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Review

# Ship ballast tanks a review from microbial corrosion and electrochemical point of view

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ABSTRACT

Microbiologically Influenced Corrosion (MIC) is the term used for the phenomenon in which corrosion is initiated and/or accelerated by the activities of microorganisms. MIC is a very serious problem for the ship industry as it reduces structural lifetime in combination with safety risks for crewmembers or inspection personal and increases maintenance costs. This review aims to focus on the importance and mechanisms of MIC in ship ballast tanks (SBTs). First section presents a literature review of general aspects of ballast tanks: structural properties including predominant environmental conditions. Second section summarizes the fundamental corrosion mechanisms within SBTs from an electrochemical point of view. Third section links microbial corrosion mechanism with electrochemical processes summarizing types of microorganisms, mechanisms of MIC and possible triggers for biofilm formation within this enclosed environment. For this an integral model, linking environmental parameters such as oxygen concentration, corrosion rate, nutrient availability and the microbial species of this environment is introduced in this paper. Fourth section gives an outlook on surface treatment and coating application in SBT. The last section considers the practical aspects of MIC detection and possible counterstrategies for engineers/operators and inspection personal. This paper gives a comprehensive overview of MIC processes in ship ballast tanks addressing engineers, equipment manufacturers and operators by offering practical solutions for an appropriate SBT management.



**Contents**



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## 1. Ship ballast tanks

### *1.1. Historical aspects and application*

A SBT is a compartment within a boat, ship or other floating structure that holds water. In most of the cases and for the discussed cases in this review the used ballast water is seawater. All vessels have ballast water tanks to adjust the ship's draft, buoyancy and trim under different operating conditions. From the 1880s onwards, water was used for ship ballasting. This decreased time-consuming load of solid material e.g. stones used as ballast. Small vessels may have a single ballast tank in the middle or multiple ballast tanks typically on both sides. Large bulk carrier and oil tanker have several ballast tanks including double bottom tanks, wing tanks as well as forepeak and aft peak tanks. In ship construction, a ballast tank is usually centered at the lowest point of the hull (Fig. 1). By positioning multiple ballast tanks around the ship, local weight reduction by fuel consumption and stormy weather conditions can be balanced increasing ship stability. Ballast tanks can be filled or emptied with water in order to adjust the amount of ballast force. Ballast tanks are usually filled when cargo is being offloaded, and discharged when cargo is being loaded. When ships take in water for ballast in port, they also take in microorganisms e.g. Sulphate reducing bacteria and phytoplankton. This problem due to organism transfer and a possible high nutrient load in the harbour has lead to substantial deballasting several kilometres off shore in many countries and ports. These organisms are transported and introduced into the waters of the harbours along the vessels' routes as ballast tanks are emptied each time cargo is loaded. It is well documented that ballast water is a major pathway for aquatic species introductions around the world (Hallegraeff and Bolch, 1992; Hamer et al., 2000; Gollasch et al., 1998). Today 80% of the world's trade volume is transported by ships (Peters, 1993). In many cases half of a given voyage must be undertaken in ballast conditions to compensate the absence of cargo. This emphasizes the huge volume of ballast water, which is transferred all over the world and the importance of SBT on the lifetime and safety of a ship.

Typical vessel types and their ballast requirements can be broadly classified as provided in Table 1. The capacity, location and flexible use of ballast tanks are a crucial point in ship design. Rough operational conditions, such as wet/dry phases during load/unload conditions and structural aspects make SBTs difficult and expensive in maintenance and inspection. The complex structure of a ballast tank results from stiffeners, edges and corners forming the basic skeleton of a ship. Inner surface areas of SBTs are enormous, classically in the range of 1.5–7 million $m^2$. Ballast capacities depend on the ship size and therefore range from single cubic meters for sailing boats up to 200.000 $m^3$ for large cargo carriers. Ballast water is taken on board using sea chests, pumps or by gravity feed. As a consequence of remaining water when

**Table 1**
Ballast requirements and corresponding ship types.[a]

| Ballast requirement (Reason for ballast water uptake) | Ship types |
|---|---|
| *Cargo replacement* | Dry bulk carriers<br>Ore carriers |
| *Return voyage* | Tankers<br>Oil bulk ore carriers |
| *Control stability, trim* | Ferries<br>General cargo vessels<br>Passenger vessels<br>Fishing vessels<br>Fish factory vessels<br>Military vessels |
| *Large volumes, discharged in same location* | Heavy lift vessels<br>Military assault vessels<br>Barge-carrying cargo vessels |
| *Vessel control* | Container ships |

[a] Stemming the Tide: Introduction of Nonindegenious Species by Ship Ballast Water (1996) Committee on ships' Ballast Operations.

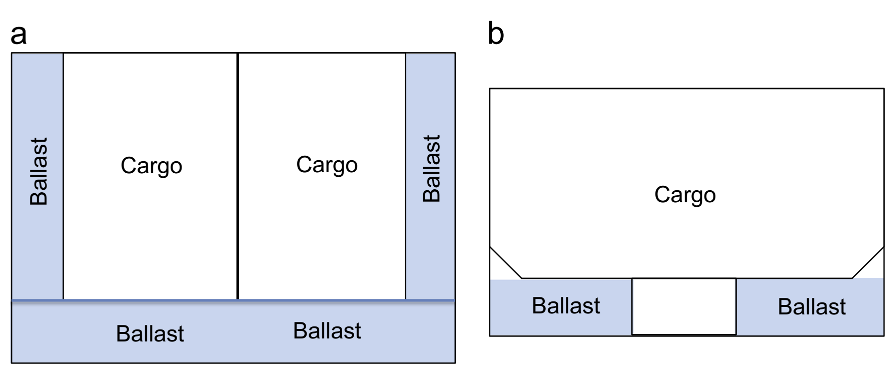


**Fig. 1.** Typical cross-sectional view of ballast tank positions within ships: (a) tanker and (b) bulk vessel.