Introduction

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Abstract Today global shipping transports over 90 % of the world's overseas trade and trends anticipate that it will continue to play an increasing role world-wide. Shipping operations inevitably include also pressures on natural environments. The most recent waterborne threat is the transfer of harmful aquatic organisms and pathogens with ballast water and sediments releases, which may result in harmful effects on the natural environment, human health, property and resources globally. The significance of the ballast water issue was already addressed in 1973 by the International Maritime Organization (IMO) as the United Nations specialised agency for the regulation of international maritime transport at the global scale. Committed work by many experts, scientists, politicians, IGOs and NGOs at IMO resulted in the adoption if the *International Convention for the Control and Management of Ships' Ballast Water and Sediments* (BWM Convention) in February 2004, which is now to be ratified and implemented. Work on ballast water management issues has also shown to be very complex, hence there are no simple solutions. Nevertheless, the BWM Convention represents a globally uniform framework for the implementation of ballast water management measures, and different supporting tools like risk assessment and decision support systems have been developed to support its efficiency. In this chapter the reader is introduced to various ballast water issues and responses to it. The intention of this book and the overview of its content is also presented.

Keywords Vessels • Ballast water • Ballast water management • Harmful aquatic organisms and pathogens • International maritime organization • Ballast water management convention • Risk assessment • Decision support system

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General Introduction

The continuous intensification of the globalization of trade and production increased the demand for new, faster and more frequent linkages among trading and commodity production areas. These transport demands can only be met by maritime shipping because of its inherent technical and technological advantages and properties. The shipping industry has reacted to these needs with new and more frequent connections, increased vessels cargo and passenger capacity, and new vessel types and technologies.

Today global shipping transports over 90 % of the world's overseas trade (IMO 2013). Future trends anticipate that global and local shipping play an increasing role world-wide. Intensified shipping and related developments has also resulted in disasters of unprecedented dimensions. Widely known examples include the *Titanic* in 1912, *Torrey Canyon* in 1967, *Amoco Cadiz* in 1978, *Exxon Valdez* in 1989, *Estonia* 1994, *Sea Empress* in 1996, *Erika* in 1999, and *Prestige* in 2003 (David 2007). Such disasters resulted in the loss of human lives, property and/or caused significant damage to coastal ecosystems. In addition another inevitable consequence of shipping disasters is the pollution of the environment caused by a variety of pollutants.

Apart from harmful effects as consequences of shipping disasters, regular shipping activities cause other negative environment effects, e.g., sea pollution through the discharges of oily water and sewage from vessels, air pollution from exhaust gases emitted by the vessel's machinery, pollution of water and marine organisms by toxic protective underwater hull coatings (anti-fouling paints), and one of the most recent waterborne threats – the transfer of harmful aquatic organisms and pathogens (HAOP) with ballast water and sediments releases (e.g., Carlton et al. 1990, 1995; Gollasch 1996; Ruiz et al. 1997, 1999, 2000; Carlton 1999; Hewitt 2002; Hewitt et al. 1999; David et al. 2007; Nellemann et al. 2008). Given its 'mysterious' nature in combination with severely harmful effects on the natural environment, human health and the global economy, the problem has attracted attention of scientists and the public worldwide, which was particularly advanced in the 1980s and 1990s due to severe impacts of only a few introduced species.

What is the problem? Vessels need additional weight as a precondition for safe navigation in cases when they are not carrying cargo or are not fully or equally laden. The weight adding material is referred to as ballast. Historically, ballast was solid (e.g., sand, rocks, cobble, iron). With the introduction of iron, replacing wood, as basic vessel building material in the middle of the nineteenth century, the doors were opened to new ballasting technologies. Loading of water (i.e., ballast water) in cargo holds or ballast water tanks has shown to be easier and more time efficient compared to solid ballast. Therefore, water as ballast was adopted as a new practice of increasing importance. Many different types of vessels have different structures of ballast tanks, as well as different ballast system capacities. Vessels ballast water operations are related to vessel type, vessel construction, cargo operations and weather conditions. However, there are no clear limits among all these factors, but the decision on ballast water operations is under the discretion of the chief officer and direct control of the captain, who is responsible for the vessels stability and safety. Nowadays vessels fundamentally rely on ballast water for safe operations. A model for the assessment of ballast water discharges has been developed and tested. It is estimated that global ballast water discharges from vessels engaged in the international seaborne trade in 2013 would be approximately 3.1 billion tonnes (see chapter "Vessels and Ballast Water").

