

TITLE OF INVENTION

BALLAST WATER TREATMENT SYSTEM AND METHOD OF BALLAST WATER TREATMENT

5 BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates generally to the field of treating ballast water containing a variety of organisms including bacteria and viruses of the many marine and coastal plants and animals, and more particularly to a system and method for treating ship ballast water to kill potentially undesirable microorganisms in the water to prevent them from being transported from one coastal area to another.

2. Description of the Prior Art

Ballast water is sea water or fresh water used to stabilize hull balance when unloading cargoes from a cargo ship. Such sea water or fresh water contains local plankton, bacteria, viruses, mud and sand of the unloading port where the ballast water is taken. Oceangoing ships may transport various organisms contained in their ballast water from any port in the world to any other ports in the world. However, it is often required that cargo holds or large ballast tanks be filled with water so that the ship's center of gravity is lowered during a voyage when no cargo is carried. When a ship unloads cargo in a foreign port, the resulting empty holds of the ship are often filled with the local water as ballast to stabilize the ship. When arriving at other loading port to take on replacement cargo, the ship typically discharges the ballast water into coastal waters in or near the port, thereby introducing nonindigenous organisms which may have a deleterious (or at least an unknown) effect on the ecosystem of the receiving coastal waters.

One current proposal for attempting to cure this problem is to require ships to exchange, in mid-ocean or on the high seas, the original local ballast water with the saline, open ocean sea water; however, such an exchange of ballast water on the high seas is potentially extremely hazardous, especially, for large cargo ships and tankers, and in any event has been shown not to be fully effective in removing all microorganisms from a ship's holds.

This mid-ocean ballast exchange is usually (but not always) safe when the space in which the water is being exchanged is small enough so as not to create a dangerous instability or structural stress condition during the water-pumping process for effecting the exchange; for example, such a ballast exchange usually (but not always) is safe when dealing with specialized ballast tanks or other similar small spaces because of the low ratio of the weight of the involved water with the overall weight of the ship, and because of the ability of the load bearing strength of the ship to accommodate a temporarily empty "small" specialized ballast tank.

The current methods for processing ballast water have been proposed in many patents and some of which are as follows:

- 5 SG200902280-7: The document discloses treatment of water to remove unwanted matter. The apparatus that employed comprises a cavitation unit which causes the formation of bubbles. The cavitation breaks down unwanted matter comprising organisms, microorganism, organic waste, inorganic waste or long chain hydrocarbon molecules. The document also discloses a method of treating ballast water by passing water through a cavitation unit to generate cavitation.
- 10 US2008/0277354 discloses a method and an apparatus for the treatment of ballast water for a water-going vessel. The steps of the method are (i) pumping water from a water source, (ii) raising the dissolved nitrogen content of at least part of the water to a level above the nitrogen saturation content. The water pumped from the ballast tank is subjected to a microorganism killing action before the release of the water into the surrounding vessel.
- 15 US 7169310 discloses a process for the treatment of water to prevent the survival of unwanted organisms in the water. The method comprises the steps of introducing a gas into the water system in an amount sufficient to establish a supersaturated condition. The document also discloses an apparatus for treatment of a ship's ballast water, comprising a pump, a gas compressor, a meter, a controller and a ballast tank.
- 20 US 6921488 discloses a process for the treatment of water to prevent the survival of unwanted organism in the water. In the method, a gas is introduced into the water system to establish a super saturated condition sufficient to kill aquatic organism.
- 25 EP 2540678 discloses a method and system for ship ballast water treatment. The ballast water is filtered and then proceed to sterilization with a sterilization unit which generate high-efficiency organism and bacteria biocide, and the biocide at least includes one or more of hydroxyl radical, hypochlorous acid, sodium hypochlorite and hydrogen peroxide. The concentration of the biocide generated by the sterilization processing unit is 0.2-10 mg/l.
- 30 US20090321260 discloses liquid treatment methods and apparatus. The apparatus comprises one or both of an electrodialysis cell and a cavitation unit. The electrodialysis cell is for producing a dilute stream and a concentrate stream, and the ratio of dilute to concentrate is controlled to maintain the pH of the product of the electrodialysis cell within a selected range. The method comprises the steps of passing only a part of the water
- 35 through an electrodialysis cell and returning a product of the electrodialysis cell to the remainder of the water.
- 40 EP 2540369 discloses a device and method for treating ballast water for ship. The device comprises a filter, a treated water nozzle, a case, a filtered water flow path and a discharge flow path. The method comprises the steps of emitting treated water via a treated water nozzle toward an outer circumferential surface of a filter, guiding filtered

water that has been transmitted through the filter and discharging discharged water that was not filtered through the filter to the outside via a discharge flow path.

