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Ballast Water Management Triad: Administration, Ship Owner and the Seafarer

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***Abstract*—**The Ballast Water Convention requires less than 5% of the world tonnage for ratification. Consequently, ships will have to comply with the requirements. Compliance evaluation and enforcement will become mandatory. Ship owners have to invest in treatment systems and shipboard personnel have to operate them and ensure compliance. The monitoring and enforcement will be the responsibilities of the Administrations. Herein, a review of the current status of the Ballast Water Management and the issues faced by these are projected. Issues range from efficacy and economics of the treatment systems to sampling and testing. Health issues of chemical systems, paucity of data for decision support etc., are other issues. It is emphasized that management of ballast water must be extended to ashore and sustainable solutions must be researched upon. An exemplar treatment system based on ship's waste heat is also suggested.

***Keywords*—**Ballast water management, Compliance evaluation, Compliance enforcement, Sustainability.

I. Introduction

CARRIAGE of invasive species by the vector of ship's ballast water has resulted in harm extending into socio-economic and ecological levels. Ballast waters are mostly oceanic waters loaded by ships primarily for stability. Global ballast water shifts are voluminous and annual estimates are around 3-5 billion tonnes [1]. On an average, oceanic and lake waters contain around 10^2 protists, 10^6 bacteria and around 10^7-10^9 viruses and the density in a liter of ballast water is estimated to be around 10^8 bacteria and 10^9 viruses [2]. Not all the species and organisms can be classified as being harmful but economic impacts are on record, which are alarming enough to influence the industry for control action. The International Convention for the Control and Management of Ships' Ballast Water and Sediments (hereafter, the Convention) of the International Maritime Organisation (IMO) is an industry initiative and has been the guiding instrument for Ballast Water Management (BWM) on board ships. As of 31 May 2014, there were 40 Contracting States totalling 30.25% of the world tonnage, while the ratification requires the acceptance of 30 countries totalling 35% of world tonnage [3]. But a number of issues relating to BWM still remain. Environmentalists and many regulatory bodies have been urging to ratify the Convention quickly and then resolve the issues by revisions. But the ship owners had expressed that unless the issues are resolved prior to ratification, the global trade could be affected adversely. Concerns have been raised in the recent Marine Environment Protection Committee (MEPC) of the IMO. This paper highlights the issues related to BWM from the perspective of three stakeholders namely, the Administration, ship owner, and the seafarer.

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BWM practices can be divided broadly as shore based and ship based (on board). The action elements of BWM can be categorised as the support and control measures. Fig. 1 shows the principal elements of BWM which objectively aim to mitigate the harm of alien invasive species (AIS) as required by the Convention. These measures affect all those involved in BWM.

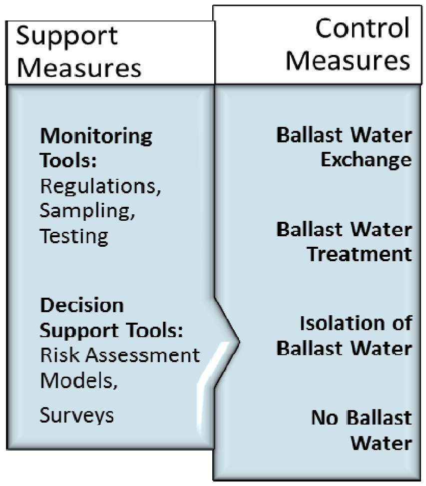

Fig. 1 Principal elements of BWM

II. BWM and Administration

For an effective BWM, compliance evaluation and compliance enforcement are two factors which comes under the purview of the Administration. Compliance evaluation refers to meeting the Convention requirements/IMO standards and Compliance enforcement refers to punitive measures due to non-compliance etc. [4]. Compliance evaluation is applicable to all the control measures but currently, ballast water exchange (BWE) and ballast water treatment (BWT) are seen as the major measures.

A. Limitations of BWE

BWE was seen as a temporary measure to comply with Regulation D1 of the Convention. Currently, Administrations check if exchanges have taken place based on record of operations. The underlying principle for this laborious practice of changing the ballast waters away from the coast is that the deeper and farther seas will have lesser organisms (lesser density). Moreover, it was presumed that these organisms will not survive the ambience when they are pumped out in the coastal regions (load ports).

