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Practical Difficulties of Sampling Ballast Tanks – What Lessons Can Be Learned?

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ABSTRACT

The adoption of the International Convention for the Control and Management of Ships' Ballast Water and Sediments (BWMC) in 2004 (herewith the Convention) has sought to prevent the spread of harmful aquatic organisms and pathogens in the ballast water and sediments of ships, threatening marine ecosystems worldwide. The Convention sets out the various requirements and the various steps vessels owners / operators and port States need to undertake in order to effectively manage ballast water and sediments. However, there are still open issues and uncertainty, including the scientific and practical challenges of sampling of ballast tanks and monitoring compliance with the Convention's standards. In order to monitor compliance with the Convention's standards, documented management practices can be inspected for appropriateness and inspection of vessel log books can give an indication that practices have been implemented. However, sampling is the most effective way to ensure compliance with standards set out in the Convention. To check compliance with the D-1 (exchange) standard, vessel log books should be inspected and sampling can be used to check for anomalies in the composition of the ballast water (e.g. salinity). D-1 compliance is intended as an interim step until treatment systems are more widely available – although, some ports may require exchange as well as treatment in the long term.

Compliance with the D-2 (performance) standard following treatment of the ballast water requires the sampling of biological, chemical and physical parameters. Whether checking compliance to the D-1 or D-2 standards, there are significant sampling challenges. These include the logistics of gaining vessel access; having multiple sample methods available to suit ballast tank access restrictions; getting a representative sample; sample analyses; sample interpretation and; what to do if a sample fails? In addition to this, local requirements can present further challenges (e.g. small time windows for bacterial analysis). This paper will highlight the difficulties of sampling ballast tanks in practice, drawing from national and international experiences, and will also comment more broadly on the sampling process and governance – such as regional differences and the role of port State control. Drawing on protocols adopted by other states will help to facilitate a more efficient, consistent and organised implementation of the Convention to the shipping community worldwide.

Keywords: Ballast water sampling; Ballast water management; non-native species

1. Introduction

Ballast water is vital for vessel stability while avoiding unnecessary stresses on a ship. However, poor ballast water operations can result in the introduction and spread of non-native species (NNS), posing a serious threat to biodiversity, human health and the economy of the receiving area. The control of NNS – a topic that has undergone extensive research since the adoption of the Convention in 2004 – is therefore of vital importance.

Once entered into force, Member States of the International Maritime Organization (IMO) will be required to check vessels for compliance with the Convention standards, which includes BW sampling (David, 2013). To demonstrate compliance with the Convention, port States may consider sampling ballast water. However, ballast water sampling is a very complex

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activity due to a combination of organism diversity and behaviour, and ship design (Gollasch & David, 2011), making it somewhat difficult to implement.

2. Policy context

The Convention states that ballast water must be exchanged (Regulation D-1) in the interim, with the goal of BW treatment to specific standards (Regulation D-2) before being released into the environment.

Regulation D-1 requires vessels to demonstrate that at least 95% volumetric exchange is met; there are several ways in which this can be met. Regulation B-4 (linked to Regulation D-1) sets out a tiered system of areas in which ballast water exchange can be undertaken, with the most attractive areas being at least 200 nm from the nearest land and in water at least 200 m in depth, secondly in areas least 50 nm from the nearest land and in water at least 200 m in depth. If these cannot be met, for example due to physical constraints such as in the North Sea, then Regulation B-4, clause 2 allows for the designation of areas of ballast water exchange.

Regulation D-2 sets out the requirements for compliance with the performance standard. This Regulation sets out limits for the number of viable organisms permitted for a particular volume of water and other indicator microbes (e.g. *Vibrio cholera*, Intestinal Enterococci and *Esc herichia coli*).

In order to effectively implement the Convention, guidelines were established. Guideline G2 sets out recommendations for ballast water sampling. Although sampling ballast water on ships arriving into port is important, this method alone is unlikely to conclusively prove whether or not BW exchange has occurred to the D-1 standard. The G2 guideline also provides advice for compliance with the D-2 standard.

