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EPA SAB Ballast Water Advisory

SAB Subgroup 2

Draft response to charge question 3:

System Development

Introduction:

This draft is divided into three sections: I) draft responses to charge question 3a, II) draft responses to the multiple queries in charge question 3.b, and III) "other" issues relevant to the broad topic of developing ballast water treatment systems

I. **Charge question 3a**: *For those systems identified in questions la and 2, are there reasonable changes or additions to their treatment processes which can be made to the systems to improve performance?*

At the July meeting, Dr. Ryan Albert (EPA) clarified charge question 3.a. to read "*system types identified in questions 1a and 2*" instead of "*those systems identified in questions 1a and 2*." This clarification allows our subgroup to focus on key processes and process combinations in general, rather than analyzing specific systems and associated mechanics. We're much more comfortable with this approach, because for very nearly all the systems listed in Table 1 in EPA's white paper, there is insufficient information to evaluate them rigorously. Given this clarification, USEPA may therefore anticipate recommendations from us such as: "UV-based systems can increase efficacy with an increase in the combination of intensity and contact time" and "reduce load (i.e., filter) from the ballast stream prior to employing an oxidant chemical." The principal disadvantage of such an approach, at least to USEPA, is that the agency will receive no recommendations concerning vendor-specific ballast-water treatment systems.

The charge would benefit by defining the words "system" and system type". In the materials we've studied, arguably none of the technologies is a "system", defined within the wastewater treatment industry as: hardware, operation and maintenance procedures (operators, standard operating procedures, control systems, etc.), and periodic operational validation.

We have been provided with the list of technology types Subgroup 1 has compiled. Some of our subgroup's members have weighed in on charge 3a in a general way and feel "tweaking" existing technologies will result only in incremental improvements. New technologies will be needed for 100X and 1000X IMO regulations. We have discussed in broad detail some changes to improve the systems' performances, but to date have not made substantive progress in specifying those changes. In section III of this report, we present a conceptual outline for

framing how technological constraints to ballast water treatment might be considered. In addition, we suggest other issues that need to be considered to address overall system performance, beyond the specific treatment technology *per se.*

II. **Charge question 3b. Part A.** *What are the principal technological constraints or other impediments to the development of ballast water treatment technologies for use onboard vessels to reliably meet any or all of the discharge standards presented in Table 1 of the White Paper and what recommendations does the SAB have for addressing these impediments/constraints?*

Constraints and impediments include:

1. Lack of system considerations—see our definition of system (above). Because ballast-water treatment technology is in the early stages of development, focus has been on the "device". Future considerations must include more consideration of maintenance, operations, monitoring, training, etc.

2. The complexity of system testing and the difficulties associated with counting live organisms combine to limit our ability to measure improvements in the technology.

3. Testing facilities are few, and there is little sharing of data and specific protocols among them.

4. There is no established compliance, monitoring, and enforcement regime, and to our knowledge, none envisioned, which will drive the development of system considerations.

With specific respect to shipboard considerations, the following is excerpted from a paper written by Glosten Associates for the NEMW Institute in 2002:

> **Meet the Demands of the Shipboard Marine Environment**
> Vibrations, accelerations, ship motions and the salt water atmosphere, are all key design parameters for any equipment placed on board a vessel. Many systems produced for shoreside use have not been designed to operate in this marine environment. Therefore, when selecting system components, service history on board ships is very helpful. Experience in other industries or applications are interesting, but are not always useful in assessing the robustness for shipboard use or its regular maintenance requirements/procedures.
>
> Also, other industries may be processing water with different characteristics (salinity, suspended solids, etc.) that may affect basic system performance. For example, filters that work well for fisheries or offshore rigs, where intakes can be carefully placed to avoid suspended solids, may not perform to ratings when

ships' ballast water is taken in the silty waters of a harbor. Flow rates, pressure drops, cleaning and maintenance requirements may be quite different.

Minimize Operational Changes to the Vessel's Existing Ballast Management Processes

Vessels are initially designed with ballasting capabilities that match their intended service and voyage profile. This includes where and when they can take ballast and the time for the ballast intake and discharge process. A treatment system should ideally fit within the current or planned ballast sequence and timing. Ballast exchange is an example of a solution that requires a complete change in ballast management operations. A treatment solution should try to avoid much of this disruption.

