The Great Lakes Protection Puzzle: A request for Collaborative review of potential ballast treatment systems research and implementation strategies designed to fit maritime industry needs.

National Park Service (NPS)and US Geological Survey (USGS) researchers have partnered with American Steamship Company(ASC) a subsidiary of GATX Corporation, Great Ships Initiative (GSI), and marine engineering firms to develop new methods of providing emergency ballast treatment for stranded vessels that lack treatment systems. This collaborative research led us to discoveries that expanded the scope of our research into developing potential new methods for interim and long-term treatment of vessels that contain ballast considered to have a high risk of introducing aquatic invasive species (AIS). Enhanced protection of the Great Lakes that meets the needs of industry is a puzzle and we are missing some of the pieces. This work seeks solutions to that puzzle.

Our principle goal is to enhance protection of the Great Lakes from AIS in ballast in the short term. Additionally, we aim to find low cost implementation options for an industry with significant variation in ship ballast design, pumping rates, and capacity. To achieve those goals we suggest the use of adaptive management to identify procedures and processes for ballast treatment testing, verification, and compliance. Finding the right balance is a puzzle that we need to piece together collaboratively.

Our work with the American Steamship Company and numerous marine engineers has been enlightening, but we recognize our limited knowledge of the diversity in Great Lakes ship designs and operations. Thus, **we ask for your input on our efforts and suggested implementation strategies presented in this paper**. We present two relatively detailed implementation strategies for interim treatment. Specifically, this paper presents two case studies: Partially reestablishing the natural barrier to AIS of Niagara Falls using biocides for ships transiting the Welland canal using a portable skid mounted system (Case 1), and port-based, skid mounted treatment at ports having AIS that we do not want to spread (Case2). We end with an overview of potential long-term options based on this research and issues related to monitoring, risk assessment and compliance.

We begin with a summary of our current research efforts and findings that underpin the proposed strategies and options. Continuing maritime industry review and collaboration with this research is welcome and is critical to ensuring that our research is targeting the most practical and feasible treatment methods. Additional documents can be provided to the reader with detailed information on our research. Some of these documents are in the USGS peer-review process and should be available as a final product in June of 2011.

Current Research: Emergency Treatment

We have developed an Emergency Ballast Treatment Salvor's Guide that outlines ways to treat a ship that runs aground in a National Park or arrives in jurisdictional waters from an area that poses a risk for the transfer of invasive species. NPS emergency managers who receive notification of groundings within or near Park boundaries would use the emergency application guidebook to evaluate the need for treatment based on a case by case risk assessment and to guide emergency treatment efforts.

A critical aspect of emergency treatment is how to mix the biocides or neutralizers likely to be used. Our work to date explored the role of passive mixing for ships in transit, the role of dilution for mixing, and active mixing technologies. Current findings suggest that passive mixing based on ships motion will result in complete mixing if the transit times are long enough. Also, dilution cannot be used as a neutralization method when the temperature differential is high between the ballast tank water and the receiving water. Finally, two active mixing technologies demonstrated the ability to mix the ballast tanks of the 1000' Great Lakes ship the Indiana Harbor within timeframes that allow neutralization within normal ballasting operational timeframes. Please note that to date, data collection has been limited to one ship. Thus, though the results advance the knowledge beyond previous work, each needs to be analyzed on its own merit and individual ship treatment needs.

Our efforts have focused on the development of a biocide-based skid mounted system. If skid mounted ballast treatment systems were available as part of oil spill response equipment, emergency treatment would be greatly enhanced. The next series of tests will complete proof of concept for a skid mounted emergency treatment system.

Current Research: Biocides

The NPS and USGS researchers are developing and testing two ballast treatment systems using two different biocides. We have funding for one treatment system that uses sodium hydroxide as a biocide, and are in the process of planning for the second round of shipboard tests on a Laker. We have also begun work with researchers at Michigan Technological University to develop another treatment system that uses sodium hypochlorite as a biocide for Salties and may potentially collaborate with the U.S. Maritime Administration and Great Ships Initiative on this project. Two chemical companies are willing to support experimental use permit registration of the two biocide tests. This research will add to our knowledge of potential options towards developing cost-effective treatment systems for both Lakers and Salties. The following implementation strategies can be further refined as treatment systems and biocides are developed.

