.0102	0.0205	0.0246	lb/day
SVOC	n-Pentadecane	0.0389	0.0952	0.0963	lb/day
SVOC	n-Tetradecane	0.0490	0.109	0.119	lb/day
SVOC	o-Cresol	0.00581	0.0116	0.0139	lb/day
SVOC	Octadecane	0.0118	0.0237	0.0284	lb/day

Appendix G.3: Vessel Scenario Total Analyte-Specific Loading Rates

Analyte Class	Analyte	Vessel Scenario 1 Total Loading Rate Fishing Harbor	Vessel Scenario 2 Total Loading Rate Large Metropolitan Harbor	Vessel Scenario 3 Total Loading Rate Recreational Harbor	Units
SVOC	p-Cresol	0.0175	0.0365	0.0416	lb/day
SVOC	Pentacosane	0.000243	0.00162	0.000811	lb/day
SVOC	Pentaethene Glycol Monododecyl Ether	0.00000225	0.0000150	0.00000750	lb/day
SVOC	Pentaethene Glycol Monododecyl Ether (01)	0.0000164	0.000110	0.0000548	lb/day
SVOC	Pentaethene Glycol Monododecyl Ether (02)	0.0000324	0.000216	0.000108	lb/day
SVOC	Phenanthrene	0.00319	0.00790	0.00762	lb/day
SVOC	Phenol	0.0365	0.0737	0.0853	lb/day
SVOC	Phthalic acid, isobutyl octyl ester	0.0000130	0.0000260	0.0000312	lb/day
SVOC	Pyrene	0.000119	0.000783	0.000381	lb/day
SVOC	Sulfur	0.0101	0.0510	0.0106	lb/day
SVOC	Tetraethylene glycol monododecyl ether	0.0000168	0.000112	0.0000559	lb/day
SVOC	Triethyl phosphate	0.000170	0.000130	0.000129	lb/day
SVOC	Triethylene glycol monododecyl ether	0.0000249	0.000166	0.0000830	lb/day
SVOC	Unknown SVOC	0.00970	0.0212	0.0226	lb/day
SVOC	Unknown SVOC (01)	0.00893	0.0205	0.0208	lb/day
SVOC	Unknown SVOC (02)	0.00957	0.0222	0.0220	lb/day
SVOC	Unknown SVOC (03)	0.000681	0.00327	0.000879	lb/day
SVOC	Unknown SVOC (04)	0.000637	0.00337	0.000902	lb/day
SVOC	Unknown SVOC (05)	0.000188	0.00117	0.000508	lb/day
SVOC	Unknown SVOC (06)	0.000124	0.000758	0.000315	lb/day
SVOC	Unknown SVOC (07)	0.00141	0.00940	0.00470	lb/day

(1) EPA suspects a limited number of the samples analyzed for selenium (even fewer for arsenic) for bilgewater, packing gland effluent, propulsion engine effluent, graywater and deck washdown water may be positively influenced (increased) by interference from high concentrations of major cations in the sample matrix. Although EPA suspects that the highest concentrations of dissolved arsenic (and to a lesser extent selenium) in fish hold effluent from a shrimping vessel could be slightly elevated due to cation interference; EPA believes the fish hold concentrations reasonably represent true effluent concentrations for the discharge (see Section 3.2.4.1). EPA considered these interferences when interpreting the potential for vessel discharges to pose a risk to human health, aquatic life, or the environment and determined that such cationic interference does not influence the major findings presented in the modeling analysis.

Appendix G.4: Real World Water Body Characterization Data for Model Input Parameter Development

Harbor Name	River Name	City Name	Harbor Salinity (PSU)[a]	Ocean Salinity (PSU)[b]	Harbor Volume (m^3)[c]	River Flow (m^3/day)[d]	fx	Flushing Time (days)	Scenario 1 Dilution	Scenario 2 Dilution	Scenario 3 Dilution
Auke Bay	Mendenhall River	Juneau, AK	26.1	35	3,090,000	2,900,000	0.254	0.271	5,800	4,170	4,060
Biscayne Bay	Miami River	Miami, FL	31	35	38,500,000	352,000	0.114	12.5	1,570	1,130	1,100
Cohasset Harbor	Gulf River	Boston, MA	30.8	35	1,170,000	89,800	0.121	1.59	377	270	264
Craford Bay	Eastern and Southern Branch Elizabeth River	Norfolk, VA	19.8	35	1,660,000	384,000	0.434	1.87	451	323	315
Dorchester Bay	Neponset River	Boston, MA	31.1	35	43,300,000	467,000	0.111	10.3	2,140	1,530	1,500
Eastern Channel	Indian River	Sitka, AK	30.8	35	8,500,000	210,000	0.12	4.84	893	641	625
Mobile Bay	Tensaw, Blakeley, and Mobile River	Mobile, AL	16.7	35	1,970,000,000	167,000,000	0.523	6.16	163,000	117,000	114,000
Yaquina Bay	Yaquina River	Newport, OR	29.3	35	6,880,000	2,060,000	0.163	0.544	6,440	4,630	4,510

[a] Sources: NOAA World Oceans Database (Auke Bay, Dorchester Bay, Eastern Channel, and Mobile Bay), USGS Changing Salinity Patterns in Biscayne Bay, Florida Study (Biscayne Bay), Massachusetts Department of Environmental Protection Total Maximum Daily Loads of Bacteria for Little Harbor (Cohasset Harbor), EPA EMAP Salinity Data (Craford Bay), Oregon State Temperature and Salinity of the Yaquina Bay Estuary and the Potential Range of Carcinus maenas Study (Yaquina Bay).

[b] Ocean salinity based on average ocean salinity of 35 PSU.

[c] Harbor volume was estimated based on surface areas and harbor depths estimated from NOAA Booklet Charts (http://ocsdata.ncd.noaa.gov/BookletChart/) accessed 7/28/2009.

[d] River flows were based on average annual flows estimated in the USGS NHD Plus GIS dataset. Alaska average annual rivers flows were calculated based on based USGS surface-water monthly statistics for site USGS 15052500 and USGS 15087700 available in the USGS National Water Information System.

Appendix G.5: Fishing Harbor Vessel Scenarios Instantaneous Concentration in the Hypothetical Harbor

Class	Analyte	Model Scenarios 1 and 3	Model Scenarios 2 and 4	Model Scenarios 5 and 7	Model Scenarios 6 and 8	Units
Bacteria	E. Coli by MF	0.64	0.0777	0.288	0.0349	CFU/100 ml
Bacteria	E. Coli by MPN	0.258	0.0313	0.116	0.0141	MPN/100 ml
Bacteria	Enterococci by MF	0.361	0.0438	0.162	0.0197	CFU/100 ml
Bacteria	Enterococci by MPN	0.0733	0.0089	0.0329	0.004	MPN/100 ml
Bacteria	Fecal Coliform by MF	1.96	0.238	0.883	0.107	CFU/100 ml
Bacteria	Fecal Coliform by MPN	0.722	0.0877	0.325	0.0394	MPN/100 ml
Bacteria	Total Coliforms by MPN	3.1	0.376	1.39	0.169	MPN/100 ml
Classicals	Biochemical Oxygen Demand (BOD)	0.208	0.0252	0.0935	0.0113	mg/l
Classicals	Chemical Oxygen Demand (COD)	0.604	0.0733	0.271	0.0329	mg/l
Classicals	Dissolved Oxygen	0.00838	0.00102	0.00377	0.000457	mg/l
Classicals	Hexane Extractable Material (HEM)	0.00373	0.000452	0.00167	0.000203	mg/l
Classicals	Silica Gel Treated HEM (SGT-HEM)	0.00432	0.000525	0.00194	0.000236	mg/l
Classicals	Sulfide	0.00000497	6.03E-07	0.00000223	2.71E-07	mg/l
Classicals	Total Organic Carbon (TOC)	0.0783	0.0095	0.0352	0.00427	mg/l
Classicals	Total Residual Chlorine	0.000132	0.000016	0.0000593	0.0000072	mg/l
Classicals	Total Suspended Solids (TSS)	0.0758	0.0092	0.0341	0.00413	mg/l
Nutrients	Ammonia As Nitrogen (NH3-N)	0.00279	0.000339	0.00125	0.000152	mg/l
Nutrients	Nitrate/Nitrite (NO3/NO2-N)	0.0000415	0.00000504	0.0000187	0.00000226	mg/l
Nutrients	Total Kjeldahl Nitrogen (TKN)	0.0321	0.00389	0.0144	0.00175	mg/l
Nutrients	Total Phosphorus	0.00451	0.000547	0.00203	0.000246	mg/l
Metals	Aluminum, Dissolved	0.658	0.0798	0.296	0.0359	µg/l
Metals	Aluminum, Total	0.835	0.101	0.375	0.0455	µg/l
Metals	Antimony, Dissolved	0.00000712	8.65E-07	0.0000032	3.89E-07	µg/l
Metals	Antimony, Total	0.0000233	0.00000283	0.0000105	0.00000127	µg/l
Metals	Arsenic, Dissolved [1]	0.00624	0.000758	0.00281	0.00034	µg/l
Metals	Arsenic, Total [1]	0.00913	0.00111	0.0041	0.000498	µg/l
Metals	Barium, Dissolved	0.0107	0.0013	0.0048	0.000582	µg/l
Metals	Barium, Total	0.0121	0.00146	0.00542	0.000658	µg/l
Metals	Cadmium, Dissolved	0.00000963	0.00000117	0.00000433	5.25E-07	µg/l
Metals	Cadmium, Total	0.000246	0.0000298	0.00011	0.0000134	µg/l
Metals	Calcium, Dissolved	214	26	96.2	11.7	µg/l
Metals	Calcium, Total	212	25.7	95.3	11.6	µg/l
Metals	Chromium, Dissolved	0.000639	0.0000775	0.000287	0.0000348	µg/l
Metals	Chromium, Total	0.00168	0.000204	0.000757	0.0000919	µg/l
Metals	Cobalt, Dissolved	0.0000244	0.00000296	0.000011	0.00000133	µg/l
Metals	Cobalt, Total	0.0000484	0.00000588	0.0000218	0.00000264	µg/l
Metals	Copper, Dissolved	0.942	0.114	0.423	0.0514	µg/l
Metals	Copper, Total	0.0518	0.00629	0.0233	0.00283	µg/l
Metals	Iron, Dissolved	0.00528	0.000641	0.00237	0.000288	µg/l
Metals	Iron, Total	0.123	0.015	0.0554	0.00672	µg/l

Appendix G.5: Fishing Harbor Vessel Scenarios Instantaneous Concentration in the Hypothetical Harbor

Class	Analyte	Model Scenarios 1 and 3	Model Scenarios 2 and 4	Model Scenarios 5 and 7	Model Scenarios 6 and 8	Units
Metals	Lead, Dissolved	0.000578	0.0000701	0.00026	0.0000315	µg/l
Metals	Lead, Total	0.00353	0.000429	0.00159	0.000193	µg/l
Metals	Magnesium, Dissolved	649	78.8	292	35.4	µg/l
Metals	Magnesium, Total	625	75.9	281	34.1	µg/l
Metals	Manganese, Dissolved	0.0392	0.00476	0.0176	0.00214	µg/l
Metals	Manganese, Total	0.0485	0.00588	0.0218	0.00264	µg/l
Metals	Nickel, Dissolved	0.0028	0.00034	0.00126	0.000153	µg/l
Metals	Nickel, Total	0.00323	0.000392	0.00145	0.000176	µg/l
Metals	Potassium, Dissolved	18.3	2.23	8.24	1	µg/l
Metals	Potassium, Total	18.4	2.23	8.26	1	µg/l
Metals	Selenium, Dissolved[1]	0.00704	0.000854	0.00316	0.000384	µg/l
Metals	Selenium, Total[1]	0.00801	0.000972	0.0036	0.000437	µg/l
Metals	Silver, Dissolved	0.00000904	0.0000011	0.00000406	4.93E-07	µg/l
Metals	Silver, Total	0.000017	0.00000206	0.00000764	9.27E-07	µg/l
Metals	Sodium, Dissolved	405	49.1	182	22.1	µg/l
Metals	Sodium,Total	473	57.4	213	25.8	µg/l
Metals	Thallium, Dissolved	0.00000472	5.73E-07	0.00000212	2.58E-07	µg/l
Metals	Thallium,Total	5.14E-08	6.24E-09	2.31E-08	2.81E-09	µg/l
Metals	Vanadium, Dissolved	0.000331	0.0000402	0.000149	0.0000181	µg/l
Metals	Vanadium,Total	0.000425	0.0000516	0.000191	0.0000232	µg/l
Metals	Zinc, Dissolved	0.101	0.0123	0.0456	0.00553	µg/l
Metals	Zinc, Total	0.248	0.0301	0.112	0.0135	µg/l
Nonylphenols	Bisphenol A	0.0000029	3.52E-07	0.00000131	1.58E-07	µg/l
Nonylphenols	Nonylphenol decaethoxylate (NP10EO)	0.000627	0.0000761	0.000282	0.0000342	µg/l
Nonylphenols	Nonylphenol dodecaethoxylate (NP12EO)	0.000499	0.0000605	0.000224	0.0000272	µg/l
Nonylphenols	Nonylphenol heptadecaethoxylate (NP17EO)	0.0000313	0.0000038	0.0000141	0.00000171	µg/l
Nonylphenols	Nonylphenol heptaethoxylate (NP7EO)	0.000401	0.0000486	0.00018	0.0000218	µg/l
Nonylphenols	Nonylphenol hexadecaethoxylate (NP16EO)	0.0000684	0.0000083	0.0000307	0.00000373	µg/l
Nonylphenols	Nonylphenol hexaethoxylate (NP6EO)	0.000284	0.0000344	0.000127	0.0000155	µg/l
Nonylphenols	Nonylphenol nonaethoxylate (NP9EO)	0.000566	0.0000687	0.000254	0.0000309	µg/l
Nonylphenols	Nonylphenol octaethoxylate (NP8EO)	0.000521	0.0000632	0.000234	0.0000284	µg/l
Nonylphenols	Nonylphenol octodecaethoxylate (NP18EO)	0.0000165	0.00000201	0.00000743	9.02E-07	µg/l
Nonylphenols	Nonylphenol pendecaethoxylate (NP15EO)	0.00013	0.0000158	0.0000586	0.00000711	µg/l
Nonylphenols	Nonylphenol pentaethoxylate (NP5EO)	0.000172	0.0000209	0.0000773	0.00000938	µg/l
Nonylphenols	Nonylphenol tetradecaethoxylate (NP14EO)	0.000232	0.0000282	0.000104	0.0000127	µg/l
Nonylphenols	Nonylphenol tetraethoxylate (NP4EO)	0.0000763	0.00000926	0.0000343	0.00000416	µg/l
Nonylphenols	Nonylphenol tridecaethoxylate (NP13EO)	0.000356	0.0000432	0.00016	0.0000194	µg/l
Nonylphenols	Nonylphenol triethoxylate (NP3EO)	0.000043	0.00000522	0.0000193	0.00000235	µg/l
Nonylphenols	Nonylphenol undecaethoxylate (NP11EO)	0.000637	0.0000774	0.000286	0.0000348	µg/l
Nonylphenols	Octylphenol decaethoxylate (OP10EO)	0.0000226	0.00000275	0.0000102	0.00000123	µg/l

Appendix G.5: Fishing Harbor Vessel Scenarios Instantaneous Concentration in the Hypothetical Harbor

