BALLAST WATER TREATMENT SYSTEM

Technical Field

The present invention relates to ballast water treatment systems, and particularly to a ballast water treatment system for removing aquatic organisms from the ballast water of a ship.

Background Art

Ships which transport ores, crude oil and the like are provided with a ballast tank
so that ballast water such as sea water and fresh water is stored in the ballast tank to perform attitude control and stability maintenance of the hull. Since ballast water is taken into the ballast tank when the ship is unloaded, and is discharged from the ballast tank as the loading of cargoes progresses, it will be discharged in a region different from the location of water intake. Therefore, aquatic organisms may be moved with the ballast water and settle in a new environment, and in such a case, there arises a concern that ecosystems are destroyed and the business activities such as fisheries are affected. Moreover, there is also a fear that pathogenic bacteria which are moved with the ballast water directly affect human health.

Accordingly, in the International Convention for the Management of Ships' Ballast Water, "The International Convention for the Control and Management of Ships' Ballast Water & Sediments," was adopted in February, 2004, making it obligatory for ships to install a ballast water treatment apparatus. The ballast water management standards stipulated by the International Maritime Organization (IMO) are as follows.

* Less than 10 viable organisms per cubic meter for organisms greater than or equal to 50 micrometers in minimum dimension.
* Less than 10 viable organisms per milliliter for organisms less than 50 micrometers in minimum dimension and greater than or equal to 10 micrometers in minimum dimension.
* Toxicogenic Vibrio cholerae (O-1 and O-139) is less than 1 colony forming unit (cfu) per 100 milliliters.
* Escherichia coli is less than 250 cfu per 100 milliliters.

* Intestinal Enterococci is less than 100 cfu per 100 milliliters.

In order to satisfy such standards, various ballast water treatment technologies for purifying ballast water are proposed. For example, conventionally, sterilization schemes have been the main stream, in which a coarse filtering is performed by a filter (physical treatment) and thereafter disinfectants are added; in Patent Citation 1, the ballast water is sterilized through the addition of chlorine-based chemicals. Moreover, Patent Citation 2 utilizes hydro peroxide to sterilize the ballast water and Patent Citation 3 utilizes ozone to sterilize the ballast water.

In recent years, in place of sterilization schemes, a coagulation/separation scheme is proposed as well. For example, in Patent Citation 4, chemicals and magnetic powder are added to the ballast water to entangle aquatic organisms, which are the target of removal, thereby forming magnetic flocs, and these magnetic flocs are recovered by use of magnets and filters thereby separating/removing the target aquatic organisms.

Patent Citation 1 Japanese Patent Application Laid-Open No. 04-322788.
Patent Citation 2 Japanese Patent Application Laid-Open No. 05-910.
Patent Citation 3 Japanese Patent Application Laid-Open No. 2006-212494.
Patent Citation 4 Japanese Patent Application Laid-Open No. 2005-218887.

Disclosure of Invention

Technical Problem

Ballast water may be taken in at any port around the world and its water quality would significantly vary depending on the place of water intake. For example, in a water area where water pollution has become worse, the aquatic organisms existent in water such as bacteria and planktons have increased due to eutrophication. Moreover, even in the same water area, the volume of aquatic organisms may significantly vary depending on the season, and a convection flow etc. may occur due to the temperature difference between day and night resulting in a change in the volume of aquatic organisms in a short period of time. For this reason, it is very difficult to constantly achieve the ballast water management standards established by the IMO, and an attempt to fulfill the standards in an unreasonable manner may cause a new, adverse effect.

For example, in Patent Citations 1 to 3, to securely achieve the standards, it is necessary to inject an excess amount of disinfectant and as a result of the injection of an excess amount of chemical liquids, there is a risk that the efficacy thereof remains thereby adversely affecting the coating of the ballast tank and killing aquatic organisms in that water area when the ballast water is discharged.

Further, in order to securely achieve the standards in Patent Citation 4, it is necessary to add an excess amount of the chemicals for forming magnetic flocs, which may cause a risk that due to the injection of such excess amount of chemicals, the amount of magnetic flocs to be recovered needlessly increases.

The present invention has been made in view of the above described circumstances, and has its object to provide a ballast water treatment system which can constantly achieve the ballast water management standards established by the IMO.

Technical Solution

In order to achieve the above described object, a first aspect of the present invention provides a ballast water treatment system including water treatment apparatus which removes substances to be removed from ballast water, and a ballast tank which stores the ballast water treated by the water treatment apparatus installed on a ship, the ballast water treatment system characterized by including: a monitoring apparatus which monitors a water quality of the ballast water; and a control apparatus which controls an operational condition of the water treatment apparatus based on a monitoring result of the monitoring apparatus.

Since the first aspect of the present invention is configured such that the water quality of the ballast water is monitored and based on that result, the operational conditions of the water treatment apparatus are controlled, it is possible to treat the ballast water enabling it to have a constant water quality even when the water quality of the ballast water significantly varies depending on water intake conditions.