Once the Convention has entered into force on 8th September 2017, all ships will be required to exchange or treat their ballast water on every voyage using an approved ballast water treatment system (Lloyd's Register 2016). Table 1a shows the implementation dates of the IMO BWM Convention, while the treatment only compliance schedule is given in Table 1b.

Table 1a. Implementation dates of IMO Ballast Water Management Convention (MCA, 2008)

<table>
<tr><th rowspan="2">Ballast Capacity (m^3)</th><th rowspan="2">Construction Date</th><th colspan="9">Application Dates of the D-1 and D-2 Standard</th></tr>
<tr><th>2009</th><th>2010</th><th>2011</th><th>2012</th><th>2013</th><th>2014</th><th>2015</th><th>2016</th><th>2017</th></tr>
<tr><td rowspan="2">< 1500</td><td>Before 2009*</td><td colspan="7">D-1 or D-2</td><td colspan="2">D-2</td></tr>
<tr><td>In/After 2009</td><td colspan="9">D-2</td></tr>
<tr><td rowspan="2">≥ 1,500
≤ 5,000</td><td>Before 2009*</td><td colspan="5">D-1 or D-2</td><td colspan="4">D-2</td></tr>
<tr><td>In/After 2009</td><td colspan="9">D-2</td></tr>
<tr><td rowspan="2">> 5,000</td><td>Before 2012*</td><td colspan="7">D-1 or D-2</td><td colspan="2">D-2</td></tr>
<tr><td>In/After 2012</td><td colspan="9">D-2</td></tr>
</table>

* Needs to be applied by the First Intermediate or Renewal Survey, whichever occurs first after anniversary date of delivery in the year indicated.

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Table 1b. Ballast water management compliance schedule for treatment (Lloyd's Register, 2016)

Ballast Capacity	Existing ships	Ships constructed after entry into force
All	Compliance by first IOPP* renewal survey after entry into force	Compliance on delivery

* The IOPP renewal survey refers to the renewal survey associated with the IOP Certificate required under MARPOL Annex I

3. BW sampling techniques

There are a number of sampling points to sample ballast water. These can be divided into in-tank (directly from a tank via manholes, sounding or air pipes) or in-line (via ship's pipes after the ballast water pumps) sampling points. For compliance with the D-1 standard, in-tank or in-line samples can be taken to check coastal biota presence or to check the water salinity (David, 2013). All available access points can be used for this, including sounding pipes, manholes, as well as the main ballast water line. However, the latter is not recommended since a non-compliant discharge to sea could cause a pollution event (David, 2013).

The preferred method of sampling for compliance with the D-2 standard is from the discharge line using an "isokinetic" sampling facility (Figure 1) since a quantitative biological approach is required (David, 2013). However, in-tank sampling may be more appropriate for certain vessels, i.e. bulk carriers / tankers that have upper side wing tanks that are emptied through direct overboard discharge valves as opposed to ballast pumps (Gollasch and David 2011), as shown in Figure 2.

Figure 1a. Isokinetic sampling: "bend" port (SGS, date unknown)

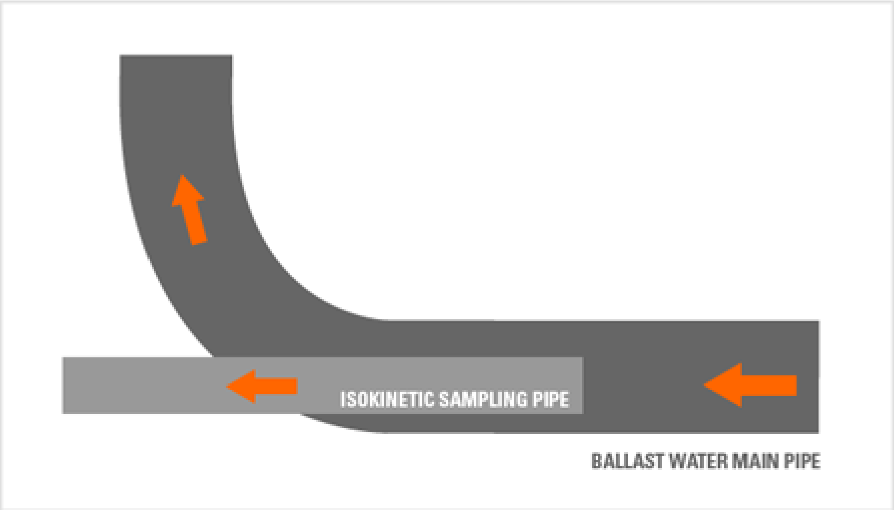

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Figure 1b. Isokinetic sampling port: "pitot" port (SGS, date unknown)

