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Ballast Water Treatment with Chlorine-based Disinfectants

August 2019

The International Maritime Organisation's (IMO) Convention for the Control and Management of Ships' Ballast Water and Sediments is a vital tool to prevent the damaging effects on aquatic ecosystems caused by the exchange of untreated ship ballast water. Chlorine chemistry, when correctly applied, is an integral part of ballast water management plans to help protect Earth's aquatic species from the impacts of non-native species.

ISSUE SUMMARY

Ballast water is marine, brackish, or fresh water taken into and discharged from ship ballast tanks to improve their stability and maneuverability. The process of adding (ballasting) and releasing (deballasting) water is vital to a ship's operation, but it can be disruptive to aquatic ecosystems by promoting the spread of invasive species. Ballast water can contain aquatic life forms that may be native to the ecosystem of the water "intake" point but foreign to the ecosystem of the water "release" point. For example, zebra mussels, which are freshwater mussels indigenous to the lakes and rivers of Russia and Ukraine, are now thriving in numerous non-native freshwater bodies worldwide. Their dense growth in these areas blocks pipelines and clogs water intakes, among other detrimental effects.

The International Maritime Organisation's (IMO) Convention for the Control and Management of Ships' Ballast Water and Sediments, commonly referred to as the Ballast Water Management Convention (BWMC), aims to prevent the spread of harmful aquatic organisms from one region to another by establishing standards and procedures for managing and controlling ship ballast water and sediments. The BWMC applies to all ships that carry ballast water and travel internationally. It sets requirements for global ballast water management, but permits national, regional, and local authorities to establish their own regulations within their respective territorial waters. The Convention requires ships to have and implement an acceptable ballast water management plan. Under the BWMC, as of 8 September 2017, ships must either perform ballast water exchange (substitution of water in ship's ballast tanks) according to specifications, or use an approved treatment system.

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Although initially vessels were to be equipped with approved treatment systems "by the date of their first International Oil Pollution Prevention Certificate renewal survey after 8 September 2017," in July 2017, the deadline for installation was delayed to between 8 September 2019 and 7 September 2024".[1,2]

Approved technologies include electrochlorination, chlorination, ozonation, peracetic acid & hydrogen peroxide treatment, and gas super-saturation. Ships must meet ballast water discharge criteria for viable organisms and concentrations of indicator microbes. Whilst the aforementioned technologies help address the significant and growing environmental problem of aquatic invasive species, some researchers are concerned about the potential environmental effects of low levels of disinfection byproducts in discharged ballast water.

INDUSTRY VIEWS

WCC recognises the damaging effects on aquatic ecosystems caused by the exchange of untreated ship ballast water and maintains the products of chlorine chemistry will be an integral part of ballast water management plans that will help protect Earth's aquatic species from invasions of non-native species.

According to the IMO, "The spread of invasive species is now recognised as one of the greatest threats to the ecological and the economic well being of the planet. These species are causing enormous damage to biodiversity and the valuable riches of the earth upon which we depend." Direct and indirect health effects are becoming increasingly serious and the damage to the environment is often irreversible." The IMO notes, "The problem increased as trade and traffic volume expanded over the last few decades, and in particular with the introduction of steel hulls, allowing vessels to use water instead of solid materials as ballast…As the volumes of seaborne trade continue overall to increase, the problem may not yet have reached its peak."

A McGill University study[3] notes 80% of world trade is carried out by ship. The study states that shipping accounts for 60-90% of marine bio-invasions, both from ballast water and

[1] Alfa Laval (February 2017) White Paper, "Ballast water management: An overview of regulations and ballast water treatment technologies." (IOPP renewal survey refers to the renewal of a ship's International Oil Pollution Prevention certificate and occurs in dry-dock)

[2] Hellenic Shipping News (July 29, 2019), "Ballast Water Management Systems: Time-Line for Compliance."

[3] Sardain, A., et al., "Global forecasts of shipping traffic and biological invasions to 2050," *Nature Sustainability,* published online March 18, 2019 (abstract and News Release).

attachment to the exterior hulls of ships. Projections indicate that shipping growth will far outweigh climate change as a factor in the global spread of invasive species.

WCC fully supports the IMO's Ballast Water Management Convention, as well as local, national, and regional efforts to develop ballast water management regulations.

