Chapter

Systems and Operation of Ballast Water in Ships with the Changing Ballast Water Management Policy

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Abstract

Bio-invasion caused due to ballast water discharge is one of many problems in marine pollution. Countries such as Canada, Brazil, USA and Australia recognized the problems associated with ballasting and deballasting. Countries affected with invasive species formulated specific laws for discharging ballast water in their respective ports. Under the coordination of IMO, countries came together and stressed for globally accepted guidelines that each and every ship has to comply with, while entering any port. In the wake of this, IMO in a convention (2004) on ballast water, proposed guidelines for performing proper ballast water management. This includes ballast water exchange, ballast water treatment, port reception facility, technology approval process, sampling ballast water, analysis methods of ballast water and risk assessment in the convention. Eventually the 2004 convention was found to be inadequate in providing complete elimination of bio invasion. Amendments are made to the 2004 convention over the years for ballast water management. It is found that the member states should share technology among developing countries in establishing sampling and testing laboratories. Region specific sampling analysis and research has to be formulated to understand the bio-invasion based on region and characteristics of different target species in evaluating risk assessment. The D2 standard mentioned in the 2004 convention should be changed from size specific to 'no organism' standard in ballast water for discharge. New combination of BWT systems and 'no ballast' system with modification to the ship design should be tested, developed and implemented to bring in ecological balance and sustenance in the marine ecosystems.

Keywords: ballast water, ballast water treatment, management policy, guidelines, systems and operations

1. Introduction

The ballast literally meaning "any material that is used to balance an object to maintain its buoyancy". Ships need ballast water to maintain its stability and maneuverability when she is empty or partially loaded. The water in ballast is adjusted continuously by the crew based on the design and weather conditions of the sea through which the ship is navigating. The quality of water and the organisms present in the ballast is primarily determined by the route and the region through which the ship is

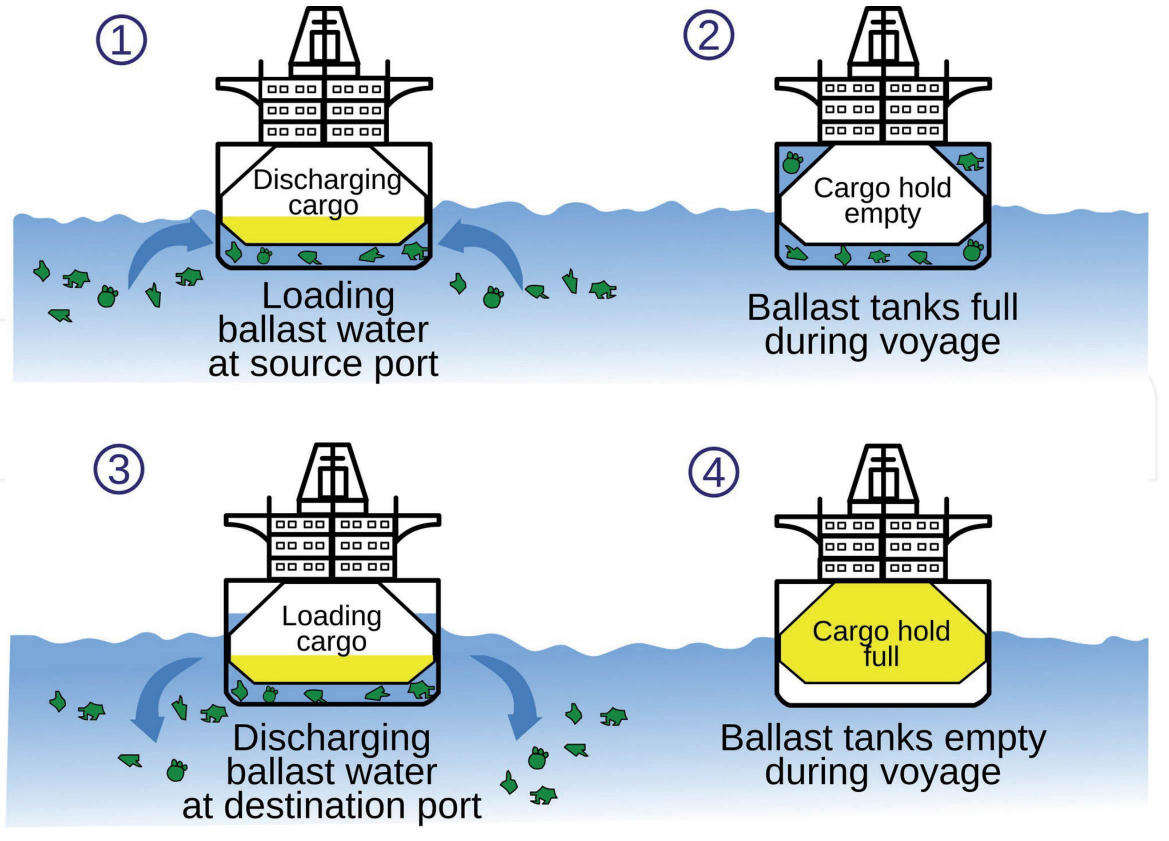

Figure 1.
Pictorial representation of ballast water. Source: MaxxL Derivative work: Thorsten Hartmann - [File:Water] File:Water pollution by ballast water de.svg, CC BY-SA 3.0, https://commons.wikimedia.org/w/index.php?curid=33556135.