WO2012/128721 discloses systems and methods for exhaust gas cleaning and/or ballast water treatment. The process is employed to remove sulfur oxides from exhaust gas.

- 5 AU 2012203894 discloses a ballast water treatment apparatus for the treatment of ballast water comprising a cavitation unit, which generates cavitation in the ballast water by flow of the ballast water into a constriction. The cavitation unit breaks down unwanted matter comprising organism, microorganism, organic waste inorganic waste or long chain hydrocarbon molecules.
- 10 US2012038751 discloses ballast water treatment equipment which can decompose fungicide included in ballast water and reduce the amount of use of fungicide adsorbing material. The device comprises a shear flow generator, a swirl flow generator connected to downstream of the swirl flow generator with a connecting pipe and the shear flow generator has one or more venture tubes with recesses arranged in parallel.
- 15 China Utility Application No. 201020150227.1 (corresponding to EP2540678) discloses device and method for treating ballast water for ship. The device comprises a filter, a treated water nozzle, a case, a filtered water flow path and a discharge flow path. The method comprises the steps of emitting treated water via a treated water nozzle toward an outer circumferential surface of a filter, guiding filtered water that has been transmitted
20 through the filter and discharging discharged water that was not filtered through the filter to the outside via a discharge flow path.

- WO 03/002406 discloses management of water ballast in marine vessels. The apparatus comprises one or more ballast tanks in a marine vessel, means for admitting ballast water to the ballast tank, and means for subjecting the ballast water during
25 admission to the tank or tanks to attain a concentration of ions in the water sufficient to render marine organism non-viable and means for discharging the ballast water from the tank or tanks with marine organism present in non-viable forms.

- US Pat. No. 5,192,451 discloses a method of controlling the growth of zebra mussels in ship ballast water by adding a polymer to the ballast water; however, the use of chemicals to treat ballast water, which has been discharged into U.S. coastal waters, may have an
30 adverse environmental effect on the ecosystem.

- US Patent Nos. 5,376,282 and 5,578,116 disclose the use of a vacuum and agitation for reducing the dissolved oxygen of natural source water specifically to a level below that sufficient to support the survival respiration of zebra mussels; however, there is no
35 disclosure of treating ship ballast water to oxygenate and then deoxygenate the water in a process which encompasses the general worldwide problem of the transfer from any one to any other coastal zone of microorganisms in the ballast water of a ship.

- US Patent No. 3,676,983 discloses an apparatus including a vacuum chamber and an agitator for removing gases from a liquid; however, there is no recognition of the problem
40 of nonindigenous microorganism treatment in ship ballast water, and the removal of dissolved oxygen in the water to a level where aerobic microorganisms are killed.

US Patent No. 4,316,725 discloses several methods, including the use of a vacuum, to remove dissolved oxygen from water.

US Patent No. 3,251,357 discloses injecting combustion/stack gases into water for treating the water to inhibit the growth of, e.g., microorganisms; however, there is no recognition of, or suggested solution for, the long felt problem of how to remove anaerobic or aerobic microorganisms from ship ballast water.

SUMMARY OF THE INVENTION

Thus, the primary and broad object of the present invention is to provide a ballast water treatment system and method of ballast water treatment. The method makes use of electrodes, employed advanced oxidation technology and electrochemical water treatment process to generate a variety of oxidants in the anodic oxidation. In the present method, electrochemical cell and the active substances and the relevant chemicals that can be produced at detectable concentrations are easily identified. Hydroxyl radical which is the active substance of this electrochemical ballast water disinfection method is produced. In addition, O_3 being a by product of the electrochemical cell was produced but will vanish once it has been used. Free active chlorine formed as a by-product on the anode surface contributes to prevent regrowth/bi-fouling in the ballast tanks and ultimately degrade back into chloride ions.

