Overall Conclusions on the Ballast Water Issue and Its Management Options

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Abstract Ballast water management was demonstrated to be a complex issue, hence there are no simple solutions. The BWM Convention was adopted to support globally a uniform approach to prevent harmful aquatic organisms and pathogens to be further spread around the world by ballast water and sediment releases, considering the aspects of safe and efficient operations of shipping, while at the same time providing for the protection of natural environments, human health, property and resources. The conclusions and the current state of knowledge is summarized here and presented thematically sorted as per the book chapters. The overall final conclusions are presented at the end including an outlook highlighting future ballast water management related issues which need to be solved.

Keywords Ballast water • Harmful aquatic organisms and pathogens • Invasive species • Transfer • Ballast water management • Ballast water risk assessment • Ballast water management decision support system

Vessels and Ballast Water

When a vessel is not fully laden, i.e., a situation when she is not at her maximum allowed draft, additional weight is required to compensate for the increased buoyancy in order to provide for the vessel's seaworthiness. This implies that not only commercial vessels, but also other vessels use ballast water to provide for adequate seaworthiness. Even when a vessel is fully laden ballast water operations may be needed due to a non-equal distribution of weights on the vessel. Other dynamic factors may also require ballast water operations, such as weather and sea conditions

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on the route, an approach to shallow waters, and the consumption of fuel during the voyage. As a result, vessels fundamentally rely on ballast water for safe operations as a function of their design and construction.

Transfer of Organisms via Ballast Water

Many ballast water studies conducted in different parts of the world proved that ships substantially facilitate the transfer of aquatic organisms across natural barriers. Almost all species types have been found in ballast water samples ranging from unicellular algae, macroalgae, invertebrates to fish. It has also been confirmed that human pathogens are being transferred with ship's ballast water and at least every 9 weeks a new species is found along the coasts of ICES member countries, which includes secondary species introductions. Voyage length critically affects the survival rate of organisms in ballast water. However, the organisms can survive in ballast water for a relatively long time. Some algae, in particular dinoflagellates, can form cysts which sink to the ballast water sediment and may remain viable for several years. There are also known cases when organisms have reproduced and expanded their population inside a tank so that a single ballast water discharge from a ship can be potentially threatening.

One might think that ballast water was moved with ships since more than 100 years and all species which may become ballast water transported have reached the areas they can colonise, but this is not the case. Studies have shown that the number of new non-indigenous species records is increasing since the last 50 years. This can also be due to the focus of scientists on this subject starting at that time and because of intensified research especially over the last two decades. The increase of newly found non-indigenous species by ballast water since the last 50 years may also be related to ever increasing ship speed and sizes. With increased speed the unfavourable conditions an organism is exposed to inside a ballast tank during transit get shorter thereby increasing the en-route survival potential. With increasing vessel size ballast tanks also tend to get bigger, which may further support organism survival due to longer lasting favourable abiotic water conditions.

In short, many of the most negatively impacting species have arrived in ballast tanks which triggered the interest to develop globally applicable organisms transfer preventing measures, i.e., the *International Convention for the Control and Management of Ships' Ballast Water and Sediments* (BWM Convention).

Ballast Water Management Policy

Due to the lack of implemented, internationally agreed ballast water management standards, national BWM requirements arose. As shipping is a truly global business, regionally or nationally different standards are a disadvantage and globally uniform rules are essential to harmonise political, institutional and geographical heterogeneity regarding BWM. This aspect triggered the International Maritime Organization (IMO) mandate to address the ballast water problem originally. Subsequently IMO worked on the preparation of the BWM Convention, which was adopted in 2004, however it is not yet in force.

In light of this different national and regional BWM requirements continued to be implemented to protect the coastal waters from introductions of HAOP as the countries along these regions saw a need to implement such (sometimes voluntary) BWM requirements even before the BWM Convention enters into force. In most occasions, these regional initiatives follow exactly the requirements as set in the BWM Convention, but they just apply earlier. However, to our knowledge only the USA adopted BWM requirements which include D-2 standard related requirements and more stringent numerical standards are also considered. Upon entry into force of the BWM Convention many of these national and regional requirements are in most cases expected to be replaced by the BWM Convention requirements.