traveling (**Figure 1**). Some organisms such as comb jelly fish, chinese mitten crabs, European green crabs, mussels, whelks, holoplankton, American jack knife clam and vibrio cholera has survived the harsh conditions inside the ballast tanks during long voyages. These organisms have established themselves in different environment when released causing disruption to the water quality and ecology of the respective ports. The ability of planktons, microbes, and pathogens to pump into ship's ballast system and survive relatively long voyages, drifting in the ballast water till the end of the voyage was identified as early as 1897 [1]. In 1904 scientist first recognized the signs of invasive species after a mass occurrence of the Asian phytoplankton algae *Odontella* (*B. sinensis*) in the North Sea [2]. With the growing awareness on protection and conservation of environment, United Nations held a conference on Human Environment in 1972 and declared the necessity for safeguarding the resources and environment. By 1973 IMO adopted an International convention for prevention of pollution from ships due to operational and accident causes (MARPOL-Marine Pollution). The protocol was later adopted in 1978 after numerous tanker leakages occurred during 1976–1977. Initially the ballast water and sediment management was first categorized under the MARPOL. Later on, IMO realizing the importance of ballast water management considered it specifically. under a separate category.

By 1980s, Canada and Australia were among the first countries in realizing the problems associated with invasive species and was brought to the attention of the international community. United Nations Conventions on the Law of the Sea, (UNCLOS) 1982 gave directions and stressed on the need for all the states to prevent, reduce, and control accidental or intentional introduction of species into the marine environment and to prevent, reduce, and control pollution of the marine environment from any source. By 1990, IMO created a separate working group within the marine environment protection committee (MEPC) to investigate the impact of ballast water operations in ports. Initially, there were ambiguity on whether to categorize ballast water discharge as marine pollution. Finally, it was construed to consider it under marine pollution in the UNCLOS. According to the convention, marine pollution means "the introduction by man, directly or indirectly of substances or energy into the marine environment, including estuaries, which results or is likely to result in such deleterious effects as harm to living resources and marine life, hazards to human health, hindrance to marine activities, including fishing and other legitimate uses of the sea, impairment of quality for use of sea water and reduction of amenities". UNCLOS provisions were found to be more effective in safe guarding the rights and responsibilities of the port rather than providing solutions to the bio-invasions and pollution caused by ballast water. The AGENDA 21 of the Rio declaration (1992) which call on nations to consider regulation of ballast water discharge to prevent the spread of non-indigenous organisms and advocates on the precautionary and polluter pays principle which could bring in more nations and ship authorities accountable in protecting the marine biodiversity, prevention of bio invasion and marine pollution by the discharge of ballast water.

