ENVIRONMENTAL CONTAMINANTS ENCYCLOPEDIA

KEROSENE ENTRY

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Like a library or many large databases (such as EPA's national STORET water quality database), this document contains information of variable quality from very diverse sources. In compiling this document, mistakes were found in peer reviewed journal articles, as well as in databases with relatively elaborate quality control mechanisms [366,649,940]. A few of these were caught and marked with a "[sic]" notation, but undoubtedly others slipped through. The [sic] notation was inserted by the editors to indicate information or spelling that seemed wrong or misleading, but which was nevertheless cited verbatim rather than arbitrarily changing what the author said.

Most likely additional transcription errors and typos have been added in some of our efforts. Furthermore, with such complex subject matter, it is not always easy to determine what is correct and what is incorrect, especially with the "experts" often disagreeing. It is not uncommon in scientific research for two different researchers to come up with different results which lead them to different conclusions. In compiling the Encyclopedia, the editors did not try to resolve such conflicts, but rather simply reported it all.

It should be kept in mind that data comparability is a major problem in environmental toxicology since laboratory and field methods are constantly changing and since there are so many different "standard methods" published by EPA, other federal agencies, state agencies, and various private groups. What some laboratory and field investigators actually do for standard operating practice is often a unique combination of various standard protocols and impromptu "improvements." In fact, the interagency task force on water methods concluded that [1014]:

> It is the exception rather than the rule that water-quality monitoring data from different programs or time periods can be compared on a scientifically sound basis, and that...
>
> No nationally accepted standard definitions exist for water quality parameters. The different organizations may collect data using identical or standard methods, but identify them by different names, or use the same names for data collected by different methods [1014].

Differences in field and laboratory methods are also major issues related to (the lack of) data comparability from media other than water: soil, sediments, tissues, and air.

In spite of numerous problems and complexities, knowledge is often power in decisions related to chemical contamination. It is therefore often helpful to be aware of a broad universe of conflicting results or conflicting expert opinions rather than having a portion of this information arbitrarily censored by someone else. Frequently one wants to know of the existence of information, even if one later decides not to use it for a particular application. Many would like to see a high percentage of the information available and decide for themselves what to throw out, partly because they don't want to seem uniformed or be caught by surprise by potentially important information. They are in a better position if they can say: "I knew about that data, assessed it based on the following quality assurance criteria, and decided not to use it for this application." This is especially true for users near the end of long decision processes, such as hazardous site cleanups, lengthy ecological risk assessments, or complex natural resource damage assessments.

For some categories, the editors found no information and inserted the phrase "no information found." This does not necessarily mean that no information exists; it simply means that during our efforts, the editors found none. For many topics, there is probably information "out there" that is not in the Encyclopedia. The more time that passes without encyclopedia updates (none are planned at the moment), the more true this statement will become. Still, the Encyclopedia is unique in that it contains broad ecotoxicology information from more sources than many other reference documents. No updates of this document are currently planned. However, it is hoped that most of the information in the encyclopedia will be useful for some time to come even without updates, just as one can still find information in the 1972 EPA Blue Book [12] that does not seem well summarized anywhere else.

Although the editors of this document have done their best in the limited time available to insure accuracy of quotes or summaries as being "what the original author said," the proposed interagency funding of a bigger project with more elaborate peer review and quality control steps never materialized.

> The bottom line: The editors hope users find this document useful, but don't expect or depend on perfection herein. Neither the U.S. Government nor the National Park Service make any claims that this document is free of mistakes.

The following is one chemical topic entry (one file among 118). Before utilizing this entry, the reader is strongly encouraged to read the README file (in this subdirectory) for an introduction, an explanation of how to use this document in general, an explanation of how to search for power key section headings, an explanation of the organization of each entry, an information quality discussion, a discussion of copyright issues, and a listing of other entries (other topics) covered.

See the separate file entitled REFERENC for the identity of numbered references in brackets.

HOW TO CITE THIS DOCUMENT: As mentioned above, for critical applications it is better to obtain and cite the original publication after first verifying various data quality assurance concerns. For more routine applications, this document may be cited as:

> **Irwin, R.J., M. VanMouwerik, L. Stevens, M.D. Seese**, and **W. Basham.** 1997. Environmental Contaminants Encyclopedia. National Park Service, Water Resources Division, Fort Collins, Colorado. Distributed within the Federal Government as an Electronic Document (Projected public availability

on the internet or NTIS: 1998).

Kerosene (Kerosine, Fuel Oil No. 1, JP-1, CAS number 8008-20-6)

Brief Introduction:

Br.Class: General Introduction and Classification Information:

NOTE: The term "kerosene" is not used in a consistent manner throughout the literature. While several sources list Jet Fuel 1 (JP-1) as an exact synonym for kerosene [366,367,560], other sources refer to kerosene as a distillation fraction or group that includes more than just JP-1 [661]. Some sources say kerosene is one of several forms of fuel oil no. 1 [560], while other sources say fuel oil no. 1 is a synonym of kerosene [580]. The spelling is also inconsistent. Most industry sources spell the term as "kerosene," but some prefer to spell it as "kerosine." Additional detail:

Fuel oil no. 1, jet fuel 1, diesel no. 1, and kerosene are basically the same products except for end use and for additives [962]. See also Diesel Oil #1 entry.

> Editor's note: synonyms for jet fuels can be confusing and are sometimes used incorrectly in the literature; for example, JP-5 is given as an exact synonym for kerosene and Fuel Oil 1 in ATSDR [962], but this is not 100% correct (see Jet Fuels, General entry). It is more precise to say that Jet fuel 5 (JP-5) is one particular form of no. 1 fuel oil [635]. JP-1 is kerosene, while JP-5 is a specially refined kerosene, a high flash point kerosene [560]. Nevertheless, the products are close enough in composition that the reader is encouraged to read the entries of products similar to the one being researched.

In the US Coast Guard CHRIS Manual [367], the only difference in the synonyms between Jet Fuel 1 and Kerosene is that kerosene also lists "illuminating oil." Therefore, if an end use is also illumination, the oil product may be labeled "kerosene" or "fuel oil no. 1" whereas if the end use is jet propulsion, a similar oil product may be labeled "JP-1." Also, the word "kerosene" is used to refer to the kerosene fraction removed during the distillation of petroleum at boiling point 175 to 330 degrees C [746]. Thus, many petroleum products, including the majority of jet fuels, are labelled "kerosene-based" since they are derived from this petroleum fraction. For the purposes of this document, we are putting information found on either JP-1, Fuel Oil No.1, and/or kerosene under the kerosene entry.

Kerosene is a thin oil distilled from petroleum or shale oil, used as a fuel and alcohol denaturant [492]. Kerosene was first processed from crude oil in the early Pennsylvania oil fields. Then known as coal oil because a similar product was being distilled from coal, kerosene took the place of the dwindling supplies of whale oil as an illuminant [637]. The word kerosine is derived from the Greek word "kero," which means wax. The spelling "kerosene" is widely used in industry, although some prefer the spelling "kerosine" [747].

Kerosene now has several other uses such as an aircraft gas turbine and jet fuel by both commercial airlines and the military service, as a heating oil, and as a spray oil to combat insects on citrus plants [637]. Because of its availability compared to gasoline during wartime, commercial illuminating kerosene was the fuel chosen for early jet engines. Consequently, the development of commercial jet aircraft following World War II centered primarily on the use of kerosene-type fuels [747].

Many commercial jet fuels have basically the same composition as kerosene, such as jet A and JP-8, but they are under more stringent specifications than those for kerosene. Other commercial and military jet fuels, such as jet B and JP-4, are referred to as wide-cut fuels and are usually made by blending kerosene fractions with lower boiling streams, such as the gasoline and naphtha fractions, to include more volatile hydrocarbons [747].

Coleman et al. determined that the major constituents of kerosene are alkanes and cycloalkanes (68.6%); benzene and substituted benzene (13.7%); and naphthalene and substituted naphthalenes [745]. Another source states that the average chemical composition by weight is 35% paraffins, 60% naphthenes, and 15% aromatics [641].

According to the US Coast Guard Emergency Response Notification System (ERNS), kerosene is one of the most commonly spilled petroleum products the U.S [635].

The various kinds of fuel oils are obtained by distilling crude oil, and removing the different fractions. Fuel oil #1, or kerosene, is the first fuel fraction after distillation of some of the very volatile fractions such as naphtha and benzene [641]. Sometimes the word "kerosene" is used to refer to the actual kerosene fraction (vapors condensing in the middle range) removed during the distillation of petroleum at boiling point 175 to 330 degrees C. This fraction contains hydrocarbons C11 to C12. Higher fractional cuts of kerosene may contain alkanes to C18 and aromatics compounds with higher molecular weight side chains than is observed in gasoline [746]. In the petroleum refining process, vapors condensing in the middle range or "middle distillates" are characteristic of kerosene hydrocarbons. The middle distillates include kerosene, aviation fuels, diesel fuels, and fuel oil no. 1 and no. 2. These fuels contain paraffins (alkanes), cycloparaffins (cycloalkanes), aromatics, and olefins from approximately C9 to C20. Aromatic compounds of concern include alkylbenzenes, toluene, naphthalenes, and polycyclic aromatic hydrocarbons (PAHs). In the middle distillate range, kerosene has the least amount of aromatic hydrocarbons with alkylbenzenes, indanes, and naphthalenes being the most aromatic components [661].