Ballast Water Management Convention

Agreements reached on a global level usually represent a combination of significant compromises coupled with action in the face of limited knowledge – and the BWM Convention is not an exception. During the BWM Convention negotiations, many issues were subject of controversial discussions and in certain cases it was extremely hard to reach a consensus, but when dealing with shipping we believe that solutions to an environmental problem should be sought at a global scale.

Although the movement of non-indigenous species usually receive predominant attention, the BWM Convention addresses all species, i.e. cryptogenic species and harmful native species are also included as IMO uses the term “Harmful Aquatic Organisms and Pathogens” (HAOP).

All IMO Conventions, Codes, Protocols etc., are written for ships involved in international voyages through international waters and may be adopted by states for domestic implementation. This Convention protects the coastal environments, mainly up to 50 NM with port State and flag state requirements relating to HAOP being discharged via ballast water into the receiving ports/areas. However, ballast water discharge can also affect international waters especially when ballast water is exchanged “on the high seas” according to the D-1 standard. The D-2 standard however relates to any discharge of ballast water from a vessel regardless of its location. The move to a discharge standard provides protection to high seas as well as coastal regions of the world’s oceans and seas.

A country considering to become a Party to the BWM Convention must make resources available to ensure that the obligations resting on the country are ensured and not underestimated. The implementation of this Convention may involve significant costs for the shipping industry, e.g., to install and operate BWMS. However, we believe that an appropriate cost/benefit analysis would reveal that funds used to achieve the aims of the BWM Convention would be well spent, assuming that new biological invasions showing economic impacts are considerably reduced, and especially when considering the essentially important environment and human health protection.

The BWM Convention will enter into force 12 months after the date on which more than 30 states, with combined merchant fleets not less than 35 % of the gross tonnage of the world's merchant shipping, have signed this Convention. As of December 2013, 38 states ratified the BWM Convention, representing 30.38 % of the world merchant shipping gross tonnage (for an update visit Status of Conventions at www.imo.org). Several expert fora assume that the entry into force of the BWM Convention may occur in 2015 or 2016.

Ballast Water Management Systems

The development of ballast water management system (BWMS) and especially their efficiency is very important for an effective prevention of the transfer of harmful aquatic organisms and pathogens across natural barriers. The BWMS review conducted has shown that there are very good perspectives to equip vessels with BWMS as certified BWMS are available. However the BWM Convention requiring their installation is not yet into force, and there are no other binding regional or national requirements like the D-2 standard applying today that would force vessels to install BWMS. However, in the USA BWM standards start to become into effect according to the Vessel General Permit (VGP) requirements starting in December 2013. This includes avoidance areas for ballast water uptake, cleaning of ballast tanks regularly to remove sediments in mid-ocean or under controlled arrangements in a port, or at a dry dock and minimizing the discharge of ballast water essential for vessel operations while in the waters subject to the VGP. The implementation schedule for the first US numerical interim BWM standards starts in 2016.

More than 100 BWMS were identified and they use different treatment technologies mostly in combination to achieve required efficiency over a large variety of ballast water flow rates. BWMS are in different development stages, but more than 30 of them were already type approved by responsible authorities. This makes certified systems available for sales to the shipping industry, however some uncertainty remains if the BWMS production capacities will be able to accommodate the installation needs of the shipping industry over certain short periods after the BWM Convention entry into force. Furthermore, shipyards installation capacities may become a bottleneck to meet the demand. This is a fast developing field as the interest is triggered by a worldwide market of close to 70,000 vessels that will need to be equipped with such systems which may result in a peak demand of 45 BWMS to be installed per day.

We believe that it would be very important for the industry to grab the impetus of this moment and be involved in the development of the BWMS, as the economic perspectives of the global shipping market are very attractive. Furthermore, the involvement of administrations in the certification processes is also important to support a fast development and to ensure the performance quality and reliability of certified BWMS, and hence also better protect the world's oceans and seas, human health, property and resources from the transfer of harmful aquatic organisms and pathogens.

