

# Emergency Response Guide for Handling Ballast Water to Control Non-Indigenous Species

Prepared for  
National Park Service  
Isle Royale National Park  
Houghton, Michigan

**File No. 09019.01**  
**21 January 2010**  
**Revision -**

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**THE GLOSTEN ASSOCIATES**  
*Consulting Engineers Serving the Marine Community*

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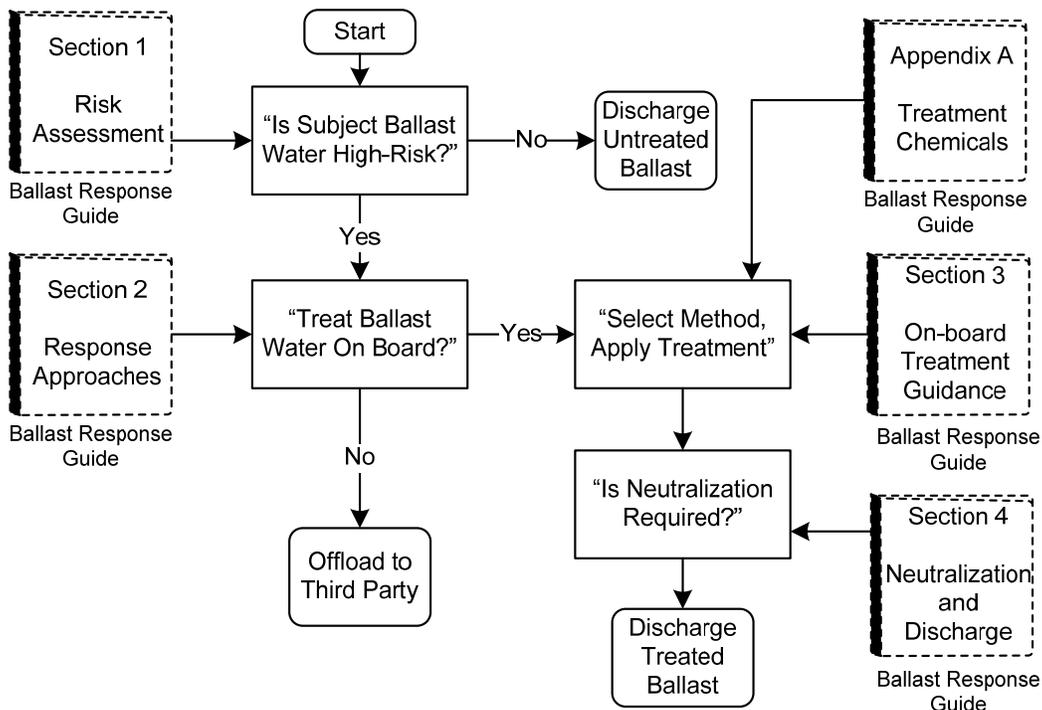
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# Introduction

This field guide has been developed as an aid to incident responders responsible for handling ships with high-risk ballast water which may be laden with non-indigenous species and harmful pathogens (NIS). Such high risk carriers may require novel intervention methods, which can be applied at sea before arrival, upon arrival in port, or at an incident location such as a grounding. This guide provides a methodology to assist responders in balancing practical field considerations, such as predicted bad weather threatening to break a ship's hull, with sound environmental practice. The Response Guide Flow Chart directs the team to the relevant section of the guide for each key inquiry when responding to a vessel with suspect ballast water.



**Figure 1 - Response Guide Flow Chart**

An effective response to high risk ballast water has become increasingly important, as commercial ships are a primary vector in the transfer of NIS throughout the world. Commercial ships currently carry cargo between the world's ports, taking in ballast water in one aquatic ecosystem and discharging it, in an industrial quantity, in another ecosystem. Foreign aquatic life may out-compete native species and multiply into pest proportions. Problems directly resulting from invasive species include the collapse of entire commercial fisheries, the displacement of native seabed communities, and the red tide contamination absorbed by filter-feeding shellfish, among many others affecting the environment and human health.

Emergency response is 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. Success in many salvage cases is 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 would be critical to the success of the operation.

- Regulatory Intervention to High Risk Vessel Arrivals: Environmental monitoring for the distribution of aquatic non-indigenous species (NIS) has led to the identification of high risk NIS areas. Port state control measures can be exercised to identify those vessels considered high risk arrivals. Suspect vessels that fail to demonstrate functioning, installed 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.

