Enforcement of Ballast Water Convention and Challenges in Australian Ports

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Abstract
Discharge of ballast water from ocean-going ships contributes to the spread of aquatic invasive species with negative impacts on the receiving environment, which in turn can influence the economy and public health. As a regulatory measure, the long awaiting International Ballast Water Management Convention (BWMC) will enter into force in September 2017 which requires ships to install treatment systems. Consequently, ballast water exchange practices will cease. However, ships might be exempted while operating in waters under Australian jurisdiction.

After a decade of introducing the convention, certain issues such as sampling methodologies and sampling analyses are still in debate. So far, much of the literature has focused on biological aspects of invasions, or the design and development of treatment systems. Less focus has been placed on the challenges that must be mitigated by the ports in the case of non-compliance, and the scale of this has been under assessed.

The objective of this study is to raise the awareness by identifying the challenges for implementing BW Convention. That is achieved by categorising them in to the operational, technical and uncertainty topics. Some of these issues can lead to suspension of the ship's operation and a delay in ship's activities, which then initiates a further dispute, putting excess pressure on the ship and the port authority. Among those, sampling is a major challenge, which is discussed more in detail for the long-term planning. Furthermore, the study highlights the high risk area by location and magnitude so investment on BW management in Australia could be made more effectively in future.

Keywords: ports, sampling, invasive species, ballast water convention.

1 Introduction

More than 90% of the world's trade is carried by shipping; an activity heavily relied upon globally for the transport of commodities. The shipping trade is predicted to grow further in the future (UNCTAD 2012), an indication of the continuing scale and risk of species transport via shipping. Invasive aquatic species are ranked by the international maritime organisation (IMO) as one of the four greatest threats to the world's oceans. Introduced species can have severely detrimental environmental and economic effects in receiving communities. A good example is the spotted handfish in Australia, which is in danger of extinction due to the introduction of Northern Pacific Seastar via ballast water. There are roughly 100 exotic species known to be present in the Australian marine environment as well as decline in number of native species [1].

In 2004, the International Convention for the Control and Management of ships' ballast water and sediments was introduced by IMO. This Convention together with the associated appendices inform measures required to prevent future introductions via ballast water (BW). Ships are one of the major contributors to the global spread of aquatic organisms, which are mainly carried in ballast tanks. Initially, vessels were required to perform mandatory ballast water exchange (BWE) during transit, to flush tanks of coastal organisms picked up in the port of origin and instead retain oceanic organisms, which would then be discharged into the destination port. This measure relies on an organism's adaptation to its native environment, i.e. coastal or oceanic, and hopes that by releasing oceanic organisms into ports they would be less able to survive and thus introductions would be reduced. BWE is recognised as an interim measure that has limited effectiveness in reducing ballast water invasion risk [2].

In addition to BWE the Convention details further measures that will be taken to minimise ballast water introductions, namely the use of ballast water treatment systems. These systems are being developed to remove/kill organisms in ballast water so that low levels are discharged at the destination port. The Convention and appendices entail testing procedures, and guidelines are developed for testing of such systems [2]. After treatment, the resulting BW must meet certain biological standards, in addition to proving that the treatment has no residual toxic effects on the water to be discharged.

The Convention was introduced in February 2004 but enforcement was delayed due to concerns among countries for several reasons, such as: lack of standardised sampling methodologies to collect and analyse BW for compliance, unified procedures for port state control authorities to assess compliance, lack of approved ballast water management systems, high cost of equipment, limited shipyard capacities, etc. However, Convention enters in to force in September 2017 and all ships will be required to carry out ballast water management (BWM) procedures to a given standard. Existing ships will be required to do the same, but after a phase-in period.

Historically, Australia has been one of the leading countries in regulating ballast water requirements for ships calling its ports. Currently, Australian government in line with the Convention has introduced Ballast Water Management Requirements (Version 6) under the Biosecurity Act 2015 to inform ships about their obligations.