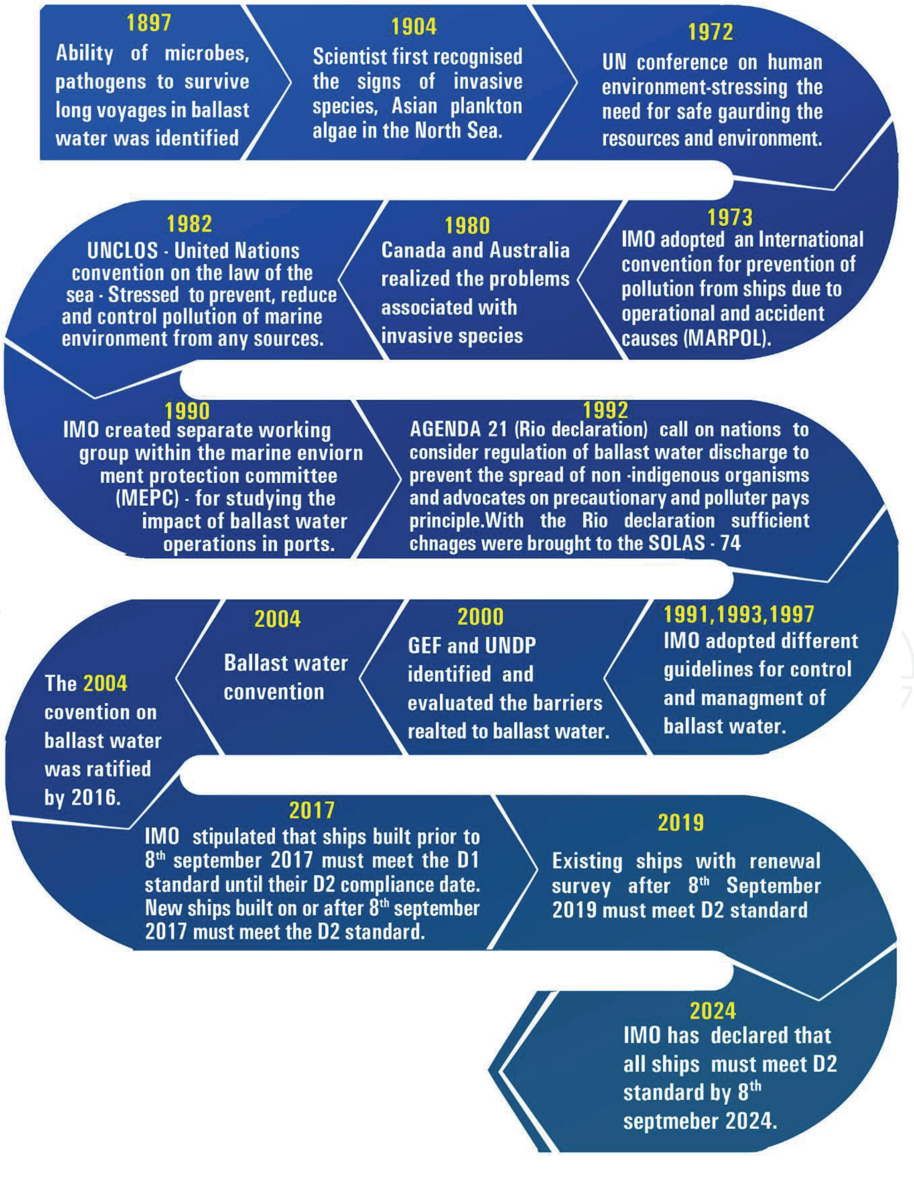

Figure 2.
Sequence of events in ballast water regulations.

SOLAS 74 – safety convention and ISM code which give guidelines for stability and safety operations, is applicable to the ballast water management in ships. With the convention on biological diversity at Rio Declaration, 1992, sufficient changes had been brought into the SOLAS 1974 and ISM code to be implemented for safe operations of ballast water. In 1991, 1993 and 1997, IMO adopted different guidelines for the control and management of ballast water to minimize the transfer of harmful and pathogenic aquatic organisms. But by 1997 with the zebra mussel invasion in US and Canada, the United Nations General assembly passed a resolution to prevent ballast water pollution. Guidelines were modified for better ballast management practices which the states could adopt by means of their national legislation [3, 4]. The guidelines gave directions to the nations in framing and enacting domestic laws for minimizing and reducing the risks associated with the ballast water discharge. A joint initiative by IMO (2000) named Globallast was launched in association with the Global Environment Facility (GEF) and UNDP to identify and overcome barriers related to ballast water effectively. The sequence of events in ballast water regulations is depicted in the **Figure 2**.

2. Ballast Water Convention 2004

General guidelines for ballast water was not giving way for a solution to the unique problems such as bio invasion and marine pollution created by ballast water intake and discharge. Numerous international laws were used as a general guideline for countries performing ballasting and de-ballasting. But no country could clearly give directions on how to manage ballast water properly. Since ballast water is a global concern, separate rules and regulations for each nation will not bring any consensus among different states for ballast water discharge.

IMO in 2004 by consensus adopted the Ballast Water Management Convention (BWMC) at a diplomatic conference held in London. The ballast water working group of IMO (2004) drafted ballast water discharge standards which aims at preventing and eliminating ballast water pollution. It comprises of 22 articles, regulations and 1 annexure detailing general obligations of states to implement the technical requirements. It has an appendix setting model formats for the issuance of international ballast water management certificate and ballast water record book.

To achieve the goal of elimination and prevention of bio-invasion the BWM Convention required all vessels to implement a Ballast Water Management Plan and adhere to clearly defined management standards. The BWM Convention established two standards of management: (1) Regulation D-1, (the ballast water exchange standard), and (2) Regulation D-2, (the ballast water performance standard).

Regulation D-1 required a minimum ballast water exchange volume of 95%, while regulation D-2 established a concentration threshold for ballast water discharge. The D-2 standard requires ballast water discharge to contain: 1) Less than 10 viable organisms per cubic meter greater than or equal to 50 mm in minimum dimension. 2) Less than 10 viable organisms per milliliter less than 50 mm in minimum dimension and greater than or equal to 10 mm in minimum dimension. 3) Less than the following concentrations of indicator microbes, as a human health standard: 1) Toxigenic *V. cholerae* (O1 and O139) with less than 1 colony forming unit (cfu) per 100 ml or less than 1.0 cfu per 1.0 g (wet weight) zooplankton samples. 2) *E. coli* less than 250 cfu per 100 ml. 3) Intestinal Enterococci less than 100 cfu per 100 ml.