Petroleum distillates in order of decreasing volatility include [363]:

1. Petroleum ether or benzine
2. Gasoline
3. Naphtha
4. Mineral spirits
5. Kerosene
6. Fuel oils
7. Lubricating oils
8. Paraffin wax
9. Asphalt or tar.

Br.Haz: General Hazard/Toxicity Summary:

Kerosene is highly toxic to humans [369]. Kerosene is irritating to the skin and mucous membranes [661].

Short-term hazards of the some of the lighter, more volatile and water soluble compounds (such as ethyl benzene compounds and toluene) in kerosene include potential acute toxicity to aquatic life in the water column (especially in relatively confined areas) as well as potential inhalation hazards. Kerosene has moderate volatility and moderate solubility [777]. Kerosene possesses moderate to high acute toxicity to biota with product-specific toxicity related to the type and concentration of aromatic compounds [777]. Kerosene spills could result in potential acute toxicity to some forms of aquatic life.

Oil coating of birds, sea otters, or other aquatic life which come in direct contact with the spilled oil is another potential short term hazard. In the short term, spilled oil will tend to float on the surface; water uses threatened by spills include: recreation; fisheries; industrial, potable supply; and irrigation [608].

Long-term potential hazards of the some of the lighter, more volatile and water soluble compounds (such as benzenes, toluene, xylenes) in kerosene include contamination of groundwater. Long-term water uses threatened by spills include potable (ground) water supply.

Long-term effects are also associated with PAHs, alkyl PAHs, and alkyl benzene (such as xylene) constituents of kerosene. Although PAHs, particularly heavy PAHs, do not make up a large percentage of kerosene by weight, there are some PAHs in kerosene, including naphthalene and alkyl naphthalenes [745]. Due to their relative persistence and potential for various chronic effects, PAHs, (and particularly the alkyl PAHs), can contribute to long term (chronic) hazards of kerosene in contaminated soils, sediments, and groundwaters. Chronic effects of some of the constituents in kerosene (benzene, toluene, xylene, naphthalenes, alkyl benzenes, and various alkyl PAHs) include changes in the liver and harmful effects on the kidneys, heart, lungs, and nervous system. Increased rates of cancer, immunological, reproductive, fetotoxic, genotoxic effects have also been associated with some of the compounds found in kerosene (see Chem.Detail section for compounds in this product, then see individual compound entries for summaries of information on individual components of this mixture).

Since Diesel oil 1 is similar in chemical composition to Fuel oil 1 (Kerosene), with the exception of additives [962], information on diesel is of some interest related to this product (see the Diesel Oil, General and Diesel Oil #1 entries). At a National Park Service spill site where sediments were contaminated by Diesel 1 and 2, the most common PAHs were alkyl PAHs (see Chem.Detail section below). In this Park Service sediment investigation at Petersburg National Battlefield performed in response to contamination by Diesel Fuels (1D and 2D), 97.6% of the PAHs concentrations detected in sediments were alkyl PAHs. All 39 PAHs and alkyl PAHs analyzed were present in the contaminated sediments (Personal Communication, Roy Irwin, National Park Service, 1996). Since alkyl PAHs are such a high percentage of total PAHs in several petroleum products, they should not be ignored in hazard or risk assessments.

Many of the PAHs found in this product (see Chem.Detail section below) are more toxic in sunlight or other UV source than elsewhere (see PAHs as a group entry).

One of the hazardous groups of compounds in fuel oils is PAHs [962] (see PAHs entry). PAHs may be translocated in plants and may accumulate in plants grown in contaminated soil [40]. Presumably this also occurs in sediments and aquatic plants and therefore might impact herbivorous species of fish and wildlife. Although some research seems to indicate that interior portions of above-ground vegetables do not accumulate high concentrations of PAHs, plants do translocate PAHs from roots to other plant parts, such as developing shoots [40]. Some plants can evidently catabolize benzo(a)pyrene, but metabolic pathways have not been clearly defined. This is an important factor since when PAHs do degrade through metabolism, they often break down into even more toxic, carcinogenic, and mutagenic compounds [40]. Metabolic transformations of PAHs into even more hazardous chemicals could also happen through microbial degradation of PAHs in soils or sediments. This provides an additional example of a situation where human health based standards are not protective of fish and wildlife, since it casts doubt on the environmental safety margin provided by EPA's human health-based soil guideline of =<100 ppm carcinogenic PAHs.

> However, in a series of soil and hydrocultures of the higher plants, tobacco, rye, and radish, as well as algae cultures of lower plants (Chlorella vulgaris, Scenedesmus obligurus, and Ankistrodesmus) /results indicate/ that certain polycyclic aromatic hydrocarbons (PAHs) have growth-promoting effects on plants. Further, the degree of the promoting effect corresponded to the oncogenic activity of the hydrocarbon. The six polycyclic aromatic hydrocarbons found in plants were tested one at a time or in combination. Considerable growth-promotion was noted (near to 100% in some cases) with the effectiveness of hydrocarbons ranked as follows: (1) Benzo(a)pyrene (2) Benzo(a)anthracene (3) Indeno (1,2,3-cd)pyrene, Benzo(b)fluoranthene (4) Fluoranthene (5) Benzo(ghi)perylene. [Graf W, Nowak W; Arch Hyg Bakt 150: 513-28 (1968) as cited in Health & Welfare Canada; Polycyclic Aromatic Hydrocarbons p.67 (1979) Report No. 80-EHD-50] [366].

See also: ATSDR toxicological profile on fuels oils in general, including this product [962].

Br.Car: Brief Summary of Carcinogenicity/Cancer Information:

There is limited evidence for carcinogenicity in experimental animals due to straight-run kerosene and/or hydrotreated kerosene. For example, two samples of straight-run kerosene and one sample of hydrotreated kerosene produced skin tumors in mice [747].

Certain carcinogenic effects have been associated with benzene and (possibly) some of the other compounds found in kerosene [609,766,767] (see Chem.Detail section for compounds in this product, then see individual compound entries for summaries of information on individual components of this mixture).

The debates on which PAHs, alkyl PAHs, and other aromatics in complex mixtures such as this product to classify as carcinogens, and the details of exactly how to perform both ecological and human risk assessments on the complex mixtures of PAHs typically found at contaminated sites, are likely to continue. There are some clearly wrong ways to go about it, but defining clearly right ways is more difficult. Perhaps the most unambiguous thing that can be said about complex PAH mixtures is that such mixtures are often carcinogenic and possibly phototoxic. One way to approach site specific risk assessments would be to collect the complex mixture of PAHs and other lipophilic contaminants in a semipermeable membrane device (SPMD, also known as a fat bag) [894,895,896], retrieve the contaminant mixture from the SPMD, then test the mixture for carcinogenicity, toxicity, and phototoxicity (James Huckins, National Biological Service, and Roy Irwin, National Park Service, personal communication, 1996).

See also: ATSDR toxicological profile on fuels oils in general, including this product [962].

Br.Dev: Brief Summary of Developmental, Reproductive, Endocrine, and Genotoxicity Information:

The results are mixed, but some immunological, reproductive, fetotoxic, and genotoxic effects have been associated with a few of the compounds found in kerosene [609,764,765,766,767] (see Chem.Detail section for compounds in this product, then see individual compound entries for summaries of information on individual components of this mixture).

In single studies, kerosene did not induce chromosomal aberrations in rat bone marrow, nor did it induce mutation in cultured mammalian cells or in bacteria [747].

Information from RTECS [607]:

Genetic effects
Mutations in microorganisms
Bacteria - S typhimurium
DOSE: 25 uL/plate; REFERENCE: Cell Biology and Toxicology 2:63, 1986.

Some of the PAHs found in fuel oils (such as this one) are either AHH active or endocrine disruptors [561].

See also: ATSDR toxicological profile on fuels oils in general, including this product [962].

See also: PAHs as a group entry.

Br.Fate: Brief Summary of Key Bioconcentration, Fate, Transport, Persistence, Pathway, and Chemical/Physical Information:

In the environment, kerosene is a source of harmful compounds such as PAHs. For the most part, the boiling range of kerosene fuel oil (fuel oil no. 1) generally precludes the occurrence of substantial quantities of polycyclic aromatic hydrocarbons (PAHs) [747].

Kerosene and diesels are middle distillate petroleum hydrocarbon products of intermediate volatility and mobility [661]. As intermediate products, kerosenes have a combination of (mostly) lighter, less persistent and more mobile compounds as well as (some) heavier, more persistent and less mobile compounds. These two different groups are associated with two distinctly different patterns of fate/pathway concerns:

> The relatively lighter, more volatile, mobile, and water soluble compounds in kerosene will tend to fairly quickly evaporate into the atmosphere or migrate to groundwater. When exposed to oxygen and sunlight, most of these compounds will tend to break down relatively quickly. However, in groundwater, many of these compounds tend to be more persistent than in surface water, and readily partition on an equilibria basis back and forth between water and solids (soil and sediment) media. Cleaning up groundwater without cleaning up soil contamination will usually result in a rebound of higher concentrations of these compounds partitioning from contaminated soils into groundwater (Roy Irwin, personal communication).
>
> The compounds in kerosene which will tend to be somewhat more persistent and more bound to solid particles will include the PAHs, alkyl PAHs, and alkyl benzenes. Higher concentrations of heavier PAHs will tend to be in adjacent contaminated soils than in groundwater, but cleaning up groundwater without cleaning up soil contamination will nevertheless usually result in at least some rebound of higher concentrations of these compounds partitioning from contaminated soils into groundwater (Roy Irwin, personal communication).