Upon arrival of ships in Australian ports, biosecurity officers may conduct on-board ballast water verification as a routine vessel inspection to ensure the compliance. If there are "clear grounds" for believing that the condition of the ship or its equipment does not correspond substantially with the particulars of the certificate, the inspection may be extended [3], where indicative sampling and detailed analysis verification of compliance are required. The new sampling requirements for the BW treatment differs from the BW exchange as these two regulations have significantly different parameters. As per the Guidelines of BW Sampling (G2), the sampling protocol should result in samples that are “representative” and that is to be achieved by analysing their physical and/or chemical parameters.

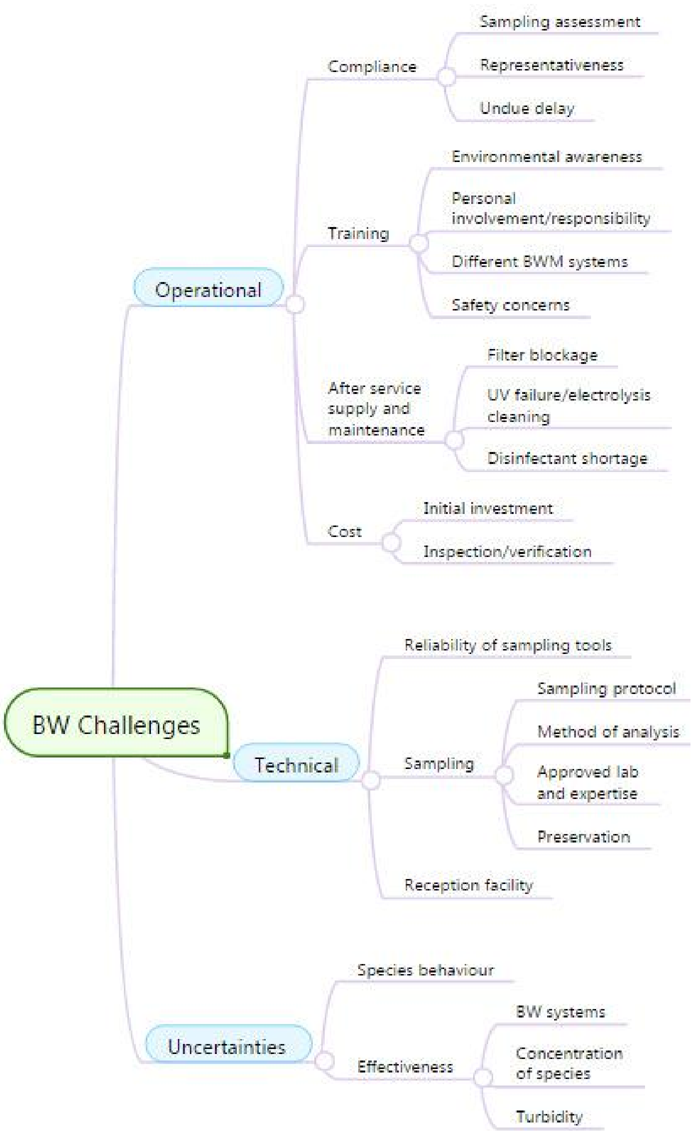

Figure 1. Categorised BW challenges that ships and ports will face upon the enforcement of the Convention

After many years of debate, there is a greater understanding of BW problems amongst IMO member states and in particular the international shipping organisations. However, certain issues such as sampling method and sampling analysis are still debatable. This paper highlights the challenges of BW compliance for ships and ports as shown in Figure 1, and discusses the sampling issues in particular. Efficiencies associated with collecting samples to assess a vessels compliance with the BW Discharge Standard are also discussed. Currently, there is no internationally agreed procedure for a unified sampling approach; an approach that must be simple, feasible, rapid and applicable at the point of ballast discharge. As such, there is still uncertainty surrounding the collection, analysis and interpretation of samples required to determine compliance.

2 Sampling and associated issues

Upon the enforcement of BW Convention there are several operational challenges that are required to be considered for effective implementation. Those challenges are shown in Figure 1, where most debatable one is the sampling.