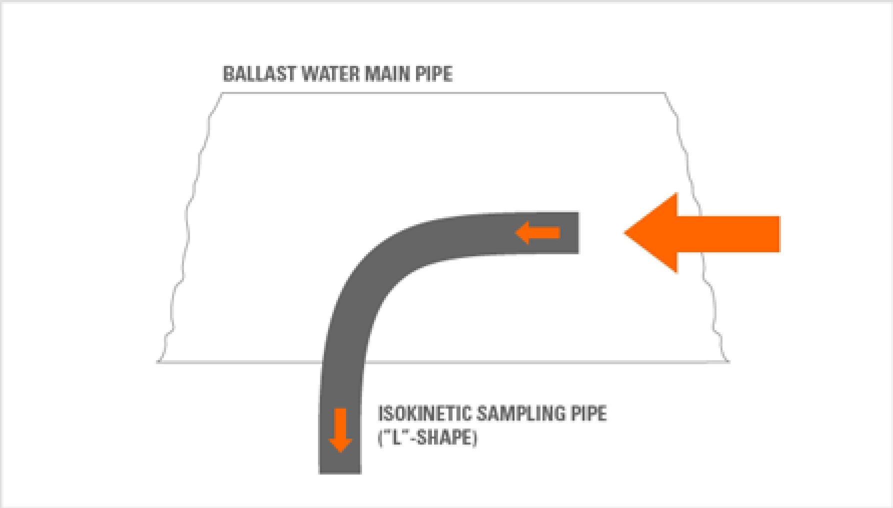

Figure 2. Ballast water discharge above pier level from the upper wing tanks of a bulk carrier. Source: Jure Barovic, with courtesy of the Port of Koper, services for protection of the sea (Consult, 2013)

In-tank sampling offers a risk-based, scientific assessment of ballast biota, while sampling at the discharge point provides compliance monitoring with the BWM requirements (Gollasch and David 2011). Tables 2 and 3 outline the sampling approach for compliance control, and the appropriateness of the sample access point for compliance control with BWM requirements, respectively.

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Table 2. Sampling approach for compliance control with ballast water management requirements (Gollasch & David, 2011)

Sampling purpose	Compliance monitoring D-1	Compliance monitoring D-2
Sampling point	In-tank	At-discharge and/or in-tank
Taxonomic coverage	Target taxa (to prove coastal origin of water)	All taxa, indicator microbes and bacteriae
Qualitative / Quantitative	Qualitative (to prove coastal origin of water)	Quantitative for organisms above 10 µm and qualitative for indicator microbes

Table 3. Appropriateness of the sample access point for compliance control with ballast water management requirements (Gollasch & David, 2011)

Sampling purpose	Compliance monitoring D-1	Compliance monitoring D-2
Sounding pipe	Recommended for abiotic parameters, suitable for target taxa	Suitable for tanks with direct discharge to sea
Manhole	Suitable for abiotic parameters, target taxa	Suitable for tanks with direct discharge to sea
Ships fire-fighting system	Not recommended, discharge to sea may occur during sampling	Not recommended, unknown negative organism impact of high pressure in the system
Ships ballast water line	Not recommended, discharge to sea occurs during sampling	Recommended

4. Sampling Challenges and Recommendations

Compliance with Regulation D-1

A number of measures can be made to ensure compliance with Regulation D-1. Salinity can help determine whether ballast water originates from coastal or ocean areas – coastal areas typically have lower salinity values (< 30 psu). Conversely, ocean water (beyond 50 or 200 nm from nearest land in water depths > 200 m) generally has salinity values ≥ 35 psu (Murphy et al., 2008). However, this compliance measure is only suitable when ballast water in the inspected vessel has been sources from a lower salinity or freshwater port. Although turbidity (the concentration of sediments) is not widely used to ensure compliance with the D-1 standard, high turbidity values could indicate that exchange has occurred in coastal waters (David, 2013). David (2013) also noted that since the D-1 standard requires at least 95% volumetric exchange, 5% may be un-exchanged and therefore ocean water could be diluted, resulting in a false non-compliant sample.