An example of this casualty risk was demonstrated by the November 1996 *M/T Igloo Moon* grounding. Emergency treatment of ballast water was necessary as ballast water from the stricken tanker had to be offloaded in order to move the ship off the reef. Because of the origins of the ballast water and the vessel's proximity to the sensitive environment of Biscayne Bay National Park, concerns were raised over the potential risk of introducing non-indigenous biota via the ballast water that could harm the reefs 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.



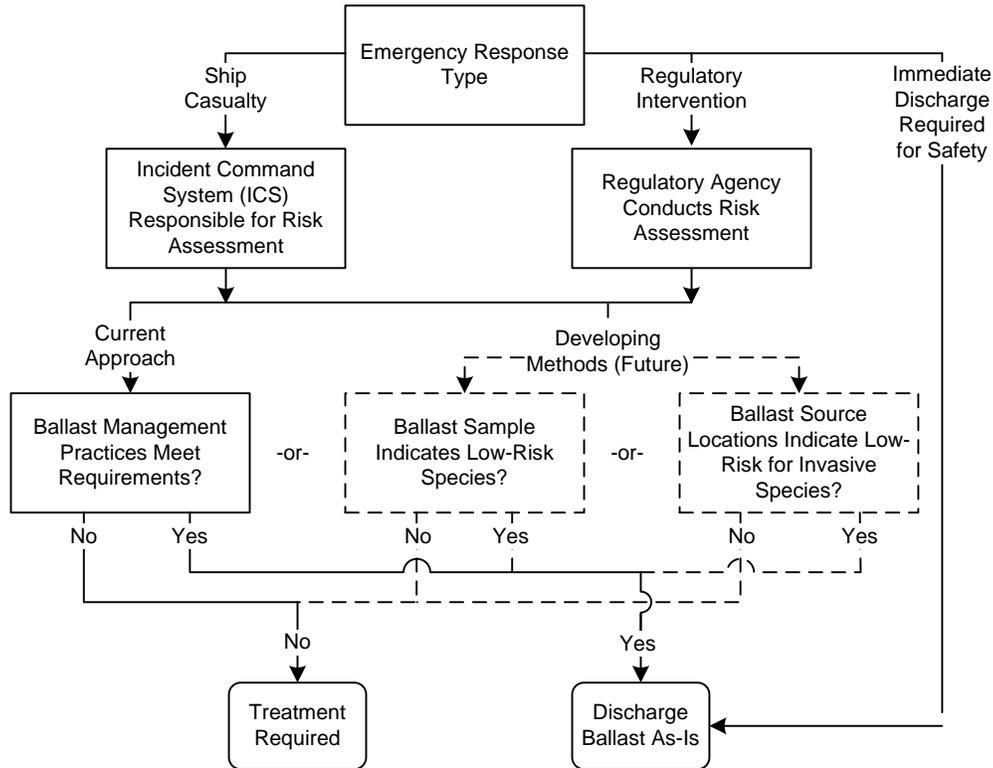
**Figure 2.** Tanker *Igloo Moon* is shown carrying suspect ballast water shown aground on a sensitive coral reef. The adjacent ship is receiving cargo from the casualty vessel.

This guidebook outlines ways to treat the ballast. 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.

This guide was developed based on shipboard field trials in the Great Lakes, but is intended for general salt and fresh water use in the United States. With continued input from the ballast water and salvage community, subsequent revisions will work to suit world-wide application needs.

# Section 1 Risk Assessment

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



**Figure 3 - Risk Assessment Flow Chart**

This section outlines current and future approaches to determine if a marine vessel’s ballast water presents a significant threat of invasive species to the local ecosystem. Current practice is 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.

Methods which determine risk based on sampling of the ballast tanks and/or analysis of the source water geographic location are outlined here. These assessments are difficult to conduct on an emergency basis, and are therefore identified as “developing” in Figure 3, Risk Assessment Flow Chart.

The risk assessment must consider the safety of the ship and personnel. There may be cases where emergency treatment can not be performed before ballast water must be discharged for safety reasons.

## 1.1 Risk Assessment Responsibility

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. Responsibility for **casualty response** depends on the scope and nature of the casualty, with large incidents requiring implementation of a Unified Command (UC) as described below.

On the federal level, the U.S. Coast Guard (USCG) has traditionally regulated marine vessel safety and environmental compliance. This mandate and tradition has positioned the USCG with the required infrastructure and experience to respond to ship incidents large and small. 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.

Risk assessment responsibility generally lays 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 U.S. Coast Guard 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 fall 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 part of the UC. The National Park Service has specific mandates which prohibits the release of NIS:

- 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.”