Class	Analyte	Model Scenarios 1 and 3	Model Scenarios 2 and 4	Model Scenarios 5 and 7	Model Scenarios 6 and 8	Units
Nonylphenols	Octylphenol dodecaethoxylate (OP12EO)	0.0000135	0.00000164	0.00000608	7.38E-07	µg/l
Nonylphenols	Octylphenol heptaethoxylate (OP7EO)	0.000000989	0.00000012	4.44E-07	5.39E-08	µg/l
Nonylphenols	Octylphenol nonaethoxylate (OP9EO)	0.0000137	0.00000166	0.00000615	7.47E-07	µg/l
Nonylphenols	Octylphenol octaethoxylate (OP8EO)	0.00000843	0.00000102	0.00000379	0.00000046	µg/l
Nonylphenols	Octylphenol undecaethoxylate (OP11EO)	0.0000146	0.00000177	0.00000655	7.95E-07	µg/l
Nonylphenols	Total Nonylphenol Polyethoxylates	0.00445	0.000541	0.002	0.000243	µg/l
Nonylphenols	Total Nonylphenols	0.00005	0.00000607	0.0000225	0.00000273	µg/l
VOC	(2-Methyl-1-Propenyl)-Benzene	0.000975	0.000118	0.000438	0.0000532	µg/l
VOC	(E)-1-Propenyl-Benzene	0.000000442	5.37E-08	1.99E-07	2.41E-08	µg/l
VOC	(E)-2-Butenal	0.00178	0.000217	0.000802	0.0000973	µg/l
VOC	1,2,3,4-Tetrahydro-1-Methylnaphthalene	0.00112	0.000136	0.000504	0.0000612	µg/l
VOC	1,2,3,4-Tetrahydro-2-Methylnaphthalene	0.00103	0.000126	0.000465	0.0000565	µg/l
VOC	1,2,3,4-Tetrahydro-5-Methylnaphthalene	0.00908	0.0011	0.00408	0.000495	µg/l
VOC	1,2,3,4-Tetrahydro-6-Ethylnaphthalene,	0.000977	0.000119	0.000439	0.0000533	µg/l
VOC	1,2,3,4-Tetrahydro-6-Methylnaphthalene	0.00828	0.001	0.00372	0.000451	µg/l
VOC	1,2,3,4-Tetrahydro-6-Methylnaphthalene (01)	0.00208	0.000252	0.000933	0.000113	µg/l
VOC	1,2,3,4-Tetrahydro-6-Methylnaphthalene (02)	0.00174	0.000211	0.00078	0.0000947	µg/l
VOC	1,2,3,4-Tetrahydronaphthalene	0.00623	0.000756	0.0028	0.00034	µg/l
VOC	1,2,3,4-Tetramethyl-Benzene	0.000211	0.0000256	0.0000947	0.0000115	µg/l
VOC	1,2,3,5-Tetramethyl-Benzene	0.00031	0.0000376	0.000139	0.0000169	µg/l
VOC	1,2,3-Trimethylbenzene	0.00101	0.000123	0.000455	0.0000552	µg/l
VOC	1,2,4,5-Tetramethylbenzene	0.000473	0.0000574	0.000213	0.0000258	µg/l
VOC	1,2,4-Trimethylbenzene	0.00202	0.000245	0.000907	0.00011	µg/l
VOC	1,3,5-Trimethylbenzene	0.000545	0.0000662	0.000245	0.0000297	µg/l
VOC	1,3-Methylnaphthalene	0.00128	0.000155	0.000575	0.0000698	µg/l
VOC	1,7-Methylnaphthalene	0.00579	0.000703	0.0026	0.000316	µg/l
VOC	1-Ethyl-2,3-Dimethyl-Benzene (01)	0.000892	0.000108	0.000401	0.0000487	µg/l
VOC	1-Ethyl-2,3-Dimethyl-Benzene (02)	0.000129	0.0000156	0.0000579	0.00000703	µg/l
VOC	1-Ethyl-2,4-Dimethyl-Benzene	0.000501	0.0000608	0.000225	0.0000273	µg/l
VOC	1-Ethyl-2-Methyl-Benzene	0.00000137	1.66E-07	6.14E-07	7.45E-08	µg/l
VOC	1-Ethyl-3-Methyl-Benzene	0.00107	0.00013	0.000482	0.0000585	µg/l
VOC	1-Ethyl-4-Methyl-Benzene	0.00211	0.000256	0.000949	0.000115	µg/l
VOC	1-Methyl-2-(1-Methylethyl)-Benzene	0	0	0	0	µg/l
VOC	1-Methyl-2-(1-Methylethyl)-Benzene (01)	0.00000111	1.34E-07	4.97E-07	6.03E-08	µg/l
VOC	1-Methyl-2-(1-Methylethyl)-Benzene (02)	0.00000386	4.69E-07	0.00000174	2.11E-07	µg/l
VOC	1-Methyl-3-Propyl-Benzene	0.000411	0.0000499	0.000185	0.0000224	µg/l
VOC	1-Methyl-4-(1-Methylidene)-Cyclohexane	0	0	0	0	µg/l
VOC	1-methyl-Indan	0.0026	0.000315	0.00117	0.000142	µg/l
VOC	1-Propenyl-Benzene	0.000000507	6.16E-08	2.28E-07	2.77E-08	µg/l
VOC	2- Heptanone	0.0000197	0.00000239	0.00000885	0.00000107	µg/l
VOC	2,3-Dihydro-1,2-Dimethyl-1H-Indene	0.000106	0.0000129	0.0000476	0.00000578	µg/l

Appendix G.5: Fishing Harbor Vessel Scenarios Instantaneous Concentration in the Hypothetical Harbor

Class	Analyte	Model Scenarios 1 and 3	Model Scenarios 2 and 4	Model Scenarios 5 and 7	Model Scenarios 6 and 8	Units
VOC	2,3-Dihydro-1,6-Dimethyl-1H-Indene	0.00117	0.000141	0.000524	0.0000636	µg/l
VOC	2,3-Dihydro-1-Methylindene	0.0017	0.000206	0.000763	0.0000926	µg/l
VOC	2,3-Dihydro-1-methylindene (01)	0.000949	0.000115	0.000426	0.0000518	µg/l
VOC	2,3-Dihydro-1-methylindene (02)	0.00201	0.000244	0.000904	0.00011	µg/l
VOC	2,3-Dihydro-4,7-Dimethyl-1H-Indene	0.0000134	0.00000163	0.00000602	7.31E-07	µg/l
VOC	2,3-Dihydro-4-Methyl-1H-Indene	0.0179	0.00217	0.00804	0.000975	µg/l
VOC	2,3-Dihydro-4-Methyl-1H-Indene (01)	0.00000157	1.91E-07	7.07E-07	8.58E-08	µg/l
VOC	2,3-Dihydro-4-Methyl-1H-Indene (02)	0.00000265	3.22E-07	0.00000119	1.45E-07	µg/l
VOC	2,3-Dihydro-5,6-dimethyl-1H-Indene	0.00092	0.000112	0.000413	0.0000502	µg/l
VOC	2,3-Dihydro-5-methyl-1H-Indene	0.000521	0.0000632	0.000234	0.0000284	µg/l
VOC	2,6-Dimethylnaphthalene	0.0126	0.00153	0.00566	0.000687	µg/l
VOC	2-Butanone	0.00974	0.00118	0.00438	0.000531	µg/l
VOC	2-Butenal	0.00111	0.000135	0.0005	0.0000607	µg/l
VOC	2-Ethyl-1,3,5-Trimethyl-Benzene	0.00134	0.000163	0.000603	0.0000732	µg/l
VOC	2-Ethyl-1,4-Dimethyl-Benzene	0.0062	0.000753	0.00279	0.000338	µg/l
VOC	2-Ethyl-1-Hexanol	0.000000364	4.42E-08	1.64E-07	1.99E-08	µg/l
VOC	2-Ethyltoluene	0.00177	0.000215	0.000797	0.0000968	µg/l
VOC	2-Hexanone	0.000857	0.000104	0.000385	0.0000468	µg/l
VOC	2-Methyl-2-Propenal	0.00207	0.000251	0.000931	0.000113	µg/l
VOC	2-Propenyl-Benzene	0.00154	0.000187	0.000693	0.0000842	µg/l
VOC	3-Buten-2-one	0.00189	0.00023	0.000851	0.000103	µg/l
VOC	4-Ethyl-1,2-Dimethyl-Benzene	0.0000014	0.00000017	6.31E-07	7.66E-08	µg/l
VOC	4-Heptanone	0.000026	0.00000316	0.0000117	0.00000142	µg/l
VOC	4-Isopropyltoluene	0.000283	0.0000344	0.000127	0.0000155	µg/l
VOC	4-Methyl-2-Pentanone	0.000295	0.0000358	0.000132	0.0000161	µg/l
VOC	Acetaldehyde	0.00599	0.000727	0.00269	0.000327	µg/l
VOC	Acetone	0.0435	0.00528	0.0195	0.00237	µg/l
VOC	Acrolein	0.0025	0.000304	0.00113	0.000137	µg/l
VOC	Benzaldehyde	0.0000777	0.00000943	0.0000349	0.00000424	µg/l
VOC	Benzene	0.00236	0.000286	0.00106	0.000129	µg/l
VOC	Benzocycloheptatriene	0.0119	0.00144	0.00534	0.000648	µg/l
VOC	Benzofuran	0.00121	0.000146	0.000542	0.0000658	µg/l
VOC	Bromodichloromethane	0.00000136	1.65E-07	6.12E-07	7.43E-08	µg/l
VOC	Butane	0.000171	0.0000207	0.0000768	0.00000932	µg/l
VOC	Butyraldehyde	0.00147	0.000178	0.00066	0.0000801	µg/l
VOC	Carbon disulfide	0.000000916	1.11E-07	4.12E-07	0.00000005	µg/l
VOC	Chloroform	0.000799	0.000097	0.000359	0.0000436	µg/l
VOC	cis-1,2-Dichloroethene	0.00000141	1.71E-07	6.33E-07	7.68E-08	µg/l
VOC	Cyclohexane	0.0000216	0.00000263	0.00000973	0.00000118	µg/l
VOC	Dibromochloromethane	0.00000134	1.62E-07	6.01E-07	7.29E-08	µg/l
VOC	Dimethocxymethane	0.00512	0.000621	0.0023	0.000279	µg/l
VOC	Ethanol	0.00000696	8.45E-07	0.00000313	0.00000038	µg/l
VOC	Ethylbenzene	0.000754	0.0000916	0.000339	0.0000411	µg/l

Appendix G.5: Fishing Harbor Vessel Scenarios Instantaneous Concentration in the Hypothetical Harbor

Class	Analyte	Model Scenarios 1 and 3	Model Scenarios 2 and 4	Model Scenarios 5 and 7	Model Scenarios 6 and 8	Units
VOC	Indene	0.0000241	0.00000292	0.0000108	0.00000131	µg/l
VOC	Isopropylbenzene	0.000431	0.0000523	0.000194	0.0000235	µg/l
VOC	Limonene	0	0	0	0	µg/l
VOC	m,p-Xylene (Sum of Isomers)	0.00239	0.00029	0.00107	0.00013	µg/l
VOC	Methyl acetate	0.000624	0.0000757	0.00028	0.000034	µg/l
VOC	Methyl tertiary butyl ether (MTBE)	0.00000283	3.44E-07	0.00000127	1.55E-07	µg/l
VOC	Methylcyclohexane	0.0000196	0.00000238	0.00000883	0.00000107	µg/l
VOC	Methylene chloride	0.000156	0.000019	0.0000703	0.00000853	µg/l
VOC	n-Butylbenzene	0.000268	0.0000326	0.000121	0.0000146	µg/l
VOC	nitro-Methane	0.000891	0.000108	0.000401	0.0000486	µg/l
VOC	Nonanal	0.0000006	7.28E-08	0.00000027	3.27E-08	µg/l
VOC	n-Propylbenzene	0.000211	0.0000256	0.0000949	0.0000115	µg/l
VOC	n-Valeraldehyde	0.0013	0.000158	0.000585	0.000071	µg/l
VOC	O-Xylene	0.00158	0.000191	0.000708	0.000086	µg/l
VOC	sec-Butylbenzene	0.000609	0.0000739	0.000274	0.0000332	µg/l
VOC	Styrene	0.000451	0.0000548	0.000203	0.0000246	µg/l
VOC	Sulfur dioxide	0.00242	0.000294	0.00109	0.000132	µg/l
VOC	Tetrachloroethene	0.00000113	1.37E-07	5.08E-07	6.17E-08	µg/l
VOC	Toluene	0.00281	0.000341	0.00126	0.000153	µg/l
VOC	Trichloroethene	0.000000986	0.00000012	4.43E-07	5.38E-08	µg/l
VOC	Trichlorofluoromethane	0.000518	0.0000628	0.000233	0.0000282	µg/l
VOC	Tridecane	0.00106	0.000129	0.000478	0.000058	µg/l
VOC	Unknown VOC	0.00124	0.000151	0.000558	0.0000677	µg/l
VOC	Unknown VOC (01)	0.000943	0.000114	0.000424	0.0000515	µg/l
VOC	Unknown VOC (02)	0.00125	0.000152	0.000562	0.0000682	µg/l
VOC	Unknown VOC (03)	0.00114	0.000138	0.000511	0.000062	µg/l
VOC	Unknown VOC (04)	0.000748	0.0000908	0.000336	0.0000408	µg/l
VOC	Unknown VOC (05)	0.000681	0.0000827	0.000306	0.0000372	µg/l
VOC	Vinyl acetate	0.000663	0.0000805	0.000298	0.0000362	µg/l
SVOC	(E)-2-Tetradecene	0.0000776	0.00000942	0.0000349	0.00000423	µg/l
SVOC	1,2,3,4-Tetrahydro-2,7-Dimethylnaphthalene	0.0000553	0.00000671	0.0000248	0.00000302	µg/l
SVOC	1,2,3-Trichloro-(Z)-1-Propene	0.0000162	0.00000197	0.00000728	8.84E-07	µg/l
SVOC	1,2,3-Trimethylbenzene (1)	0.000236	0.0000286	0.000106	0.0000129	µg/l
SVOC	1,2,3-Trimethylbenzene (2)	0.0003	0.0000365	0.000135	0.0000164	µg/l
SVOC	1,2,4,5-Tetramethylbenzene (1)	0.000033	0.00000401	0.0000148	0.0000018	µg/l
SVOC	1,2,4,5-Tetramethylbenzene (2)	0.0000306	0.00000372	0.0000138	0.00000167	µg/l
SVOC	1,2-Diethyl-Cyclobutane	0.00305	0.00037	0.00137	0.000166	µg/l
SVOC	1,3-Dimethylnaphthalene	0.0000269	0.00000327	0.0000121	0.00000147	µg/l
SVOC	1,3-Dimethylnaphthalene (01)	0.00173	0.00021	0.000777	0.0000943	µg/l
SVOC	1,4-Dimethyl-1,2,3,4-tetrahydronaphthalene	0.00256	0.00031	0.00115	0.000139	µg/l
SVOC	1,4-Dimethylnaphthalene	0.00275	0.000334	0.00124	0.00015	µg/l
SVOC	1,4-Dimethylnaphthalene (01)	0.00183	0.000222	0.000823	0.0000999	µg/l

Appendix G.5: Fishing Harbor Vessel Scenarios Instantaneous Concentration in the Hypothetical Harbor

Class	Analyte	Model Scenarios 1 and 3	Model Scenarios 2 and 4	Model Scenarios 5 and 7	Model Scenarios 6 and 8	Units
SVOC	1,5-Dimethylnaphthalene	0.000241	0.0000293	0.000109	0.0000132	µg/l
SVOC	1,6-Dimethylnaphthalene	0.013	0.00157	0.00582	0.000707	µg/l
SVOC	1,7,7-tri-(methyl)-bicyclo[2.2.1]heptane	0	0	0	0	µg/l
SVOC	1-Dodecanol	0.00000869	0.00000105	0.0000039	4.74E-07	µg/l
SVOC	1-Hexadecene	0.000000805	9.77E-08	3.62E-07	4.39E-08	µg/l
SVOC	1-Methyl-2-Propyl-Benzene (01)	0.000249	0.0000302	0.000112	0.0000136	µg/l
SVOC	1-Methyl-2-Propyl-Benzene (02)	0.0000718	0.00000871	0.0000323	0.00000392	µg/l
SVOC	1-Methylnaphthalene	0.0117	0.00142	0.00527	0.00064	µg/l
SVOC	1-Phenyl-1-Butene	0.00000039	4.73E-08	1.75E-07	2.13E-08	µg/l
SVOC	2-(dodecyloxy)-Ethanol	0.0000109	0.00000132	0.00000488	5.92E-07	µg/l
SVOC	2-(hexadecyloxy)-Ethanol	0.00000279	3.38E-07	0.00000125	1.52E-07	µg/l
SVOC	2-(tetradecyloxy)-Ethanol	0.00000805	9.77E-07	0.00000362	4.39E-07	µg/l
SVOC	2,3-Dimethylnaphthalene	0.00225	0.000274	0.00101	0.000123	µg/l
SVOC	2,4,6-Trichlorophenol	0.00000465	5.64E-07	0.00000209	2.53E-07	µg/l
SVOC	2,4-Dimethyl-Benzaldehyde	0.000000726	8.81E-08	3.26E-07	3.96E-08	µg/l
SVOC	2,4-Dimethylphenol	0.000648	0.0000787	0.000291	0.0000354	µg/l
SVOC	2,6,10,14-Tetramethyl Pentadecane	0.00405	0.000492	0.00182	0.000221	µg/l
SVOC	2,6,10,14-Tetramethylhexadecae	0.00271	0.000329	0.00122	0.000148	µg/l
SVOC	2,6,10,14-Tetramethylhexadecae (01)	0.0000875	0.0000106	0.0000393	0.00000477	µg/l
SVOC	2,6-dimethyl-Heptadecane	0.00442	0.000536	0.00199	0.000241	µg/l
SVOC	2,7-Dimethylnaphthalene	0.00317	0.000385	0.00142	0.000173	µg/l
SVOC	2-Cyclopenten1-one	0.000304	0.0000369	0.000137	0.0000166	µg/l
SVOC	2-Ethyl-Hexanoic acid	0.031	0.00376	0.0139	0.00169	µg/l
SVOC	2-Hydroxy-Benzaldehyde	0.00471	0.000572	0.00212	0.000257	µg/l
SVOC	2-Mercaptobenzothiazole	0	0	0	0	µg/l
SVOC	2-Methyl Tridecane	0.0000463	0.00000562	0.0000208	0.00000253	µg/l
SVOC	2-Methyl-Benzaldehyde	0.00199	0.000241	0.000894	0.000109	µg/l
SVOC	2-Methyl-Dodecane	0.0000384	0.00000466	0.0000172	0.00000209	µg/l
SVOC	2-Methylnaphthalene	0.015	0.00182	0.00675	0.000819	µg/l
SVOC	2-Naphthalenecarboxaldehyde	0.000333	0.0000404	0.00015	0.0000182	µg/l
SVOC	3,4-Dimethylphenol	0.000000341	4.14E-08	1.53E-07	1.86E-08	µg/l
SVOC	3,5-Dimethyl-Benzaldehyde	0.000000441	5.35E-08	1.98E-07	2.4E-08	µg/l
SVOC	3,6-Dimethylundecane	0.000000671	8.15E-08	3.02E-07	3.66E-08	µg/l
SVOC	3-Methyl-Benzaldehyde	0.00423	0.000513	0.0019	0.000231	µg/l
SVOC	3-Methyl-Benzaldehyde (01)	0.00474	0.000576	0.00213	0.000259	µg/l
SVOC	3-Methyl-butanoic acid	0.000147	0.0000178	0.000066	0.00000801	µg/l
SVOC	3-Methyl-Phenanthrene	0.00198	0.000241	0.000892	0.000108	µg/l
SVOC	3-Methylphenol	0.000222	0.0000269	0.0000997	0.0000121	µg/l
SVOC	3-Phenyl-2-Propenal	0.00015	0.0000182	0.0000673	0.00000817	µg/l
SVOC	4,4-Dimethylbiphenyl	0.00206	0.00025	0.000927	0.000113	µg/l
SVOC	4-Hydroxy-2-Butanone	0.00231	0.00028	0.00104	0.000126	µg/l
SVOC	4-Methyl-1H-Benzotriazole	0.00000232	2.82E-07	0.00000104	1.27E-07	µg/l
SVOC	4-METHYL-PENTANOIC ACID	0.0000978	0.0000119	0.000044	0.00000534	µg/l

