Recommendation to Grant Conditional Approval to the BalPure™ Ballast Water Treatment System

Executive Summary

In order to eliminate one of the more common routes for the introduction of invasive species into state waters, RCW 77.120.030(2) forbids the discharge of unexchanged or untreated ballast water into waters of the state after July 1, 2007. WAC 220-77-095 describes the process for approval of ballast water treatment systems by the Washington Department of Fish and Wildlife (WDFW). Severn Trent De Nora has applied to WDFW for approval of the BalPure™ Ballast Water Treatment System (BWTS). The Washington Department of Ecology Water Quality Program (WQP) will be advising WDFW on environmental safety issues and setting conditions on the discharge of biocide-treated ballast water. WAC 220-77-095(2)(d)(v) provides the WQP with the criteria for this review: "The discharge from a technology must be environmentally sound and in compliance with existing water quality discharge laws."

The BalPure™ BWTS uses electricity to generate chlorine and related oxidants from the chloride in seawater in order to destroy living organisms in ballast water. Dechlorination using sodium sulfite is then used prior to discharge to neutralize the toxicity by reducing the oxidants. The WQP required Severn Trent De Nora to do toxicity testing of seawater treated by a bench scale version of the BalPure™ BWTS including dechlorination using sodium sulfite. The WQP predicts with a large degree of confidence that a discharge of ballast water treated with the BalPure™ BWTS will be environmentally safe based upon the lack of toxicity at test concentrations much higher than will be used on ships and the physical controls which will be included in an installation on a ship. The WQP recommends that WDFW grant conditional approval for the use of the BalPure™ BWTS on one vessel to allow further evaluation of its effectiveness and environmental safety. The conditions for approval must include installing and maintaining the physical controls described in the attached September 1, 2005 memorandum from Severn Trent De Nora and discussed below. Further toxicity testing of ballast water treated on the ship by the BalPure™ BWTS must be another condition of approval and is also discussed below. Questions about the recommendation or conditions should be directed to Randall Marshall at rmar461@ecy.wa.gov or 360-407-6445.

Results of Toxicity Testing of Seawater Treated by the BalPure™ BWTS

When chlorine is added to water, the solution will contain two forms of free chlorine: hypochlorous acid (HOCl) and the hypochlorite ion (OCl^-). If ammonia is also present, then the addition of chlorine will result in two forms of combined chlorine: monochloramine and dichloramine. Taken together these four forms of chlorine are known as "total residual chlorine" (TRC) and the EPA analytic method for TRC detects them in combination. Because saltwater contains bromide, the addition of chlorine to saltwater will also form hypobromous acid (HOBr), hypobromous ion (OBr^-), and bromamines. The term for the combination of chlorine and bromine compounds formed by the addition of chlorine to saltwater is "chlorine-produced oxidants" (CPO) and the EPA method for measuring TRC also detects them.

Dechlorination with a reducing agent such as sodium sulfite is a well-established method for removing toxicity from chlorinated water. The stoichiometric ratio of sulfite to TRC is 1.6:1 but dechlorination of treated ballast water will be done around a ratio of 2:1 in order to provide about 25% excess sodium sulfite as a safety margin for dechlorination. A 3 ppm TRC solution dechlorinated with 6 ppm sodium sulfite was tested for toxicity to Pacific herring embryos and the lack of toxicity to this regionally important species was verified for a 2:1 ratio of sodium sulfite to TRC.

University of Washington researchers have determined that a 3 ppm concentration of TRC produced by electrochlorination will usually meet state of Washington and International Maritime Organization standards for elimination of living organisms in ballast water. A 5 ppm TRC concentration might be required to meet standards during warmer weather. Three ppm will be the usual TRC concentration generated by the BalPure™ BWT System and 5 ppm will be the maximum needed to meet standards.