The protocol of exchanging coastal waters with mid-oceanic waters requires establishment of exchange zones. BWE efficiencies vary between 95-99% [5] and ships cannot perform BWE at all times and in any location (e.g., enclosed seas such as Baltic, Mediterranean and Middle East Gulf because of 200nm requirement). Studies have shown that BWE is ineffective based on results of organism counts which had increased after the exchange [6].

Further, operational safety may be affected due to varying hull girder stresses experienced during pumping out and filling in. There are other variables which affect the practice considerably. Exchange location, water quality (density, temperature, salinity etc.), darkness, light, effluent mixing are some which affect the density of organisms and hence the effectiveness of the exchange process.

In terms of costs, BWE could be very economical but from an operational point of view, BWE is seen only as a temporary measure to be replaced by BWT for meeting the D2 standards.

B. BWT Systems

Administrative bodies and Classification Societies evaluate compliance of treatment systems guided by the IMO Guidelines. The type approval procedure involves land based and ship based tests with additional requirements for systems employing active substances. The performance standards of Regulation D2 applied during type approval stages is applicable while the system is used in ship operations.

The primary issue with BWT systems is on efficiency. Type approved BWT systems assure efficiencies to the IMO standards, but at least one instance is on record where a type approved system has been withdrawn from the market after doubts on capabilities to meet the standards [7].

C. Sampling and Testing

Under compliance enforcement, there are issues with standards, sampling, testing and the punitive measures. Some of the Administrations have been advocating for stricter standards than that of IMO. The Phase 2 standards the United States Coast Guard (USCG) demand close to ‘zero organism’ in discharges but such levels are not achievable with the current technologies [8]. Table I in Appendix compares the IMO standards with the USCG standards.

Stricter standards would reduce the risks but threshold limits have to be established empirically [2]. Reference [9] had suggested that D2 stipulations on bacteria may be revised comparing the background populations in discharge areas including other input sources (sewerage etc.).

During inspections for compliance monitoring and enforcement, two levels of tests are recommended. The first will be an indicative analysis which has to be carried out quickly by a direct or indirect measurement. The methods would include naked eye counting, microscopy, photometry etc.

The next level of detailed analysis will be a complex process as it demands an estimation of viable organisms to be compared with the D2 standards. For organism size classes >50µm, microscopic examinations might do but for microorganisms of lesser size classes (bacteria etc.), expensive test like flow cytometry etc., would be required.

Sampling itself appears to be a complex process. The Guidelines recommend samples to be drawn from the discharge line. Grab sampling (from ballast tanks) are recommended only for indicative analysis. Presently, two sampling methods are identified. The first protocol involves taking specific number of equal volumes over a period. The second one is a continuous sampling process. In this, flow integration is achieved for better representation by drawing small samples throughout the entire discharge period. This could be in specified time periods (say every 10 minutes) or repeatedly during the discharge period.

Withstanding the above complexities, simple, universal protocols are yet to be formulated. Apprehensions about sampling errors due to light induced effects inside tanks, samples being less representative etc., remain [8].

D. Non-Compliance and Punitive Measures

The IMO Guidelines do attempt to clarify various queries. The vessel status if the initial analysis by Post State Control (PSC) finds discharge above D2 standards, salinity measurement for exchange standards, extent of acceptance to visual analysis, volumes and time required for quick tests etc., are some issues which will require operational experience for further clarifications.

A serious concern is that the Convention recommends that sanctions be provided by the State under whose jurisdiction the violations are committed. This gives scope for varying interpretations resulting in punitive sanctions with varying intensity (fines to detentions etc.). Some Administrations have stricter codes and this would be a matter of concern for both the ship owner and the sea farer.

III. BWM AND THE SHIP OWNER

For the ship owner, the primary concern relates to the choice of the BWT system for fitting on board. The voyages, ballast volumes and rates etc., will vary with the type of vessel and any BWT system might not suit any type of ship. Guidelines from Classification Societies are available but when the Convention gets ratified, there are anxieties if the industry will be able to meet the demand. From the projected capacities of 11011 units per year, the industry appears well geared to meet the requirements of vessels [8] in the range of >5000m^3 (43.8%) ballast capacities which are the maximum [10].