The proposed method is designed for purification and disinfection in both high and low flow applications of conductive media such as natural freshwater and seawater. In short, the present method, electrochemical cell technology, is used to treat ballast water on ship and the present invention provides a method and apparatus by which ship ballast water is treated in a cost-effective and time-effective manner.

Another object of my invention is to provide such a method and apparatus which efficiently and inexpensively reduce the impacts of the ecosystem in the sea area which causes a global-scale environmental damage.

A main object of the present invention is to provide a ballast water management system for treating ballast water containing a variety of organisms, said apparatus comprising:

(i) a pre-treatment system including filtering device to purify water by removing suspended solids, silts, and scaling caused by precipitation of soluble salts in the conductive medias of the ballast water;

(ii) ballast water pump for generating a pressurized ballast water stream for treating;

(iii) an electrochemical cell having titanium coated anode and a titanium plated cathode, wherein an inlet of the cell is connected to the ballast water pump and an outlet of the electrochemical cell is connected to a ballast tank which is used to collect treated ballast water;

(iv) a control panel being used to control the management system by sending signal and reading to operational team, the control panel being in communication with equipment of the system; and

(v) a ballast water tank for storing treated ballast water for discharging,

thereby water in the electrochemical cell is oxidized to produce oxidizing agent to remove the microorganism in the ballast tank.

Another main object of the present invention is to provide a method of treating ballast water for a cargo ship, comprising the steps of:

(i) pumping conductive medias (ballast water) to a pre-treatment system of the ballast water treatment system to remove;

(ii) introducing pre-treated conductive medias into an electrochemical cell to proceed to a water electrolysis process to generate active chlorine, ozone and hydrogen;

(iii) discharging treated conductive medias to a ballast tank, and then discharged to the outside of the tank.

Another object of the invention is further provide a ballast water management system for treating ballast water containing a variety of organisms, wherein the electrodes of the electrochemical cell is catalytically inactive electrodes with high oxygen and hydrogen over-potentials, and the electrodes selectively produce highly oxidative hydroxyl radicals without forming chlorine electrolysis.

Still yet another object of the present invention is to provide a ballast water management system for treating ballast water containing a variety of organisms, wherein the capacity of the electrochemical cell has a flowrate ranging from $8\text{m}^3/\text{hr}$ to $15\text{m}^3/\text{hr}$, and the highly oxidative hydroxyl radicals has a half-life in the order of nanoseconds.

Another object of the present invention is to provide a method of treating ballast water, wherein a by-product on the anode surface is a small amount of chlorine (Cl_2) and the chlorine gas (Cl_2) further interacts with the cathode to form free active chlorine species, including $\text{HOCl}^\cdot$ and or $\text{OCl}^\cdot$, depending on the pH value of the treated water, preventing the formation of harmful chlorinated organics.

Still another object of the present invention is to provide a ballast water management system and an apparatus for treating ballast water, wherein a trace of Ozone by product is produced in the electrochemical cell and hydrogen gas is formed at the cathode of the cell as a result of water electrolysis.

Another object of the invention is to provide a method and apparatus of ballast water management system, wherein marine water passing through the system is treated and stored in ballast water tank directly without further processes and without the need to circulate the ballast water within the tank for long hours.

Another object of the present invention is to provide a method and an apparatus of ballast water management system, wherein the amount of free active chlorine species is around 5-10 ppm.

Yet a further object of the present invention is to provide a method and an apparatus of ballast water management system, wherein no modification work is needed on existing ship, but just installed in series on existing marine water delivery main.

5 Yet another object of the present invention is to provide a method and apparatus of ballast water management system, wherein the apparatus can be used for treatment of flow between 100 to 5000 m³/h.

BRIEF DESCRIPTION OF THE DRAWINGS

10 It is preferred that the method of the present invention is practised using the invention in all its many embodiments as described above. In addition to the novel features and advantages mentioned above, other objects and advantages of the present invention will be readily apparent from the following description of the drawings and preferred embodiments.

15 FIG. 1A is a diagrammatic view of an apparatus for ballast water management system in accordance with the present invention.

FIG. 1B is a flowchart showing the apparatus and method for ballast water management system in accordance with the present invention.

FIG. 2 is a schematic view showing blasting process for fresh water in accordance with the present invention.

20 FIG. 3 is a schematic view showing blasting process for brackish water and marine water in accordance with the present invention.

FIG. 4 is a schematic view showing de-ballasting process in accordance with the present invention.

