Emergency Response Guidance for Handling Ballast Water to Control Aquatic Invasive Species

Prepared for
Isle Royale National Park
Houghton, Michigan

File No. 09078.01
17 January 2012
Rev. B

THE GLOSTEN ASSOCIATES
Consulting Engineers Serving the Marine Community

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SIGNED ORIGINAL ON FILE

PREPARED: ______________________ ________

Kevin J. Reynolds, PE
Project Manager

CHECKED: ______________________ ________

Jon K. Markestad, PE
Senior Marine Engineer

APPROVED: ______________________ ________

David W. Larsen, PE
Principal-in-Charge

THE GLOSTEN ASSOCIATES
Consulting Engineers Serving the Marine Community

1201 Western Avenue, Suite 200, Seattle, Washington 98101-2921 | **TEL** 206.624.7850 | **FAX** 206.682.9117 | **www.**glosten.com

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References

1 *Stemming the tide: Controlling introductions of nonindigenous species by ships' ballast water*, NRC (National Research Council), Marine Board Committee on Ships' Ballast Operations, Wash. DC: National Academy Press, 1996.

2 *Evaluation of Chemicals for Potential Treatment of Ballast Water*, US Coast Guard Research and Development Center, October 2004.

3 *Ballast Water Treatment Technology*, Lloyd's Register, September 2008.

4 *Guidelines For Risk Assessment Under Regulation A-4 of the BWM Convention (G7)*, Resolution MEPC.162(56), International Maritime Organization, 13 July 2007.

5 *Chinese Submersible Barge "LUCKY ANGEL" Arrives in Bellingham – Cooperative ballast water treatment and hull fouling investigation case,* Washington Department of Fish & Wildlife, 7 January 2009.

6 Jeffery R. Cordell, et al., "Factors influencing densities of non-indigenous species in the ballast water of ships arriving at ports in Puget Sound, Washington, United States," Aquatic Conservation Marine and Freshwater Ecosystems (2009) Vol 19, Iss. 3 pp 322-343, 27 October 2008.

7 *Ballast Water Treatment During Emergency Response Operations Planning Issues*, Region 4 Regional Response Team for Area Contingency Plan Development, US National Response Team, 9 May 2002.

8 Mearns, A.; Benggio, B.; Waite, T.; "Ballast Water Treatment During Emergency Response: The Case of The M/T Igloo Moon," Division of Hazardous Matter Response, NOAA, Seattle, Washington, 1999.

9 Reynolds, K.; "Ship's Ballast Discharge Dispersion, Benchmark Dye Tracer Test," The Glosten Associates, 14 January 2005.

10 Reynolds, K.; "Mixing Chemicals into Ship's Ballast Water - Efficiency of Novel Mixing Methods," The Glosten Associates, 26 November 2008.

11 Reynolds, K.; "Mixing Chemicals into Ship's Ballast Water – Results of Great Lakes Bulk Carrier Field Trials," The Glosten Associates, 2012.

Section 1 Introduction

This field guide is intended as an aid to incident responders responsible for handling ships with high-risk ballast water that may be laden with potentially harmful non-indigenous species and pathogens collectively referred to as aquatic invasive species (AIS). The methods presented were developed in coordination with the US Geological Survey (USGS) and trialed aboard a Great Lakes bulk carrier (Reference 11). High risk carriers may wish to utilize these novel intervention methods at sea before arrival, upon arrival in port, or at an incident location, such as a grounding site. The decision process outlined in this guide can assist responders in balancing practical field considerations with sound environmental practice in emergency situations; for example, upon prediction of bad weather threatening to break a ship's hull. The response guide flow chart in Figure 1 maps the relevant section of this guide for each key inquiry during a response.

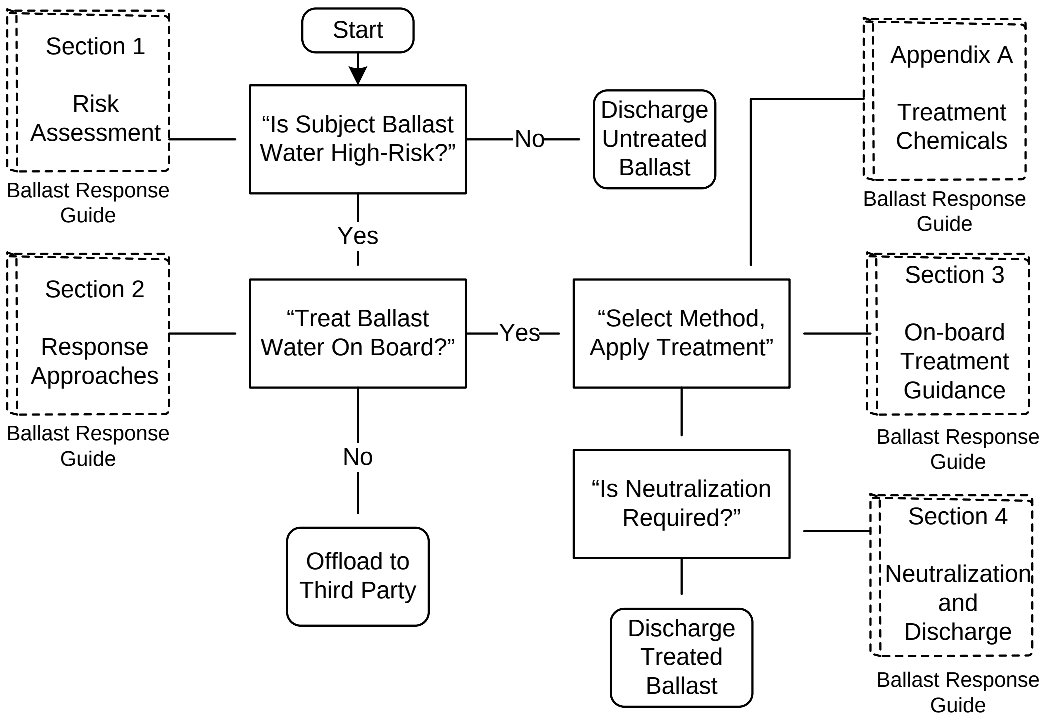

Figure 1 - Response Guide Flow Chart

Emergency responses described in this guide may be needed to treat suspect ballast water onboard in the following situations:

- Ship Casualty: This scenario involves a salvage situation where a vessel runs aground and cannot be freed without decreasing the ground reaction. Salvage cases may be time critical, making the discharge of ballast water a favored early response technique. The risk of discharging suspect ballast water in an environmentally sensitive area may be mitigated by directing the salvor to introduce, and possibly later neutralize, a chemical disinfecting agent into the casualty's ballast tanks. In this case, the deployment of the appropriate mixing technology could be critical to the success of the operation.

- Regulatory Intervention to High Risk Vessel Arrivals: Environmental monitoring for the distribution of AIS has led to the identification of high risk areas. Port State Control measures can be exercised to identify those vessels considered high risk arrivals. Suspect vessels that fail to demonstrate functioning ballast water treatment systems or evidence of volumetric open ocean exchange can then be mandated to undergo emergency interventions similar to that discussed for ship casualties.

A relevant example of casualty risk was demonstrated by the November 1996 *M/T Igloo Moon* grounding (Reference 8). Ballast water from the stricken tanker had to be offloaded in order to move the ship off the reef. Emergency treatment of ballast water was deemed necessary due to the origins of the ballast water and the vessel's proximity to the sensitive environment of Biscayne Bay National Park, and concerns were raised over the potential risk of introducing AIS via the ballast water that could harm the reef's natural biota. Twelve days after the grounding, 1.1 million gallons of the ship's ballast water was treated with calcium hypochlorite. The treated ballast water was then discharged overboard, after which assisting vessels safely towed the ship off the reef without incident or spillage.

The methods used in the *Igloo Moon* emergency response were better than inaction for reducing the risk of a new AIS introduction. The situation clarified the need for further research to develop scientifically-verified methods to dose ballast tanks with a biocide proven to be effective and that could be neutralized to a safe level for discharge.

Photo 1 - Tanker *Igloo Moon* carrying suspect ballast water shown aground on a sensitive coral reef. The adjacent ship is receiving cargo from the casualty vessel.

This guide broadly outlines considerations for determining whether treatment is appropriate, and on-board approaches to treating ballast water trialed aboard an operating Great Lakes bulk carrier. Actual treatment could be 1) conducted voluntarily under the responsibility of the vessel Master or Owner, 2) initiated by emergency response personnel when they have the authority, or 3) required through legal mandates by the agency with authority over the waters where discharge is to take place.

The Great Lake field trials were held aboard a single vessel and used dye to simulate and assess the methods of introduction of a biocide and in-tank mixing needs. With respect to mixing, the dye constituted a worst-case scenario, as it does not naturally diffuse through a water body as is common with some other chemicals. While the trials were conducted in freshwater, the methods discussed should work effectively in salt water and thus, the guide is suitable for general salt and fresh water use. The trials were conducted in two, 1 million gallon ballast tanks of a similar cathedral design filled with 800 thousand gallons of ballast water. While the volume of water tested was close to a worst case scenario, the application of these methods may be of limited practicality for other tank designs. With continued input from the ballast water and salvage community, subsequent revisions could address broader application needs. Currently, this guide intends to provide a framework for ship personnel and interested parties involved in either a casualty or regulatory intervention situation, and gives practical examples based on the trials conducted.

Section 2 Risk Assessment

Is there a significant threat of invasive species from release of this ballast water?