Water loaded as ballast from a vessel's surrounding environment contains suspended matter and organisms. Ballast water sampling studies have shown that various bacteria, plant and animal species can survive in the ballast water and ballast tank sediment (e.g., Medcof 1975; Carlton 1985; Williams et al. 1988; Locke et al. 1991; Hallegraeff and Bolch 1991; Carlton and Geller 1993; Gollasch 1996; Gollasch et al 2000, 2002; Hamer et al. 2001; Murphy et al. 2002; David et al. 2007; McCollin et al. 2008; Briski et al. 2010, 2011). Some organisms stay viable in ballast tanks for several months duration (e.g., Gollasch 1996; Gollasch et al. 2000) or longer (Hallegraeff and Bolch 1991). Estimates indicate that 3,000–4,000 (Carlton and Geller 1993; Gollasch 1996) and possibly even 7,000 (Carlton 2001) different species are transferred daily via ballast water. Species types found range from unicellular algae to fish (e.g., Gollasch et al. 2002; David et al. 2007). Of those, more than 850 are known as successfully introduced and established into new regions (Hayes and Sliwa 2003). It was concluded that each vessel has the potential to introduce a species and that any single introduced species has the potential to cause a significant negative impact to the recipient environment (e.g., Gollasch 1996). Therefore, loading ballast water and sediment in one port and discharging in another represents a potential risk to transfer HAOP into new environments (see chapter "The Transfer of Harmful Aquatic Organisms and Pathogens with Ballast Water and Their Impacts").

The United Nations also recognised the transfer of HAOP as one of the four greatest anthropogenic pressures to the world's oceans and seas, causing global environmental changes, and posing a threat also to human health, property and resources. Ballast water is one of the prime vectors of this global issue (e.g., Carlton 1985, 1989, 1992, 1996a, b; Wiley 1997; Gollasch et al. 2002; Bax et al. 2003; Bailey et al. 2005; Davidson and Simkanin 2012). The unwanted impacts caused by introduced species are manifold and include changes of species biogeography, biodiversity modifications, introduction of predators, bloom-forming harmful algae, ecosystem engineers, parasites and disease agents resulting in economic problems of marine resource users, such as loss in fisheries, fouling of industrial water pipes and on fishing or aquaculture gear. Even negative impacts on human health are reported because, e.g., harmful algae causing amnesic, diarrhetic or paralytic shellfish poisoning and *Vibrio cholerae* as well as other disease agents were found in ballast water (e.g., Hallegraeff 1993, 1998; Rigby and Hallegraeff 1994; Carlton 1996a, b; Ruiz et al. 2000; van den Bergh et al. 2002; Hayes and Sliwa 2003; Bauer 2006; Gollasch et al. 2009; Romero et al. 2011). In total more than 1,000 aquatic non-indigenous and cryptogenic[1] species are known from Europe (Gollasch 2006; Vila et al. 2010), and Hewitt and Campbell (2010), Hayes and Gollasch

[1] Cryptogenic species are species which cannot reliable be assigned as being non-indigenous or native because their origin is uncertain (Carlton 1996a, b).

(both unpublished), suggest >2,000 aquatic non-indigenous species have been introduced world-wide. The monetary impact caused by these species is difficult to quantify (van den Bergh et al. 2002). However, comprehensive studies concluded that the estimated yearly damage or control costs of introduced aquatic non-indigenous species is $14.2 billion in the USA (Pimentel et al. 2005) and costs for repair, management and mitigation measures of such species in Europe was estimated to more than 1.2 billion Euro annually (Shine et al. 2010) (see chapter "The Transfer of Harmful Aquatic Organisms and Pathogens with Ballast Water and Their Impacts").

Following the primary species introduction from, e.g., the coasts of one continent to another, secondary spread within the recipient continents coastal waters may occur because introduced species may be further transferred by, e.g., coastal or local shipping, pleasure craft, fisheries etc., or may also spread by natural means (e.g., Minchin et al. 2005; Simkanin et al. 2009; Rup et al. 2010; Bailey et al. 2011; Darling et al. 2012; David et al. 2013) thereby increasing their impact (see chapter "The Transfer of Harmful Aquatic Organisms and Pathogens with Ballast Water and Their Impacts").

