Maritime Environmental Resource Center:
Addressing Critical Environmental Issues
Facing the Maritime Industry

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www.maritime-enviro.org
Commercial Shipping and Invasive Species

- Invasive species causing economic and environmental damage
- Transported in both ballast water and as fouling organisms
- Ballast water is being regulated and treatment systems are being developed
Treating Ballast Water

- Adjust trim and draft
- Rates 100 - 12,000 m$^3$/hr
- Volumes 5,000 - 100,000 m$^3$

- Effective at killing/removing organisms and reliably meet discharge standards
- Safe for vessel and crew
- Environmentally benign
- Feasible and affordable
Ballast Water Discharge Regulations

- International, Federal and State regulations are in place or will be soon
- Vary in requirements but extremely low levels of organisms can be released

<table>
<thead>
<tr>
<th>Standard</th>
<th>≥50 µm / m³</th>
<th>10-50 µm / ml</th>
<th>Bacteria / ml</th>
<th>V. cholera / ml</th>
<th>E. coli / ml</th>
<th>Enterococci / ml</th>
</tr>
</thead>
<tbody>
<tr>
<td>IMO D-2</td>
<td>10</td>
<td>10</td>
<td>no limit</td>
<td>.01</td>
<td>2.5</td>
<td>1</td>
</tr>
<tr>
<td>USCG Phase 1</td>
<td>10</td>
<td>10</td>
<td>no limit</td>
<td>.01</td>
<td>2.5</td>
<td>1</td>
</tr>
<tr>
<td>USCG Phase 2</td>
<td>0.01</td>
<td>0.01</td>
<td>10 cfu</td>
<td>.01</td>
<td>1.26</td>
<td>0.33</td>
</tr>
<tr>
<td>California</td>
<td>no detectable</td>
<td>0.01</td>
<td>10 cfu</td>
<td>.01</td>
<td>1.26</td>
<td>0.33</td>
</tr>
</tbody>
</table>
Physical Separation

• Filtration
• Hydrocyclone

Chemical Treatment (Biocides)

• Oxidizing – sodium hypochlorite, ozone
• Non-Oxidizing – menadione, alkylamines
• Most “neutralize” prior to discharge

Physical/Chemical Treatment

• Cavitation
• Deoxygenation
• Flocculation
• Heat
• Ultrasound
• Ultraviolet Radiation

Most are Combinations

• e.g., Separation + Chemical
• Two to five phases
• Uptake and discharge
Maritime Environmental Resource Center

Foci

- Evaluating the mechanical and biological evaluations of ballast water treatment systems – laboratory, land-based and shipboard

- Assessing the economics of ballast water regulations and management approaches

- Facilitating the development and adoption of green ship technologies

Partners
MERC Centered on the Chesapeake Bay

- Diverse physical conditions for system testing
- Abundant and taxonomically diverse plankton
- Expertise and experience
- More than 150 known aquatic invasive species in the Bay
- Economically and politically important region
MERC Land-Based Testing
MERC Mobile Test Platform

- Port of Baltimore, 5 – 12 psu
- Port of Norfolk, 21 – 28 psu
- NRL Anacostia River, 0 psu
Sampling Approach and Volumes

Enumerating Sparse Organisms in Ships’ Ballast Water: Why Counting to 10 Is Not So Easy
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ABSTRACT To reduce ballast water borne aquatic invasions worldwide, the International Maritime Organization and United States Coast Guard have established discharge standards specifying maximum concentrations of living biota that may be released in ships’ ballast water (BW), but these regulations lack guidance for standardized type approval and size-based quantification of BW discharge rates. Verifying whether BW meets a discharge standard poses significant challenges. Poorly treated BW will contain extremely sparse numbers of live organisms, and robust estimates of rare events require extensive sampling efforts. A balance of analytical rigor and practicality is essential to determine the volume of BW that can be reasonably sampled and processed, yet yield accurate live counts. We applied statistical modeling to a range of sample volumes, plankton concentrations, and regulatory scenarios (i.e., levels of type I and type II errors), and calculated the statistical power of such combinations to detect noncompliant discharge concentrations. The model expressed illustrates the roles of sampling error, BW volume, and burden of proof on the detection of noncompliant discharge in order to establish a rigorous lower limit of sampling volume. The potential effects of recovery errors (i.e., incomplete recovery and detection of live biota) in relation to sample volume are also discussed.