Moreover, according to the first aspect, since water treatment is performed in accordance with the water quality of the ballast water, it is possible to prevent an excessive or insufficient injection of the chemical liquid which is used for water treatment. For example, when a sterilization scheme is adopted for the water treatment apparatus, it is possible to prevent an excessive or insufficient injection of disinfectant,

thereby preventing the disinfectant from imposing a burden on the coating of the ballast tank and the environment.

A second aspect of the present invention is characterized in that in the first aspect, the water treatment apparatus includes: a coagulation apparatus which coagulates the substance to be removed by injecting a coagulant into and agitating the ballast water; and a separation/removal apparatus which separates and removes aggregates which occurs in the coagulation apparatus.

The second aspect is based on a coagulation/separation scheme which makes the substances to be removed in the ballast water to coagulate thereby being separated/removed, and there is no need of injecting disinfectants as in a sterilization scheme, thereby eliminating a burden on the coating of the ballast tank and the environment. It is noted that a separation/removal apparatus can utilize a gravity settling, floatation, magnetic separation, filter separation, etc.

A third aspect of the present invention is characterized in that in the second aspect, the control apparatus controls the coagulation apparatus based on the monitoring result of the monitoring apparatus to adjust an injection amount of the coagulant.

According to the third aspect, since the injection amount of the coagulant is controlled in accordance with the water quality of the ballast water, it is possible to inject a just enough amount of the coagulant. Therefore, it is possible to prevent the coagulant from being remained due to an excess injection of the coagulant, and to minimize the burden on the environment when the ballast water is discharged.

A fourth aspect of the present invention is characterized in that in the second or third aspect, the separation/removal apparatus is configured as a combination of a magnetic separation and a filter separation.

According to the fourth aspect, since a magnetic separation and a filter separation are combined, it is possible to perform the separation/recovery of aggregates at a high speed and a high accuracy. It is noted that in the fourth aspect, it is preferable to admix magnetic powder into the ballast water before coagulation. Moreover, magnetic separation is preferably performed by using a magnet such as a permanent magnet, a superconducting magnet, etc., and filter separation is preferably performed by using a filter of 10 to 15 μm made of metal or resin.

A fifth aspect of the present invention is characterized in that in any of the first to the fourth aspects, the monitoring apparatus monitors the ballast water by measuring at least one of a turbidity and a chromaticity of the ballast water.

According to the fifth aspect, since the monitoring is performed by measuring at least one of a turbidity and a chromaticity, it is possible to indirectly obtain a rough estimate of the concentration of the aquatic organisms in the ballast water. Moreover, many multipurpose apparatuses have been developed for a turbidimeter and colorimeter.

A sixth aspect of the present invention is characterized in that in any of the first to the fourth aspects, the monitoring apparatus monitors the ballast water by performing an image analysis of the ballast water.

According to the sixth aspect, since the water quality of the ballast water is monitored by performing an image analysis of the ballast water, it is possible to directly determine the concentration of the aquatic organisms in the ballast water.

A seventh aspect of the present invention is characterized in that in any of the first to sixth aspects, the control apparatus controls a treatment volume that is treated by the water treatment apparatus per unit time.

According to the seventh aspect, since the treatment volume per unit time, that is, a dwell time in the water treatment apparatus is controlled, it is possible to efficiently remove the substances to be removed even when the substances to be removed are in a large amount in the ballast water. For example, when a water treatment apparatus based on a sterilization scheme is used, it is possible to control a contact time period with a disinfectant by controlling the treatment volume per unit time. Therefore, even when there is an inflow of a high concentration of organisms due to a red tide, etc., it is possible to efficiently perform a sterilization treatment. Moreover, when a water treatment apparatus based on a coagulation/separation scheme is used, it is possible to control the dwell time in the coagulation apparatus by controlling the treatment amount per unit time. Therefore, even when there is an inflow of a high concentration of organisms due to a red tide etc., it is possible to securely perform the coagulation treatment of aquatic organisms.

An eighth aspect of the present invention is characterized in that in any of the first to the seventh aspects, the monitoring apparatus monitors the water quality of the

ballast water at an inlet part of the water treatment apparatus, at an outlet part of the water treatment apparatus, and/or in the ballast tank.

According the eighth aspect, it is possible to perform water treatment in accordance with the variation of water quality of the ballast water at the time of water intake by monitoring the water quality of the ballast water at an inlet part of the water treatment apparatus. Moreover, it is possible to cope with a performance change (a degradation of performance, etc.) of the water treatment apparatus by monitoring the water quality of the ballast water at an outlet part of the water treatment apparatus. Further, it is possible to cope with the case in which the water quality is degraded in the tank by monitoring the water quality of the ballast water in the tank.

A ninth aspect of the present invention is characterized in that in any of the first to the eighth aspects, the ballast water treatment system includes a line for returning the ballast water in the ballast tank or the ballast water to be discharged from the ballast tank to the outside to the water treatment apparatus, and the ballast water is retreated by the water treatment apparatus.

According to the ninth aspect, it is possible to retreat the ballast water, and for example, when a large amount of the substances to be removed are included in the ballast water at the time of water intake, when the substances to be removed are not sufficiently removed by the water treatment, or when the substances to be removed have grown in the tank, the ballast water is retreated. As a result of this, it is possible to discharge ballast water in a state in which it securely satisfies the standards. It is noted that retreatment of the ballast water is preferably performed while the ship navigates and when the ballast water is discharged.