Appendix G.5: Fishing Harbor Vessel Scenarios Instantaneous Concentration in the Hypothetical Harbor

Class	Analyte	Model Scenarios 1 and 3	Model Scenarios 2 and 4	Model Scenarios 5 and 7	Model Scenarios 6 and 8	Units
SVOC	5-Butyl-Hexadecane	0.000000517	6.27E-08	2.32E-07	2.82E-08	µg/l
SVOC	5-Methyl-2-(1-methyl)-Cyclohexanol	0.00000227	2.76E-07	0.00000102	1.24E-07	µg/l
SVOC	9-Methyl-9H-Fluorene	0.00212	0.000258	0.000954	0.000116	µg/l
SVOC	Acenaphthylene	0.00115	0.00014	0.000517	0.0000628	µg/l
SVOC	Acetophenone	0.0000146	0.00000177	0.00000655	7.94E-07	µg/l
SVOC	Benzeneacetic Acid	0.0000747	0.00000906	0.0000336	0.00000407	µg/l
SVOC	Benzenepropanoic Acid	0.0000824	0.00001	0.000037	0.00000449	µg/l
SVOC	Benzothiazole	0.0000096	0.00000116	0.00000431	5.24E-07	µg/l
SVOC	Benzyl alcohol	0.0000152	0.00000185	0.00000684	0.00000083	µg/l
SVOC	Biphenyl	0.00116	0.00014	0.000519	0.000063	µg/l
SVOC	Bis(2-ethylhexyl) phthalate	0.000485	0.0000588	0.000218	0.0000264	µg/l
SVOC	Caprolactam	0.0000082	9.95E-07	0.00000368	4.47E-07	µg/l
SVOC	Cholesterol	0.000227	0.0000275	0.000102	0.0000124	µg/l
SVOC	Cyclic octaatomic sulfur	0.0073	0.000886	0.00328	0.000398	µg/l
SVOC	Cyclodecane	0.0000795	0.00000964	0.0000357	0.00000433	µg/l
SVOC	Cyclododecane	0.00000901	0.00000109	0.00000405	4.91E-07	µg/l
SVOC	Cyclotetradecane	0.00000475	5.77E-07	0.00000214	2.59E-07	µg/l
SVOC	Diethene Glycol Monododecyl Ether	0.00000896	0.00000109	0.00000403	4.89E-07	µg/l
SVOC	Dimethyl phthalate	0.0000271	0.00000329	0.0000122	0.00000148	µg/l
SVOC	Di-n-butyl phthalate	0.000596	0.0000723	0.000268	0.0000325	µg/l
SVOC	Di-n-octyl phthalate	0.0000173	0.0000021	0.00000778	9.44E-07	µg/l
SVOC	Disopropylene glycol	0.00000264	3.21E-07	0.00000119	1.44E-07	µg/l
SVOC	Dodecane	0.000000386	4.68E-08	1.73E-07	2.1E-08	µg/l
SVOC	Dodecanoic acid	0.0000065	7.89E-07	0.00000292	3.55E-07	µg/l
SVOC	Eicosane	0.0101	0.00122	0.00453	0.000549	µg/l
SVOC	Ethanol, 2,2-oxybis-	0.000292	0.0000355	0.000131	0.0000159	µg/l
SVOC	Ethanol, 2-Butoxy	0.00258	0.000313	0.00116	0.000141	µg/l
SVOC	Fluorene	0.00123	0.000149	0.000552	0.0000669	µg/l
SVOC	Heneicosane	0.00301	0.000365	0.00135	0.000164	µg/l
SVOC	Heptadecane	0.0179	0.00218	0.00806	0.000979	µg/l
SVOC	Hexaethylene Glycol Monododecyl	0.00000545	6.62E-07	0.00000245	2.97E-07	µg/l
SVOC	Hexaethylene Glycol Monododecyl (01)	0.00000218	2.65E-07	9.82E-07	1.19E-07	µg/l
SVOC	Hexaethylene Glycol Monododecyl (02)	0.00000069	8.37E-08	0.00000031	3.76E-08	µg/l
SVOC	Hexagol	0.00000315	3.82E-07	0.00000141	1.72E-07	µg/l
SVOC	Indane	0.000257	0.0000312	0.000116	0.000014	µg/l
SVOC	Indole	0.000412	0.00005	0.000185	0.0000225	µg/l
SVOC	Isopropylbenzene-4,methyl-1	0	0	0	0	µg/l
SVOC	m-Cresol	0.0000235	0.00000285	0.0000106	0.00000128	µg/l
SVOC	Naphthalene	0.00547	0.000663	0.00246	0.000298	µg/l
SVOC	N-Butyl-Benzenesulfonamide	0.0000009	1.09E-07	4.04E-07	4.91E-08	µg/l
SVOC	n-Hexadecane	0.0171	0.00207	0.00768	0.000932	µg/l
SVOC	n-Hexadecanoic acid	0.0000046	5.58E-07	0.00000207	2.51E-07	µg/l
SVOC	Nonadecane	0.0138	0.00168	0.0062	0.000753	µg/l

Appendix G.5: Fishing Harbor Vessel Scenarios Instantaneous Concentration in the Hypothetical Harbor

Class	Analyte	Model Scenarios 1 and 3	Model Scenarios 2 and 4	Model Scenarios 5 and 7	Model Scenarios 6 and 8	Units
SVOC	Nonadecane (01)	0.00425	0.000516	0.00191	0.000232	µg/l
SVOC	Nonanoic Acid	0.00335	0.000407	0.00151	0.000183	µg/l
SVOC	n-Pentadecane	0.0127	0.00155	0.00573	0.000695	µg/l
SVOC	n-Tetradecane	0.0161	0.00195	0.00722	0.000876	µg/l
SVOC	o-Cresol	0.0019	0.000231	0.000856	0.000104	µg/l
SVOC	Octadecane	0.00388	0.000471	0.00174	0.000211	µg/l
SVOC	p-Cresol	0.00573	0.000696	0.00258	0.000313	µg/l
SVOC	Pentacosane	0.0000797	0.00000968	0.0000358	0.00000435	µg/l
SVOC	Pentaethene Glycol Monododecyl Ether	0.000000738	8.95E-08	3.31E-07	4.02E-08	µg/l
SVOC	Pentaethene Glycol Monododecyl Ether (01)	0.00000539	6.54E-07	0.00000242	2.94E-07	µg/l
SVOC	Pentaethene Glycol Monododecyl Ether (02)	0.0000106	0.00000129	0.00000477	5.79E-07	µg/l
SVOC	Phenanthrene	0.00105	0.000127	0.00047	0.0000571	µg/l
SVOC	Phenol	0.0119	0.00145	0.00537	0.000652	µg/l
SVOC	Phthalic acid, isobutyl octyl ester	0.00000426	5.17E-07	0.00000192	2.32E-07	µg/l
SVOC	Pyrene	0.0000391	0.00000474	0.0000176	0.00000213	µg/l
SVOC	Sulfur	0.00332	0.000403	0.00149	0.000181	µg/l
SVOC	Tetraethylene glycol monododecyl ether	0.00000549	6.67E-07	0.00000247	0.0000003	µg/l
SVOC	Triethyl phosphate	0.0000557	0.00000676	0.000025	0.00000304	µg/l
SVOC	Triethylene glycol monododecyl ether	0.00000816	0.00000099	0.00000367	4.45E-07	µg/l
SVOC	Unknown SVOC	0.00318	0.000386	0.00143	0.000173	µg/l
SVOC	Unknown SVOC (01)	0.00293	0.000355	0.00132	0.00016	µg/l
SVOC	Unknown SVOC (02)	0.00313	0.00038	0.00141	0.000171	µg/l
SVOC	Unknown SVOC (03)	0.000223	0.0000271	0.0001	0.0000122	µg/l
SVOC	Unknown SVOC (04)	0.000209	0.0000253	0.0000938	0.0000114	µg/l
SVOC	Unknown SVOC (05)	0.0000616	0.00000747	0.0000277	0.00000336	µg/l
SVOC	Unknown SVOC (06)	0.0000407	0.00000494	0.0000183	0.00000222	µg/l
SVOC	Unknown SVOC (07)	0.000462	0.0000561	0.000208	0.0000252	µg/l

(1) EPA suspects a limited number of the samples analyzed for selenium (even fewer for arsenic) for bilgewater, packing gland effluent, propulsion engine effluent, graywater and deck washdown water may be positively influenced (increased) by interference from high concentrations of major cations in the sample matrix. Although EPA suspects that the highest concentrations of dissolved arsenic (and to a lesser extent selenium) in fish hold effluent from a shrimping vessel could be slightly elevated due to cation interference; EPA believes the fish hold concentrations reasonably represent true effluent concentrations for the discharge (see Section 3.2.4.1). EPA considered these interferences when interpreting the potential for vessel discharges to pose a risk to human health, aquatic life, or the environment and determined that such cationic interference does not influence the major findings presented in the modeling analysis.

Appendix G.6: Metropolitan Harbor Vessel Scenarios Instantaneous Concentration in the Hypothetical Harbor

Class	Analyte	Model Scenarios 9 and 11	Model Scenarios 10 an 12	Model Scenarios 13 and 15	Model Scenarios 14 and 16	Units
Bacteria	E. Coli by MF	3.2	0.388	1.44	0.175	CFU/100 ml
Bacteria	E. Coli by MPN	1.15	0.14	0.518	0.0629	MPN/100 ml
Bacteria	Enterococci by MF	1.81	0.219	0.812	0.0985	CFU/100 ml
Bacteria	Enterococci by MPN	0.0643	0.00781	0.0289	0.00351	MPN/100 ml
Bacteria	Fecal Coliform by MF	5.89	0.715	2.65	0.321	CFU/100 ml
Bacteria	Fecal Coliform by MPN	3.61	0.438	1.62	0.197	MPN/100 ml
Bacteria	Total Coliforms by MPN	15.5	1.88	6.96	0.845	MPN/100 ml
Classicals	Biochemical Oxygen Demand (BOD)	0.158	0.0191	0.0709	0.0086	mg/l
Classicals	Chemical Oxygen Demand (COD)	0.43	0.0522	0.193	0.0235	mg/l
Classicals	Dissolved Oxygen	0.0122	0.00149	0.0055	0.000668	mg/l
Classicals	Hexane Extractable Material (HEM)	0.00626	0.00076	0.00281	0.000341	mg/l
Classicals	Silica Gel Treated HEM (SGT-HEM)	0.0068	0.000825	0.00305	0.000371	mg/l
Classicals	Sulfide	0.00000934	0.00000113	0.0000042	0.00000051	mg/l
Classicals	Total Organic Carbon (TOC)	0.0606	0.00735	0.0272	0.0033	mg/l
Classicals	Total Residual Chlorine	0.000239	0.000029	0.000108	0.0000131	mg/l
Classicals	Total Suspended Solids (TSS)	0.0678	0.00823	0.0305	0.0037	mg/l
Nutrients	Ammonia As Nitrogen (NH3-N)	0.00199	0.000241	0.000894	0.000109	mg/l
Nutrients	Nitrate/Nitrite (NO3/NO2-N)	0.0000664	0.00000806	0.0000298	0.00000362	mg/l
Nutrients	Total Kjeldahl Nitrogen (TKN)	0.0224	0.00272	0.0101	0.00122	mg/l
Nutrients	Total Phosphorus	0.00292	0.000354	0.00131	0.000159	mg/l
Metals	Aluminum, Dissolved	0.556	0.0675	0.25	0.0304	µg/l
Metals	Aluminum, Total	0.885	0.107	0.398	0.0483	µg/l
Metals	Antimony, Dissolved	0.0000364	0.00000442	0.0000163	0.00000198	µg/l
Metals	Antimony, Total	0.000114	0.0000138	0.0000512	0.00000622	µg/l
Metals	Arsenic, Dissolved [1]	0.00933	0.00113	0.00419	0.000509	µg/l
Metals	Arsenic, Total [1]	0.0118	0.00143	0.00528	0.000641	µg/l
Metals	Barium, Dissolved	0.0245	0.00297	0.011	0.00133	µg/l
Metals	Barium, Total	0.0293	0.00356	0.0132	0.0016	µg/l
Metals	Cadmium, Dissolved	0.0000142	0.00000172	0.00000637	7.74E-07	µg/l
Metals	Cadmium, Total	0.000215	0.0000261	0.0000968	0.0000118	µg/l
Metals	Calcium, Dissolved	184	22.3	82.7	10	µg/l
Metals	Calcium, Total	185	22.5	83.3	10.1	µg/l
Metals	Chromium, Dissolved	0.00147	0.000178	0.000659	0.00008	µg/l
Metals	Chromium, Total	0.00292	0.000354	0.00131	0.000159	µg/l
Metals	Cobalt, Dissolved	0.0000603	0.00000732	0.0000271	0.00000329	µg/l
Metals	Cobalt, Total	0.0000859	0.0000104	0.0000386	0.00000468	µg/l
Metals	Copper, Dissolved	1.63	0.198	0.733	0.0889	µg/l
Metals	Copper, Total	0.0586	0.00712	0.0264	0.0032	µg/l
Metals	Iron, Dissolved	0.0152	0.00185	0.00685	0.000831	µg/l
Metals	Iron, Total	0.268	0.0326	0.121	0.0146	µg/l

Appendix G.6: Metropolitan Harbor Vessel Scenarios Instantaneous Concentration in the Hypothetical Harbor

Class	Analyte	Model Scenarios 9 and 11	Model Scenarios 10 an 12	Model Scenarios 13 and 15	Model Scenarios 14 and 16	Units
Metals	Lead, Dissolved	0.00111	0.000134	0.000497	0.0000604	µg/l
Metals	Lead, Total	0.00506	0.000614	0.00227	0.000276	µg/l
Metals	Magnesium, Dissolved	493	59.8	221	26.9	µg/l
Metals	Magnesium, Total	483	58.6	217	26.3	µg/l
Metals	Manganese, Dissolved	0.0755	0.00916	0.0339	0.00412	µg/l
Metals	Manganese, Total	0.097	0.0118	0.0436	0.00529	µg/l
Metals	Nickel, Dissolved	0.00459	0.000557	0.00206	0.00025	µg/l
Metals	Nickel, Total	0.00541	0.000657	0.00243	0.000295	µg/l
Metals	Potassium, Dissolved	34.5	4.19	15.5	1.88	µg/l
Metals	Potassium, Total	34.3	4.17	15.4	1.87	µg/l
Metals	Selenium, Dissolved [1]	0.0135	0.00164	0.00606	0.000736	µg/l
Metals	Selenium, Total [1]	0.0144	0.00175	0.00648	0.000787	µg/l
Metals	Silver, Dissolved	0.00000723	8.78E-07	0.00000325	3.94E-07	µg/l
Metals	Silver, Total	0.0000136	0.00000165	0.00000611	7.42E-07	µg/l
Metals	Sodium, Dissolved	806	97.8	362	44	µg/l
Metals	Sodium,Total	944	115	424	51.5	µg/l
Metals	Thallium, Dissolved	0.0000233	0.00000282	0.0000105	0.00000127	µg/l
Metals	Thallium,Total	2.57E-07	3.12E-08	1.16E-07	1.4E-08	µg/l
Metals	Vanadium, Dissolved	0.000658	0.0000799	0.000296	0.0000359	µg/l
Metals	Vanadium,Total	0.000882	0.000107	0.000397	0.0000481	µg/l
Metals	Zinc, Dissolved	0.0968	0.0117	0.0435	0.00528	µg/l
Metals	Zinc, Total	0.201	0.0244	0.0903	0.011	µg/l
Nonylphenols	Bisphenol A	0.00000581	7.05E-07	0.00000261	3.17E-07	µg/l
Nonylphenols	Nonylphenol decaethoxylate (NP10EO)	0.00111	0.000134	0.000497	0.0000604	µg/l
Nonylphenols	Nonylphenol dodecaethoxylate (NP12EO)	0.000885	0.000107	0.000398	0.0000483	µg/l
Nonylphenols	Nonylphenol heptadecaethoxylate (NP17EO)	0.0000557	0.00000675	0.000025	0.00000304	µg/l
Nonylphenols	Nonylphenol heptaethoxylate (NP7EO)	0.000689	0.0000837	0.00031	0.0000376	µg/l
Nonylphenols	Nonylphenol hexadecaethoxylate (NP16EO)	0.000119	0.0000144	0.0000534	0.00000648	µg/l
Nonylphenols	Nonylphenol hexaethoxylate (NP6EO)	0.00048	0.0000583	0.000216	0.0000262	µg/l
Nonylphenols	Nonylphenol nonaethoxylate (NP9EO)	0.000983	0.000119	0.000442	0.0000536	µg/l
Nonylphenols	Nonylphenol octaethoxylate (NP8EO)	0.000882	0.000107	0.000397	0.0000481	µg/l
Nonylphenols	Nonylphenol octodecaethoxylate (NP18EO)	0.0000268	0.00000325	0.000012	0.00000146	µg/l
Nonylphenols	Nonylphenol pendecaethoxylate (NP15EO)	0.000224	0.0000272	0.000101	0.0000122	µg/l
Nonylphenols	Nonylphenol pentaethoxylate (NP5EO)	0.000282	0.0000342	0.000127	0.0000154	µg/l
Nonylphenols	Nonylphenol tetradecaethoxylate (NP14EO)	0.000406	0.0000493	0.000182	0.0000221	µg/l
Nonylphenols	Nonylphenol tetraethoxylate (NP4EO)	0.000128	0.0000155	0.0000575	0.00000698	µg/l
Nonylphenols	Nonylphenol tridecaethoxylate (NP13EO)	0.000627	0.0000762	0.000282	0.0000342	µg/l
Nonylphenols	Nonylphenol triethoxylate (NP3EO)	0.000074	0.00000898	0.0000332	0.00000403	µg/l
Nonylphenols	Nonylphenol undecaethoxylate (NP11EO)	0.00112	0.000136	0.000505	0.0000613	µg/l
Nonylphenols	Octylphenol decaethoxylate (OP10EO)	0.0000832	0.0000101	0.0000374	0.00000454	µg/l
Nonylphenols	Octylphenol dodecaethoxylate (OP12EO)	0.00004	0.00000485	0.000018	0.00000218	µg/l