Employing biological sampling to ensure compliance with the D-1 standard has its limitations as few organisms are exclusively found in coastal waters. The exception to this is harpacticoid copepods and barnacles, the former are benthic organisms and although their presence can indicate coastal water, they can also be found in the sediment of tanks

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(Gollasch & David, 2011). Furthermore, *Escherichia coli*, *Enterococci* or *Vibrio cholera* tend to have quite a fast decay rate and therefore their presence in BW could indicate whether exchange has occurred in the coastal zone. Other trace elements, such as nitrogen and phosphorus, could also be used to test for compliance with the D-1 standard, i.e. in river run-off (David 2013).

Compliance with Regulation D-2

Compliance with the D-2 standard is focussed on the selected indicator microbes and examines the number of living organisms (Gollasch & David, 2011). The Convention suggests that the most appropriate sampling location for Regulation D-2 compliance is the discharge line; however, in-tank sampling is sometimes the only option since many vessels lack sampling points (Gollasch & David, 2011). Gollasch and David (2011) also noted that in-tank sampling allows BW to be sampled prior to discharge if unwanted NNS are present.

Currently, the D-2 standard can be interpreted in two ways: an instantaneous standard applying to any water volume discharged, or an average standard applying to the total discharge amount (Gollasch & David, 2011), which can have significant implications in instances of non-compliance. For instance, Gollasch and David (2011) noted that recording the number of organisms above 50 μm in minimum dimension is very difficult as less than 10 viable organisms per m^3 are acceptable, and therefore more than 1000 litres of water may be required in order to demonstrate compliance. David (2013) noted that different groups of organisms generally require different sampling approaches, and therefore sampling techniques need to be rigorously scrutinised for their robustness.

Vessel constraints

Vessels have markedly different configurations (types, sizes, cargo profiles, etc.), which can result in markedly different ballast water discharge profiles and times (David, 2013). BW discharge can be conducted “at once” or “in sequences”, which can take approximately one hour to up to several days (David, 2013). For instance, emptying the ballast tank of large tankers, bulk carriers and some general cargo ships can take several days given the duration required to load the cargo (Gollasch & David, 2011). This can affect the sample collected and could mean that the sampling team have to stay onboard for several days, which is costly (Costa et al., 2015).

Tank selection is another aspect to consider as some vessels may have ballast water sourced from different areas and with different uptake dates and therefore, there may be a requirement to sample all tanks (David, 2013). Sampling priority should be given to tanks with higher environmental compatibility of the discharge area with the BW origin, tanks with BW origin area where Harmful Aquatic Organism and Pathogens (HAOP) or NNS are present, and tanks with shorter in-tank holding time as these pose the highest risk (David, 2013). Sampling point accessibility may also help choose which tank to sample for in-tank sampling.

5. Recommendations

The majority of BW sampling is undertaken onboard, away from a controlled laboratory (David, 2013). It has been suggested in studies by Gollasch and David (2009; 2010; 2013) that sampling duration, timing, number of samples and the water quantity sampled are the principal factors influencing organism concentration results.

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Longer sampling times can negatively affect organisms ≥ 50 μm (underestimation in the viable organism concentration), with shorter sampling windows (approximately 10 minutes) providing a more representative sample (David, 2013).

Sample timing is important as organism concentrations can vary considerably if samples are collected at the beginning or the end of the discharge process given the patchiness in organism distribution, and therefore it is not recommended to take samples within the first or last five minutes of the BW discharge (David, 2013). Instead, a random sampling sequence is recommended for durations of around 10 minutes within the middle of the discharge from a tank(s) (David, 2013).

