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Critical review of the IMO international convention on the management of ships' ballast water and sediments

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Abstract

The International Maritime Organization (IMO), the United Nations body which administers the international regulatory regime for shipping, noted the negative impact of non-indigenous organisms transported in the ballast water of ships already in the early 1970s. Consequently, measures were taken with the aim to minimize ballast water mediated species invasions through IMO Marine Environmental Protection Committee (MEPC) Resolutions. As a result of long-term IMO efforts, it was determined that an international convention would best meet the needs of the global community, hence the *International Convention for the Control and Management of Ships' Ballast Water and Sediments* was adopted in a Diplomatic Conference in 2004 and is now open for signature by IMO Member States. This very complex (and by no means "simple") Convention aims to reduce the transfer and subsequent impact of aquatic organisms in the ballast water and sediment of ships by acting to reduce the load of these organisms in discharged ballast water. A set of 15 guidelines provides technical guidance for the implementation of the Convention principles. This review considers critical aspects of this Convention and selected guidelines seen from perspectives of biological, shipping and regulatory concerns.

Keywords: Ballast water; Sediments; Shipping; Ballast water management convention

1. Introduction

The first biological study that suspected shipping as a vector of non-native species introductions was published in the early 1900s where Ostenfeld (1908) reported the Asian phytoplankton species *Odontella* (*Biddulphia*) *sinensis* after a mass occurrence in the North Sea in 1903.

The first Ballast Water Sampling study was carried out 70 years later by Medcof (1975) followed by several others (e.g. Carlton, 1985; Williams et al., 1988; Hallegraeff and Bolch, 1991; Locke et al., 1991; Gollasch, 1996; Lucas et al., 1999; David and Perkovic, 2004). Various studies have reported large numbers and densities of species in ballast water samples. A summary of European shipping studies revealed that

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more than 1000 species are transported in the ballast water of ships. Taxa found range from unicellular algae to fish (e.g. Gollasch et al., 2002 and references therein, David et al., 2007).

Numerous regulations were developed and concerns had previously been raised on the likelihood of ballast sediments bringing diseases into port environments. The concerns of the global community of the negative impact of introduced species were first raised with the International Maritime Organization (IMO) in the early 1970s and the IMO, through its Marine Environment Protection Committee (MEPC), started to develop an instrument to cope with this problem in the early 1990s. As a first effort, the *International Guidelines for Preventing the Introduction of Unwanted Aquatic Organisms and Pathogens from Ships Ballast Water and Sediment Discharges* were adopted at the 31st Session of MEPC in July 1991. In 1993, the IMO Assembly adopted these guidelines by Resolution A.774(18). It became clear shortly thereafter that species' movements in ballast water cannot be completely *prevented* and it was agreed that work on this matter should be continued at IMO to *minimize* the transfer of organisms in ballast water. As a consequence, in 1997, the *Guidelines for the Control and Management of Ships' Ballast Water to Minimize the Transfer of Harmful Aquatic Organisms and Pathogens* were adopted by Resolution A.868(20), which replaced Resolution A.774(18).

The importance of biological invasions was brought into greater focus as several devastating introductions in many countries occurred (e.g. the Atlantic comb jelly, *Mnemiopsys leidyi*, in the Black Sea; the zebra mussel, *Dreissena polymorpha*, in the North American Great Lakes; the Northern Pacific seastar, *Asterias amurensis,* in Australia) and given the limitations of the IMO Guidelines, which were only voluntary, it was recommended that IMO work towards a mandatory, legally-binding international instrument to address this problem. Consequently the *International Convention for the Control and Management of Ships' Ballast Water and Sediments* (hereafter the Convention) was prepared and was adopted in a Diplomatic Conference in 2004 (IMO, 2004). This Convention aims to prevent, minimize and ultimately eliminate the risks to the environment, human health, property and resources arising from the transfer of harmful aquatic organisms and pathogens via ships' ballast waters.

This Convention shall enter into force 12 months after the date on which not less than 30 States, the combined merchant fleets of which constitute not less than 35% of the gross tonnage of the world's merchant shipping, have signed the Convention. As of July 2006, six countries have ratified or acceded to the Convention with less than 1% of the world's merchant shipping gross tonnage (for an update visit ''Status of Conventions'' at http://www.imo.org).

Table 1
Guidelines to the Convention and their development status

No	Title	Work progress
G 1	Guideline for Sediment Reception Facilities	Adopted at MEPC 55 (October 2006)
G 2	**Guideline for Ballast Water Sampling**	**FSI 14 (June 2006) & BLG 11 (April 2007), pending**
G 3	Guideline for Ballast Water Management Equivalent Compliance	Adopted at MEPC 53 (July 2005)
G 4	Guidelines for Ballast Water Management and Development of Ballast Water Management Plans	Adopted at MEPC 53 (July 2005)
G 5	Guideline for Ballast Water Reception Facilities	Adopted at MEPC 55 (October 2006)
G 6	Guidelines for Ballast Water Exchange	Adopted at MEPC 53 (July 2005)
G 7	**Guidelines on Risk Assessments under Regulation A-4**	**BLG 11 (April 2007), pending**
G 8	Guidelines for the Approval of Ballast Water Management Systems	Adopted at MEPC 53 (July 2005)
G 9	Procedure for Approval of Ballast Water Management Systems that make use of Active Substances	Adopted at MEPC 53 (July 2005)
G 10	Guideline for Approval and Oversight of Prototype Ballast Water Treatment Technology Programmes	Adopted at MEPC 54 (March 2006)
G 11	Guideline for Ballast Water Exchange Design and Construction Standard	Adopted at MEPC 55 (October 2006)
G 12	Guidelines for Sediment Control on Ships	Adopted at MEPC 55 (October 2006)
G 13	**Guidelines for Additional Measures Including Emergency Situations**	**Recommended adoption at MEPC 56 (June 2007), pending**
G 14	Guidelines on Designation of Areas for Ballast Water Exchange	Adopted at MEPC 55 (October 2006)
G 15	**Guidelines for Port State Control**	**FSI 15 (June 2007), target completion date 2008, FSI 14/19), pending**

BLG: IMO Sub-Committee on Bulk, Liquid and Gases; FSI: IMO Sub-Committee on Flag State Implementation; MEPC: IMO Marine Environment Protection Committee. Guidelines formatted in bold are pending.