INTRODUCTION

Maritime transportation is a foundation of the global market. There are well over 50,000 commercial ships worldwide, moving goods around the world. Since 1700, the ballast water associated with merchant vessel traffic is also responsible for the transfer and introduction of aquatic invasive species to coastal waters where they can cause enormous ecological and economic damage.1–3

In an attempt to minimize the risk of BW introductions, the International Maritime Organization (IMO) and U.S. Coast Guard (USCG) have established discharge standards limiting maximum concentrations of living organisms that can be released with BW, including new regulations requiring ship operators to meet these limits. The USCG has proposed to implement regulations in two phases: phase 1 proposes to set standards similar to current IMO standards and phase 2 proposes standards up to 1,000 times stricter. The IMO and USCG phase 1 standards require BW discharged by ships to contain:

1. Fewer than 10 viable organisms/mL < 50 μm in minimum dimension or smallest measure among length, width, and height excluding fine appendages such as sensory antennae and setae (the majority of organisms in this size class are zooplankton).
2. Fewer than 10 viable organisms/mL < 50 μm and ≥ 10 μm in minimum dimension. (The majority of organisms in this size class are protozoa, including zooplankton).
3. Fewer than the following concentrations of indicator microbes, as a human health standard: (a) entericogenic Vibrio cholerae (serotypes O1 and O139) with ≥1 colony-forming unit/100 mL; (b) Rhotochoria sp < 200 cfu/10 mL; and (c) enteric Vibrio <100 cfu/10 mL.

To achieve the above discharge standards, technology developers and manufacturers around the world are advancing on-board BW treatment systems that use methods such as filtration, UV radiation, deoxygenation, onization, and chlorination.

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Phased Approach to Compliance Monitoring

• Reporting
• Inspections
• Measures of system performance
• Indirect measures of non-compliance
• Direct measures of discharge standards

Verifying Compliance with Ballast Water Discharge Regulations

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U.S. and international rules have been proposed to reduce the risks associated with invasive aquatic organisms by requiring that ships’ ballast water be treated to kill or remove living organisms and achieve certain standards before being discharged. Ensuring these rules requires verifying when a discharge violates these standards. A preliminary comparison of verification systems indicates that mandatory reporting and inspecting treatment equipment do not provide an acceptable level of confidence and that sampling and analyzing enough ballast water to achieve acceptable confidence is prohibitively costly. The most cost-effective alternative that achieves an acceptable level of confidence involves indirect measures of ballast water using sensors that indicate whether discharge standards are met.

Keywords ballast water regulations, enforcement, invasive species

Introduction

The international maritime industry, with more than 70,000 merchant vessels, is responsible for transporting more than 80% of the goods traded in world markets, and is a foundation for the global economy. However, commercial shipping is also responsible for transporting ballast water and introducing aquatic invasive species to coastal waters where they can cause enormous ecological and economic damage.

The 1990 U.S. Non-indigenous Aquatic Nuisance Prevention and Control Act (NANPCA) was the first federal law to address the problem of aquatic invasive species. It focused mainly on ballast water introductions. The NANPCA contained provisions that required ships headed for the Great Lakes to exchange their ballast water at sea. The law was reauthorized in 1996, renamed the National Invasive Species Act (NISA) and expanded to encourage, but not require, ballast water exchange for all ships arriving from outside the 200-mile U.S. exclusive economic zone (EEZ). NISA also made reporting of ballast water management to a national registry mandatory for all ships entering U.S. ports. In 2004, the U.S. Coast Guard (USCG) published regulations requiring vessels to maintain a ballast water management plan that involves mid-ocean exchange of ballast water, retention of...
Indirect Measures for Compliance Monitoring

- TRO/TRC sensor and analyzer evaluations

- ATP, DNA and genetic probes as indicators
The Economics of Ballast Water Regulations

Kick-starting Ballast Water Treatment Markets

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Let’s assume International Maritime Organization (IMO) ballast water discharge regulations are ratified and similar U.S. Coast Guard (USCG) rules are established in 2011 or 2012, and governments make commitments to implement and enforce them a year later. Then what? Does it make sense to trust fledging ballast water treatment system (BWT) markets to mature fast enough with enough supply capacity to allow widespread compliance and significant reductions in harmful ballast water discharges? If not, what interventions in BWT markets will be required to kick-start them, so they have a chance of doing what will be expected of them?

