

On the 10th birthday of a convention not yet in force obstacles for implementing BWM Convention

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Abstract

In 2014, the International Maritime Organization (IMO) chose "IMO Conventions: Effective Implementation" as the World Maritime Day theme in order to deal with obstacles and problems related to effective and appropriate implementation and enforcement of conventions and regulations approved and entered into force so far. The International Convention for the Control and Management of Ships' Ballast Water and Sediments was approved in 2004, as a result of a suitable performance and a strong background with a number of global projects, support from international environmental organizations, and the enthusiasm of some countries representing their respective continents for the dual aim of protecting the marine environment and human health against dangers resulting from transfer of harmful and pathogenic aquatic organisms through ballast water. After 10 years, and ratification of 43 countries, however, this convention has not reached the required tonnage to enter into force, since developed industrial countries with high tonnage of shipping have shown no interest in ratifying the convention due to obstacles in correct and proper implementation or the challenging nature of the provisions themselves! Threats of invasive species for biodiversity and communities have been widely recognized at the global level. According to Article 8 of the Convention on Biological Diversity (CBD), Parties shall take measures to prevent, control and eliminate transfer of invasive species that threaten indigenous species, habitats and ecosystems. Other legal frameworks dealing with this issue are International Plant Protection Convention (IPPC), Ballast Water Management Convention, ICAO Resolution on Aerial Transfer of Invasive Species, and Transfer of Invasive Species under Convention on International Trade in Endangered Species of Wild Flora and Fauna. The main challenge here would relate to gaps in the chain for successful implementation of the convention requirements. This paper deals with major issues blunting the interest of countries for ratifying and implementing this convention.

Keywords: Ballast Water Management Convention, Effective Implementation, BWM Requirements

Introduction

Invasive aquatic species are one of the most serious threats to biodiversity and human health that has incited researchers to action in order to prevent loss of biodiversity in different areas. Such transfer of non-indigenous species destroys local and regional flora and fauna, disrupts human health and hygiene, marine environment, and causes socio-economic damages.

According to Article 8 of the Convention on Biological Diversity (CBD), the Parties shall take measures to prevent, control and eliminate the transfer of invasive species that threaten indigenous species, habitats and ecosystems [1]. The International Convention for the Control and Management of Ships' Ballast Water and Sediments was approved by the International Maritime Organization (IMO) in the year 2004, and Parties undertake to implement and enforce its provisions on all vessels that carry ballast water [2]. However, this does not mean that all the species present in the ballast water are transferred into the new environment. Most of these non-indigenous species are unable to survive, and one cannot readily label them as invasive unless their transfer and establishment in the new environment has been internationally recognized and proven.

Despite being ratified by 43 countries, this convention has not yet reached the quota of 35 percent in terms of global tonnage in order to enter into force. Industrial and developed countries, as well as those with large shipping fleets show no particular interest in ratifying the convention, the reason for which could be the obstacles for proper and suitable implementation of the convention or the challenging nature of the requirements themselves.

Invasive Aquatic Species

Through years, aquatic species have freely spread to different areas by oceanic currents, forces of nature, winds, clinging to floating items and so on, and have only been challenged by biological and environmental factors such as differing water temperature and salinity, as well as natural predators. Today, ballast water on ships has been accounted for the transfer of 7 to 10 thousand various types of marine animals, plants and microbes around the world. These invaders are one of the four serious threats to the oceans, with the other three being land-based marine pollution, excessive use of marine biological resources and destruction of marine habitats.

Ships are designed and built to navigate waters and transfer cargos such as oil, minerals, containers, etc, and therefore need to take up ballast water for a safe and efficient operation, whether totally unloaded, or partially loaded and moving towards the next port. This means the ship needs to be sufficiently submerged for the propeller and rudder to function properly, the bow does not surface and the hull receives no undue pressure, which is especially vital in stormy weather and high seas.

Ballast water is technically defined as the water (and the items suspended therein) taken up in order to control and balance the differing drafts of bow, stern and sides, as well as the relevant pressures. Ballast water is taken on board using ballast pumps and ducts located astern and on the sides of the ship, which include meshes to prevent large objects from entering the ballast tank. In the past ancient ships used solid ballast, such as rocks, timber or sand, which was substituted in the 1880s by ballast water. However, ancient seafarers were unaware how safe and harmless their ballast had been for marine environment and human health, and what troubles did the transition to ballast water caused for the seas and aquatic species [2].

The problem starts with the fact that thousands of aquatics species (or anything else small enough to be taken up by the pumps) can be transferred by ballast water, including zooplanktons, crustaceans, bacteria, microbes, cysts and even larvae. Not all these, however, survive the unfavorable conditions and lack of light and food in the tanks, and only those potentially capable of settling in the new environment(s) remain.

Another problem is the sediment layer at the bottom of the ballast tanks that becomes an environment for survival of aquatic species. This layer is composed of items taken up with the water and deposit later at the bottom of the tank, becoming a haven for the travelling species or a means for their discharge. A bigger problem occurs when the non-indigenous species transferred are capable of biological and ecological adaptation to the new environment, whether at the larval or mature stages. These species survive and spread in the absence of natural predators and bring about destructive consequences to the host environment, its native species and human health.

A non-indigenous species will potentially survive in the new environment if it:

- is a powerful species in its own ecosystem;
- is highly resistant to physical factors, such as temperature and salinity;
- has a wide and diverse food range;
- has a long mating season and/or high reproduction rate and/or a rapid herbal growth;
- grows faster than local species;
- can produce resting stages, such as cysts, dormant cells or spores;
- breeds bisexually;
- can cross-breed with local species and cause genetic changes;

- can host diseases or parasites transferrable to plants, animals and humans;
- can threaten survival or spread of local species as a rival or predator; or
- can have adverse impacts on human health, welfare and economic activities [3].