25 DESCRIPTION OF PREFERRED EMBODIMENTS

30 Illustrated in FIG. 1 is a diagrammatic representation of an apparatus for ballast water management system, which is used to treat ballast water in cargo ships. The present invention relates to the apparatus and method for treating ballast water which contains potentially undesirable organisms. The present system and method thereof is used for killing the undesirable organisms containing in conductive medias, such as seawater, brackish water or fresh water. These undesirable organisms are potentially harmful to living things, and may have unfavourable impact to our ecosystem.

35 As shown in FIG. 1A, the method according to the present ballast water treating system comprises supplying filtered water 150/160 to an electro-chemical cell 300. The filtered water 150/160 is undergone an electrolysis process within the electro-chemical cell 300, and is then discharged outbound or into a ballast tank 400 for discharging.

The system in accordance with a preferred embodiment of the present invention is used for purification and disinfection in low and high flow application of conductive medias, such as natural seawater, brackish water, and fresh water.

FIG. 1B illustrates schematically a preferred embodiment of ballast water management system in accordance with the present invention. The ballast water treating system comprises a pre-treating unit 200, a flowmeter 250, an electrochemical cell 300 and a ballast tank 400 which are interconnected with a plurality of valves being mounted at the entrance point to each of the components. As mentioned, conductive medias such as natural seawater, brackish water or fresh water 150/160 are to be treated in the present ballast water management system of the present invention.

In accordance with the present invention, the system provides two modes of operations such as salinity process control mode (FIG. 3) and fresh water process control mode (FIG. 2). In the preferred embodiment, in the case the total dissolved solids (TDS) is more than 8 practical salinity unit (psu), the system will be proceeded to operate in the salinity process control mode. The system will be proceeded to operate in the fresh water control mode when the TDS is smaller than 8 psu.

The system essentially comprises a pre-treatment unit 200, an electrochemical cell unit 300, and a control panel for controlling the operation of the process. Pretreatment process in the ballast water management system of the present invention is very important, as the pretreatment is to protect the electrochemical element against water fouling which is caused by suspended silts, sand, and scaling caused by precipitation of sparingly soluble salts concentrated beyond the solubility limit.

In accordance with the preferred embodiment of the present invention, the operation of the system, such as the start-up and shut down of all the units of the system, load dispatching, electrical switching functions and supervision, is controlled with the control panel.

Salinity Process Control Mode For Brackish Water or Marine Water

When TDS sensor of the ballast water treating system shows that the TDS value is more than 8 psu, the system operates the Salinity Process Control Mode. Referring to FIG. 2 the water flows to the pre-treatment unit, 200 which is a filter, having a size of 40 micro, and then following by the electrochemical cell, via a flow meter 250. After that the treated water flows into the ballast water tank 400. The flow meter 250 will monitor the flowrate of the water to the electrochemical cell 300. A Total Residual Oxidant sensor is mounted to the exit of the electrochemical cell 300 such that the range of the water is controlled to be in the range of 10-13 ppm. In this Salinity Process Mode, the electrochemical cell 300 will produce the oxidizing agents, for instance, Chlorine (Cl_2), Hydroxyl Radical ($\text{OH}\bullet$) and Ozone (O_3) to remove the microorganism in the ballast tank 400. In accordance with the present invention, the amount of the oxidizing agent produced, from high to low, is $\text{Cl}_2 > \text{OH}\bullet > \text{O}_3$ as the TRO is controlled in the range of 10 to 13 ppm. The main oxidizing reagent produced under this mode is Chlorine (Cl_2) following by Hydroxyl Radical ($\text{OH}\bullet$) and lastly the Ozone, O_3 . Finally, water will flow into the ballast water tank 400.

Fresh Water Process Control Mode

As shown in FIG.3, when TDS sensor of the ballast water treating system shows that the TDS value is less than 8psu, the ballast water management system of the present invention will operate the Fresh Water Process Control Mode. The open intake water will diverge into two (2) lines. Some portion of open intake water will flow directly to the pre-treatment filter (40 micro) 200, and another portion of water will to the ejector where the water in the Existing Seawater Tank (not shown) will be suck into the system.

The ejector's discharge water will mix with the open intake water and to the pre-treatment filter 200 following by the electrochemical cell 300, and then to the ballast water tank 400.