Interim Treatment

During the time until a regulatory framework is enacted and shipboard treatment is fully developed and available for all ships, we can reduce risk of AIS invasions and spread within the Great Lakes with interim options that do not require full shipboard installations. Aspects of the emergency treatment system lend themselves well to using a skid mounted system for interim treatment, especially for salt water vessels. **The advantages of this type of skid mounted treatment system could include minimal retrofitting to the vessel, increased shore based support that minimizes the vessel crew's work load, and a decrease in the requirement for scarce space onboard the vessel. Additionally, skid mounted delivery systems operating at ports are easier for regulators to observe and document data collected.**

The sodium hydroxide system for the freshwater fleet has additional challenges that would have to be overcome. For example, our current findings suggest that by installing in-line metering systems capable of handling liquid injection (or in the case of NaOH a gaseous neutralizer) with piping to the deck, a ship could interface with a skid mounted system.

We have identified two potential interim treatment methods. Both cases will present a first cut of how such options could be implemented, recognizing that this first attempt has gaps that will have to be filled in by folks more knowledgeable of shipboard operations and state, provincial and federal regulations, than the authors. These potential methods are presented as a work in progress to enhance dialog that could ultimately create more practical and effective treatment systems for Great Lakes shippers.

Any ship participating in an interim treatment program would need to evaluate various ship specific characteristics with the treatment method under consideration including: ship type and capacity, ballast water handling practices including NOBOBS (no ballast on board ships), ballast water characteristics, vessel service characteristics, ballast system and piping characteristics, power requirements, impacts on ballast tank and pipe corrosion, and health and safety (handling, operation and maintenance), and develop load data for the structural integrity of the area where a skid would be placed on the deck. Vessels may need to have access into each tank to accommodate mixing equipment currently sized for a standard ballast deck access port depending upon the interim treatment method under consideration.

In all cases, the degree of success and timelines for implementation have the potential to be adjusted if industry voluntarily implemented one or all of their various proposals ranging from: sediment control actions; the Lake Carriers GLRI proposal to install metering systems into primary ballast lines from the deck with standardized couplings on board; and a risk assessment analysis to prioritize the need for interim treatment were agreed upon. Compliance monitoring ports will also need to be installed and testing protocols developed for both verification and regulatory certification of the treatment system and further treatment efficacy compliance. Please note: none of the case studies can be implemented without fully successful shipboard trials and preliminary analysis that systems can achieve efficacy rates equal to or greater then ballast exchange. In addition, there is a need for common technology based standards.

Establish common technology standards for the Great Lakes.

While many agencies are working on the adoption of biological standards (maximum number of species per unit of water), another option for interim treatment is the use of technology standards where the installed technology must be shown to function properly. In the case of NaOH, one could test that the proper pH was obtained. All technology standards have a basis in biological standards. For example, a regulator would determine the pH standard adopted for NaOH based on biological efficacy tests conducted in labs and on shipboard trials. We suggest that a panel of experts from Canada and the US establish mandatory treatment levels for all known biocide processes based on best available science and analysis of surrogate species' toxicity rates. States that already have biological standards but lack the monitoring and compliance procedures to implement them could choose to use these technology standards as interim implementation step and help standardize the regulatory framework in the Great Lakes.

Establishing target efficacy rates above ambient demand (organic matter in water uses up biocide before it can kill the intended species) is critical. Currently, EPA registration of biocides under the

Federal Insecticide Fungicide and Rodenticide Act (FIFRA) cites the need for species specific data for registration. To test and develop efficacy rates for all known potential invaders is cost and time prohibitive, not to mention having to import the invasive species for testing in certified labs which carries an additional risk. Subject matter experts could use one of two techniques: review known efficacy data on species considered to be reasonable surrogates and establish technology standards for toxicity levels. Or follow the processes established for drinking water safety where the most difficult to kill organism is used to established Ct for all known biocodes. (The “C” value is the residual concentration after the time segment and “t” is the time segment that the water has been exposed to the biocide.) A table could be generated relating it to ambient biocide demand calculations. This would then become the technology standard for that biocide. The manufacturers of systems using the same biocides would then set the same target for efficacy dose. Discharge standards would be harmonized using similar techniques using residual toxicity rates to neutralize effects on local species by vetting discharge against sensitive local surrogate species. The manufacturers of systems using the same biocides would then use those targets to set residual dosage levels.

Currently even discharge standards vary across the basin and a manufacturer would have to have the capacity to operate to the most stringent denominator to operate in all states and provinces.

Case 1: Re-establishing an AIS barrier for ballast vector hitchhikers using biocides at the Welland Canal.