To meet the D-2 standard it may also be considered necessary to combine BWE and ballast water treatment until BWMS become more efficient. By doing so, the efficacy of existing BWMS may be enhanced when the ballast water taken onboard is treated during the exchange.

Risk Assessment

There are two fundamentally different implementation approaches of the BWM Convention, the selective and the blanket approach. The selective approach means that appropriate BWM measures are required depending on different risk levels posed by the intended ballast water discharge. The level of risk is a result of a risk assessment (RA), and the BWM measures are then adapted to the RA result and the acceptance of certain risks. Base on low level risk, an acceptable risk, under G7 Guidelines conditions vessels may be also exempted from BWM requirements up to 5 years, subject to renewal. On the other side, when unacceptable or even extreme risks are identified, BWM is required and some additional measures may need to be implemented.

RA may also support port State control actions. When high risk ballast water is being planned for discharge, a port State authority (PSA) may be interested to ascertain if all necessary BWM measures were undertaken properly, and that there was no failure in the BWM process. On the other side, when a vessel may not be able to comply with basic BWM requirements or was found non-compliant by port State control (PSC), but RA results in low risk level, in such a case PSA may have grounds to allow a vessel to discharge unmanaged ballast water, as this would be understood that such ballast water is not posing a threat to harm the environment, human health, property and resources. This may be a very important point in regards of the Articles 9 and 10 of the BWM Convention, which otherwise require PSA not to let the vessel that was found non-compliant to discharge ballast water which presents a threat of harm to the environment, human health, property or resources.

Reliability of environmental and biological data needed to conduct RA for BWM purposes was found to be crucial, what is in line with the precautionary approach when RA relates to environmental and human health protection. If there is no recent data available about the possible presence of HAOP in ports or areas where ballast water is being loaded or discharged, no species-specific and species' biogeographical RA can be conducted. To ensure biological data reliability, port baseline surveys should be undertaken, and as additional species may be introduced through time, regular monitoring programmes need to be established. When undertaking port baselines surveys, a harmonized approach for the sampling standards and protocols is needed so that all studies generate reliable and comparable results. In this process the frequency of studies, the habitats to be included, i.e., plankton, benthos, fouling, the number of sampling stations, and the availability of taxonomic expertise would need to be considered. If environmental matching RA results in acceptable low risk, no biological data is needed.

Ballast Water Sampling and Sample Processing

Many different ballast water sampling (BWS) methods and equipment have been used for different BWS purposes. Shipboard sampling is also conducted for BWMS testing for type approval. Hence, BWS methods for testing BWMS actually exist, and these have been approved by different national responsible authorities. However, studies have shown that BWS results may be biased by different sampling processes because of, e.g., patchy distribution of organisms in tanks, die-off of organisms during sampling etc. As there is still no commonly agreed BWS methodology or approach, this may impact representative sampling, and certain vessels may be found in compliance with BWM requirements in one port, but not in another due to different sampling methods and approaches chosen.

BWS studies have shown that different methods and sampling equipment may be used for different sampling goals, e.g., sampling for D-1 or D-2 standards, indicative or detailed sampling. Sampling methods and equipment also depend on ballast water access points, i.e., in-tank via manholes, sounding pipes or air vents, or in-line installed sampling points, and on the target groups of organisms, i.e., organisms greater than or equal to 50 μm in minimum dimension, organisms less than 50 μm and greater than or equal to 10 μm in minimum dimension, and indicator microbes.

Sampling inaccuracy remains a significant issue and it may therefore be easier to prove non-compliance rather than compliance to the D-2 standard. From a legal and biological perspective, proving non-compliance is easier and more defensible.