2.1 Ballast Water Management and Ratification with the Convention

The BWM Convention came into force 12 months after ratification by 30 States representing not less than a combined 35% of the world's merchant shipping gross tonnage. Regulations D-1 and D-2 will be implemented on a phased schedule based on age and ballast water capacity of each vessel, with all vessels eventually required to meet the D-2 standard [5].

There is no universally applicable currently available method for shipboard treatment of ballast water. This creates the space for a diverse research and development in the ballast water management. A more consolidated effort has to be put in for developing an effective ballast water management. Initially, community composition of the ballast water in ships coming to ports around the world were documented and recorded. Gradually, with the growing awareness on marine environment, different studies were being focused on the tolerance levels of species transported by ships to different ports. There is currently insufficient data to confidently quantify the probability of invasion associated with any particular inoculum density (or discharge standard). As a result, laboratory, field and modeling studies examining the relationship between invasion risk and size of the initially released population (the 'risk-release relationship') are an emerging, high priority field of study [6]. The Brazilian experience shows that there is non-compliance with ballast water management for the Brazilian port authorities [7]. Ever since Brazil signed the Ballast Water Management Convention on 25th January 2005 and adopted its own NORMAM-20 regulations, there has been a decrease in compliance of ballast water regulations with the port authorities. Brazil, with the adoption of national legislation and implementation of an inspection regime require further scientifically validated data for evaluation of its efficacy, besides monitoring and survey campaigns to control the spread of non-native species [8]. It is reported that, more detailed studies are required to assess the reasons for non-compliance and for the most noticeable impacts resulting from them in the waters of Brazil [7]. In European countries, one among the many recommendations that have come up is that all the European Union countries has to ratify the BWM convention which would result in meeting the criteria of the convention and the routine operations of ballast water management systems before the BWM convention enters into force. They are encouraging non-European countries which are bordering European seas to implement common European Union BWM requirements as a pan European application [9]. The major stumbling block appears to be the non-ratification of the convention by countries around the world. Some countries USA, Canada, Australia, Panama, Liberia and the Bahamas has developed unilateral ballast water management legislation which needs to be ratified so that they can monitor the effectiveness of the convention and suggest improvements as technology and compliance advances [10]. After becoming a party for 2004 convention, Malaysian Government has come up with various implications for the stipulated treatment technology as well as for monitoring activities. This would be the major undesirable result which the stakeholders should have to bear when the IMO convention 2004 comes into force [11].

Canada was the first among a few countries to develop a centralized model of control for ballast pollution after the destruction of its marine sanctuaries by bio-invasions. The Canadian law is called the Ballast Water Control and Management (2001) regulations. The law stipulates that every effort by the master and crew has to be performed to minimize the ballast water exchange in the Canadian water or atleast make them harmless before discharging in the Canadian waters through BWE, treatments, retentions and discharge into reception facilities. Within the law distinctions are clearly set for transoceanic ships and non-transoceanic ships when ballast water exchange is done. Transoceanic ships from outside Canada are not encouraged to make ballast water exchange in the mid-oceans. The law directs for a clear ballast water management plan, which should describe the ballast water management process, safety procedures, sediment disposal procedures, design specifications officers in-charge for monitoring and for coordinating BWMP with officials.

3. Systems and Operations in Ballast Water

3.1 Ballast water exchange

The 2004 convention prescribes ballast water exchange as an interim method for prevention of bio invasion till an effective ballast water management plan is in effect for all member states. According to the convention ships have to exchange 95% of the ballast water volume and organisms from the ballast water. The ballast water standards are set based on the ship's age and its capacity. The convention, stipulates that ships shall undertake ballast exchange at 200 nm (nautical mile) from the nearest land and at water depths of 200 m. If it is not possible BWE may be done at 50 nm from the nearest land and at 200 m depth. It also states that during emergency situation, when the prescribed distance and depth measures cannot be maintained, the port states can designate BWE areas with the time required, shipping route and safety requirements kept under consideration. But new suggested route by port states can cause undue delay to the ships further resulting in payment of heavy compensation by vessel owners.

Many studies have proved that the BWE is not a permanent solution to the problem of bio invasion as it can remove only 95% of the organism with one time exchange [12]. Moreover, the organisms settled in sediments may not be removed by single BWE. It is observed that conducting two to three BWE can only help reduce the bio invasion. Ballast water exchange is being gradually phased out depending on the age of the vessel and ballast water capacity. Most of the vessels are in the transition of moving onto ballast water treatment systems from the process of ballast water exchange.