## 1.2 Assessment and Response Expertise

Current best practice is to assess risk by determining compliance with regulations. More advanced methods of assessing risk are under development, but not yet broadly available. The expertise in determining compliance with regulations will generally be found within the regulatory agency itself.

Once a risk has been identified, an appropriate response will need to be determined and executed 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. Resources for this personnel are the U.S. Coast Guard, U.S. EPA, state/local water quality representatives, and the Aquatic Nuisance Species Task Force. These experts should work together to:

- Conduct the risk assessment process outlined in this section.
- Determine what chemical can be applied to inactivate high risk ballast water. This includes required chemical concentration and residence (soak) time required.
- Determine if neutralization of treatment chemical is required prior to discharge and, if so, the proper means.

The U.S. EPA may allow use of a biocide for an unregistered use during a crisis. There are specific exemptions which support NIS rapid response and control efforts, specifically FIFRA (Federal Insecticide, Fungicide and Rodenticide Act) Section 18 - Emergency Exemptions at:

[http://www.epa.gov/owow/invasive\\_species/invasives\\_management/fifra18.html#when](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](http://www.epa.gov/owow/invasive_species/invasives_management/fifra24.html#when)

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

The United States has developed 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 aquatic nuisance species. Contact information for various experts in each state through their web-site:

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

## 1.3 Do Ballast Management Practices Meet Requirements?

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. Generally **vessels in compliance with the requirements are not considered to have high risk ballast water** on board. 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 extra effort for analysis during emergency response.

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%.

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, and is expected to be completed by 2018. The technology is very broad, ranging 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 a combination.

### 1.3.1 Compliance Survey – Ballast Water Exchange

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.

#### *Coast Guard Massena Detachment*

The United States Coast Guard 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. Salinity readings which are lower than 30 parts per thousand are expected for oceanic water 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. The 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.

### 1.3.2 Compliance Survey – Ballast Water Treatment

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 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.

## 1.4 Using Ballast Samples to Determine Risk

In some cases, it may be possible to use samples 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 samples can not reach the remote locations which are most likely to hold high concentrations of high risk organisms.

One example of such 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. This method can take days to get qualified personnel and equipment on hand. The results are shown in the table below.

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

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

## 1.5 Using Ballast Source Locations to Determine Risk

The metrics for using ballast source locations to determine risk is 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 NIS 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 Environmental Protection Council (MEPC) of the IMO has produced “Guidelines for Risk Assessment Under Regulation A-4 of the BWB convention (G7).” Although developed to guide IMO members in exempting certain “low-risk” vessels from ballast management practices, the same principals 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

## **1.6 Emergency Management of High-Risk Ballast Water**

Once a vessel has been identified as carrying high-risk ballast water, emergency management measures must be taken. 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 the challenges associated with each approach to assist the response team in selecting the right option.

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## Section 2 Response Approaches

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

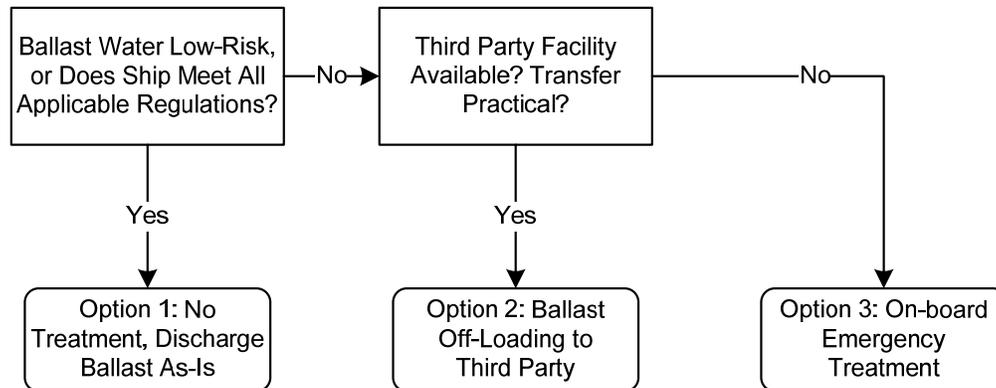


Figure 4 - Response Approach Flow Chart

### 2.1 Option 1: No Treatment

The previous section, Risk Assessment, outlines approaches 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 requires further management, as outlined in the following options.

### 2.2 Option 2: Ballast Off-Loading to 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 of the 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 Plant:** 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 and toxicity requirements**, before it is discharged into local waters. 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.