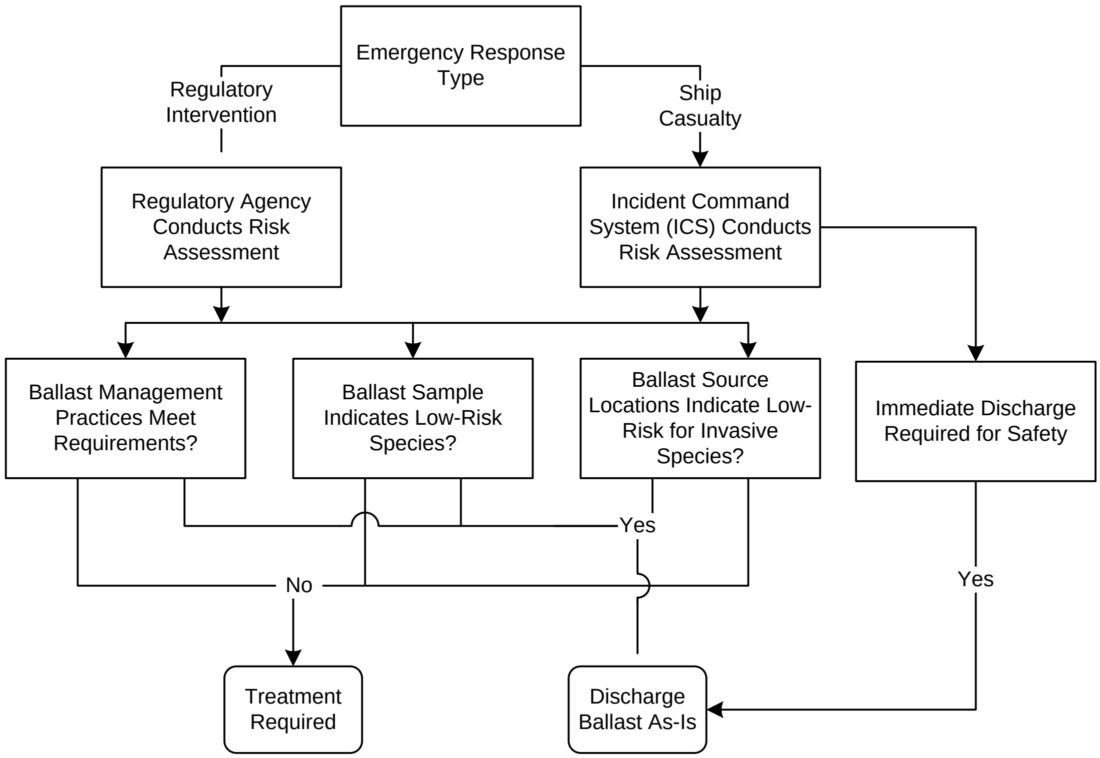

Figure 2 - Risk Assessment Flow Chart

This section outlines a process for determining whether a marine vessel's ballast water presents a significant threat of introducing AIS to the local ecosystem. Current practice calls for the response team to determine if required ballast management practices have been followed. If they have not been, the conservative practice is to consider the ballast water high risk. Other methods may determine risk based on sampling of the ballast tanks and/or analysis of the source water's geographic location. These assessments can be difficult to conduct on an emergency basis, and are therefore identified as "developing" in Figure 2.

Due to considerations for the safety of the ship and personnel, there may be cases where neither assessments nor emergency treatment can be performed before ballast water must be discharged for safety reasons.

2.1 Risk Assessment Responsibility

As commercial shipping regulations in the United States are enforced by a combination of federal and local agencies, risk assessment responsibility for:

- **Regulatory Intervention** generally lies with the intervening entity.
- **Casualty Response** depends on the scope and nature of the casualty, with large incidents requiring implementation of a Unified Command (UC) as described below.

2.1.1 Regulatory Intervention

On the federal level, the U.S. Coast Guard (USCG) has traditionally regulated marine vessel environmental compliance. The U.S. Environmental Protection Agency (EPA) has recently begun regulation of ship effluent discharges into U.S. waters. EPA response teams provide off-ship support when an incident threatens general populations or the environment.

On a local level, some U.S. states have developed and enforce their own ballast water discharge requirements to minimize the spread of non-indigenous species and/or to ensure that discharges are non-toxic. For example, Washington State Department of Fish and Wildlife regulates ballast water in accordance with state law. This agency coordinates with Washington State Department of Ecology to ensure that discharges meet state toxicity requirements.

2.1.2 Casualty Response

On the federal level, the USCG has traditionally regulated marine vessel safety. This mandate and tradition has positioned the USCG with the required infrastructure and experience to respond to ship incidents large and small. State and local level responders may include port authorities, emergency responders, and law enforcement, among others.

2.1.3 Level of Response

Risk assessment responsibility generally lies with the lowest level of command which has the capacity to handle the incident. Responsibility moves to higher levels of command depending on the location, circumstances, and scale of the incident or intervention. A low level incident might be a ship which did not exchange its ballast water and is waiting to discharge cargo. This incident might be assessed by a local USCG or state regulatory agency inspection team. A high level incident might be a grounded ship threatening to break-up and spill oil in an ecologically sensitive area. This incident might have several competing priorities, such as a high risk ballast water versus a possible oil spill, and therefore falls under the responsibility of UC as part of the Incident Command System (ICS).

The UC consists of the federal on-scene coordinator, the state on-scene coordinator, and the responsible party; i.e., vessel owner. The ICS organizes resources into operations, planning, logistics, and finance sections. The ICS planning section includes an Environmental Unit, which would likely assist the health and safety officers in performing the risk assessment.

In National Parks, the Natural Resources Trustee will be part of the UC. The National Park Service (NPS) Park Rangers generally have authority to respond to accidents in a park's jurisdiction. Additionally, NPS has specific mandates which prohibit the release of AIS:

- Preservation of natural, cultural and archeological resources, 36 CFR 2.1(a)(2). This section prohibits "Introducing wildlife, fish or plants, including their reproductive bodies, into a park area ecosystem."
- Park System Resources Protection Act, 16 U.S.C Section 19jj-2(b)(1) directs the Secretary to "undertake all necessary actions to prevent or minimize the destruction, loss of, or injury to park system resources, or to minimize the imminent risk of such destruction, loss, or injury."
- NPS Management Policies, Chapter 4.4.1.1, *Plant and Animal Population Management Principles*. "Prevent the introduction of exotic species into units of the

national park system, and remove, when possible, or otherwise contain individuals or populations of these species that have already become established in parks."

2.2 Assessment and Response Expertise

Once a situation is identified as requiring an emergency response, the appropriate responding agency or team will:

1) Assess the risk of AIS introduction.
2) Determine an appropriate response including compliance with applicable regulations.
3) Execute the response as outlined in Sections 2 and 3.

The expertise required to make these decisions will include roles for a chemical engineer, toxicologist, and a biologist familiar with ballast water treatment. Potential resources include the USCG, EPA, state/local water quality representatives, and the Aquatic Nuisance Species Task Force. This expertise may be critical to carry out many of the tasks listed in this guide, most notably:

- Conducting the compliance survey outlined below.
- Determining what chemical can be applied to inactivate high risk ballast water. This includes required chemical concentration and residence (soak) time required.
- Determining if neutralization of treatment chemical is required prior to discharge and, if so, the proper means.

All applicable regulatory requirements and approvals must be completed prior to executing a response. The expertise in determining compliance with regulations will generally be found within the regulatory agency itself.

The methods outlined in this guide rely on the addition of biocides to ballast tanks. Generally, biocide application is regulated by the EPA under the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA). The EPA may allow use of a biocide for an unregistered use during a crisis. There are specific exemptions which support AIS rapid response and control efforts, specifically FIFRA Section 18 - Emergency Exemptions at:

http://www.epa.gov/owow/invasive_species/invasives_management/fifra18.html#when

and FIFRA Section 24(c) - Special Local Need Registrations at:

http://www.epa.gov/owow/invasive_species/invasives_management/fifra24.html#when

The EPA may be contacted for consultation directly at 703-308-8179, or 703-305-5447 and ask for the Section 18 Emergency Exemption Team Leader.

Use of a biocide may also require approval from appropriate water quality regulatory authorities at the state level. Applicable regulations may be waived during an emergency. In the Great Lakes region, a list of pollution control agencies is provided at:

http://www.great-lakes.net/links/envt/orgs_pollution.html#p2

The United States has established the Aquatic Nuisance Species Task Force, "an intergovernmental organization dedicated to preventing and controlling aquatic nuisance species, and implementing the Nonindigenous Aquatic Nuisance Prevention and Control Act (NANPCA) of 1990." Although not typically focused on field response efforts, this task force is a source of expertise related to AIS. Contact information for various experts in each state through their web-site:

http://anstaskforce.gov/experts/search.php

2.3 Do Ballast Management Practices Meet Requirements?

Current best practice is to assess risk by determining compliance with regulations. Generally, **vessels in compliance with the requirements are not considered to have high risk ballast water** on board. The invasive species experts should be able to advise on the ballast management practices required by regulatory agencies for vessels operating in specific jurisdictions. Generally, this involves either **ballast water exchange** or **treatment**. These measures are considered, by regulation, as the minimum requirements to protect local waters. In the case of marine protected areas, sanctuaries, and National Parks, however, the release of invasive or exotic organisms is prohibited. Consequently, these cases may require analysis during emergency response.

2.3.1 Compliance Survey – Ballast Water Exchange

The International Maritime Organization (IMO) identifies three acceptable methods of ballast water exchange: 1) sequential, where ballast tanks are emptied and then refilled; 2) flow-through, where ballast tanks are overfilled by a prescribed amount; and 3) dilution, where a ballast tank is filled on top while it is being discharged from the bottom. These exchange events are generally required to be conducted in deep oceanic waters, and are expected to have a volumetric exchange efficiency of 95%.

Verification of ballast water exchange practice requires a review of the ship's ballast water management log. Various survey methods have been developed to assess the accuracy of these logs, and compliance with regulatory requirements.

Salinity Verification

The USCG fields a detachment at the Snell Lock on the Saint Lawrence Seaway in Massena, New York. A primary function of this detachment is to ensure that vessels entering the Great Lakes have conducted a mid-ocean exchange. This survey is conducted by taking a water sample from the ship's ballast tank and testing salinity. This can be achieved by a conductivity meter or light refractometer. An efficient oceanic water exchange requires salinity readings to be over 30 parts per thousand. Readings below 30 parts per thousand are considered non-compliant for fresh waters such as the Great Lakes.

Dakota Technologies BEAM

Dakota Technologies (http://www.dakotatechnologies.com/) developed and is currently testing a product called BEAM. BEAM (Ballast Exchange Assurance Meter) is a portable, handheld fluorimeter designed to generate a response relative to the amount of colored dissolved organic matter (CDOM) in ballast water. The CDOM related response is determined by exciting the sample with near-UV light and measuring the resulting fluorescence to Raman scatter ratio. This handheld device is designed to determine if ballast water is from near-coastal locations (out of compliance) or from oceanic locations (in compliance) for ship's from outside the EEZ.

Newcastle Method

Australian authorities developed a method which compared the electrical loads in engine room logs, with the ballast management logs maintained on the bridge. This method was trialed on almost 200 ships in Newcastle in 1998. During the listed ballast exchange event in mid-ocean locations, authorities would look for a corresponding increase in electrical loads indicating that the ballast water pumps were running. Additionally, authorities would review pumping capacities and tank volumes, to determine if the timeframe in which exchanges took place satisfied requirements. Similar techniques are currently used in Washington State. Effective execution of such a survey requires specific training and experience.

2.3.2 Compliance Survey – Ballast Water Treatment

Ballast water treatment is being phased in on international, national, and local levels to replace the less effective ballast water exchange methods. In general, this phase-in has already begun with various trial and testing programs. The potential technologies range broadly from filtration and ultraviolet radiation to the use of active chemicals such as chlorine. Systems either treat the ballast water upon uptake, while in the tank, upon discharge, or in combination.

With ballast water treatment systems generally under development, there is little in the way of compliance history. In general, inspections should follow the guidance provided in the IMO Ballast Water Management Convention as follows:

- Identify Type Approval Certificate for treatment device.
- Inspect Maintenance Logs to ensure unit is in proper repair.
- Operational test of treatment system to ensure unit is functional.
- Inspect Ballast Management Logs to ensure subject ballast water has been treated.

2.4 Using Ballast Samples to Determine Risk

In some cases, it may be possible to conduct sampling to prove that the ballast water is high risk. However, it is very difficult to use samples to prove that ballast water is low risk, because sampling may not be possible in the remote locations which are most likely to hold high concentrations of high risk organisms and the number of samples needed would be significant.