Appendix G.6: Metropolitan Harbor Vessel Scenarios Instantaneous Concentration in the Hypothetical Harbor

Class	Analyte	Model Scenarios 9 and 11	Model Scenarios 10 an 12	Model Scenarios 13 and 15	Model Scenarios 14 and 16	Units
Nonylphenols	Octylphenol heptaethoxylate (OP7EO)	0.00000494	0.0000006	0.00000222	0.00000027	µg/l
Nonylphenols	Octylphenol nonaethoxylate (OP9EO)	0.0000265	0.00000321	0.0000119	0.00000144	µg/l
Nonylphenols	Octylphenol octaethoxylate (OP8EO)	0.0000422	0.00000512	0.000019	0.0000023	µg/l
Nonylphenols	Octylphenol undecaethoxylate (OP11EO)	0.0000494	0.000006	0.0000222	0.0000027	µg/l
Nonylphenols	Total Nonylphenol Polyethoxylates	0.0076	0.000923	0.00342	0.000415	µg/l
Nonylphenols	Total Nonylphenols	0.00004	0.00000486	0.000018	0.00000218	µg/l
VOC	(2-Methyl-1-Propenyl)-Benzene	0.00195	0.000237	0.000877	0.000106	µg/l
VOC	(E)-1-Propenyl-Benzene	0.00000221	2.68E-07	9.94E-07	1.21E-07	µg/l
VOC	(E)-2-Butenal	0.00357	0.000433	0.0016	0.000195	µg/l
VOC	1,2,3,4-Tetrahydro-1-Methylnaphthalene	0.00224	0.000272	0.00101	0.000122	µg/l
VOC	1,2,3,4-Tetrahydro-2-Methylnaphthalene	0.00207	0.000251	0.00093	0.000113	µg/l
VOC	1,2,3,4-Tetrahydro-5-Methylnaphthalene	0.0182	0.00221	0.00819	0.000994	µg/l
VOC	1,2,3,4-Tetrahydro-6-Ethylnaphthalene,	0.00195	0.000237	0.000879	0.000107	µg/l
VOC	1,2,3,4-Tetrahydro-6-Methylnaphthalene	0.0168	0.00204	0.00754	0.000915	µg/l
VOC	1,2,3,4-Tetrahydro-6-Methylnaphthalene (01)	0.00415	0.000504	0.00187	0.000226	µg/l
VOC	1,2,3,4-Tetrahydro-6-Methylnaphthalene (02)	0.00347	0.000422	0.00156	0.000189	µg/l
VOC	1,2,3,4-Tetrahydronaphthalene	0.0125	0.00152	0.00562	0.000682	µg/l
VOC	1,2,3,4-Tetramethyl-Benzene	0.0014	0.000171	0.000631	0.0000766	µg/l
VOC	1,2,3,5-Tetramethyl-Benzene	0.00207	0.000251	0.000929	0.000113	µg/l
VOC	1,2,3-Trimethylbenzene	0.00675	0.000819	0.00303	0.000368	µg/l
VOC	1,2,4,5-Tetramethylbenzene	0.00315	0.000383	0.00142	0.000172	µg/l
VOC	1,2,4-Trimethylbenzene	0.0092	0.00112	0.00413	0.000502	µg/l
VOC	1,3,5-Trimethylbenzene	0.00268	0.000326	0.00121	0.000146	µg/l
VOC	1,3-Methylnaphthalene	0.00256	0.000311	0.00115	0.00014	µg/l
VOC	1,7-Methylnaphthalene	0.0116	0.00141	0.00521	0.000632	µg/l
VOC	1-Ethyl-2,3-Dimethyl-Benzene (01)	0.00313	0.00038	0.00141	0.000171	µg/l
VOC	1-Ethyl-2,3-Dimethyl-Benzene (02)	0.000859	0.000104	0.000386	0.0000469	µg/l
VOC	1-Ethyl-2,4-Dimethyl-Benzene	0.00334	0.000405	0.0015	0.000182	µg/l
VOC	1-Ethyl-2-Methyl-Benzene	0.00000683	8.29E-07	0.00000307	3.72E-07	µg/l
VOC	1-Ethyl-3-Methyl-Benzene	0.00217	0.000264	0.000977	0.000119	µg/l
VOC	1-Ethyl-4-Methyl-Benzene	0.0141	0.00171	0.00632	0.000768	µg/l
VOC	1-Methyl-2-(1-Methylethyl)-Benzene	0	0	0	0	µg/l
VOC	1-Methyl-2-(1-Methylethyl)-Benzene (01)	0.00000553	6.71E-07	0.00000248	3.01E-07	µg/l
VOC	1-Methyl-2-(1-Methylethyl)-Benzene (02)	0.0000193	0.00000234	0.00000868	0.00000105	µg/l
VOC	1-Methyl-3-Propyl-Benzene	0.00274	0.000333	0.00123	0.000149	µg/l
VOC	1-Methyl-4-(1-Methylidene)-Cyclohexane	0	0	0	0	µg/l
VOC	1-methyl-Indan	0.00657	0.000798	0.00296	0.000359	µg/l
VOC	1-Propenyl-Benzene	0.00000254	3.08E-07	0.00000114	1.38E-07	µg/l
VOC	2- Heptanone	0.000131	0.0000159	0.000059	0.00000716	µg/l
VOC	2,3-Dihydro-1,2-Dimethyl-1H-Indene	0.000706	0.0000858	0.000318	0.0000385	µg/l
VOC	2,3-Dihydro-1,6-Dimethyl-1H-Indene	0.00338	0.00041	0.00152	0.000184	µg/l
VOC	2,3-Dihydro-1-Methylindene	0.0034	0.000413	0.00153	0.000186	µg/l

Appendix G.6: Metropolitan Harbor Vessel Scenarios Instantaneous Concentration in the Hypothetical Harbor

Class	Analyte	Model Scenarios 9 and 11	Model Scenarios 10 an 12	Model Scenarios 13 and 15	Model Scenarios 14 and 16	Units
VOC	2,3-Dihydro-1-methylindene (01)	0.0019	0.00023	0.000853	0.000104	µg/l
VOC	2,3-Dihydro-1-methylindene (02)	0.00402	0.000489	0.00181	0.00022	µg/l
VOC	2,3-Dihydro-4,7-Dimethyl-1H-Indene	0.000067	0.00000813	0.0000301	0.00000365	µg/l
VOC	2,3-Dihydro-4-Methyl-1H-Indene	0.0391	0.00475	0.0176	0.00213	µg/l
VOC	2,3-Dihydro-4-Methyl-1H-Indene (01)	0.00000787	9.55E-07	0.00000354	4.29E-07	µg/l
VOC	2,3-Dihydro-4-Methyl-1H-Indene (02)	0.0000133	0.00000161	0.00000596	7.24E-07	µg/l
VOC	2,3-Dihydro-5,6-dimethyl-1H-Indene	0.00184	0.000223	0.000827	0.0001	µg/l
VOC	2,3-Dihydro-5-methyl-1H-Indene	0.00347	0.000422	0.00156	0.000189	µg/l
VOC	2,6-Dimethylnaphthalene	0.0252	0.00306	0.0113	0.00137	µg/l
VOC	2-Butanone	0.0201	0.00244	0.00903	0.0011	µg/l
VOC	2-Butenal	0.00223	0.00027	0.001	0.000121	µg/l
VOC	2-Ethyl-1,3,5-Trimethyl-Benzene	0.00268	0.000326	0.00121	0.000146	µg/l
VOC	2-Ethyl-1,4-Dimethyl-Benzene	0.0124	0.00151	0.00557	0.000677	µg/l
VOC	2-Ethyl-1-Hexanol	0.00000243	2.95E-07	0.00000109	1.32E-07	µg/l
VOC	2-Ethyltoluene	0.00686	0.000832	0.00308	0.000374	µg/l
VOC	2-Hexanone	0.00184	0.000223	0.000827	0.0001	µg/l
VOC	2-Methyl-2-Propenal	0.00427	0.000519	0.00192	0.000233	µg/l
VOC	2-Propenyl-Benzene	0.0103	0.00125	0.00462	0.000561	µg/l
VOC	3-Buten-2-one	0.00384	0.000466	0.00173	0.00021	µg/l
VOC	4-Ethyl-1,2-Dimethyl-Benzene	0.00000702	8.52E-07	0.00000316	3.83E-07	µg/l
VOC	4-Heptanone	0.000174	0.0000211	0.000078	0.00000947	µg/l
VOC	4-Isopropyltoluene	0.000612	0.0000743	0.000275	0.0000334	µg/l
VOC	4-Methyl-2-Pentanone	0.000597	0.0000725	0.000268	0.0000326	µg/l
VOC	Acetaldehyde	0.0122	0.00148	0.00546	0.000663	µg/l
VOC	Acetone	0.0889	0.0108	0.04	0.00485	µg/l
VOC	Acrolein	0.00508	0.000617	0.00228	0.000277	µg/l
VOC	Benzaldehyde	0.000155	0.0000189	0.0000698	0.00000847	µg/l
VOC	Benzene	0.00681	0.000826	0.00306	0.000371	µg/l
VOC	Benzocycloheptatriene	0.0238	0.00289	0.0107	0.0013	µg/l
VOC	Benzofuran	0.00241	0.000293	0.00108	0.000132	µg/l
VOC	Bromodichloromethane	0.00000908	0.0000011	0.00000408	4.96E-07	µg/l
VOC	Butane	0.00114	0.000138	0.000512	0.0000621	µg/l
VOC	Butyraldehyde	0.003	0.000365	0.00135	0.000164	µg/l
VOC	Carbon disulfide	0.00000183	2.22E-07	8.23E-07	9.99E-08	µg/l
VOC	Chloroform	0.0016	0.000194	0.000718	0.0000872	µg/l
VOC	cis-1,2-Dichloroethene	0.00000282	3.42E-07	0.00000127	1.54E-07	µg/l
VOC	Cyclohexane	0.000144	0.0000175	0.0000646	0.00000785	µg/l
VOC	Dibromochloromethane	0.00000891	0.00000108	0.00000401	4.86E-07	µg/l
VOC	Dimethocxymethane	0.00427	0.000518	0.00192	0.000233	µg/l
VOC	Ethanol	0.0000464	0.00000563	0.0000209	0.00000253	µg/l
VOC	Ethylbenzene	0.00375	0.000455	0.00168	0.000204	µg/l
VOC	Indene	0.00012	0.0000146	0.0000541	0.00000657	µg/l
VOC	Isopropylbenzene	0.00106	0.000129	0.000476	0.0000578	µg/l

Appendix G.6: Metropolitan Harbor Vessel Scenarios Instantaneous Concentration in the Hypothetical Harbor

Class	Analyte	Model Scenarios 9 and 11	Model Scenarios 10 an 12	Model Scenarios 13 and 15	Model Scenarios 14 and 16	Units
VOC	Limonene	0	0	0	0	µg/l
VOC	m,p-Xylene (Sum of Isomers)	0.0136	0.00165	0.0061	0.00074	µg/l
VOC	Methyl acetate	0.00125	0.000152	0.000562	0.0000682	µg/l
VOC	Methyl tertiary butyl ether (MTBE)	0.0000185	0.00000224	0.00000831	0.00000101	µg/l
VOC	Methylcyclohexane	0.000131	0.0000158	0.0000587	0.00000712	µg/l
VOC	Methylene chloride	0.00034	0.0000413	0.000153	0.0000185	µg/l
VOC	n-Butylbenzene	0.000537	0.0000651	0.000241	0.0000293	µg/l
VOC	nitro-Methane	0.00178	0.000216	0.000801	0.0000972	µg/l
VOC	Nonanal	0.0000012	1.46E-07	5.39E-07	6.55E-08	µg/l
VOC	n-Propylbenzene	0.00103	0.000125	0.000461	0.000056	µg/l
VOC	n-Valeraldehyde	0.00268	0.000326	0.00121	0.000146	µg/l
VOC	O-Xylene	0.00876	0.00106	0.00394	0.000478	µg/l
VOC	sec-Butylbenzene	0.00122	0.000148	0.000548	0.0000666	µg/l
VOC	Styrene	0.00121	0.000146	0.000542	0.0000658	µg/l
VOC	Sulfur dioxide	0.0126	0.00153	0.00568	0.000689	µg/l
VOC	Tetrachloroethene	0.00000259	3.14E-07	0.00000116	1.41E-07	µg/l
VOC	Toluene	0.0137	0.00166	0.00614	0.000746	µg/l
VOC	Trichloroethene	0.00000197	2.39E-07	8.86E-07	1.08E-07	µg/l
VOC	Trichlorofluoromethane	0.00104	0.000126	0.000465	0.0000565	µg/l
VOC	Tridecane	0.00213	0.000258	0.000956	0.000116	µg/l
VOC	Unknown VOC	0.00297	0.000361	0.00134	0.000162	µg/l
VOC	Unknown VOC (01)	0.00196	0.000237	0.000879	0.000107	µg/l
VOC	Unknown VOC (02)	0.00255	0.000309	0.00114	0.000139	µg/l
VOC	Unknown VOC (03)	0.00232	0.000281	0.00104	0.000126	µg/l
VOC	Unknown VOC (04)	0.00158	0.000192	0.000711	0.0000863	µg/l
VOC	Unknown VOC (05)	0.00142	0.000173	0.000639	0.0000775	µg/l
VOC	Vinyl acetate	0.00133	0.000162	0.000599	0.0000727	µg/l
SVOC	(E)-2-Tetradecene	0.000388	0.0000471	0.000174	0.0000212	µg/l
SVOC	1,2,3,4-Tetrahydro-2,7-Dimethylnaphthalene	0.000368	0.0000447	0.000166	0.0000201	µg/l
SVOC	1,2,3-Trichloro-(Z)-1-Propene	0.000108	0.0000131	0.0000485	0.00000589	µg/l
SVOC	1,2,3-Trimethylbenzene (1)	0.00157	0.00019	0.000705	0.0000856	µg/l
SVOC	1,2,3-Trimethylbenzene (2)	0.002	0.000243	0.0009	0.000109	µg/l
SVOC	1,2,4,5-Tetramethylbenzene (1)	0.00022	0.0000267	0.0000989	0.000012	µg/l
SVOC	1,2,4,5-Tetramethylbenzene (2)	0.000204	0.0000248	0.0000917	0.0000111	µg/l
SVOC	1,2-Diethyl-Cyclobutane	0.0061	0.00074	0.00274	0.000333	µg/l
SVOC	1,3-Dimethylnaphthalene	0.000135	0.0000163	0.0000605	0.00000734	µg/l
SVOC	1,3-Dimethylnaphthalene (01)	0.00346	0.000419	0.00155	0.000189	µg/l
SVOC	1,4-Dimethyl-1,2,3,4-tetrahydronaphthalene	0.00511	0.00062	0.0023	0.000279	µg/l
SVOC	1,4-Dimethylnaphthalene	0.00606	0.000735	0.00272	0.00033	µg/l
SVOC	1,4-Dimethylnaphthalene (01)	0.00366	0.000445	0.00165	0.0002	µg/l
SVOC	1,5-Dimethylnaphthalene	0.00151	0.000183	0.000678	0.0000823	µg/l
SVOC	1,6-Dimethylnaphthalene	0.026	0.00315	0.0117	0.00142	µg/l

Appendix G.6: Metropolitan Harbor Vessel Scenarios Instantaneous Concentration in the Hypothetical Harbor