3.2 Ballast water treatment

By 2001, the world maritime community recognized that the BWE alone cannot provide solution to the problem of bio-invasion. There is a need for an alternative method in ballast water management. Researchers found that BWT can be effective in managing ballast water compared to ballast water exchange. The IMO convention 2004 has given guidelines (G8, G9, G10) for the approval of different treatment systems for ballast water management. The ballast water convention does not provide specific requirement for treatment methods to be followed in the BWMS. The treatment designs are reviewed, approved, installed and operated by a Type Approval to be in compliance with the IMO convention for an effective prevention and elimination of invasive species.

Ballast water collected from fresh water, estuary or sea water may contain physicochemical parameters, aquatic organisms and sediments as pollutants. The technologies currently available in inactivating organisms and treating the pollutants are grouped into three categories – Mechanical, Physical and chemical.

It is observed that some of the treatment systems which use chemical biocides or de-oxygenation may require additional treatment prior to water being discharged into the sea. The chemical biocides produce toxic by-products which has so far been land tested and models are developed based on the results. The risk assessment of ballast water treatment systems within the IMO approval procedure is primarily based on exposure from the land based testing and modeling done based on laboratory results.

There are variety of combinations of mechanical, physical and chemical treatment technologies available in the market. Most companies promote combinations for a better result and cost effectiveness. The Article 4 of the convention states that every ship has to exercise control of the transfer of harmful aquatic organisms and pathogens through ship's ballast water and sediments. In order to meet the standard requirements the ships need to conduct ballast water exchange and other ballast water management. This includes treatment systems, all associated control equipment, monitoring and sampling facilities. The systems are required to meet standards of regulation D2 and the conditions established in regulation D3 of the convention. Recommendations regarding the design, installation, performance, testing environmental acceptability and approval of ballast water management facility are provided in the guideline. The ballast water treatment equipment has to undergo Type Approval for operations with active substances and without active substances. The procedure followed are pre-test evaluation of system documentation, Type Approval tests, issuing a Type Approval certificates, and on-board inspections.

With the growing awareness on marine pollution different companies started research and development for the management of ballast water. From the 2004 convention onwards the research in this domain gained new directions and guidelines for the innovation of new ballast water management systems developed in compliance with the D1 and D2 standards. The 2004 convention was ratified by 2016 with a much more effective guidelines and methods for BWMS. With these guidelines the BWT convention came into force by 8th Sept 2017. Majority of the vessels are still in BWE mode and are gradually shifting to the ballast water treatment systems.

The scientific community and stakeholders introduced a number of viable, practical and effective management solutions by 2003 after much deliberation over ballast water management methods. It is found that a single technology will not be suitable for all vessel types and voyage profiles. According to researchers a combination of treatment technology with filtration (primary treatment) followed by biocidal treatments (secondary treatment) based on the vessel type has to be used for a better management of ballast water [13]. According to World Maritime University (Sweden) with other Stakeholders developed many commercially available treatment systems. Among them, 7 of the systems had Type Approval certificate while 20 were in various stages of approval process. Besides the testing protocols the scientific community evaluated the provisions for reception facilities in ports, regulatory, technical and environmental challenges to be in compliance with the convention. They also considered the challenges faced by ship owners in ratifying the convention.

With the increasing Type Approved Systems 30–40 systems are different stages of development, the maritime community considered on sampling of ballast water, monitoring analysis and risk assessment. They observed that still there is dearth in the operational experience for all the available technology in sampling, monitoring and risk assessment of Ballast Water Management Systems. Further, maritime researchers found that ultra violet light used in water treatment can be a better and effective physical treatment method for ballast water. IMO then focused on finding alternatives to on-board treatment systems port based contingency measures, mobile ballast water treatment facilities and treatment boats placed in ports. By 2016 national maritime administrations, ship owners and operators, ship builders and repair yards, test facilities, commercial treatment system manufacturers, research and development communities and financing communities were brought to a global platform for ballast water management.

3.3 Port reception facility

Many ships cannot perform ballast water exchange in the mid-sea due to safety and adverse weather situations. Under these circumstances, they use reception facilities in ports given in the G5 guideline MEPC (Marine Environment Protection committee), 2006. Ships use reception facility for ballast water and sediment management in ports. But it is not mandatory under the convention that the port states should provide this facility for ballast water. The establishment of reception facility requires exorbitant expenses in setting new treatment plants, new pipe connections and more human resources both on board and in the port. Majority port states especially ports in developing countries would advise for ballast water exchange or ballast water treatment as an alternate for port reception facilities.