Based on planned IMO compliance deadlines, over 50,000 merchant ships will need to install certified BWT systems by 2016 or 2017, that’s about 10,000 ships per year for five or six years thereafter. Since many large ships may need to install multiple BWT units to meet IMO discharge standards, the number of actual BWT units that will need to be manufactured and installed during those years to achieve widespread compliance may be closer to 20,000 or 30,000 per year. If these numbers are off a bit, or the IMO and USCG compliance schedules are relaxed by a year or two, the overall situation is still the same - for ballast water regulations to succeed, BWT supplies will need to grow very large, very fast.

In business, however, there is usually a multiyear lag between when decisions are made to invest in manufacturing capacity and when large-scale production can take place. This means significant investments in BWT manufacturing capacity will need to be made very soon for BWT markets to provide what ballast water regulations need to succeed. Tuffy or no BWT vendors, mostly small startups, are flitting with entering the market, some large shipping companies are dabbling with shipboard demonstrations, and a few actual transactions have taken place. However, no serious investments are being made in BWT supply capacity, and one can be expected until there is more certainty about the size and timing of global demand for BWT systems. That certainty of demand, of course, will not exist until nations make credible commitments to enforce ballast water regulations with certain and meaningful penalties. Unfortunately, it will be politically and practically impossible for nations to commit to enforce these regulations as long as inadequate BWT supplies make it impossible for many ship owners to comply with them. This

During September, 2010 two London-based meetings will address ways to resolve global ballast water (BW) problems. One, a well-publicized industry conference, will focus on emerging global markets for ballast water treatment (BWT) systems. The other, a less publicized meeting at the International Maritime Organization (IMO), will focus on intergovernmental strategies for implementing and enforcing IMO ballast water regulations. Although different in focus, the two meetings could hardly be more interrelated. The emergence of markets for BWT systems will depend on when and how BW regulations are implemented and enforced. Conversely, the willingness and ability of IMO member countries to implement and enforce BW regulations will, out of necessity, depend on whether BW systems are able to develop the required supply capacity to allow widespread compliance.

The topics of the two meetings are also intertwined because in regulation-driven markets buyers are only as quality-conscious as regulators require them to be. Whether the IMO sets weak or strict standards for determining compliance, in other words, will have an enormous effect on supply and demand and on who wins and loses in BWT markets. If complying with BW regulations merely requires having a “certified” BW system on board, for example, the lowest cost “certified” BW system will dominate the market, perhaps to the exclusion of higher cost and more effective and reliable systems. If compliance requires installing and properly maintaining and using a certified BWT system with the capacity to treat BW during all of a ship’s ballasting operations, and if BW discharge standards are enforced using direct or indirect treatment performance measures, on the other hand, providers of higher quality, more reliable, and more appropriately engineered BWT systems and global maintenance and support services will have markets and be able to survive.

Of course, the cost of any BWT system will always need to compete fairly directly with the cost of not complying, which depends on the likelihood of violations being detected and prosecuted and whether penalties for violations are

http://www.imo.org/includes/bishDataOnly.asp?data_id=8138941
Beyond Ballast

• **Ship Biofouling and Invasive Species**
  Tolerance of fouling organisms to conditions found during common ocean voyages
  Methods for quantifying effectiveness of ship biofouling management guidelines

• **Ship Alternative Fuels**
  Analysis of Alternative Fuels for Coastal Support Vessels
  Alternative Fuels and Exhaust Emissions

• **Port Discharge Database**
MERC Port Discharge Database

• A resource for vessel operators, crew, and ports
• Up-to-date, searchable and map-based regulatory information
• Prevent unnecessary/unintentional infractions and environmental degradation

• Air Emissions
• Oily Water
• Solid Waste
• Black Water
• Grey Water
• Ballast Water
• Fuel Restrictions
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