The sheer diversity of aquatic organisms makes it extremely difficult to rapidly determine whether treated BW is fully in compliance with the Discharge Standard. If detailed analysis is required, the process of collecting a large number of samples is expensive, time consuming and often impractical. To quantify viable organisms, equipped laboratories is required, to be staffed by technicians with sufficient expertise to accurately analyse the samples. Currently, services are available to provide indicative analysis through mobile laboratories for rapid check to ensure compliance, however, in the case of marginal compliance the analysis should be supported by testing locations.

2.1. Representativeness of samples

Indicative analysis is relatively quick and is carried out in the form of direct or indirect measurements. However, upon completion of “initial” inspection and sampling, the authority may decide to exercise “detailed” analysis to verify the compliance through further sampling. The sampling protocol in use should result in a representative sample of the whole discharge of the ballast water from any single tank or any combination of tanks being discharged as emphasised in the convention. Approaches of this kind carry with them various well known limitations, such as ceasing of cargo operation, as well as being a time consuming process. The time required for proper analysis of samples could be long, should authorities decide to suspend the ship’s operation prior to the result of the samples; the delay in ship’s operation as a result, initiates further disputes.

Questions have been raised about what volume of ballast discharge should be analysed to be representative of the entire discharge. Investigating representativeness is a continuing concern within compliance monitoring. Due to practical constraints, it would be impossible to sample the entire discharge or to collect large numbers of samples. Therefore, representativeness of the sample would always be debatable [4] regardless of the applied method of analysis, either direct or indirect.

2.2. Sample analysis

The BW is influenced by external factors throughout the voyage that could affect the distribution of organisms within the ballast tanks. The proximity of the engine room bulkhead and/or fuel tanks to ballast tanks are good examples of such influences. Therefore, samples collected from a ballast tank are considered to be biased since each member of the population does not have the same chance of being selected. As a result, the sampling statistics may not be reliable to determine the mean and standard deviation of the whole BW due to quite a large variation. Furthermore, organism heterogeneity in tanks makes collecting representative samples extremely difficult and adds more complications to the statistical computations. Sampling statistics are the parameters such as the mean or the standard deviation of a sampling distribution. Three statistical distributions and testing methods are proposed by the IMO Guidelines [5], where the pros and cons are discussed below.

One of these methods suggests Normal distribution and a t-test for the statistical handling of the BW sampling. In this approach, the challenge is to determine the sampling protocol and the volume of samples to make sure that a Gaussian distribution is applicable. Collected data from indicative sampling could possibly be used for this statistical distribution. Nonetheless, the available techniques for indicative sampling are developed for initial monitoring to shed some light on whether the ship is in compliance. These techniques are simple but disputes arise when the results are close to D-2 regulation described as ballast water performance standard in the Convention. Therefore, to prove compliance a greater number of samples are required. In this situation, the sampling uncertainty can be obtained by the null-hypothesis to state that ‘there is no difference between the average concentration of organisms ($\bar{x}$) and that of the D-2 standard (μ) at a selected level of significance, i.e. $H_0 : \bar{x} = \mu$’. For a large ship with high ballast capacity e.g. Panamax bulk-carrier, the populations (the entire ballast) could be considered as infinite, therefore, confidence coefficient (z) when sample size (N) is larger than 30 is given by Equation 1, where s is standard error.

$$z = \frac{\bar{x} - \mu}{\frac{s}{\sqrt{N}}} \quad (1)$$

For small samples, the standard error is modified by Bessel's Correction in the t-test formula given in Equation 2:

$$|t| = \frac{\bar{x} - \mu}{\frac{s\sqrt{\left(\frac{N}{N-1}\right)}}{\sqrt{N}}} \quad (2)$$

Figure 2 illustrates the number of samples required at two different confidence levels for a range of standard error. The variation between the sample mean and the population is considered to be one.

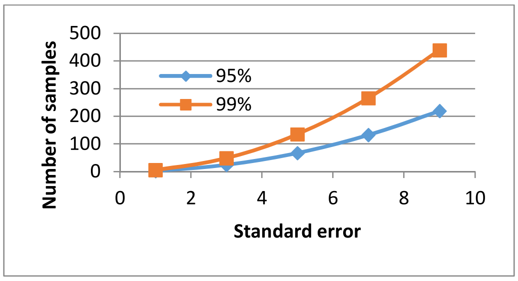

Figure 2. The number of samples required at two different confidence level to verify compliance with the D-2 Discharge Standard.

