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MARITIME TRANSPORT - AN ENVIRONMENTAL PROBLEM WITH BALLAST WATER: TECHNICAL PREVENTIVE MEASURES

Włodzimierz Freda, Zbigniew Otremba

Gdynia Maritime University
Faculty of Marine Engineering
Department of Physics
Morska Street 81-87, 81-225 Gdynia, Poland
tel.: +48 58 6901669, fax: +48 58 6206701
e-mail: wfreda@am.gdynia.pl, zotremba@am.gdynia.pl

Abstract

The fast development of marine transport causes a lot of environmental concerns connected with possible accidents of ships transporting hazardous cargoes as well as oil pollution coming from an exploitation of engine rooms. Moreover, a significant problem is connected with a ballast water handling. The use of ballast water is necessary for the safe movement of large ships. Namely, in maritime transport a ship unloading causes a reduction in its draft – it is a cause of lower steering or even completely prevents the safe movement of the ship. Therefore, in place of the discharged freight the ballast water is collected (often just during the unloading). This water is pumped out from a ship at the site of re-loading. However, this implies the risk of transportation of living organisms over large distances, which (if at the point of discharge of ballast water will find suitable conditions) can become invasive species. Because of the risks involved in carriage of these organisms, the International Maritime Organization (IMO) has developed rigorous standards for permissible amounts of organisms in the discharged ballast water. A number of methods of biological neutralization of ballast water, that meet the requirements of the IMO, have been developed. The topic of this paper is to review currently used methods of neutralization of ballast water. We consider clearing of ballast water from point of view of physics, especially by using electromagnetic radiation and ultrasonic waves.

***Keywords**: marine transport, ballast water, invasive species, environmental protection*

1. Introduction

The progressive development of sea transport causes a lot of threats to the marine and coastal environment in particular. These risks arise not only from the possibility of accidents and disasters at sea. One of the most important problems is the management and treatment of ballast water [5]. The use of ballast water is essential for safety and manoeuvrability of moving ships. Since the unloading of a ship causes a reduction in its draft, ballast water causes an increase in weight put on the ship so that it reaches the optimum immersion. Ballast water taken during the unloading of the vessel is transported in ballast tanks to the place of re-loading (Fig. 1). However, it causes the risk of transport of live organisms over large distances [8], which (if at the place of ballast water discharge will find suitable conditions) may become invasive species (see [6] and [4]). The most unwanted species that have already spread beyond the place of its natural habitat, are the bacteria of cholera, toxic algae, and some larger organisms such as the *Round Goby, European Green Crab, Mitten Crab, Zebra Mussel or North Pacific Seastar* ([9] and [10]). These organisms displace native species from their own environment, causing irreversible damage to the ecosystem. For that reason, the International Maritime Organization (IMO) has developed ways of ballast water management, and rigorous standards for the permissible quantity of living organisms in discharged ballast water (see [7]).