Advantageous Effects

According to the present invention, since the water quality of the ballast water is monitored and based on the result, the operational conditions of the water treatment apparatus are controlled, it is possible to treat the ballast water which significantly varies depending on water intake conditions so that it has a desired water quality. Therefore, it is possible to securely satisfy the standards for the discharge of the ballast water and thereby preventing the destruction of ecosystem due to the discharge of the ballast water.

Brief Description of Drawings

[Figure 1] Figure 1 shows a first embodiment of the ballast water treatment system relating to the present invention.

[Figure 2] Figure 2 shows a ballast water treatment system which is different from that of Figure 1.

[Figure 3] Figure 3 shows the flow of water discharge in the ballast water treatment system of Figure 1.

[Figure 4] Figure 4 shows a second embodiment of the ballast water treatment system relating to the present invention.

[Figure 5] Figure 5 shows a ballast water treatment system which is different from that of Figure 4.

[Figure 6] Figure 6 shows the flow of water discharge in the ballast water treatment system of Figure 4.

[Figure 7] Figure 7 is a table to show the relationship between the concentrations of aquatic organisms of ballast water and the concentrations of chemical liquids.

[Figure 8] Figure 8 is a table to show the relationship between the turbidity of ballast water and the adding amounts of coagulants.

Explanation of Reference

10...Ballast water treatment system, 12...Ship, 14...Water treatment apparatus, 16...Ballast tank, 18...Monitoring apparatus, 20...Control apparatus, 22...Physical removal apparatus, 24...Sterilizing apparatus, 26...Raw-water piping, 28...Pump, 30...Valve, 32...Treated water piping, 34 to 38...Sampling Pipe, 40...Ballast water treatment system, 42...Circulation line, 44...Circulation line, 46...Bypass line, 50...Ballast water treatment system, 52...Water treatment apparatus, 54...Chemicals adding unit, 56...Coagulation unit, 58...Separation unit, 60...Magnetic powder adding apparatus, 62...Inorganic coagulant adding apparatus, 64...Polymeric coagulant adding apparatus, 66...High-speed agitation vessel, 68...Low-speed agitation vessel, 70...Piping, 72...Magnetic separation apparatus, 74...Filter separation apparatus, 80...Ballast water treatment system, 82...Circulation line

Best Mode for Carrying out the Invention

Hereafter, preferable embodiments of the ballast water treatment system relating to the present invention will be described according to the appended drawings.

Figure 1 schematically shows the configuration of a first embodiment of the ballast water treatment system relating to the present invention. The ballast water treatment system 10 shown in the figure is installed in a ship 12 and is primarily made up of a water treatment apparatus 14, a ballast tank 16, a monitoring apparatus 18, and a control apparatus 20.

The water treatment apparatus 14, which is an example of "sterilization scheme", is made up of a group of apparatuses including a physical removal apparatus 22 and a sterilizing apparatus 24.

The physical removal apparatus 22 physically removes large aquatic organisms and suspended solids, etc., for which an apparatus utilizing, for example, a filter, a cyclone, a cavitation effect, and others are used singly or in combination. A raw-water piping 26 is connected to the physical removal apparatus 22, and a pump 28 and a valve 30 are arranged in the raw-water piping 26. With the pump 28 being driven, sea water or fresh water is withdrawn into the raw-water piping 26 and is fed to the physical removal apparatus 22. The pump 28 and the valve 30 are connected to the control apparatus 20, and the revolutional speed of the pump 28 and the opening of the valve 30 are controlled by the control apparatus 20. It is noted that depending on the design of the sterilizing apparatus 24 in the latter stage, an embodiment in which the physical removal apparatus 22 is not installed may be possible. Further, instead of using the pump 28, a difference in water level may be utilized to feed sea water or fresh water.

The physical removal apparatus 22 is connected to a ballast tank 16 via a treated water piping 32, and the sterilizing apparatus 24 is provided at some point in the treated water piping 32. The sterilizing apparatus 24 kills small aquatic organisms, for which an apparatus utilizing, for example, sodium hypochlorite, ozone, chlorine dioxide, peracetic acid, hydrogen peroxide, ultra-violet light and others are used singly or in combination. A specific example of the sterilizing apparatus 24 is made up of a chemicals storage vessel for storing a disinfectant (not shown) and an injection apparatus (not shown) for injecting the disinfectant into the treated water piping. Moreover, an embodiment which includes a generation apparatus (not shown) for generating a disinfectant is also possible.

The treated water from which aquatic organisms are removed by the physical removal apparatus 22 and the sterilizing apparatus 24 is fed to and stored in the ballast tank 16. It is noted that as water discharge means for discharging the ballast water in the ballast tank 16 to the outside, an embodiment which discharges water by use of the raw-water piping 26 and the pump 28, and an embodiment which discharges water by connecting a new water-discharging piping (not shown) to the ballast tank 16 may be possible.