By looking at the number of required samples, one can imagine the level of workload in taking so many samples. However, It is unlikely that this test will be used, which is not normally applied to rare populations [6].

The alternate method proposed by IMO Guidelines is the Poisson distribution with Chi-square test. When the number of samples increases (usually >10) then Poisson is a good approximation for binomial distribution.

$$e^{-\lambda}\left(1 + \lambda + \frac{\lambda^2}{2!} + \frac{\lambda^3}{3!} + \cdots\right) \quad (3)$$

The Poisson distribution, given in Equation 3, is a discrete probability distribution that assumes organisms are randomly distributed during the BW discharge. Jørgensen et al. [7] and Miller et al. [8] proposed application of Poisson distribution to quantify variability in counts of living organisms in samples taken from BW discharge. In contrast, Gollasch and David [9] showed that the variability in counts of living organisms in samples is larger than can be explained by the chance-like processes of the Poisson distribution. The weakness lies on the sampling rate (λ), which cannot be confidently defined for a reliable estimate of mean concentrations; Poisson distribution assumes that mean and variance are the same. Yet, organisms in ballast tanks might be over-dispersed, an indication that extra variation is greater than the mean.

However, non-parametric Chi-square tests could be useful since the results obtained from the sampling trials are rarely the same as the results predicted by statistical theories. These tests are concerned with the individual members of the BW sampling set and do not rely on the statistical parameters. The measure of the discrepancy between the observed frequencies and the expected frequencies estimated by Poisson distribution can be determined by calculating the Chi-square value (χ^2). Predictions can be made as to whether the differences are due to random errors, due to some fault in the method of sampling, or due to the assumptions made.

The largest strength of Chi-square test for BW sampling is that it is easier to compute than some other statistics, however, there are some limitations that must be taken into consideration. This test is sensitive to sample size and mostly recommended not to be used if sample size is less than 50. As a result, in addition to uncertainty in the results, the problem of workload discussed above is of concern here.

The third suggested method is the Wilcoxon signed-rank test, which is a non-parametric statistical hypothesis test used with paired samples from the same population. The objective is to assess whether the population mean ranks differ, and hence, the method uses a specific significance level to check if treated BW is in compliance. It can be used as an alternative to the t-test, when we cannot assume that the population will be normally distributed; samples are chosen randomly and independently.

The Wilcoxon method is geared towards hypothesis testing rather than estimating the number of organisms required in performance standard. It is often possible to obtain estimates and associated confidence intervals, but this is not straightforward, therefore, does not provide solid evidence for the inspecting officer to claim non-compliance and hence detain the ship.

3 High risk area

The great portion of BW in Australian territorial waters is discharged in ports and therefore, ports are considered as the highest risk area. In order to develop a strategic plan for long term BW management it is essential to quantify the amount of discharge and a measure of potential risk. Enshaei & Mesbahi [10] developed a methodology for the estimation of ballast water imported to the UK ports. The investigation was based on the ship's cargo tonnages and the ballast water capacity considering ship's types and sizes. Coefficients were derived after analysing five years of data received from 50 ports. A similar approach was carried out by Xiao & Enshaei [11] to quantify the BW discharged in major Australian ports. Figure 3 highlights the location and magnitude of major ports through analysis of five years of data from 2009 to 2013.

Highest discharge is estimated for Port Hedland and Dampier. A significantly large amount of BW discharge is also estimated in Newcastle and Hay Point. In figure 3, the magnitude of BW discharged in each location highlights the importance of establishing a well-equipped laboratories, staffed by technicians with sufficient expertise for analysing the BW samples. This study can be further expanded to investigate the impact of the quality of BW imported from different regions of the world on the sensitivity of localised marine species.

4 Discussion

One of the feasible options to avoid discharge of high risk BW from ships in any Australian ports is ensuring the availability of reception facilities. It is even essential for effective implementation of the BW Convention. Lack of such facilities put excess pressure both on the ship's crew and port authority in case of need. A similar policy from the marine pollution Convention (MARPOL) for "zero tolerance of illegal discharges from ships" may be established for adequate reception facilities. However, the facilities should be different than those designed for the MARPOL requirements and should take into account:

- The technical problems for the transfer of polluted BW between ship and shore.
- Type and capacity of port reception facilities.
- Development of a guideline for good practices for port reception facility providers and users.