Fit within the Normal and Existing Operational Procedures of Shipboard Personnel

Commercial vessel crews are quite small and usually fully taxed with current operational procedures. Therefore, any new system must be easy to operate and maintain. Ideally, this means the system can be fully remotely controlled from the ballast control console and not require attendance in the engine room or pump room by an engineer. To relieve the crew of additional duties when in or near port, which is typically a busy time for shipboard personnel, its operation should be automated and not require constant monitoring or intervention. Likewise, durability and ease of maintenance is desired. Reliability must be especially considered with regard to ultimate efficacy standards – will the ship be prevented from discharging ballast if the treatment system becomes unavailable due to mechanical failure?

Minimize Initial Capital and Life Cycle Costs

The full economic impact of the treatment system, including initial purchase, installation and long-term operational costs, must be considered. The long-term costs depend on system reliability, durability, cost of spares and ease of maintenance. Designing for proper access for routine maintenance, such as filter element or bulb replacement, is essential. For some larger systems 1.5 to 2.0 m of clear space around each treatment unit may be required for access.

Meet the Existing Safety Standards of the Industry, Regulatory Bodies and the Target Vessel Operating Company

Most importantly, the treatment system or method should not pose any unreasonable health risk for the crew. It should also not create a higher risk for vessel safety nor require exceptions to the vessel owner's safety procedures. The equipment installation and operation procedures must also meet Classification

Society, Flag State, and Port State control authorities' requirements. This may include special pressure vessel or hazardous space design guidelines.

Charge question 3 b. Part B. *Are these impediments more significant for certain size classes or types of organisms (e.g., zooplankton versus viruses)?*

Can currently available treatment processes reliably achieve sterilization (no living organisms or viable viruses) of ballast water onboard vessels or, at a minimum, achieve zero or near zero discharge for certain organism size classes or types?

If ballast water were sterile, it would be "free from living organisms and viruses" (Madigan and Martinko, 2006). Given the volumes of water involved, our subgroup maintains that on-board sterilization of ballast water is not possible. There simply isn't enough energy on a ship to implement steam autoclaving. Further, as a practical matter, the assurance of sterilization is impossible to verify if the methodology for collecting organisms and assessing their viability is variable or uncertain.

We do consider, however, that existing system types, or combinations of system types, are capable of removing (e.g., filtration) or killing (e.g., biocides) all or nearly all organisms >50 micrometers in shortest dimension. Indeed, the near-term, pragmatic approach will be to focus on eliminating the larger organisms in ballast water, then to assess the extent to which viable, smaller ones survive the treatment and direct reasonable resources to reduce their numbers.

If not sterilization, then is it possible to achieve zero or near zero discharge for certain organism size classes or types? In the full Committee's discussion of "zero discharge", USEPA (Ryan Albert) indicated the goal was not "zero", but "no detectable organisms". Our sub-group unanimously concurs with USEPA's clarification about its goal regarding "zero discharge". Such a value is not measureable in a scientifically defensible way and instead represents a social preference. For example, no one in fields of toxicology or waste-water treatment, fields represented by members of our sub-group, seeks such a goal; it is an unreasonable requirement in those cases as well as for ballast-water treatment.

The Subgroup notes, however, that the suggested alternative, "no detectable organisms", is unspecific and fraught with a different set of problems. The value of "undetectable" will depend upon the number of samples, the error of false positives and negatives, and technical capabilities and financial resources available for measurement. Furthermore, while "no detectable" may be possible in a careful test facility testing at full scale, it may never be possible at "end of pipe" for a working ship. The water in the tank might be "clean", but it will be pushed through piping which will not be. Particularly with non-biocide units, there will always be

pipe dead ends, crosses, etc., where organisms can find refuge, then emerge and be found during testing.

III. "Other" issues relevant to ballast water treatment

From the outset, our subgroup has taken a holistic approach to our specific charge. In addition to our thoughts above, we have also considered:

- A Issues of water and sediment management to reduce aquatic invasions
- B Issues associated with on-shore treatment of ballast water
- C Using resistant life stages of organisms to test the effectiveness of treatment processes
- D The anticipated discontinuance of requirements for mid-ocean exchange

We understand from the Committee Chair that issues A and B, at least, have been considered in greater detail by Subgroup 3. We look forward to reading those thoughts and will contribute to them as we can. We anticipate developing the issues C and D as this report progresses.

In addition, we have had very preliminary discussions about a conceptual outline for framing discussions about developing systems for treating ballast water. The conceptual structure is:

I. Ballast-water treatment technologies in the context of risk assessment – need better specification of goals and context, including the limits of practical applications to ships

II. On-shore treatment as an idealized "upper bound" on ballast water treatment technology effectiveness to help identify potential improvements and impediments.