Sampling pipes 34, 36, and 38 are respectively connected to the raw-water piping 26 (that is, an inlet part of the water treatment apparatus 14), the treated water piping 32 (that is, an outlet part of the water treatment apparatus 14), and the ballast tank 16, and each of the sampling pipes 34, 36, and 38 is connected to the monitoring apparatus 18. The monitoring apparatus 18 automatically samples the ballast water withdrawn via the sampling pipes 34, 36, and 38 to investigate the water quality thereof. The method of investigating water quality is not specifically limited, and for example, there is a method of directly measuring the concentration of aquatic organisms by acquiring image data of the ballast water by photographing and performing an image analysis of the image data. Further, water quality may also be determined indirectly by using a turbidity meter for measuring a turbidity in water and a calorimeter for measuring a chromaticity in water.

The monitoring apparatus 18 is connected to the control apparatus 20 and the data of monitoring result is transmitted to the control apparatus 20. The control apparatus 20 is connected to the pump 28, the valve 30, the physical removal apparatus 22, and the sterilizing apparatus 24 so that based on the monitoring result, the operational conditions of the physical removal apparatus 22 and the sterilizing apparatus 24, the revolutional speed of the pump 28, and the opening of the valve 30 are adjusted. This allows for the control of the operational conditions of the water treatment apparatus 14 such as the treatment volume of aquatic organisms and the treatment flow rate per unit time, etc.

Next, the operation of the ballast water treatment system 10 which is configured as described above will be described.

In the present embodiment, the ballast waters of the raw-water piping 26, the treated water piping 32, and the ballast tank 16 are sampled. That is, the water qualities

of the ballast water at the time of water intake, the ballast water immediately after the treatment by the water treatment apparatus 14, and the ballast water stored in the ballast tank 16 are monitored. Then, the control apparatus 20 controls the operational conditions of the water treatment apparatus 14 in accordance with the water quality, thus performing ballast water treatment.

For example, when the water quality of the ballast water of the raw-water piping 26 (that is, the ballast water at the time of water intake) degrades resulting in an increase in the concentration of aquatic organisms, the treatment capacity of the water treatment apparatus 14 is increased such as by increasing the amount of disinfectant to be inputted to the sterilizing apparatus 24 and decreasing the treatment flow rate by the pump 28 and/or the valve 30. On the contrary, when the water quality of the ballast water at the time of water intake improves resulting in a decrease in the concentration of aquatic organisms, the treatment capacity of the water treatment apparatus 14 is decreased such as by decreasing the amount of disinfectant to be inputted to the sterilizing apparatus 24 and increasing the treatment flow rate by the pump 28 and/or the valve 30. This will make it possible to cope with variations in the water quality of the raw water of ballast water thereby stabilizing the water quality of the ballast water after treatment. Moreover, by controlling the operational conditions of the water treatment apparatus 14 in accordance with the water quality of the raw water of ballast water, it is made possible to prevent the disinfectant being excessively injected from the sterilizing apparatus 24, thus preventing the redundant disinfectant from adversely affecting the local ecosystem when the ballast water is discharged.

Similarly, it is possible to cope with a case in which the water quality of the ballast water of the treated water piping 32 (that is, the ballast water immediately after treatment) varies. That is, when the concentration of aquatic organisms increases, the treatment capacity of the water treatment apparatus 14 is increased such as by increasing the amount of the disinfectants to be inputted to the sterilizing apparatus 24 and decreasing the treatment flow rate by the pump 28 and the valve 30. On the contrary, when the concentration of aquatic organisms decreases, the treatment capacity of the water treatment apparatus 14 is decreased such as by decreasing the amount of the disinfectants to be inputted to the sterilizing apparatus 24 and increasing the treatment flow rate by the pump 28 and the valve 30. This will make it possible to perform a

feedback control of the water treatment apparatus 14 thereby stabilizing the water quality of the ballast water after treatment. It is noted that comparing the water quality of the ballast water of the raw-water piping 26 with the water quality of the ballast water of the treated water piping 32 will make it possible to more quickly and accurately cope with variations in the water quality of the raw water of the ballast water thereby further stabilizing the water quality of the ballast water after treatment.

In the present embodiment, the water quality of the ballast water in the ballast tank 16 is also monitored thereby allowing for the supervision of the water quality of the ballast water in the ballast tank. It is noted that when the water quality in the ballast tank degrades, it can be coped with by a method in which the ballast water in the ballast tank is circulated into the water treatment apparatus 14 and is retreated, a method in which when the ballast water in the ballast tank is discharged, it is fed to the water treatment apparatus 14 and is retreated to be discharged, or further a method in which the sterilizing apparatus 24 is connected to the ballast tank so that the inside of the ballast tank is sterilized, or the like.

Thus, according to the present embodiment, since the water quality of the ballast water is monitored and based on the result thereof, the operational conditions of the water treatment apparatus 14 are controlled, it is possible to always maintain a constant water quality of the ballast water even when the water quality of the ballast water significantly differs depending on water intake conditions.