An eleven hour transit time in the Welland Canal allows for an adequate soak time for at least four IMO approved shipboard treatment processes. The problem is they are not currently installed on all ships, nor tested for freshwater. In addition, verification and compliance monitoring has not been established within the US. With industry collaboration a palletized (skid) system which treats with a biocide upon entry into the canal and then neutralizes in tank prior to leaving would eliminate ballast hitchhikers into the Great Lakes from foreign waters.

Biocide #1 - Sodium Hypochlorite (NaOCl) - Sodium hypochlorite (bleach) could be used for partial or full ballast tanks with saltwater vessels. GSI has continued to collect data relative to chlorine compounds’ efficacy during ballast treatment. NPS has secured industry support for potential FIFRA registration of sodium hypochlorite. Given limited funds for shipboard testing, we are using a case study approach and want to target a representative ship for the most common vessel. It would only take 80 gallons of standard 12.5 % NaOCl to treat 1 million gallons of ballast and meet Michigan treatment standards of 10 mg/l (this is a technology-based standard). By knowing ambient demand and soak time options, the adequate efficacy could be reached with potentially less chemical use and fewer corrosion problems. For example, the operating water of NPS' Ranger III has an ambient chlorine demand of .5 to 0.7 mg/l thus a target dose of 3 to 3. 5 mg/l with a minimum soak time of 2.5 hours, which was considered to be an effective dose by subject matter experts. For Lake Superior waters, that means only about 28 gallons would be needed for 1 million gallons to dose to this level. Ten mg/l is a shock dose that accounts for a full range of ambient demand in the Great Lakes. Michigan will be reviewing their regulations in 2012 and new data that incorporates processes for dealing with ambient demand for the chemical may help lead to more standardized regulation at lower concentrations.

Biocide #2 - Sodium Hydroxide (NaOH)*:* NaOH is an option for freshwater ships with unlined tanks and a potential option for Salties in NOBOB status. Ambient demand still has to be established via titration or in the future, computer modeling may be able to be substituted over time for demand analysis based on titration results over time. After a few runs it is expected values could be established to fine tune models. Please note that any ship that would use stack gas to neutralize would have pre-treated the diesel engine gas so that the gas used to neutralize would have been scrubbed. The feasibility of using this biocide for interim treatment needs further development and a practicality analysis after shipboard testing this summer. It may be more practical to provide this treatment via tender support versus as skid mounted support.

Shipboard pre–treatment actions for chlorine: Safety plans and chemical fact sheets are reviewed with critical staff in preparation for application team arrival on the ship and implementation of the treatment. Then 24 hours prior to entering the Welland canal from the east the appropriate crew member would conduct a test for the ambient chlorine demand of the water for the chemical by pulling sample and using a standardized test kit which is read multiple times (at most once an hour) over an 8 hour period. The ship calls in the chlorine demand figures, numbers of tanks to be treated and volumes in each tank to the treatment application team who then determine dosage levels.

Note that we need regulator agreement on treatment dosages above ambient demand for sodium hypochlorite. Presently, the water industry uses a Ct for 3-log kill (99.9%) of Giardia Lamblia cysts as guidance for determining disinfection for drinking water. The "C" value is the residual chlorine concentration after the time segment and "t" is the time segment that the water has been exposed to the chlorine. The largest Ct value for 3-log kill Giardia Lamblia is about 300 mg-min/L and can be used as guidance until more information on biocide Ct values are available for AIS .So using this as guidance, if we assume a C value 3 mg/L chlorine residual and a t value of 240 minutes (4 hr) we would have a Ct value of 730 mg-min/L which is about 2.4 times higher than the most stringent Ct drinking water requirement(Dr. Hand, 1/12/11).   For sodium hydroxide the target pH is 12, though at the beginning there may be ships dosing to pH 11.5 in order to collect comparative toxicity data. We need to start trialing systems to determine the ability to meet the highest standards.

Treatment activated: Upon arrival in the Welland canal a skid mounted treatment system with neutralization components is sling loaded onto the ship. The team has received ambient demand and tank treatment needs. Mixing equipment (submersible pumps) are inserted into tanks via access ports and trained personnel deliver the biocide. After the soak time for the biocide is accomplished, samples for interim compliance and IMO testing are collected on a variety of ships that cover the diversity of ships entering the Great Lakes. Then the tank is neutralized and samples taken to determine discharge compliance. Note: if the ship has the capacity to safely mix tanks via circulation systems the mixing technology may not need to be employed. If there is not clearance to the bottom of the tank from the access port mixing will be complicated.   Treatment crew removes all skid mounted equipment and mixers prior to leaving the canal.