3.4 Technology approval process

There are many technologies that produce or utilize a substance that has a general or specific action on or against harmful aquatic organisms and pathogens. These substances are called Active Substances according to the Regulation A-1.7. If a ballast water treatment facility uses an Active Substance, then to comply with the Convention it should be approved by IMO in accordance with the 'Procedure for approval of ballast water management systems that make use of Active Substances – G 9' {adopted in MEPC (The Marine Environment Protection Committee) 53rd session}. The following steps has to be followed if a system uses an active substance as per G9 guidelines. It comprises: 1) Initial approval of environmental impact of discharged ballast water {GESAMP- BWWG, Joint group of experts on the scientific aspects of marine environmental protection}. 2) Approval of the system through land-based testing and shipboard trials received by the Flag state. 3) Final approval of environmental impact of discharged ballast water received by GESAMP BWWG. 4) An approval certificate issued by the Flag state. The certification of a system that does not use an active substance should be conducted by skipping the second and the last steps. The testing procedure is outlined in the IMO's Guidelines for Approval of Ballast Water Management Systems (G8 Guidelines). As mentioned, the potential technology should be evaluated during both shore-based testing (6 weeks to 6 months) and ship based testing (6 months). Worldwide, there are few testing facilities for evaluating treatment technologies for ballast water. Since the implementation of the convention, many technologies have been certified [6]. From the time the BWM convention, 2004 and the initial adaptation of the G8 guidelines for approval of ballast water management systems in 2005, substantial number of treatment systems have been developed globally.

3.5 Sampling ballast water

Sampling of ballast water needs to be in compliance with D1 and D2 guidelines. Sampling design given by G9 does not suffice different scenarios of water being ballasted into ships. Samples degrade very quickly and need to be analyzed immediately which depends on the time, place, and holding condition. Moreover, safe limits could not be finalized before sampling process and analysis. More extensive work has to be done towards sampling design and procedure for ballast water. Appropriate physicochemical parameters has to be included in the analysis of ballast water. Inter calibration experiments cannot be compared as there is no uniform sampling methodology currently available for ballast water to prove compliance.

Ballast water management convention has been working on, to evolve scientific sampling methods based on conditions of water and sample sizes. But it was difficult to come to consensus for such complicated issues such as how to sample and analyze ballast water for different organisms. Hence, it has been addressed very loosely in G8 guidelines. Some of the research organizations developed their own standards and sampling methods, with difference in specific details but within the general G8 guidelines. EPA, 2002 has come up with a sampling design. Initially, 1.0 m^3 sample of ballast water was collected to quantify concentration of living organisms larger than 50 micrometer after treatment. Complying with the D2 standard of less than 10 organisms of 50 micrometer size, quantification of the 10 organisms of 50 micrometer size would be easy with 1.0 m^3 ballast samples. Enumeration of the organisms present is represented by the Poisson distribution, and therefore the cumulative or total count is the key test statistic [14]. Further, a chi-square transformation can be utilized to approximate the confidence intervals. Assuming, for organisms ≥50 μm, the desired minimum precision in the upper bound of the chi-square statistic should not exceed twice the observed mean (this corresponds to a coefficient of variation of 40%) and count of 6 organisms is required. The volume required to successfully count 6 organisms is dependent on the gross water sample volume, concentration factor, number of sub-samples counted, and the target concentration. For enumeration using subsamples, statistical analysis indicated that 30 m^3 must be sampled to enumerate 10 organisms per m^3, with the desired level of precision. The complexities associated with minimum sample volumes raise additional important issues.

Counting of 10 organisms of 50 micrometer size in such a large volume of water sample is susceptible to error [15]. In none of the studies, count of organisms was made with accurate precision. Samples degrade very quickly and need to be analyzed immediately which depends on the time, place and holding condition. These studies could not finalize the maximum preservation time required before a sample is processed and analyzed [15]. As there is no uniform sampling methodology currently available for ballast water, the biological results obtained from different ships to prove compliance, cannot be compared without inter calibration experiments. Moreover, vessels which show compliance in one port may not be in compliance with another port. In order to get a good representation of the organisms and other chemical parameters of the ballast tank, a most suitable sample access point and frequency of sampling has to be selected accurately. By adopting combination of different sampling equipments a greater range of taxa can be obtained than from any single method. Larger organisms may also be sampled by the use of different collecting methods, such as light traps or baited traps. However, this approach is time-consuming and requires installation of traps prior to sampling which is impossible for control sampling to be in compliance [16].

The ballast water sampling guidelines are mostly used on a trial basis and different organizations develop methodology suitable for their purpose but within the guidelines of the convention. The convention is not able to provide any specific sampling, analysis protocols and legal requirements that can be adopted by any administration. Some member states and ship owners propose to avoid sampling and insist on BWMP, Type approval certificate of BWMS and Ballast water record book for compliance with the convention.