Further, according to the present embodiment, since the water treatment is performed in accordance with the water quality of the ballast water, it is possible to inject a proper amount of chemical liquid in accordance with the concentration of aquatic organisms. Here, the relationship between the concentration of aquatic organisms and each disinfectant is shown in the table of Figure 7. In the present embodiment, it is possible to inject an appropriate amount of a chemical liquid based on such relationship, thereby allowing for the prevention of excessive or insufficient injection of the chemical liquid. Therefore, it is possible to prevent the residual chemical liquid from imposing a burden on the coating of the ballast tank 16 and the ecosystem in the area of water discharge.

It is noted that in the table of Figure 7, the standard for aquatic organism A is "less than 10 viable organisms per cubic meter for organisms greater than or equal to 50

μm in minimum dimension," and the standard for aquatic organism B is "less than 10 viable organisms per milliliter for organisms less than 50 μm and greater than or equal to 10 μm in minimum dimension."

It is noted that although in the above described embodiment, the water quality of the ballast water is monitored at three places (the raw-water piping 26, the treated water piping 32, and the ballast tank 16), the location and the number of points to be monitored are not limited to these and, for example, the water quality of the ballast water may be sampled at one or two of the above described places.

Figure 2 is a schematic diagram of a system in which a function of retreating the ballast water in the ballast tank 16 is provided in the ballast water treatment system of Figure 1. The ballast water treatment system 40 shown in the figure is configured such that a circulation line 42 is connected to the ballast tank 16, and the front end of the circulation line 42 is connected to the raw-water piping 26. The circulation line 42 is provided with a pump and a valve which are not shown, and the pump and the valve are controlled by a control apparatus 20. It is noted that, the front end of the circulation line 42 may be connected to the piping of the upstream side (the left side in Figure 2) of the pump 28 so that the pump 28 and the valve 30 are used for both water intake and circulation.

In the ballast water treatment system 40 configured as described above, the water quality of the ballast water in the ballast tank 16 is monitored and based on the monitoring result, the operational conditions of the water treatment apparatus 14 are controlled. For example, when the water quality of the ballast water in the ballast tank 16 degrades, the ballast water in the ballast tank 16 is circulated to the water treatment apparatus 14 through the circulation line 42 and retreatment of the ballast water is carried out. Then, in accordance the water quality of the ballast water in the ballast tank 16, the operational conditions of the water treatment apparatus 14 are controlled to carry out retreatment of the ballast water until the concentration of aquatic organisms becomes less than or equal to a permissible value. This makes it possible to improve the water quality of the ballast water in the ballast tank 16 and keep it less than or equal to the permissible value.

Thus, in the present embodiment, it is possible to circulate and purify the ballast water in the ballast tank 16 and, for example, the purification of the ballast water can be performed while the ship navigates.

It is noted that in the above described embodiment, although the ballast water in the ballast tank 16 is returned to a former stage of the physical removal apparatus 22, it may be returned to the former stage of the sterilization point by the sterilizing apparatus 24 as shown by the circulation line 44 indicated in Figure 2. In this case, a retreatment including only a sterilization treatment is possible.

Further, although in the above described embodiment the water quality of the ballast water in the ballast tank 16 is monitored and in accordance with the result thereof, retreatment of the ballast water is controlled, configuration may be such that the water quality of the ballast water in the ballast tank 16 is compared with the water quality of the ballast water immediately after the treatment and in accordance with the comparison result, the operational conditions at the time of retreatment are controlled. For example, configuration may be such that when the water quality of the ballast water immediately after the treatment becomes equivalent to the water quality of the ballast water in the ballast tank 16, retreatment of the ballast water is stopped.

Figure 3 is a schematic view to show the flow in performing the water discharge in the ballast water treatment system 10 of Figure 1. It is noted that although the flow of water discharge in the figure shows an example of performing water discharge by use of the water treatment apparatus 14, the pump 28, and the valve 30 of Figure 1, the method of water discharge is not limited to this method, and water discharge may be performed by providing a water treatment apparatus, a pump, and a valve which are different from those for the time of water intake.

The ballast water treatment system 10 shown in Figure 3 is configured such that with the valve 30 being opened and the pump 28 being driven, the ballast water in the ballast tank 16 is discharged to the outside through the water treatment apparatus 14. The control apparatus 20 controls the water treatment apparatus 14 in accordance with the monitoring result of the water quality of the ballast water in the ballast tank 16. For example, when the water quality (the concentration of aquatic organisms) of the ballast water in the ballast tank 16 exceeds a permissible value, the water treatment apparatus 14 is driven to start retreatment of the ballast water, and the operational conditions (a treatment volume such as the injection amount of disinfectant, and a treatment flow rate per unit time) of the water treatment apparatus 14 are controlled in accordance with the water quality of the ballast water. This will improves the water quality of the ballast

water to be discharged and the ballast water is controlled to be less than or equal to a permissible value and is discharged.

Thus, according to the present embodiment, since configuration is made such that the water treatment apparatus 14 is disposed on the discharge line of the ballast water, it is possible to perform retreatment of ballast water at the time of discharge. Therefore, even when the water quality of the ballast water in the ballast tank 16 degrades during navigation, it is possible to satisfy the discharge standard for ballast water by retreating the ballast water at the time of discharge.

