DAGUA-BWT

A NEW TECHNOLOGY FOR THE TREATMENT OF BALLAST WATER

INTRODUCTION

Cargo ships and oil tankers commonly carry ballast water in an effort to provide stability, trim and structural integrity after they unload their cargo at their destination. The discharge of ballast water and sediments by the ships, after loading cargo at their home port, has a negative impact on the marine ecosystem as they contain variety of plants, animals, aquatic microorganisms and pathogenic substances that may disrupt the biodiversity of marine environment and affect their economic viability. The invasive species may also introduce toxic substances and diseases with potential impact on the human health.

It is believed that ballast water is the major source of invasive species in the U.S. marine environment, which has posed serious public health and environmental risks, affected the water and power utilities, commercial and recreational fisheries, as well as agriculture and tourism [1]. For example, the introduction of pest zebra mussels, Asian clam, and other mollusks to the U.S. aquatic ecosystems has been reported to cost more than $6 billion per year [2].

BALLAST WATER DISCHARGE REGULATIONS

The discharge of ballast water and sediments by ships is governed by the International Convention for the Control and Management of Ships Ballast Water and Sediments (BWM Convention) which was adopted by the members of the International Maritime Organization (IMO) in 2004. This convention which introduced global regulations to control the transfer of potentially invasive species came into force in September 2017, requiring that the ships manage their ballast water. According to the BWM treaty requirement, most ships will need to install an on-board ballast water treatment (BWT) system [3], producing water qualities that conform to the D-2 ballast water performance standards that set limits on the concentration of viable organisms allowed to be in the ballast water at discharge [4]. According to these

standards, less than 10 per m^3 of organisms larger than 50 micron and less than 10 per mL of organisms larger than 10 microns but smaller than 50 microns are allowed to be discharged. The standard also targets the concentration of three indicator microbes in terms of colony forming units (cfu), i.e toxigenic *Vibrio cholera* (less than 1 cfu per 100 mL), *Escherichia coli* (less than 250 cfu per 100 mL) and intestinal *Enterococci* (less than 100 cfu per 100 mL).

BALLAST WATER TREATMENT (BWT) METHODS

One method for reducing the harmful effects of ballast water discharge at the ports is re-ballasting at sea. This technique involves replacing the ballast water at the sea at a distance of least 200 nautical miles from the nearest land and in water of at least 200 metres in depth, as recommended by the IMO guidelines. Although this technique reduces the risk of transfer of harmful aquatic species, it is not fully effective and does not provide adequate removal of invasive species. Hence, a number of physical, chemical and mechanical processes are used to treat the ballast water and remove the non-indigenous aquatic species before its discharge. They include filtration, chemical oxidation, electrochemical catalysis, thermal treatment, ozonation, UV irradiation, deoxygenation, cavitation, magnetic field treatment and chemical disinfection [5]. However, none of these processes alone has showed to be sufficient for the removal of all invasive species and the proper treatment of ballast water, requiring the combined use of two or more processes to achieve the required treatment standards. The inherent complexity of most existing treatment systems, intensive use of electricity or chemicals with the associated generation of toxic chemical waste, large footprint of components, as well as hardware and software failures and operator skills and maintenance requirements have introduced serious difficulties in the operation and maintenance of ballast water treatment (BWT) systems, rendering them expensive and unreliable and limiting their successful conduct. The encountered challenges during the operation of BWT systems by the ship owners include frequent clogging of filtration systems, limited lifetime and limited supply network of the required chemical compounds (e.g. disinfectants and coagulants), frequent failure of probes and sensors, improper software response, frequent instrument calibration requirements, frequent failure of UV lamps and large footprint of the treatment system [6]. Hence, the treatment of ballast water is still a crucial challenge that must be resolved for the protection of our marine environment.

One technology that is particularly suitable for the efficient and cost-effective treatment of ballast water is the Dagua-BWT technology. This treatment process utilizes a combination of rotary screen filter and ozonation for effective water purification and disinfection.

DAGUA-BWT TECHNOLOGY

Description: The Dagua-BWT system contains the following cleaning processes:

1- **Rotary screen filter (20 µm) with automatic suction backwash (ABW):** This compact and cost-effective separation process provides efficient removal of sediments and partial removal of planktons and microalgae. The filters used in the Dagua-BWT process are complete with stainless steel screens and can be set up in parallel for unlimited flow capacities. When the pressure drop reaches a preset level, the cleaning cycle is initiated. The vacuum screen cleaner suctions the separated particles from the inside of the screen and flushes them out the drain. The backwash cycle is accomplished in seconds without interrupting the main flow and supports the maintenance of the low operating pressure of filter. The screen filter with ABW allows the separation of sediments, aquatic organisms and other suspended solids to 20µm.