However, in some cases sampling can be used successfully. For example, a risk assessment was performed by the Washington State Department of Fish and Wildlife, in conjunction with University of Washington science teams, on a bulk carrier in the Columbia River in 2009. Ballast water samples were taken on-site and evaluated. A high concentration of coastal organisms was found, resulting in the ship leaving port to conduct ballast water exchange 50 miles off-shore. The results are shown in Table 1. This method can take days to get qualified personnel and equipment on hand.

Table 1 - Ikan Acapulco Ballast Sample Analysis (University of Washington, 2009)

	Before Exchange (1/22/09)	After Exchange (1/26/09)
Tank	Density m^{-3} coastal + non-indigenous	Density m^{-3} coastal + non-indigenous
Forepeak	32,541	3
#1 SWB-S	25,239	8

2.5 Using Ballast Source Locations to Determine Risk

The metrics for using ballast source locations to determine risk are not widely documented, and therefore not generally suitable for emergency response situations. When used, it should consider a comparison between the ballast water source location and planned discharge location ecosystems. This comparison should include any known AIS threats and similarities of ecosystems. Additional factors include the duration of the voyage, volume of the ballast water to be discharged, and the ballast water/sediment management practices which have been conducted.

The Marine Environment Protection Committee (MEPC) of the IMO has produced "Guidelines for Risk Assessment Under Regulation A-4 of the BWM convention (G7)." Although developed to guide IMO members in exempting certain "low-risk" vessels from ballast management practices, the same principles may be applied to emergency response risk assessment. The IMO guidelines provide metrics for the following approaches:

- Environmental Matching Risk Assessment
- Species' Biogeographical Risk Assessment

2.6 Emergency Management of High-Risk Ballast Water

Once a vessel has been identified as carrying high-risk ballast water, emergency management measures may be used. The primary options are to:

- Off-load the ballast water to a third party, or
- Treat the ballast water onboard prior to discharging in local waters.

The next section, Response Approaches, discusses challenges identified during the field trials, with a description of each approach taken to selection of the appropriate option.

Section 3 Response Approaches

Should high risk ballast water be treated onboard, or off-loaded to a third party?

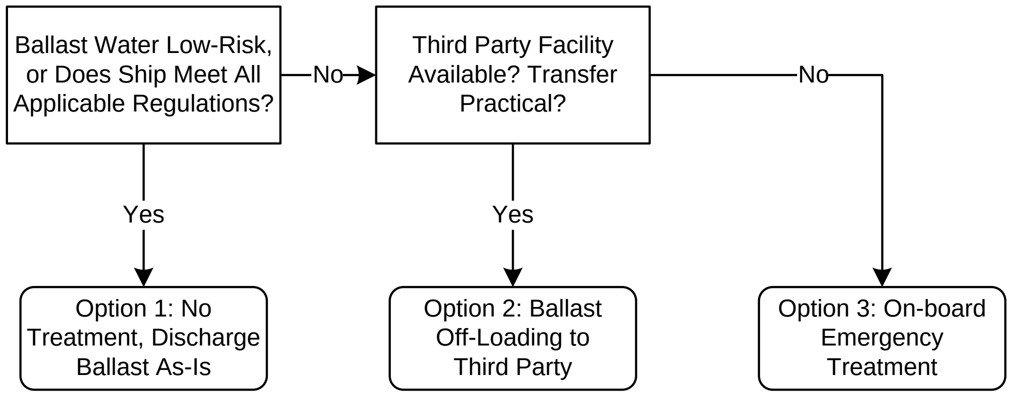

Figure 3 - Response Approach Flow Chart

3.1 Option 1: No Treatment

The previous section, Risk Assessment, outlines the field trial approaches used to determine the risk of a marine vessel's ballast water introducing an invasive species or harmful pathogens to the local ecosystem. A "low risk" conclusion of this risk assessment should allow discharge of the ballast water as-is, without further management.

A "high risk" conclusion may require further management, as outlined in the following options.

3.2 Option 2: Ballast Off-Loading to a Third Party

It is typical in salvage cases to discharge harmful liquids, such as fuel oil, to waiting tank barges to prevent pollution. The salvor may determine that such off-loading is preferred over on-board emergency ballast water treatment. If the situation allows, off-loading of ballast water to a third party in the same manner is an attractive alternative as it fits within the existing methods and tools of salvage teams. A primary consideration is the timing necessary to acquire third party resources. Off-loading ballast presents the following opportunities:

- Transfer to Holding Tank(s): The salvage team uses the vessel's pumps, or salvage team pumps to remove the ballast water to adequate holding tanks off vessel. Typically this is achieved by transferring the water to a tank barge, but could also be transferred to another ship or a shore facility. The third party will then need to consult with local authorities on how to treat the transferred high risk ballast water.
- Transfer to Treatment Facility: A third party ballast treatment system, possibly mounted in a container, is located either at a shore facility or on a deck barge (possibly on the ship's deck). Ballast water is pumped to the device, which then treats the water in **compliance with local efficacy requirements**, before it is discharged into local waters in **compliance with local toxicity discharge standards**. Such an operation

was conducted using the Hyde Guardian ballast treatment system on the lift barge "Lucky Angel" in Puget Sound, Washington (see Photo 2). The third party may require some tank holding capacity to handle waste streams that result from the treatment process, such as from back-flushing filters.

Off-loading the ballast water to a third party, to a holding tank or to a treatment plant, presents significant practical challenges. The challenges will vary significantly between various vessel classes, and individual vessel installations. Generally, ballast piping is of large diameter and located deep within the vessel, as close to the bottom plating as possible. While such installations limit energy consumption and power requirements during normal operations, it results in installed piping systems that are not capable or outfitted to send ballast water to the main deck for ease of third party access.

It should also be understood that, in many salvage situations, the subject vessel may not be under its own power. These cases require the salvage team to either provide power to the desired equipment, or to bring independently powered equipment. Some opportunities for third-party access are outlined here:

- Vessels with lower ballast water capacities and flow rates may have interconnected ballast and fire-main piping. This is common with salt water bulk carriers, container ships, roll-on/roll-off carriers, and many specialty vessels. In these cases, it is recommended that the vessel's fire pump(s) be used to off-load the high-risk ballast through the main deck located fire-main International Shore Connection.
- Typical ballast water discharges are either through an overboard pipe or through a sea-chest. It may be possible to secure a containment arrangement around such a discharge, secured to the outside of the vessel's hull. Although some leakage is likely, a third party may then be able to pump out the containment while the vessel discharges its ballast water in a traditional manner.
- Salvage teams typically carry submersible pumps that are independently powered and capable of high flow rates. Such operations require vertical access to the ballast tank(s), such as a hatch or manhole cover, or for a new opening of adequate size to be cut into the tank top. This may only be applicable for upper wing tanks. These pumps are then operated from the weather deck and lowered into the subject tank. The water is then pumped "over the top," the vessel's main deck, and to the third party.

Photo 2 - Hyde Guardian System As Used for Emergency Treatment of Ship Lift Barge "Lucky Angel" in Puget Sound (Hyde Marine, 2009)

3.3 Option 3: Onboard Emergency Treatment

If the high-risk ballast water cannot be transferred to a third party, onboard emergency treatment should be considered. For the passive treatment options described in this document, the required equipment will typically exist aboard the ship, with only the treatment chemicals requiring sourcing. The active mixing methods described herein, however, require additional equipment that must be brought aboard the ship for treatment or even pre-installed while not in ballast. The response team, in consultation with local, state, and federal agencies, will need to consider the following issues:

- Stability of vessel, and amount/location of untreated ballast water
- Current and forecast weather
- Sea conditions
- Hazards imposed to on-site responders
- Health Hazards imposed to the local community
- Areas of special environmental concern (coral reef, state park, etc.)

Additionally, some treatment chemicals may be neutralized prior to discharge by addition of a second chemical or through degradation over time. Unneutralized treatment water could be hazardous to aquatic organisms and may violate pollution regulations. A risk analysis should consider the potential harm of an unneutralized discharge versus the potential harm of an introduced species. Pollution regulations may be waived during an emergency, but this issue would need to be assessed.

After gaining an idea of the risks as itemized above, a decision can be made as to whether onboard emergency treatment can proceed. In general, emergency treatment considers mixing a liquid chemical into a full ballast tank. The next section, Onboard Treatment Guidance, was developed based on 2009 and 2010 trials aboard a 1,000 foot, 16 million gallon ballast capacity, Great Lakes bulk carrier. The suggested methods were field verified in one or more tanks of approximately 1 million gallons on this working ship. The first of the methods outlined in the following section use simple equipment readily available in a ship's locker, while the later methods outline active mixing methods which require some specialized equipment.

Section 4 Onboard Treatment Guidance

What onboard mixing method is practical given the physical constraints of the ship, and equipment on-hand?

4.1 Determine Chemical Quantity

If onboard treatment is advised, chemicals may be used to treat ballast water and prevent the introduction of AIS. The type of chemical must be chosen carefully to avoid harming humans, the ship, or the environment. The experts, particularly the chemical engineer, (see Section 1 – Risk Assessment) can provide valuable resources in selecting, handling, applying, and monitoring the treatment chemical. The following worksheet provides a worked example.

Table 2 - Worksheet to Determine Chemical Volume

Invasive Species Expert Inputs	User Input	*Example*
1. Designate Ballast Treatment Chemical		*Sodium Hypochlorite*
Target Concentration (TC) (parts per million)		*3.00*
Chemical Solution Concentration (CSC) (%)		*12%*
Specific Gravity of CSC (SGC)		*1.165*
Ballast Quantity to be Treated (BQT) (gallons)		*1,000,000*
Specific Gravity of BQT (SGB)		*1.025*
2. Determine Chemical Solution Amount (gallons)		
=(TC*BQT*SGB) / (CSC*SGC*1,000,000)		*22.00*
3. Designate Residence (Soak) Time (hours)		12
4. Is Neutralization Required Before Discharge?		TBD

Photo 3 - Measuring Dye for Ballast Water Treatment

Note: Appropriate Personal Protective Equipment (PPE) should be used when handling hazardous chemicals. Materials in photo are non-toxic.

4.2 Chemical Introduction and Mixing Methodology

To select a method for introducing and mixing a chemical treatment agent into ballast tanks, the applicability of each method needs to be evaluated. This guidance will cover four different passive methods and four different active methods of chemical introduction and mixing, as well as when the methods can be used.

Table 3, *Mixing Method Selection*, provides a framework to determine the most effective mixing method that can be practically deployed. Methods are ranked based on the combination of effectiveness and ease of installation from the ship's deck, as experienced during the shipboard trials. Testing for these methods occurred on one vessel in tanks of nearly identical design and size. Differences in effectiveness could occur under different situations, however, so this discussion should be considered guidance rather than a simple set of instructions. In particular, some chemicals will naturally diffuse through a water body until it reaches equilibrium. Different chemicals achieve equilibrium at different rates.