It is noted that although, in the above described embodiment, configuration is made such that the ballast water at the time of water discharge flows to the physical removal apparatus 22 as well, the configuration may be such that a bypass line 46 of the physical removal apparatus 22 is provided so that water is discharged without passing through the physical removal apparatus 22 as shown in Figure 3.

Figure 4 schematically shows the configuration of the ballast water treatment system of a second embodiment. It is noted that the members which have the same functions as those of the ballast water treatment system 10 shown in Figure 1 are given the same reference numbers thereby omitting the description thereof.

As shown in Figure 4, compared with the ballast water treatment system 10 of the first embodiment shown in Figure 1, the ballast water treatment system 50 of the second embodiment is different in that a water treatment apparatus 52 based on a coagulation/separation scheme is used. The water treatment apparatus 52 based on a coagulation/separation scheme, which coagulates the substances to be removed (aquatic organisms) in the ballast water to be separated and removed, is made up of a chemicals adding unit 54, a coagulation unit 56, and a separation unit 58 as shown in Figure 4.

The chemicals adding unit 54, which adds chemicals necessary for coagulating the substances to be removed (aquatic organisms) in the ballast water, includes a magnetic powder adding apparatus 60, an inorganic coagulant adding apparatus 62, and a polymeric coagulant adding apparatus 64 in the present embodiment. The magnetic powder adding apparatus 60 is configured to add magnetic powder to the ballast water to be fed to a high-speed agitation vessel 66 of the coagulation unit 56, and as the magnetic powder, for example, triiron tetraoxide (Fe_3O_4) is preferably used. The inorganic coagulant adding apparatus 62 is configured to add inorganic coagulants to the ballast

water which is fed to the high-speed agitation vessel 66 of the coagulation unit 56, and as the inorganic coagulant, polyaluminum chloride, iron chloride, ferric sulfate, etc. are preferably used. The polymeric coagulant adding apparatus 64 is configured to add a polymeric coagulant to the ballast water to be fed to the low-speed agitation vessel 68 from the high-speed agitation vessel 66 of the coagulation unit 56, and as the polymeric coagulant, anionic and nonionic coagulants, etc. may be preferably used. It is noted that the kind of chemicals to be added is not limited to the above described embodiment and, for example, an embodiment which does not include the magnetic powder adding apparatus 60 is possible as well, when the magnetic separation apparatus 72 is not used in the separation unit 58 in the latter stage.

The coagulation unit 56 includes a high-speed agitation vessel 66 to which ballast water is fed from the raw-water piping 26, and a low-speed agitation vessel 68 which is connected to the high-speed agitation vessel 66 through a piping 70. The high-speed agitation vessel 66 is configured to rapidly agitate the ballast water, magnetic powder, and a coagulant by rotating an agitator blade which is not shown at a high speed. The agitating blade in the high-speed agitation vessel 66 has preferably a rotational peripheral speed of about 1 to 2 m/sec at its tip end part, and by using the high-speed agitation vessel 66 like this, minute magnetic flocs having a size of several tens of micrometers are formed, in which magnetic powder, solid floating particles in the ballast water, bacteria, planktons, etc. are taken in. The ballast water containing magnetic flocs is fed to the low-speed agitation vessel 68 via the piping 70.

The low-speed agitation vessel 68 is configured to slowly agitate the ballast water containing magnetic flocs and a polymeric coagulant by rotating the agitator blade which is not shown at a low speed. The agitator blade of the low-speed agitation vessel 68 is controlled to have a lower rotational peripheral speed than that of the agitator blade of the high-speed agitation vessel 66. By using such low-speed agitation vessel 68, it is possible to grow magnetic flocs, and large magnetic flocs having a size of several hundred micrometers to several millimeters are formed. The ballast water containing grown magnetic flocs is fed to the separation unit 58. It is noted that although in the present embodiment, the coagulation unit 56 is made up of the high-speed agitation vessel 66 and the low-speed agitation vessel 68, the configuration of the coagulation unit 56 is not limited to this configuration, and various embodiments, for example, one in

which several kinds of agitation vessels of different agitating methods are provided, are possible.

The separation unit 58 includes a magnetic separation apparatus 72 and a filter separation apparatus 74. The magnetic separation apparatus 72 adsorbs and separates magnetic flocks in the ballast water by magnetic force, and not less than about 99% of the magnetic flocks in the raw water is separated and removed by the magnetic separation apparatus 72. The treated water which has been treated by the magnetic separation apparatus 72 is fed to the filter separation apparatus 74. The filter separation apparatus 74 utilizes a rotating drum filter (not shown) having a filter of a pore size of 10 to 50 μm, and the ballast water is supplied to the inner side of the rotating drum filter so that the ballast water is fed from the inner side to the outer side thereby being filtered, and thus small fish and shrimps, which cannot be removed by coagulation, are removed. This makes it possible to remove contaminants such as dusts, solid floating particles, bacteria, planktons, etc. in the ballast water thereby purifying the ballast water. The purified ballast water is fed to the ballast tank 16 through treated water piping 32 to be stored therein. It is noted that the configuration of the separation unit 58 is not limited to the above described embodiment, and various embodiments are possible such as an embodiment in which no filter separation apparatus 74 is provided, and an embodiment in which in place of the magnetic separation apparatus 72, separation apparatuses such as those based on settling separation and floatation separation, etc. are utilized.