Concerning cleanup issues, kerosene falls under the

Diesel-like Products category. The following grouping is used by NOAA to identify basic cleanup options [741,771,777]:

Diesel-like Products and Light Crudes (Jet Fuels, Diesel, No. 2 Fuel Oil, Kerosene, West Texas Crude):

-Moderately volatile.
-Refined products can evaporate with no residue.
-Light crude will leave residue (up to one-third of spill amount) after a few days.
-Moderately soluble, especially distilled products.
-Low and moderate viscosity; spread rapidly into thin slicks.
-Can form stable emulsions.
-Moderate to high acute toxicity to biota; product-specific toxicity related to type and concentration of aromatic compounds.
-Will "oil" intertidal resources with long-term contamination potential.
-Has potential for subtidal impacts (dissolution, mixing, sorption onto suspended sediments).
-Tend to penetrate substrate; fresh spills are not adhesive.
-Stranded light crudes tends to smother organisms.
-No dispersion necessary.
-Cleanup can be very effective.

Petroleum distillates in order of decreasing volatility include [363]:

1. Petroleum ether or benzine
2. Gasoline
3. Naphtha
4. Mineral spirits
5. Kerosene
6. Fuel oils
7. Lubricating oils
8. Paraffin wax
9. Asphalt or tar.

See also: ATSDR toxicological profile on fuels oils in general, including this product [962].

Synonyms/Substance Identification:

See also: Br.Class section above.

Jet Fuel 1 (JP-1) is listed as an exact synonym for kerosene according to several sources [366,367,560].

Coal oil [580,607]
Fuel oil no 1 [580,615]

Kerosine [580,607,615]
Range oil [580,615]
JP-1 [615]
Deobase [607]
Straight-run kerosene [607]
Range Oil [962]

Jet Fuel 5 is "heavy kerosene" [560] (see the Jet Fuel 5 entry). Editor's note: synonyms for Jet Fuels can be confusing and are sometimes incorrect in the literature; for example, JP-5 is given as an exact synonym for kerosene and Fuel Oil 1 in ATSDR [962], but this is not 100% correct. It is more precise to say that Jet fuel 5 (JP-5) is one particular form of no. 1 fuel oil [635]. JP-1 is kerosene, while JP-5 is a specially refined kerosene, a high flash point kerosene [560]. Nevertheless, the products are similar enough that the reader is encouraged to read the entries of products similar to the one being researched.

Associated Chemicals or Topics (Includes Transformation Products):

See also individual entries:

Fuel Oil, General
Jet Fuel, General
Jet Fuel A
Jet Fuel 4
Jet Fuel 5
Jet Fuel 8
Oil Spills
Petroleum, General

Site Assessment-Related Information Provided by Shineldecker (Potential Site-Specific Contaminants that May be Associated with a Property Based on Current or Historical Use of the Property) [490]:

Raw Materials, Intermediate Products, Final Products, and Waste Products Generated During Manufacture and Use:

- Benzene
- Butadiene
- Cyclohexane
- Cyclohexene
- Cyclopropane
- Ethyl benzene
- Methylcyclohexene
- n-Heptane
- n-Hexane
- Naphthalene
- Polynuclear aromatic hydrocarbons (PAHs, PNAs)
- Toluene
- Xylenes

Water Data Interpretation, Concentrations and Toxicity (All Water Data Subsections Start with "W."):

W.Low (Water Concentrations Considered Low):

No information found; see Chem.Detail section for compounds in this product, then see individual compound entries for summaries of information on individual components of this mixture.

W.High (Water Concentrations Considered High):

No information found; see Chem.Detail section for compounds in this product, then see individual compound entries for summaries of information on individual components of this mixture.

W.Typical (Water Concentrations Considered Typical):

No information found; see Chem.Detail section for compounds in this product, then see individual compound entries for summaries of information on individual components of this mixture.

W.Concern Levels, Water Quality Criteria, LC50 Values, Water Quality Standards, Screening Levels, Dose/Response Data, and Other Water Benchmarks:

W.General (General Water Quality Standards, Criteria, and Benchmarks Related to Protection of Aquatic Biota in General; Includes Water Concentrations Versus Mixed or General Aquatic Biota):

No information found; see Chem.Detail section for compounds in this product, then see individual compound entries for summaries of information on individual components of this mixture.

W.Plants (Water Concentrations vs. Plants):

No information found; see Chem.Detail section for compounds in this product, then see individual compound entries for summaries of information on individual components of this mixture.

W.Invertebrates (Water Concentrations vs. Invertebrates):

Acute Toxicity, Oil in Water Emulsion [560] (mg/L):

Genus/Species	96h LC50
Frog Larvae (freshwater)	
1. Flowthrough apparatus	45.8 uL/L

W.Fish (Water Concentrations vs. Fish):

Aquatic Toxicity [560] (mg/L):

Genus/Species	24h TLm
Bluegill	
1. Freshwater	2900

Acute Toxicity, Oil in Water Emulsion [560] (mg/L):

Genus/Species	96h LC50
Fathead Minnow (freshwater)	
1. Flowthrough apparatus	56.7 uL/L

W.Wildlife (Water Concentrations vs. Wildlife or Domestic Animals):

No information found; see Chem.Detail section for compounds in this product, then see individual compound entries for summaries of information on individual components of this mixture.

W.Human (Drinking Water and Other Human Concern Levels):

No information found; see Chem.Detail section for compounds in this product, then see individual compound entries for summaries of information on individual components of this mixture.

W.Misc. (Other Non-concentration Water Information):

No information found; see Chem.Detail section for compounds in this product, then see individual compound entries for summaries of information on individual components of this mixture.

Sediment Data Interpretation, Concentrations and Toxicity (All Sediment Data Subsections Start with "Sed."):

Sed.Low (Sediment Concentrations Considered Low):

No information found; see Chem.Detail section for compounds in this product, then see individual compound entries for summaries of information on individual components of this mixture.

Sed.High (Sediment Concentrations Considered High):

No information found; see Chem.Detail section for compounds in this product, then see individual compound entries for summaries of information on individual components of this mixture.

Sed.Typical (Sediment Concentrations Considered Typical):

No information found; see Chem.Detail section for compounds in this product, then see individual compound entries for summaries of information on individual components of this mixture.

Sed.Concern Levels, Sediment Quality Criteria, LC50 Values, Sediment Quality Standards, Screening Levels, Dose/Response Data and Other Sediment Benchmarks:

Sed.General (General Sediment Quality Standards, Criteria, and Benchmarks Related to Protection of Aquatic Biota in General; Includes Sediment Concentrations Versus Mixed or General Aquatic Biota):

No information found; see Chem.Detail section for compounds in this product, then see individual compound entries for summaries of information on individual components of this mixture.

Sed.Plants (Sediment Concentrations vs. Plants):

No information found; see Chem.Detail section for compounds in this product, then see individual compound entries for summaries of information on individual components of this mixture.

Sed.Invertebrates (Sediment Concentrations vs. Invertebrates):

No information found; see Chem.Detail section for compounds in this product, then see individual compound entries for summaries of information on individual components of this mixture.

Sed.Fish (Sediment Concentrations vs. Fish):

No information found; see Chem.Detail section for compounds in this product, then see individual compound entries for summaries of information on individual components of this mixture.

Sed.Wildlife (Sediment Concentrations vs. Wildlife or Domestic Animals):

No information found; see Chem.Detail section for compounds in this product, then see individual compound entries for summaries of information on individual components of this mixture.

Sed.Human (Sediment Concentrations vs. Human):

No information found; see Chem.Detail section for compounds in this product, then see individual compound entries for summaries of information on individual components of this mixture.

Sed.Misc. (Other Non-concentration Sediment Information):

No information found; see Chem.Detail section for compounds in this product, then see individual compound entries for summaries of information on individual components of this mixture.

Soil Data Interpretation, Concentrations and Toxicity (All Soil Data Subsections Start with "Soil."):

Soil.Low (Soil Concentrations Considered Low):

No information found; see Chem.Detail section for compounds in this product, then see individual compound entries for summaries of information on individual components of this mixture.

Soil.High (Soil Concentrations Considered High):

No information found; see Chem.Detail section for compounds in this product, then see individual compound entries for summaries of information on individual components of this mixture.

Soil.Typical (Soil Concentrations Considered Typical):

No information found; see Chem.Detail section for compounds in this product, then see individual compound entries for summaries of information on individual components of this mixture.

Soil.Concern Levels, Soil Quality Criteria, LC50 Values, Soil Quality Standards, Screening Levels, Dose/Response Data and Other Soil Benchmarks:

Soil.General (General Soil Quality Standards, Criteria, and Benchmarks Related to Protection of Soil-dwelling Biota in General; Includes Soil Concentrations Versus Mixed or General Soil-dwelling Biota):

No information found; see Chem.Detail section for compounds in this product, then see individual compound entries for summaries of information on individual components of this mixture.

Soil.Plants (Soil Concentrations vs. Plants):

See also: Br.Hazard section above.