Table 3 - Mixing Method Selection

Mixing Method	Time to Reach 90% Mixing (hrs)	Setup Difficulty	Relative Ranking	Reasoning
Nozzle Active Mixing	1.5	Moderate	1	Rapid mixing and moderate installation/operation effort.
Air Lift Point Diffuser Mixing	1.25	Moderate	2	Rapid mixing only using air. Installation more challenging than nozzle.
In Line Dosing	4	Moderate	3	Rapid mixing. Requires transfer of all ballast water, so not always practical for emergency use
Air Lift Grid Diffuser Mixing	1.25	Hard	4	Rapid mixing. Not practical to install in full ballast tank, so not always practical for emergency use
Bulk-on-Bottom Dosing		Easy	5	Easy application, mixing times could be improved by applying chemical close to ballast intake
Moderate Seas	24			
Mild Seas	48			
Perforated Hose Dosing	16	Easy	6	Moderate mixing rate. Simple application. Could be improved by introducing chemical in multiple locations
Vent Dosing		Easy	7	Slow mixing relying on ships motions for majority of mixing. Mixing would be very slow for stationary ship
Moderate Seas	24			
Mild Seas	36			
Internal Transfer Dosing	36	Moderate	8	Slow mixing for effort required. Increase transfer rate to reduce mixing time, or add nozzle for rapid mixing.

4.2.1 Method 1: Nozzle Active Mixing

Application: Full or Partially Full Ballast Tank

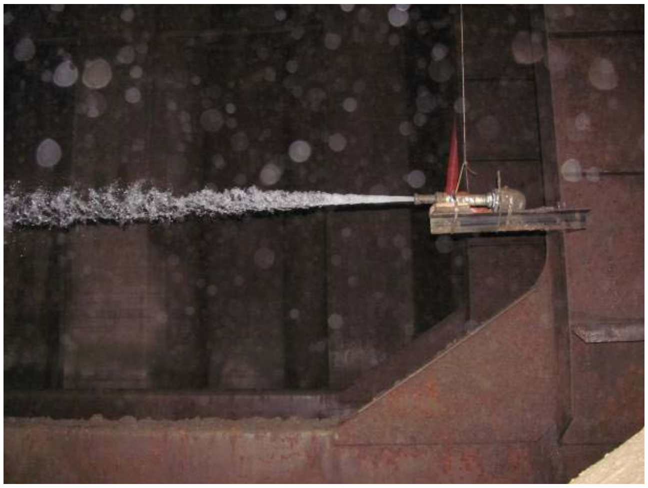

Photo 4 - Parallel Nozzle Setup

Photo 5 - 45° nozzle setup (lower nozzle part of parallel setup)

As many nozzles as practical are lowered into tank through manholes or hatches and proper location is dependant on tank geometry. Nozzles should be installed such that the water jet creates movement in the whole tank.

No. of Nozzles	Orientation	Test Results
2	Center in tank, each facing 45° off the outboard wall.	< 2 hours
3	Distribute across tank, each facing parallel towards the centerline.	< 1.5 hours

Chemical is metered into the water flow, and mixes into the ballast water by a combination of turbulent water movement and chemical diffusion.

1. Obtain source water supply. Ships firemain or deck washdown can be utilized if ~350 gpm and ~50psi at the outlet is available and the addition of water to the tank is acceptable. Alternatively, lower a submersible pump into the ballast tank to make a closed loop system. Plan on 100-150 gpm per nozzle to size pumps.
2. Lower nozzle on rigid pipe until ~3' above bottom structure. Secure support pipe at deck to maintain water source jets in proper direction. Note that the rigid pipe must be capable of supporting the thrust imparted by the nozzles.
3. Add required quantity of chemical to treat tank into drum, and dilute with water.
4. Set up chemical injection. Use small, high head metering pump. Connect in line with water source.
5. Start water source to establish in tank circulation, this can take 10-20 minutes.

6. Inject chemical into water source over a period of 10-20 minutes. Flush chemical drum with as much water as practical, pumping into water source.
7. Continue to run water through nozzles for 2 hours after start of chemical injection to complete mixing.

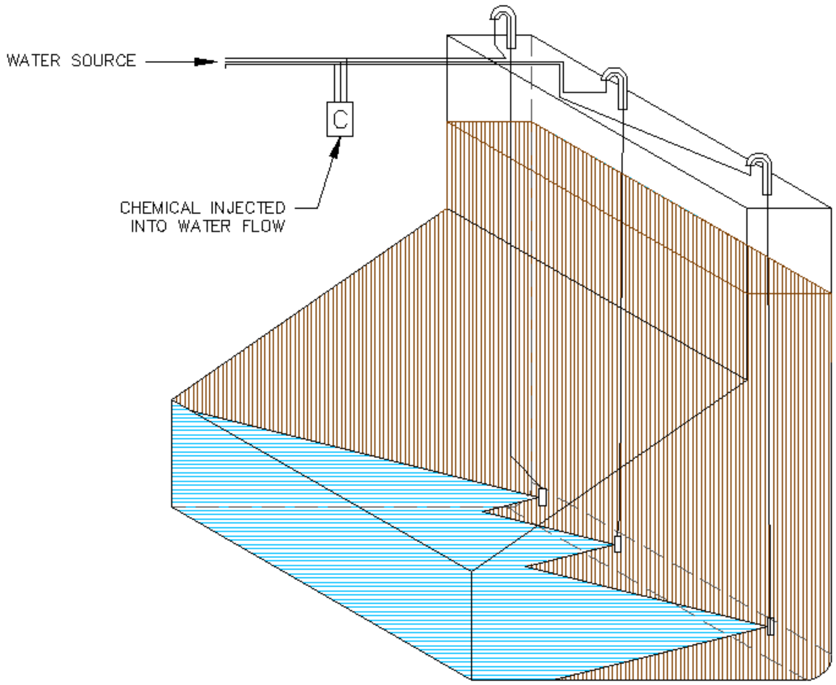

Figure 4 - Three Parallel Nozzle Arrangement

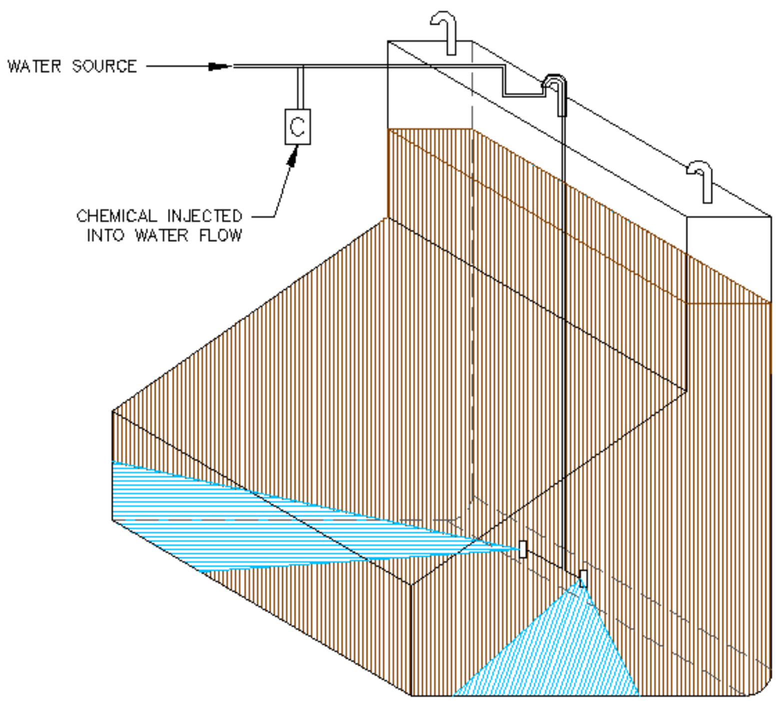

Figure 5 - Two 45 Degree Nozzle Arrangement

4.2.2 Method 2: Air Lift Point Diffuser Active Mixing

Application: Full or Partially Full Ballast Tank

Point diffusers are dropped into the tank along outboard sideshell, centered between deep frames, spaced equally through vents or manholes. The chemical is introduced to the tank just above each point diffuser using a pump and tubing. The chemical is expected to mix into the ballast water by a combination of turbulent water movement and chemical diffusion. During tests, this method mixed a partially full ballast tank in just under 1-1/4 hours.

Photo 6 - Point diffuser in tank

1. Connect suction side of small pump to a drum, and connect the discharge side to a manifold with enough ports to supply chemical to each diffuser. Connect tubing between manifold and each point diffuser tying tubing to air supply hose. Terminate tubing 1' above diffuser. Start small pump and adjust flow to equalize all branches.
2. Lower point diffusers into tank using air supply hose until ~4' above the bottom. Insure there is enough weight attached to keep them submerged.
3. Start air supply to establish in tank circulation, this can take 10-20 minutes.
4. Add required quantity of chemical to treat tank into drum, and dilute with water.
5. Inject ballast tank with chemical over a period of 5-10 minutes. Rinse drum with water and continue to inject into tank until drum is clean.
6. Continue to run air through point diffusers for 2 hours after start of chemical injection to insure complete mixing.

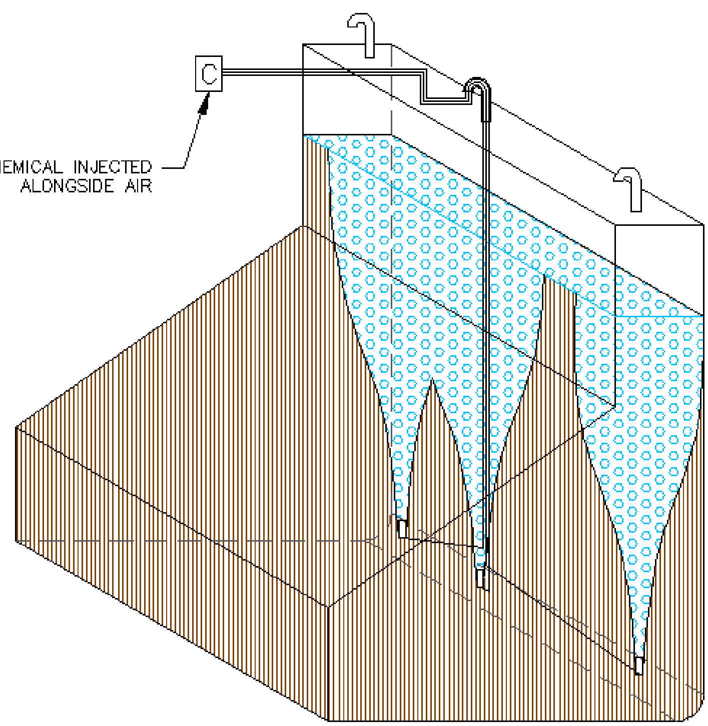

Figure 6 - Three point diffuser diagram

4.2.3 Method 3: In-Line Dosing

Application: Empty Ballast Tank (During Uptake or Transfer)

"In-line dosing" injects the chemical directly into the ballast main while the ballast is being gravitated or pumped into the ballast tank. The mixing takes place both in the piping, as well as in the tank.