With the increased commercial transactions today, more shipping occurs and more species are also transferred across geographical borders. That is while in the past, certain species were intentionally transferred to serve special purposes of fish farming, agriculture and husbandry, such as corn, tomato, certain types of fish, and so on that were economically and recreationally justified (Figure 1).

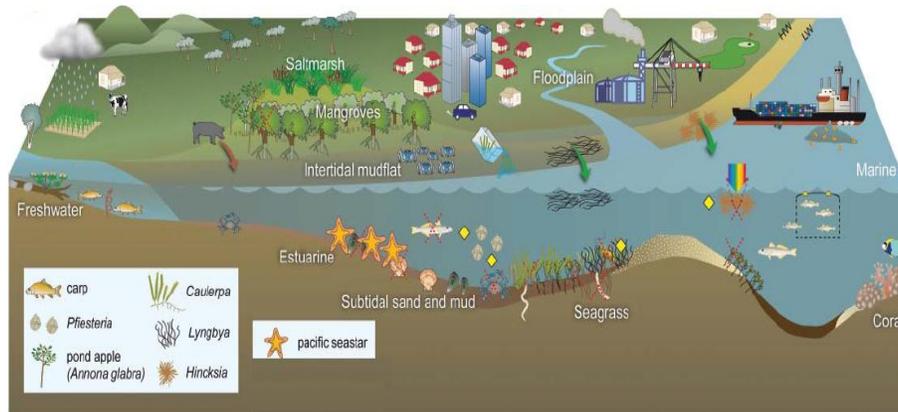


Figure 1: Species spreading through ballast water, escaping aquarium and fish farms

Unintentional transfer of species disrupts ecosystems not only at sea, but also on land, such as the following instances:

- Gray squirrels replacing native red squirrels in Italy and England (2001-2006);
- Excessive population of zebra mussels in Europe, inflicting some 2 million Euros of damage only in Spain (2001-2004);
- Fresh water crayfish transferred from northern America to Europe, which replaced the indigenous crayfish and bore a fungus (*Aphanomyces astaci*) and the disease *Crayfish Plague* there;
- Asian marine algae transferred to Europe and disrupting marine habitats, reducing seaweeds and the Mediterranean seabed hills (2003-now); and
- Water Pennywort transferred from northern America to western Germany, Netherlands and England, covering the sea surface, killing aquatic species and also disturbing navigation (1990-1994) [4].

By definition, an invasive aquatic species is one transferred from its natural habitat by accidental or intentional human activities and spread in a new environment [2].

Population immigration, cargo transport growth, changing meteorological conditions and pollution from marine and land sources increase the risk of such a transfer.

Environmental Impacts of Invasive Species

Among the negative impacts of invasive species on indigenous biodiversity of the host ecosystems, one could mention the following:

- Competition with indigenous organisms and species over food and habitat, such as the *Mnemiopsis leidyi* in the Caspian Sea, which rapidly put in danger of elimination the Caspian Sea sprat food reserves of the regional seals, as well as the livelihood of local fishers;
- Spread of parasite and intestinal diseases in countries with lower hygiene levels, such as cases of cholera;
- Causing extinction of native species, e.g. displacement of native species is known for the invasive multicolored Asian ladybeetle (by intra-guild predation) and the Argentine ant (superior competitiveness); and
- Transferring pathogenic parasites and fungi, such as the rainbow trout that can transfer Giardia parasite
- Hunting the native species, such as the American Mink (*Mustela vison*) transferred in ship holds to Scandinavia and Baltic Sea that hunts birds, fish and small aquatic species;
- Mingling with indigenous species and breeding potentially problematic new species;
- Disrupting the ecosystem food chain, such as entry of new herbal species that compete with native plants in consuming nutrient materials, but are not consumable by the herbivorous species of the host area and destroy the food chain sequence.
- Changing the characteristics of ecosystem by altering seabed texture, and digging or obstructing canal, which could further affect natural parameters such as light, wind and currents; and
- Jeopardizing health through skin diseases, such as a type of *Heracleum mantegazzianum* that can cause severe allergy or even blindness [4].

Socio-economic Impacts of Invasive Species

Invasive species can jeopardize human health, destroy animals and plants, deform coasts and sceneries, produce toxic fumes and unpleasant smell, damage tourist and recreational resources and inflict huge costs. Preventing, controlling and removing invasive species requires extensive and continued funding and the earlier action would mean lower costs.

- The costs of preventing, controlling and/or eradicating IAS and the environmental and economic damages are significant. The annual economic losses caused by introduced pests to crops, pastures, and forests in the United States, United Kingdom, Australia, South Africa, India, and Brazil amount to nearly US\$ 230 billion. The annual environmental loss caused by introduced pests in the same countries were calculated at over \$100 billion. The calculated cost per capita for the losses incurred due to biological invaders in the six nations investigated were approximately \$240 per year. Assuming similar costs worldwide, damage from invasive species would be more than \$1.4 trillion per year, representing nearly 5% of the world economy (2001);
- The *Mnemiopsis leidyi* invasion in Black Sea caused 17 million US Dollars damage to the anchovies in 2001;
- The *Fallopia japonica* spread rapidly to internal waters of Germany and caused 32 million Euros damage, while *Heracleum mantegazzianum* and Muskart (*Ondatra zibethicus*) damaged around 12 million Euros;
- The introduction of the salmon parasite *Gyrodactylus salaricus* to more than 46 rivers and 37 aquaculture facilities in Norway has decreased the density of salmon by 86% in infected rivers. Losses of income and opportunities for recreational fishing due to *Gyrodactylus salaricus* have been calculated to about 20 million Euros; and
- A surge of insects and the resulting diseases destroyed trees and forests along the coasts of Norway and Netherlands, and significantly reduced their economic and tourism value [4].