A set of 15 guidelines supports the uniform implementation of the Convention (Table 1) and provides technical guidance to support the implementation of the Convention principles. The majority of these guidelines have already been adopted or were adopted at the October 2006 meeting of MEPC. However, four guidelines need to be finalised, i.e. the *Guideline for Ballast Water Sampling* (G2) which outlines requirements for sampling ships for compliance control with the ballast water discharge standard as set forth in the Convention, the *Guidelines on Risk Assessment* (G7) aiming to allow Parties to exempt vessels from compliance with Ballast Water Management (BWM) requirements prior to discharge if an acceptably low risk can be discerned, *Guidelines for Additional Measures Including Emergency Situations* (G13) which gives guidance in case additional Ballast Water Management requirements other than stated in the Convention are requested, and the *Guidelines for Port State Control* (G15) with the purpose to harmonize Port State Control activities and to define criteria for a detailed inspection of the ship (Article 9 in the Convention).

The following acronyms are frequently used in this manuscript and mean

BWE	Ballast Water Exchange
BWM	Ballast Water Management
BWMS	Ballast Water Management Systems
BWTS	Ballast Water Treatment Systems
BWWG	Ballast Water Working Group
D-1	Ballast Water Exchange Standard
D-2	Ballast Water Performance Standard
IMO	International Maritime Organization
LME	Large Marine Ecosystems
MEPC	Marine Environment Protection Committee (of IMO)

2. Review of the IMO Ballast Water Management Convention and Guidelines thereto

Agreements reached on a global level usually represent a compromise—this Convention is not an exception. During the Convention negotiations many issues were controversial and in certain cases it proved extremely hard to reach agreement. The following review highlights certain aspects of the Convention and its Guidelines which are of concern to the authors who have participated in the development of the Convention and Guidelines as members of national delegations to the IMO MEPC Ballast Water Working Group. It should be noted however that this review is solely the view of the authors and does not necessarily reflect the views of their delegations.

The Convention consists of 22 Articles followed by five sections with Regulations. Two Appendices show standard formats regarding the issuance of the International Ballast Water Management Certificate as well as operational recording for reporting and verification, i.e. the Ballast Water Record Book.

Regulations for the control and management of ships' ballast water and sediments are presented in five sections:

- Section A: General provisions: Definitions, general applicability, exceptions, exemptions, equivalent compliance;
- Section B: Management and control requirements for ships: Ballast Water Management;
- Section C: Special requirements in certain areas;
- Section D: Standards for Ballast Water Management; and
- Section E: Survey and certification requirements for Ballast Water Management.

There are obligations to be met by all stakeholders including the ship, the Administrations (both in the capacity as Flag State as well as Port State and as the representative of a Party) and the IMO.

Standards for BWM are dealt with by the Convention in Regulations D-1 and D-2. The Convention introduces these two different protective regimes as a sequential "phase-in" implementation:

1. Regulation D-1 *Ballast Water Exchange Standard* requiring ships to exchange a minimum of 95% ballast water volume;
2. Regulation D-2 *Ballast Water Performance Standard* requires that the discharge of ballast water have organism concentrations below specified limits (see Section 2.4).

Eventually ships need to meet the more stringent Ballast Water Performance Standard. This standard will come into force (subject to ratification of the Convention) between 2009 and 2016, depending on the ballast water capacity and age of the ship. The phase-in of the two standards is shown in Fig. 1.

Critical aspects of the Conventions' Articles and Regulations are outlined in the following sections where we focus on selected Guidelines.

2.1. Ballast Water Exchange (G6)

In the absence of readily available full scale Ballast Water Treatment Systems (BWTS), it was suggested by

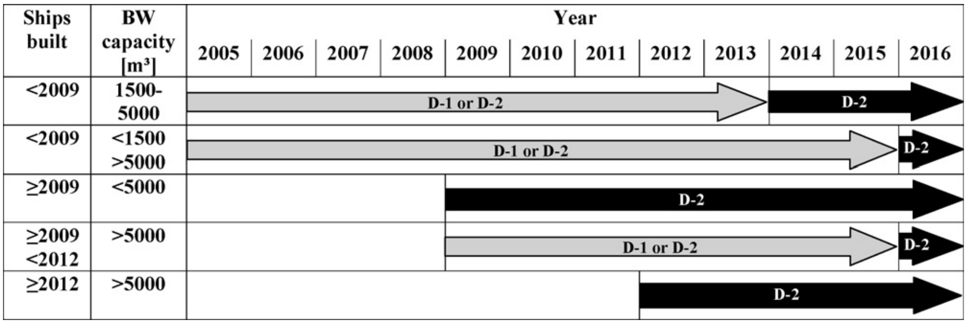

Fig. 1. Planned phase-in of the Convention standards regarding Ballast Water Exchange (Regulation D-1) and the more stringent Ballast Water Performance Standard (Regulation D-2). Modified after Gollasch (2004).

MEPC that the exchange of ballast water at sea may reduce the risk of species introductions. Most vessels are able to carry out Ballast Water Exchange (BWE) without needing extra pipework to be installed. BWE may be conducted by emptying and refilling tanks in sequence or by in-tank continuous flushing or pump through of ballast water (e.g. the dilution method).

According to the Convention, a ship shall whenever possible, undertake a BWE at least 200 nautical miles (nm) from the nearest land and in water depths of at least 200 m. When this is impossible, the BWE shall be conducted at least 50 nm from the nearest land and in water at least 200 m in depth. Further, a ship shall not be required to substantially deviate from its intended voyage, or delay the voyage, in order to comply with this particular requirement. In cases where the depth and distance requirements cannot be met, the port state(s) may designate BWE areas (see Section 2.2).

When planning to undertake BWE, some issues need to be considered:

- The total time required. The exchange operations on larger vessels may typically take 1–3 days;
- The location. Some shipping routes do not comply with the minimum distance from shore and depth requirements of the Convention;
- Safety implications. Safety is of paramount importance and on some vessels a safe BWE may only be undertaken under certain weather conditions or may not be undertaken at all.

The philosophy behind BWE is that coastal organisms when discharged at sea are unlikely to survive and that high sea organisms when pumped onboard during the water exchange will not likely survive when released in coastal regions. Further, it is well-established that organism densities are much lower in high sea areas compared to the coastal situation thereby reducing the risk of species introductions. However, shipping studies have shown that in certain instances after an exchange more organisms were found in the ballast water (e.g. Macdonald and Davidson, 1998; McCollin et al., 2001, this volume). This is especially the case when such water exchanges were undertaken in shallower seas or during high organism concentrations, such as algal blooms, on high seas.

Other limitations include that due to ballast tank design a certain volume of unpumpable water and sediments always remains in the tank on almost all ships. As a result a one time exchange of the ballast water will not be sufficient to reduce the organism load. IMO noted this and Regulation D-1 of the Convention requires at least a 95% water exchange which may be achieved by emptying and refilling of the tank or by pumping through three times the volume of the tank (Rigby and Hallegraeff, 1994). It should be noted that a 95% volumetric exchange of water may not always be equivalent to a 95% organism removal as the organisms are not homogeneously distributed in a tank (e.g. Murphy et al., 2002). However, under certain circumstances the 95% volumetric exchange may result in an even higher organism removal than 95%.