III. Next generation ship design: big changes are needed to meet 100 x IMO or better.

The following is a preliminary elaboration of these points.

I. Ballast water treatment technology in the context of risk assessment:

A. Establishment of an invasive or an emergent disease.

The establishment of an invasive or an emergent disease is the joint probability and how often the invasive would be introduced, an initial population size to ensure reproduction and the

probability that it would find a suitable environment for propagation. This joint probability is low for any one species or likely shipping event. However, a large number of species can be transported via ship and thousands of ships arrive at U. S. Ports making the probability of an invasive or a new pathogen becoming established a substantial probability. Given that shipping is a major industrial activity and that it will continue indefinitely, even a small probability for each ship and for each species, will result in successful invasions. The goal of a BWT program is to lower that probability, especially for especially damaging species and pathogens. In order for a BWT to be successful the goals need to be specific and measureable and the operational context of the port need to be understood.

B. Ballast water treatment goals and the decision making, risk assessment context

In order to evaluate the various types of BWT it is important to understand how this fits into a decision making context. This means that the management goal has to be clearly defined. Additionally, the effectiveness of the treatment of the ballast water has to be evaluated within the context of a ship with cargo, human food and waste, and a number of organisms attached to the hull. There is also the possibility of human error in the treatment process that may lead to the escape of organisms or the release of toxic materials. Each of these items will be covered in the paragraphs below.

C. Operational definitions and defining criteria, goals, and context.

What does zero discharge mean as a goal since such a value is essentially not measureable. The volumes to be sampled are enormous, there are refugia from treatment within the ballast water tanks, and the discharge is into an environment with multiple sources of invasive species. There are operational definitions that may prove more useful in making a decision about ballast water treatment options.

1. Defining criteria: Does zero mean that a discharge from a specific ship will not have any organisms that will colonize or infect a port environment for that one particular disinfection treatment and ship discharge? This is a very specific criterion but it is not necessarily protective. Measuring the effectiveness of each discharge event requires monitoring of the performance of the treatment and sampling of the discharge. Zero could also mean that the treatment technology or system will prevent the introduction of an invasive organism or disease to that port over a ten-year period? This is a very different criterion. In the second instance this is a performance-based requirement that gives the stated goal (no invasion or infection) over a specified time-frame. Individual treatments on certain ships may fail but an overall system would ensure that invasives are eradicated early in a colonization event or that other methods would prevent propagation. These two goals are very different and would put the on-board or land based treatment options into specific contexts. In order to rank the various technologies and treatment systems the specific goals of the program need to be carefully defined.

2. Defining goals. There is also the question about specific goals for the protection of the port from pest invasives and pathogens. Are there going to be specific requirements for each category of organism or is a combination approach to be attempted. In ballast water a large proportion of the organisms are likely to not be pathogenic, but the human welfare implications may be (but not necessarily) be higher for the pathogenic organisms. Is the goal protection against human pathogens or those pathogens that may infect shellfish and fish populations, destroy important sea grass beds, or other segments of the ecological structure of the receiving port?

3. Defining context of a cargo or tanker ship and the port facility. As the specifications for the treatment process are made it is also important to understand the context of a ship and its port facility. Ballast water would only be one of the potential sources of invasives and pathogens brought by ship.

The ship has more that ballast water as a source of invasive species. Ships contain cargos of varied types, crew, food, human waste, and hull foiling organisms. The port facility may also have a variety of other ships using the facility that may be sources of invasives and pathogens. In understanding the efficacy of the treatment program needs to be placed into this broader context.

Cargo, food, human waste, and attached sea life will be accompanying ship and can be additional sources of invasives and pathogens. Cargo may contain insects, fungi, seeds and spores that may be released to the environment as the cargo is unloaded or transported. Food can be another source of materials if organisms are being transported. Human waste can be a source of pathogens, but can be disposed of using appropriate facilities. Fouling of the hull of the ship can be a source of invasives depending or pathogens depending upon the origin of the ship, route and time of transit, and the effectiveness of the anti-fouling paint and the overall condition of the hull.

A confounding factor is that a number of other vessels will be using the same facilities and are sources of invasion. Fishing fleets and pleasure craft often take very long voyages and may be sources of invasives. These vessels also exist in different regulatory environments that may be more permissive in the transport of invasives. Although not directly affecting the infection potential of any single ship, these vessels can be confounding variables in the identification of the effectiveness of treatment or the identification of source.