Higher biodiversity means more economic, social and recreational assets for the present and coming generations, therefore all efforts need to be concentrated on preventing or minimizing loss or damage to the ecosystem.

Taking international measures to prevent future disasters

The threat of invasive species to biodiversity and societies has been recognized at the global level. According to Article 8 of the Convention on Biological Diversity (CBD), the Parties shall take measures to prevent, control and eliminate the transfer of invasive species that threaten indigenous species, habitats and ecosystems.

Other legal frameworks active in this purpose are:

- The International Plant Protection Convention (IPPC),
- The ICAO resolution on aerial transfer of invasive species,
- The resolution on transfer of invasive species under the Convention on International Trade in Endangered Species of Wild Flora and Fauna (CITES), and
- The International Convention on Management of Ballast Water and Sediments from Ships [1].

Although some countries possess legislations to counter the transfer of non-indigenous species, few countries follow a nationally integrated framework for that purpose, while other are either preparing their legislations, or believe firmly in precise implementation of biodiversity requirements. Therefore, the first challenge would be establishing a legal system to define violation and mandate prosecution of violators.

There is no uniform system to control invasive species either, which can be related to a few missing links in the ballast water management process. These links need to be located and analyzed, such as a uniform strategy, legal regime, financial mechanisms, field studies, quick response and data exchange systems, active participation of industries and beneficiaries, etc, in an attempt towards successful management and sustainable development.

Obstacles for Implementing BWM Requirements

Preparing an efficient and comprehensive strategy

An efficient strategy with a defined framework needs to be prepared, considering the following:

- Considering intentional and accidental transfer of non-indigenous and dangerous species;
- Defining suitable response methods in order to prevent, control or eliminate invasion;
- Establishing an alerting system to identify invasive species quickly and exchange information and real data;
- Establishing an aerial and surface monitoring system, capable of being activated by normal people, as well;
- Establishing a financial mechanism for cases requiring response measures, including prevention, control or elimination;
- Interacting and cooperating with national and regional relevant bodies; and
- Promoting public awareness and interest in the related fields in order to facilitate cooperation [2].

An effective strategy should cover the potentially vulnerable areas in a manner that does not conflict with other national and international requirements, and include a number of executive measures in response to risk or threat of invasion using suitable methods and equipment. In some cases, adoption of the proper methodology requires conferring with other interested parties, especially for control or elimination by costly and time-consuming methods that need middle- to long-term planning.

The measures required within a strategy can be divided into 5 categories:

- Response measures, including prevention, control and monitoring;
- Cooperation and coordination
- Joint measures
- Information exchange and quick alerting systems
- Public participation

Executive measures to respond to invasions

A strategy needs to include a number of measures to respond to and combat the entry of invasive aquatic species, such as:

- Prevention: the most suitable and economical method to prevent settling and spreading of invasive species;
- Quick elimination: If identified at earlier stages, the invasive species could be eliminated and prevent the spread and infliction of extensive resulting costs;
- Long-term monitoring and elimination: If the invasive species could not be eliminated immediately, its population needs to be monitored to prevent its spreading. This would certainly require long-term planning and extensive costs [3].

Prevention

For a comprehensive management, preventive measures could prove effective if the risk potential is correctly and promptly identified. A common method is listing invasive species according to their risk and potential damage. These invasive species need to be categorized in order to define further measures as needed. Such categorization would follow assessment methods for risks and potential damage, such as:

Black list prohibited species with defined risks and potential damages, usually identified and announced by wildlife research centers;

White list species with low risk, or no record of damage

Gray list species with undefined risk level, whose original habitat is not identified, and need further risk assessment and precautionary measures in order to determine which of the lists to transfer them to [3].

These surveys need to be conducted by scientific institutes and research centers, and the more numerous and precisely analyzed data would yield better and more flexible lists that can assist authorities in choosing proper response actions. Preventive measures should cover accidental or intentional transfer, and preferably focus on possible entry points of invasive species, such as ports, and cargo transfer border, as well as fishing and recreational coasts.

Prevention measures for species intentionally transferred including:

- Species transferred for research or economic reasons, which have the potential for becoming invasive;
- Species transferred to combat another invasive species;
- Supervising trades of endangered animal and herbal species, which may lead to invasion and transfer of invasive species [3].

Prevention measures for species accidentally transferred, including:

- Defining the trajectory of species, including shipping routes, tourist and recreational activities, transport, etc.
- Accidental transfer through ballast water of ships, fishing, aquaculture, bio-fouling, fishing equipment, etc.
- Informing the public and having volunteer groups for research and monitoring activities;
- Preparing and identifying practical and efficient methods for implementing legal requirements; and
- Establishing information exchange and quick alerting systems [3].

Long-Term Control and Elimination

In England, for instance, eliminating the Japanese Fallopian Ivy in 2003 cost around 1.5 billion pounds, and Wales alone spent 53 million pounds to eliminate that within 3 years. If the same project had been conducted in 2007, the cost would have amounted to around 76 million pounds (Table 1).