Photo 7 - Inline dosing setup

1. Determine how much chemical is needed to treat target ballast tank.
2. Connect small pump and hose between the drum and the ballast pump (preferably on pump suction side).
3. Fill drum with water. Start chemical dosing pump. Continue filling drum with water such that it stays partially full.
4. Start ballasting. Add chemical to drum in proportion to amount of ballast water loaded. If ballast tank is 25% full, then 25% of chemical should have been used. Continue filling drum with water such that it stays partially full.
5. Finish adding chemical early. Make sure 100% of chemical has been added to drum before finished ballasting, such that drum can be flushed and emptied into ballast line.

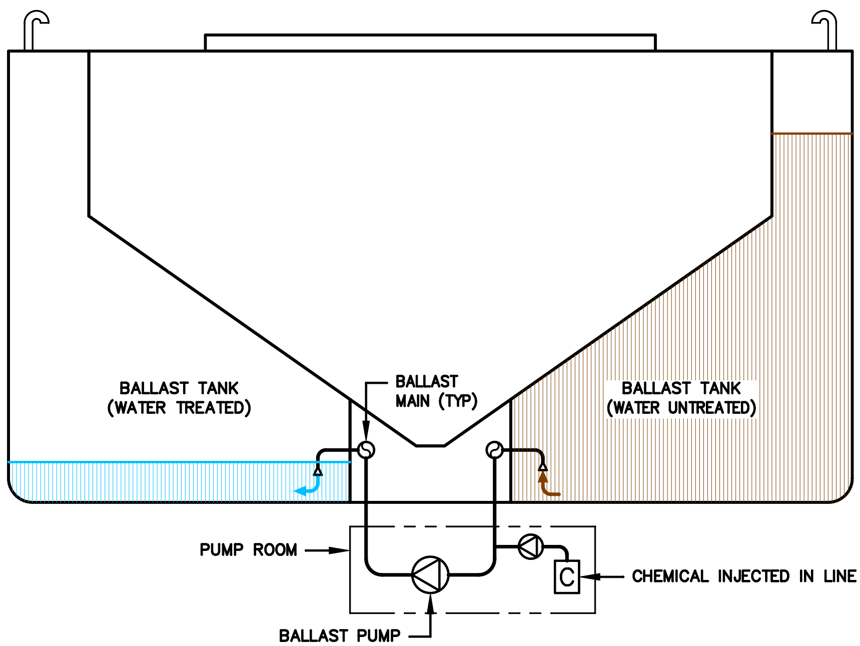

Figure 7 - Inline dosing diagram

4.2.4 Method 4: Air Lift Grid Diffuser Active Mixing

Application: Empty Ballast Tank (perminant/semiperminant installation)

Grid diffusers are installed into tank along outboard sideshell, centered between deep frames. The chemical is introduced to the tank just above each diffuser grid using a pump and tubing. The chemical is expected to mix into the ballast water by a combination of turbulent water movement and chemical diffusion. During tests, this method mixed a partially full ballast tank in just under 1 hour.

Photo 8 - Grid diffuser in tank

1. Connect suction side of small pump to a drum, and connect the discharge side to a manifold with enough ports to supply chemical to each diffuser. Connect tubing between manifold and each diffuser tying tubing to air supply hose. Terminate tubing at the midpoint of diffuser. Start small pump and adjust flow to equalize all branches.
2. Install diffuser grids in tank ~4' above the bottom. Insure there is enough weight attached to keep them submerged or tie grids to structure.
3. Fill tank with water.
4. Start air supply to establish in tank circulation, this can take 10-20 minutes.
5. Add required quantity of chemical to treat tank into drum, and dilute with water.
6. Inject ballast tank with chemical over a period of 5-10 minutes. Rinse drum with water and continue to inject into tank until drum is clean.
7. Continue to run air through grid diffusers for 2 hours after start of chemical injection to insure complete mixing.

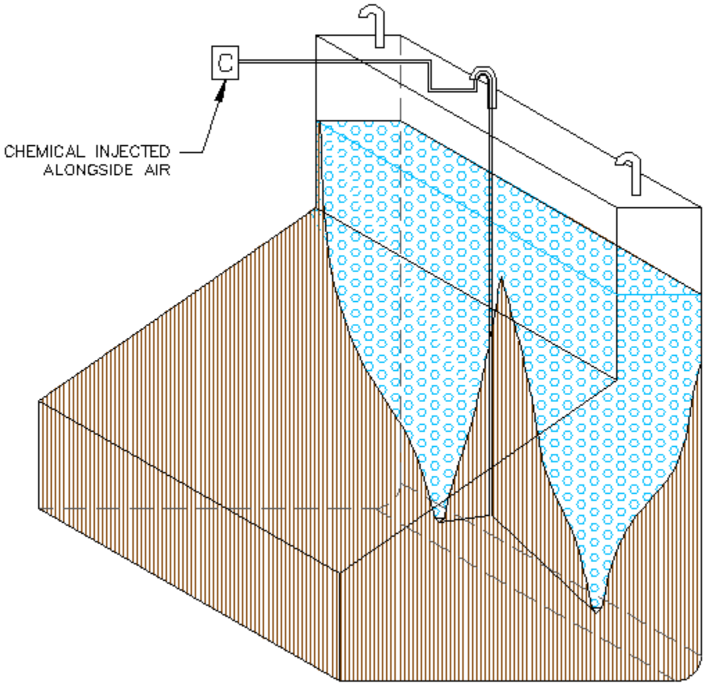

Figure 8 - Grid diffuser diagram

4.2.5 Method 5: Bulk-On-Bottom Dosing

Application: Empty Ballast Tank (During Uptake or Transfer)

"Bulk-on-bottom dosing" pumps chemical into the tank before it is filled by means of a manhole, vent, sounding tube, or other access. The tank is then filled with ballast, which mixes with the chemical as the tank is filled.

Photo 9 - Dosing setup on deck

1. Add required quantity of chemical to treat tank into drum, and dilute with water.
2. Target pumping chemical as close as possible to where the ballast water fill is located to promote mixing.
3. Pump chemical mixture into empty ballast tank. Flush out drum with as much water as possible, "chasing" chemical placed in ballast tank with as much water as reasonable (~250 gallons or more).
4. Start ballast transfer operations as soon as possible, at as high of a rate as possible. There is concern that sediment may absorb chemicals given enough time.

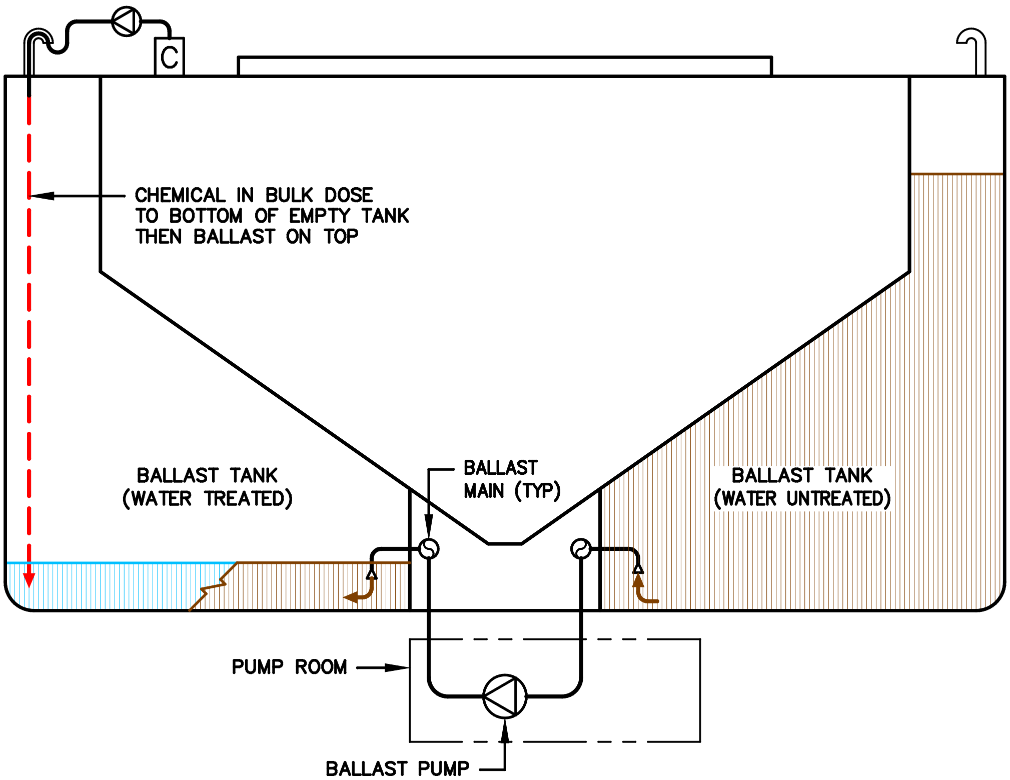

Figure 9 - Bulk on bottom dosing diagram

4.2.6 Method 6: Perforated Hose Dosing

Application: Full or Partially Full Ballast Tank

"Perforated hose dosing" *sprays* the chemical into the water column in the ballast tank. This can be done at one tank location (manhole, vent, or other tank top access), or if available, at several tank locations.

1. Set-up perforated hose (see equipment section) of a length to suit water level in the ballast tank.
2. Add required quantity of chemcial to treat tank into drum and dilute with water.
3. "Spray" the chemical into the ballast tank by running the small pump at maximum pressure. Flush as much water after the chemical as practical (at least 20 minutes).

Photo 10 - Perforated hose setup on deck during dye study

Note: Appropriate PPE should be used when handling hazardous chemicals.

4. If more than one tank location is available, divide the chemical accordingly, and repeat steps 2 – 4 in each additional location.