4. Potential environmental impacts of decontamination. It will be important to assess the potential impacts of decontamination and the effluent upon the environment. Does disinfection for pathogens increase the risk o the environment from the treatment? The number of ships that use a port may also contribute to the trade-off. Decontamination activities that release an effluent with some residual toxicity may not pose an important risk to a facility that has a low volume, but may be important in a busier port. Some ports are very specialized. Port Valdez AK specializes in the shipping of crude oil and some oil product. Cherry Point WA is a port that

currently receives crude from a limited number of sites to the refineries and bauxite for the smelter. Other facilities such as New Orleans or Seattle-Tacoma receive a variety of container ships and cargoes from across the world.

5. Shipboard operations. Shipboard emergencies, accidents and equipment failure should be considered in the risk analysis and decision making process. Weather conditions or shipboard emergencies may preclude the operation of ship-board treatment facilities. Operator error or equipment failure in the operation of the process may happen on ship-board or on-shore facilities just as it does in waste-treatment facilities. In parts of the United States hurricanes and northeasters can create damage to ships and on-shore equipment. No matter the type of treatment weather, accidents and equipment failure will occur and will introduce invasives to a port facility. Maximizing reliability of the process should be an important part of the risk analysis process.

6. BWT in an overall management program. Large-scale establishment of species from what appear to be multiple invasions have occurred. Kolar and Lodge (2001, 2002, Kolar 2004) have demonstrated that the Great Lakes are examples in which populations of European fish have been established from multiple invasion events. European Green Crab were established in San Francisco in the late 1980s and have spread north along the west coast (Behrens and Hunt 2000). Invasions take time, often decades, are often due to multiple releases, and are difficult to control once established. A BWT management strategy to decrease the rate of successful invasions should be part of an overall plan for the reduction of invasion events, monitoring, containment and eradication. Emphasis only on one aspect, the intial invasion event, is not likely to reduce the risk of invasives to an acceptable probability.

III. On-shore treatment as an idealized "upper bound" on ballast water treatment technology effectiveness.

This section presents a brief description of design parameters for an on-shore ballast water treatment system.

A. Design Basis Assumptions

1) Salt water system treated for direct discharge
2) Treatment of 20,000 m^3/d with capacity to accept 10,000 m^3 in ballast water in a single "batch" (vessel).
3) Influent key parameters (aside from biota)
   - 10 mg/L total organic carbon
   - 25 mg/L total suspended solids
   - assume ammonia levels are acceptable for discharge

B. Process Sequence

Based on these assumptions, the conclusion is that biological treatment (for organic removal) is not required. So the key unit operations in sequence are as follows:

- equalization (holding)
- plain sedimentation (solids and some TOC)
- granular media filtration (for solids removal and some TOC removal)
- UV disinfection (for inactivation of remaining biologicals)

From the above, the design basis flow is 20,000 cubic meters per day (5.3 million gallons/day) (MGD)

C. Calculations of Areas

Equalization: 20,000 m^3 tank; let this be 10 m high liquid level, therefore area = 2000 m^2 or 0.5 acres

Plain Sedimentation: Use conservative loading rate of 500 gpd/ft^2 = 10,600 ft^2 or 0.24 acres

Granular Media Filtration: Use conservative loading rate of 3 gpm/ft^2 = 1227 ft^2 or 0.03 acres

UV Disinfection: Use Siemens V-48E-A300 unit. Use 3x mfr requirement for municipal wastewater (more knowledge needed about UV transmittances of the treated ballast water). Each unit can handle 4 MGD of wastewater, so we'll need 4 units. Each unit requires a channel area of 30 inches * 50 inches(~1 ft^2) Allowing for ancillary equipment, spaces between processes, and tankage, we'll figure an area per unit of 2 ft^2, therefore the total area needed is 8 ft^2 or 0.0002 acres.

D. Total Area Estimate:

From the above a total area for the processes required is 0.8 acres. Even allowing a factor of 3 for buildings, pumps, maintenance storage, labs, etc., clearly a footprint of 3 acres would be more than sufficient.

E. Other Issues:

1) This does not include facilities for treatment of sludge from sedimentation or backwash. If this is located near sewer lines, the backwash could be discharged to a sewer. More thought needs to be done with respect to the nature of the sludge and whether it could be suited for direct landilling or perhaps trucking to a sewage treatment plant.

2) Sand filters are likely to give good performance at removing the phyto and zoo plankters, but we might discuss the need for a supplemental membrane system particularly for the more stringent criteria.

III. Next generation ship design: This section is yet to be developed by the Subgroup, but would draw upon the idealized system to consider how closely new ship designs could approximate the "ideal" system.