Compliance development: Ideally in year one, a small number of ships that represent the range of ships passing through the Welland canal would participate. In the US the Great Ships Initiative is advancing verification work. Researchers with funding from GLRI would install sampling ports and acquire data to determine verification for IMO as a hybrid treatment system (pallet mounted with some ship technology installation to enhance treatment) and to develop the means for quick and easy compliance determinations. In year two and three, treatment capacity would be expanded to include all ships with or without treatment enhancing installs. Note: without some additional limited technology installs treatment time may be greater.

Case 2: Skid mounted treatment support established at ports.

Skid mounted treatment support could be established at ports determined to be high risk for either export or potential import of AIS. This delivery system works very similar to the Welland canal scenario, but because of the difficulty in dealing with cargo unloading time constraints, it sets up more complexity in being able to apply the biocide and neutralizers.

Suggested Biocides: Same as in case study 1- sodium hypochlorite for partial or full ballast tanks with salt water vessels, and NaOH for freshwater ships with unlined tanks and as a potential option for Salties in NOBOB status.

Pre – treatment actions shipboard: Although this process could rely on emergency treatment options developed to date for it to fill the gap until shipboard installations, to meet industry timelines for minimum time in port, ships would have to pre-install some equipment to enable treatment on the intake of ballast in this port. Then they would have to know their transit times and perhaps either carry a tote to neutralize or utilize an instantaneous neutralization process prior to discharge at the port of ballast discharge. Ideally you would have a skid mounted system in every port for either biocide application or neutralization or an option of picking up and dropping off a skid mounted system. But these details cannot be worked out without more collaboration with industry. Ships participating in this process would install in-line metering systems similar to those described in the Lake Carriers Associations GLRI application with piping to the deck for biocide application.

Treatment Activated: Upon arrival in Port, a skid mounted biocide treatment system with or without the neutralization components is sling loaded onto the ship. The treatment team has received ambient demand and tank treatment data. Mixing equipment is inserted into tanks via access ports and trained personnel deliver the biocide. After the soak time for the biocide is accomplished, samples for interim compliance and IMO testing are collected on a variety of ships that cover the diversity of ships entering the Great Lakes. Since in this case study ballast is treated in-line when it is pulled into the tank, the soak time is accomplished after the ship leaves the port. It cannot be implemented with adequate soak times on short runs unless shock doses of biocides are administered and that may not be feasible. At the start, most short runs appear to be within basins; so risk assessments on feasibility will be critical to this analysis.

The tank would be neutralized using a skid mounted system at the arrival port if an instantaneous neutralizer can be used. If the ship has the capacity to carry the neutralizer the neutralizer component could be carried out on board after the biocide soak time has been achieved. It would have to be returned to the port or dropped where it can be moved to a needed location if the transit time included both soak time and neutralization time. Samples would be taken to determine discharge compliance. Note: if the ship has the capacity to safely mix tanks via circulation systems the mixing technology may not need to be employed. Treatment crew removes all skid mounted equipment and mixers prior to leaving the port in the case of the biocide, and either sets up the neutralization system for implementation on board during transit, or a team meets the ship at the new port.

Compliance Development: Developing a system to determine treatment compliance will be more difficult as the ships will be on the move prior to completion of soak times, setting up a system to obtain samples prior to neutralization would be critical to verify that target doses have been achieved. Grab samples to document neutralization may be difficult to obtain depending on the ballast piping configuration. All these issues would need to be addressed by regulatory agencies and scientists engaged in the development of compliance testing.

Developing the capacity for Long-Term Treatment Options

Some of the treatment methods developed in this research may be adaptable into practical, cost-effective options for long-term use. Ballast treatment methods can be discussed in three general categories: on-board treatment systems, shore-based treatment systems and hybrid treatment systems that have elements of both. The following brief discussion will relate our potential treatment methods to each of the three general ballast treatment categories.

On-Board treatment

On-board treatment systems allow the vessel complete flexibility to travel to any port and adjust their ballast at will. Each type of treatment system requires varying amounts of vessel space and crew time for operation and maintenance. Sodium hypochlorite could also be used as a long-term treatment option for Salties with coated tanks, and permanent shipboard treatment would require space to install storage tanks for the biocide and a neutralization chemical. Other forms of chlorine, such as electrolytic chlorine and chlorine dioxide are also available and should be evaluated by the vessel operator to determine the best fit for their situation. But the availability of the chemicals suggests another option for ships with limited space.

