Regrowth in ship's ballast water tanks: Think again!

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ABSTRACT

With the imminent ratification of the International Maritime Organisation’s Ballast Water Management Convention, ship owners and operators will have to choose among a myriad of different Ballast Water Treatment Systems (BWTS) and technologies to comply with established discharge standards. However, it has come to our attention that decision-makers seem to be unaware of the problem of regrowth occurring in ballast water tanks after treatment. Furthermore, the information available on the subject in the literature is surprisingly and unfortunately very limited. Herein we summarise previous research findings that suggest that regrowth of bacteria and phytoplankton could occur 18 h to 7 days and 4 to 20 days after treatment, respectively. By highlighting the problem of regrowth, we would like to encourage scientists and engineers to further investigate this issue and to urge ship owners and ship operators to inform themselves on the risks of regrowth associated with the implementation of different BWTS.

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1. Introduction

In order to maintain stability and manoeuvrability, commercial ships need to compensate for the weight loss after unloading their cargo by taking up water at the port of arrival. This water, called ballast water, is kept in ballast water tanks for the duration of the voyage and usually released into the environment back at the loading port, which can be located thousands of miles away from where the water was taken up. Aquatic organisms capable of surviving in ballast water can become invasive species when released into new environments at discharge. (Battle, 2009; Control and management of ballast water-Detailed guidance-GOV.UK, 2012). To address this issue, the International Maritime Organisation (IMO) adopted in 2004 the International Convention for the Control and Management of Ships’ Ballast Water and Sediments (BWM Convention). Following IMO’s example, in 2012 the United States Coast Guard (USCG) published their own Ballast Water Management Regulations, intended for vessels operating in American waters. Indeed, in order to minimise the risk of species invasion through ballast water, IMO’s D-2 Standards and USCG have defined maxima discharge levels for the following three categories of organisms: (1) those ≥50 μm in size, (2) those ≥50 and ≥10 μm and, (3) indicator pathogenic bacteria Escherichia coli, Enterococci and Vibrio cholerae.

IMO’s BWM Convention will enter into force 12 months after ratification by 30 States (countries) representing 35% of the world’s merchant shipping tonnage. As of the 8th of March 2016, 49 States holding 34.82% of the word’s tonnage had signed the treaty (IMO, Summary of Status of Conventions), hence ratification is imminent. Ship owners and ship operators are therefore at the turning point where they need to choose an appropriate BWTS to ensure they comply with IMO and/or USCG discharge standards.

Most ballast water treatment systems include a primary filtration step to remove organisms larger than 20–55 μm in size (Anwar, 2015), such as eggs, larvae and adults of many benthic or pelagic plankton (Veldhuis et al., 2006), that are likely to survive secondary treatments such as UV irradiation, ozonation or electrochlorination (Chase et al., 2001; Gregg et al., 2009; Lloyd’s Register’s Marine, 2015). However, regardless of the BWTS used, there is sufficient evidence to say that there is not one ballast water treatment method, or even a combination of primary and secondary methods, that can guarantee 100% kill of all marine organisms (Chase et al., 2001; Waite et al., 2003; Tsolaki and Diamadopoulos, 2010; Gregg et al., 2009; Veldhuis et al., 2010; Ibrahim and El-Naggar, 2012).

One major implication of the fact that no BWTS can remove or inactivate all organisms in ballast water is the potential for regrowth after treatment, yet little attention has been paid to this issue in the past 15 years or so (Fig. 1). In order to raise awareness on the subject, herein we summarise the limited information on regrowth in ballast water currently available in the scientific and engineering literature.

2. The problem with regrowth

Some treatments are more effective in killing microorganisms (mainly bacteria) than larger organisms such as phytoplankton and zooplankton (Chase et al., 2001; Wright and Dawson, 2002; Gregg et al., 2009; Lloyd’s Register Marine, 2015). Therefore, depending upon the treatment used, organisms belonging to different size categories, as defined by IMO/USCG, will be more likely to survive than others, and some of the
survivors will have a greater potential for regrowth. Zooplankton (e.g. copepods), phytoplankton (e.g. diatoms) and bacteria groups will all be present in ballast water, with the former generally dominating the ≥50 μm size category and phytoplankton usually dominating the <50 and ≥10 μm size range. Species composition, on the other hand, will vary depending upon the origin of intake water. Below we present a summary of the results obtained from various scientific studies dealing with survival and regrowth of these organisms after treatments used for ballast water disinfection. The technologies used in each case are not specified, as the objective of this summary is to highlight the regrowth problem and not to compare the efficiency of different BWTS. For more details, please refer to the literature cited.