The pre-treatment filter has the auto backwash mode where control by the Differential Pressure Transmitter. As soon as the Differential Pressure is achieved to particular set point, the Auto backwash mode will proceed. Before the water flow to the electrochemical cell 300, the flow rate will be monitored by a magnetic flow transmitter (not shown). There is a setpoint for the flowrate of the system. If the flowrate < setpoint, the whole system will shut down. On the other way, if the flowrate is > setpoint, the system will function normally and the DC power supply to the electrochemical cell 300, then electrochemical cell 300 will start its function. The product water from the electrochemical cell 300 will monitor by the Total Residual Oxidant Sensor (not shown) in the range from 6 to 8 ppm.

In the present Fresh Water Process Control Mode, the system of the present invention produce the oxidizing agent of Chlorine (Cl_2), Hydroxyl Radical ($\text{OH}\bullet$), and Ozone, O_3 to remove the microorganism in the ballast tank. The quantity of the oxidizing agent produced in this method, from high to low is, $\text{OH}\bullet > \text{O}_3 > \text{Cl}_2$ as the TRO is controlled in the range of 6 to 8 ppm. Therefore the main oxidizing reagent produce in this mode is Hydroxyl Radical ($\text{OH}\bullet$) following by Ozone, O_3 and lastly the Chlorine (Cl_2). Finally the water will flow into the ballast water tank 400.

De-Ballasting Process

After a few days, the water in ballast tank 400 may need to drain out. At this point, the ballast water management system of the present invention is used to proceed with a deballasting process, as shown in FIG. 4. FIG. 4 is a schematic view showing deballasting process in accordance with the present invention. In this deballasting process, the water supply 420 from the ballast water tank 400 will bypass the pre-treatment filter 200 and electrochemical cell 300 via pipe 210 and pipe 310 as shown in FIG. 4.

To start with the deballasting process, first of all, the ballast water pump (not shown) will transfer the water from the ballast water tank 400 to the ballast water management system. A plurality of valves are opened and closed accordingly to proceed to bypass the pre-treatment filter 200 and the electrochemical cell 300, and to let the water discharge into the sea. The total residual oxidant system will monitor the level of TRO of the water in the ballast water tank be in the range of <0.2 ppm.

In order to control the TRO within the range, a metering pump (not shown) is used to inject Sodium Bisulfite which is stored in the sodium bisulfite solution tank (not shown), to the ballast water tank 400.

5 In accordance with the present invention, a control panel is mounted so as to fully control the operation of the salinity process control mode, fresh water process control mode, and de-ballasting process mode. The control panel includes three (3) operation modes which are Manual Control, Local Control and Remote Control.

10 In accordance with the preferred embodiment of the present invention, a ballast water management system for treating ballast water containing a variety of organisms is disclosed, and the said apparatus comprises:

- (i) a pre-treatment system including filtering device 200 to purify water by removing suspended solids, silts, and scaling caused by precipitation of soluble salts in the conductive medias of the ballast water;
- (ii) ballast water pump for generating a pressurized ballast water stream for treating;
- 15 (iii) an electrochemical cell 300 having titanium coated anode and a titanium plated cathode, wherein an inlet of the cell is connected to the ballast water pump and an outlet of the electrochemical cell is connected to a ballast tank which is used to collect treated ballast water;
- (iv) a control panel being used to control the management system by sending signal and reading to operational team, the control panel being in communication with equipment of the system; and
- 20 (v) a ballast water tank 400 for storing treated ballast water for discharging,

thereby water in the electrochemical cell 300 is oxidized to produce oxidizing agent to remove the microorganism in the ballast water tank 400 .

25 The present invention also relates to a method of treating ballast water for a cargo ship, comprising the steps of:

- (i) pumping conductive medias (ballast water) to a pre-treatment system of the ballast water treatment system to remove suspended solids, silts, and scaling caused by precipitation of soluble salts in the conductive medias of the ballast water;
- 30 (ii) introducing pre-treated conductive medias into an electrochemical cell 300 to proceed to a water electrolysis process to generate active chlorine, ozone and hydrogen;
- (iii) discharging treated conductive medias to a ballast water tank 400, and then discharged to outboard.

35 The conductive medias in the present invention includes natural seawater, brackish water and freshwater. The method of treating ballast water further comprises the step of controlling the treating ballast water management with a control panel by sending signal

and reading to operational team, the control panel being in communication with equipment of the system.