No other information found; see Chem.Detail section for compounds in this product, then see individual compound entries for summaries of information on individual components of this mixture.

Soil.Invertebrates (Soil Concentrations vs. Invertebrates):

No information found; see Chem.Detail section for compounds in this product, then see individual compound entries for summaries of information on individual components of this mixture.

Soil.Wildlife (Soil Concentrations vs. Wildlife or Domestic Animals):

No information found; see Chem.Detail section for compounds in this product, then see individual compound entries for summaries of information on individual components of this mixture.

Soil.Human (Soil Concentrations vs. Human):

No information found on this complex and variable mixture. See Chem.Detail section for chemicals found in this product, then look up information on each hazardous compound. Some individual compounds found in petroleum products have low-concentration human health benchmarks for soil (see individual entries).

Soil.Misc. (Other Non-concentration Soil Information):

As of 1996, several States were considering allowing natural attenuation (the "do nothing and let nature clean up the mess through bioremediation" option) to proceed near leaking storage tanks in situations where drinking water was not being impacted and where human rather than environmental resources were the main resources in the immediate area (Roy Irwin, National Park Service, personal communication, 1996).

The trend of thinking towards natural attenuation was given a boost by a Lawrence Livermore National Laboratory (LLNL) report entitled "Recommendations to Improve the Cleanup Process for California's Leaking Underground Fuel Tanks;" which stressed the use of passive bioremediation for petroleum product contaminated soils, whenever possible, based on the relatively low number of cases where drinking water was impacted [969]. EPA has pointed out some limitations of the LLNL report, including the lack of adequate consideration of PAHs and additives such as MTBE, as well limited consideration of (non-human) exposure pathways and various geologic conditions [969].

Others would point out that fuel oil spills into soils are not necessarily a trivial environmental threat related to ecotoxicology (emphasis on living things other than humans), due to the many hazardous compounds in this product (see Chem.Detail section below).

No other information found; see Chem.Detail section for compounds in this product, then see individual compound entries for summaries of information on individual components of this mixture.

Tissue and Food Concentrations (All Tissue Data Interpretation Subsections Start with "Tis."):

Tis.Plants:

A) As Food: Concentrations or Doses of Concern to Living Things Which Eat Plants:

No information found; see Chem.Detail section for compounds in this product, then see individual compound entries for summaries of information on individual components of this mixture.

B) Body Burden Residues in Plants: Typical, Elevated, or of Concern Related to the Well-being of the Organism Itself:

No information found; see Chem.Detail section for compounds in this product, then see individual compound entries for summaries of information on individual components of this mixture.

Tis.Invertebrates:

A) As Food: Concentrations or Doses of Concern to Living Things Which Eat Invertebrates:

No information found; see Chem.Detail section for compounds in this product, then see individual compound entries for summaries of information on individual components of this mixture.

B) Concentrations or Doses of Concern in Food Items Eaten by Invertebrates:

No information found; see Chem.Detail section for compounds in this product, then see individual compound entries for summaries of information on individual components of this mixture.

C) Body Burden Residues in Invertebrates: Typical, Elevated, or of Concern Related to the Well-being of the Organism Itself:

No information found; see Chem.Detail section for compounds in this product, then see individual compound entries for summaries of information on individual components of this mixture.

Tis.Fish:

A) As Food: Concentrations or Doses of Concern to Living Things Which Eat Fish (Includes FDA Action Levels for Fish and Similar Benchmark Levels From Other Countries):

No information found; see Chem.Detail section for compounds in this product, then see individual compound entries for summaries of information on individual components of this mixture.

B) Concentrations or Doses of Concern in Food Items Eaten by Fish:

No information found; see Chem.Detail section for compounds in this product, then see individual compound entries for summaries of information on individual components of this mixture.

C) Body Burden Residues in Fish: Typical, Elevated, or of Concern Related to the Well-being of the Organism Itself:

No information found; see Chem.Detail section for compounds in this product, then see individual compound entries for summaries of information on individual components of this mixture.

Tis.Wildlife: Terrestrial and Aquatic Wildlife, Domestic Animals and all Birds Whether Aquatic or not:

A) As Food: Concentrations or Doses of Concern to Living Things Which Eat Wildlife, Domestic Animals, or Birds:

No information found; see Chem.Detail section for compounds in this product, then see individual compound entries for summaries of information on individual components of this mixture.

B) Concentrations or Doses of Concern in Food Items Eaten by Wildlife, Birds, or Domestic Animals (Includes LD50 Values Which do not Fit Well into Other Categories, Includes Oral Doses Administered in Laboratory

Experiments):

The oral LD50 of one brand of kerosene was 28 mg/kg body weight (bw) in rabbits and 20 mg/kg bw in guinea pigs. A dose of 28 mg/l killed 4 of 15 rats [747].

Information from RTECS [607]:

LDLO/LCLO - Lowest published lethal dose/conc
Dog: LDLo; Route: Oral; Dose: 4 gm/kg; Toxic effects: lungs, thorax, or respiration - Structural or functional change in trachea or bronchi; Lungs, thorax, or respiration - Acute pulmonary edema; Reference: American Journal of the Medical Sciences 221:531, 1951.

LD50/LC50 - Lethal dose/conc 50% kill
Rat: LD50; Route: Oral; Dose: >5 gm/kg; Reference: Acute Toxicity Data. Journal of the American College of Toxicology, Part B 1:30, 1990.

Rabbit: LD50; Route: Oral; DOSE: 2835 mg/kg; Toxic effects: behavioral - Muscle weakness; Lungs, thorax, or respiration - Respiratory stimulation; Endocrine - Hypoglycemia; Reference: Annals of Internal Medicine 21:803, 1944.

Guinea pig: LD50; Route: Oral; Dose: 20 gm/kg; Toxic effects: behavioral - Muscle weakness; Lungs, thorax, or respiration - Respiratory stimulation; Endocrine - Hypoglycemia; Reference: Annals of Internal Medicine 21:803, 1944.

C) Body Burden Residues in Wildlife, Birds, or Domestic Animals: Typical, Elevated, or of Concern Related to the Well-being of the Organism Itself:

No information found; see Chem.Detail section for compounds in this product, then see individual compound entries for summaries of information on individual components of this mixture.

Tis.Human:

A) Typical Concentrations in Human Food Survey Items:

No information found; see Chem.Detail section for compounds in this product, then see individual compound entries for summaries of information on individual components of this mixture.

B) Concentrations or Doses of Concern in Food Items

Eaten by humans (Includes Allowable Tolerances in Human Food, FDA, State and Standards of Other Countries):

Information from RTECS [607]:

TDLO/TCLO - Lowest published toxic dose/conc
Man: TDLo; Route: Oral; Dose: 3570 mg/kg; Toxic effects: Lungs, thorax, or respiration - Cough; Gastrointestinal - Nausea or vomiting; Nutritional and gross metabolic - Body temperature increase; REFERENCE: El Torax 15:263, 1966.

LDLO/LCLO - Lowest published lethal dose/conc
Man: LDLo; Route: Oral; Dose: 500 mg/kg; Reference: Gekkan Yakuji. Pharmaceuticals Monthly 22:883, 1980.

C) Body Burden Residues in Humans: Typical, Elevated, or of Concern Related to the Well-being of Humans:

Tis.Misc. (Other Tissue Information):

See Diesel Oil, General and Diesel Oil #1 entries. No other information found; see Chem.Detail section for compounds in this product, then see individual compound entries for summaries of information on individual components of this mixture.

Bio.Detail: Detailed Information on Bioconcentration, Biomagnification, or Bioavailability:

No information found; see Chem.Detail section for compounds in this product, then see individual compound entries for summaries of information on individual components of this mixture.

Interactions:

No information found; see Chem.Detail section for compounds in this product, then see individual compound entries for summaries of information on individual components of this mixture.

Uses/Sources:

Fuel oil no. 1 (kerosene) is a light distillate intended for use in vaporizing type burners, in which the oil is converted to a vapor by contact with radiation or a heated surface. A highly volatile oil is needed for these burners to ensure that evaporation proceeds with a minimum of residue [641]. Its main uses are as a jet engine fuel, an illuminant, for heating purposes and as a fuel for certain types of internal combustion engines [747].

Information from HSDB [580]:
Major Uses:

In kerosene lamps, flares and stoves; as degreaser and cleaner.

Used in illuminating fuels, motor fuels; as heating fuel; in paint thinners; vehicle for insecticides & fungicides.

Jet fuel; range oil used mostly for space heating.

Forms/Preparations/Formulations:

Kerosene is derived from crude oil, normally as the third product stream category from an atmospheric distillation tower, following removal of gases, light ends and naphtha streams. Principal impurities include nitrogen and sulfur compounds. Kerosene is often hydrotreated in order to lower the nitrogen and sulfur contents as well as saturate any olefins that may be present [747].

Information from HSDB [580]:

A /colorless/...Deodorized form of kerosene is marketed under the trade name deobase. Kerosene is deodorized and decolorized by washing with (fuming) sulfuric acid, followed by sodium plumbite soln and sulfur (doctor sweetening).

