Chemical Disinfection of Ballast Water

The Problem

The unintentional introduction of nonindigenous (not native) aquatic species through the release of ballast water has had a profound impact on aquatic ecosystems worldwide. This impact is particularly evident in the Great Lakes where the introduction of species such as the zebra mussel has altered important ecological processes and caused serious economic damage.

Most foreign vessels currently entering the Great Lakes carry between 50 and 210 metric tons of un-pumpable water and residual sediment. For the majority of Great Lakes vessels reporting No-Ballast-on-Board (NOBOB), these residuals have not been subject to high seas ballast exchange and potentially contain nonindigenous aquatic species.

Figure 1: Ballast pump intakes are typically located a few inches off the tank floor resulting in the accumulation of residual water and sediment after the tanks have been emptied. Photo credit: Captain Phil Jenkins.

Chemical Disinfectants: One Tool in the Toolbox

Open-ocean exchange (of salt water for freshwater) is the only ballast water management technique currently practiced on ships entering the Great Lakes. This treatment option may not completely eliminate the risk of nonindigenous aquatic species introduction and does not address the risk of introductions by NOBOB vessels which do not carry pumpable ballast.

A 1996 National Research Council report identified a range of promising options for treating ballast water. Included in this list as an option for both ballasted and non-ballasted tanks were chemical treatments or biocides. Other promising technologies include filtration, thermal treatment and UV light. Each of these developing technologies, including biocides, are likely to have strengths and weaknesses which limit their applicability and effectiveness in specific situations.

Either alone or in combination with other treatment technologies, biocides are an important potential tool for limiting the introduction of nonindigenous aquatic species via ballast water. Biocides may be especially promising for use on residual ballast water and sediments in NOBOB vessels.

Figure 2: *Hyalella azteca*, a freshwater amphipod, was extremely resistant to glutaraldehyde. Photo Credit: Scott Bauer.

Toxicity

Assessing the toxicity of a biocide to its specific target is a key step in determining its potential usefulness for the treatment of ballast water. Toxicity determines the amount of chemical that will be needed to kill the target organism (in this case aquatic species in ballast water). Toxicity is one key factor in determining the ultimate treatment cost and the practicality of shipboard use.

GLERL researchers have examined the toxicity of four potential biocides: glutaraldehyde, glutaraldehyde + a surfactant (Disinfekt 1000®), hypochlorite, and SeaKleen™ to a variety of freshwater animals including amphipods (Figure 1) and oligochaetes (Figure 2). In water, all the these biocides were effective at killing the typical freshwater organisms tested. However, zebra mussels were resistant to hypochlorite and the amphipod was resistant to glutaraldehyde, requiring high concentrations of the biocide to kill them. Further, toxicity declined when mud was added in the experiments—up to 4000 times in the case of hypochlorite. Mud both reacts with the biocides (directly reducing its effectiveness) and provides a refuge where the animals can hide from the biocide. These results indicate that biocides will be most effective when used in combination with management techniques that minimize the amount of sediment (mud) in ballast tanks.

Figure 3: *Lumbriculus variegatus*, an Oligochaete worm, was partially protected from the effects of glutaraldehyde when sediments were present. Photo credit: Chris Ingersoll, USGS.

Great Lakes Environmental Research Laboratory~2205 Commonwealth Blvd.~Ann Arbor, MI~734-741-2235~February 2002.

Simulating Real-World Conditions

Conditions inside a real ballast tank are significantly different from the conditions inside most controlled laboratory experiments. Effectiveness of a particular biocide may be affected by many of these conditions.

GLERL researchers have developed a simple system for simulating ballast tank conditions in a controlled laboratory setting. This system allows the researcher to examine the effects of different temperatures, light, amounts of sediment (mud), and even the amount of sloshing of the mixture in the tank. Early experiments have shown that planted organisms can be effectively eliminated in short 24 hour exposures in this system.