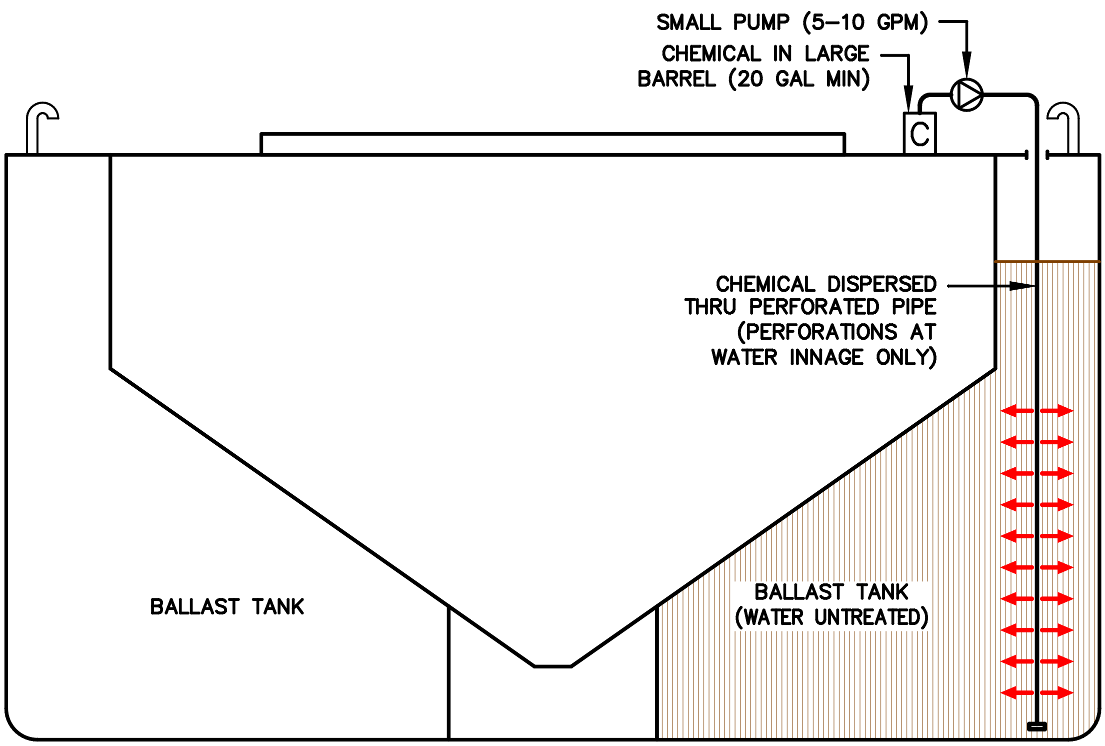

Figure 10 - Perforated hose diagram

4.2.7 Method 7: Vent/Sounding Tube Dosing

Application: Full or Partially Full Ballast Tank

"Vent/sounding tube dosing" pumps chemical through any available tank opening into a full ballast tank. The chemical is expected to mix into the ballast water by a combination of chemical diffusion, and of any motion undergone by the ship. Although this method was used during the *Igloo Moon* response, and is currently required by jurisdictions such as Argentina for resonding to cholera outbreaks, it is considered the least effective mixing method reviewed here.

1. Add required quantity of chemical to treat tank into drum, and dilute with water.
2. Inject partially full ballast tank with chemical, flushing out drum with as much water as practical (~250 gallons or more), "chasing" chemical placed in ballast tank with as much water as possible.
3. If more than one tank location is available, divide the chemical accordingly, and repeat steps 2 – 4 in each additional location.

Photo 11 - Vent Dosing setup on deck

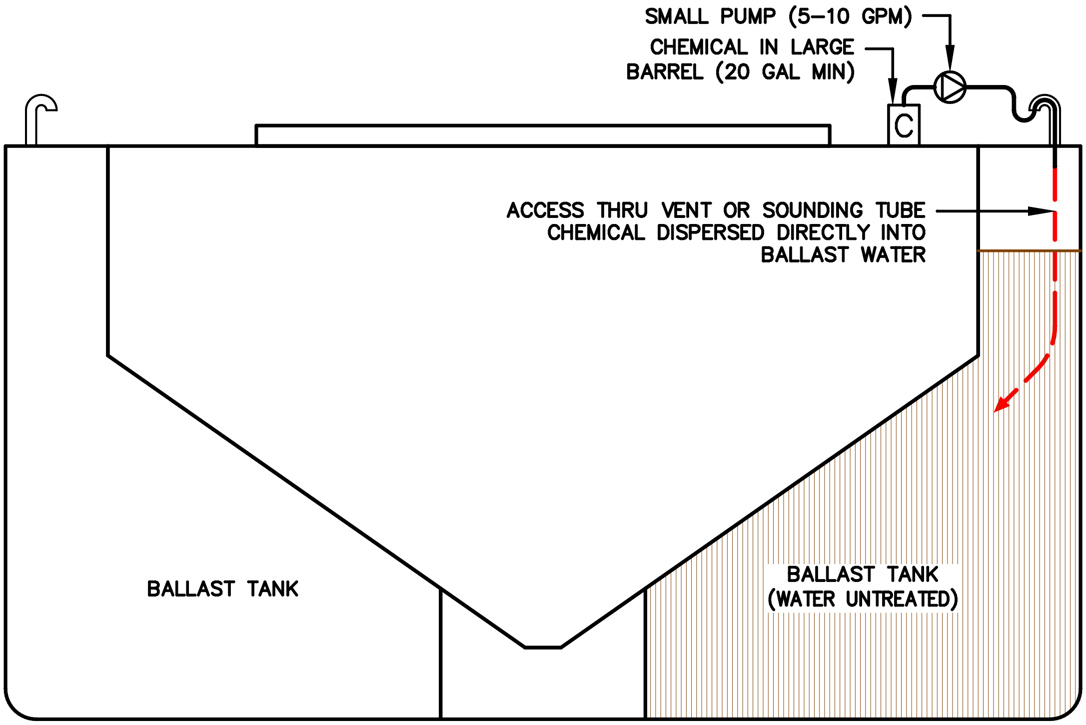

Figure 11 - Vent/sounding tube dosing diagram

4.2.8 Method 8: Internal Transfer Dosing and Mixing

Application: Full or Partially Full Ballast Tank

"Internal transfer dosing" circulates the ballast water internally within a single tank, while metering in chemical during this circulation process.

1. Internal Transfer Equipment Set-up. See Equipment List section.
2. Start the large circulation pump. This will be run during dosing, and for as long afterwards as needed to achieve mixing (perhaps several days).
3. Set-up small dosing pump and hoses, connecting to the suction manifold. Add required quantity of chemcial to treat tank into drum, and dilute with water.

Photo 12 - Internal transfer setup in hold

4. Inject the chemical into the circulation loop over a period of no less than two hours. Flush chemical drum with as much water as practical, pumping into the circulation loop.
5. Continue running circulation loop until mixing is achieved.

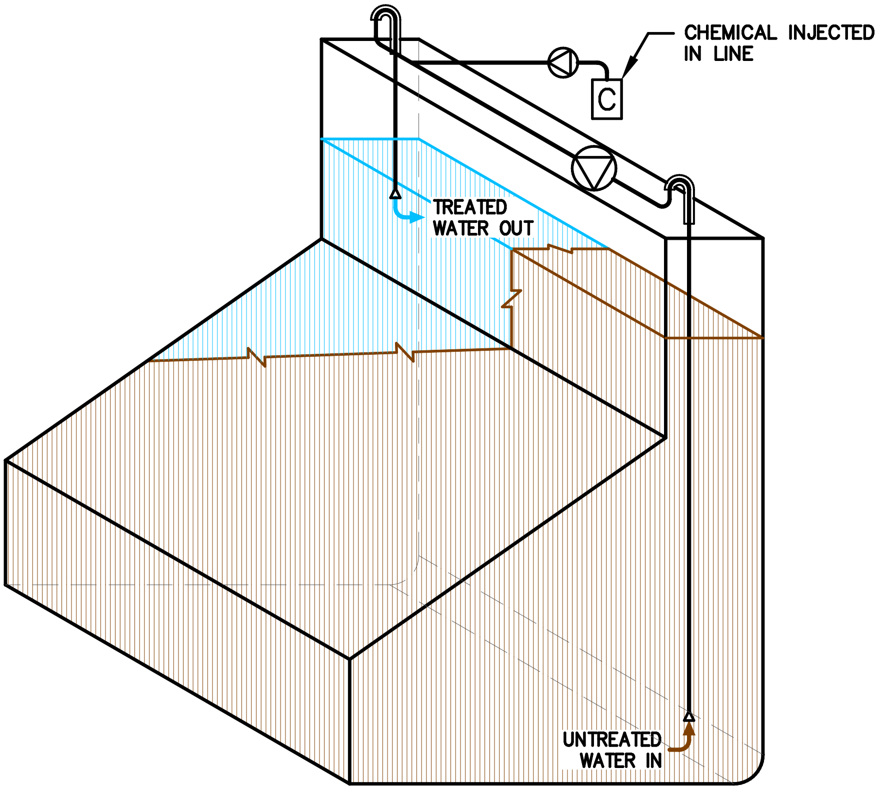

Figure 12 - Internal transfer mixing diagram

4.3 Equipment Requirements

The methods developed for this guide assume that the response team only has access to typical ship's equipment. In general, this includes a small pump(s), hoses, fittings, and drums. The ability to apply advanced equipment will improve the effectiveness of the response.

4.3.1 Basic Equipment

- Pump (1): Small pump with capacity between 5 and 20 gallons per minute. Must have check valve on discharge side, and adequate head to overcome ballast main pressure.
- Drum (1): 20 to 50 gallon capacity, to add chemical diluted with water.
- Hose (2): ~ 3/4" to 1" diameter, with length and fittings to suit. Rated to the greater of the ballast main pressure or small pump head.
- Generator: Diesel powered generator sized to power the basic equipment and any advanced equipment required (only required if ship is without power).

Photo 13 - Typical drum and small pump with hoses connected

4.3.2 Method Specific Equipment

- Nozzle Equipment (2 or 3 nozzles): This supports the "Nozzle Active Mixing" Method 1.
  - Hose (2 or 3): Two inch (2") diameter for individual nozzles, rigid hose, with length and fittings to suit. The length should reach from the water supply on the main deck to each of the nozzle locations. The hoses should be run in parallel with each other.
  - Nozzle (2 or 3): one and one-half inch (1-1/2") NST base solid stream nozzle with three quarter inch (3/4") or seven-eighths inch (7/8") outlet. It is expected

that ~150 gallons of water a minute at 50 pounds per square inch is required at each nozzle outlet. If relying on the ships firemain to provide water a reasonable estimate of water supply is a maximum of 325 gallons per minute on a large ship.

- Flow meter (2 or 3): Used to measure the flow to each of the nozzles.
- Valves (2 or 3): Sized to suit hose. Used to balance the flow between each of the nozzles.
- Fittings to allow injection of chemical into each hose.
- Use of Basic Equipment described in this section.

Photo 14 - Nozzle mounted to ship's structure in tank in parallel nozzle arrangement

Photo 15 - Nozzle equipment on deck: hoses, valves, meters, chemical injection equipment

- Air Lift Equipment: This supports the "Air Lift Point Diffuser Active Mixing" Method 2.
  - Air compressor(s): Air compressor(s), diesel powered, to provide 150 scfm per point diffuser.
  - Pressure reducing station: To reduce air pressure to ~15psi at the tank bottom.
  - Mist eliminator or air dryer (if needed): To prevent icing during pressure reduction.
  - Hoses: One and one-half inch (1-1/2") diameter for each point diffuser, 30psi minimal rating, with length and fittings to suit. The length should reach from the air supply on the main deck to each of the diffuser locations. The hoses should be run in parallel with each other.
  - Point Diffusers: Largest diameter PVC pipe (schedule 40) that will fit through manhole or cut off vent pipe, roughly three feet (~3') long, capped and plumbed with fittings to attach to air hose, one eighth inch (1/8") holes drilled on three inch (3") centers over whole surface of pipe.
  - Valves: Sized to suit air hose. Used to balance the flow between the point diffusers.
  - Hose: Small diameter hose to suit chemical pump with length to match each air hose. Used to inject chemical at each diffuser location. Fittings to split and balance flow between all lines.
  - Use of Basic Equipment described in this section.