The significance of the ballast water issue was already addressed in a 1973 International Maritime Organization (IMO) Resolution (IMO 1973). IMO as the United Nations specialised agency for the regulation of international maritime transport at the global scale, was tasked to deal with this issue further. After more than one decade of intensive and committed work by many experts, scientists, politicians, IGOs and NGOs at IMO, the final text of the *International Convention for the Control and Management of Ships' Ballast Water and Sediments* (BWM Convention) was completed and adopted in February 2004 at a diplomatic conference in London (IMO 2004; Gollasch et al. 2007). The BWM Convention introduced new BWM related requirements for port States and vessels all around the world. However, the implementation of this Convention is far from being simple. After the adoption of the BWM Convention several countries and regions have implemented (voluntary) ballast water management approaches (Gollasch et al. 2007; David 2007; David and Gollasch 2008) (see chapters "Policy and Legal Framework and the Current Status of Ballast Water Management Requirements" and "Ballast Water Management Under the Ballast Water Management Convention").

Due to global efforts of industry, Member states and IMO, efficient, financially feasible, environmentally friendly and safe methods of preventing the translocation of HAOP via ballast water were developed. More than 30 ballast water management systems (BWMS) have already been certified (type approved) so that most vessels can today be equipped with such systems. We are aware that this is a very fast developing area and market, at least 20 more systems are currently in the certification process (see chapter "Ballast Water Management Systems for Vessels").

The BWM Convention is at the moment of this writing not yet in force, but does today represent a solid and uniform framework for preventive measures to avoid HAOP introductions and it needs to be implemented by individual countries or joint approaches. The BWM Convention enters 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).

Nonetheless it must be emphasized that efficient ballast water management (BWM) does not imply the prevention of HAOP introductions at any cost, thereby laying an additional burden on and generating higher costs for the shipping industry. Undoubtedly, the cost of prevention should not be higher than the benefits it generates.

Conditioned by the lack of on board installed BWMS on existing vessels, ballast water exchange (BWE) is today the most widespread available BWM method also approved by the BWM Convention. Nevertheless, ballast water exchange has drawbacks which make it inefficient or even impracticable under certain conditions (e.g., on shorter voyages where "intended routes" are too close to the shore, attain insufficient water depths, a lack of knowledge of the presence of HAOP in the water exchange area). Further, other issues related to an efficient BWM system arise which are outside of the vessels' responsibility, e.g., targeting of vessels for ballast water sampling as part of port State compliance control procedures.

As a result, countries wishing to protect their seas, human health, property and resource from the introduction of HAOP with ballast water are confronted with a significant challenge. Given that BWM requirements may result in inefficiencies, lower safety margins and higher costs in the shipping industry, the reasons described above make the 'blanket approach' (i.e., mandatory BWM for all ships) unjustifiable in a range of different local conditions. An alternative to the blanket approach is the 'selective approach' where BWM is required for selected vessels. This selection should be based on a suite of information needs and procedural decisions to aid transparent and robust BWM decisions. Such systems have been developed in a variety of applications where a large number of complex decisions must be made in a consistent, transparent and defensible manner. These systems are typically referred to as decision support systems (DSS). Such a DSS as applied to BWM implies adjusting the intensity level of BWM measures to each voyage based on risk assessment (RA), and recommends also compliance monitoring and enforcement (CME) actions (see chapters "Ballast Water Management Under the Ballast Water Management Convention", "Ballast Water Management Systems for Vessels", "Risk Assessment in Ballast Water Management", "Ballast Water Sampling and Sample Analysis for Compliance Control" and "Ballast Water Management Decision Support System").

A BWM DSS provides essentially needed support to responsible agencies for the implementation of effective BWM measures. The introduction of BWM practices adds burden and costs mostly to the shipping industry, on the other side, their efficiency is critical. In light of these, the BWM DSS needs to provide for (David 2007):

- an effective protection against the introduction of HAOP;
- proper RA as one of the key elements of the BWM DSS;
- local specifics are addressed in direct relation with the effectiveness of the BWM (e.g., geographical, hydrological, meteorological, important resources, shipping patterns, regulatory regime);

- a selection of most effective and safe BWM methods according to the RA;
- the consideration of impacts to the shipping industry (including safety);
- the consideration of impacts on international trade;
- timely decision making;
- the reduction of subjectiveness in the decision process; and
- a consistent and transparent decision making process.