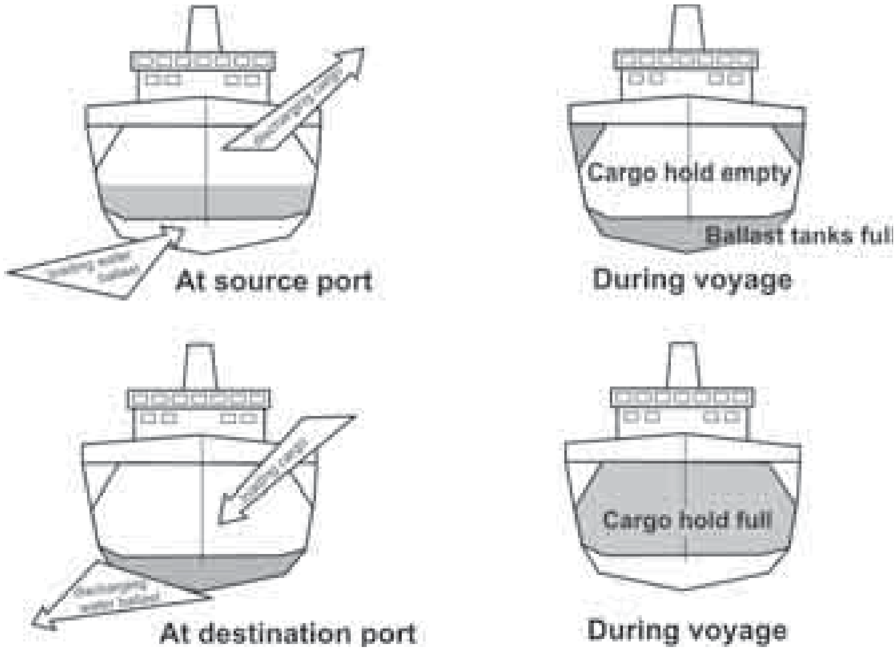

Fig. 1. Principle of ballast water operating

2. Functioning of the International Convention for the Control and Management of Ships' Ballast Water and Sediments.

International Convention for the Control and Management of Ballast Water and Sediments was adopted by IMO in 2004. The Convention will force ships to fulfil the requirements for ballast water exchange standards or to fulfil the concentration limits of number of living organisms in discharged ballast water. Ballast water management standards should be implemented in accordance with the schedule associated with the construction of the ship date and quantity of ballast water on board.

Ratification of the Convention by individual states is slow. Convention enters into force shall be 12 months after ratification by 30 states, representing 35 percent of the gross tonnage of goods transported by sea. Currently (as of 31 May 2012) 35 countries representing 27.95% of the tonnage ratified the convention. Due to the slow pace of adoption, some regulations stored in the convention will become obsolete before they take effect. This requires changes in the timelines. The tentative schedule makes the implementation of the requirements of the Convention (planning and installation of necessary equipment) is even more difficult for owners, builders and manufacturers of ships.

Pending the entry into force of the Convention, when the timetable for implementation will be binding throughout the world, efforts to solve the problem of invasive species are increasingly occurring at national, regional and local levels. More than a dozen countries as diverse as the countries of northwestern Europe, countries bordering the Persian Gulf, around the Great Lakes and the Antarctic, have introduced specific regulations dealing with the discharge of ballast water in their waters [1]. Further complicating the problem, government authorities, such as those in California, Michigan, New York and elsewhere in the U.S. and the state of Victoria in Australia, introduced requirements for ballast water management. A small number of these jurisdictions may prohibit the discharge of ballast water completely (e.g., Panama in the Panama Canal), require chlorination (e.g. Buenos Aires), or limit the discharge of ballast water into port reception facilities. Despite the obvious threat posed by ballast water, the legal situation is very complicated.

IMO Convention contains two provisions that define the standards for ballast water management, regulation D-1 on ballast water exchange standards and Regulation D-2 on specific standards of permitted levels of organisms in discharged ballast water.

Ballast water exchange is based on the principle that organisms and pathogens in ballast water collected from the coastal waters will not survive if released into the deep ocean waters and open seas, because of different water temperature, salinity and chemical composition. Similarly, the deep ocean waters or open sea water, compared to coastal waters contain less body to pathogens and those that do exist are less likely to adapt to new conditions of coastal or freshwater environment. Therefore, the probability of survival of organisms and the transfer of pathogens through ballast water is significantly reduced.

The Convention needs to be updated to install ballast water treatment systems, according to a schedule [7]. Regulation D-2 defines the performance standard for ballast water treatment system. This criterion is in the form of specific limits to aquatic life in the discharge of ballast.

- Less than 10 viable organism per m^3 > 50μm in minimum dimension, and
- Less than 10 viable organisms per ml < 50μm and >10μm in minimum dimension, and
- Less than the following concentrations of indicator microbes:
  - Toxicognic Vibrio cholera less than 1 colony forming unit (cfu) per 100 ml, or less than 1 cfu per 1 gram zooplankton samples;
  - Escherichia coli less than 250 cfu per 100 ml;
  - Intestinal Enterococci less than 100 cfu per 100 ml.

IMO defines ballast water treatment equipment as "…the equipment which mechanically, physically, chemically or biologically processes either singularly or in combination to remove, render harmless or avoid the uptake or discharge of harmful organisms or pathogens. Ballast water treatment equipment may operate at the uptake or discharge of ballast water, during the voyage, or at a combination of these events."