3.6 Analysis methods of ballast water

Different analysis methods available for ballast water samples are DNA method, RNA method, ATP methods, chlorophylla method, oxygen measurement, pulse amplitude modulated fluorometry, flow cytometry, holographic microscopy, visual inspection, and stereo microscope. Presence of DNA and RNA in water can be used as an indication of presence of phytoplanktons in the water. ATP methods are used for detection of viable organisms in water. chlorophylla, oxygen measurement, Pulse amplitude modulated fluorometry detects the presence of phytoplankton in water. DNA, RNA, ATP, chlorophylla, oxygen measurement, PAM, flow camera, holographic microscope methods can be used for analysis of organisms less than 50micrometre size but greater than 10 micrometer size whereas DNA, RNA, ATP, visual inspection, stereomicroscope, flow camera can be used for the detection of organisms greater than or equal to 50 micrometers in minimum dimension [15]. These methods can be used by ports to assess whether it is compliant with the D2 standard of the convention.

3.7 Risk assessment

The convention has outlined guidelines for assessing the risk involved in carrying out ballasting and de-ballasting in relation to granting an exemption in accordance with A-4 of the convention. There are three methods for risk assessment: Environmental matching risk assessment, species' bio-geographical risk assessment, and species specific risk assessment.

Environmental matching risk assessment compares the environmental conditions between locations. Species bio geographical risk assessment compares the overlap of the native and non–indigenous species to evaluate the environmental similarity and to identify high risk invaders. While species specific risk assessment evaluates the distribution and characteristics of identified target species [17].

Environmental matching risk assessment evaluate the salinity, temperature, nutrients and oxygen of the donor and recipient ballast water. The seasonal variations in surface and bottom depths of both the environment are evaluated. If the water is well mixed over the entire year, evaluation of salinity, temperature, nutrient and oxygen depth profiles is not required. If organisms present in the donor regions are tolerant of extreme environmental conditions and can survive in the recipient environment then species specific risk assessment has to be done. Species bio geographical risk assessment compares the distribution of non-indigenous, cryptogenic and harmful native species that presently exist in the donor and recipient ports and biogeographic regions. If the species present in donor port has invaded other biogeographic regions and other related environments, then the organism pose a high risk to the recipient port that has the potential to affect health, ecology and economy of the region [17].

Species specific risk assessment identifies target species which has the potential to impair the environment, human health, property or resources and to survive or complete its life cycle in the recipient port. In this assessment they compare and identify the characteristics of species which has the capability to transfer, survive and reproduce in the new environment. Species specific assessment are done when the donor and the recipient ports are in different biogeographic region. Species specific data with respect to its characteristic behavior in the new environment is very much important for analyzing the risk scenario. More the number of species in the invasive list along with non availability of information on the characteristics of the species more are the chances for risk [17].

Parties may undertake the risk assessment themselves in order to grant exemptions or require the ship-owner or operator to undertake the risk assessment. The recipient port can reject any application for exemption when found not to be in accordance with the guidelines. The exemption has to be renewed every five years from the date it is granted permission. New data and information has to be submitted to show compliance to the exemption.

3.8 Alternative methods

Regulation B-3.7 directs that other methods of ballast water management may also be accepted as alternatives to the ballast water exchange and ballast water treatment, provided that such methods ensure atleast the same level of protection to the environment, human health, property or resources and are approved in principle by IMO's Marine Environment Protection Committee (MEPC). Over the years, new alternative methods to ballast water exchange and ballast water treatment has been introduced into the global shipping community. Some of them are 'no ballast', 'zero discharge', 'ballast free' and 'continuous flow' methods.

In 'No ballast' water eliminates the risk and avoids any ballast water management requirements. This method uses new hull design for the ship or use of solid ballast TEU (Twenty foot equivalent unit) to provide unladen stability and trim without need for ballast water. It avoids cost from fuel and greenhouse gas emissions but has higher hull build costs, operational costs from increasing hull drag and cost incurred from the logistics of handling additional solid ballast TEUs. The stability and buoyancy of the ship when in unloaded condition without ballast water was achieved by widening the ship's beam and moving the displacement volume outward from the centreline by Delft University of Technology (DUT), Netherlands and Det Norse Veritas (DNV), Norway. In the design developed by Daewoo shipbuilding & marine engineering (DSME), Korea the conventional displacement hull retained as the ballast water is replaced by 25 tonnes solid ballast TEU containers. The 'no ballast' water method is applicable to new ro-ro pax, car, containers, livestock ships and other high volume cargo ships.