**Figure 5 - Hyde Guardian System As Used for Emergency Treatment of Ship Lift Barge "Lucky Angel" in Puget Sound (Hyde Marine, 2009)**

## 2.3 Option 3: Onboard Emergency Treatment

If the high-risk ballast water cannot be transferred to a third party, onboard emergency treatment should be considered. Typically the required equipment will already be aboard the ship, with only the treatment chemicals requiring sourcing. The response team, in consultation with local, state, and federal agencies, should 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.).

After gaining an idea of the risks as itemized above, a decision can be made on 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 trials aboard a 1,000 foot, 16 million gallon ballast capacity, Great Lakes bulk carrier. The suggested methods were field verified on this working ship. All of the methods outlined in the following section use simple equipment readily available in a ship's locker.

Although not presently covered in this guidance, future tests are planned to explore the use of axial flow propellers, eductor lines, or air lift mixing chemicals like carbon dioxide, liquid nitrogen, or dry ice. These novel methods will require additional set-up and equipment, but have the potential for increasing the efficacy of the mixing methods outlined here.

## Section 3 Onboard Treatment Guidance

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

### 3.1 Determine Chemical Quantity

If onboard treatment is advised, chemicals may be used to treat ballast water and prevent the introduction of ANS. 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) will be 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		<i>Sodium Hypochlorite</i>
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



**Figure 6 - Measuring Chemicals for Ballast Water Treatment**

### 3.2 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 5 different methods of chemical introduction and mixing, as well as when the methods can be used.

The following table provides step by step questions to determine the most effective mixing method that can be practically deployed. Methods are ranked best to worst, with 4 as the most effective. “Ship in Place” assumes a grounded or stationary ship. “Ship in Motion” assumes typical ship motions in a seaway which over time acts as an effective means of mixing chemical within a tank regardless of the chemical application method.

**Table 3. Mixing Method Selection**

<b>Criteria</b>	<b>Corresponding Methods</b>	<b>Effectiveness, Ship in Place</b>	<b>Effectiveness, Ship in Motion</b>
A. <i>Can ballast water be transferred from full tank to empty tank? If yes, Methods 1 or 2 can be used. If no, go to B.</i>	Method 1: In-Line Dosing	4/4	4/4
	Method 2: Bulk-on-Bottom Dosing	3/4	4/4
B. <i>Is there vertical access to tank contents? If yes, Method 3 can be used. If no, go to C.</i>	Method 3: Perforated-Hose Dosing	3/4	4/4
C. <i>Can ballast water be transferred aft to forward or high to low within tank? If yes, Method 4 can be used. If no, go to D.</i>	Method 4: Internal Transfer Dosing	2/4	3/4
D. <i>Is there access to a vent or sounding tube? If yes, Method 5 can be used. If no, treatment cannot occur.</i>	Method 5: Vent/Sounding Tube Dosing	1/4	2/4