It is of prime importance to consider the appropriate BWS approach for compliance monitoring and enforcement (CME) according to the BWM Convention. The BWS methods described in the chapter "Ballast Water Sampling and Sample Analysis for Compliance Control" were extensively used on board vessels to test BWMS to proof compliance especially with the D-2 standard, and these methods were scientifically validated by additional tests and studies. These BWS methods have also shown to be relatively simple, cost effective and they are generally applicable on all vessel types and in all geographic regions. With this these BWS methods and recommendations may result in a workable, equitable and pragmatic solution to ease port State CME efforts, and to support the entry into force and efficient implementation of the BWM Convention. However, it is also believed that the developed sampling methods and approaches can be improved further, which highlights the need of future work on this subject.

There are two approaches to analyse ballast water samples to proof compliance with BWM requirements, i.e., the samples may be analysed indicatively or in detail. A comprehensive review of sample processing technology, conducted by the authors, revealed that organism detection technologies that enable both an indicative and detailed inspection of ballast water samples are already available today. This conclusion was also supported by our tests conducted on board of commercial vessels to evaluate the suitability of such technologies for practical work by PSC. In summary, for an indicative sample analysis, it is recommended to use Pulse-Amplitude Modulated (PAM) fluorometry to check for viable phytoplankton, use enzyme-chemistry for bacteria analysis and a stereomicroscope for the analysis of the zooplankton organisms above 50 μm in minimum dimension. It should be noted that the PAM method does not deliver organism counts, but it gives a semi-quantitative measurement so that the higher the reading of the instruments is, the higher is the viable biological content. Enzyme-chemistry for bacteria gives a presence/absence indication, but cannot evaluate colony forming units as required by the D-2 standard. However, the presence or absence of the indicator microbes are to be taken as an indication that the BWM method used was successful or not.

The instruments for indicative analysis referred to above are portable and, with the exception of the microscope, of hand-held design and deliver results possibly in less than 10 min so that PSC could check for compliance already on board of the inspected vessels. However, a certain training level is needed to use these organism detection tools that a PSC officer can operate the tools.

For a detailed sample analysis, the recommended methods are more cumbersome and include flow-cytometry and epifluorescence microscopy for the analysis of phytoplankton, with a viability test using stains. Zooplankton should be analysed by a microscope either using gentle poking or a stain to check the organism viability. For bacteria analysis it is recommended to use selective media and it seems that an incubation time of at least 48 h is needed to proof compliance with the D-2 standard so that these results may only become available when the vessel has already left the port. In these cases PSC may keep record of such a vessel for a future inspection of the vessel should she call for this port again or notify the next port of call. The sample processing methods for a detailed analysis are not portable and require a high experience level of a trained biologist so that the samples either need to be brought to a laboratory for subsequent analysis or a van may be equipped with these methods and driven to the port for a sample analysis on the pier.

Final Conclusions

Noting the problems caused by unmanaged ballast water movements naval architects considered to design vessels which would not require the use of water as ballast. Other attempts to solve the problem included a vessel design with continuous flow through of ballast water. However, all alternative ballast concepts so far did not reach a commercially viable level so that the use of ballast water in segregated ballast tanks and/or in cargo holds seems to be the only practicable ballast method today.

In the absence of the globally applicable BWM requirements of the BWM Convention, some countries and regions require BWM already today. Most of these initiatives are based upon BWE as BWMS are largely not installed on vessels. Although more than 30 BWMS are type approved already and annually this number increases, only few vessel owners started to install BWMS on their vessels. One of the reasons for this may be the (substantial) costs involved and the unclarity when the BWM Convention will enter into force.

Countries that wish to protect their seas from the introduction of HAOP via ballast water are confronted with the challenge of balancing the efficiency of BWM measures and the safety and higher costs in the shipping industry as the result of management efforts. For these reasons, the ‘blanket approach’ of requiring all vessels to undertake BWM is unreasonable in many cases. Alternatively, the ‘selective approach’ allows for the adjustment of the intensity of BWM measures to each vessel and voyage-specific RA, thus both reducing safety risks and costs to the shipping industry, while simultaneously allowing for improved environmental, human health, property and resources protection. However, a selective approach requires more extensive data gathering for port States, more data and reporting requirements for vessels, and may require higher skills and knowledge from port State personnel. All this can be overcome with an appropriate BWM decision support system (DSS).