As mentioned, in the present invention, the pretreatment system by a filter device is very important as the pretreatment system or step is use to protect the electrochemical cell 300 elements from water fouling caused by suspended solids, silts, sand, as well as scaling caused by precipitation of sparingly soluble salts concentrated beyond their solubility limit.

The present preferred embodiment is well designed to operate with minimum number of staff consistent with safe and efficient operation all the units, whether on open cycle or combined cycle operation will be controlled and supervised primarily with the control panel.

Example 1: Electro-Chemical Cell Disinfection Process and Operation

In accordance with the present invention, the electrochemical cell uses system employs electrodes to proceed with the process.

The electrochemical water treatment processes generating a variety of oxidants is the anodic oxidation. This efficiency method is provided by dual oxidation pathways involving the direct electron transfer between target chemical compounds and anode surface, and also indirect electron transfer mediated by reactive intermediate species formed from water oxidation and other reactants, such as for instance the hydroxyl radical ($\bullet\text{OH}$), Ozone (O_3) and Chlorine (Cl_2).

By electrochemical treatment of waters, either a partial (reduction of toxicity) or a complete decomposition of the pollutants can be achieved. In the case of organic materials, a complete decomposition means the oxidation to carbon dioxide and as consequence relatively high energy consumption for large organic molecules. The electrochemical oxidizing water treatment is classified into two categories: direct oxidation at the anode or indirect oxidation mediated by oxidative species produced at the anode.

However, in accordance with the present invention, the ballast water treating system is designed for purification and disinfection in both low and high flow applications with natural seawater, brackish water and fresh water. In the present electrochemical cell system utilizing electrodes with high oxygen over-potential, and therefore producing powerful disinfectants such as the hydroxyl radical directly into the media and also providing direct oxidation of microorganisms and other contaminants on the electrode surface. In addition, small amounts of harmless disinfecting by-products from the cell prevent re-growth in the ballast water tank and biofouling, and by the cell design and electrode configuration preventing the formation of secondary chlorinated organic such as for example trihalomethanes (THM:s). The present electrochemical cell 300 by using catalytically inactive electrodes with high oxygen- and hydrogen over-potentials which selectively produce the desired highly oxidative species (i.e. hydroxyl radicals, $\text{OH}\bullet$). This species under normal circumstances has a half-life in the order of nanoseconds, and thus never leaves the cell (or the reaction zone) with the water flow. The hydroxyl radical very efficiently inactivates and breaks down microorganisms and other contaminants. No

chemically active long-lived residuals are formed at relevant concentrations in this process using this electrochemical treatment method and specially developed electrochemical cell. Indirect disinfection and also direct oxidation of microorganisms on the electrodes will only contribute to reduce the Total Organic Carbon (TOC) level.

- 5 The electrochemical cell the active substances and relevant chemicals that can be produced at detectable concentrations in accordance with the present invention are easily identified. These are as follows:-

10 **Hydroxyl radical, OH•:** The hydroxyl radical is referred to as an “active substance” of the present electrochemical ballast water disinfection method. It is recognized in biological systems as the most active reactive oxygen species, and can cause organisms of DNA, protein and lipid oxidative damage. Hydroxyl radical is a very reactive oxidative species with half-life in the order of nanoseconds, thus never leaving the reactor. Secondary radicals may also be formed in very small amounts as intermediates in the degradation processes of other oxidative species.

15 **Active Chlorine:** Free active chlorine is also referred to as an “active substance” due to their oxidative and disinfecting abilities. The sea water content of chloride ions, small amounts of chlorine gas (Cl_2) will form as a by-product on the anode surface and will further, by favourable interactions with the cathode, immediately form other free active chlorine species (5 – 10ppm) HOCl and OCl depending on the pH. These small amounts of free active chlorine will contribute to prevent re-growth / bio-fouling in the ballast water tank and to the most extent ultimately degrade back into chloride ions. Due to the composition of the electrochemical cell of the present invention, the primary produced chlorine gas will form active chlorine species very rapidly (by cathodic interactions and water), thus preventing the formation of harmful chlorinated organics such as for example THM:s

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Ozone O_3 : is made of oxygen and reverts to pure oxygen, a trace of by product O_3 produced from the electrochemical cell of the present invention. O_3 vanishes without trace once it has been used.