Unlike MARPOL, ships do not have shore connections to safely transfer the BW to shore and possible solutions should be sought in due course. The alternative feasible approaches [12] could form the basis of the marine services in the future BWM policy. For example, cross-ballasting and discharge of BW in to a floating barge carrying installed treatment facilities could be an option, where operational, technological and practical constraints could be considered in a new design.

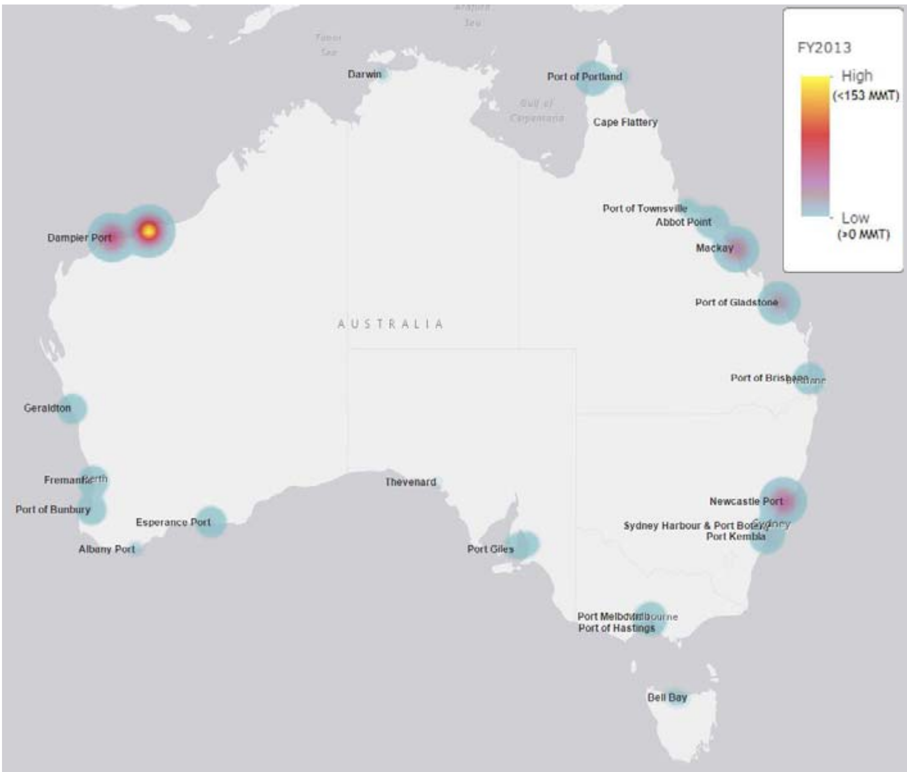

Figure 3. Location and magnitude of ship's ballast water discharged in Australian ports [11]

The key element of BW Convention is performance of the treatment system. Regular maintenance of BW equipment is essential to ensure compliance at discharge. These activities include inspection, testing, measurement, replacement and adjustment of the BW management system. Inadequate maintenance can cause a discharge outside the D2 criteria and hence, after installation backup becomes extremely vital to any ship for effective operation. Currently, there are number of BW systems in the market produced by less recognized companies who may not have sufficient offices or agents to support after-sale services.

Many systems that work with active substances use neutraliser for BW treatment and therefore, the security of supply becomes a key factor for a safe discharge of the BW. Supply and replacement of damaged UV lamps is another example of services required on time.

5 Conclusion

The International Ballast Water Management Convention that will come into force in September 2017 brings challenges to port authorities as well as ship owners. This paper emphasizes that sampling and assessment techniques should be further investigated and unified approaches should be developed. Moreover, the development of port reception facilities is necessary for the successful implementation of the convention. The analysis of location and magnitude of ship's ballast water discharge is an initial step to plan such facilities for the future maritime traffic.

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