Class	Analyte	Model Scenarios 9 and 11	Model Scenarios 10 an 12	Model Scenarios 13 and 15	Model Scenarios 14 and 16	Units
SVOC	1,7,7-tri-(methyl)-bicyclo[2.2.1]heptane	0	0	0	0	µg/l
SVOC	1-Dodecanol	0.0000579	0.00000703	0.000026	0.00000316	µg/l
SVOC	1-Hexadecene	0.00000537	6.52E-07	0.00000241	2.93E-07	µg/l
SVOC	1-Methyl-2-Propyl-Benzene (01)	0.00166	0.000201	0.000745	0.0000904	µg/l
SVOC	1-Methyl-2-Propyl-Benzene (02)	0.000478	0.0000581	0.000215	0.0000261	µg/l
SVOC	1-Methylnaphthalene	0.0242	0.00293	0.0109	0.00132	µg/l
SVOC	1-Phenyl-1-Butene	0.00000195	2.37E-07	8.77E-07	1.06E-07	µg/l
SVOC	2-(dodecyloxy)-Ethanol	0.0000724	0.00000879	0.0000325	0.00000395	µg/l
SVOC	2-(hexadecyloxy)-Ethanol	0.0000186	0.00000226	0.00000835	0.00000101	µg/l
SVOC	2-(tetradecyloxy)-Ethanol	0.0000536	0.00000651	0.0000241	0.00000293	µg/l
SVOC	2,3-Dimethylnaphthalene	0.00451	0.000547	0.00203	0.000246	µg/l
SVOC	2,4,6-Trichlorophenol	0.00000929	0.00000113	0.00000418	5.07E-07	µg/l
SVOC	2,4-Dimethyl-Benzaldehyde	0.00000363	0.00000044	0.00000163	1.98E-07	µg/l
SVOC	2,4-Dimethylphenol	0.00133	0.000161	0.000597	0.0000724	µg/l
SVOC	2,6,10,14-Tetramethyl Pentadecane	0.00827	0.001	0.00372	0.000451	µg/l
SVOC	2,6,10,14-Tetramethylhexadecae	0.00542	0.000657	0.00243	0.000295	µg/l
SVOC	2,6,10,14-Tetramethylhexadecae (01)	0.000583	0.0000708	0.000262	0.0000318	µg/l
SVOC	2,6-dimethyl-Heptadecane	0.00884	0.00107	0.00397	0.000482	µg/l
SVOC	2,7-Dimethylnaphthalene	0.00675	0.000819	0.00303	0.000368	µg/l
SVOC	2-Cyclopenten1-one	0.000609	0.0000739	0.000274	0.0000332	µg/l
SVOC	2-Ethyl-Hexanoic acid	0.207	0.0251	0.0929	0.0113	µg/l
SVOC	2-Hydroxy-Benzaldehyde	0.00957	0.00116	0.0043	0.000522	µg/l
SVOC	2-Mercaptobenzothiazole	0	0	0	0	µg/l
SVOC	2-Methyl Tridecane	0.000309	0.0000375	0.000139	0.0000168	µg/l
SVOC	2-Methyl-Benzaldehyde	0.00399	0.000484	0.00179	0.000218	µg/l
SVOC	2-Methyl-Dodecane	0.000192	0.0000233	0.0000862	0.0000105	µg/l
SVOC	2-Methylnaphthalene	0.0313	0.0038	0.0141	0.00171	µg/l
SVOC	2-Naphthalenecarboxaldehyde	0.000666	0.0000808	0.000299	0.0000363	µg/l
SVOC	3,4-Dimethylphenol	0.0000017	2.07E-07	7.66E-07	9.29E-08	µg/l
SVOC	3,5-Dimethyl-Benzaldehyde	0.0000022	2.68E-07	9.91E-07	0.00000012	µg/l
SVOC	3,6-Dimethylundecane	0.00000336	4.07E-07	0.00000151	1.83E-07	µg/l
SVOC	3-Methyl-Benzaldehyde	0.00846	0.00103	0.0038	0.000462	µg/l
SVOC	3-Methyl-Benzaldehyde (01)	0.00949	0.00115	0.00426	0.000518	µg/l
SVOC	3-Methyl-butanoic acid	0.0000978	0.0000119	0.000044	0.00000534	µg/l
SVOC	3-Methyl-Phenanthrene	0.00397	0.000482	0.00178	0.000216	µg/l
SVOC	3-Methylphenol	0.000444	0.0000539	0.000199	0.0000242	µg/l
SVOC	3-Phenyl-2-Propenal	0.0003	0.0000364	0.000135	0.0000163	µg/l
SVOC	4,4-Dimethylbiphenyl	0.00412	0.000501	0.00185	0.000225	µg/l
SVOC	4-Hydroxy-2-Butanone	0.00462	0.00056	0.00208	0.000252	µg/l
SVOC	4-Methyl-1H-Benzotriazole	0.00000465	5.64E-07	0.00000209	2.54E-07	µg/l
SVOC	4-METHYL-PENTANOIC ACID	0.0000652	0.00000792	0.0000293	0.00000356	µg/l
SVOC	5-Butyl-Hexadecane	0.00000258	3.14E-07	0.00000116	1.41E-07	µg/l
SVOC	5-Methyl-2-(1-methyl)-Cyclohexanol	0.0000152	0.00000184	0.00000681	8.27E-07	µg/l

Appendix G.6: Metropolitan Harbor Vessel Scenarios Instantaneous Concentration in the Hypothetical Harbor

Class	Analyte	Model Scenarios 9 and 11	Model Scenarios 10 an 12	Model Scenarios 13 and 15	Model Scenarios 14 and 16	Units
SVOC	9-Methyl-9H-Fluorene	0.00424	0.000515	0.00191	0.000231	µg/l
SVOC	Acenaphthylene	0.00232	0.000281	0.00104	0.000126	µg/l
SVOC	Acetophenone	0.0000728	0.00000884	0.0000327	0.00000397	µg/l
SVOC	Benzeneacetic Acid	0.0000498	0.00000604	0.0000224	0.00000272	µg/l
SVOC	Benzenepropanoic Acid	0.0000549	0.00000667	0.0000247	0.000003	µg/l
SVOC	Benzothiazole	0.0000233	0.00000283	0.0000105	0.00000127	µg/l
SVOC	Benzyl alcohol	0.0000761	0.00000923	0.0000342	0.00000415	µg/l
SVOC	Biphenyl	0.00251	0.000305	0.00113	0.000137	µg/l
SVOC	Bis(2-ethylhexyl) phthalate	0.00119	0.000144	0.000534	0.0000648	µg/l
SVOC	Caprolactam	0.0000546	0.00000663	0.0000246	0.00000298	µg/l
SVOC	Cholesterol	0.000151	0.0000183	0.0000679	0.00000824	µg/l
SVOC	Cyclic octaatomic sulfur	0.0399	0.00484	0.0179	0.00217	µg/l
SVOC	Cyclodecane	0.000397	0.0000482	0.000179	0.0000217	µg/l
SVOC	Cyclododecane	0.0000598	0.00000725	0.0000269	0.00000326	µg/l
SVOC	Cyclotetradecane	0.0000317	0.00000385	0.0000142	0.00000173	µg/l
SVOC	Diethene Glycol Monododecyl Ether	0.0000597	0.00000725	0.0000268	0.00000326	µg/l
SVOC	Dimethyl phthalate	0.0000542	0.00000658	0.0000244	0.00000296	µg/l
SVOC	Di-n-butyl phthalate	0.00134	0.000163	0.000603	0.0000732	µg/l
SVOC	Di-n-octyl phthalate	0.000113	0.0000137	0.0000506	0.00000614	µg/l
SVOC	Disopropylene glycol	0.0000176	0.00000214	0.00000792	9.61E-07	µg/l
SVOC	Dodecane	0.00000193	2.34E-07	8.67E-07	1.05E-07	µg/l
SVOC	Dodecanoic acid	0.0000433	0.00000526	0.0000195	0.00000236	µg/l
SVOC	Eicosane	0.0209	0.00254	0.0094	0.00114	µg/l
SVOC	Ethanol, 2,2-oxybis-	0.00195	0.000236	0.000876	0.000106	µg/l
SVOC	Ethanol, 2-Butoxy	0.00516	0.000626	0.00232	0.000282	µg/l
SVOC	Fluorene	0.00247	0.0003	0.00111	0.000135	µg/l
SVOC	Heneicosane	0.00712	0.000864	0.0032	0.000388	µg/l
SVOC	Heptadecane	0.0362	0.0044	0.0163	0.00198	µg/l
SVOC	Hexaethylene Glycol Monododecyl	0.0000363	0.00000441	0.0000163	0.00000198	µg/l
SVOC	Hexaethylene Glycol Monododecyl (01)	0.0000146	0.00000177	0.00000655	7.94E-07	µg/l
SVOC	Hexaethylene Glycol Monododecyl (02)	0.0000046	5.58E-07	0.00000207	2.51E-07	µg/l
SVOC	Hexagol	0.000021	0.00000255	0.00000943	0.00000114	µg/l
SVOC	Indane	0.00171	0.000208	0.00077	0.0000935	µg/l
SVOC	Indole	0.000275	0.0000333	0.000123	0.000015	µg/l
SVOC	Isopropylbenzene-4,methyl-1	0	0	0	0	µg/l
SVOC	m-Cresol	0.000117	0.0000143	0.0000528	0.00000641	µg/l
SVOC	Naphthalene	0.0129	0.00157	0.00581	0.000706	µg/l
SVOC	N-Butyl-Benzenesulfonamide	0.000006	7.28E-07	0.0000027	3.27E-07	µg/l
SVOC	n-Hexadecane	0.0346	0.0042	0.0155	0.00189	µg/l
SVOC	n-Hexadecanoic acid	0.0000307	0.00000372	0.0000138	0.00000167	µg/l
SVOC	Nonadecane	0.0278	0.00338	0.0125	0.00152	µg/l
SVOC	Nonadecane (01)	0.00851	0.00103	0.00382	0.000464	µg/l
SVOC	Nonanoic Acid	0.00671	0.000814	0.00301	0.000366	µg/l

Appendix G.6: Metropolitan Harbor Vessel Scenarios Instantaneous Concentration in the Hypothetical Harbor

Class	Analyte	Model Scenarios 9 and 11	Model Scenarios 10 an 12	Model Scenarios 13 and 15	Model Scenarios 14 and 16	Units
SVOC	n-Pentadecane	0.0312	0.00379	0.014	0.0017	µg/l
SVOC	n-Tetradecane	0.0357	0.00433	0.016	0.00195	µg/l
SVOC	o-Cresol	0.00381	0.000462	0.00171	0.000208	µg/l
SVOC	Octadecane	0.00775	0.000941	0.00348	0.000423	µg/l
SVOC	p-Cresol	0.012	0.00145	0.00537	0.000652	µg/l
SVOC	Pentacosane	0.000532	0.0000645	0.000239	0.000029	µg/l
SVOC	Pentaethene Glycol Monododecyl Ether	0.00000492	5.97E-07	0.00000221	2.68E-07	µg/l
SVOC	Pentaethene Glycol Monododecyl Ether (01)	0.0000359	0.00000436	0.0000161	0.00000196	µg/l
SVOC	Pentaethene Glycol Monododecyl Ether (02)	0.0000707	0.00000859	0.0000318	0.00000386	µg/l
SVOC	Phenanthrene	0.00259	0.000314	0.00116	0.000141	µg/l
SVOC	Phenol	0.0241	0.00293	0.0109	0.00132	µg/l
SVOC	Phthalic acid, isobutyl octyl ester	0.00000852	0.00000103	0.00000383	4.65E-07	µg/l
SVOC	Pyrene	0.000257	0.0000311	0.000115	0.000014	µg/l
SVOC	Sulfur	0.0167	0.00203	0.00751	0.000911	µg/l
SVOC	Tetraethylene glycol monododecyl ether	0.0000366	0.00000444	0.0000165	0.000002	µg/l
SVOC	Triethyl phosphate	0.0000427	0.00000518	0.0000192	0.00000233	µg/l
SVOC	Triethylene glycol monododecyl ether	0.0000544	0.0000066	0.0000244	0.00000297	µg/l
SVOC	Unknown SVOC	0.00695	0.000844	0.00312	0.000379	µg/l
SVOC	Unknown SVOC (01)	0.00672	0.000816	0.00302	0.000367	µg/l
SVOC	Unknown SVOC (02)	0.00727	0.000883	0.00327	0.000397	µg/l
SVOC	Unknown SVOC (03)	0.00107	0.00013	0.000481	0.0000584	µg/l
SVOC	Unknown SVOC (04)	0.00111	0.000134	0.000497	0.0000603	µg/l
SVOC	Unknown SVOC (05)	0.000383	0.0000465	0.000172	0.0000209	µg/l
SVOC	Unknown SVOC (06)	0.000248	0.0000301	0.000112	0.0000135	µg/l
SVOC	Unknown SVOC (07)	0.00308	0.000374	0.00138	0.000168	µg/l

(1) EPA suspects a limited number of the samples analyzed for selenium (even fewer for arsenic) for bilgewater, packing gland effluent, propulsion engine effluent, graywater and deck washdown water may be positively influenced (increased) by interference from high concentrations of major cations in the sample matrix. Although EPA suspects that the highest concentrations of dissolved arsenic (and to a lesser extent selenium) in fish hold effluent from a shrimping vessel could be slightly elevated due to cation interference; EPA believes the fish hold concentrations reasonably represent true effluent concentrations for the discharge (see Section 3.2.4.1). EPA considered these interferences when interpreting the potential for vessel discharges to pose a risk to human health, aquatic life, or the environment and determined that such cationic interference does not influence the major findings presented in the modeling analysis.

Appendix G.7: Recreational Harbor Vessel Scenarios Instantaneous Concentration in the Hypothetical Harbor

Class	Analyte	Model Scenarios 17 and 19	Model Scenarios 18 and 20	Model Scenarios 21 and 23	Model Scenarios 22 and 24	Units
Bacteria	E. Coli by MF	0.533	0.0647	0.24	0.0291	CFU/100 ml
Bacteria	E. Coli by MPN	0.208	0.0252	0.0935	0.0113	MPN/100 ml
Bacteria	Enterococci by MF	0.301	0.0365	0.135	0.0164	CFU/100 ml
Bacteria	Enterococci by MPN	0.0395	0.0048	0.0178	0.00216	MPN/100 ml
Bacteria	Fecal Coliform by MF	1.47	0.178	0.659	0.0799	CFU/100 ml
Bacteria	Fecal Coliform by MPN	0.602	0.0731	0.271	0.0328	MPN/100 ml
Bacteria	Total Coliforms by MPN	2.59	0.314	1.16	0.141	MPN/100 ml
Classicals	Biochemical Oxygen Demand (BOD)	0.129	0.0156	0.0578	0.00701	mg/l
Classicals	Chemical Oxygen Demand (COD)	0.361	0.0438	0.162	0.0197	mg/l
Classicals	Dissolved Oxygen	0.0135	0.00164	0.00609	0.000739	mg/l
Classicals	Hexane Extractable Material (HEM)	0.00573	0.000695	0.00257	0.000312	mg/l
Classicals	Silica Gel Treated HEM (SGT-HEM)	0.00682	0.000828	0.00307	0.000372	mg/l
Classicals	Sulfide	6.67E-06	8.09E-07	0.000003	3.64E-07	mg/l
Classicals	Total Organic Carbon (TOC)	0.0483	0.00586	0.0217	0.00263	mg/l
Classicals	Total Residual Chlorine	0.000185	0.0000225	0.0000832	0.0000101	mg/l
Classicals	Total Suspended Solids (TSS)	0.061	0.00741	0.0274	0.00333	mg/l
Nutrients	Ammonia As Nitrogen (NH3-N)	0.00166	0.000202	0.000747	0.0000907	mg/l
Nutrients	Nitrate/Nitrite (NO3/NO2-N)	0.0000333	4.04E-06	0.000015	1.82E-06	mg/l
Nutrients	Total Kjeldahl Nitrogen (TKN)	0.0193	0.00235	0.00868	0.00105	mg/l
Nutrients	Total Phosphorus	0.00254	0.000308	0.00114	0.000138	mg/l
Metals	Aluminum, Dissolved	0.539	0.0654	0.242	0.0294	µg/l
Metals	Aluminum, Total	0.852	0.103	0.383	0.0465	µg/l
Metals	Antimony, Dissolved	0.0000154	1.87E-06	6.92E-06	8.41E-07	µg/l
Metals	Antimony, Total	0.0000448	5.44E-06	0.0000201	2.44E-06	µg/l
Metals	Arsenic, Dissolved [1]	0.0084	0.00102	0.00378	0.000458	µg/l
Metals	Arsenic, Total [1]	0.0103	0.00125	0.00465	0.000564	µg/l
Metals	Barium, Dissolved	0.0218	0.00265	0.00981	0.00119	µg/l
Metals	Barium, Total	0.0232	0.00282	0.0104	0.00127	µg/l
Metals	Cadmium, Dissolved	0.00001	1.22E-06	4.51E-06	5.47E-07	µg/l
Metals	Cadmium, Total	0.000181	0.0000219	0.0000812	9.85E-06	µg/l
Metals	Calcium, Dissolved	173	21	77.7	9.43	µg/l
Metals	Calcium, Total	175	21.3	78.7	9.55	µg/l
Metals	Chromium, Dissolved	0.00139	0.000169	0.000625	0.0000758	µg/l
Metals	Chromium, Total	0.00234	0.000284	0.00105	0.000128	µg/l
Metals	Cobalt, Dissolved	0.0000254	3.09E-06	0.0000114	1.39E-06	µg/l
Metals	Cobalt, Total	0.0000352	4.28E-06	0.0000158	1.92E-06	µg/l
Metals	Copper, Dissolved	0.902	0.109	0.405	0.0492	µg/l
Metals	Copper, Total	0.0542	0.00658	0.0244	0.00296	µg/l
Metals	Iron, Dissolved	0.00474	0.000576	0.00213	0.000259	µg/l
Metals	Iron, Total	0.197	0.0239	0.0884	0.0107	µg/l
Metals	Lead, Dissolved	0.00112	0.000135	0.000501	0.0000608	µg/l
Metals	Lead, Total	0.00465	0.000564	0.00209	0.000253	µg/l
Metals	Magnesium, Dissolved	456	55.3	205	24.8	µg/l
Metals	Magnesium, Total	447	54.3	201	24.4	µg/l
Metals	Manganese, Dissolved	0.0835	0.0101	0.0375	0.00456	µg/l
Metals	Manganese, Total	0.105	0.0128	0.0473	0.00574	µg/l
Metals	Nickel, Dissolved	0.00437	0.000531	0.00197	0.000239	µg/l

Appendix G.7: Recreational Harbor Vessel Scenarios Instantaneous Concentration in the Hypothetical Harbor