BWE is seen as an interim solution as several scientific studies have proven its limited effectiveness and the water depth and distance from shore requirements as set forth in the Convention cannot be met in many circumstances (e.g. intra-European shipping, domestic shipping of many countries). However, whenever possible and until BWTS become available, BWE should be undertaken. Provided safety permits, it is assumed that most vessels operating in oceanic voyages are enabled to undertake BWE.

2.2. Ballast Water Exchange Areas (G14)

Vessels operating in coastal shipping are not likely to meet the distance (200 nm or 50 nm distance from nearest land) and depth (200 m depth) requirements of the Convention. Further, routes may be too short to carry out complete BWE of all ballast tanks. Management options for those vessels may therefore be based on a selective approach i.e., the use of designated BWE areas or granting exemptions based on risk assessment (see Section 2.10).

In areas where the distance and depth requirements cannot be met the port state(s) may designate BWE areas. This is of particular importance in seas where shipping routes are relatively close to shore and/or depth requirements may not be met. These BWE areas should be selected in consultation with adjacent or other states, as appropriate. Any such designation should follow the principles of guideline G14.

The rationale for the designation of a BWE area is that it provides an area where ships can safely exchange ballast water as a risk reducing measure while minimising harmful environmental effects. However, the challenge is to identify areas that provide an acceptable risk reduction from a biological perspective. It is understood that (near-shore) exchange areas pose a higher risk of species introduction compared to mid-ocean exchange, but at the same time it may be preferred to use specially designated areas for BWE rather than to discharge unmanaged ballast water in a port or across the entire coastal zone.

Concerns have already been expressed that the designation of near-shore BWE areas may expose certain regions to additional ballast water discharges and this may pose a risk to those ballast water receiving environments. This is why these areas need to be selected very carefully. At best the area should have off-shore directed water currents and it should be as far from nearest the land and as deep as possible, free of pollution or invasive species (the Convention refers to *harmful aquatic organisms and pathogens*), hence providing for environmentally safe and effective BWE. On the other side, considering shipping aspects, the area needs to be designed as large as possible and as close as possible to existing shipping routes.

This in practice implies some difficulties especially for the designation of BWE areas in shallow seas (e.g. North Sea, Baltic Sea) or semi enclosed seas (e.g. Adriatic). Consideration should be given to the trade-offs between (a) additional ballast water discharges in such areas, (b) the dimension of the BWE area to allow full BWE of vessels and (c) to its location to avoid major deviations from their intended routes. However, vessels with bigger ballast water capacities may slow down when travelling through BWE areas to gather extra time to allow for a complete BWE or to exchange just the "critical" (i.e. assessed as highest risk) ballast water. They may also be required to deviate from their intended route to meet such BWE areas. A decision on the minimum management measure required should be taken according to the level of risk assessed (see Section 2.10).

Another problematic matter is that BWE areas should be biologically monitored frequently to document the presence/absence of introduced species. A worst case scenario may be that species become introduced and established in such an area and are rapidly spread due to the ongoing BWE activities of ships.

Europe faces a unique situation as some of the busiest ports are located in estuaries with brackish or even freshwater conditions (e.g. Antwerp, Hamburg and parts of Rotterdam). A high risk for a species introduction exists when freshwater organisms (e.g. the zebra mussel) are transported in ballast tanks between two freshwater ports which are separated by marine water conditions. The freshwater species would not likely be able to spread with their natural means between these freshwater ports as the higher saline water between them poses a migration barrier. In those instances a (nearshore) BWE in higher saline waters may be a risk reducing measure. However, some organisms show a very wide salinity tolerance, i.e. BWE will not completely eliminate the risk of species introductions.

BWE in such areas results in a risk reduction and may be used until efficient ballast water treatment technology is available. It is therefore proposed that ballast water taken onboard in a freshwater port should be exchanged in waters with higher salinity (even if close to the coast) provided that the voyage duration is sufficiently long to exchange the ballast water en-route completely in more haline water conditions.

2.3. Undue Delay and Deviation from Planned Route

One principle of the Convention is that ships should not be forced to deviate or be unduly delayed by any BWM requirement. The Convention provides the ship the right for compensation in cases where it has been unduly delayed. However, the term "undue delay" has never been clearly defined by IMO in relation to the Convention or other IMO applications.

The designation of BWE areas should not require *major* vessel deviation. However, a cost/benefit assessment, taking into account the costs caused by negative impacts of introduced species versus shipping costs for the re-routing, may reveal that a slight re-routing of vessels is acceptable. Similarly, if a risk assessment identifies a vessel as possibly an unacceptable risk, then cause has been established for delay and it is therefore not ‘‘undue’’. It may therefore be considered to request vessels to use specific routes even if it delays the ship a few hours. One example for acceptable re-routing of vessels is the oil exporting shipping route from northern Russia with large tankers originally operating very close (7–12 nm) to the Norwegian coast. Requests from the Norwegian coastguard for a more distant routing resulted in nearly all ships now operating not closer than 20–40 nm from the coast. However, this requirement was driven primarily by concerns regarding potential ship accidents resulting in major pollution of the Norwegian coast by oil, rather than BWE.

Vessels on their usual route from the Mediterranean to the North Sea and other North European ports are always closer than 200 nm distances from shore and barely outside 50 nm distances at 200 m depths when crossing the Bay of Biscay. Using a slightly more western route (i.e. less than 100 nm longer than the normal route) after passing Gibraltar when being bound for northern European ports (or in the other direction) may result in a few hours delay only, but at the same time enables BWE according to the IMO depth and distance requirements in the Atlantic Ocean west of Portugal and the Bay of Biscay (Dragsund et al., 2005).

2.4. Ballast Water Performance Standard

The Ballast Water Performance Standard as outlined in Regulation D-2 stipulates that ships meeting the requirements of the Convention must discharge:

- less than 10 viable organisms per cubic meter greater than or equal to 50 μm in minimum dimension, and
- less than 10 viable organisms per ml less than 50 μm in minimum dimension and greater than or equal to 10 μm in minimum dimension, and
- less than the following concentrations of indicator microbes, as a human health standard:
  - ○ Toxigenic *Vibrio cholerae* (serotypes O1 and O139) with less than 1 colony forming unit (cfu) per 100 ml or less than 1 cfu per 1 g (wet weight) of zooplankton samples,
  - ○ *Escherichia coli* less than 250 cfu per 100 ml, and
  - ○ intestinal *Enterococci* less than 100 cfu per 100 ml.