3. Review of technologies for the ballast water treatment

All currently available or in development technologies can be broadly grouped into three categories (based on the basic mechanism of deactivation of living organisms). These types are the mechanical, physical and chemical technologies [1, 3] that with the most promising technologies, associated with each of them, are shown as a diagram in Fig. 2 and described briefly below.

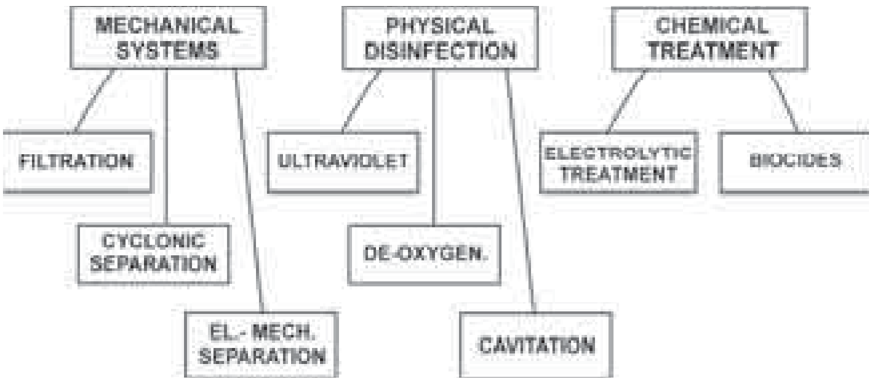

Fig. 2. Main technologies for deactivation living organisms in ballast waters.

Mechanical Systems:

- filtration – used during the collection of ballast water. The disk and screen filters separate the sediment and particles. They are often equipped with self-cleaning system and flush accumulated sediment back into the water source. In these filtration systems drops of the pressure reductions of the flow rate may occur due to the resistance in the filter elements and procedures of self-cleaning,
- cyclonic separation - centrifugal forces are used to separate solid particles from seawater. The disadvantage of this system is the separation of only those particles that have a density greater than water,

– electro-mechanical separation - is based on the addition of flocculent to the ballast water, which attaches to organisms and sediment. Then follows the magnetic separation and filtration, which leads to the removal of particulate matter.

Physical disinfection

– ultraviolet light - UV radiation directly kills or destroys the body's ability to reproduce by attacking and distribution of the cell membrane. The effectiveness of UV radiation depends on the concentration of sediment or turbidity of water that could reduce the transmission of UV radiation in water. UV radiation must reach out to all organisms, hence the need for separation of larger organisms, which might obstruct, and thereby protect against radiation smaller organisms. Energy consumption should be taken into account,
– de-oxygenation - Removal of oxygen not only kills aerobic organisms, but may also have a positive impact on the prevention of corrosion, provided that the oxygen content is maintained at appropriate levels. Various methods are used to remove dissolved oxygen in the water ballast and replace it with inactive gases such as nitrogen or other inert gas. De-oxygenation may require a longer time to make these organisms and pathogens harmless to receiving waters,
– cavitation / ultrasound - high energy accompanying the formation and collapse of bubbles resulting hydrodynamic forces and oscillations of ultrasonic or high frequency noise, which destroys the cell walls of organisms and effectively kills them. For the cavitation, bubbles are used in the Venturi tube or in slit plate.

Chemical Treatment

– electrolytic chlorination - in the flow the electric current is generated, which yields to create free chlorine, sodium hypochlorite and hydroxyl radicals, which causes electrochemical oxidation through the creation of ozone and hydrogen peroxide,
– disinfecting biocides – typical biocides are chlorine, chloride ions, chlorine dioxide sodium hypochlorite and hydroxyl radicals. These disinfectants are dosed into the ballast water to kill the living organisms by oxidation or chemical poisoning.

Choosing the right technology that could be used to ship the selected depends on many factors. These include the type and size of ship, characteristics of collected ballast water, treatment time, pressure drops occurring in the selected treatment systems, the size of equipment and space required on the vessel, the required power, the corrosion effects of tanks and pipelines, health and safety of people operating the system, ease of handling and control, reliability and cost of use.