NaOH is non-corrosive which makes it an attractive treatment option for vessels with uncoated tanks. An on-board system could be developed for vessels that have the space to house tanks for NaOH storage and CO_2 storage for neutralization. Further research could develop ways to use the vessels stack gases as a source for CO_2 and thus eliminate the need to store and purchase additional CO_2. An additional advantage could be a reduction in the discharge of various pollutants from the stack gas.

Shore-Based Treatment

Past attempts to create shore-based treatment have been based upon moving the ballast off the ship and treating it on-shore. Very few, if any, vessels have the capacity to discharge ballast in this way and would require extensive restoration. Shore- based supported and skid (pallet) mounted treatment systems could be applicable to vessels that trade among a set number of ports. Voyages to ports without a compatible treatment system would be restricted and in-transit ballast adjustments could be a problem. So if the timing of the treatment and neutralization cannot accommodate routine in-transit ballasting operations it may not be a treatment option, unless the ship owner can adjust for these needs. Space at many ports is scarce and finding room to store and treat large quantities of ballast have also been a limiting factor. The methods developed in our research could allow the ballast to be treated on the vessel from a relatively small shore- based supported system, thus eliminating the need for large volumes of water to be moved from the vessel.

Hybrid-Treatment System

This category of treatment would operate on the same principal as shore-based treatment only it would include some small capacity for on-board treatment that would allow for treating relatively small amounts of ballast needed for in transit ballast adjustments.

The general treatment categories discussed above are intended to provide the reader with a brief idea of possible situations. Other combinations may be feasible for different vessel requirements. Some type of shore-based treatment may reduce costs and crew time for operations while limiting some voyage options. Further discussions with specific vessel operators will be required to collaboratively determine which option best fits their requirements. The ability to take successes from case one and two will inform industry and regulators on the viability of this option. At that point a practicality review based on accurate data from participating ships, ports and agencies would be initiated.

Monitoring, Risk Assessment, and Compliance

Monitoring, risk assessment and compliance work has received significant funding from GLRI in order to create the methodology and science to support these actions. We need test platforms and coordinated support so efforts to advance treatment and accelerate AIS risk reduction by working on parallel technology development concurrently: bridging between the actions by coordinating efforts and using adaptive management. The Great Ships Initiative and Wayne State University have lead roles in verification, monitoring and compliance testing and there needs to be communication mechanisms developed for easy flow of status and knowledge of the work. Norte Dame, through David Lodge, has significant funding on risk assessment. Other government and academic researchers are certainly working on many of these issues. It is important with as many unknowns as there are in these fields to allow more than one track for success to develop. Supporting parallel tracks to solutions in monitoring, risk assessment and compliance will allow for further development and tailoring of solutions to critical needs. However, the leads from the various assessments underway should be encouraged to sit down and discuss their work and where they are headed.

Any ship that enters into working with us to help demonstrate the capability to conduct shore station skid mounted treatment should consider allowing us to coordinate data collection with these entities to enhance our capacity to stop AIS invasion via ballast. A lead agency such as EPA should consider sponsoring regular calls to facilitate communication amongst researchers or researchers should consider forming an ad hoc group with consisting of their project leaders and a least talk monthly on progress and line of inquiry they are developing.

Please take the time to respond to this white paper with your comments, questions and thoughts on how to proceed. We have included starter questions to stimulate discussion.

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Data researchers need ASAP:

Range in size of ballast tank volumes on individual ships smallest, largest.

Range in size of total volumes of ballast requiring treatment on a ship for the range of ships entering the Great Lakes. Whether there is a minimum clear path or lane on top the deck of ships such that skid mounted systems could be wheeled or moved along the deck depending on weight. What are the typical problems to overcome for a temporary pallet on the deck?

Questions the authors can't answer, and hope collaborators can suggest options?

What are Canada's discharge regulations for sodium hypochlorite and NaOH?

Are there provisions for incidental release during research testing?

What permits would be required to test?

Are there enough ship-owners interested in participating in preliminary trials or in a voluntary program if details are worked out?

Who should pay for the interim treatment? Voluntary treatment supported by government funds?? Mandated ships pay for costs?

If there are regulations that prevent the re-suspension of sediments, is there a conflict if the sediments are delayed in settling when mixing techniques are applied?

Questions collaborators can't answer, but hope researchers will address prior to moving to full implementation of case study 1?

Your thoughts here:

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