Several aspects of this standard formed the basis for significant discussion and continuing controversy at the IMO. The acceptable numbers of organisms and the method for determining size classes was debated, however few delegations brought the biological expertise necessary for in-session discussions. This compromise was attained through deliberations between views from various countries which ranged from a tolerable number of organisms above 50 μm in minimum dimension between 100 and 0.01 per cubic meter. The current version of the standard was acknowledged as a considerable reduction to the amount of organisms released in ballast water compared to untreated water or even that obtained by BWE.

It should be noted that the D-2 standard for organisms greater than or equal to 50 μm in minimum dimension and organisms less than 50 μm in minimum dimension and greater than or equal to 10 μm in minimum dimension refer to all organisms, not per species. As a result the individual species identification of organisms is not required for purposes of compliance testing.

Also of note is the incorporation of a discharge standard for target or ‘‘indicator’’ microbes with a human health impact. A number of delegation insisted on incorporating these standards in hopes of directing a strong signal to R&D interests. While current ballast water treatment technologies are unable to meet these standards, it may be possible to achieve these results through a combination of methods and those combinations are currently being tested.

However, noting that vessels carry up to 100,000 tonnes of ballast water or more, a high number of organisms may still be discharged in compliance with this Convention. Assuming that 10,000 tonnes of water are discharged, the acceptable organism concentration for individuals greater than or equal to 50 μm in minimum dimension is 100,000. The minimum organism number to establish a founder population in new regions is unknown, but we suspect that 100,000 individuals (although of different species) may not *eliminate* the risk of species introductions in all cases. Further, the D-2 standard does not address organisms below 10 μm (in minimum dimension), but a considerable number of species, including bloom forming harmful algae, are smaller than 10 μm (e.g. *Phaeocystis* spp., *Pfiesteria* spp. and *Chrysochromulina* spp.).

Another problematic aspect with the Convention is that the requirements of Regulation D-2 apply to vessels (i.e. the regulations reads ‘‘Ships . . . shall discharge less than . . .’’), not to treatment systems. As a result some uncertainty exists whether or not ships are in compliance with the D-2 standard even if the treatment systems water outflow (when pumping ballast water into the ballast tanks) meets the D-2 requirements as proven in land-based tests prior onboard installation and also after onboard installation. Regrowth of organisms may occur in the tank after treatment and also organisms remaining in the tank from the previous fillings may become re-suspended. Consequently, upon discharge, treated water may contain more organisms than acceptable although the treatment systems proved that the D-2 standard was met during water uptake. To ensure that ships ballast water discharges meet the D-2 standard it is therefore recommended to treat the ballast water during uptake *and* discharge and also to develop treatment technologies which exceed the standards set forth in the Convention. It should be noted that the D-2 Standard applies to *any* discharge from a vessel, regardless of location.

2.5. Ballast Water Reception Facilities (G5)

The BWE and treatment requirements in the Convention do not apply to ships intending to discharge ballast water to a (land-based) water reception facility. Such facilities should be designed according to guideline G5. However, there are no mandatory requirements in the Convention for a port to make available such facilities. In larger ports this may be problematic as additional pipework may need to be installed at each pier and also that (temporary) storage facilities for large volumes of water need to be available.

Today ships are lacking a (standardised) connection, i.e. relevant pipework, which would enable them to discharge ballast water to reception facilities. All tankers have standardized piping and manifolds for cargo transfers and the concept of standard fittings is embedded in ship design and construction so this could easily be achieved provided the cargo transfer pipes may be used for ballast water discharge. Hence, ships (other than tankers) planning to use this option will need to have additional equipment installed.

It was also discussed to design mobile reception facilities (e.g. a barge). We believe that this option is only applicable under very special circumstances, e.g. in ports with limited berths, such as in some oil exporting ports where only one or two ships may be moored alongside the facility at the same time.

The fact that major crude oil export ports, such as Valdez and Scarpa Flow have long (since 1970/80s) provided massive shore-based facilities for the reception and treatment of oily ballast from crude oil tankers—thereby proving that the engineering, pumping, storage, etc. of massive quantities of ballast from the world's largest ports is technically possible and economically viable within the operating cost structures of modern shipping and ports. Developing these concepts to include biological treatment to remove organisms from ballast is not likely to be any more challenging or less viable than the original development of these facilities—especially as technology has advanced.

Land-based facilities may also be used to provide biologically clean ballast water at the source ports, thereby preventing the problem at ballast water update.

2.6. The "Do Nothing Option" and the No Ballast Water Discharge Option

A number of scenarios exist whereby a vessel cannot meet the requirements of the Convention: if ships cannot meet the requirements for BWE or adverse weather conditions do not permit a water exchange in high seas; if the port state has not identified BWE areas or does not provide land-based Ballast Water Reception Facilities (or the ship is not equipped with the needed pipe work to connect to those facilities); and BWTS are unavailable for installation. In the absence of alternative options, the Convention allows ballast water discharge anywhere inside 50 nm from the nearest land. These ships are required to document why BWE was not carried out. This further highlights the need for appropriate BWTS.

For certain vessels it may be an option to minimise or avoid the discharge of ballast water. This is relevant for vessels carrying low density cargo (e.g. passenger vessels) or vessels normally only partly utilising their loading capacity, e.g. container vessels, RORO's, cruise vessels. The avoidance of ballast water discharges may be achieved through proper planning of BWM, e.g. by pumping the ballast water from one tank into another to compensate cargo operations.

In any case, it is imperative that the discharge is of the absolute minimum amount of ballast water necessary, even if the water was managed, as all management approaches reduce but do not eliminate the risk of introducing new species. An incentive in some form may trigger ships to focus on their loading policies in order to minimise the use of ballast discharges.

2.7. Approval of Ballast Water Management Systems (G8 and G9)

To ensure the uniform and proper application of the standards contained in the Convention, the G8 guideline provides the necessary framework for Approval of Ballast Water Management Systems (BWMS) to meet the D-2 standard. The core objectives of the G8 are summarised in the Convention as follows:

- define test and performance requirements for the approval of BWMS;
- assist Administrations in determining appropriate design, construction and operational parameters necessary for the approval of BWMS;
- provide a uniform interpretation and application of the requirements of Regulation D-3 (*Approval requirements for Ballast Water Management Systems*);
- provide guidance to equipment manufacturers and ship owners in determining the suitability of equipment to meet the requirements of the Convention; and
- assure that BWMS approved by Administrations are capable of achieving the standard of Regulation D-2 in land-based and shipboard evaluations.