Class	Analyte	Model Scenarios 17 and 19	Model Scenarios 18 and 20	Model Scenarios 21 and 23	Model Scenarios 22 and 24	Units
Metals	Nickel, Total	0.00475	0.000577	0.00214	0.000259	µg/l
Metals	Potassium, Dissolved	37	4.49	16.6	2.02	µg/l
Metals	Potassium, Total	36.9	4.47	16.6	2.01	µg/l
Metals	Selenium, Dissolved [1]	0.0145	0.00176	0.00652	0.000792	µg/l
Metals	Selenium, Total [1]	0.0154	0.00187	0.00694	0.000842	µg/l
Metals	Silver, Dissolved	4.52E-06	5.49E-07	2.03E-06	2.47E-07	µg/l
Metals	Silver, Total	0.0000085	1.03E-06	3.82E-06	4.64E-07	µg/l
Metals	Sodium, Dissolved	902	110	406	49.2	µg/l
Metals	Sodium,Total	1070	130	480	58.3	µg/l
Metals	Thallium, Dissolved	3.93E-06	4.78E-07	1.77E-06	2.15E-07	µg/l
Metals	Thallium,Total	4.29E-08	5.2E-09	1.93E-08	2.34E-09	µg/l
Metals	Vanadium, Dissolved	0.000742	0.0000901	0.000334	0.0000405	µg/l
Metals	Vanadium,Total	0.000833	0.000101	0.000375	0.0000455	µg/l
Metals	Zinc, Dissolved	0.085	0.0103	0.0382	0.00464	µg/l
Metals	Zinc, Total	0.169	0.0205	0.0759	0.00922	µg/l
Nonylphenols	Bisphenol A	6.97E-06	8.46E-07	3.13E-06	3.8E-07	µg/l
Nonylphenols	Nonylphenol decaethoxylate (NP10EO)	0.00103	0.000125	0.000462	0.0000561	µg/l
Nonylphenols	Nonylphenol dodecaethoxylate (NP12EO)	0.000837	0.000102	0.000376	0.0000456	µg/l
Nonylphenols	Nonylphenol heptadecaethoxylate (NP17EO)	0.0000548	6.65E-06	0.0000246	2.99E-06	µg/l
Nonylphenols	Nonylphenol heptaethoxylate (NP7EO)	0.00058	0.0000704	0.000261	0.0000316	µg/l
Nonylphenols	Nonylphenol hexadecaethoxylate (NP16EO)	0.000117	0.0000142	0.0000525	6.38E-06	µg/l
Nonylphenols	Nonylphenol hexaethoxylate (NP6EO)	0.000383	0.0000464	0.000172	0.0000209	µg/l
Nonylphenols	Nonylphenol nonaethoxylate (NP9EO)	0.000906	0.00011	0.000407	0.0000494	µg/l
Nonylphenols	Nonylphenol octaethoxylate (NP8EO)	0.000784	0.0000951	0.000352	0.0000428	µg/l
Nonylphenols	Nonylphenol octodecaethoxylate (NP18EO)	0.0000273	3.31E-06	0.0000123	1.49E-06	µg/l
Nonylphenols	Nonylphenol pendecaethoxylate (NP15EO)	0.000221	0.0000269	0.0000994	0.0000121	µg/l
Nonylphenols	Nonylphenol pentaethoxylate (NP5EO)	0.000195	0.0000237	0.0000878	0.0000107	µg/l
Nonylphenols	Nonylphenol tetradecaethoxylate (NP14EO)	0.000398	0.0000482	0.000179	0.0000217	µg/l
Nonylphenols	Nonylphenol tetraethoxylate (NP4EO)	0.0000567	6.88E-06	0.0000255	3.09E-06	µg/l
Nonylphenols	Nonylphenol tridecaethoxylate (NP13EO)	0.000604	0.0000733	0.000271	0.0000329	µg/l
Nonylphenols	Nonylphenol triethoxylate (NP3EO)	0.0000309	3.75E-06	0.0000139	1.69E-06	µg/l
Nonylphenols	Nonylphenol undecaethoxylate (NP11EO)	0.00105	0.000128	0.000473	0.0000574	µg/l
Nonylphenols	Octylphenol decaethoxylate (OP10EO)	0.0000274	3.32E-06	0.0000123	1.49E-06	µg/l
Nonylphenols	Octylphenol dodecaethoxylate (OP12EO)	0.0000125	1.52E-06	5.64E-06	6.84E-07	µg/l
Nonylphenols	Octylphenol heptaethoxylate (OP7EO)	8.24E-07	0.0000001	3.7E-07	4.49E-08	µg/l
Nonylphenols	Octylphenol nonaethoxylate (OP9EO)	0.0000102	1.24E-06	4.58E-06	5.56E-07	µg/l
Nonylphenols	Octylphenol octaethoxylate (OP8EO)	7.03E-06	8.53E-07	3.16E-06	3.83E-07	µg/l
Nonylphenols	Octylphenol undecaethoxylate (OP11EO)	0.0000165	0.000002	7.41E-06	8.99E-07	µg/l
Nonylphenols	Total Nonylphenol Polyethoxylates	0.00705	0.000856	0.00317	0.000385	µg/l
Nonylphenols	Total Nonylphenols	0.000025	3.03E-06	0.0000112	1.36E-06	µg/l
VOC	(2-Methyl-1-Propenyl)-Benzene	0.00234	0.000284	0.00105	0.000128	µg/l
VOC	(E)-1-Propenyl-Benzene	1.77E-06	2.15E-07	7.95E-07	9.65E-08	µg/l
VOC	(E)-2-Butenal	0.00428	0.00052	0.00192	0.000234	µg/l
VOC	1,2,3,4-Tetrahydro-1-Methylnaphthalene	0.00269	0.000327	0.00121	0.000147	µg/l
VOC	1,2,3,4-Tetrahydro-2-Methylnaphthalene	0.00248	0.000302	0.00112	0.000136	µg/l
VOC	1,2,3,4-Tetrahydro-5-Methylnaphthalene	0.0218	0.00264	0.00978	0.00119	µg/l
VOC	1,2,3,4-Tetrahydro-6-Ethylnaphthalene,	0.00235	0.000285	0.00105	0.000128	µg/l
VOC	1,2,3,4-Tetrahydro-6-Methylnaphthalene	0.0198	0.0024	0.00888	0.00108	µg/l
VOC	1,2,3,4-Tetrahydro-6-Methylnaphthalene (01)	0.00498	0.000605	0.00224	0.000272	µg/l

Appendix G.7: Recreational Harbor Vessel Scenarios Instantaneous Concentration in the Hypothetical Harbor

Class	Analyte	Model Scenarios 17 and 19	Model Scenarios 18 and 20	Model Scenarios 21 and 23	Model Scenarios 22 and 24	Units
VOC	1,2,3,4-Tetrahydro-6-Methylnaphthalene (02)	0.00417	0.000506	0.00187	0.000227	µg/l
VOC	1,2,3,4-Tetrahydronaphthalene	0.0149	0.00181	0.00671	0.000814	µg/l
VOC	1,2,3,4-Tetramethyl-Benzene	0.000702	0.0000853	0.000316	0.0000383	µg/l
VOC	1,2,3,5-Tetramethyl-Benzene	0.00103	0.000125	0.000465	0.0000564	µg/l
VOC	1,2,3-Trimethylbenzene	0.00338	0.00041	0.00152	0.000184	µg/l
VOC	1,2,4,5-Tetramethylbenzene	0.00158	0.000191	0.000709	0.000086	µg/l
VOC	1,2,4-Trimethylbenzene	0.00577	0.0007	0.00259	0.000315	µg/l
VOC	1,3,5-Trimethylbenzene	0.00155	0.000189	0.000698	0.0000848	µg/l
VOC	1,3-Methylnaphthalene	0.00307	0.000373	0.00138	0.000168	µg/l
VOC	1,7-Methylnaphthalene	0.0139	0.00169	0.00625	0.000758	µg/l
VOC	1-Ethyl-2,3-Dimethyl-Benzene (01)	0.00241	0.000293	0.00108	0.000131	µg/l
VOC	1-Ethyl-2,3-Dimethyl-Benzene (02)	0.000429	0.0000521	0.000193	0.0000234	µg/l
VOC	1-Ethyl-2,4-Dimethyl-Benzene	0.00167	0.000203	0.000751	0.0000912	µg/l
VOC	1-Ethyl-2-Methyl-Benzene	5.46E-06	6.63E-07	2.45E-06	2.98E-07	µg/l
VOC	1-Ethyl-3-Methyl-Benzene	0.00259	0.000314	0.00116	0.000141	µg/l
VOC	1-Ethyl-4-Methyl-Benzene	0.00704	0.000855	0.00317	0.000384	µg/l
VOC	1-Methyl-2-(1-Methylethyl)-Benzene	0	0	0	0	µg/l
VOC	1-Methyl-2-(1-Methylethyl)-Benzene (01)	4.42E-06	5.37E-07	1.99E-06	2.41E-07	µg/l
VOC	1-Methyl-2-(1-Methylethyl)-Benzene (02)	0.0000154	1.88E-06	6.94E-06	8.43E-07	µg/l
VOC	1-Methyl-3-Propyl-Benzene	0.00137	0.000167	0.000617	0.0000749	µg/l
VOC	1-Methyl-4-(1-Methylidene)-Cyclohexane	0	0	0	0	µg/l
VOC	1-methyl-Indan	0.00651	0.00079	0.00292	0.000355	µg/l
VOC	1-Propenyl-Benzene	2.03E-06	2.46E-07	9.12E-07	1.11E-07	µg/l
VOC	2- Heptanone	0.0000656	7.96E-06	0.0000295	3.58E-06	µg/l
VOC	2,3-Dihydro-1,2-Dimethyl-1H-Indene	0.000353	0.0000429	0.000159	0.0000193	µg/l
VOC	2,3-Dihydro-1,6-Dimethyl-1H-Indene	0.00297	0.00036	0.00133	0.000162	µg/l
VOC	2,3-Dihydro-1-Methylindene	0.00408	0.000495	0.00183	0.000223	µg/l
VOC	2,3-Dihydro-1-methylindene (01)	0.00228	0.000276	0.00102	0.000124	µg/l
VOC	2,3-Dihydro-1-methylindene (02)	0.00483	0.000586	0.00217	0.000263	µg/l
VOC	2,3-Dihydro-4,7-Dimethyl-1H-Indene	0.0000134	1.63E-06	6.02E-06	7.31E-07	µg/l
VOC	2,3-Dihydro-4-Methyl-1H-Indene	0.0436	0.00529	0.0196	0.00238	µg/l
VOC	2,3-Dihydro-4-Methyl-1H-Indene (01)	6.29E-06	7.64E-07	2.83E-06	3.43E-07	µg/l
VOC	2,3-Dihydro-4-Methyl-1H-Indene (02)	0.0000106	1.29E-06	4.77E-06	5.79E-07	µg/l
VOC	2,3-Dihydro-5,6-dimethyl-1H-Indene	0.00221	0.000268	0.000992	0.00012	µg/l
VOC	2,3-Dihydro-5-methyl-1H-Indene	0.00174	0.000211	0.00078	0.0000947	µg/l
VOC	2,6-Dimethylnaphthalene	0.0302	0.00367	0.0136	0.00165	µg/l
VOC	2-Butanone	0.0231	0.00281	0.0104	0.00126	µg/l
VOC	2-Butenal	0.00267	0.000324	0.0012	0.000146	µg/l
VOC	2-Ethyl-1,3,5-Trimethyl-Benzene	0.00322	0.000391	0.00145	0.000176	µg/l
VOC	2-Ethyl-1,4-Dimethyl-Benzene	0.0149	0.00181	0.00669	0.000812	µg/l
VOC	2-Ethyl-1-Hexanol	1.21E-06	1.47E-07	5.45E-07	6.62E-08	µg/l
VOC	2-Ethyltoluene	0.00492	0.000597	0.00221	0.000268	µg/l
VOC	2-Hexanone	0.00202	0.000246	0.00091	0.00011	µg/l
VOC	2-Methyl-2-Propenal	0.00492	0.000597	0.00221	0.000268	µg/l
VOC	2-Propenyl-Benzene	0.00514	0.000624	0.00231	0.000281	µg/l
VOC	3-Buten-2-one	0.00452	0.000548	0.00203	0.000246	µg/l
VOC	4-Ethyl-1,2-Dimethyl-Benzene	5.62E-06	6.82E-07	2.52E-06	3.06E-07	µg/l
VOC	4-Heptanone	0.0000868	0.0000105	0.000039	4.74E-06	µg/l
VOC	4-Isopropyltoluene	0.000689	0.0000836	0.000309	0.0000376	µg/l

Appendix G.7: Recreational Harbor Vessel Scenarios Instantaneous Concentration in the Hypothetical Harbor

Class	Analyte	Model Scenarios 17 and 19	Model Scenarios 18 and 20	Model Scenarios 21 and 23	Model Scenarios 22 and 24	Units
VOC	4-Methyl-2-Pentanone	0.000705	0.0000855	0.000317	0.0000384	µg/l
VOC	Acetaldehyde	0.0143	0.00173	0.00642	0.00078	µg/l
VOC	Acetone	0.103	0.0126	0.0465	0.00564	µg/l
VOC	Acrolein	0.00598	0.000726	0.00269	0.000326	µg/l
VOC	Benzaldehyde	0.000186	0.0000226	0.0000838	0.0000102	µg/l
VOC	Benzene	0.00596	0.000723	0.00268	0.000325	µg/l
VOC	Benzocycloheptatriene	0.0285	0.00346	0.0128	0.00156	µg/l
VOC	Benzofuran	0.00289	0.000351	0.0013	0.000158	µg/l
VOC	Bromodichloromethane	4.54E-06	5.51E-07	2.04E-06	2.48E-07	µg/l
VOC	Butane	0.000569	0.0000691	0.000256	0.0000311	µg/l
VOC	Butyraldehyde	0.00349	0.000424	0.00157	0.00019	µg/l
VOC	Carbon disulfide	0.0000022	2.67E-07	9.88E-07	1.2E-07	µg/l
VOC	Chloroform	0.00192	0.000233	0.000862	0.000105	µg/l
VOC	cis-1,2-Dichloroethene	3.38E-06	4.1E-07	1.52E-06	1.84E-07	µg/l
VOC	Cyclohexane	0.0000723	8.78E-06	0.0000325	3.95E-06	µg/l
VOC	Dibromochloromethane	4.46E-06	5.41E-07	0.000002	2.43E-07	µg/l
VOC	Dimethocxymethane	0.00384	0.000466	0.00173	0.000209	µg/l
VOC	Ethanol	0.0000232	2.82E-06	0.0000104	1.27E-06	µg/l
VOC	Ethylbenzene	0.00219	0.000265	0.000982	0.000119	µg/l
VOC	Indene	0.0000308	3.74E-06	0.0000139	1.68E-06	µg/l
VOC	Isopropylbenzene	0.00107	0.00013	0.000482	0.0000585	µg/l
VOC	Limonene	0	0	0	0	µg/l
VOC	m,p-Xylene (Sum of Isomers)	0.00733	0.00089	0.0033	0.0004	µg/l
VOC	Methyl acetate	0.0015	0.000182	0.000672	0.0000816	µg/l
VOC	Methyl tertiary butyl ether (MTBE)	9.62E-06	1.17E-06	4.32E-06	5.25E-07	µg/l
VOC	Methylcyclohexane	0.0000656	7.97E-06	0.0000295	3.58E-06	µg/l
VOC	Methylene chloride	0.000376	0.0000456	0.000169	0.0000205	µg/l
VOC	n-Butylbenzene	0.000644	0.0000782	0.000289	0.0000351	µg/l
VOC	nitro-Methane	0.00214	0.00026	0.000961	0.000117	µg/l
VOC	Nonanal	1.44E-06	1.75E-07	6.47E-07	7.86E-08	µg/l
VOC	n-Propylbenzene	0.000626	0.000076	0.000281	0.0000341	µg/l
VOC	n-Valeraldehyde	0.00309	0.000375	0.00139	0.000169	µg/l
VOC	O-Xylene	0.00476	0.000578	0.00214	0.00026	µg/l
VOC	sec-Butylbenzene	0.00146	0.000177	0.000657	0.0000797	µg/l
VOC	Styrene	0.00112	0.000135	0.000501	0.0000608	µg/l
VOC	Sulfur dioxide	0.00316	0.000383	0.00142	0.000172	µg/l
VOC	Tetrachloroethene	2.54E-06	3.09E-07	1.14E-06	1.39E-07	µg/l
VOC	Toluene	0.00832	0.00101	0.00374	0.000454	µg/l
VOC	Trichloroethene	2.37E-06	2.87E-07	1.06E-06	1.29E-07	µg/l
VOC	Trichlorofluoromethane	0.00124	0.000151	0.000558	0.0000678	µg/l
VOC	Tridecane	0.00255	0.00031	0.00115	0.000139	µg/l
VOC	Unknown VOC	0.00308	0.000373	0.00138	0.000168	µg/l
VOC	Unknown VOC (01)	0.00223	0.000271	0.001	0.000122	µg/l
VOC	Unknown VOC (02)	0.00298	0.000362	0.00134	0.000163	µg/l
VOC	Unknown VOC (03)	0.00271	0.000328	0.00122	0.000148	µg/l
VOC	Unknown VOC (04)	0.00175	0.000213	0.000788	0.0000957	µg/l
VOC	Unknown VOC (05)	0.00161	0.000195	0.000722	0.0000877	µg/l
VOC	Vinyl acetate	0.00159	0.000193	0.000714	0.0000867	µg/l
SVOC	(E)-2-Tetradecene	0.0000776	9.42E-06	0.0000349	4.23E-06	µg/l

Appendix G.7: Recreational Harbor Vessel Scenarios Instantaneous Concentration in the Hypothetical Harbor