Moreover, the IUCN Gland Institute studied the advantages of response measures against invasive species in the United States in 2001, and calculated the benefits as a fraction of the costs dedicated for such measures eq.(1).

$$I = \frac{\Sigma \text{benefits}}{\Sigma \text{cost}} \quad (1)$$

Table 1: Benefit/cost rate of US response measures against invasive species

BENEFIT - COST RATIOS FOR MANAGING IAS IN THE USA (\$US IN MILLIONS)			
Invasive alien species	Benefits of control/ prevention/eradication	Cost (US\$)	Ratio Benefit - cost
Melaleuca	183.0	16.0	11.4/1
Water hyacinth	3.8	.28	13.6/1
Sea lamprey	296.0	9.8	30/1
Alfalfa blotch leafminer	17.0	2.0	8.5/1
Purple loosestrife	53.0	2.0	26.5/1
Mediterranean fruitfly	1,829.0	93.0	19.6/1
Foot and mouth disease	25,275.0	1013.0	25/1
Siberian log imports	64,704.0	39.0	1659/1

Considering ship particulars and characteristics of on-board ballast water management systems

A large volume of global trade today is conducted by the sea, and when the ship itself plays a central role in returning the capital, any changes in its structure, design or performance – whether for environmental or economic

purposes – would no doubt call to mind cost/benefit equations and the question of "How much will it cost?". Installing, operating and maintaining ballast water treatment systems on board ships would entail huge costs, mostly due to the fact that the ship type is often the single most important factor for choosing the appropriate treatment system.

Such classifications would be based on differences in total ballast water capacity, amount of discharge in a port and the ballast water flow rate. A vast range of capacity and pumping rate is common among commercial vessels, and thus issues such as ship type and capacity, ballast water operations, the voyage particulars, treatment method, pressure falling in the treatment system and the required power; need to be fully elaborated on [5]

Ship Type and Capacity

In most instances, the ship type will be the largest single determinant in selecting a suitable treatment system. For this purpose it is convenient to consider two groups of ship types: high ballast dependent ships such as tankers and bulkers; and low ballast dependent ships such as containerships, general cargo ships, and cruise ships (table2). These groupings are based on differences in total ballast capacity, amount of discharge at any one port and ballast flow rates. There is a wide range of ballast capacities and pumping rates common to the commercial ship sector. Notably, the high ballast-dependent vessels regularly sail in ballast only conditions (without cargo). Their pump rates are designed to allow full load or discharge in a fixed period of time to facilitate rapid port turnaround times. The low ballast dependent vessels generally have smaller ballast capacities and also may rarely undertake a ballast only voyage. Their pumps do not typically have to handle a full load of ballast on a regular basis. Movement of ballast is more limited and often is a shift (one tank to another to adjust trim or heel) rather than a simple full ballast load/discharge operation [5].

Table 2: Ballast Water Capacity and Pump Rate by Ship Type

Vessel Category	Vessel Type	Representative Ballast Capacity (m ³)	Representative Pump Rate (m ³ /hr)
High Ballast Dependent Vessels	Bulk Carriers		
	Handy	18,000	1,300
	Panamax	35,000	1,800
	Capesize	65,000	3,000
	Tankers		
	Handy	6,500	1,100
	Handymax-Aframax	31,000	2,500
	Suezmax	54,000	3,125
	VLCC	90,000	5,000
	ULCC	95,000	5,800
High Ballast Dependent Vessels	Containerships		
	Feeder	3,000	250
	Feedermax	3,500	400
	Handy	8,000	400
	Subpanamax	14,000	500
	Panamax	17,000	500
	Postpanamax	20,000	750
	Other Vessels		
	Chemical Carriers	11,000	600
	Passenger Ships	3,000	250
	General Cargo	4,500	400
	Ro/Ro	8,000	400
	Combination Vessels	7,000	400

Ballast Water Handling Practices

The proper sizing of a treatment system depends on the amount of ballast that has to be treated at any given port, more so than the total ballast capacity or maximum flow rate. If, through active ballast management, discharge can be reduced or eliminated then treatment demands decrease. For example, most container ships rarely need to discharge a full ballast load at any one time (Figure2).

It also should be noted that a large amount of the treatment system prototype testing is done on moderately sized systems (<250 m³/hour) or is scaled up from other industries and not all systems scale up well to the sizes required for the high ballast capacity pumping rates or volumes of several thousand m³/hour. Another ballast practice issue that impacts treatment selection is how accumulated mud and silt in the ballast tanks is addressed. This residue itself can contain invasive species even when the tank is empty of water (a NOBOB – no ballast on board condition). Even if ballast is loaded locally it can become contaminated by the residue in the tank. This may necessitate the treatment of ballast water on discharge as well as loading. If there is little mud accumulation and the tanks are cleaned regularly, this may be less of a concern and the treatment system can be selected accordingly [5].

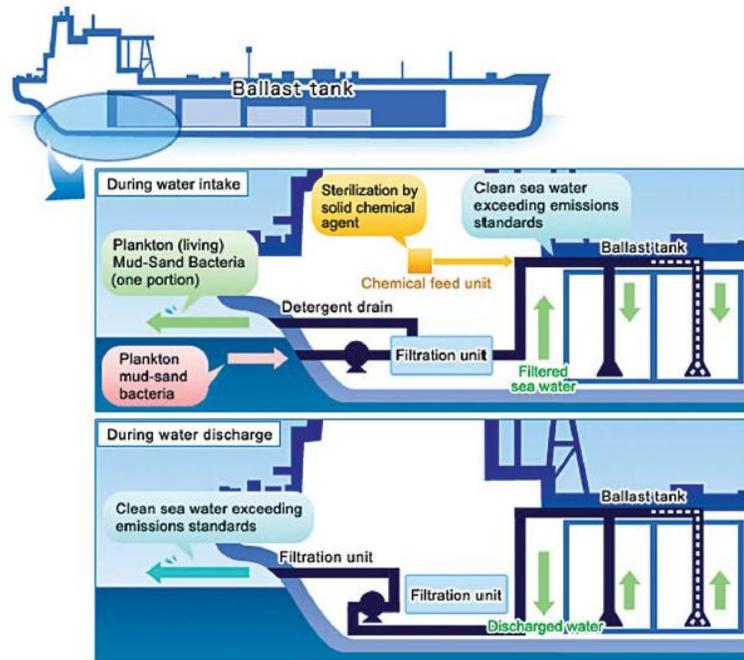


Figure 2: Diagram of Ballast Water Management System

Ballast Water Characteristics

Turbidity, salinity and silt content can impact the efficacy, maintenance or reliability of some technologies. If regular calls in a port are planned where the water has high mud/silt content or has a low salt content (fresh or brackish) these should be considered in the treatment technology selection [5].