Chem.Detail: Detailed Information on Chemical/Physical Properties:

Caution: Every individual petroleum product has a unique "fingerprint," or distinct set of constituents most commonly identified by a gas chromatograph analysis. Due to the varying properties of the same general category of a petroleum product (each source and weathering stage of a No. 1 fuel oil, or kerosene, has a unique gas chromatograph "fingerprint"), careful assessment of the toxicity, specific gravity, and other physical characteristics of each individual oil must be taken into consideration to determine the exact effects of the product on the environment. Therefore, the below comments on kerosene are to be considered as representative, but not absolute values typical of every batch of the product with the same name.

Since PAHs are important hazardous components of this product, risk assessments should include analyses of PAHs and alkyl PAHs utilizing the NOAA protocol expanded scan [828] or other rigorous GC/MS/SIM methods.

Coleman et al. determined that the major constituents of kerosene are alkanes and cycloalkanes (68.6%); benzene and substituted benzene (13.7%); and naphthalene and substituted naphthalenes [745]. Another source states that fuel oil no. 1 (kerosene) usually contains 10 to 16 carbon atoms per molecule, with an average of 12. The average chemical composition by weight is 35% paraffins, 60% naphthenes, and 15% aromatics [641].

Dimethylnaphthalines, anthracene, n-dodecane, and n-tetradecane are chemical indicators for kerosene and diesel fuel contamination; benzene and numerous substituted benzenes were present in the unleaded gasoline, kerosene, and diesel fuel, but high concentrations of these compounds generally indicated gasoline contamination. (Thomas, Debra H., and J. Joseph. 1991. A gas chromatographic/chemical indicator approach to assessing ground water contamination by petroleum products. Ground Water Monitor Rev. 11, no 4:90-100).

The basic component of kerosene used for aviation is the straight-run kerosene stream which consists of hydrocarbons with carbon numbers predominantly in the range of C9 to C16 (C4 to C16 for wide-cut fuels) and which boil at approximately 150 to 290 degrees C. The final boiling point specification was raised to 300 degrees C in the early 1980s in order to allow increased availability of kerosene for jet fuel use [747].

Alkanes and cycloalkanes are saturated with respect to hydrogen and are chemically stable, clean-burning components, which, together, constitute the major part of kerosene. Aromatics can be present from about 10 to 20% of the product, depending on the source of crude oil. Kerosene in the C9 to C16 range normally has a boiling range well above the boiling-point of benzene; accordingly, the benzene content of the kerosene fraction is usually below 0.02%. However, wide-cut products such as JP-4 and Jet B are usually made by blending kerosene with some of the gasoline fractions and, therefore, may contain more benzene (normally <0.5%). Depending of the source of crude, dinuclear aromatic naphthalenes, with two benzene rings in a condensed structure, are also likely to be present in kerosene in the concentration range of 0.1% to 3%. However, the 300 degrees C maximum final boiling range tends to exclude the presence of high-boiling three to seven-ring polycyclic aromatic hydrocarbons. Olefins are normally present in straight-run kerosene at concentrations of about 1% or less because olefins are essentially eliminated by the hydrotreating processes used in finishing kerosene [747].

The chemical composition of kerosene and most jet fuels is approximately similar, except for the additives that may also be added to jet fuels. For example, the International Air Transport Association recommendations require the addition of an antioxidant. Metal deactivators may also be added at concentrations not exceeding 5.7 mg/l. Fuel system icing inhibitors, electrical conductivity additives, corrosion inhibitors, lubrication improvers, biocides, and/or thermal stability improvers may also be added, as agreed upon by the supplier and purchaser [747].

Since Diesel oil 1 is similar in chemical composition to Fuel oil 1 (Kerosene), with the exception of additives [962], information on diesel is of some interest related to this product (see the Diesel Oil, General and Diesel Oil #1 entries). At a National Park Service spill site where sediments were contaminated by Diesel 1 and 2, the most common PAHs were alkyl PAHs (see Chem.Detail section below). In this Park Service sediment investigation at 1111111111111111111111Petersburg National Battlefield performed in response to contamination by Diesel Fuels (1D and 2D), 97.6% of the PAHs concentrations detected in sediments were alkyl PAHs. All 39 PAHs and alkyl PAHs analyzed were present in the contaminated sediments (Personal Communication, Roy Irwin, National Park Service, 1996). Since alkyl PAHs are such a high percentage of total PAHs in several petroleum products, they should not be ignored in hazard or risk assessments.

Because JP-1 (kerosene) can be derived from different stocks of crude oil, there is considerable variability in the concentrations of major components between JP-1 samples from different crudes. That is why petroleum product specifications list "ranges," and "max" or "min" values, instead of absolute numbers. The following table lists specifications for JP-1. For a comparison of the specifications for four common jet fuels; namely JP-1, JP-4, JP-5, and JP-A; see the Jet Fuel, General entry [635,637]:

Principle Characteristics of Selected Military Aircraft Turbine Fuels [637]:

CHARACTERISTIC	JP-1
API Gravity, max	35
Flash point, F, min	110
Viscosity, centistokes at:	
-30 F, max	--
-40 F, max	10
Freezing point, F, max	-76
Total sulfur, % max	0.2
Total aromatics, % max	20
Olefins**, % max	--
Total potential residue, mg/100 ml, max	8

** Olefins (alkenes and cycloalkenes) are generated by cracking operations during the refining process [558]. Olefins are normally present in straight-run kerosene at concentrations of about 1% or less because olefins are essentially eliminated by the hydrotreating processes used in finishing kerosene [747].

Physicochemical information from various sources:

NOTE: In this section, for properties with more than one value, each value came from its own source; in other words, if API Gravity at 60 F was measured several times and several different answers were obtained, all of the answers are provided [560]:

API GRAVITY (60/60 degrees F) [560]:

NOTE: API gravity = (141.5/specific gravity [60/60 degrees F]) - 131.5, where specific gravity [60/60 degrees F] is the oil density at 60 degrees F divided by the density of water at 60 degrees F.

39.4 to 34.8
45.4

DENSITY (g/mL) [560]:

For temperatures of oil (T) between 0 and 30 C:
Density = 0.97871 - 0.000710 T

NOTE: The densities of crude oils and oil products are dependent on the temperature and degree of weathering. The following density values are at "0% Weathering Volume" - in other words, fresh kerosene.

Temp(C)		Density (at 0% Weathering Volume)
0		0.837 to 0.847
15		0.827 to 0.850
	max	0.8495
		0.7993
20		0.823 to 0.847

Density/Specific Gravity [580]: ABOUT 0.80

Specific gravity [607]: 0.81 0.85 at 15 degrees C (liquid)

HYDROCARBON GROUP [560]:

NOTE: The main constituents of oil are generally grouped into the below categories. Asphaltene content increases with increasing weathering, as does wax content.

Hydrocarbon Group Analysis (Weight %):

Paraffins	35
Naphthenes	60
Aromatics	15

Solubilities [580]:

Insol (sic, actually "relatively insoluble") in water; miscible with other petroleum solvents

Information from HSDB [580]:

CHEMICAL & PHYSICAL PROPERTIES:

Color/Form: Pale yellow or water-white, mobile, oily liquid

Boiling Point: 175-325 DEG C

Other Chemical/Physical Properties: Can react with oxidizing materials

Information from the CHRIS Database [607]:

PHYSICAL AND CHEMICAL PROPERTIES

Physical state at 15 degrees C. and 1 ATM:Liquid

Boiling point at 1 ATM:380 560 degrees F = 193-293 degrees C = 466-566 degrees K

Freezing point:-45 to -55 degrees F = -43 to -48 degrees C = 230 to 225 degrees K

Latent heat of vaporization:110 Btu/lb = 60 cal/g = 2.5 X 10(5) J/kg

Heat of combustion:-18,540 Btu/lb = -10,300 cal/g = -431.24 X 10(5) J/kg

Additional Physicochemical information from Environment Canada [560]:

> NOTE: In this section, for properties with more than one value, each value came from its own source; in other words, if API Gravity at 60 F was measured several times and several different answers were obtained, all of the answers are provided [560]:

VISCOSITY

NOTE: The viscosities of crude oils and oil products are dependent on the temperature and degree of weathering. The following viscosity values are at "0% Weathering Volume" - in other words, fresh kerosene.

Dynamic Viscosity (mPa.s or cP):

Temp(C)	Dynamic Viscosity (at 0% Weathering Volume)
1.7	1.909
15	1.322

Kinematic Viscosity (mm2/sec or cSt):

Temp(C)	Kinematic Viscosity (at 0% Weathering Volume)
0	3.1 to 5.0
15	2.1 to 3.5
	1.6
20	1.9 to 3.3
38	1.4 to 2.2

Pour Point (degrees C):

Pour point is the lowest temperature at which an oil sample is observed to flow when cooled under prescribed conditions. It is affected by weathering.

-18
max -18
-45.6

INTERFACIAL TENSIONS

NOTE: Interfacial tension is the force of attraction between molecules at the interface of a liquid. These tensions are essential for calculating the spreading rates and the likely extent to which the oil will form oil-in-water and water-in-oil emulsions. The interfacial tensions of crude oils and oil products are dependent on the temperature and degree of weathering. The following tension values are at "0% Weathering Volume" - in other words, fresh kerosene.

Air-Oil (mN/M or dynes/cm):

Temp(C)	Air-Oil Tension (at 0% Weathering Volume)
20	23 to 32

Oil-Water (mN/M or dynes/cm):

Temp(C)	Oil-Water (at 0% Weathering Volume)
20	47 to 49

FIRE AND REACTIVITY

Flash Point (C):
38 to 74
min 38
min 37.8 (C.C.)