A DSS is a supporting tool enhancing the decision-making process that uses a combination of models, analytical techniques, and information retrieval to help develop and evaluate appropriate decision alternatives. DSSs today are widely supporting decision-making processes in business, social programs, medicine, policy, games, information technologies, transport, and are major building blocks in environmental management and science. Decision-makers are frequently faced with taking decisions on very complex issues requiring a large data input, and forced to do so rapidly. This is also the case with the BWM issue. DSS helps decision makers to reduce uncertainties, as well as ease and speed-up the decision process.

The BWM DSS model presented in this book was developed in line with the BWM Convention and related guidelines, and further tested using real condition data from the Port of Koper (Slovenia). The geographical, hydrological, meteorological, important resources, shipping patterns, shipping safety and regulatory regimes were considered in the DSS model and analysed in relation with the effectiveness of the BWM. The results show some important advantages and effectiveness of the selective approach supported by the presented BWM DSS model, especially regarding problems that arise from proximity to the shore and limited water depths on existing vessel routes, as well as the length of voyages, demonstrated to be the main limiting factors for effective BWE. In such cases, implementing the blanket approach would practically mean that vessels would need to ‘do nothing’ to be compliant with the BWM Convention, until the D-2 standard enters into force and BWMSs are installed on vessels. The blanket approach, supported with a designated BWEA with requiring all vessels to use it as an additional measure, shows some potential, especially because it is relatively simple to implement. However, different vessels would be unnecessarily exposed to additional BWM measures. BWM DSS shows also different advantages when the D-2 standard will be in place, especially to support compliance monitoring and enforcement, and in cases when a BWM was not conducted satisfactory.

The BWM DSS model was designed to be transparent, adaptable and reviewable, if necessary. This yields the potential to be used in different parts of the world for more effective prevention of HAOP transfers via ballast waters, and concurrently to the sustainable development of the shipping industry.

Although some BWM related facts are unquestionable, issues to be clarified/solved remain. These may include:

- Our experience resulted in a sampling approach which we believe is representative of the ballast water discharged. However, future work on this subject may result in changes to this suggested sampling approach, which would need to be validated.
- Sample processing methods are available for both an indicative and a detailed analysis. Organism detection tool manufacturers have recognised the special needs to proof compliance with BWM approaches and currently new organism detection tools are under development. A testing and validation phase of these systems is required.
- Appropriate training of PSC officers is needed to address all implementation needs of the BWM Convention.
- Do the current BWM Convention requirements substantially reduce the number of new HAOP introductions or are stricter standards needed? However, this may be very difficult to document as other organism transport vectors may overlap with ballast water so that a clear identification of the responsible vector is impossible.
- Can BWMS systems be cost-efficiently enhanced in their performance to even achieve better protection, e.g., USA ballast water performance standards? Is a zero detectable organism discharge standard achievable?
- Sufficiently developed RA-based exemptions from BWM requirements are needed to address all requirements of the G7 Guidelines and the precautionary principle not to undermine the BWM Convention purpose.
- Self-funding mechanisms, such as fees and penalties, may be developed to support the implementation of all BWM Convention needs.
- The applied CME measures should be harmonised in minimum on a regional level to avoid that vessels are compliant in one port, but not in another, because different methods and approaches are implemented to proof compliance.
- As agreed by IMO, the BWM Convention and its guidelines may have to be reviewed as new knowledge developed and experience was gained. However, such a review process may only be initiated after its entry into force.

By summarizing BWM related aspects from many disciplines and by providing insights of latest research results and regulatory aspects we hope that this book clarified many ballast water issues. We also believe that the proposed RA and DSS approaches will reduce the BWM burden of ships by providing at the same time an adequate protection from HAOP introductions by ballast water.

Although some issues raised above are critical, our view is that the BWM Convention should enter into force soon to reduce the risks of future ballast water mediated species introductions.