Vessel Service Characteristics

The vessel service or trade route may also be critical for treatment system selection. For example, certain ship types may not be discharging ballast in the US so there will be no concern for US regulations other than the reporting and recordkeeping requirements. The key regulatory requirement and efficacy standards will be those from IMO. If treatment options for local requirements are too expensive, then operators that trade in those areas only occasionally may opt to forego shipboard installation of additional treatment capability. Instead they may adjust their ballast management to avoid discharge or pay high use costs for a shore/port based system (where available) [5].

Common Ballast System Characteristics

There are also a number of other vessel features related to ship type that are not exclusive to the high/low ballast dependent categorization defined above yet have an impact on treatment system selection. These include the number of separate ballast systems (e.g., oil tankers often have two, one in way of the cargo area and one aft of the cargo), whether educators are used to supplement ballast discharge, small or crowded engine rooms, or explosion proof ballast equipment requirements. How these features represent design challenges for treatment systems are discussed in the following sections [5].

Treatment Technology Factors

The second most important set of factors in selecting a suitable treatment system, after ship type and service, are the operating characteristics and requirements of the individual treatment technologies. There are several type approved technologies that have satisfied the IMO D-2 standard and numerous technologies being actively researched and implemented that should be able to meet the IMO discharge standards.

These technologies differ in method and rate of application, scalability, required holding time, power and related system requirements, impacts on corrosion and inherent safety. Each ship's design, as well as an owner's particular operating practices and internal risk assessments, will determine how important each of these factors is in the selection process. Taken together, these factors and how the treatment systems address them, indicate the level of analysis required for effective implementation of the particular treatment system [5].

Treatment Method

The methods and technologies being considered for ballast water treatment can be grouped by basic approach as follows:

- Mechanical systems (filtration or separation);
- Physical disinfection (UV radiation, cavitation, de-oxygenation, etc.); and
- Chemical treatment (biocides and electro chlorination).

Each system has a few fundamental characteristics that impact its suitability for certain ship types, service or flow rates. Most of the treatment systems use a combination of two or more of these technologies to overcome an individual technology's shortcomings (table3).

Mechanical Systems These require redirecting the full ballast flow through filters, hydro cyclones or other separators. For high volume applications, the size of the equipment required can be problematic. If they are used during ballast discharge, the filtrate must be maintained on board. High sediment loads can cause problems for filters.

Physical Disinfection Ultraviolet radiation and cavitation require processing of the entire ballast flow but holding time is not required as treatment is complete once the water passes through the equipment. UV exposure is usually done at both intake and discharge. Its effectiveness degrades with cloudy or turbid water that restricts light penetration. De-oxygenation can be done at intake to the full ballast flow or directly in the ballast tanks with bubblers. However, the full kill rates may take several days to achieve so the ballast tanks must also have a closed vent system and be fully inserted [5].

Chemical Treatment These treatments are dosed into the existing ballast piping during intake or directly into the ballast tanks. The dosage rates must be adjusted to provide the desired kill rate. The chemicals are usually lethal within several hours of treatment so long holding times are not required. However, the chemicals must be neutralized or be allowed to become biologically ineffective before the ballast water can be considered safe for discharge.

Table 3: Important Treatment Method Characteristics

Treatment Process	Method of Treatment	When Applied	Time for Lethality	Corrosion Potential
Chlorine Generation	Use electrolytic cell to generate chlorine and bromine that act as biocides. Next, sodium sulfate neutralizes the ballast water prior to discharge. As long as free chlorine exists in the tank, biocide will be active so dosage can be adjusted to keep biocide always active.	At uptake and neutralize at discharge	Hours	High dosage levels promote steel corrosion
Chemical Application	Mix proprietary chemicals with the ballast water in metered dosage rates at intake to kill living organisms. Chemicals degrade over time so ballast will be safe to discharge.	At uptake via eductor	24 hours	High dosage levels promote steel corrosion
Filtration & Radiation	Filtration of the incoming water, usually with self-cleaning 50 micron filters, in parallel with discharge of filtrate to the waters where intake takes place. Ballast water is exposed to a form of radiation, such as UV energy or other hydroxyl radical generator, to kill smaller organisms and bacteria.	At uptake for filter and UV and at discharge for UV	At treatment	No effect
De-oxygenation	Mix inert gas generated on board with the ballast water, either by a venturi eductor or by bubbling from pipes in the tanks. This removes oxygen from the water and lowers pH, therefore killing the living organisms. This process requires the atmosphere in the ballast tank be maintained in an inert condition.	At uptake for some systems and in tanks for others	4 to 6 days	Relatively less corrosive
Ozone Generation	Ozone is generated on board and acts as a biocide. It is applied during the ballast pumping process by eductor either at uptake or discharge. It can be combined with filtration or other methods of treatment.	At uptake for some systems and at discharge for others	Up to 15 hours	Limited effect as ozone has short life. If treated at discharge, no effect.

Treatment System Pressure Drops

The treatment systems that process the full ballast flow through filters, separation systems or venturi's, create added resistance to ballast flow. The pressure drops for such elements vary, with most systems claiming from less than 1 bar to about 2 bar. In some cases, back pressure valves may need to be added to the system after a separator to provide sufficient backpressure for clearing out sludge and/or self-cleaning. If the installation requires significant lengths of new ballast piping and valving then some additional pressure drops will be introduced that could prove significant. The self cleaning or back-flushing operation will redirect some of the ballast flow directly overboard and reduce the flow rate into the tank further. Some hydro cyclones redirect between 5 percent to 10 percent of the flow stream for sludge removal.