Auto Ignition Temperature (C):
229

Explosion Limits of Vapour in Air (% volume):

Upper	5.0 %
	5.0 %
Lower	0.7 %
	0.7 %

DISTILLATION

NOTE: Distillation data provides an indication of an oil's volatility and relative component distribution. Distillation data is reported as volume % recovered vs. the measured vapor temperature.

Distillation (C):

(Vol%)	Vapor Temp
10	max 215
90	max 288

Boiling Range (C):

174 to 266
200 to 260

NON-METAL CONTENT

Sulphur (Weight %):
max 0.5

SENSATION

Colour
Colourless to light brown

OTHER

Reid Vapor Pressure (kPa):

Temp(C)	Pressure
37.8	0.69

BIOLOGICAL OXYGEN DEMAND (BOD)

This is a standard way of describing how much oxygen dissolved in water is consumed by biological oxidation of the chemical during a stated period of time. In this case, BOD is expressed as a percent to indicate the number of pounds of oxygen consumed by each 100 pounds of the chemical during the stated time.

Percent (%)	Days
53	5

The following is a detailed analysis of three fuel oil no. 1 (kerosene) samples. Note that differences due to the type of crude oil and process are most evident in the distribution of saturated hydrocarbon types. Even so, the basic compositions are not notably divergent (all values are reported in % volume) [747]:

HYDROCARBON TYPE, VOLUME %	STRAIGHT-RUN NO. 1 FURNACE OIL (2 samples)		HYDROTREATED NO. 1 FURNACE OIL
Paraffins (n- and iso-)	50.5	54.3	42.6
Monocycloparaffins	25.3	18.4	19.3
Bicycloparaffins	5.6	4.5	8.9
Tricycloparaffins	--	0.8	--
Total saturated			

hydrocarbons	81.4	78.0	70.9
Olefins	--	--	--
Alkylbenzenes	12.7	14.3	14.7
Indans/tetralins	2.9	3.8	7.5
Dinaphthenobenzenes/ indenes	--	0.9	--
Naphthalenes	3.0	2.6	6.9
Biphenyls/acenaphthenes	--	0.4	--
Fluorenes/acenaphthylenes	--	--	--
Phenanthrenes	--	--	--
Total aromatic hydrocarbons	18.4	29.1	22.0

NOTE: The boiling range of kerosene fuel oil (fuel oil no. 1) generally precludes the occurrence of substantial quantities of polycyclic aromatic hydrocarbons (PAHs) [747].

See also Diesel Oil, General and Diesel Oil #1 entries. No other information found; see Chem.Detail section for compounds in this product, then see individual compound entries for summaries of information on individual components of this mixture.

Fate.Detail: Detailed Information on Fate, Transport, Persistence, and/or Pathways:

Absorption, Distribution and Excretion [580]:

Kerosene was given to baboons by nasogastric tube after tracheostomy. 6 Hr later brain, lung, liver, spleen & kidney contained radiolabel: (3)h-toluene-labeled kerosene was absorbed more than (14)c-hexadecane-labeled. GI tract absorption slight; does not cause gross neurologic signs.

See also Diesel Oil, General and Diesel Oil #1 entries. No other information found; see Chem.Detail section for compounds in this product, then see individual compound entries for summaries of information on individual components of this mixture.

Laboratory and/or Field Analyses:

The relative proportions of hazardous compound constituents present in petroleum-based oil contamination is typically quite variable. The lab analyses most appropriate for measuring different types of oil contamination depend upon the type of oil involved and the reason for measuring the contamination.

PAHs are important components of fuel oils in general [962] and of kerosene specifically (see Chem.Detail section above).

Many lab methods have been used to determine PAHs, BTEX compounds, and other common components of this fuel [861], but when potential biological effects are to being considered, many of the methods historically used have been determined to be inferior to the NOAA protocol expanded scan [828] being recommended by many risk assessment experts in 1996. Many historically used methods, including EPA standard semi-volatile scan number 8270, do not cover important alkyl PAHs and do not utilize low-enough detection limits to use in ecological risk assessments.

Aromatics can be present from about 10 to 20% of a kerosene product, depending on the source of crude oil. Depending on the source, dinuclear aromatic naphthalenes, with two benzene rings in a condensed structure, are also likely to be present in kerosene in the concentration range of 0.1% to 3%. However, the 300 degrees C maximum final boiling range tends to exclude the presence of high-boiling three to seven-ring polycyclic aromatic hydrocarbons [747]. Although large amounts of PAHs are typically not found in kerosene, they are among the most persistent and hazardous compounds after the spill has aged.

Recent (1991) studies have indicated that EPA approved methods used for oil spill assessments (including total petroleum hydrocarbons method 418.1, semivolatile priority pollutant organics methods 625 and 8270, and volatile organic priority pollutant methods 602, 1624, and 8240) are all inadequate for generating scientifically defensible information for Natural Resource Damage Assessments [468]. These general organic chemical methods are deficient in chemical selectivity (types of constituents analyzed) and sensitivity (detection limits); the deficiencies in these two areas lead to an inability to interpret the environmental significance of the data in a scientifically defensible manner [468].

In choosing a lab method, it should be kept in mind that this product (as well as Diesel, No. 2 Fuel Oils, and Light Crudes) can be expected to exhibit the following characteristics [741]:

-Moderately volatile; will leave residue (up to 1/3 of spilled amount)
-Moderate concentrations of toxic (soluble) compounds
-Will "oil" intertidal resources with long-term contamination potential
-Has potential for subtidal impacts (dissolution, mixing, sorption onto suspended sediments)
-No dispersion necessary
-Cleanup can be very effective

Decision Tree (dichotomous key) for selection of lab methods for measuring contamination from light crude oils and middle distillate petroleum products (all diesels, jet fuels, kerosene, Fuel oil 2, Heating Oil 2):

1a. Your main concern is biological effects of petroleum products..2

1b. Your main concern is cleanup or remediation but no ecological or human resources are at risk............3

2a. The resource at risk is primarily humans via a drinking water pathway, either the contamination of groundwater used for drinking water, or the fresh* or continuing contamination of surface waters used as drinking water, or the risk is primarily to aquatic species in confined** surface waters from a fresh* spill, or the risk is to surface waters re-emerging from contaminated groundwater resources whether the spill is fresh* or not; the medium and/or pathway of concern is water rather than sediments, soil, or tissues 4

2b. The resource at risk is something else......................5

3a. The spilled substance is a fresh* oil product of known composition: If required to do so by a regulatory authority, perform whichever Total Petroleum Hydrocarbon (TPH) analysis specified by the regulator. However, keep in mind that due to its numerous limitations, the use of the common EPA method 418.1 for Total Petroleum Hydrocarbons is not recommended as a stand-alone method unless the results can first be consistently correlated (over time, as the oil ages) with the better NOAA protocol expanded scan*** for polycyclic aromatic hydrocarbons (PAHs) and alkyl PAHs. If not required to perform an EPA method 418.1-based analysis for TPH, instead perform a Gas Chromatography/Flame Ionization Detection (GC/FID) analysis for TPH using the spilled substance as a calibration standard. GC/FID methods can be sufficient for screening purposes when the oil contamination is fresh*, unweathered oil and when one is fairly sure of the source [657]. If diesel 1D was spilled, perform TPH-D (1D) using California LUFT manual methods (typically a modified EPA method 8015) [465] or a locally available GC/FID method of equal utility for the product spilled. However, no matter which TPH method is used, whether based on various GC/FID or EPA method 418.1 protocols, the investigator should keep in mind that the effectiveness of the method typically changes as oil ages, that false positives or false negatives are possible, and that the better Gas Chromatography-Mass Spectrometry-Selected Ion Mode (GC/MS/SIM) scans (such as the NOAA expanded scan***) should probably be performed at the end of remediation to be sure that the contamination has truly been cleaned up.

3b. The spilled product is not fresh* or the contamination is of unknown or mixed composition.......................6

4. Analyze for Benzene, Toluene, Ethyl Benzene, and Toluene (BTEX) compounds in water as part of a broader scan of volatiles using EPA GC/MS method 8240. The standard EPA GC/MS method 8240 protocol will be sufficient for some applications, but the standard EPA method 8240 (and especially the less rigorous EPA BTEX methods such as method 8020 for soil and method 602 for water) are all inadequate for generating scientifically defensible information for Natural Resource Damage Assessments [468]. The standard EPA methods are also

inadequate for risk assessment purposes. Thus, when collecting information for possible use in a Natural Resource Damage Assessment or risk assessment, it is best to ask the lab to analyze for BTEX compounds and other volatile oil compounds using a modified EPA GC/MS method 8240 method using the lowest possible Selected Ion Mode detection limits and increasing the analyte list to include as many alkyl BTEX compounds as possible. Also analyze surface or (if applicable) ground water samples for polycyclic aromatic hydrocarbons (PAHs) and alkyl PAHs using the NOAA protocol expanded scan*** modified for water samples using methylene chloride extraction. If the contaminated water is groundwater, before the groundwater is determined to be remediated, also analyze some contaminated sub-surface soils in contact with the groundwater for BTEX compounds (EPA GC/MS method 8240), and PAHs (NOAA protocol expanded scan***). The magnitude of any residual soil contamination will provide insight about the likelihood of recontamination of groundwater resources through equilibria partitioning mechanisms moving contamination from soil to water.