Compared to other IMO type approval tests (e.g for ship-board oily-water separators or sewage treatment plants), this is a very comprehensive test procedure, which may involve a great deal of resources including man power, time, and last but not least, costs. To illustrate the difficulties arising from this test guideline, the following example is given: The IMO type approval for sewage treatment plants (according MARPOL 73/78 Annex IV), addresses four parameters (total suspended solids, biochemical oxygen demand, chemical oxygen demand, *Escherichia coli*). The tests may be carried out land based or ship-board. The duration of the tests is regularly 10 days. In contrast, the ballast water type approval tests according to the guideline G8 require both, *land-based tests* and *ship-board tests* and a test duration of at least 6 months. However, we believe that the relative impacts and costs of biological invasions versus ship-sourced sewage and the potential severity of the former relative to the latter may justify a more stringent and rigorous test procedure.

2.7.1. Land-based tests

The land-based tests are to be carried out at two different salinities (which should be separated by at least 10 PSU) under defined challenge water conditions. These include defined numbers of organisms and a defined water quality. In principle, there are three different ways to undertake land-based tests:

- at a single established test facility, where two different water qualities have to be available;
- at two different test facilities with suitable water qualities;
- on a barge that can be relocated to suitable test sites.

In any case, the tests address a variety of parameters including the biological efficacy (D-2 standard) measured after a retention time of the treated water of 5 days. A total of 10 valid test cycles are needed, resulting in a minimum duration of the land-based tests of 50 days.

As the review process of available ballast water treatment technologies at MEPC55 (October 2006) clearly demonstrated, the availability of suitable test facilities for land-based tests is a bottle neck for a timely availability of type approved BWMS. This problem is the reason why several states now have opened up for manufacturers to establish their own land-based test facilities. This will happen e.g. in Japan and Korea. As it may be suspected that each test facility is especially designed to fit the technology under consideration, such test facilities challenge the integrity of the test results even when independent laboratories are used for the analysis. Consequently, the need for standardised test procedures, organism viability assessments and inter-calibration discussed in the next paragraphs is even more relevant.

The land-based tests bear more challenges than just finding a suitable test location/institution. According to the guidelines, the samples should be analysed as soon as possible after sampling, and analysed live within 6 h or treated in such a way so as to ensure that proper analysis can be performed. The guideline also requires to take nine samples at day 0 (uptake of test water), i.e. three each before the treatment, after the treatment and from the control test. With all of the organisms and inorganic particles required in the challenge water, the preparation and analysis of an individual sample may take up to 3 h. By simple mathematics, this adds up to $9 \times 3 = 27$ working hours for the analysis. Consequently, a minimum of four highly skilled scientists have to be available, in order to perform the viability tests simultaneously to meet the 6 h time limit. This results not only in excessive costs, but also in an increase of the variability of the results due to individual counting errors, and a proper quality management as well as quality assurance becomes rather a challenge.

Alternatively, one can apply semi-automated counting methods, which are still under development. If the results obtained with these methods form a consensus for the evaluation of the biological efficacy, is still a matter of discussion given that if one test facility/institution applies one semi-automated method, while a second test facility/institution applies a different method the tests results may not be comparable. In order for these objectives to be met, cross-comparability of test systems must be agreed in advance of approvals.

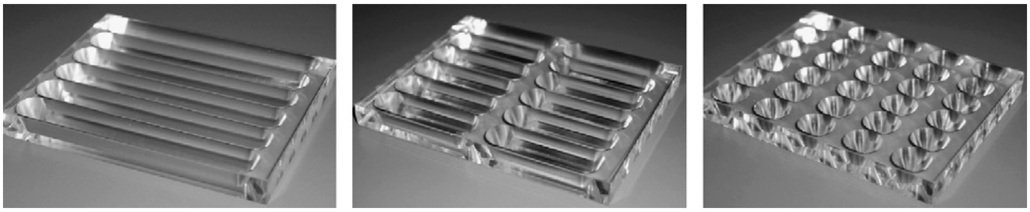

Fig. 2. Newly designed zooplankton counting chambers. Photos courtesy of http://www.hydrobios.de.

A further point of discussion is the retention time of the treated water (5 days) after the treatment of the ballast water. Do the results also show that a treatment is effective after just a single day of retention time, or after a couple of weeks? We can just make assumptions, if no data are provided for the individual treatment technology/system. For the ship owner this means, that he should be asking for additional data (preferably collected under challenge water conditions) that mirror the typical ballast water operations in routine trade (route).

2.7.2. Ship-board tests

The ship-board tests focus on the practicability of the treatment system as well as on the biological efficacy. While the abiotic test water criteria are not specifically outlined, the numbers of organisms in the intake ballast water must at least be 10 times higher than the D-2 standard (except for bacteria) and the untreated control water must exceed organism numbers in D-2 (except for bacteria) at discharge. The D-2 standard has to be reached to full extent for all three classes of organisms and pathogens. Three consecutive valid test cycles have to be carried out, spread over the required testing period of 6 months. Consequently the minimum time needed for ship-board tests is at least 6 months.

Sampling ballast water tanks is a challenge (see Section 2.8). For organisms above 50 μm in minimum dimension four samples are needed, i.e. three for treated water and one for the control experiment. Here D-2 requires that treatment should result in less than 10 viable organisms per cubic metre of water and samples should be taken in three replicates. Consequently up to 12 m^3 of water need to be analysed. Sampling of such large volumes of ballast water from the discharge pipe in the very restricted space of engine rooms and/or pump rooms, is even more challenging. Furthermore, the samples taken onboard of the ship have to be analysed shortly after sampling—as the IMO standards refers to living organisms, i.e. samples taken during a ships voyage need to be analysed or at least stained and conserved onboard. Analysis of larger organisms onboard is also a challenge, especially when the ship is in motion. When using Petri dishes and a stereomicroscope, organism counting may not be accurate as the ship movement induces water movements in the Petri dish. As a result organisms may be counted twice and some may be missed out from counting. To avoid this, a Bogorov counting chamber may be used. During minimal ship movements, this chamber proved to be efficient. However, with increasing ship movements the Bogorov chamber looses its advantage. To cope with this three new counting chambers were designed which may be used during stronger ship movements. These chambers have separated water channels and thereby add to the counting accuracy (Fig. 2).

Because the space for both, laboratory facilities and for accommodation for scientists is very limited on commercial vessels, it becomes nearly impossible to fulfil the requirements of the G8 guideline. A lot of very creative scientific input is needed to develop suitable sampling protocols as well as suitable testing protocols for Ballast Water Sampling.

Apart from the scientific aspects, there are also some practical/commercial considerations, which should not be neglected. At the time when the ship-board tests are carried out, the BWTS has to be readily installed on the vessel. This could involve very significant costs and a significant amount of engineering. However, if it turns out, that the selected treatment technology/system is not suitable for the type of ship and/or for the normal BWM on that specific vessel, the owner is stuck with a costly and impracticable system, even if the type approval tests may have been successful.