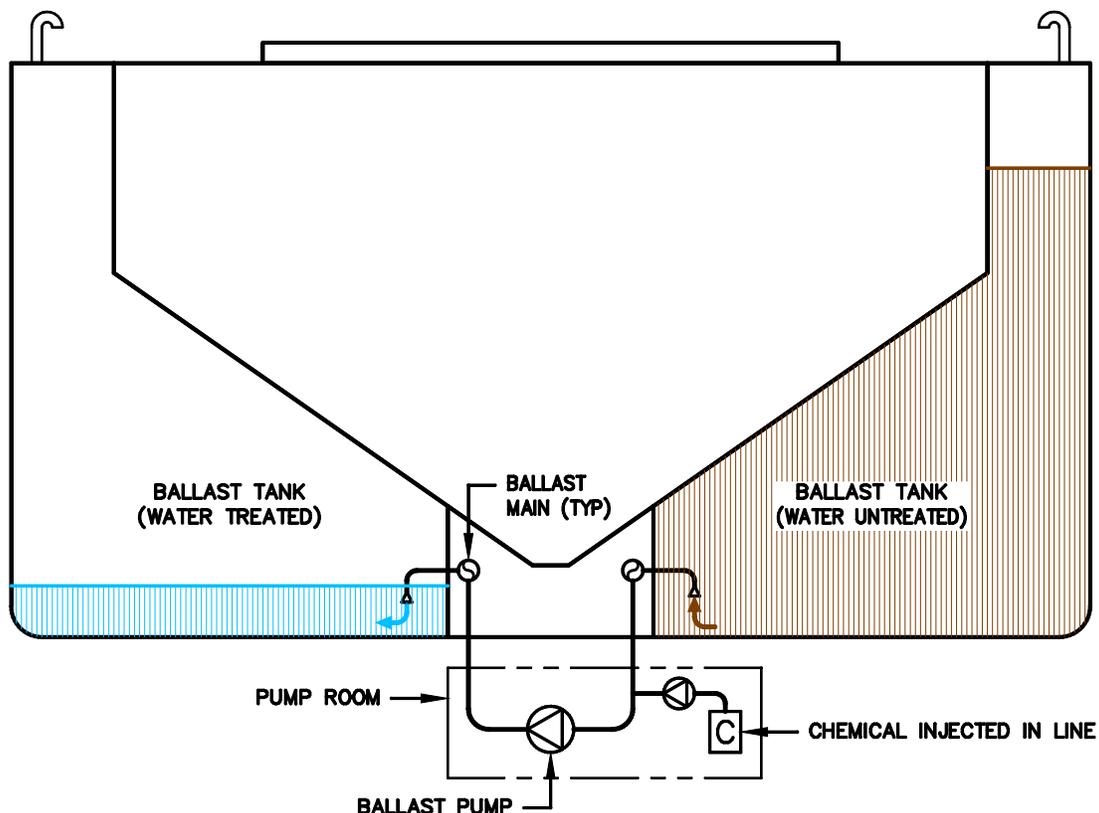
### 3.3 Method 1: In-Line Dosing

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.



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.



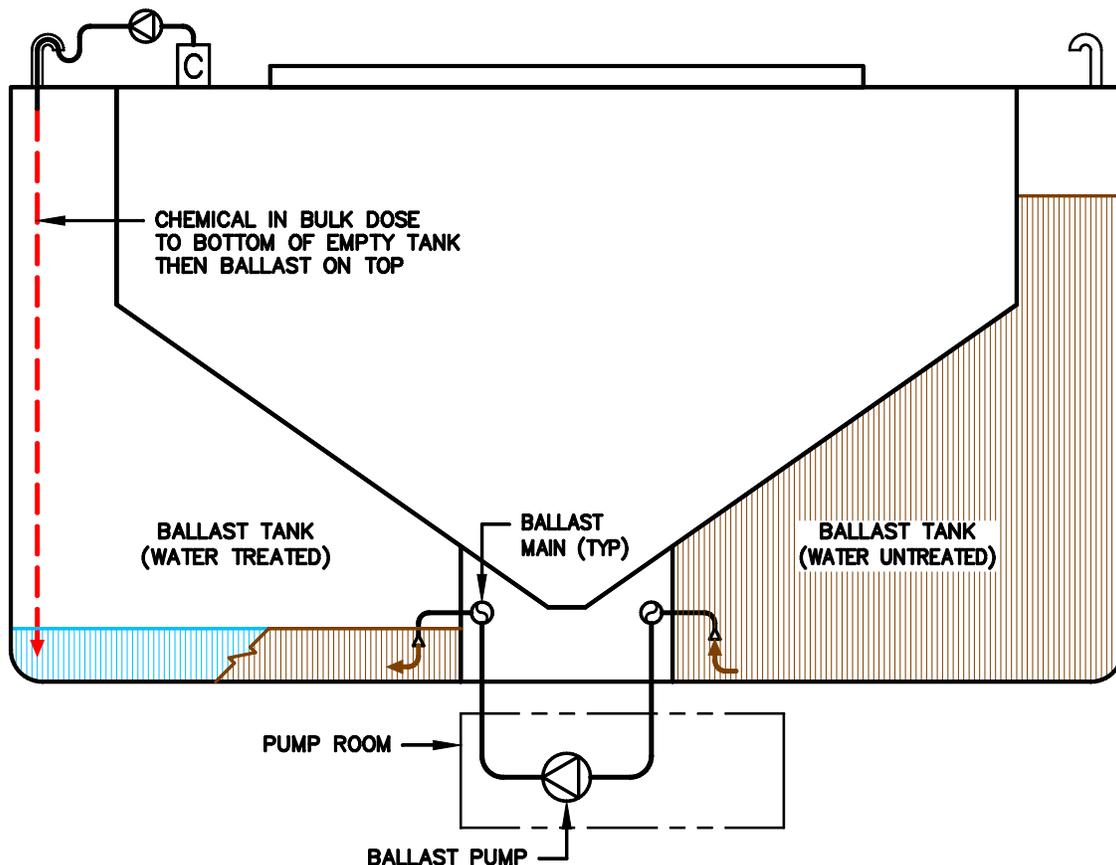
### 3.4 Method 2: Bulk-On-Bottom Dosing

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.



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.