5a. The medium of concern is sediments or soils..................6

5b. The medium of concern is biological tissues..................7

6. Perform the NOAA protocol expanded scan*** for polycyclic aromatic hydrocarbons (PAHs) and alkyl PAHs. If there is any reason to suspect fresh* or continuing contamination of soils or sediments with lighter volatile compounds, also perform EPA GC/MS method 8240 using the lowest possible Selected Ion Mode (SIM) detection limits and increasing the analyte list to include as many alkyl Benzene, Toluene, Ethyl Benzene, and Xylene (BTEX) compounds as possible.

7a. The problem is direct coating (oiling) of wildlife or plants with spilled oil product.....................................8

7b. The problem is something else...............................9

8. Perform NOAA protocol expanded scan*** for polycyclic aromatic hydrocarbons (PAHs) and alkyl PAHs and/or GC/FID fingerprinting of the coating oil only if necessary to identify the source or exact oil. If the source is known and no confirmation lab studies are necessary: dispense with additional chemical laboratory analyses and instead document direct effects of coating: lethality, blinding, decreased reproduction from eggshell coating, etc., and begin cleaning activities if deemed potentially productive after consolations with the Fish and Wildlife Agencies.

9a. The concern is for impacts on water column organisms (such as fish or plankton)..10

9b. The concern is for something else (including benthic organisms)..11

10. If exposure to fish is suspected, an HPLC/Fluorescence scan for polycyclic aromatic hydrocarbon (PAH) metabolites in bile may be performed to confirm exposure [844]. For bottom-dwelling fish such as flounders or catfish, also analyze the bottom sediments (see Step 6 above). Fish which spend most of their time free-swimming above the bottom in the water column can often avoid toxicity from toxic petroleum compounds in the water column, but if fish are expiring in a confined** habitat (small pond, etc.), EPA GC/MS method 8240 and the NOAA protocol expanded scan*** for PAHs could be performed to see if Benzene, Toluene, Ethyl Benzene, and Xylene (BTEX), naphthalene, and other potentially toxic compounds are above known acute toxicity benchmark concentrations. Zooplankton populations impacted by oil usually recover fairly quickly unless they are impacted in very confined** or shallow environments [835] and the above BTEX and PAH water methods are often recommended rather than direct analyses of zooplankton tissues.

11a. The concern is for benthic invertebrates: analyze invertebrate whole-body tissue samples and surrounding sediment samples for polycyclic aromatic hydrocarbons (PAHs) and alkyl PAHs using the NOAA protocol expanded scan***. If the spill is fresh* or the source continuous, risk assessment needs may also require that the sediments which form the habitat for benthic invertebrates be analyzed for Benzene, Toluene, Ethyl Benzene, and Xylene (BTEX) and other volatile compounds using EPA GC/MS method 8240 or modified EPA method 8240 in the Selected Ion Mode (SIM). Bivalve invertebrates such as clams and mussels do not break down PAHs as well or as quickly as do fish or many wildlife species. They are also less mobile. Thus, bivalve tissues are more often directly analyzed for PAH residues than are the tissues of fish or wildlife.

11b. The concern is for plants or for vertebrate wildlife including birds, mammals, reptiles, and amphibians: polycyclic aromatic hydrocarbons (PAHs) and other petroleum hydrocarbons break down fairly rapidly in many wildlife groups and tissues are not usually analyzed directly. Instead direct effects are investigated and water, soil, sediment, and food items encountered by wildlife are usually analyzed for PAHs and alkyl PAHs using the NOAA protocol expanded scan***. If the spill is fresh* or the source continuous, risk assessment needs may also require that these habitat media also be analyzed for Benzene, Toluene, Ethyl Benzene, and Xylene (BTEX) and other volatile compounds using EPA GC/MS method 8240 or modified EPA method 8240 in the Selected Ion Mode (SIM). Less is known about plant effects. However, the same methods recommended above for the analyses of water (Step 4 above) and for sediments or soils (Step 6 above) are usually also recommended for these same media in plant or wildlife habitats. If wildlife or plants are covered with oil, see also Step 8 (above) regarding oiling issues.

* Discussion of the significance of the word "fresh": The word "fresh" cannot be universally defined because oil breaks down faster in some environments than in others. In a hot, windy, sunny, oil-microbe-rich, environment in the tropics, some of the lighter and more volatile compounds (such as the Benzene, Toluene, Ethyl Benzene, and Xylene compounds) would be expected to disappear faster by evaporation into the environment and by biodegradation than in a cold, no-wind, cloudy, oil-microbe-poor environment in the arctic. In certain habitats, BTEX and other relatively water soluble compounds will tend to move to groundwater and/or subsurface soils (where degradation rates are typically slower than in a sunny well aerated surface environment). Thus, the judgement about whether or not oil contamination would be considered "fresh" is a professional judgement based on a continuum of possible scenarios. The closer in time to the original spill of non-degraded petroleum product, the greater degree the source is continuous rather than the result of a one-time event, and the more factors are present which would retard oil evaporation or breakdown (cold, no-wind, cloudy, oil-microbe-poor conditions, etc.) the more likely it would be that in the professional judgement experts the oil would be considered "fresh." In other words, the degree of freshness is a continuum which depends on the specific product spilled and the specific habitat impacted. Except for groundwater resources (where the breakdown can be much slower), the fresher the middle distillate oil contamination is, the more one has to be concerned about potential impacts of BTEX compounds, and other lighter and more volatile petroleum compounds.

To assist the reader in making decisions based on the continuum of possible degrees of freshness, the following generalizations are provided: Some of the lightest middle distillates (such as Jet Fuels, Diesel, No. 2 Fuel Oil) are moderately volatile and soluble and up to two-thirds of the spill amount could disappear from surface waters after a few days [771,835]. Even heavier petroleum substances, such as medium oils and most crude oils will evaporate about one third of the product spilled within 24 hours [771]. Typically the volatile fractions disappear mostly by evaporating into the atmosphere. However, in some cases, certain water soluble fractions of oil including Benzene, Toluene, Ethyl Benzene, and Xylene (BTEX) compounds move down into groundwater. BTEX compounds are included in the more volatile and water soluble fractions, and BTEX compounds as well as the lighter alkanes are broken down more quickly by microbes than heavier semi-volatiles such as alkyl PAHs and some of the heavier and more complex aliphatic compounds. Thus after a week, or in some cases, after a few days, there is less reason to analyze surface waters for BTEX or other volatile compounds, and such analyses should be reserved more for potentially contaminated groundwaters. In the same manner, as the product ages, there is typically less reason to analyze for alkanes using GC/FID techniques or TPH using EPA 418.1 methods, and more reason to analyze for the more persistent alkyl PAHs using the NOAA protocol expanded scan***.

** Discussion of the significance of the word "confined": Like the word "fresh" the word "confined" is difficult to define precisely as there is a continuum of various degrees to which a habitat would be considered "confined" versus "open." However, if one is concerned about the well-being of ecological resources such as fish which spend most of their time swimming freely above the bottom, it makes more sense to spend a smaller proportion of analytical funding for water column and surface water analyses of Benzene, Toluene, Ethyl Benzene, and Xylene (BTEX) and other volatile or acutely toxic compounds if the spill is in open and/or deep waters rather than shallow or "confined" waters. This is because much of the oil tends to stay with a surface slick or becomes tied up in subsurface tar balls. The petroleum compounds which do pass through the water column often tend to do so in small concentrations and/or for short periods of time, and fish and other pelagic or generally mobile species can often swim away to avoid impacts from spilled oil in "open waters." Thus in many large oil spills in open or deep waters, it has often been difficult or impossible to attribute significant impacts to fish or other pelagic or strong swimming mobile species in open waters. Lethality has most often been associated with heavy exposure of juvenile fish to large amounts of oil products moving rapidly into shallow or confined waters [835]. Different fish species vary in their sensitivity to oil [835]. However, the bottom line is that in past ecological assessments of spills, often too much money has been spent on water column analyses in open water settings, when the majority of significant impacts tended to be concentrated in other habitats, such as benthic, shoreline, and surface microlayer habitats.

*** The lab protocols for the expanded scan of polycyclic aromatic hydrocarbons (PAHs) and alkyl PAHs have been published by NOAA [828].

End of Key.

It is important to understand that contaminants data from different labs, different states, and different agencies, collected by different people, are often not very comparable (see also, discussion in the disclaimer section at the top of this entry).

As of 1997, the problem of lack of data comparability (not only for water methods but also for soil, sediment, and tissue methods) between different "standard methods" recommended by different agencies seemed to be getting worse, if anything, rather than better. The trend in quality assurance seemed to be for various agencies, including the EPA and others, to insist on quality assurance plans for each project. In addition to quality control steps (blanks, duplicates, spikes, etc.), these quality assurance plans call for a step of insuring data comparability [1015,1017]. However, the data comparability step is often not given sufficient consideration. The tendency of agency guidance (such as EPA SW-846 methods and some other new EPA methods for bioconcentratable substances) to allow more and more flexibility to select options at various points along the way, makes it harder in insure data comparability or method validity. Even volunteer monitoring programs are now strongly encouraged to develop and use quality assurance project plans [1015,1017].