The next concern is the cost. On an average, a treatment system for 200m^3/h would cost US$298444. A system catering for 1000m^3/h would average about US$877500, while the installation costs etc., would be additional [8]. The operational costs of systems are also considerable, especially on systems employing active substances.

Other concerns relate to compliance enforcement. Non-consistent application of sanctions (*ibid*) and varying requirements are going to be causes for non-planned expenses. For example, the Australian requirements demand that if a vessel repeatedly fails to meet the discharge standards, it will be asked to employ independent surveyors to certify that no high-risk ballast waters have been discharged. Such surveys are required to be carried out on arrival and departure at every Australian port of call.

IV. BWM and the Seafarer

One year after the ratification, the Convention comes into effect. Ships under the flags who are party to the Convention, and ships entering their jurisdiction will be subject to compliance. In general, the Convention will apply to ships >400GT [1].

After the ratification, vessels will need to be certified and a BWM Plan, Ballast Water Record Book and a BWM Certificate will be the required documentation for compliance. Currently, the BWE operations are required to be documented. The BWM Plan must include the implementation scheme, safety measures, reporting procedures, methods of residue disposals etc. The operations must be well documented in the Ballast water Record Book. Fig. 2 shows the entries required in the Record book.

Ballast operations

- Ballast taken on board
- Ballast circulated or treated
- Ballast discharged into sea
- Ballast discharged to reception facilities
- Ballast accidentally taken on board
- Ballast accidentally discharged
- When no BWE or BWT was carried out as per Regulations

Specific information for discharges

- Date, time and location or latitude/longitude
- Estimated volume discharged and
- remaining volume
- Whether approved BWM procedures were followed and general remarks
- Signature of Officer in charge

Every completed page to be signed by the Master

Fig. 2 Information required in Ballast water Record Book

The primary issue with the seafarer will be the training required on the shipboard BWT system. Every type of ship is likely to have different type of treatment system. The ship board personnel at management, operational and support levels have to be not only knowledgeable about operating the systems but also must understand the methods. BWT systems are broadly divided under physical and chemical methods, but are invariably employed as a combination of methods [11].

While operating the systems employing active substances, the seafarer will be the most exposed and affected by the ingredients and the byproducts as compared with the PSC personnel. The potential for exposure is present during ballasting, deballasting, storage, treatment, calibration, sampling, testing and tank inspections [12].

The next concern is on sampling and testing. The tests required are purposefully biological and the sampling protocols will be aligned to get the best representative results for the organism standards. The responsibility of compliance monitoring lies with the Administration but awareness of sampling and testing procedures is necessary for the ship board personnel. It has been emphasized that quick and convenient compliance control tests for personnel without biological training need to be developed [13]. This will apply to the shore based PSC also, who monitors compliance.

V. Need for a Sustainable BWM

A. Innovations and Issues

In the regular scheme of support measures, Risk Assessment (RA) strategies are seen as a major support measure for decision making. Species specific and environmental similarity methods etc., can lead to exemptions from treatment and for allowing free discharges. Though there are many developed RA approaches and many being researched upon, it will take time before these approaches are integrated effectively with BWM. The reason for this is the lack of comprehensive data [8].

On the design front, innovative solutions such as fresh water ballast, optimised designs for ballast ship structure, natural BWE and ballast free ship [14], [15] have been investigated**.** Other examples include new hull designs, longitudinal ballast trunk, seldom-discharge designs, ship buoyancy control (flushing/controlling tank waters without pumping etc.,) as also solid ballast options [16]. Better BWE practices and incentives to improve BWM have also been discussed [8]. While most of the solutions need further investigations, many are suitable only for certain class and type of vessels.

In the recently concluded MEPC sitting of the IMO, it was urged that amendments to the Guidelines for approval of ballast water management systems (G8) is effected. The concerns expressed lack of confidence in the type approval testing procedures. There was also support for a study on the Ballast water performance standards (D2). Another serious concern was regarding the documentation of adverse effects of systems where chemicals are employed for treatment. Information on by products from active substances and health effects are lacking [12].