30 **Hydrogen gas $\text{H}_2(\text{g})$:** Hydrogen gas will be referred to as a “Relevant chemical” in this process due to the safety aspects of the gas. Hydrogen gas forms at the cathode due to water electrolysis (Max. 0.5%), however, due to the composition of the electrochemical cell of the present invention, the main cathode reactions will be reduction of oxygen gas (O_2) and the small amounts of chlorine.

Example 2: Electrochemical Cell Oxidation

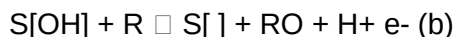
35 **Direct oxidation at the Anode**

In accordance with the present invention, a model has been developed to describe the course of the anodic oxidation of an organic molecule assuming three major steps (a-c): (S indicates surface)

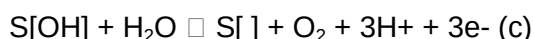
Discharge of water forming an adsorbed hydroxyl species:



The adsorbed OH is the – “activated state” of water in oxygen-transfer reactions to the organic molecule R:



- 5 Co-evolution of O₂ by oxidation of water diminishing the current efficiency:

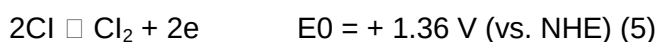
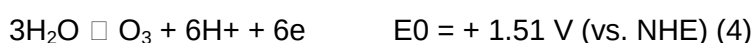


- 10 An organic contaminant (such as e.g. a microorganism in ballast water) may this way be rendered harmless by direct oxidation at the anode surface in an electrochemical cell. The electrodes used in the electrochemical cell of the present invention works at high over-potentials and thus have a high efficiency for direct oxidation (i.e. – combustion”). The mechanism is induced even further by the favourable mass transport characteristics of the present electrochemical cell and by the fact that the cell wall of pathogenic microorganisms is negatively charged by nature and will be electrically attracted to the anode surface.

15 Indirect Oxidation

- In accordance with the present invention, in pure water medium, the most typical anodic reaction is the oxygen evolution resulting from water oxidation through two-electron transfer reaction as described below by (Equation 1), similar to equation (c) above. This reaction is composed of two one-electron transfer reactions expressed by equations (2) and (3), involving the production of •OH as the reactive intermediate. At a high anodic potential, also ozone can be generated by a six electron transfer mechanism (Equation 4), in the case of seawater electrolysis because of the content of dissolved ions. When chloride ions (Cl⁻) are present in the electrolyte (similar to marine water or brackish water), chlorine gas evolution can occur simultaneously as described by (Equation 5) below.

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While a current embodiment of the ballast water treatment system and method of treating ballast water has been described in detail it should be apparent that modifications and variations thereto are possible, all of which fall within the true spirit and scope of the invention. With respect to the above description then, it is to be realized that the optimum
5 dimensional relationships for the parts of the invention, to include variations in size, materials, shape, form, function and manner of operation, assembly and use, are deemed readily apparent and obvious to one skilled in the art, and all equivalent relationships to those illustrated in the drawings and described in the specification are intended to be encompassed by the present invention. The present invention may also be adapted for
10 use with a variety of components that are required by the present invention.

Therefore, the foregoing is considered as illustrative only of the principles of the invention. Further, since numerous modifications and changes will readily occur to those skilled in the art, it is not desired to limit the invention to the exact construction and operation
15 shown and described, and accordingly, all suitable modifications and equivalents may be resorted to, falling within the scope of the invention.