Because the effectiveness of dechlorination is well-established in wastewater treatment, the main concern is the toxicity of the sodium sulfite dechlorinating agent. A 3 ppm solution of TRC was dechlorinated with 22 ppm of sodium sulfite and then tested for toxicity to marine species. The toxicity tests included survival and growth for larval silverside minnows (*Menidia beryllina*) and mysids (*Americamysis bahia*). Mussel embryos (*Mytilus sp.*) were tested for survival and normal larval development. Giant kelp zoospores (*Macrocystis pyrifera*) were tested for germination and germ tube length. Pacific herring embryos (*Clupea pallasi*) were tested for survival and normal development. None of these biological endpoints was adversely affected by 22 ppm of sodium sulfite added to 3 ppm TRC. Kelp spore germination at 22 ppm was significantly different statistically from the control but the reduction was only 12% and not biologically significant. EPA considers a 25% reduction to be the threshold for a significant effect.

Conclusion

A 2:1 ratio of sodium sulfite to TRC will effectively eliminate toxicity by dechlorinating ballast water treated by electrochlorination. Because the highest TRC concentration will be 5 ppm, 10 ppm sodium sulfite is the highest concentration that will be needed for dechlorination. Toxicity testing has demonstrated that up to 22 ppm sodium sulfite can be considered safe. As long as no more than 5 ppm of TRC is generated and the ratio of sodium sulfite to TRC is at least 2:1 without dosing more than 22 ppm of sodium sulfite, the BalPure BWT System will produce ballast water that is nontoxic at discharge.

Approval Conditions

Approval for the shipboard trials of the BalPure™ BWTS must be conditioned on installing and operating the physical controls as described in the September 1, 2005 memorandum from Severn Trent De Nora:

1. The system's operating computer shall match the amperage in the electrolytic cell to the ballast water flow in order to maintain a TRC concentration of at least 3 ppm but no more than 5 ppm.
2. A chlorine monitor shall be used as check on the TRC concentration and if it is not within ± 0.5 ppm of the target concentration it must alarm and if the TRC concentration ever goes above 5.5 ppm it must alarm and shut off the electrochlorination.
3. The hypochlorite generator shall be sized for the ship's designed ballast water flow rate in order to be able to produce no more than 5.5 ppm TRC.
4. An in-line sulfite analyzer shall control a metering pump so that a residual of 1-2 ppm sodium sulfite beyond that necessary for dechlorination will be present in the ballast water discharge. An alarm must sound if the residual sulfite level is measured at 0 ppm or greater than 5 ppm in the discharge stream.
5. A sensor must measure the change in redox potential during dechlorination to verify that chlorine is being neutralized and residual sulfite is present.
6. The sulfite addition metering pump shall be sized to the vessel's designed deballast flow rate so that a maximum 11 ppm sodium sulfite concentration will result if the pump operates at its highest flow rate.
7. Logs shall be kept of the operation of the BWTS and all of its controls, sensors, and alarms.

The following toxicity testing requirements must also be conditions of approval:

1. Flow-weighted composite samples from the entire duration of each discharge of BalPure™ treated ballast water shall be tested for toxicity to silverside minnows (*Menidia beryllina* in EPA-821-R-02-014), a mysid (*Americamysis bahia* in EPA-821-R-02-014), bivalve survival and development (*Mytilus sp.* in EPA/600/R-95-136), and giant kelp (*Macrocystis pyrifera* in EPA/600/R-95-136).
2. If Severn Trent De Nora wants to meet international recommendations, a 72-hour growth inhibition test with a marine diatom (*Skeletonema costatum* according to ISO 10253) may also be performed.
3. If any discharge occurs from the beginning of February until the beginning of June, a Pacific herring 10-day survival and growth test shall be substituted for the silverside minnow test. Contact Randall Marshall at rmar461@ecy.wa.gov or 360-407-6445 for instructions on herring toxicity testing.
4. If no toxicity occurs in 3 consecutive discharges of treated ballast water (at least one nearly full tank per discharge event), the lack of toxicity will be considered verified and toxicity testing may cease.