2- **Ozonation:** Following the ABW filtration, water is injected with ozone that is safely produced on-site by commercial ozone generators. The injection of ozone (10-12 mg/L) into the water is done by a venturi injector for high mass transfer and efficient dissolution of ozone in water. During a retention time of 4 to 6 minutes, ozone, which is a powerful disinfectant and oxidizing agent, disinfects the ballast water and significantly reduces the concentration of pathogenic substances including viruses and bacteria, as well as phytoplanktons, zooplanktons and microalgae. In addition to the disinfection capacity of ozone which kills most aquatic species by direct contact, ozonation benefits from the reactions of ozone with chemicals in seawater, such as bromides, with the resulting production of hypobromous acid, which is potent disinfectant. The use of ozone for disinfection is advantages compared to chemical disinfectants since no chemical agents need to be carried aboard the ships. Moreover, ozone is more effective than chlorine and hypochlorite disinfectants in the removal of pathogenic substances from the water. In addition, as a potent oxidant, ozone oxidizes organic and inorganic contaminants,

including natural organic matter, residual hydrocarbons in oil tankers and inorganic oxidizable matter, and removes the biofilm deposits. In the Dagua-BWT technology, the generation of ozone is automatically adjusted by on-line ozone analyzers in response to the concentration of contaminants in the feed water.

There are many reports on the effective removal of invasive species in ballast waters by screen filtration systems and ozonation processes. More than 70% removal of zebra mussels at public facilities by a backwash filtration system was reported by Dardeau et al. [7], while Waite et al. [8] removed 50% zooplanktons by screening the seawater through 50μm filters. The effectiveness of ozone treatment of marine ballast water in replicated mesocosm (280 L) was evaluated by Perrins et al. [9] who found that ozone treatment was effective in removing all species of marine environment examined with initial oxidant concentrations of 2–5 mg/L. Moreover, Herwig et al. [10] reported that ozone treatment inactivated large portions of culturable bacteria (>99.9), phytoplankton (especially dinoflagellates >99%) and zooplankton (96%) in the ballast water of the oil tanker S/T Tonsina.

DAGUA-BWT-UF TECHNOLOGY

If a higher degree of treatment is required, for example, in case of a significant level of contamination in the ballast water, or if the discharge of dead microorganisms and aquatic organisms to the receiving waters is prohibited, then the Dagua-BWT-UF technology can be used which benefits from the use of ultrafiltration (UF) membranes downstream of the ozonation process. In this treatment system, after the ozonation process, water passes through the ultrafiltration (UF) membranes with the pore size of 0.01 to 0.1 microns, removing particles down to this size range. During the treatment of ballast water, the dead microorganisms, phytoplanktons, zooplanktons and the existing colloidal and suspended particles will be retained by the UF membranes and removed from the water, producing a clean permeate which is ready for discharge into the most sensitive receiving waters. The ultrafiltration membranes operate at low pressure (30-40 psi) and have low power consumption. A modular unit of the Dagua-BWT-UF system is presented in Figure 1.

Figure 1. A modular unit of the Dagua-BWT-UF system

As a unique attribute, the Dagua-BWT-UF technology benefits from the generation and use of microbubbles that provide a continuous cleaning mechanism for the downstream ultrafiltration membranes. Finely distributed microbubbles provide continuous, deep cleaning of membrane capillaries, preventing fouling without the use of chemical cleansers or the production of chemical waste sludge. In this technology, the backwash cleaning of membranes by using acid/base is carried out on an infrequent basis, once every 12 to 18 months, unlike conventional membrane-based treatment technologies that need frequent use of acid/base (every three to four weeks) for membrane cleaning and de-clogging. The continuous cleaning by the microbubbles will prolong the active life of UF membranes and avoids additional maintenance and control requirements. Frequent automatic backwashing of every 20 minutes using air and filtered water ensures that the membrane permeate is clean and well treated.

The operation of the Dagua-BWT and Dagua-BWT-UF treatment systems is controlled by automatic control systems containing programmable logic controllers (PLC) equipped with human-machine interface (HMI), providing reliable and continuous operation of the treatment process, with the possibility of remote control.

Specific characteristics: The Dagua-BWT and Dagua-BWT-UF technologies provide chemical-free ballast water treatment. They take advantage of ozone's disinfection and oxidation properties, thereby eliminating the use of expensive and toxic chemicals and the generation of toxic sludge by-products, commonly associated with the use of chemical processes. Dagua plants

are scalable, require minimum maintenance and can be fabricated as modular units for the treatment of ballast water onboard the ships or at the ports. The Dagua-BWT and Dagua-BWT-UF systems can be designed for the treatment of ballast water at the flow rates of 4 m^3/hr up to 15,000 m^3/hr. Easy to operate (labor < 30 min/day), Dagua plants can be installed onboard the cargo ships and oil tankers or at the ports. They self-adjust to maintain water quality, consistently meeting or exceeding the regulatory standards. The successful operation of the Dagua technology for water disinfection and clarification has been demonstrated in eight full-scale plants treating surface waters at the flow rates of 30 m^3/hr to 1200 m^3/hr.

Advantages:

- Effective disinfection and removal of invasive aquatic species
- Lack of coagulant or flocculant use
- No generation of toxic waste: No need for the handling and treatment of toxic waste
- Entirely automated operation with the possibility of remote control
- Modular design, allowing for scalable prefabricated treatment plants
- Limited fouling of membranes: low frequency of cleaning, extended longevity of membranes
- High efficiency of treatment

WHAT WE OFFER:

Dagua Technologies Inc. offers system design and engineering, procurement, installation and training of personnel as well as support during the treatment of ballast water by the Dagua-BWT and Dagua-BWT-UF technologies.

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