The pressure drops and self cleaning process will impact in-service flow rates and system design pressure. For most ships it is not expected that ballast pumps will need to be upgraded. However, the actual flow rates of ballast delivered to the tanks achievable with the selected system must be used when evaluating ballasting times and operation of the treatment system. It could be that ballasting with some treatment systems with high pressure drops and self-cleaning systems could take 20 percent longer than ballasting without treatment.

It should also be noted that at some level of additional system resistance, gravity ballasting may no longer be feasible because the pressure differentials with the sea water are reduced and acceptable flow rates cannot be

maintained. Some separation equipment simply cannot run without sufficient system pressure drop. This will ultimately increase the total power required for the ballasting operation because the main pumps will have to be operated for a longer period [5].

Power Requirements

Electrical power consumption by ballast water treatment systems is potentially a significant hurdle for some technologies on the high ballast dependent ships. Large power consumers such as UV light banks, electrolytic chlorination systems and de-oxygenation systems can require 150 to over 200 kW for a 2,000/m³ treatment flow rate. If these systems must operate when other large shipboard consumers are also operating, total ship service electrical generating capacity may be insufficient.

The large electrical loads are also the main operating cost for these systems. In contrast, treatment systems that rely on chemical biocides and preparations that can be dosed into the ballast flow have an almost insignificant electrical load impact but require storage space, handling and dispensing equipment [5].

Impacts on Ballast Tank & Pipe Corrosion

For all ships, but especially the high ballast dependent ships, the battle against steel wastage due to salt water-induced corrosion can be the single largest maintenance cost as the vessel ages. Treatment systems that change the chemical composition of the ballast water and/or the atmosphere in the ballast tanks can impact the corrosion rates in the tanks and piping. If not designed and handled properly, treatment systems may also damage ballast tank coatings resulting in increased coating maintenance and ultimately increased corrosion as well.

Systems that remove oxygen and maintain an inert, oxygen-deprived condition in the tanks can offer significant reductions in corrosion rates. Some of the change in oxidation rate is attributable to changes in pH caused by the treatment. Some vendor studies have actually concluded that savings on steel and coating renewals over the life of the vessel are much greater than the life cycle costs of the treatment systems. Alternatively, many of the chemical biocides and preparations, including ozone, have been linked to increased corrosion rates.

Experimental data is not always conclusive regarding the impact of chemical disinfectants in actual service conditions in ships' ballast tanks with standard tank coatings and anodes, normal cycling of ballast levels and chemical concentrations required for treatment. Even de-oxygenation systems can cause accelerated corrosion if they completely remove the oxygen and create a condition that promotes anaerobic-type, microbiologically-influenced corrosion. This could be in the form of acid-producing bacteria (APB) and sulfate-reducing bacteria (SRB). The condition may be accentuated if there is an alternating oxygenated/de-oxygenated condition. In order for de-oxygenation to be beneficial for corrosion protection, it has to reduce the oxygen levels sufficiently to slow oxidation and kill any biofilms that might form, but not so low as to provide an atmosphere conducive to the growth of APBs and SRBs.

With the current available data, it is difficult to predict how different treatment systems will change corrosion rates. At this point, it is necessary to move forward with an understanding of this uncertainty and plan maintenance and inspection intervals to suit expected risks appropriately. Coating manufacturers should also be consulted regarding the reaction of their coatings to the planned additives. Only when sufficient operational experience is gained with given treatment systems will clearer guidelines be possible [5].

Health & Safety (Handling, Operation & Maintenance)

The use of chemical biocides and other active substances on board ships raises a concern over the health and safety of those responsible for operating the equipment and handling the materials, as well as the risk of unintentional discharge into the environment. Treatment systems that use active substances or preparations must undergo a strict review and approval process to identify persistence, bioaccumulation and toxicity. If the system is given final approval by IMO, this indicates that persistence, bio-accumulation and toxicity are below threshold levels and that, if the substances are handled as directed, they are considered acceptable for shipboard use [5].

Vendor Qualifications & Reputation

As with any piece of equipment, the ability of the vendor or manufacturer to deliver the product on time and in the quantities requested is very important. However with this emerging technology, the production capacity is unproven and still very small in most cases. Some manufacturers may suffer from long lead times on orders, especially if demand increases rapidly. Even though production facilities are subject to quality control review by the type approval authority, until a track record is established, manufacturing quality and reliability can be an unknown. Those systems relying on existing technologies or marine components will have an advantage in this regard [5].

Maintenance Requirements & System

There is insufficient experience with treatment system options to establish a good baseline for system reliability. Those systems relying on existing technologies or marine components will be able to provide better reliability estimates. Lacking in-service experience, an indication of reliability risk may be available by considering the system complexity. Filters, UV light chambers and simple chemical dosing systems are among the least complex options and regular maintenance is possible with ship's crew. Electro chlorination and other chemical generating systems as well as systems with more than two stages of treatment can be considered among the most complex [5].

Simple Operation: Control & Monitoring

All treatment systems should provide a simple to use remote control panel at or near the main ballast control panel. It should include indicator lights for key valves and system operations and an on/off control. Most systems will provide main control panels near the equipment that allow local operation but also monitor system operation. Beyond this, it is up to the owner how far integration of the treatment system is carried in the main control/alarm/monitoring system. If full integration is required, additional tie-ins with system electronics may need to be special ordered from the manufacturer [5].