Ballast water standards will be phased in over time. According to BWMC Regulation D-2, by 2024, all newly built ships will require ballast water management systems to remove, sterilise, or kill organisms before they are discharged. Approved chemical technologies under the BWMC include electrochlorination, chlorine-based disinfectants, ozone, gas super-saturation, and peracetic acid & hydrogen peroxide. Additionally, anti-fouling systems for ship hulls include paints, coatings, and surface treatments to help prevent the attachment of unwanted organisms. Many of the products of chlorine chemistry will help control the spread of aquatic invasive species and help achieve UN Sustainable Development Goal #14, "Life Below Water" ("conserve and sustainably use the oceans, seas and marine resources for sustainable development").

No single technology applies universally for all ballast water treatment plans. Ship owners should consider their vessel's size and operating conditions when choosing from the system. Ideally, technologies can be adapted to minimise the production of disinfection byproducts.

Most ballast water treatment systems incorporate pre-treatment and main treatment steps. Pre-treatment removes solid matter and larger microorganisms. The table below presents an overview of the available main treatment technologies for ballast water and some considerations for each technology.[4]

[4] See Alfa Laval (February 2017) White Paper, "Ballast water management: An overview of regulations and ballast water treatment technologies."

Technology	Operation	Considerations
Chlorination	Approximately 1-10 ppm sodium hypochlorite is added to ballast tank to kill organisms and pathogens that have bypassed a separation step. Neutralisation, usually with sodium meta-bisulfite or sodium thiosulfate, is needed prior to discharge.	Can create disinfection byproducts and may, therefore, require additional post-treatment; requires consumables and special ventilated storage rooms. Requires careful handling to avoid splashes in contact with skin or eyes. Do not mix with acids as this can generate chlorine gas which is harmful if inhaled.
Electrochlorination	Passes seawater through an electrolytic cell where chlorine and hydrogen gases are produced. Chlorine gas dissolves to form sodium hypochlorite and bromine hypochlorite, which neutralises microorganisms. Neutralisation, usually with sodium meta-bisulfite or sodium thiosulfate, is needed prior to discharge.	To be effective in brackish or fresh water, requires adding salt or brine, which must be stored on board. Low water temperature impacts effectiveness. There is significant power consumption when operating in low-salinity or colder water. Hydrogen gas is explosive, so the equipment requires hydrogen traps, flame arrestors, or other methods to safely handle the gas. Electrode cleaning requires acid wash or other cleaning methods. Requires special ventilation.
Ozonation	Generates ozone by either UV light or high-voltage electricity; ballast water passes through a *Venturi* throat, which creates a vacuum, pulling ozone gas into the water.	Auxiliary equipment is needed; e.g., compressors, dryers, and air chillers. More effective than chlorination against bacteria and viruses, but can produce harmful byproducts, especially insoluble metal oxides.
Peracetic acid & hydrogen peroxide	Disinfects via a chemical blend with few known harmful byproducts.	Chemicals are relatively expensive and require high mixing concentrations and considerable storage space.
Chlorine dioxide	Disinfects quickly when added to ballast water as an aqueous solution in order to avoid potential problems with handling gases.	Requires safe storage and handling on board. It is rarely used despite its fast-acting disinfecting capabilities, due to excessive amounts of toxic chlorite that are produced in some circumstances.

Gas super-saturation (combination of chemical and physical disinfection)	Depletes the oxygen supply (suffocates) available to marine microorganisms by injecting nitrogen gas into ballast water in sealed ballast tanks.	A treatment time of several days is required for the method to be effective. A nitrogen generator must be installed on board that has a large physical footprint.

WCC supports research to improve understanding of the environmental effects of disinfection byproducts from ballast water treatment and releases on aquatic organisms.

Like human exposure to low levels of disinfection byproducts in treated drinking water, the unintended consequence of treating ballast water before discharge is the generation of some disinfection byproducts. While ideally and readily minimised via treatment steps based on each ship's size and operating conditions, exposure of aquatic organisms to disinfection byproducts should be evaluated in the context of managing the much greater risk of the spread of invasive aquatic species.

ADDITIONAL RESOURCES

International Maritime Organisation, *International Convention for the Control and Management of Ship's Ballast Water and Sediments*, online, available: http://www.imo.org/en/About/Conventions/ListOfConventions/Pages/International-Convention-for-the-Control-and-Management-of-Ships'-Ballast-Water-and-Sediments-(BWM).aspx (accessed August 2019)

US Coast Guard, *Ballast Water Frequently Asked Questions* (Revised April 24, 2018), online, available: https://www.dco.uscg.mil/Portals/9/MSC/BWMS/Ballast_Water_FAQs.pdf?ver=2018-06-06-123015-850 (accessed August 2019)