'Zero discharge' or 'minimal discharge' uses storm ballast water, internal ballast water, and potable water for stability. In storm water, the ship is designed as V-shaped hull which alters the vertical distribution of hull buoyancy causing a deeper draught in unloaded condition. It avoid costs of installing and operating a large BWT systems but need more investment in building the hull. New bulk carriers especially liquid carrier vessels use storm water for ballast water management. 'Internal ballast' concept uses fresh water, which is shifted from one tank to another tank are relatively small to control trim based on the cargo distribution and loading/unloading patterns and are not routinely discharged in ports. Internal ballasting vessels has reduced cargo capability and capacity to make air-draught adjustments. Using this system can avoid the installation and operation of ballast water treatment system. New container ships, ro-ro pax, liners and livestock carriers use internal ballasting. 'Potable water' method use fresh water for filling up the ballast tanks so it can be discharged in any port. By using 'potable water' the ship owners can save cost of installation and space for ballast water treatment system. They usually use modular and compact reverse osmosis systems where the membranes are protected by two or three filtration stages. Depending on the unit size and available power supply these units produce 2–30 tonnes of fresh water per day which is very cost intensive [17].

Continuous flow method is used by longitudinal trunks and ship buoyancy control. In longitudinal trunks, buoyancy trunks replaces ballast tanks to enable continuous flushing without pumping. The longitudinal trunk, flush out the water as much as possible within 1-2 hrs at normal unladen voyage speed with minimal retention of sediment and the organisms will be carried only for short distances. It reduces the cost of installing and operating a large ballast water treatment system but requires high investment for building the ship and valve servicing.

Ship buoyancy control method commonly uses multiple below waterline valves. They convert each ballast water tank into a free flooding buoyancy compartment for continuous flushing without pumping. It has benefits of not installing and operating a large ballast water systems but has to spend on installing valves, control system, valve servicing, coating and cleaning cost to maintain ship safety and bio-fouling. Enhanced ballast water exchange concepts are used in AUBAFLOW, Loop ballast exchange and Dyna ballast where AUBAFLOW and Loop ballast exchange use enhanced blue water BWE by flushing without using pumps for transoceanic voyages and Dyna ballast uses a specialized aerator- educators to all ballast water tanks. Since there are no ballast water treatment available in the continuous flow method, sediment and organisms in the low flow zone can cause impedance to the D2 standard. As compared to normal ballast water exchange, ballast pump servicing costs, fuel consumption, and greenhouse gas emissions will also increase.

4. Conclusion

The 2004 convention on ballast water management is found to be inadequate in providing a solution for a complete elimination of bio-invasion and the already invaded organisms. It provides BWE as a solution to the ballast water management with a specified distance and depth at which it can be performed. It could not give directions on how to perform BWE at the designated site during an emergency situation. It also do not give explanation on how to select the designated area for each port states. The convention fails to address the delay in issuing port clearance for some ships due to difference in sampling facilities available in different countries. Amendments has been brought to the 2004 convention over the years for development of ballast water management plan, ballast water exchange, approval of methods used for ballast water treatments, and control of ballast water and sediments. By 2018 an elaborate regulation and guidelines were provided for covering every aspect of ballast water management.

The member states should share technology to developing countries in establishing sampling and testing laboratories. The monitoring of the system could not be accomplished due to lack of proper training to the port officers and equipment transfer. Proper training of Port officers or each state head for maritime management in sampling, monitoring, analysis and other ballast water management systems should be conducted by IMO worldwide.

Region specific sampling methods and analysis has to be developed for each country based on the occurrence of bio-invasion specific to the region. Region specific elaborate research and data has to be generated to understand the characteristics of different target species in evaluating the risk assessment. New guidelines has to be formulated and implemented to manage the already established invasive species in each country.

The D2 standards should be changed from size specific standard to 'no organism' to be present in ballast water for discharge. Ships gradually transiting from ballast water exchange to ballast water treatment can find new combination of ballast water treatments for achieving the 'no organism' standard. Ships which are newly constructed should invest in new alternate designs of 'zero ballast' or 'no ballast' or 'continuous flow method' so that no organisms are harmed in the quest for achieving the regulations and guidelines stipulated by the convention. The zero ballast method can bring in balance and sustainability in the marine ecosystem.

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Abbreviations

BWM	Ballast water management
BWT	Ballast water treatment
BWMP	Ballast water management plan
BWE	Ballast water exchange
BWMC	Ballast water management convention
BWMS	Ballast water management systems
IMO	International Maritime Organization
MEPC	Marine Environment Protection Committee
UNCLOS	United convention on the law of the sea
UNDP	United Nations development program
GEF	Global environment facility
EPA	Environment protection agency
TEU	Twenty foot equivalent unit
DNA	Deoxyribo nucleic acid
RNA	Ribo nucleic acid
ATP	Adenosine triphosphate
MARPOL	International Convention for the Prevention of Pollution from Ships
SOLAS	Safety of life at sea
ISM	International safety management

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