At minimum, before using contaminants data from diverse sources, one should determine that field collection methods, detection limits, and lab quality control techniques were acceptable and comparable. The goal is that the analysis in the concentration range of the comparison benchmark concentration should be very precise and accurate.

It should be kept in mind that quality control field and lab blanks and duplicates will not help in the data quality assurance goal as well as intended if one is using a method prone to false negatives. Methods may be prone to false negatives due to the use of detection limits that are too high, the loss of contaminants through inappropriate handling, or the use of inappropriate methods. The use of inappropriate methods is particularly common related to oil products.

Additional Detailed Information:

The relative proportions of hazardous compound constituents present in petroleum-based oil contamination is typically quite variable. The lab analyses most appropriate for measuring different types of oil contamination depend upon the type of oil involved and the reason for measuring the contamination. The farther one progresses from lighter towards heavier oils (the general progression from light towards heavy is the following: Diesel, No. 2 Fuel Oil, Light Crudes, Medium Crude Oils, Heavy Crudes, No. 6 Fuel Oil, etc.) the greater the percentage of PAHs and other semi-volatiles (many of which are not so immediately toxic as the volatiles but which can result in long term/chronic impacts). Heavier oils such as fuel oil 5 thus need to be analyzed for the semi volatile compounds which typically pose the greatest long term risk, PAHs and alkylated PAHs.

Screening scans: Certain screening scans may be used to monitor the position and magnitude of contamination. Below are a few notes related to screening scans versus distillate fuels:

GC/FID:

> While a screening analysis such as GC/FID should be adequate for mid-range products such as diesels, fuel oil no. 2, and possibly jet fuels, lighter gasoline fractions will be lost in a GC/FID analysis (which uses extraction and burning) [657]. Distillate fuels in the C9 to C16 range normally have a boiling range well above the boiling-point of benzene; accordingly, the benzene content of this fraction is usually low [747].

Method 8015:

EPA Method 8015 (for Non-halogenated Volatile Organics) is a gas chromatographic method sometimes recommended for the analysis of volatile and semivolatile compounds. It can be used to characterize light and midrange petroleum distillates such as gasoline, diesel, fuel oil, and kerosene. This method can be used to obtain some gross fingerprint information for differentiation between petroleum products, as well as detailed information that can be used to differentiate between different batches of the same product. The major limitation of Method 8015 is its inability to detect nonvolatile compounds. The State of California recommends a "modified method 8015" (different from EPA's method 8015 and also different from EPA method 418.1) for gasoline, kerosene, diesel oil, or other fuels in soil and groundwater, as specified in the Leaking Underground Fuel Tank (LUFT) Manual [465].

In California, a "modified method 8015" (different from EPA's method 8015 and also different from EPA method 418.1) is used for gasoline, kerosene, diesel oil, or other fuels in soil and groundwater, as specified in the Leaking Underground Fuel Tank Manual [465]. Thus what is TPH in California is totally different from what may be reported as TPH in other states. In other States TPH often refers to something more similar to TRPH (EPA method 418.1 or some similar modification). One has to be careful with TPH or TRPH values because different labs use different methods for preparation of the samples. Most (but possibly not all) labs use a mixture of three different hydrocarbons (n-hexadecane, isooctane, and chlorobenzene) to calibrate instruments. California allows use of a "modified method 8015" wet weight method (which is different from EPA's method 8015) for TPH analysis of gasoline; this method detects volatile, non-halogenated hydrocarbons for TPH analysis [465].

The California LUFT methods call for packed GC columns which have poor resolving power and make it difficult to obtain detailed information about the hydrocarbon type [810]. Superior GC columns and superior methods (such as ASTM 2887) are available [810]. For example, narrow-bore capillary columns can analzye most of the gasoline, entire diesel fractions, and a substantial portion of the crude oil range [810].

Using the California LUFT manual methods, only an experienced analyst will be able to differentiate diesel fractions from aged gasoline [810]. The oversimplified California methods and models are plagued with many problems [808,810]. Choosing an appropriate solvent for semivolatile analyses always presents a problem; some solvents extract certain compounds better than others and many present environmental or health risks [810].

HPLC screening scans:

In cases where a less expensive screening scan is desired, consider using an HPLC/Fluorescence scan method for sediment or bile metabolite samples. Such scans are available from laboratories at Texas A. and M., Arthur D. Little, and the NOAA lab in Seattle. This scan is less prone to false negatives and various other problems than some of the more common screening methods (TPH-EPA 418.1 and Oil and Grease). HPLC/Fluorescence is less expensive than some of the more rigorous scans. The HPLC/fluorescence scan can be used for analyses of fish bile: the scan looks at bile directly for the presence of metabolites of PAHs: naphthalene, phenanthrene, and benzo(a)pyrene. The technique does not identify or quantify actual PAH compounds, but subsequent gas chromatography analyses can be done to confirm the initial findings. Even the semi-quantitative Total Scanning Fluorescence (TSF) done inexpensively by labs such as GERG are a better measure of PAH contamination than GC/FID, which measures less persistent and less hazardous aliphatics.

Additional Pros: HPLC Fluorescence screening methods have been performed extensively by NOAA to locate hotspots for crude oil contamination. NOAA's experience with the Exxon Valdez spill indicated that concentrations of aromatic hydrocarbons measured by HPLC/Fluorescence screening were highly correlated with the sums of Aromatic hydrocarbons determined by GC/MS, thus validating the screening method as an effective tool for estimating concentrations of petroleum-related aromatic hydrocarbons in sediments. Moreover, differences in HPLC chromatographic patterns among sediments suggested different sources of contamination, e.g., crude oil or diesel fuel. Allows crude determinations related to sources: HPLC/Fluorescence analyses allowed at least rough differentiation between aromatic hydrocarbons which may have originated from diesel fuel versus those from boat traffic [521] and The procedure was successfully applied to fingerprinting' gasolines, kerosines, diesel oils, heavy fuel oils, lubricating oils, and ship bilge oils [AUTHOR: Saner WA; Fitzgerald GE, II PUBLICATION YEAR: 1976 TITLE: Thin-Layer Chromatographic Technique for Identification of Waterborne Petroleum Oils JOURNAL: Environmental Science and Technology SOURCE: Vol. 10, No. 9, p 893-897, September 1976. 6 fig, 4 tab, 7 ref.].

EPA 418.1 for TPH:

Although EPA method 418.1: Petroleum Hydrocarbons expressed as Total Petroleum Hydrocarbons (TPH), is recommended by many State agencies, some consulting firms, and some laboratories for certain regulatory and screening applications (often leaking underground storage tanks), this method is not well suited to fuel oil no. 6 contamination or to the more persistent hazardous constituents in oil. Low values tend to give the mistaken impression that a site is clean when it really isn't (prone to false negatives). For example, a field test of bioremediation of soils contaminated with Bunker C at a refinery in Beaumont, Texas, utilized oil and grease data, which (although the data was quite variable) seemed to indicate bioremediation was taking place [728]. A comparison of the oil and grease data at this site with TPH data at this site suggested the same thing, that the data was quite variable but if anything, the oil was slowly being cleaned up by bioremediation (Bruce Herbert, Texas A. and M., Department of Geology, personal communication, 1995). However, a later study of the same site utilizing the expanded scan for PAHs (a modified EPA 8270 including alkyl homologues and lower detection limits), indicated that very little bioremediation of hazardous alkyl PAHs and multi-ring PAHs was actually taking place [727]. Thus, utilizing either oil and grease or TPH analyses would tend to lead one to the faulty conclusion that the harmful compounds were being naturally cleaned up at an acceptable rate. This is partly because the TPH and oil and grease methods tend to favor the lighter and less alkylated PAHs, whereas many of the carcinogenic and longer lasting PAHs are the heavier multi-ringed and alkylated compounds. For more information, see Petroleum Hydrocarbons entry.

EPA Methods 602,610, and 625:

The following abstract was generated by searching for "kerosene" in Louisiana Applied Oil Spill Research and Development Program's Selected Abstracts and Bibliography of International Oil Spill Research [742]:

> Thomas, Debra H., and J. Joseph. 1991. A gas chromatographic/chemical indicator approach to assessing ground water contamination by petroleum products. Ground Water Monitor Rev. 11(4):90-100.
> Key words: Oil Spill, Underground Storage Facility, Water Pollution
> The results of EPA Methods 602, 610, and 625

analyses allowed the identification of several indicator compounds in the water-soluble fractions of individual samples of an unleaded gasoline, kerosene, and diesel fuel. Benzene and numerous substituted benzenes were present in the unleaded gasoline, kerosene, and diesel fuel, but high concentrations of these compounds generally indicated gasoline contamination. Dimethylnaphthalines, anthracene, n-dodecane, and n-tetradecane were chemical indicators for kerosene and diesel fuel contamination. Normal octadecane and phenanthrene were indicative of diesel fuel contamination. Water-soluble fractions of unleaded gasoline, kerosene, and diesel fuel cannot be differentiated solely by quantitative or qualitative results using Method 602 alone. The results of Method 610 can be misleading and should be verified by an alternative method.

See also: Laboratory and/or Field Analyses section in Oil Spills entry for information on biological indicators of oil exposure.

See also: PAHs as a group entry.