The ballast water treatment system 50 of the above described second embodiment is configured such that as with the first embodiment, sampling pipes 34, 36, and 38 are respectively connected to the raw-water piping 26, the treated water piping 32, and the ballast tank 16, and each of the sampling pipes 34, 36, and 38 is connected to the monitoring apparatus 18. The monitoring apparatus 18 automatically samples the ballast water withdrawn via the sampling pipes 34, 36, and 38 to investigate the water quality thereof. The method of investigating water quality is not specifically limited, and for example, there is a method of directly measuring the concentration of aquatic organisms by acquiring image data of the ballast water by photographing and performing an image analysis of the image data. Further, water quality may also be determined indirectly by using a turbidity meter for measuring a turbidity in water and a calorimeter for measuring a chromaticity in water.

The monitoring apparatus 18 is connected to the control apparatus 20 and the data of monitoring result is transmitted to the control apparatus 20. The control apparatus 20 is connected to the pump 28, the valve 30, the chemicals adding unit 54, and the coagulation unit 56, and based on the monitoring result, the operational conditions of the chemicals adding unit 54 and the coagulation unit 56, the revolutional speed of the pump 28, and the opening of the valve 30 are adjusted. This allows for the control of the operational conditions of the water treatment apparatus 52 such as the treatment volume of aquatic organisms and the treatment flow rate per unit time, etc.

According to the second embodiment configured as described above, since the water quality of the ballast water is monitored and, based on the result thereof, the operational conditions of the water treatment apparatus 52 are controlled, it is possible to always maintain a constant water quality of the ballast water even when the water quality of the ballast water significantly differs depending on water intake conditions.

For example, when the water quality of the ballast water of the raw-water piping 26 degrades resulting in an increase in the concentration of aquatic organisms, the treatment capacity of the water treatment apparatus 52 is increased such as by increasing the amount of chemicals to be inputted in the chemicals adding unit 54, enhancing the agitating effect in the coagulation unit 56 to increase the amount of coagulation, and decreasing the treatment flow rate by the pump 28 and/or the valve 30. On the contrary, when the water quality of the ballast water at the time of water intake improves resulting in a decrease in the concentration of aquatic organisms, the treatment capacity of the water treatment apparatus 52 is decreased such as by decreasing the amount of chemicals to be inputted to the chemicals adding unit 54, decreasing the agitating effect in the coagulation unit 56 to decrease the amount of coagulation, and increasing the treatment flow rate by the pump 28 and/or the valve 30. This will make it possible to cope with variations in the water quality of the raw water of ballast water, thereby stabilizing the water quality of the ballast water after treatment. Moreover, by controlling the operational conditions of the water treatment apparatus 52 in accordance with the water quality of the raw water of ballast water, it is made possible to prevent the chemicals of the chemicals adding unit 54 being excessively added thus preventing adverse effects on the local ecosystem when the ballast water is discharged.

Similarly, it is possible to cope with a case in which the water quality of the ballast water of the treated water piping 32 (that is, the ballast water immediately after treatment) varies. That is, when the concentration of aquatic organisms increases, the treatment capacity of the water treatment apparatus 52 is increased in the same fashion as described above, and when the concentration of aquatic organisms decreases, the treatment capacity of the water treatment apparatus 52 is decreased. This will make it possible to perform a feedback control of the water treatment apparatus 52 thereby stabilizing the water quality of the ballast water after treatment. It is noted that comparing the water quality of the ballast water of the raw-water piping 26 with the water quality of the ballast water of the treated water piping 32 will make it possible to more quickly and accurately cope with variations in the water quality of the raw water of the ballast water thereby further stabilizing the water quality of the ballast water after treatment.

In the present embodiment, the water quality of the ballast water in the ballast tank 16 is also monitored thereby allowing for the supervision of the water quality of the ballast water in the ballast tank 16. It is noted that when the water quality in the ballast tank 16 degrades, as described later, it can be coped with by a method in which the ballast water in the ballast tank 16 is circulated into the water treatment apparatus 52 and is retreated, or a method in which when the ballast water in the ballast tank 16 is discharged, it is fed to the water treatment apparatus 52 and is retreated to be discharged, or the like.

As described above, in the second embodiment, since the operational conditions of the water treatment apparatus 52 are controlled in accordance with the water quality of the ballast water, it is possible to add an appropriate amount of coagulant in accordance with the concentration of aquatic organisms. Here, the relationship between the turbidity of the ballast water and the adding amount of coagulant is shown in the table of Figure 8. According to the present embodiment, it is possible to add an appropriate amount of coagulant based on such relationship.

It is noted that the table of Figure 8 shows a case in which polyaluminum chloride is used as an example of the inorganic coagulant.