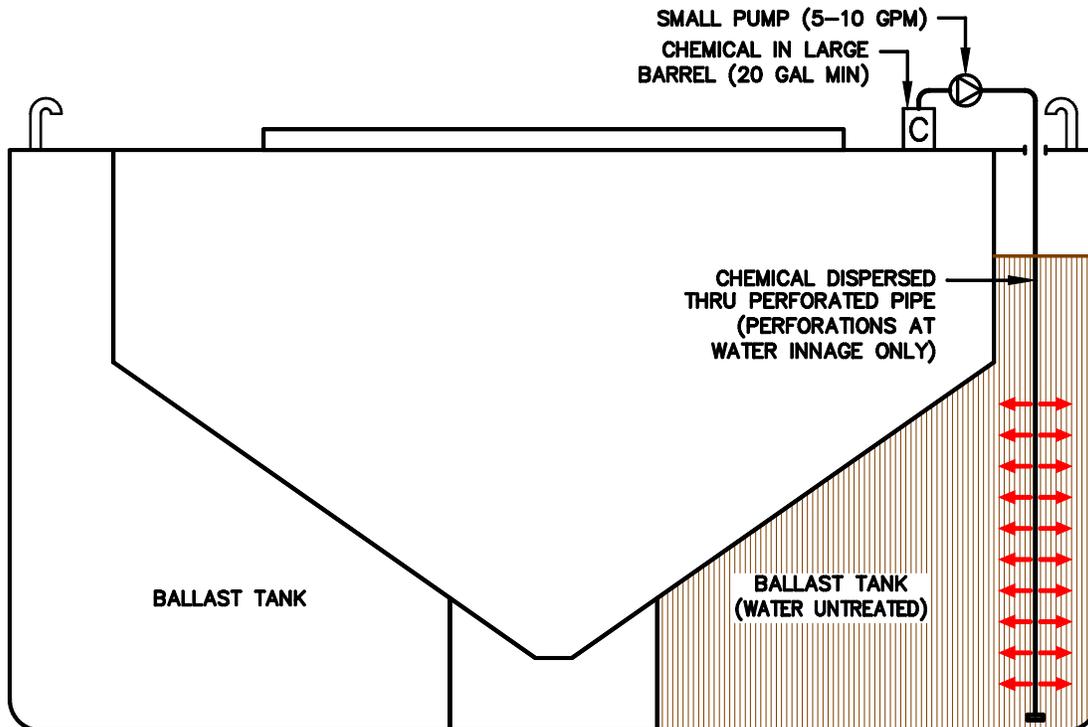
### 3.5 Method 3: Perforated Hose Dosing