2.1. Zooplankton

Although filtration at intake seems to be an adequate method to remove these organisms from ballast water, not all of them are retained by filters and many species have been shown to be likely to survive certain ballast water treatments (Gregg et al., 2009). Furthermore, zooplankton can provide shelter for bacteria, protecting them and therefore allowing them to survive specific treatments (Tang et al., 2011). Given the right conditions, surviving zooplankton could potentially benefit from regrowth of organisms that constitute their food source (e.g. phytoplankton) and increase their numbers in turn.

2.2. Phytoplankton

It has previously been shown that phytoplankton can survive in the darkness of ballast tanks for up to 23 days (Kang et al., 2010), and that after treatment a variety of photosynthetic organisms can regrow within 4 to 20 days of being put back into benign conditions (Stehouwer et al., 2010, 2015; van der Star et al., 2011; Liebich et al., 2012; Martinez et al., 2013). Again, regardless of the BWTS used, these results showed clear evidence of the high potential of different phytoplankton groups to regrow after treatment.

2.3. Bacteria

Bacterial regrowth is favoured by both the release of nutrients from dead organisms in the form of dissolved organic matter (Carney et al., 2011; Lasternas and Agustí, 2014; Buchan et al., 2014) and a decrease in the number of predators (Hess-Erga et al., 2010). If ballast water is treated during uptake, there will be a recolonization by heterotrophic bacteria during transport (Hess-Erga et al., 2010). Different studies have shown that bacterial regrowth is a reality following a variety of methods used to treat ballast water. Indeed, regrowth of free-living bacteria, including Vibrio spp. (Tryland et al., 2010; Wennberg et al., 2013), E. coli (Rubio et al., 2013) and sheltered bacteria (Tang et al., 2011), has been observed after 18 h to 7 days of subjecting them to different treatments (Waite et al., 2003; Hess-Erga et al., 2010; Li et al., 2013; van Slooten et al., 2015; First and Drake, 2014).

3. Summary of considerations

3.1. Why should we care about regrowth?

International ISO-certified standard culture methods including incubation periods of at least 24 h and up to 48 h have been established to determine the number of Colony Forming Units (CFUs) of bacteria in environmental samples. These methods are also used to determine the number of CFUs of the pathogenic bacteria Vibrio spp., E. coli and Enterococcus in ballast water (BWM.2/Circ.42/Rev.1). If these bacteria were to survive treatment and regrow between 18 and 48 h after treatment (e.g. Waite et al., 2003; Rubio et al., 2013), then their numbers could easily exceed discharge standards. The IMO circular BWM.2/Circ.42/Rev.1 also mentions culture methods to assess recovery, regrowth and maturation of viable organisms in the ≥50 μm as well as in the <50 and ≥10 μm size categories. Given the clear potential for regrowth, we believe the establishment of international standard methods to monitor the recovery of different organisms after treatment is only a matter of time.

3.2. How quickly can it happen?

The time scale for regrowth will be different for organisms with different growth requirements, but overall it seems to occur between 18 h (bacteria) and 20 days (phytoplankton) after treatment (see above). Depending upon the length of the voyage, it would take only a few surviving organisms to potentially exceed the discharge standards when deballasting.

3.3. What can be done about it?

The first thing to do is to highlight the existence of the problem of regrowth and bring it to the attention of interested parties, which is the purpose of the present article. Only well informed individuals can make appropriate choices and decisions. For instance, ship owners and
ship operators with no knowledge on regrowth could choose a BWTS that treats at intake thinking that this would be enough to meet discharge standards after a 7-day voyage. However, the evidence presented above suggests that regrowth could easily occur within this period of time, increasing the probability of exceeding the established standards at discharge. The authors believe that expanding the current knowledge on ballast water regrowth by engaging in new scientific research would help decision-makers in choosing the most appropriate BWTS according to their own requirements, such as intake flow rates, type of vessel and duration of the voyage.

4. Conclusions

The main objective of this article is to raise awareness on the subject of regrowth in ballast waters among research scientists and engineers, ship owners and ship operators as well as policy and decision-makers. The authors would like to encourage the scientific and engineering communities in both the industry and academia to further investigate the issue of regrowth after ballast water treatment and assess the impact that this could have on the aquatic environment. At the same time, we think again that this could have on the aquatic environment. At the same time, we think again. By taking this issue into consideration when choosing the most suitable BWTS for their business, ship owners and ship operators would not only avoid exceeding discharge standards (as well as hefty fines on discharge), but would also contribute towards avoiding new species invasion altogether.

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