4. Selected physical technologies for the ballast water treatment

Many producers from around the world are trying to endorse their ballast water neutralization system, by the IMO. In 2011, only 13 systems received the so-called Type Approval Certification. A dozen or so received a partial approval, and is also trying to get the Type Approval Certification. Approved technologies to achieve good performance usually combine chemical or physical methods of mechanical separation of larger particles. In this article, we focused on those technologies that have been approved by the IMO, and use the physical methods of treatment of ballast water.

The first group of technologies that work in similar ways are technologies using filtration and ultraviolet light [2]. The producers of such technologies are Hyde Marine, Inc. (USA), Optimarin AS (Norway) and Panasia Co., Ltd., (Korea). While ballast water passes through the filter system, which rejects molecules or organisms greater than 40-50 micrometers. The water then passes through the UV lamp for sterilization and is pumped into ballast tanks. Back-flushing water is directed over the side in place of ballasting. During deballasting, the filters are bypassed and the water is replaced by a second dose of UV radiation. Similar technology used the Alfa Laval company (Norway) on your system. The technology uses the pre-filtration and ultraviolet light too, but the radiation in the presence of titanium dioxide generates free radicals that break down the cell membrane of microorganisms. This advanced oxidation technology neutralizes the ballast water without using harmful chemicals or residues.

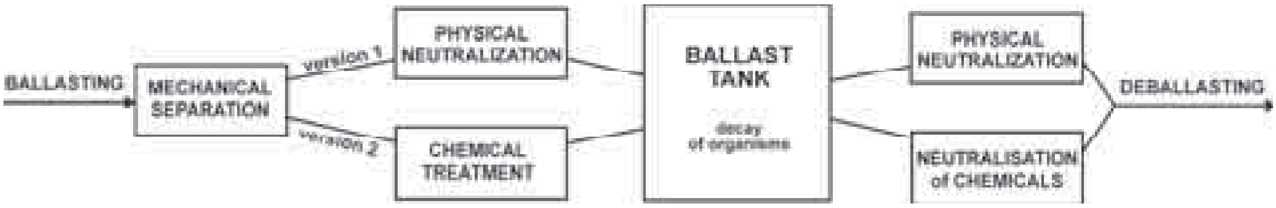

Fig.3. Overview of the ballast water management principles

A completely different technology based on cavitation, de-oxygenation and lowering the pH was used in the NEI Treatment System LLC (USA). During the ballast water intake the inert gas is introduced through a venturi system. Cavitation caused by the venturi system damage organisms as the first stage of neutralization. The inert gas removes oxygen from the water and lowers pH. Such conditions shall be maintained for 48 hours to complete neutralization of ballast. This technology requires no active substances.

Another technology was used in the OceanSaver AS (Norway). The purification process is based on a combination of filtration, hydrodynamic cavitation, de-oxygenation and electrodialytic process. After the initial filtration, the cavitation processes are triggered by intense pressure pulses. Ballast water is then super-saturated by nitrogen, which releases the oxygen dissolved in water. Both oxygen and nitrogen are then evacuated by a controlled ventilation system. The final stage of neutralization is the electrodialytic process, which is based on the electrochemical activation technology. The activated substances naturally degrade over a short period of time.

5. Summary

Ballast water and organisms that with their help are transported over long distances are a major threat to the marine environment. In the case of marine disasters, resulting in oil spills occur, their effects diminish with time. In the case of invasive species introduction into the environment, the consequences of such unintended actions are irreversible.

For that reason, the International Maritime Organization (IMO) has taken legislative action to force the ships to provide the ballast water management. Unfortunately, the insufficient number of countries ratified the International Convention for the Control and Management of Ballast Water and Sediments. The convention has not entered into force till now.

Nevertheless, many companies work to develop new technologies that allow for treatment of ballast water on board. The most interesting of them are physical methods, which, unlike chemical methods do not require dosing any active chemicals into ballast water.

Physical neutralization of ballast water is often safer for both the crew handling the system equipment (the lack of the dangerous chemicals that should be dosed into ballast tanks, and no risk of entering the active chemicals into the sea water during deballasting). Unfortunately, these systems are inefficient for the very large ships such as tankers, or obtaining the required efficiency is associated with too high costs or too much space needed to install them.

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