A uniform DSS methodology and RA concerning HAOP introductions via ballast water has not yet been developed. Several foundations have already been laid, e.g., Australian DSS (Hayes and Hewitt 1998, 2000), GloBallast[2] Ballast Water Risk Assessment (GloBallast 2003), Det Norske Veritas (DNV) Environmental Ballast Water Management Assessment – EMBLA (Behrens et al. 2002), and BWM RA and DSS for Slovenia (David 2007). More recently BWRA according to the BWM Convention requirements was developed for HELCOM (David et al. 2013) and OSPAR. Currently BWRA and BWM DSS for European Seas is being developed under the EU-funded VECTORS[3] project, and for the Adriatic Sea under the IPA Adriatic strategic project BALMAS.[4] Yet the complexity and intrinsically modern character of the problem leaves several questions, as revealed by the inefficiency of these applied systems, unanswered. The need for answers bears vital significance for the international environment, the goal being the future implementation of an efficient BWM system in tandem with considerations for a sustainable shipping industry (see chapters "Risk Assessment in Ballast Water Management", "Ballast Water Management Decision Support System" and "Ballast Water Management Decision Support System Model Application").

Intention of This Book

According to our knowledge this is the first comprehensive book on BWM worldwide. This book provides an overview of the possible solutions to the complex issue of BWM and will further outline consequences and implications to address the ballast water "problem" following the provisions of the BWM Convention. There is a need for good insights to the ship ballast operations, environmental and other aspects of the issue as well as international requirements. Further in-depth knowledge is needed on options how to approach and manage it in a most effective way, especially considering specifics on a case-by-case basis. The editors and authors of this book are scientists of different disciplines including professors of universities in the maritime sphere and biological arena who have been involved in or are

[2] GEF/UNDP/IMO, Global Ballast Water Management Program.

[3] Vectors of Change in Oceans and Seas Marine Life, Impact on Economic Sectors (VECTORS), European Community's Seventh Framework Programme (FP7/2007–2013) under Grant Agreement No. [266445].

[4] Ballast Water Management System for Adriatic Sea Protection (BALMAS), IPA Adriatic Cross-Border Cooperation Programme strategic project.

leading researchers in this field. This includes the involvement in the policy making processes at the highest international (IMO), national and regional levels. Experience of this group has been gained through years of committed work in this field, which gave an unique opportunity to gain specific knowledge and experience to offer an in-depth insight and some possible solutions to the related issues. Complimentary, the book contributions reflect the industry, administrations and academic views regarding BWM. Therefore, the book is expected to be of primary interest to students and scientists in various fields, including maritime transport, naval architecture, biology, decision and policy making at national and international levels, especially related to the shipping industry and environmental protection. The book is also written to be of interest to the wider public to broaden the scope of audience and to raise awareness to the topic.

Book Content

After this general introductory chapter, the book continues to describe vessels' ballast water systems, considering stability, structural and safety aspects as well as ballast water volumes being carried by ships and how its discharge (in ports) can be calculated. Next, the types and dimensions of organisms transported with ballast water and their impact is described followed by a chapter which comprehensively summarizes worldwide ballast water policies and regulations implemented to avoid species introductions. The BWM Convention as overarching instrument and its supporting guidelines are introduced by also mentioning the port and flag State requirements. Exemptions from and additional BWM measures as well as BWM exceptions are explained. In continuation, a comprehensive overview of BWMS is given. Recommendations and options for compliance control measurements with the BWM Convention's standard are provided, separated in indicative and in detailed ballast water sampling and sample processing methods. This is followed by a description of the integration of RA, BWM and CME in a DSS. The RA exemptions process is shown in detail highlighting the RA principles and the need for a precautionary approach. Flow charts guide the reader through a RA model for granting exemptions from BWM requirements. While the RA result is a simple risk quantifying answer (high, medium, low), an approach is needed when a decision on "what to do" is to be taken. This DSS considers the RA results and forms the core part of this book. Theoretical and practical profiles of the ballast water RA and DSSs are presented and analysed as BWM tools. These provide a solid framework for the DSS model. The DSS model is presented in the form of flow charts as a step by step approach from the highest level to the details. The generic DSS model is further analysed decision by decision and element by element, also considering their interactions. This BWM DSS approach provides a mechanism to aid transparency and consistency in the decision process regarding BWM needs. The BWM DSS model is then validated in a case study, by using real ballast water discharge data of the Port of Koper, Slovenia as well as data on vessel voyages, including vessel movements, main routes, navigational constraints and ballast water patterns, i.e., amount of ballast water to be managed per vessel and type, ballast water exchange (BWE) capacity rates per vessel type and source ports. The book ends with BWM related conclusions also identifying knowledge gaps and highlighting further research needs.

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