2.7.3. Treatment Systems Using Active Substances

In addition to G8, if the treatment systems use what the Convention calls an active substance either by adding chemicals or generating agents in the water flow, the system shall be approved by IMO in accordance with the guideline G9 to ensure the environmental acceptability of the system. Active substances are defined as *a substance or organism, including a virus or a fungus that has a general or specific action on or against harmful aquatic organisms and pathogens*. The G9 approval procedure combines elements from regional legislation, pesticides, biocides, handling and use, but still does not guarantee world wide permission for its use due to national legislation as active substance generators may need additional national approval. The IMO approval of such treatment systems is structured in a two step process. Firstly, a basic approval is given after in detail consideration of the active substance by the GESAMP Ballast Water Working Group (BWWG). The GESAMP BWWG provides recommendations to IMO whether or not an active substance should receive basic approval. If basic approval is given by IMO the active substance may be used in G8 tests. Once the G8 tests are completed a final IMO approval of the substance is needed prior the treatment technology becomes commercially available.

There is no basis in the Convention or the guidelines that a basic approval under G9 is a precondition for start-up of the ship-board tests under G8. The documentation needed for a G9 final approval shall be collected in the land-based G8 tests. Shipboard installation is therefore not needed for the G9 process and start up of land-based tests is handled by national environmental regulations through discharge permissions etc. The understanding of GESAMP BWWG had been that basic approval is a necessary qualification before further tests can be carried out using only one or a few ships in the ship-board testing under G8. Before the G9 and G8 were adopted, several systems employing active substances were already installed on several ships.

The majority of systems currently under development will probably fall within the category active substance. However, there are no clear definitions of the term active substance in the Convention and the definition given in G9 leaves some room for interpretation. Currently, BWTS which make use of UV and/or electrolysis are considered to fall into the category of systems which make use of active substances. However, there was a debate on this matter at MEPC55, but no clear agreement was reached. Future IMO meetings will address this issue. A manufacturer of a treatment system shall send an application for approval to a Flag State. According to the review group set up during MEPC53, it is up to the Administration to decide whether the system use active substance or produce harmful residuals or by-products.

A disturbing fact is that the approval procedure is not yet finalized by IMO. Especially the guidance for final approval has to be developed. The GESAMP BWWG requested IMO to provide guidance on which scenario(s) for discharge of treated ballast water should be used to evaluate the risks of such treatment systems. It is considered to develop a so-called Emission Scenario Document for risk assessment. Before such guidance is available a full risk assessment is impossible. At the last meeting of MEPC (MEPC55, October 2006) the lack of such a risk assessment tool was noted and member states are asked to submit guidance how to assess the risk. However, no clear guidance is given how the guidelines G8 and G9 are interlinked. Furthermore, the G9 has some major time constraints:

- the availability of laboratory facilities for combined G8 and G9 testing and
- the limited capacity of the GESAMP BWWG.

Even under favourable conditions, the combined G8 and G9 testing is estimated to take up to 2 years. All stakeholders have to work closely together for type approval testing under the guidelines G8 and G9 and at best should include the:

- manufacturer of the equipment,
- ship owner of the test ship,
- yard, where the equipment is fitted,
- classification society,
- flag state administration, and
- testing body.

Once final approval has been granted by IMO, governments, administrations and ship owners can be sure that the system is robust, safe and environmentally friendly.

2.8. Port State Control and Ballast Water Sampling (G2)

In accordance with Article 9.1, ships to which the Convention applies may be subject to inspections for the purpose of revealing violations of the provisions of the Convention. These inspections shall:

- verify that the ship is carrying a valid Ballast Water Management Certificate;
- verify that a Ballast Water Management Plan specific to the ship and approved by the Flag State is onboard;
- undertake an inspection of the Ballast Water Record Book.

As a part of the Port State Control and to demonstrate compliance with the D-2 standard, port authorities may consider sampling ballast water for subsequent analyses. IMO is to provide guidance on sampling ballast water in guideline G2. However as this document is far from being agreed upon, we are unable to comment on the specific approaches recommended by the guideline, but can comment on some critical issues that still need to be addressed.

Unlike sampling for approvals of BWMS (see Section 2.7), sampling for Port State Control does not require demonstration of compliance with a standard, but demonstration of non-compliance. As a consequence, the representativeness of samples may not be required: at present the D-2 standard can be interpreted either as an instantaneous standard (i.e. the standard applies to *any* metric volume discharged) or as an average standard (i.e. the standard applies to the sum total of discharge). This debate, while unreconciled within the IMO, is of key importance as sample analysis will have legal implications in cases of non-compliance.

If the sampling must demonstrate compliance with the standard, then documenting the number of organisms above 50 μm is especially challenging since less than 10 viable organisms per cubic meter of water are acceptable. Various aspects of challenge can be identified, the volume of sampling to ascertain compliance suggests that more than 1000 l of water need to be sampled—and this needs to be carried out multiple times as several replicates are required to meet general scientific standards and accuracy in the estimated concentration. To meet these requirements new sampling techniques are currently developing. These technologies are especially designed for the purpose of Ballast Water Sampling and may be easier to use onboard vessels compared to standard plankton sampling technologies. One example is pictured in Fig. 3. It shows a sampling tool with a non-stick, non-filtering bag and a cod-end with filtering panels. The filtering panels can be removed and the entire cod-end can be unscrewed from the sampling bag. This allows consecutive samplings by using the identical tool as cross contamination of organisms which may stick to the tool is avoided. Onboard tests have proven that this sampling kit efficiently sampled in maximum more than 2500 l of water in less than 30 min. The integrated flow-meter adds to the accuracy (Gollasch, 2006).

The accuracy of the sampling technique must be determined; inefficient sampling techniques may result in false positives as a result of missing organisms. The most representative samples may be taken when the ballast water is sampled over the entire discharge time of a ballast tank due to the heterogeneous nature of the species distributions in the tank. Unfortunately, this is (in most instances) infeasible due to logistic constraints.

Similarly, an organism viability assessment may be required and is of particular concern. Organisms may be assessed by visual inspection and intact individuals may be assumed as viable. However, the uncertainty for this method is high and it is not recommended for most species. E.g. dinoflagellates and zooplankton organism assumed intact may be dead. Consequently all individuals should be inspected for movement or organ activity. To initiate movements in zooplankton individuals may have to be poked.

Fig. 3. Newly designed Ballast Water Sampling tool. Photo courtesy of http://www.hydrobios.de.

In phytoplankton species an inspection of the photopigments may reveal additional information to assess viability. However, for many species a major limitation for application is that once cells have lost their pigments, they tend to rapidly disintegrate to unrecognizable detritus.