Life Cycle Costs

The bottom line concern for owners is the true life cycle cost of the system. Acquisition costs are the most straightforward to determine because they are directly quoted by the vendors and include all their sunk costs for research and development, approvals and certification. Installation costs vary from system to system and are more difficult to quantify. Installation costs include changes to existing piping, equipment and structure, as well as the direct equipment installation, connection, startup, testing and survey by the approval authority. Most systems will require some out of service time for the ship in order to complete the installation but none of those currently on the market is likely to require dry docking.

Establishing both installation and operating costs is difficult as both will vary significantly depending upon the type and size of ship, the system selected and prevailing market conditions. When evaluating the probable operating costs of a system, the following should be taken into account:

- Energy required to operate the system including electric power and fuel for generating treatment materials (ozone, inert gas and other biocides)
- Consumables such as chemicals, lamps and filter elements
- Crew labor to operate and maintain the system, including training [5].

Serviceability & Availability of Spare/Replacement Parts

As noted in the Annex to Resolution MEPC.174(58), "Guidelines for approval of ballast water management systems (G8)," all working parts of the ballast water management system that are susceptible to wear or damage should be easily accessible for maintenance. Accordingly, owners and operators are to install the system in such a manner so the ship's crew can perform routine maintenance which may include the replacement of filters, UV lights or other consumables in an efficient manner. In addition, owners and operators are encouraged to confirm the availability of spare or replacement parts and repair technicians on a worldwide basis [5].

Intake/Discharge Isolation: Cross-Contamination

When designing the piping system modification required for treatment system installation, care is required to prevent any accidental cross-contamination of intake and discharge water. This is a concern for systems that redirect the main ballast flow. Cross-contamination can occur if contaminated water, either from the sea chest or a tank which may require treatment prior to discharge, passes through a pipe that is shared by the treated ballast water being discharged. Valves which do not provide a reliable seal may also allow some contamination of treated ballast.

Ballast Water and Sediments Reception and Treatment Facilities

In managing ballast water to prevent invasive species, the most common methods are 1) receiving and treating ballast water in ports, 2) treating ballast water onboard ships and 3) exchanging ballast water.

According to the convention, there is no requirement for receiving ballast water from ships; yet Article 5 calls for suitable facilities for sediments reception in ports and terminals where cleaning or repair of ballast tanks are conducted without undue delay to ships. The sediments discharge should be handled with sufficient safety in order not to jeopardize the environment, human health, and properties or resources of that country or any other's.

According to the D-5 Guideline, the following criteria need to be considered when receiving and treating ballast water:

- Safety considerations related to the ship and crew;
- Environmental considerations, in order not to cause more damage to the environment than the process is supposed to prevent;
- Feasibility for the ship structure and operation;
- Cost-effectiveness of the process; and
- Biological impacts in order to eliminate or neutralize harmful aquatic pathogens or organisms present in ballast water [5].

Guideline on Sediment Reception in Repair Ports (G1)

This guideline is applied to sediment reception equipment according to Article 5 of the Convention and Regulation B-5, in compliance with the following:

- Local, national and regional regulations that could affect reception equipment;
- Choosing location;
- Gathering, handling and transporting sediments;
- Sampling, testing and analyzing sediments;
- Storing sediments and the required conditions;
- Estimated necessary capacity (volume/weight), including sediment moisture for being transported;
- Environmental advantages and costs;
- Proximity of the facilities to the above ports or terminals;
- Environmental impacts of constructing and operating equipment;

- Training personnel about the equipment;
- Equipment needed to discharge sediments from ship, such as cranes;
- Personnel health/safety requirements;
- operational limitations;
- Waterway accessibility, proximity and traffic management; and
- Treating, handling and disposing of received sediments

Methods of treating, handling and disposing sediments need to avoid any collateral impacts that may jeopardize or damage the environment, human health, properties and resources of the host Party or others. Moreover, the personnel engaged in such activities should be made aware of the risks involved, receive proper trainings and use sufficient protective equipment and clothes. In designing the capabilities of the reception equipment, the types of ships expected to use them needs to be duly considered, so that tank washing and repair services would also be provided to such vessels.

Details of the capabilities and the limitations of the reception equipment should be announced to the interested ships, including:

- Maximum capacity (weight and volume) of sediments;
- Maximum volume or weight received each time;
- Packing and labeling requirements;
- Working hours;
- Ports, berths and areas with access to reception equipment;
- Details of sediment transfer from ship to shore;
- Ship crew or port personnel needed for transfer operation;
- How to use the reception services, including notification deadline and ship particulars required; and
- Costs and other relevant information [2].

Design and Construction to Facilitate Sediment Control on Ships (G12)

According to Regulation B-5.2 of the Convention, ships subject to Regulations B-3.3 to B-3.5 should, without compromising safety or operational efficiency, be designed and constructed with a view to minimize the uptake and undesirable entrapment of sediments, facilitate removal of sediments, and provide safe access to allow for sediment removal and sampling.

Water taken on board as ballast could contain solid particles that would deposit on the bottom of the ballast tank or over the structures inside it, once the ship movement has become stable. Aquatic organisms could also deposit in the same manner and continue living inside the sediment, even for long periods after the ballast water has been discharged. These organisms may therefore be removed from their natural habitat, transferred to another port or area, and cause damage or destruction to the environment, human health, equipment or resources. Regulation B-5.1 of the Convention also requires that all ships remove and dispose of sediments from spaces designated to carry ballast water in accordance with the Ballast Water Management Plans. These Guidelines are to assist ship designers, ship builders, owners and operators to design ships to minimize the retention of sediment. Ballast water tanks and their internal structures need to be designed in a manner that prevent sediment accumulation, and preferably follow the recommendations below:

- horizontal surfaces are to be avoided wherever possible;
- where longitudinals are fitted with face bar stiffeners, consideration should be given to fit the face bar stiffeners below the horizontal surfaces to aid drain off from the stiffeners;
- arrange for induced flows of water, either by pump forces or gravitational forces, to wash along horizontal or near horizontal surfaces so that it re-suspends already settled sediment;
- where horizontal stringers or webs are required, drainage holes to be as large as possible, especially if edge toe-stops are fitted where horizontal stringers are used as walkways, to encourage rapid flow of water off them as the water level in the tank falls;
- internal girders, longitudinals, stiffeners, intercostals and floors, where fitted, should incorporate extra drain holes which allow water to flow with minimal restriction during discharge and stripping operations;
- where inner members butt against bulkheads, their installation should be such as to prevent the formation of stagnant pools or sediment traps;
- scallops should be located at the joints of the inner bottom (tank top) longitudinals or intercostals and floors to allow for good airflow, and thus drying out of an empty tank. This will also allow air to escape to the air pipe during filling so that minimum air is trapped within the tank;
- pipeline systems should be designed such that, when deballasting, disturbance of the water in the tank is as powerful as possible, so that the turbulence re-suspends sediment; and
- flow patterns in ballast water tanks should be studied (for example by the use of Computational Fluid Dynamics (CFD)) and considered, so that internal structure can be designed to provide effective flushing. The amount of internal structure in double bottom tanks will reduce the scope for improving flow patterns. The hydrodynamic performance of the ballast tank is crucial to ensure sediment scouring [2].

Any designs depending upon water flow to re-suspend sediment should, as far as possible, be independent of human intervention, in order that the workload of ships' crews is minimal when operating the system. The benefits of design concepts for reducing sediment accumulation are that there is likely to be good sediment removal while deballasting, with minimum retention of sediment in the tanks, and therefore a reduction or no need for removal by other means. The design of all ships should provide safe access to allow for sediment removal and sampling. The design of ballast water systems should, as far as practicable, facilitate installation of high sea suction points on each side of the ship. When practical, equipment to remove suspended matter at the point of uptake should be installed.

Communications, Training and Public Awareness

Promoting public awareness and culture-building, as well as training the crew and personnel of vessels would play an important role in management of invasive aquatic species. Management strategies would only be efficient as a part of a larger whole that encompasses quick alerting systems of invasions, monitoring research, extensive programs for training and promoting public awareness. Such programs can especially minimize spread and transfer of invasive species.

According to Article 9 of the Convention, the inspecting officer should make sure the ship master or crew are sufficiently familiar with necessary onboard operational procedures related to ballast water management.

Personnel and officials in charge of ports and terminals cleaning or repairing ballast tanks, or treating and disposing of sediments also need to be trained and advised in regard with the following:

- Objectives and principles of the Ballast Water Management Convention;
- Environmental and health risks;

- Risks of handling sediments, including general safety and health risks;
- Sufficient knowledge of involved equipment;
- Sufficient knowledge of vessels using the reception facilities and operational limitations;
- Communication between vessels and port; and
- Sufficient knowledge of local controls of sediment disposal [2].

Moreover, according to Article 6, parties shall endeavor, individually, to promote and facilitate scientific and technical research on Ballast Water Management and monitor the effects of Ballast Water Management in waters under their jurisdiction.

- The method of communication and liaison between public bodies and private entities also needs to be clarified in the strategy:
- Training and public awareness in regard with invasive aquatic species
- Preventing entry of invasive species
- Controlling spread of invasive species
- Minimizing adverse impacts of invasive species already transferred.

Port Requirements in Implementing the Convention

Ports are directly involved in the ballast water management process as the most significant players. The three points where measures can be taken to minimize possible entry and spread of harmful and pathogenic species into the ballast water are taking up the ballast water, during the voyage and the deballasting stage.

The first and third stages mentioned above relate to the ports and that calls for a ballast water management plan to be prepared for the ports, in order to elaborate on the measures each ship needs to take when entering the port. The objective of such a plan would be integrating the various operational criteria and measures into a logical whole that makes its efficient and timely implementation possible. The plan would cover topics such as designating ballasting and deballasting areas, establishing sediment reception facilities, inspection procedures and methods, and response programs for emergency cases.

IMO guidelines provide port officials with recommendations that facilitate implementation of their ballast water management plan, one of which is considering the risk of harmful and pathogenic species spreading via ballast water.

- Large differences between ballasting and deballasting areas can minimize survival chances for aquatic species;
- Ballast water life could also determine the number of species living in it; the longer ballast water remains in the tanks (minimum 100 days), the less likely will the species in it be to survive;
- In certain conditions, it could be determined if one or more target species lived in the waters of a particular port, and had entered the ship through the ballast water; and
- Ports are encouraged to conduct environmental research through their management plans, the results of which need to be considered in assessing probable and potential risks [3].

Environmental Research

In countries with long coastlines or numerous coastal provinces, their ballast water management strategy needs to cover not only preparation of management plans, but also scientific and environmental research and monitoring, including:

- Conducting environmental monitoring and risk assessment;
- Gathering and organizing a database of the indigenous aquatic species;
- Identifying and determining the diversity of the indigenous aquatic species;
- Updating the data related to shipping routes

Compliance Monitoring and Enforcement

In order to guarantee reasonable and satisfactory implementation of ballast water management requirements in different countries, a mechanism called Compliance Monitoring and Enforcement (CME) is necessary to be established from a combination of IMO guidelines and conventions, as well as the requirements special to each Party. Despite their obvious differences, all CMEs need to be based on the following principles:

- Focusing on, and fully complying with the ballast water management strategy;
- Complying with IMO guidelines and conventions; and
- Determining if ballast water management requirements have been implemented by the ports, and taking the required measures if they have not.

Proposal

- Supporting industries regarding modern technologies and scientific research;
- Encouraging participation of researchers & scholars in environmental monitoring studies;
- Encouraging cooperation and research on ship designs focused on minimizing BW sediments.

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