Photo 16 - Point diffusers, 10" diameter pipes 36" long with ~100 1/8" holes

- Air Lift Equipment: This supports the "Air Lift Grid Diffuser Active Mixing" Method 4.
  - Air compressor(s): Air compressor(s), diesel powered, to provide 250 scfm to each grid diffuser.

- Pressure reducing station: To reduce air pressure to ~15psi at the tank bottom.
- Mist eliminator or air dryer (if needed): To prevent icing during pressure reduction.
- Hose: Two inch (2") diameter to each grid diffuser, 30psi minimal rating, with length and fittings to suit. The length should reach from the air supply on the main deck to each of the diffuser locations. The hoses should be run in parallel with each other.
- Grid of Diffusers: Grid of course bubble puck diffusers, spaced in a twelve inch (12") grid, diffuser array sized to fit between deep web frames. Fittings to make air tight connections to pucks and air hose.
- Mounting system to hold diffuser grid in place.
- Valves: Sized to suit air hose. Used to balance the flow between each of the diffuser grids.
- Hose: Small diameter hose to suit chemical pump with length to match each air hose. Used to inject chemical at each diffuser location. Fittings to split and balance flow between all lines.
- Use of Basic Equipment described in this section.

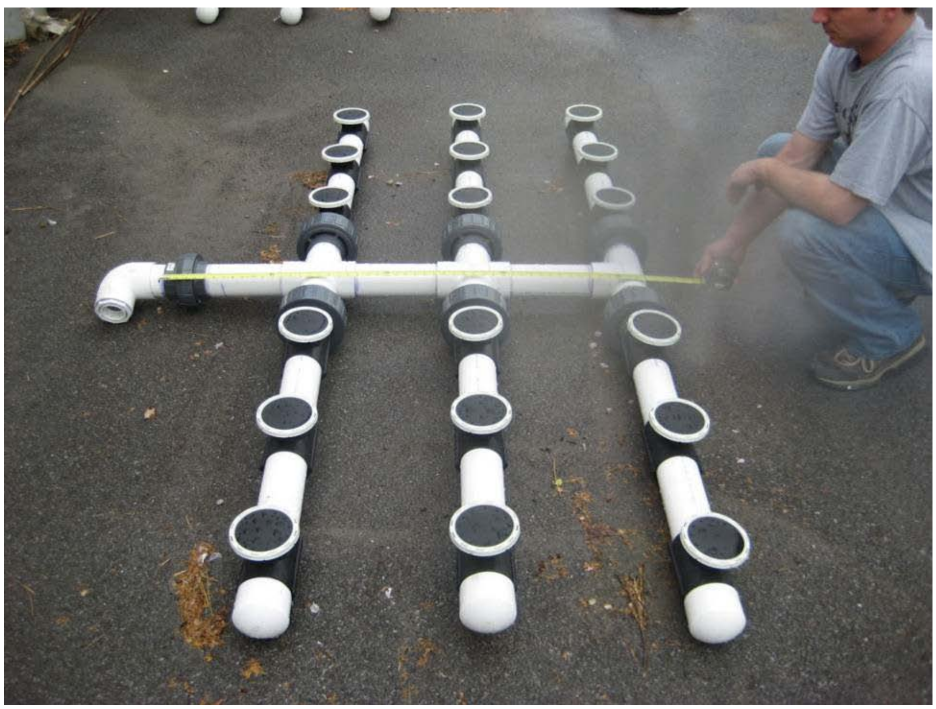

Photo 17 – Diffuser grid of 18 coarse bubble puck diffusers

Photo 18 – Air supply equipment on deck for point diffuser and grid diffuser trials

- Perforated Hose (1): This supports the "Perforated Hose" Method 6.
    - ~ 3/4" to 1" diameter hose, with length and fittings to suit. The length of the hose should be cut to match the vertical depth of the ballast water in the subject tank. The hose should be drilled with twenty 1/8" diameter holes, evenly distributed on all sides of the hose for the length which will be submerged in the ballast water. The end of the hose should be plugged. The end of the hose should be weighted so that it hangs vertically (about 5 pounds).

Photo 19 - Testing the spray pattern of the perforated hose

- Internal Transfer Equipment: This supports the "Internal Transfer" Method 8.
  - Transfer Pump (1): Maximum volume throughput, suitable for continuous use for 24 to 72 hours. The pump may be driven by any suitable means, including diesel engine, electrical motor, hydraulic pump, or pneumatic if freezing can be avoided.
  - Hose (2): Hose diameter to suit pumping capacity, rigid hose, with length and fittings to suit. The suction length should reach from the bottom of the deepest portion of the ballast tank to the transfer pump. The discharge length should reach from the transfer pump to the top of the opposite end of the ballast tank.
  - Chemical Injection Manifold (1): The manifold consists of a tee fitting connected to the inlet side of the pump. A valve and reducer is connected to the branch side of the tee for injection of the chemical.

Photo 20 - Rigging transfer pump and hose on main deck

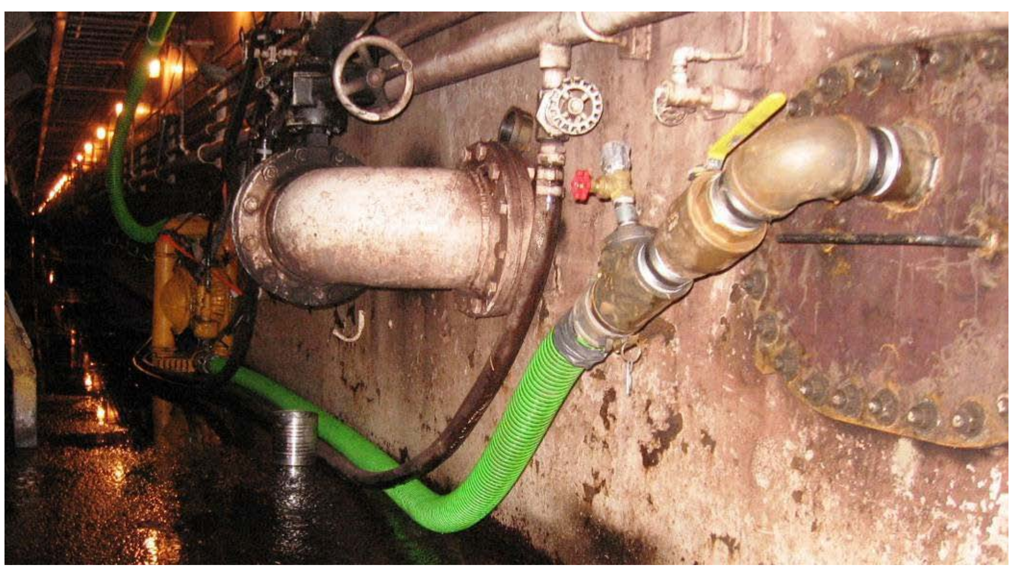

Photo 21 - Chemical injection manifold tee fitting shown, transfer pump in background

Section 5 Neutralization and Discharge

Will the chemicals used to kill the AIS and pathogens in the ballast water harm the local waters? Is neutralization required before discharge?

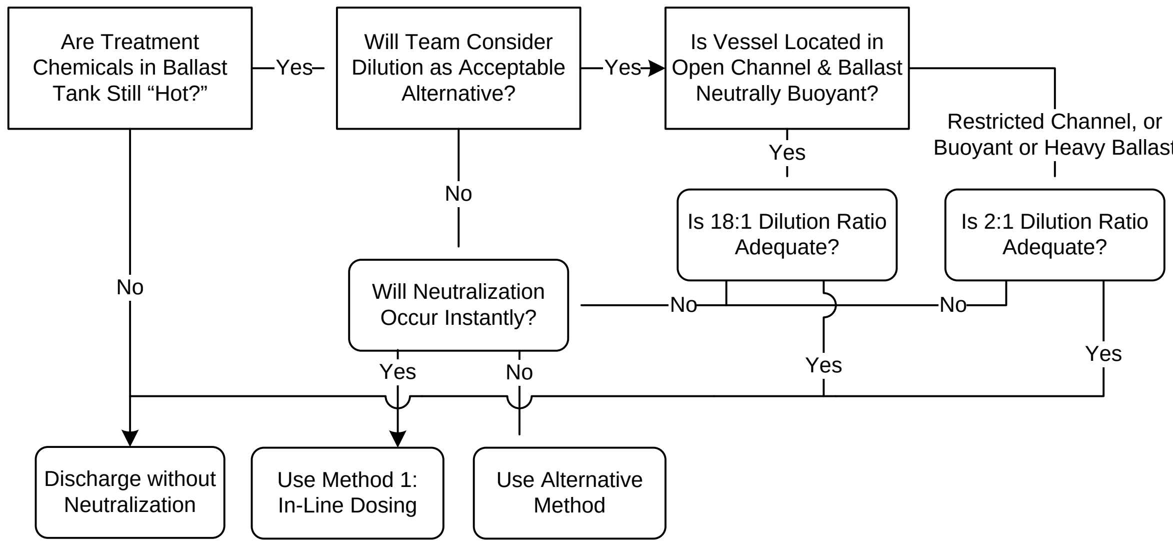

Figure 13 - Neutralization Flow Chart

Typically, a ballast tank will be dosed with a high enough concentration of chemical so that the tank remains "hot" even after adequate time has elapsed to kill the harmful organisms and pathogens. This approach gives a cushion in case the dose is not perfectly mixed, and also to prevent re-growth from the few remaining viable organisms and pathogens. Thus, only one dose of chemicals is needed. The response team, at this point, needs to determine if a neutralization step is required. The Neutralization Flow Chart provides guidance in making this assessment.

5.1 Chemical Analysis

The response team must analyze the chemical used to kill the harmful organisms and pathogens prior to discharging it into local waters. The key factors to determine are the:

- Concentration of chemical in the subject ballast tank(s).
- Concentration of chemical acceptable for local waters.

If the concentration in the subject ballast tank(s) is less than the acceptable discharge concentration, then no neutralization is required.