For many species an alternative and promising method is to use stains together with epifluorescence microscopy or flow cytometry. Two different methods have so far been tested for its use to analyse ballast water samples. One is based on the integrity of the plasma membrane of the cell applying DNA-specific dyes. Non-viable cells with permeable cell membranes will be found with a green fluorescence emission spectrum. This method is found a suitable candidate to examine viability in algal cells as well as bacteria. The other method stains the cell membrane of living cells. The dye is hydrolysed by enzyme systems in living cells into fluorescent end products. These end products are trapped inside the cellular compartment and may be observed in an epifluorescence microscope using an excitation filter of 485 nm and an emission filter of 530 nm. However, neither of the methods works for all types of species within the two size groups as stated in D-2.

A unique problem remains with the viability assessment in case resting stages are found in the ballast water. For those individuals hatching experiments are recommended. However, for certain algae, it is not clear how excystment may be initiated and cultivation may also be a time consuming process.

In contrast, if the sampling is to document non-compliance (i.e. violation of the standard), much less onerous sampling requirements are posed to the port state as a demonstration that an explicit value is exceeded becomes much more feasible. For example, if a sample of 1 l contained 20 living organisms greater than 50 μm in minimum dimension, then it can be assumed that more than 10 organisms were present in that metric ton, and therefore the vessel was in violation under an instantaneous standard.

According to the draft IMO *Ballast Water Sampling Guideline* (as per June 2006) three replicate sampling events need to be undertaken when assessing the efficacy of Ballast Water Treatment Systems in Port State Control sampling efforts. Filling a ballast water tank is a unique event as the species composition and density cannot be replicated over time. To avoid ''pseudo-replication'' each tank should be considered as one replicate. To allow for replicate sampling it may be considered to install various sampling points in the ballast water discharge line and to sample the treated ballast water during discharge simultaneously at all sampling points (WGBOSV, 2006).

Sampling points in the discharge line of the ship should be standardised. Currently efforts are underway to test various sampling point designs with the aim to find a design that most accurately samples the number of organisms in the ballast water discharged. It appears that a sampling point from the centre of the discharge line flow is preferred as it creates less flow induced mortality and results in more accurate sampling. To avoid effects of bends in the ships' pipework, the sampling point should be installed in a straight section of the discharge line with a sufficiently large straight pipe prior and after the sampling point.

It is also controversial to measure the minimum dimension of organisms. Many plankton species have thin spines or antenna and some scientists believe this should be measured to identify the minimum dimension. We believe that this assessment should be based upon an investigation of the organism ''body'', thereby ignoring sizes of spines, antenna, etc. In e.g. flat worms or diatoms the minimum dimension should be the smallest part of their ''body'', i.e. the dimension between the body surfaces when looked at the individual from the side. However, this is extremely difficult to measure for some organisms (e.g. diatoms and dinoflagellates) as microscopic investigations are needed and it is unlikely that, after settlement, a cell is oriented in the counting chamber on the side. The chance to see a diatom from the side in a counting chamber may be equal to – when flipping a coin – the chance of a coin to fall to its side. In ball shaped organisms the minimum dimension should be the spherical diameter.

Another problem refers to colony forming species. The IMO ballast water discharge standard refers to organism number per size class. A question arose in which size category a colony falls when the single cell is below 50 μm but the colony is above 50 μm. A team of experts, i.e. ICES/IOC/IMO Working Group on Ballast and Other Ship Vectors (WGBOSV), believes that in those cases the individual specimen size should be measured. This group finding is based upon the D-2 standard as it refers to organisms and not to colonies. Further, viability tests should address the smallest unit able to reproduce which is the individual and not the colony. However, one problem remains in case the individual is below 10 μm (not addressed in the D-2 standard), but the colony is above 10 μm (e.g. *Phaeocystis* spp.). When considering here the individual size alone some species are excluded. However, it is believed that the above explanation why individuals should be measured should apply (WGBOSV, 2006).

However, one key problem remains and this is that compliance or non-compliance can only be proven while the ballast water is being discharged as the Regulation D-2 reads ''*Ships ... shall discharge less than ...*''. Consequently, the potentially non-compliant ballast water must already have been released before it is clear whether or not it is in compliance with the Convention. Given this, the sharing of compliance information between Parties, specifically the next port of call, to aid an early identification of potentially non-compliant vessels is imperative. Also, in cases where non-compliant vessels revisit the port, additional Ballast Water Management measures may be imposed for those ships.

2.9. Ballast Water Management Under a Blanket or Selective Approach

The Convention has incorporated two different basic BWM approaches i.e., ''blanket'' or ''selective''. A blanket approach means that all ships intending to discharge ballast water in a port are requested by the port state to conduct BWM. The selective approach means that appropriate BWM measures vary dependent on different levels of risk posed by the intended ballast water discharge. In one instance such ships may be exempted from BWM requirements provided that the level of risk of such discharge is acceptable (based on G7). In another instance, if the risk is identified as (very) high, such ships may be requested to take additional measures (based on G13). The level of risk is a result of a risk assessment.

The IMO convention introduces the selective BWM approach with Article 4.2. This article requests a Party to develop BWM policies, strategies or programs in regard to its particular conditions and capabilities. Different states may have different geographical, environmental, socio-economic, organizational, political and other conditions as well as different shipping patterns. In the light of exemptions, these can be given on the basis of Regulation A-4, while additional measures may be introduced based on Regulation C-1 (Fig. 4).

The advantages of the blanket approach include low data and skill requirements and it is simple for port state implementation, while the main disadvantages are that more burden is given to ship crews with ''unnecessary'' BWM requirements (in case of low risk), and with this also more costs for the shipping industry. Depending on the BWM method used also more pressures may be placed on the environment (e.g. in case chemical treatment of ballast water is required).

The selective approach places less ''unnecessary'' BWM burden on vessels, but it requires more extensive data gathering for port states, more data and reporting requirements for vessels. It may require higher skills and knowledge for port state personnel, however with an appropriate Decision Support System this can be overcome.

2.10. Risk Assessment (G7)

Risk can be defined as the probability of an undesired event occurring as a consequence of behavior or action. Risk assessment is the means to identify the frequency and consequences of such events, accompanied by an expression of all uncertainties in the assessment process (Hewitt and Hayes, 2002). The risk inherent to ballast water and sediment discharge can be defined as the likelihood of an undesired event occurring as a consequence of ballast discharge from a ship.

Risk assessment under the Convention has two different approaches, i.e. ''environmental matching'' and ''species specific''. Risk estimation on the assessment of environmental matching between the areas of ballast water origin and discharge considers salinity and temperature as surrogates for the species capability of survival in the new environment. The risk identification in the species specific approach is focused on the assessment of the potential invasiveness of each species and anticipations of the harm that it could cause in the new environment.