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

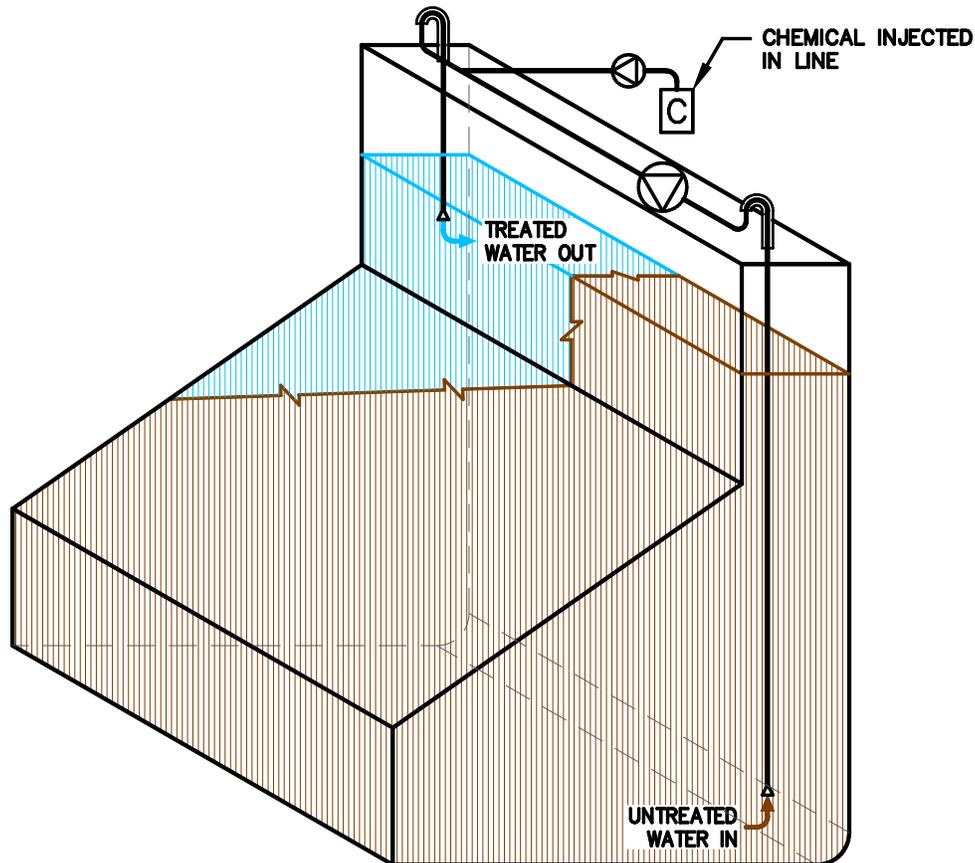


### 3.6 Method 4: Internal Transfer Dosing

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 chemical to treat tank into drum, and dilute with water.
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.

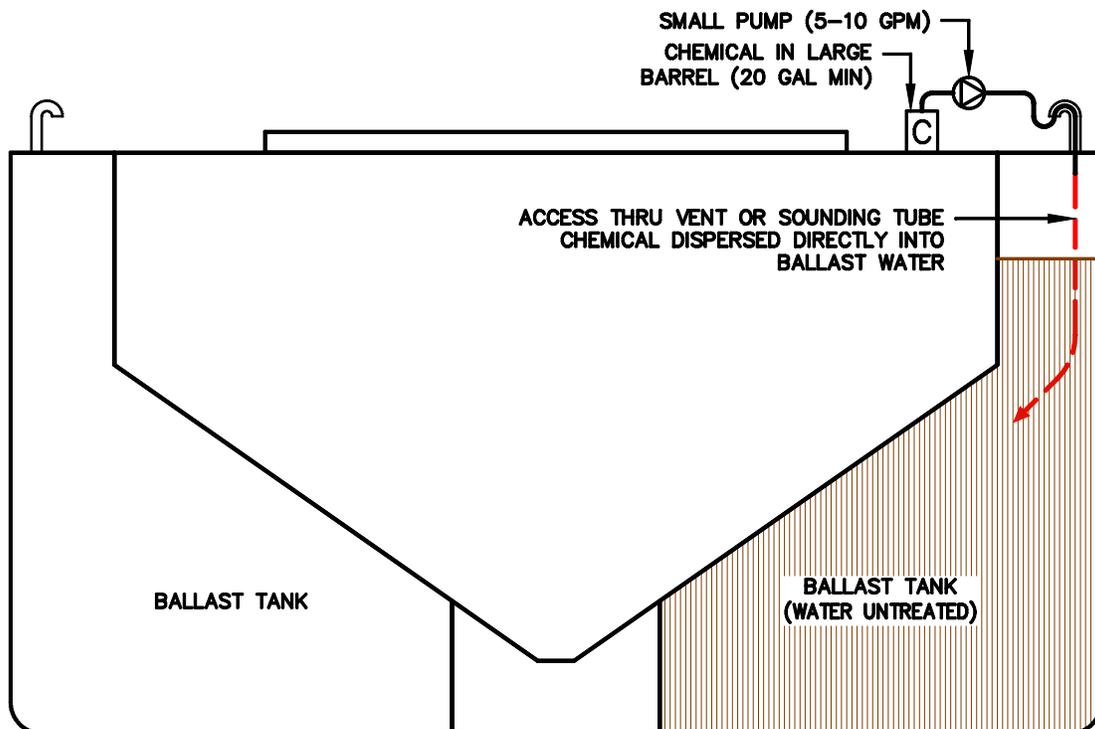


### 3.7 Method 5: Vent/Sounding Tube Dosing

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 responding to *Chlorea* 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.



## 3.8 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.

### 3.8.1 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 inch diameter, with length and fittings to suit. Rated to the greater of the ballast main pressure or small pump head.



Figure 7 - Typical Drum and Small Pump with Hoses Connected

### 3.8.2 Method Specific Equipment

- Perforated Hose (1): This supports the “Perforated Hose” Method. ~ 3/4 to 1 inch 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 inch 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).



**Figure 8 - Testing the Spray Pattern of the Perforated Hose**

- Internal Transfer Equipment: This supports the “Internal Transfer” Method.
  - 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.