5.2 Dilution

The response team should determine if the use of a dilution zone is acceptable for local waters. The approach accepts that the water immediately in way of the discharge pipe will have the same concentration of chemical as the ballast tank during the discharge. It is also understood that the concentration decreases at increasing distances from the point of discharge. The factors that impact how quickly this dilution takes place include:

- Ballast Volume - Large volumes may overwhelm restricted channels.
- Ballast Flow Rate - The higher the flow rate, the greater the ability to overwhelm restricted channels.
- Ballast Velocity - Higher velocities can encourage mixing with local waters, which increases dilution ratios.
- Ballast Density - Density is mostly impacted by salinity and temperature; this has a significant impact on dilution ratios.
    - Neutrally buoyant ballast water (same density as the local waters) will effectively mix and result in high dilution ratios.
    - Buoyant ballast water (less dense than local waters) will tend to float on the surface and result in low dilution ratios.
    - Heavy ballast water (more dense than local waters) will tend to sink, particularly in shallow channels, and result in low dilution ratios.
- Channel Bathymetry - The shape of the channel, depth and width of the local body of water, has significant impact on dilution ratios.
    - An open bathymetry, deep and unrestricted waters, allows mixing with local waters and can result in high dilution ratios.
    - A closed bathymetry, shallow and restricted waters, may cause the ballast water to be kept close to the point of discharge, concentrating the discharge and resulting in low dilution ratios.
- Current and Tide - Currents and tides have a significant impact on dilution ratios.
    - An active current, tide, or significant weather can serve to move discharged ballast water away from the discharge point, which results in higher dilution ratios.
    - A lack of current, slack tide or calm weather can serve to concentrate the ballast water at the discharge point, which results in lower dilution ratios.

Field studies with ballast water have shown dilution ratios within 50' of the discharge point to range from 2:1 in non-ideal conditions, to 18:1 in ideal conditions (Reference 9). The response team will need to consider the specific conditions of the planned discharge and determine a reasonable factor.

5.3 Neutralization

Certain chemicals can be neutralized almost instantly when exposed to a second chemical. Instant neutralization allows Method 3, *In-Line Dosing*, to be effectively used by directly pumping the neutralization chemical into the ballast main during ballast discharge. This method avoids the complications of mixing additional chemicals as a batch process in the ballast tank.

One installed ballast treatment prototype uses such an in-line process to neutralize ballast water treated with sodium hypochlorite (NaOCl). Sodium bisulfite ($NaHSO_3$) is injected in-line during ballast discharge, and has been found to mix completely and neutralize the hypochlorite within just a few pipe lengths.

Chemicals which require significant contact time (more than one minute) in order to neutralize the treatment chemical will need to be neutralized as a batch process. In other words, the chemical will need to be added to the full tank for the required period of contact time prior to discharge. The full ballast tank mixing methods (Methods 1, 2, 6, 7, and 8), as outlined in Section 4, can be considered for this effort.

Section 6 Acknowledgements

We thank Dr. Barnaby Watten, Noah Adams, Matt Sholtis, Gary Rutz and Travis Tucker of USGS for their identification, engineering, and testing of the active mixing techniques evaluated in Phase III trials, as well as the development and implementation of appropriate methods for characterizing ship dynamics in Phase II and III.

In addition, we thank Scott Smith of the USGS Western Fisheries Research Center for his efforts in partnership development, industry outreach, and consultation of program development.

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- ***M/V Indiana Harbor***. Captain Yowell and his crew provided significant support to all phases of our testing efforts. The support of the conveyor men and engineers was critical to project success.
- **Phase II Field Team**. Dr. Barnaby Watten, Noah Adams, and Gary Rutz of the U.S. Geological Survey; and Kevin Reynolds, Jon Markestad and Dan Clopton of The Glosten Associates conducted 8 days and nights of field trials.
- **Phase III Field Team**. Dr. Barnaby Watten, Gary Rutz, Matt Sholtis, and Travis Tucker of the U.S. Geological Survey; and Jon Markestad and Robin Madsen of The Glosten Associates conducted 11 days and nights of field trials.
- **Phase II Discharge Team**. Jay Austin and his team from Minnesota Technical University, Jay Glase of National Park Service, and the NPLSF volunteers Dave Miller and Chris Gale performed discharge sampling from the vessel and two small crafts during the Phase II ballast discharge.

- **Phase II Discharge Team**. Jay Austin and his team from Minnesota Technical University and the NPLSF volunteer Dave Miller performed discharge sampling from the vessel and a small craft during the Phase III ballast discharge.
- **Review and comment on the first draft came from broad sources including**: U.S. EPA – Great Lakes, U.S. EPA – Region 5, U.S. Coast Guard Cleveland, NOAA, American Salvage Association, California State Lands Commission, and University of Wisconsin-Superior.

Section 7 Guide Revisions

This Guide is a working document, and subject to revision as the community continues to gain experience in responding to high risk ballast water. The authors will continue to work to update this guide as additional information becomes available. The following items have been identified as critical to the utility of this guide:

- The non-indigenous species experts (chemical engineering, marine engineers, toxicologist, biologist) should be identified prior to an emergency response, including a means to access these individuals at all times.
- A means of determining compliance with applicable ballast management regulations should be clearly established to enable first responders to conduct this effort easily and immediately.
- Each jurisdiction is encouraged to develop area contingency plans or a net benefit analysis. Such an effort should consider acceptable chemicals, concentrations, soak times, and neutralization steps.
- Logistics for gaining third party barge mounted treatment systems must be established with expected lead times prior to an emergency response to be an effective option.
- Sampling and source risk assessment processes need to be further developed.
- This guide should be expanded to include areas outside of the United States.

Please provide field reports and case histories relevant to this topic, such that these lessons learned can be shared with the larger community. The National Park Service will maintain an updated online copy of drafts as part of its National Spill Response Management. A copy will be available as part of Area Contingency Plans for waters within NPS jurisdictions. After concurrence is gained by multiple agencies, NPS will transfer management of the document and updates to an appropriate clearinghouse. During this review process, please send comments and case studies to:

Dave L. Anderson
NPS National Spill Response Coordinator
D_L_Anderson@nps.gov
Phone: 970-225-3539

Phyllis A. Green
Superintendent, Isle Royale National Park
Phyllis_Green@nps.gov
Phone: 906-487-7140

Appendix A Treatment Chemical Overview

This appendix is based on the U.S. Coast Guard "Evaluation of Biocides for Potential Treatment of Ballast Water," Reference 3. This evaluation report contains valuable guidance and data, which is summarized in Table A.1, below.

Table A.1. – Ballast Treatment Chemicals. Group A = Kills Broad Spectrum of Organisms, Group B = Kills Narrow Spectrum of Organisms (USCG, 2004)

Biocide	Effective against Broad Range of Organisms?*	pH Inhibition	Adsorp-tion	Toxic byproducts	Recalci-trance	Shipboard Application Difficult	Cost Prohibitive	Safety Concerns	Regulatory Concerns
Group A Biocides									
Chlorine	Yes	Yes	Yes	Yes	Some	Yes	Somewhat	Yes	Yes
Chlorine dioxide	Yes	No	No	Yes†	Some	Somewhat	Yes	Yes	Some
Hydrogen peroxide	Yes	Yes	Un-known	Yes†	No	Somewhat	Somewhat	Yes	Some
Glutaraldehyde	Yes	Yes	No	No	No	No	Somewhat	No	No
Peraclean®	Yes	Unknown	Yes	Unknown	Unknown	No	No	Yes	Some
Cationic surfactants	Yes	Unknown	No	Unknown	Some	Unknown	Somewhat	Yes	Some
SeaKleen®	Yes	Unknown	No	No	No	No	No	No	No
Phenol	Yes	Unknown	Yes	No	No	Somewhat	Somewhat	Yes	Yes
Group B Biocides									
Copper	Yes	Some	Yes	No	Some	Somewhat	No	Yes	Yes
Bromine	No	Yes	Yes	Yes	Unknown	Yes	No	Yes	No
Iodine	No	Unknown	Un-known	Yes	Unknown	Somewhat	Somewhat	Yes	No
Sodium chlorite	No	Unknown	Un-known	Yes	Some	Somewhat	No	Yes	Yes
Chloramines	No	No	Some	Yes	Some	Somewhat	No	Yes	Unknown
Ozone	No	No	Yes	Yes†	No	Yes	Yes	Yes	Yes
Formaldehyde	No	Some	Un-known	No	No	Somewhat	Somewhat	Yes	Yes
Ethylene oxide	No	No	No	Yes†	No	Yes	Unknown	Yes	Yes
Dowicil® 75	No	No	Yes	Yes	No	Unknown	Unknown	Yes	Some

* If the biocide was found to be effective against six or more of the nine target organisms, a "yes" was entered. If it was effective against fewer than six, a "no" was entered.
† Toxic byproducts may form depending on existing environmental conditions

Chemicals should maximize mortality while minimizing environmental impact. Consequently, the effective use of chemicals in ballast water treatment requires a balance between the amount of time required to achieve inactivation of organisms, with the time needed for those chemicals and residuals to degrade or be treated to environmentally-acceptable levels.

Chemical effectiveness (and time needed for effective dosing) varies as a function of pH, ballast water temperature, organic content, sediment load, and mixing methodology. The ability to sample the ballast water prior to treatment assists the water quality regulatory authority in evaluating which chemical should be used, the time for treatment, and the need for neutralization after treatment.

Many regulations apply to the application of chemicals, which is why it is important to contact the Water Quality Regulatory Authority for authorization before using them. Some (but not all) of these regulations include the:

- United States Federal Water Pollution Control Act (Clean Water Act) of 1972, as amended.

- Marine Protection, Research, and Sanctuaries Act (MPRSA) of 1972.
- Endangered Species Act (ESA) of 1973.
- Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) of 1947.
- The Occupational Safety and Health Act (OSHA) of 1970.

Concerns about chemical use specific to shipboard operation include corrosion, safety (personnel and ship safety), and vessel design limitations that impact the availability of space onboard for chemical storage.

A.1 Neutralizing Treated Ballast Water—Toxicity Concerns

Mixing is not only important for introducing a chemical into the ballast water, it is also a factor in neutralizing treated ballast water. It is important that discharged treated ballast water not be toxic to the environment. Previous work by the project team indicated that dilution ratios formed by a plunging ballast water discharge stream exceeded 1:18, and may only reach 2:1 in cases of high volume discharges in restricted channels (Reference 9).

In cases where overboard dilution by the receiving body of water is not acceptable, a means of neutralizing the chemical before discharge is required. The mixing methods suggested in this guidance are also applicable to neutralizing or reversing the toxicity of 'treated' ballast water before it is discharged to the surrounding environment.

A.2 How Mixing Efficiency Affects Efficacy

In all emergency applications, ballast tank geometry, tank capacity, and liquid levels (e.g., the volume of ballast water contained in each tank) will present responders with challenges to dosing and mixing. Baffled tank geometry is complex by design to help maintain vessel stability by inhibiting the uncontrolled movement of water within the tank. As ship sizes have increased to leverage economies of scale, ballast tank capacities have increased proportionally. Consequently, concentrations of AIS may differ from one part of the tank to another, and mixing may result in an uneven concentration of chemical depending on tank geometry and current patterns within the tank. Disproportional concentrations of AIS and chemical decrease the efficacy of any chemical used. Onboard dye testing helps clarify which mixing methods are most effective under a variety of conditions.

A.3 Sediment Control

Sediment control is an important issue in chemical mixing efficacy, as sediment can directly interfere with the chemical treatment being applied. It also can become encrusted on cross members, beams and other physical structures within ballast tanks, providing a medium for trapping cysts, eggs, and other forms of aquatic life, which can subsequently be released in ballast water discharges. Best practices for managing this sediment will improve any chemical treatment and reduce the risk of introducing AIS.