Class	Analyte	Model Scenarios 17 and 19	Model Scenarios 18 and 20	Model Scenarios 21 and 23	Model Scenarios 22 and 24	Units
SVOC	1,2,3,4-Tetrahydro-2,7-Dimethylnaphthalene	0.000184	0.0000224	0.0000828	0.0000101	µg/l
SVOC	1,2,3-Trichloro-(Z)-1-Propene	0.000054	6.55E-06	0.0000243	2.95E-06	µg/l
SVOC	1,2,3-Trimethylbenzene (1)	0.000786	0.0000954	0.000353	0.0000429	µg/l
SVOC	1,2,3-Trimethylbenzene (2)	0.001	0.000122	0.00045	0.0000546	µg/l
SVOC	1,2,4,5-Tetramethylbenzene (1)	0.00011	0.0000134	0.0000494	0.000006	µg/l
SVOC	1,2,4,5-Tetramethylbenzene (2)	0.000102	0.0000124	0.0000459	5.57E-06	µg/l
SVOC	1,2-Diethyl-Cyclobutane	0.00731	0.000888	0.00329	0.000399	µg/l
SVOC	1,3-Dimethylnaphthalene	0.0000269	3.27E-06	0.0000121	1.47E-06	µg/l
SVOC	1,3-Dimethylnaphthalene (01)	0.00415	0.000503	0.00186	0.000226	µg/l
SVOC	1,4-Dimethyl-1,2,3,4-tetrahydronaphthalene	0.00613	0.000745	0.00276	0.000335	µg/l
SVOC	1,4-Dimethylnaphthalene	0.00668	0.000811	0.003	0.000364	µg/l
SVOC	1,4-Dimethylnaphthalene (01)	0.0044	0.000533	0.00198	0.00024	µg/l
SVOC	1,5-Dimethylnaphthalene	0.000664	0.0000806	0.000298	0.0000362	µg/l
SVOC	1,6-Dimethylnaphthalene	0.0311	0.00377	0.014	0.00169	µg/l
SVOC	1,7,7-tri-(methyl)-bicyclo[2.2.1]heptane	0	0	0	0	µg/l
SVOC	1-Dodecanol	0.000029	3.51E-06	0.000013	1.58E-06	µg/l
SVOC	1-Hexadecene	2.68E-06	3.26E-07	1.21E-06	1.46E-07	µg/l
SVOC	1-Methyl-2-Propyl-Benzene (01)	0.000828	0.000101	0.000372	0.0000452	µg/l
SVOC	1-Methyl-2-Propyl-Benzene (02)	0.000239	0.000029	0.000108	0.0000131	µg/l
SVOC	1-Methylnaphthalene	0.0281	0.00341	0.0126	0.00153	µg/l
SVOC	1-Phenyl-1-Butene	1.56E-06	1.89E-07	7.01E-07	8.51E-08	µg/l
SVOC	2-(dodecyloxy)-Ethanol	0.0000362	4.39E-06	0.0000163	1.97E-06	µg/l
SVOC	2-(hexadecyloxy)-Ethanol	9.29E-06	1.13E-06	4.18E-06	5.07E-07	µg/l
SVOC	2-(tetradecyloxy)-Ethanol	0.0000268	3.26E-06	0.0000121	1.46E-06	µg/l
SVOC	2,3-Dimethylnaphthalene	0.00541	0.000657	0.00243	0.000295	µg/l
SVOC	2,4,6-Trichlorophenol	0.0000112	1.35E-06	5.01E-06	6.08E-07	µg/l
SVOC	2,4-Dimethyl-Benzaldehyde	0.0000029	3.52E-07	0.0000013	1.58E-07	µg/l
SVOC	2,4-Dimethylphenol	0.00154	0.000187	0.000693	0.0000841	µg/l
SVOC	2,6,10,14-Tetramethyl Pentadecane	0.00965	0.00117	0.00434	0.000526	µg/l
SVOC	2,6,10,14-Tetramethylhexadecae	0.0065	0.000789	0.00292	0.000355	µg/l
SVOC	2,6,10,14-Tetramethylhexadecae (01)	0.000292	0.0000354	0.000131	0.0000159	µg/l
SVOC	2,6-dimethyl-Heptadecane	0.0106	0.00129	0.00477	0.000578	µg/l
SVOC	2,7-Dimethylnaphthalene	0.0075	0.000911	0.00337	0.000409	µg/l
SVOC	2-Cyclopenten1-one	0.00073	0.0000886	0.000328	0.0000398	µg/l
SVOC	2-Ethyl-Hexanoic acid	0.103	0.0125	0.0465	0.00564	µg/l
SVOC	2-Hydroxy-Benzaldehyde	0.0112	0.00136	0.00505	0.000613	µg/l
SVOC	2-Mercaptobenzothiazole	0	0	0	0	µg/l
SVOC	2-Methyl Tridecane	0.000154	0.0000187	0.0000694	8.42E-06	µg/l
SVOC	2-Methyl-Benzaldehyde	0.00478	0.00058	0.00215	0.000261	µg/l
SVOC	2-Methyl-Dodecane	0.0000384	4.66E-06	0.0000172	2.09E-06	µg/l
SVOC	2-Methylnaphthalene	0.036	0.00437	0.0162	0.00196	µg/l
SVOC	2-Naphthalenecarboxaldehyde	0.000799	0.0000969	0.000359	0.0000436	µg/l
SVOC	3,4-Dimethylphenol	1.36E-06	1.65E-07	6.12E-07	7.43E-08	µg/l
SVOC	3,5-Dimethyl-Benzaldehyde	1.76E-06	2.14E-07	7.92E-07	9.62E-08	µg/l
SVOC	3,6-Dimethylundecane	5.59E-07	6.79E-08	2.51E-07	3.05E-08	µg/l
SVOC	3-Methyl-Benzaldehyde	0.0102	0.00123	0.00456	0.000554	µg/l
SVOC	3-Methyl-Benzaldehyde (01)	0.0114	0.00138	0.00512	0.000621	µg/l
SVOC	3-Methyl-butanoic acid	0.0000917	0.0000111	0.0000412	0.000005	µg/l
SVOC	3-Methyl-Phenanthrene	0.00476	0.000578	0.00214	0.00026	µg/l

Appendix G.7: Recreational Harbor Vessel Scenarios Instantaneous Concentration in the Hypothetical Harbor

Class	Analyte	Model Scenarios 17 and 19	Model Scenarios 18 and 20	Model Scenarios 21 and 23	Model Scenarios 22 and 24	Units
SVOC	3-Methylphenol	0.000532	0.0000646	0.000239	0.000029	µg/l
SVOC	3-Phenyl-2-Propenal	0.000359	0.0000436	0.000162	0.0000196	µg/l
SVOC	4,4-Dimethylbiphenyl	0.00495	0.000601	0.00222	0.00027	µg/l
SVOC	4-Hydroxy-2-Butanone	0.00554	0.000673	0.00249	0.000302	µg/l
SVOC	4-Methyl-1H-Benzotriazole	5.58E-06	6.77E-07	2.51E-06	3.04E-07	µg/l
SVOC	4-METHYL-PENTANOIC ACID	0.0000611	7.42E-06	0.0000275	3.34E-06	µg/l
SVOC	5-Butyl-Hexadecane	4.31E-07	5.23E-08	1.94E-07	2.35E-08	µg/l
SVOC	5-Methyl-2-(1-methyl)-Cyclohexanol	7.58E-06	9.2E-07	3.41E-06	4.13E-07	µg/l
SVOC	9-Methyl-9H-Fluorene	0.00509	0.000618	0.00229	0.000278	µg/l
SVOC	Acenaphthylene	0.00275	0.000334	0.00124	0.00015	µg/l
SVOC	Acetophenone	0.0000146	1.77E-06	6.55E-06	7.94E-07	µg/l
SVOC	Benzeneacetic Acid	0.0000467	5.66E-06	0.000021	2.55E-06	µg/l
SVOC	Benzenepropanoic Acid	0.0000515	6.25E-06	0.0000231	2.81E-06	µg/l
SVOC	Benzothiazole	0.0000239	0.0000029	0.0000107	0.0000013	µg/l
SVOC	Benzyl alcohol	0.0000152	1.85E-06	6.84E-06	8.3E-07	µg/l
SVOC	Biphenyl	0.00273	0.000331	0.00122	0.000149	µg/l
SVOC	Bis(2-ethylhexyl) phthalate	0.00114	0.000138	0.000511	0.000062	µg/l
SVOC	Caprolactam	0.0000273	3.32E-06	0.0000123	1.49E-06	µg/l
SVOC	Cholesterol	0.000142	0.0000172	0.0000636	7.72E-06	µg/l
SVOC	Cyclic octaatomic sulfur	0.012	0.00146	0.00539	0.000654	µg/l
SVOC	Cyclodecane	0.0000795	9.64E-06	0.0000357	4.33E-06	µg/l
SVOC	Cyclododecane	0.0000296	3.59E-06	0.0000133	1.61E-06	µg/l
SVOC	Cyclotetradecane	0.0000158	1.92E-06	7.12E-06	8.64E-07	µg/l
SVOC	Diethene Glycol Monododecyl Ether	0.0000299	3.62E-06	0.0000134	1.63E-06	µg/l
SVOC	Dimethyl phthalate	0.0000651	0.0000079	0.0000292	3.55E-06	µg/l
SVOC	Di-n-butyl phthalate	0.00139	0.000168	0.000624	0.0000757	µg/l
SVOC	Di-n-octyl phthalate	0.0000571	6.94E-06	0.0000257	3.12E-06	µg/l
SVOC	Disopropylene glycol	8.81E-06	1.07E-06	3.96E-06	4.8E-07	µg/l
SVOC	Dodecane	3.21E-07	3.9E-08	1.44E-07	1.75E-08	µg/l
SVOC	Dodecanoic acid	0.0000217	2.63E-06	9.74E-06	1.18E-06	µg/l
SVOC	Eicosane	0.0243	0.00295	0.0109	0.00133	µg/l
SVOC	Ethanol, 2,2-oxybis-	0.000974	0.000118	0.000438	0.0000531	µg/l
SVOC	Ethanol, 2-Butoxy	0.00619	0.000752	0.00278	0.000338	µg/l
SVOC	Fluorene	0.00294	0.000356	0.00132	0.00016	µg/l
SVOC	Heneicosane	0.00744	0.000903	0.00334	0.000406	µg/l
SVOC	Heptadecane	0.0429	0.00521	0.0193	0.00234	µg/l
SVOC	Hexaethylene Glycol Monododecyl	0.0000182	2.21E-06	8.17E-06	9.91E-07	µg/l
SVOC	Hexaethylene Glycol Monododecyl (01)	7.28E-06	8.84E-07	3.27E-06	3.97E-07	µg/l
SVOC	Hexaethylene Glycol Monododecyl (02)	0.0000023	2.79E-07	1.03E-06	1.25E-07	µg/l
SVOC	Hexagol	0.0000105	1.27E-06	4.71E-06	5.72E-07	µg/l
SVOC	Indane	0.000858	0.000104	0.000386	0.0000468	µg/l
SVOC	Indole	0.000257	0.0000313	0.000116	0.000014	µg/l
SVOC	Isopropylbenzene-4,methyl-1	0	0	0	0	µg/l
SVOC	m-Cresol	0.0000245	2.98E-06	0.000011	1.34E-06	µg/l
SVOC	Naphthalene	0.0133	0.00161	0.00596	0.000723	µg/l
SVOC	N-Butyl-Benzenesulfonamide	0.000003	3.64E-07	1.35E-06	1.64E-07	µg/l
SVOC	n-Hexadecane	0.0408	0.00495	0.0183	0.00223	µg/l
SVOC	n-Hexadecanoic acid	0.0000153	1.86E-06	6.89E-06	8.36E-07	µg/l
SVOC	Nonadecane	0.033	0.00401	0.0148	0.0018	µg/l

Appendix G.7: Recreational Harbor Vessel Scenarios Instantaneous Concentration in the Hypothetical Harbor

Class	Analyte	Model Scenarios 17 and 19	Model Scenarios 18 and 20	Model Scenarios 21 and 23	Model Scenarios 22 and 24	Units
SVOC	Nonadecane (01)	0.0102	0.00124	0.00459	0.000557	µg/l
SVOC	Nonanoic Acid	0.00805	0.000977	0.00362	0.000439	µg/l
SVOC	n-Pentadecane	0.0316	0.00383	0.0142	0.00172	µg/l
SVOC	n-Tetradecane	0.039	0.00474	0.0175	0.00213	µg/l
SVOC	o-Cresol	0.00457	0.000555	0.00205	0.000249	µg/l
SVOC	Octadecane	0.0093	0.00113	0.00418	0.000508	µg/l
SVOC	p-Cresol	0.0136	0.00165	0.00612	0.000743	µg/l
SVOC	Pentacosane	0.000266	0.0000323	0.000119	0.0000145	µg/l
SVOC	Pentaethene Glycol Monododecyl Ether	2.46E-06	2.98E-07	0.0000011	1.34E-07	µg/l
SVOC	Pentaethene Glycol Monododecyl Ether (01)	0.000018	2.18E-06	8.07E-06	9.8E-07	µg/l
SVOC	Pentaethene Glycol Monododecyl Ether (02)	0.0000354	4.29E-06	0.0000159	1.93E-06	µg/l
SVOC	Phenanthrene	0.0025	0.000303	0.00112	0.000136	µg/l
SVOC	Phenol	0.0279	0.00339	0.0126	0.00152	µg/l
SVOC	Phthalic acid, isobutyl octyl ester	0.0000102	1.24E-06	0.0000046	5.58E-07	µg/l
SVOC	Pyrene	0.000125	0.0000151	0.0000561	6.81E-06	µg/l
SVOC	Sulfur	0.00346	0.00042	0.00156	0.000189	µg/l
SVOC	Tetraethylene glycol monododecyl ether	0.0000183	2.22E-06	8.23E-06	9.99E-07	µg/l
SVOC	Triethyl phosphate	0.0000422	5.13E-06	0.000019	0.0000023	µg/l
SVOC	Triethylene glycol monododecyl ether	0.0000272	0.0000033	0.0000122	1.48E-06	µg/l
SVOC	Unknown SVOC	0.00742	0.0009	0.00333	0.000405	µg/l
SVOC	Unknown SVOC (01)	0.00681	0.000826	0.00306	0.000371	µg/l
SVOC	Unknown SVOC (02)	0.0072	0.000874	0.00324	0.000393	µg/l
SVOC	Unknown SVOC (03)	0.000288	0.0000349	0.000129	0.0000157	µg/l
SVOC	Unknown SVOC (04)	0.000295	0.0000359	0.000133	0.0000161	µg/l
SVOC	Unknown SVOC (05)	0.000166	0.0000202	0.0000748	9.08E-06	µg/l
SVOC	Unknown SVOC (06)	0.000103	0.0000125	0.0000464	5.63E-06	µg/l
SVOC	Unknown SVOC (07)	0.00154	0.000187	0.000692	0.000084	µg/l

(1) EPA suspects a limited number of the samples analyzed for selenium (even fewer for arsenic) for bilgewater, packing gland effluent, propulsion engine effluent, graywater and deck washdown water may be positively influenced (increased) by interference from high concentrations of major cations in the sample matrix. Although EPA suspects that the highest concentrations of dissolved arsenic (and to a lesser extent selenium) in fish hold effluent from a shrimping vessel could be slightly elevated due to cation interference; EPA believes the fish hold concentrations reasonably represent true effluent concentrations for the discharge (see Section 3.2.4.1). EPA considered these interferences when interpreting the potential for vessel discharges to pose a risk to human health, aquatic life, or the environment and determined that such cationic interference does not influence the major findings presented in the modeling analysis.

Appendix H
Responsiveness Summary

EPA received 24 separate comment letters from 23 different commenters. These included 19 trade associations (Alaska Longline Fishermen's Association, Alaska Trollers Association, American Coatings Association, American Waterways Operators, Boat U.S., California Wetfish Producers Association, two comments from Conference of Professional Operators for Response Towing (C-PORT), Garden State Seafood Association, National Association of Charterboats, National Marine Manufacturers Association, Offshore Marine Service Association, Passenger Vessel Association, Recreational Fishing Alliance – South Carolina Chapter, Sefood Producers Coop, Southeast Alaska Fishermen's Alliance, United Cook Inlet Drift Association (UCIDA), the United Fishermen of Alaska, and West Coast Seafood Processors Association), 4 vessel operators or businesses (3 in Alaska or the Pacific Northwest, 1 in New Jersey) and 1 state agency (Alaska Department of Environmental Conservation). EPA considered the comments received in finalizing the Report and thanks these commenters for providing us with their feedback on the report. We have summarized significant or reoccurring comments below.

COMMENT:
Some commenters noted that EPA did not sample a sufficient number of vessels.

RESPONSE:
EPA believes that the dataset used to characterize discharges from nonrecreational vessels less than 79 feet in length and all commercial fishing vessels regardless of length is from a representative cross-section of vessels and is adequate to evaluate the vessel population. In conducting this study, EPA worked with 14 trade associations and 27 individual companies to obtain information regarding the shipboard processes, equipment, materials, and operations that contribute to the discharges, as well as the discharge rates, duration, frequency, and location.

EPA collected samples of nine vessel discharges from a total of 61 vessels (one to four discharges sampled per vessel) in nine vessel classes to characterize discharge pollutant concentrations and flow. These vessels were located in 15 different towns/cities in nine separate states, representing several of the major regions of the United States.

In preparing the Report to Congress, EPA used all of the technically appropriate data provided by industry and collected from EPA's vessel sampling program. EPA released the pre publication version of the draft report to congress to the public on March 2, 2010 (announced in the March 8th Federal Register Notice (75 FR 10477)) and solicited comment on all aspects of the report as well as specific comment on the existence of additional data or data sources. As previously discussed, EPA received 24 separate comment letters from 23 different commenters, including 19 trade associations, 4 vessel operators or businesses, and 1 state agency. EPA evaluated the comments and information received and revised the draft report to incorporate additional technically appropriate information. EPA believes that the final report is based on adequate EPA-gathered and industry-supplied data, which includes primary sampling data and an extensive review of existing peer-reviewed literature and other government reports.

COMMENT:
Several commenters questioned the representativeness of the sampled vessels, particularly for commercial fishing vessels.

RESPONSE:
EPA believes that the dataset used to characterize discharges from nonrecreational vessels less than 79 feet in length and all commercial fishing vessels regardless of length, including sampling data from 61 vessels, is from a representative cross-section of vessels and is adequate for the purposes of this national, screening-level evaluation. EPA sampled vessels from each of the nine most common vessel classes and sampled more commercial fishing vessels (33 vessels) than any other vessel class due to the large number of fishing vessels in the P.L. 110-299 study universe. EPA notes that additional sampling to characterize the less common vessel classes/types and discharges would not influence the major findings of this study as the total discharge volume from these vessels are an insignificant portion of discharges from the total industry population. Given that EPA has limited data with which to base this study, EPA's approach is reasonable.