Figure 4: Ballast tank simulator.

Environmental Risks

One risk for biocide treatment of ballast water is the risk of environmental release of the chemical in ballast discharges. Potential biocide harm to the receiving water is generally limited by the ability of the biocide to breakdown into non-toxic forms over time (degradation) or by dilution of the biocide to concentrations too low to cause damage. Glutaraldehyde concentrations such as those one might expect as ballast is diluted by the water in the receiving harbor can be rapidly (half of the material degraded completely in less than 5 days) broken down by naturally occurring bacteria so long as the receiving waters are warm and contain oxygen. A similar glutaraldehyde degradation rate was found using Disinfekt 1000®. Hypochlorite degrades much faster than glutaraldehyde. SeaKleen™ degradation has not been tested.

Chronic, or long-term, toxicity is an important factor to consider in assessing the risk of releasing even low concentrations of biocides to our native ecosystems. Generally speaking, the amount of a biocide needed to cause chronic toxicity problems (for example, animals become sick or unable to reproduce) is much lower than the amounts needed to immediately kill these same creatures. Early GLERL experiments indicate that algae may be particularly sensitive to low concentrations of glutaraldehyde and fish embryos about to hatch may also be vulnerable if the chemical remains in the water for a significant time.

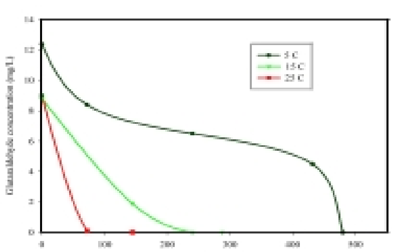

Figure 5: Glutaraldehyde degradation.

Resting Stages

Just as particular species of organisms may be more resistant to biocide treatment than others, so too, particular life stages of organisms may be more resistant to treatment. Of particular concern are a group known as resting stages. Many aquatic plants, invertebrates, and microbes produce resting stages when under conditions that threaten their well-being such as declining food supply, low oxygen, dark, or extremes of temperature — exactly the conditions likely to be found inside a ballast tank.

Both hypochlorite and Disinfekt 1000® were tested for their effectiveness to prevent hatching of *Artemia* cysts. The amount of biocide needed to prevent 90% of the cysts from hatching was similar to the amounts needed to kill resistant animals in the water testing. Because the cysts were so small, it was not possible to test the biocides in the presence of mud. However, the finding that they are susceptible to disinfection is a good first step. More tests will be needed to show that mud does not protect these resting stages more than other freshwater animals.

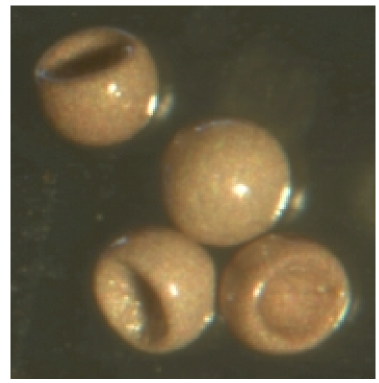

Figure 6: *Artemia* cysts (brine shrimp eggs). Resting stages, such as these cysts, may prove particularly resistant to biocide treatment.

Next Steps

Practicality of use in a shipboard situation remains to be tested. Experimental designs that demonstrate the effectiveness of biocides in actual ballast tanks under operating conditions have yet to be developed. In addition, it is critical to perform risk assessments for the potential discharge of biocide residues (leftover un-degraded material) to insure that long-term use will not damage the environment. GLERL expects to pursue research and modeling for risk assessment over the next several years.

Contacts

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This project is supported in part by the Great Lakes Fishery Trust. Collaborators include Larissa Sano and Mark Mapili, Cooperative Institute for Limnology and Ecosystems Research; Dr. Russell Moll, California Sea Grant; and Dr. Michael Parsons, Department of Naval Architecture and Marine Engineering at the Univ. of Michigan.

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