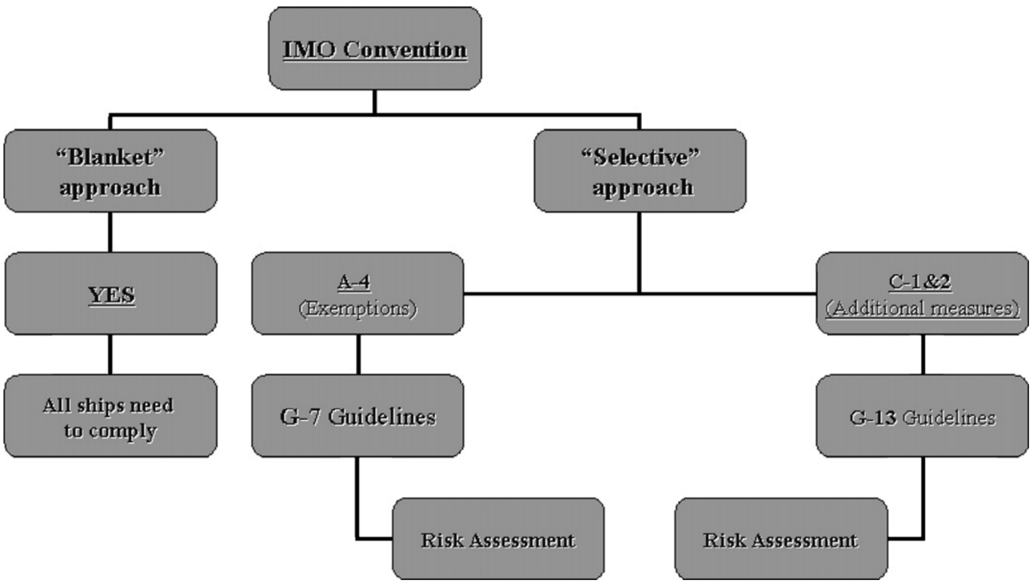

Fig. 4. Risk assessment procedures according to the IMO Convention.

Bio-provinces are identified as being large enough to represent environments as surrogates for species living there. The environmental matching approach is used if the source and destination ports are located in different bio-regions. In the case that the source and destination ports are in the same bio-region, it is assumed that environmental conditions are similar, hence species specific risk assessment is needed.

Various concepts exist to divide the world's oceans into bio-provinces and after considerable discussions the IMO recommends the use of Large Marine Ecosystems (LME, see e.g. http://www.edc.uri.edu/lme/) for risk assessment based exemptions. LMEs are relatively large regions that have been defined according to continuities in their physical and biological characteristics.

2.11. More Stringent or Additional Measures

In essence the risk reducing principle of the Convention is based on the requirement of BWE as a measure until the finalisation of the phase-in of the Ballast Water Performance Standard as defined in Regulation D-2.

However, a more stringent level of protection can be achieved by:

1. requirements by a port state for use of treatment technologies prior standard D-2 comes into force,
2. provision by a Port State of Ballast Water Reception Facilities,
3. designation of BWE areas by Port State(s),
4. no acceptance of risk assessment based exemptions,
5. setting stricter standards compared to D-2,
6. re-routing of vessels, and
7. re-location of port terminals.

The two latter options are likely to be unrealistic in most cases and in short timeframes. The designation of BWE areas may be problematic, particularly in semi-enclosed sea-areas, such as many European coastal waters (see Section 2.2). Similarly, BWTS have yet to be approved for use. In case systems make use of active substances IMO approval is required. Other technologies may be approved by national authorities (see Section 2.7). Full scale experiments onboard ships are ongoing and show promising results. Thus, a more stringent approach may be to request ships using treatment technologies exceeding the organism removal capability of BWE before the D-2 standards becomes into effect.

The Convention does not prevent any country from taking more stringent measures, individually or jointly with other Parties, to establish a higher protection level against species introductions. However, such measures must be consistent with international law and the implementing country should consult with adjacent or other countries. Such additional measures may be permanent or may have a limited time of application. A number of obligations apply:

- communication of such measures to IMO,
- provision of facilities and/ or services available to ease the burden on the ship, including e.g. notification of mariners, alternative routes or ports, facilities for BWM, and
- obtaining IMO acceptance if required by applicable international law.

2.12. Warnings Concerning Ballast Water Uptake in Certain Areas

The Convention encourages Administrations to monitor their waters, i.e. typical ballast water uptake zones, and to notify mariners if restrictions on ballast water uptake are necessary. Such notification may include suggestions for alternative ballast water uptake locations. Ballast water uptake warnings are useful in cases of outbreaks of toxic algal blooms (Hallegraeff, 1998), human pathogens, etc. Ballast water uptake should also be avoided near sewage outfalls and in areas of limited tidal flushing. Relevant notifications should be communicated to IMO and potentially affected states.

Countries should consider the need for and the extent of any monitoring for the purpose to notify stakeholders of BWM avoidance areas. This may be considered within the framework of regional cooperation. One key problem is that existing monitoring programmes in many countries were created for other purposes and do not include sampling sites in ports or port regions, i.e. areas where ballast water uptake is likely to be carried out.

3. Conclusions

Agreements reached on a global level usually represent a combination of significant compromise coupled with action in the face of limited knowledge—and this Convention is not an exception. During the Convention negotiations, many issues were subject of controversial discussions and in certain cases it was extremely hard to reach a consensus. When dealing with shipping we believe that solutions to an environmental problem should be sought at a global scale, however implementation may occur through specific regional agreements. These regional agreements however should be consistent with a globally applicable instrument and provide for additional measures that might be of specific importance in those regions. Despite this intent, it should be noted that ballast water legislation is already in place in several countries (e.g. Argentina, Australia, Canada, New Zealand and USA).

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 is a Port State Convention relating to a marine pollution or quarantine issue with unwanted aquatic organisms being discharged via ballast water into the receiving ports. 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 protections to high seas as well as coastal regions of the world's oceans.

To meet the D-2 standard it may also be considered necessary to combine BWE and treatment until BWTS become more efficient. By doing so, the efficacy of existing treatment systems may be enhanced when the ballast water taken onboard is treated during exchange, however the outcomes of this option must be evaluated for biological efficacy.

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.

A country considering to become a Party to the Convention must make resources available to ensure that the obligations resting on the country are ensured and not underestimated.

As outlined above the implementation of this Convention may involve significant costs, e.g. to test BWTS according to the Guidelines G8, G9 and G10. However, we believe that an appropriate cost/benefit analysis would reveal that funds used to achieve the aims of the Convention would be well spent, assuming that new biological invasions showing economic impacts are considerably reduced.

Although some issues raised above are critical, the authors hope that the Convention will enter into force soon to reduce the risks of future ballast water mediated species introductions.

Acknowledgement

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