In response to comments, EPA further evaluated the representativeness of the sampled commercial fishing vessels by comparing their size, class, and geographic distribution to those of the overall industry population.

Size. The following table compares the size distribution of the sampled vessels to the total industry population.

	Percentage of Vessels	
Vessel Length	**Sampled Commercial Fishing Vessel Population**	**Overall Commercial Fishing Vessel Population***
Less than 26 feet	0%	10%
26 to 50 feet	52%	70%
50 to 79 feet	39%	16%
79 feet or more	9%	4%

* – Size distribution of those vessels that reported vessel length in the U.S. Coast Guard MISLE Database, 2009.

Commenters noted, and EPA concurs, that the sampled commercial fishing vessel population does not represent discharges from vessels less than 26 feet in length. EPA observed that these small vessels typically store their catch in coolers (which do not have a discharge) rather than in refrigerated seawater or ice holding tanks, as allowed by their relatively short fishing voyages. EPA attempted to interview small commercial fishing vessel captains to obtain information on fishing operations and discharges; however, none of the contacted vessel captains volunteered their vessels to remain at the pier long enough for EPA to collect information or to sample their holding tanks (if any), but rather offloaded their catch within a few minutes (e.g., physically transferred bushels of crabs or lobsters from the cooler to the dock) and immediately returned to the fishing grounds.

For the remaining categories of vessel length, the sampled vessel population reasonably agrees with the overall vessel population, albeit somewhat more heavily weighted toward the largest of commercial fishing vessels (i.e., 50 feet or more) as compared to the overall vessel population. Again, due to the time required to collect the necessary data, captains of larger vessels were more willing to participate in the study because they had more time shoreside during large offloads than the captains of smaller vessels.

In summary, with the exception of the smallest commercial fishing vessels, EPA believes that the sampled vessel population is a representative cross-section of vessels and is adequate to evaluate the vessel population for the purpose of this study. With respect to small vessels, as a conservative estimate, EPA assumed vessel discharge characteristics for small vessels similar to those of larger vessels.

<u>Class</u>. The following table compares the distribution by vessel class for the sampled fishing vessel types to the total industry population.

	Percentage of Vessels	
Vessel Class	**Sampled Commercial Fishing Vessel Population**	**Overall Commercial Fishing Vessel Population***
Gillnetter	15%	9%
Pot/Trap	3%[1]	27%
Longliner	9%	6%
Seiner	15%	2%
Shrimper/Scalloper/Dredge	18%	23%
Tender	9%	<1%
Trawler	12%	12%
Troller/Hook and Line	18%	19%

* – Vessel class distribution of those vessels that reported vessel subtype in the U.S. Coast Guard MISLE Database, 2009.

EPA's sampled commercial fishing vessel population includes vessels in all of the fishing vessel classes. Furthermore, the percentage of sampled vessels by class is similar to or greater than the percentage of the overall vessel population by class for all vessel classes except for Pot/Trap vessels. Pot/Trap vessels include many of the smallest commercial vessels that are not represented by EPA's sampled vessel population as discussed above, and in general have flow-through seawater holding tanks used to keep crabs and lobsters alive until reaching the seafood processing facility. As such, discharges from seafood holding tanks on Pot/Trap vessels are generally seawater. EPA also notes that it sampled a much larger percentage of seiners than the overall vessel population (15% of vessels sampled versus only 2% of the overall vessel population). EPA sampled all vessels

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[1] EPA did sample a lobster hold tank on a 63-foot trawler.

(where the permission of the captains was granted) that arrived at the docks at the seafood processors while the EPA sampling crew was at the docks. Sampling in Sitka, AK occurred at the start of the salmon fishing season, resulting in a preponderance of Seiners at the docks of seafood processers.

In summary, with the possible exception of Pot/Trap vessels, EPA believes that the sampled vessel population is a representative cross-section of vessels and is adequate to evaluate the vessel population for the purpose of this study. With respect to Seiners, fish hold effluent analyte concentrations from these vessels were neither the lowest nor the highest among the fish hold effluent discharged by the sampled vessel population. Therefore, EPA believes that any overrepresentation of Seiner fish hold effluent in EPA's analyses of vessel discharges would provide neither a high nor low bias to EPA's findings or conclusions.

Geographic Distribution. EPA sampled commercial fishing vessels in the following regions: Alaska (21 vessels); Gulf Coast (6 vessels); and New England (6 vessels). According to the National Marine Fisheries Service[2], in 2008 Alaska had nearly 55% of U.S. domestic commercial landings; the Gulf Coast had approximately 15% of U.S. domestic commercial landings; and New England had just over 7% of U.S. domestic commercial landings. Combined, these three areas represent approximately 77% of U.S. domestic commercial landings in 2008. Among the remaining geographic regions that EPA was unable to sample, the Pacific Coast (excluding Alaska) has the greatest landings in 2008 at 13%; commercials fishing vessels in this region are expected to be similar to those in Alaska. Finally, many of other remaining geographic regions that EPA was unable to sample, such as Chesapeake, Middle Atlantic, Great Lakes, and Hawaii, are likely dominated by small fishing vessels that may not have fish hold effluent discharges. Therefore, EPA believes that the geographic distribution of the sampled vessel population is a representative cross-section of vessels and is adequate to evaluate the vessel population for the purpose of this study.

COMMENT:

Some commenters noted that the assumptions used for estimating discharge volumes for the screening-level water quality model (Chapter 4 of the Report to Congress) resulted in higher estimates of volumes discharged. For example, commenters noted that some commercial fishing vessels do not clean their hulls daily or empty their holds daily.

RESPONSE:

Based on review and analysis of the comments, EPA ran a supplemental model run with the adjusted model assumptions presented in the table below and recalculated the associated discharge flows and loads. EPA performed this supplemental model run using the revised values to assess the impacts on the model results. EPA observed no significant change in model results based on the revised values. EPA revised Chapter 4 to describe this supplemental model run and to present the findings.

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[2] National Marine Fisheries Service (NMFS). 2009. Fisheries of the United States 2008. NMFS Fisheries Statistics Division. Silver Spring, MD.

Revised Model Assumptions

Vessel Class	Vessel Subclass	Discharge	Old Assumption	New Assumption
Fishing	Gillnetter	Fish Hold	Offloads daily	Offloads once per five days
Fishing	Longliner	Fish Hold	Offloads once per two days	Offloads once per five days
Fishing	Toller	Fish Hold Clean	Offloads daily	Offloads once per seven days
Fishing	Toller	Fish Hold	Offloads daily	Offloads once per seven days
Fishing	Toller	Fish Hold	840 ft^3 fish hold	595 ft^3 fish hold
Fishing	Toller	Fish Hold	5.5 tons of ice per offload	2 tons of ice per offload
Fishing	Toller	Deck Wash	125 gallons per deck wash	50 gallons per deck wash
Fishing	Shrimping	Bilge Water	150 gallons per minute bilge pump rate	20 gallons per minute bilge pump rate
Tour Boat	NA	Bilge Water	14.3 gallons per day	5 gallons per day

COMMENT:
Many commenters noted that some vessels do not have discharge types discussed in the report, for example, towing vessels do not have fish hold waste.

RESPONSE:
EPA agrees with this statement and believes that this point is clear in the report when describing discharge types. Furthermore, in its model, EPA estimates certain discharge types to occur from only some vessels.

COMMENT:
Some commenters noted that too few vessels, or too few vessels of a certain vessel type were sampled. For example, one commenter stated that EPA should have sampled charter fishing vessels. Others stated that EPA should have sampled different types of vessels than those selected.

RESPONSE:
See above response to comment regarding the sufficiency of the number of vessels sampled. Charter fishing vessels are often manufactured or used primarily for pleasure, or leased, rented or chartered to a person for the pleasure of that person. Many are not inspected by the US Coast Guard. Charter fishing vessels which are not inspected are exempted form NPDES permitting requirements by the Clean Boating Act (P.L. 110-288). Other charter fishing vessels are inspected by the US Coast Guard. These inspected, non-recreational vessels are not exempted from NPDES by the Clean Boating Act and are study vessels. Charter fishing vessels were not one of the most common vessels seen by EPA in its sampling program and the opportunity to sample charter fishing vessels did not present itself during the course of EPA's sampling.

COMMENT:
Some commenters noted that the MISLE database is not a completely accurate database for estimating vessel numbers or vessel location.

RESPONSE:
EPA agrees that use of the database may result in shortcomings. For example, the database under- or overcounts certain categories of vessels due to gaps in documentation or reporting requirements, differences in how the categories are defined, or missing information. Additionally, while a vessel may list New Orleans as its hailing port, it may rarely, if ever, operate in waters in and around New Orleans. However, based on its research, EPA concluded that the MISLE database was the best source of information for estimating the numbers and locations of study vessels. Several commenters pointed EPA to other databases. EPA reviewed these sources of information, and qualified the data in Chapter 1 of the report where appropriate.

Specifically, commenters raised concerns regarding estimates provided for two particular categories of vessels – passenger vessels and tank and freight barges – for which they believed MISLE misrepresents the number of active vessels less than 79 feet in length. EPA reviewed the MISLE database records and used additional information to further qualify the estimates presented in the report. For example, EPA revised the report to (1) detail the various types of vessels included in each category where the category definition differed from the types of vessels mentioned by commenters; (2) emphasize and further clarify limitations and potential shortcomings of the analyses; and (3) where possible, present ranges rather than unique estimates for the number of in-scope vessels.

In general, while EPA agrees that information provided by the MISLE database is uncertain, subject to potential errors and omissions, or potentially outdated, the Agency believes that this source still provides the most complete data available on vessel characteristics, particularly for smaller undocumented vessels which are of key concern in this study. EPA consulted with U.S. Coast Guard personnel on the estimates presented in the report and compared numbers obtained from MISLE with those presented in other sources, when such sources are available. No other public database provides the same breadth of information, however, from which to develop estimates of the number or characteristics of study vessels.

COMMENT:
Several commenters recommended that EPA analyze data on a regional basis, particularly for discharges from commercial fishing vessels.

RESPONSE:
Based on public comments received on EPA's Draft version of this report, EPA conducted a regional analysis of vessel fish hold discharges. While the preliminary analysis does suggest potential regional differences, issues with small sample size and an unbalanced distribution of vessels across regions suggest that additional sampling would be required to make a definitive determination. This regional analysis, which also includes additional analyses to determine the degree to which regional differences were an artifact of differences in vessel type (fishing method), or discharge type (refrigerated water vs. ice vs. ice slurry) are now included as a new subsection within the fish hold discharge section in Chapter 3 of the report.

COMMENT:
Some commenters noted that EPA should distinguish between different types of fish hold effluent in the analytical results. For example, one commenter stated that the Agency needed to more clearly distinguish between the discharge of refrigerated seawater and sea ice or sea ice slurry. Other commenters noted that EPA needed to more clearly distinguish between fish hold discharge and fish hold cleaning discharge.

RESPONSE:
In response to the first comment (distinguishing results between types of discharge (refrigerated vs. sea ice or sea ice slurry), EPA conducted additional screening analyses. EPA conducted an analysis comparing potential differences between refrigerated seawater, sea ice, or sea ice slurry. Differences in the type of fish hold discharge were separately investigated both for all 26 vessels included in this study and for the 20 vessels from Alaska. In both instances, there were no statistically significant differences between fish hold discharges between vessels as a function of whether the discharge was refrigerated seawater, ice, or ice slurry. These analyses are discussed within the regional analysis section within the fish hold discharge section in Chapter 3 of the Report.

EPA disagrees with the second comment because the data presented in the report clearly indicate few, if any, distinguishable differences between results obtained for fish hold and fish hold cleaning discharge, and where those differences occur, EPA discusses them in text.

COMMENT:
One commenter noted that the report is not conducted on recreational vessels and that the report needs to be clearer to this effect. Other commenters noted that the potential cumulative environmental impacts from all study vessels should be compared to the potential cumulative environmental impacts from all recreational vessels.

RESPONSE:
EPA believes the report is clear that the vast majority of samples are from vessels which were not in recreational service. However, two vessels sampled were recreational vessels, while discharges from several others were fundamentally similar to those which may originate from recreational vessels (e.g., engine effluent from certain towing vessels).

For purposes of this study, EPA does not believe that the cumulative impact of study vessels should be compared to those of recreational vessels, as an analysis of this kind is beyond the original congressional charge and beyond the original scope of the study design.

COMMENT:
Some commenters noted that EPA should examine the impacts of invasive species from recreational vessels, or what would happen if EPA were to prohibit practices designed to reduce the transport of invasive species (e.g., anti-foulant hull coatings). A commenter

noted that EPA should add additional references to the impact of invasive species caused by boating, specifically in the absence of cuprous oxide anti-foulant hull coatings.

RESPONSE:
EPA and EPA scientists, among others have conducted numerous studies on the impacts of invasive species. EPA further discusses the impacts of invasive species in regulatory documents such as the fact sheet and other supporting documents for its recently issued Vessel General Permit. EPA agrees with the commenter that the risks of increasing the likelihood of invasive species being transported needs to be weighed against any regulatory limits placed on discharges. However, this report does not make recommendations regarding regulatory limits or best management practices.

COMMENT:
Two commenters noted that EPA needed to further research and clarify its statements regarding anti-foulant paints.

RESPONSE:
One commenter noted that the issue of invasive species was inadequately discussed in relationship to the regulation of anti-foulant coatings (AFCs). As discussed in the previous response, the focus of the study was not on invasive species. Additionally, based on comments regarding AFCs, EPA removed one sentence: “On the other hand, improvements to water quality, including improvements associated with AFC restrictions and BMPs may allow native ecosystems to recover from acute and chronic impacts and become more resistant to invasions of non-native species” attributed to Johnson and Gonzalez (2006), which appeared to be speculative.

Additional test data for copper AFC leaching rates were provided to EPA by the Antifouling Coatings Work Group (AFWG) of the American Coatings Association (ACA) during the public comment period. EPA added a footnote in Section 3.2.8 acknowledging receipt of additional test data for copper AFC leaching rates, and noted that this data substantially agrees with EPA's "best estimate" of copper AFC leaching rate used for water quality modeling.

One commenter noted that statements regarding the regulation of AFCs in other countries were misleading and/or incorrect. Upon review, EPA found that the regulation of AFCs in Europe and other countries are dynamic and evolving. Therefore, EPA elected to remove the text in question, which appeared to be outdated.

COMMENT:
One commenter noted that EPA needs to clarify in the executive summary that the National Recommended Water Quality Criteria (NRWQC) benchmarks used are conservative in nature.

RESPONSE:
EPA disagrees and feels the information provided in Chapter 3 on the NRWQC benchmarks is clear. This level of detail is not appropriate for discussion in a short executive summary.

COMMENT:
Some commenters stated that they believed the release or leaching of metals or other biocides from hull coatings did not constitute a discharge.

RESPONSE:
EPA disagrees, and would consider these releases as discharges from the vessel. EPA has consistently determined that the release of metals or leaching of metals or other biocides constitutes the addition of pollutants from a point source to waters of the United States, i.e., a discharge. (See EPA's 2008 Vessel General Permit or Uniform National Discharge Standards (UNDS) Phase I rule and CWA section 502). The CWA definition of "point source" includes "vessel or other floating craft."

COMMENT:
One commenter noted that EPA should clearly distinguish between commercial fishing vessels and charter fishing vessels. The commenter also noted that charter fishing vessels are more similar to recreational vessels than many of their commercial fishing counterparts.

RESPONSE:
The charter fishing vessels discussed by these commenters may fall under the definition of recreational vessel as defined in the Clean Boating Act of 2008. Charter fishing vessels are often manufactured or used primarily for pleasure, or leased, rented, or chartered to a person for the pleasure of that person. Many are not inspected by the US Coast Guard. Charter fishing vessels which are not inspected are exempted form NPDES permitting requirements by the Clean Boating Act (P.L. 110-288). Other charter fishing vessels are inspected by the US Coast Guard. These inspected, non-recreational vessels are not exempted from NPDES by the Clean Boating Act, and are study vessels,. EPA did not sample any charter fishing vessels as part of the sampling program.

In addition to sampling two recreational vessels, EPA studied several recreational vessels used for non-recreational purposes as part of the study (some tow/salvage boats and research vessels). Vessel discharges such as engine effluent are likely fundamentally similar to the engine effluent between the two vessel classes, provided they are similar engine types and maintained in a similar manner.

COMMENT:
Several commenters noted that they recommended Congress continue to extend the P.L. 110-299 moratorium or that Congress devise an alternate regulatory program. For example, several commenters noted that commercial fishing vessels less than 79 feet should be regulated similarly to those under the Clean Boating Act of 2008 (P.L. 110-288). Other commenters requested exemptions from NPDES permitting or any permit EPA may promulgate under the NPDES permitting program for smaller commercial fishing vessels.

RESPONSE:
On July 30, 2010, President Obama signed Senate Bill S. 3372 to extend an existing moratorium from July 31, 2010 to December 18, 2013. This moratorium exempts all incidental discharges except ballast water from commercial fishing vessels and non-recreational vessels less than 79 feet from having to obtain an NPDES permit.

EPA notes that this is not the proper forum for requesting that the Agency grant exemptions to certain classes of vessels from the NPDES program. Please see discussion in the 2008 VGP Fact Sheet for additional information about why EPA now regulates certain vessel discharges and for additional information on Congressional legislation that did grant permanent exemptions to certain types of vessels.

COMMENT:
One commenter requested an extension of time to review the report and provide further comments.

RESPONSE:
Due to the short time granted to EPA to conduct the study, EPA believes it would be inappropriate to grant any extensions to review the report as the Agency wants the final report to be available for congressional decision makers and others as soon as possible.

Appendix I
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