Given this patchiness, a single 10-minute sample could misrepresent the concentration discharged, and it has been noted that the average concentration of organisms of two random sequential samples provide very similar results to the average of three random samples (David, 2013). Therefore, at least two random samples are recommended with samples analysed immediately after the completion of each sampling event, and subsequently averaged (David, 2013).

Following studies by Gollasch and David (2009; 2010; 2013), it is recommended that:

- For organisms ≥ 50 μm in minimum dimension, between 300 and 500 litres should be filtered and concentrated;
- For organisms ≤ 50 μm but ≥ 10 μm, a "continuous drip" sample with a total volume of no less than five litres should be taken (i.e. 0.5 litres collected every minute during the entire sequential sampling duration, or 0.5 litres of sample water collected every 30 to 45 litres of BW sampled, depending on the flow rate) – the resulting five litres of sampled water should be mixed and sub-sampled in two sets, one set of alive samples and another preserved. A sub-sample volume of 60-100 ml is recommended.
- For indicator microbe samples, a sample of approximately one litre should be collected as a sub-sample after mixing from the five litre continuous drip sample (David 2013).

Flow rate can also have an effect on organism concentration and therefore it is recommended that the flow valve be opened as much as possible, but should not exceed 50 l/min.

6. UK sampling strategies

Although there are currently no specific sampling or analysis protocols in place, a number of nations have adopted different sampling approaches for BW tanks in order to ensure compliance with the D-1 and D-2 standards. Here, the focus is on the UK.

Intertek has experience in undertaking ballast water sampling on oil tankers in the UK. This has allowed first-hand experience of the difficulties and practicalities in collecting and analysing samples. These include uncertainty in boarding times (i.e. keeping sample teams on standby); vessel and ballast tank access problems for sample collection (e.g. tanks being barred, restricting the space available for plankton net sample collection) and; complications with analysis of the bacterial samples within a suitable timeframe. In terms of analysing the bacterial samples, Intertek has endeavoured to commence the sample analysis within 24 hours following sampling – after this time the bacteria decay and therefore the sample is not considered to be representative.

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Although the Convention has been ratified and will enter force on 8th September 2017, the Maritime and Coastguard Agency (MCA) appear to be taking a relatively passive stance according to the latest British Port Association's (BPA) newsletter. The MCA advised that there would be no compulsory elements for UK ports and that any decisions relating to shore-side reception facilities, data gathering or surveys would be voluntary rather than regulatory (BPA, 2016).

7. Conclusion

It has been shown that ballast water sampling is a very complex activity and there is yet to be an agreed methodology or approach. Many factors influence the type of sampling technique to be adopted (sampling point availability, access issues, tank depth, for example). This impedes the adoption of a common approach making it difficult to directly compare compliance monitoring results. This could result in a vessel being compliant at one port, but not at another – something that is both unacceptable and worrying. Therefore, significant R&D into the most effective sampling methods is required, taking due account of the disparities in ship design, to ensure that the Convention requirements for ballast water management are implemented in an efficient and coordinated manner.

Acknowledgements

Intertek, a leading Total Quality Assurance provider to industries worldwide, is recognised as offering world-leading expertise in BW and environmental water testing solutions and works with a number of organisations providing in-depth knowledge to development policy, methods and tools to ensure compliance with the BW Management (BWM) Convention. Indeed, Intertek's work on the implementation of the BWM Convention has been pioneering in helping ports prepare for International Maritime Organization and European requirements. The scientific rigour of Intertek's work has earned recognition from stakeholders and statutory consultees.

As the first UK-based company to support the development of policies and procedures that assess the impact of the release of BW within the marine environment, Intertek recognises the need to in develop BWM policies and procedures, to both sustain a high level of environmental protection and facilitate commercially important shipping activities.
Intertek also ensures that its clients' policies are compliant with all relevant European and National legislation (including EU Habitats Directive and Merchant Shipping Regulations) and its experts provide reliable advice based on testing and treatment solutions for issues such as NNS introduction and defending protected sites.
Intertek's network of more than 1,000 laboratories and offices and over 40,000 people in more than 100 countries, delivers innovative and bespoke Assurance, Testing, Inspection and Certification solutions for our customers' operations and supply chains.
http://www.intertek.com/energy-water/ballast-water-management/

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