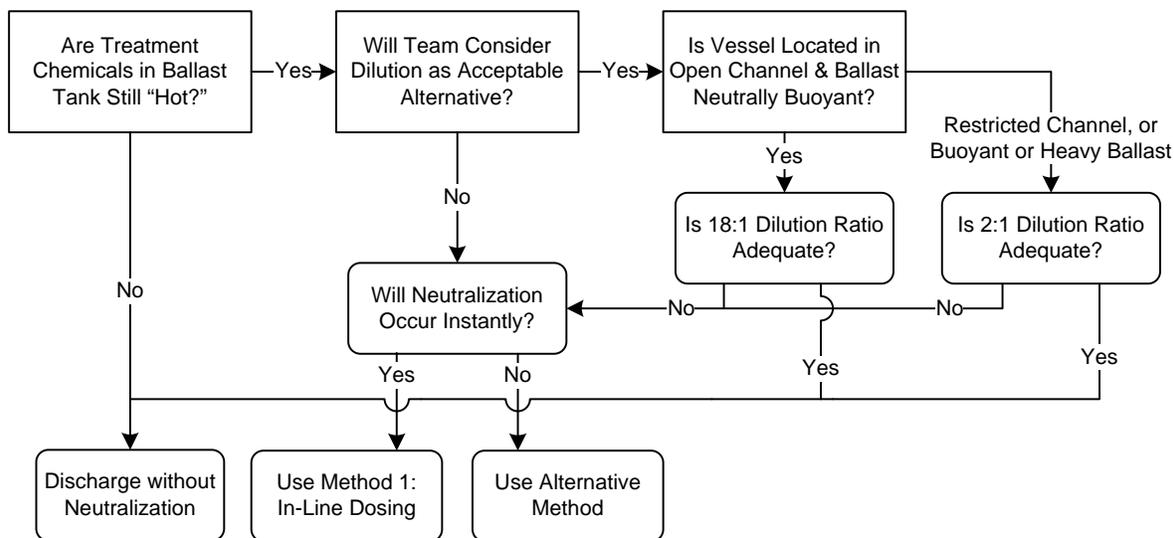
**Figure 9 - Rigging Transfer Pump and Hose on Main Deck**



**Figure 10 - Chemical Injection Manifold Tee Fitting Shown, Transfer Pump in Background**

## Section 4 Neutralization and Discharge

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



**Figure 11 - 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. The ballast tanks will actually be sterilized from one dose of chemicals. 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.

### 4.1 Chemical Analysis

The response team must analyze the chemical used to kill the harmful organisms and pathogens in relation to being able to discharge 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.

### 4.2 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 ballast volumes can 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.
  - Slack tide, and 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 feet of the discharge point to range from 2:1 in non-ideal conditions, to 18:1 in ideal conditions. The response team will need to consider the specific conditions of the planned discharge and determine a reasonable factor.

### 4.3 Neutralization Step

Certain chemicals can be neutralized almost instantly when exposed to a second chemical. Instant neutralization allows Method 1, 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<sub>3</sub>) 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, 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 time prior to discharge. The full ballast tank mixing methods (Methods 3, 4, and 5) as outlined in the Onboard Treatment section can be considered for this effort.

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## Section 5 Acknowledgements

Development of this guide was possible because of broad support from multiple sources.

- **National Parks Service.** Phyllis Green of Isle Royal identified the need for this guide, formed the project team, and provided broad coordination of multiple stakeholders.
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- **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 ship and two small crafts during the 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.**

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## Section 6 Guide Revisions

This Guide is new, 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 NIS 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 an 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, if to be an effective option, must be established with expected lead times prior to an emergency response.
- Sampling and source risk assessment processes need to be further developed.
- The guide should be developed for 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:

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## 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 the below table.

**Table 4 – 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	Adsorption	Toxic byproducts	Recalcitrance	Shipboard Application Difficult	Cost Prohibitive	Safety Concerns	Regulatory Concerns
<b>Group A Biocides</b>									
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	Unknown	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
<b>Group B Biocides</b>									
Copper	Yes	Some	Yes	No	Some	Somewhat	No	Yes	Yes
Bromine	No	Yes	Yes	Yes	Unknown	Yes	No	Yes	No
Iodine	No	Unknown	Unknown	Yes	Unknown	Somewhat	Somewhat	Yes	No
Sodium chlorite	No	Unknown	Unknown	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	Unknown	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’ Clean Water Act of 1972.
- 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.

## **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 has documented that dilution ratios formed by a plunging ballast water discharge stream exceeded 1:18 in close proximity to the vessel hull. In other cases, high volume discharges in restricted channels, the dilution ratio may only reach 3:1 in close proximity to the vessel hull.

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.

## **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 NIS 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 NIS 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.

## **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 introduction of aquatic NIS.