CLAIMS

1. A ballast water management system for treating ballast water containing a variety of organisms, said apparatus comprising:
 - (i) a pre-treatment system including filtering device to purify water by removing suspended solids, silts, and scaling caused by precipitation of soluble salts in the conductive medias of the ballast water;
 - (ii) ballast water pump for generating a pressurized ballast water stream for treating;
 - (iii) an electrochemical cell having titanium coated anode and a titanium plated cathode, wherein an inlet of the cell is connected to the ballast water pump and an outlet of the electrochemical cell is connected to a ballast tank which is used to collect treated ballast water;
 - (iv) a control panel being used to control the management system by sending signal and reading to operational team, the control panel being in communication with equipment of the system; and
 - (v) a ballast water tank for storing treated ballast water for discharging, thereby water in the electrochemical cell is oxidized to produce oxidizing agent to remove the microorganism in the ballast tank .
2. The ballast water management system of claim 1, wherein the electrodes of the electrochemical cell is catalytically inactive electrodes with high oxygen and hydrogen over-potentials.
3. The ballast water management system of claim 2, wherein the electrodes selectively produce highly oxidative hydroxyl radicals without forming chlorine electrolysis.
4. The ballast water management system of claim 1, wherein the capacity of the electrochemical cell has a flowrate ranging from 8m³/hr to 15 m³/hr.
5. The ballast water management system of claim 3, wherein the highly oxidative hydroxyl radicals has a half-life in the order of nanoseconds.
6. The ballast water management system of claim 3, wherein a by-product on the anode surface is a small amount of chlorine (Cl₂).
7. The ballast water management system of claim 6, wherein the chlorine gas (Cl₂) further interacts with the cathode to form free active chlorine species, including HOCl[•] and or OCl[•], depending on the pH value of the treated water, preventing the formation of harmful chlorinated organics.
8. The ballast water management system of claim 1, wherein a trace of Ozone by product is produced in the electrochemical cell.

9. The ballast water management system of claim 1, wherein hydrogen gas is formed at the cathode of the cell as a result of water electrolysis.
- 5 10. The ballast water management system of claim 7, wherein the amount of free active chlorine species is around 5-10 ppm.
- 10 11. A method of treating ballast water for a cargo ship, comprising the steps of:
- (i) pumping conductive medias (ballast water) to a pre-treatment system of the ballast water treatment system to remove ;
 - (ii) introducing pre-treated conductive medias into an electrochemical cell to proceed to a water electrolysis process to generate active chlorine, ozone and hydrogen;
 - (iii) discharging treated conductive medias to a ballast tank, and then discharged to the outside of the tank.
- 15 12. The method of treating ballast water of claim 11, wherein the pre-treatment system in step (i) of Claim 11 is to remove suspended solid, silts, sand as well as scaling caused by the precipitation of sparingly soluble salts.
- 20 13. The method of treating ballast water of Claim 11, wherein the conductive medias includes natural seawater, brackish water and freshwater.
- 25 14. The method of treating ballast water of Claim 11, further comprising the step of controlling the treating ballast water management with a control panel by sending signal and reading to operational team, the control panel being in communication with equipment of the system.
- 30 15. The method of treating ballast water of Claim 11, wherein a variety of oxidants are generated in the electrochemical cell via the anodic oxidation process.
- 35 16. The method of treating ballast water of Claim 15, wherein a direct electron transfer between target chemical compounds and the anode surface of the electrochemical cell is taking place.
- 40 17. The method of treating ballast water of Claim 15, wherein an indirect electron transfer mediated by reactive intermediate species formed from water oxidation and hydroxyl radical, ozone and chlorine takes place.
18. The method of treating ballast water of Claim 16, wherein the direct oxidation is taking place at the anode.
19. The method of treating ballast water of Claim 17, wherein the indirect oxidation mediated by oxidative species is at the anode.

20. The method of treating ballast water ballast of claim 11, wherein the electrodes selectively produce highly oxidative hydroxyl radicals without forming chlorine electrolysis.
- 5 21. The method of treating ballast water ballast of claim 11, wherein the capacity of the electrochemical cell has a flowrate ranging from 8m³/hr to 15 m³/hr.
22. The method of treating ballast water ballast of claim 11, wherein the highly oxidative hydroxyl radicals has a half-life in the order of nanoseconds.
- 10 23. The method of treating ballast water ballast of claim 11, wherein a by-product on the anode surface is a small amount of chlorine (Cl₂).
- 15 24. The method of treating ballast water ballast of claim 11, wherein the chlorine gas (Cl₂) further interacts with the cathode to form free active chlorine species, including HOC[·] and or OCl[·], depending on the pH value of the treated water, preventing the formation of harmful chlorinated organics .
- 20 25. The method of treating ballast water ballast of claim 11, wherein a trace of Ozone by product is produced in the electrochemical cell.
26. The method of treating ballast water ballast of claim 11, wherein hydrogen gas is formed at the cathode of the cell as a result of water electrolysis.
- 25 27. The method of treating ballast water ballast of claim 11, wherein the amount of free active chlorine species is around 5-10 ppm.