As seen from above discussions, the BWM issues with major control and support measures are yet to be resolved. But the present trend shows that treatment will be the major recourse for effective BWM.

B. Sustainable Solutions

An ideal solution for BWM would be to build ships with no ballast requirement. This could be possible for a certain range of capacities, whereas most merchant vessel will need to carry ballast for stability conditions. IMO's requirements for the BWM systems are that they should be safe for the crew, environmentally acceptable, practical, cost effective and biologically efficient. The present systems satisfy these; however, the intensity is arguable. For example, systems employing chemicals have issues related to crew safety and environmental acceptance. Economics of all treatment systems are discouraging since all are expensive. All systems invariably require additional space and retrofitting will also be at a high cost for the ship owner.

A sustainable solution would be to facilitate reuse of treated waters. Extending the BWM to shore based levels with reception and treatment facilities would be favorable. Compliance monitoring for the Administration, need for training of sea farers on new technologies, operating costs for the ship owners are issues which can be addressed with shore based BWM.

In the 66th session of MEPC meeting, port based treatment system (referred to as BWTBoat) was proposed. The floating facility included the treatment unit for treating the ballast prior discharge. Ships can receive treated waters also from the BWTBoat.

Control of sediments also would be easier [17] and new jobs could be created [18] if such shore based solutions are adopted. Sustainable treatment solutions must be pursued while information on species, RAs and treatment methods are collected. Heat treatment based on shipboard waste heat in combination with other methods would be one such method. For certain class of vessels such as tankers, waste heat harvesting will be beneficial. Reference [19] had analyzed heat availability on board an operational tanker and had proposed a sustainable system [20]. Fig. 3 shows the schematic layout of the system. The system harvests not only the heat from the engine cooling water but also from the other low temperature systems, steam systems and the exhaust gases of the engine. Sea water from ship's systems will be routed through the microfiltration modules, the heat exchanger and the supplementary treatment unit. The supplementary unit can be a UV based unit or a system employing a proven technology. The economics of such a system would fare well in the long run.

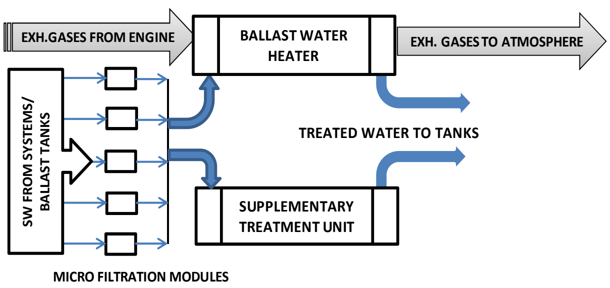

Fig. 3 Schematic layout of waste heat based system

VI. Conclusion

The environmental problem of AIS is complex unlike the other causes of marine pollution such as oils, chemicals etc. The BWM scenario is seen to be still evolving. While data for effective decision making are lacking, experience on use of treatment systems is yet to be realized. The ranges of issues encompass and are interlinked with the three major entities of Administration, ship owner and the seafarer. It would be prudent to orient solutions towards sustainability lest corrections become difficult and damages irreversible.

Appendix

TABLE I
Comparison of Ballast Water Performance Standards

Organism Size Class	USCG Phase 1	USCG Phase 2	IMO D2
Organisms ≥ 50 μm in minimum dimension	<10cells/m^3	0.01cells/m^3	<10cells/m^3
Organisms 10 – 50 μm in minimum dimension	<10cells/ml	0.01cells/ml	<10cells/ml
Bacteria	No limit	10/ml	
Viruses	No limit	100/ml	
Escherichia coli	<250cfu/100ml		<250cfu/100ml
Intestinal enterococci	<100cfu/100ml		<100cfu/100ml
Toxicogenic *Vibrio cholerae*	<1cfu/100ml		<1cfu/100 ml or <1cfu/gram wet weight zoological samples

cfu: Colony Forming Unit. A measure of viable bacteria numbers;
μm: One millionth of a meter

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