Further, in the second embodiment, since the water treatment apparatus 52 based on a coagulation/separation scheme is used, it is possible to prevent adverse effects on

the ecosystem as in a case in which disinfectants are used. Further, since when the water treatment apparatus 52 based on a coagulation/separation scheme is used, mud (dirt, dead bodies of organisms, etc.) will not be accumulated in the ballast tank 16, it is possible to prevent an increase of aquatic organisms in mud. Therefore, it is possible to inhibit the water quality of the ballast water in the ballast tank 16 from being degraded.

It is noted that although in the above described embodiment, the water quality of the ballast water is monitored at three places (the raw-water piping 26, treated water piping 32, and ballast tank 16), the location and the number of points to be monitored are not limited to these and, for example, the water quality of the ballast water may be sampled at one or two of the above described places.

Figure 5 is a schematic view of a system in which a function of retreating the ballast water in the ballast tank 16 is provided in the ballast water treatment system of Figure 4. The ballast water treatment system 80 shown in the figure is configured such that a circulation line 82 is connected to the ballast tank 16, and the front end of the circulation line 82 is connected to the raw-water piping 26. The circulation line 82 is provided with a pump and a valve which are not shown and the pump and the valve are controlled by a control apparatus 20. It is noted that, the front end of the circulation line 82 may be connected to the upstream side (the left side in Figure 5) of the pump 28 so that the pump 28 and the valve 30 are used for both the times of water intake and circulation.

In the ballast water treatment system 80 configured as described above, the water quality of the ballast water in the ballast tank 16 is monitored and based on the monitoring result, the operational conditions of the water treatment apparatus 52 are controlled. For example, when the water quality of the ballast water in the ballast tank 16 degrades, the ballast water in the ballast tank 16 is circulated to the water treatment apparatus 52 through the circulation line 82 and retreatment of the ballast water is started. Then, in accordance with the water quality of the ballast water in the ballast tank 16, the operational conditions of the water treatment apparatus 52 are controlled to carry out retreatment of the ballast water until the water quality becomes less than or equal to a permissible value. As a result of this, the water quality of the ballast water in the ballast tank 16 is improved and controlled to be less than or equal to a permissible value.

Thus, in the present embodiment, it is possible to circulate and purify the ballast water in the ballast tank 16 and, for example, the purification of the ballast water can be performed while the ship navigates.

Further, although in the above described embodiment, the water quality of the ballast water in the ballast tank 16 is monitored and in accordance with the result thereof, retreatment of the ballast water is controlled, configuration may be such that the water quality of the ballast water in the ballast tank 16 is compared with the water quality of the ballast water immediately after the treatment and in accordance with the comparison result, the operational conditions at the time of retreatment are controlled. For example, configuration may be such that when the water quality of the ballast water immediately after the treatment becomes equivalent to the water quality of the ballast water in the ballast tank 16, retreatment of the ballast water is stopped.

Figure 6 is a schematic view to show the flow in performing water discharge in the ballast water treatment system 50 of Figure 4. It is noted that although the flow of water discharge in the figure shows an example of performing water discharge by use of the water treatment apparatus 52, the pump 28, and the valve 30 of Figure 4, the water discharge method is not limited to this method, and water discharge may be performed by providing a water treatment apparatus, a pump, and a valve different from those for the time of water intake.

The ballast water treatment system 50 shown in Figure 6 is configured such that with the valve 30 being opened and the pump 28 being driven, the ballast water in the ballast tank 16 is discharged to the outside through the water treatment apparatus 52. The control apparatus 20 controls the water treatment apparatus 52 in accordance with the monitoring result of the water quality of the ballast water in the ballast tank 16. For example, when the water quality (the concentration of aquatic organisms) of the ballast water in the ballast tank 16 exceeds a permissible value, it starts retreatment of the ballast water by driving the water treatment apparatus 52 and controls the operational conditions (a treatment volume such as the injection amount of coagulant, and a treatment flow rate per unit time of ballast water, etc.) of the water treatment apparatus 52 in accordance with the water quality of the ballast water. Since this will improve the water quality of the ballast water to be discharged, it is possible to discharge ballast water which is controlled to be less than or equal to the permissible value.

Thus, since according to the present embodiment, configuration is made such that the water treatment apparatus 52 is incorporated on the discharge line of ballast water, it is possible to perform retreatment of ballast water at the time of discharge thereby improving the water quality. Therefore, even when the water quality of the ballast water in the ballast tank 16 degrades during navigation, it is possible to satisfy the discharge standard for ballast water by retreating the ballast water at the time of discharge.

CLAIMS

1. A ballast water treatment system including a water treatment apparatus which removes a substance to be removed from ballast water, and a ballast tank which stores the ballast water treated by the water treatment apparatus installed on a ship, the ballast water treatment system characterized by comprising:

a monitoring apparatus which monitors a water quality of the ballast water; and

a control apparatus which controls an operational condition of the water treatment apparatus based on a monitoring result of the monitoring apparatus.

2. The ballast water treatment system according to claim 1, wherein

the water treatment apparatus comprises:

a coagulation apparatus which coagulates the substance to be removed by injecting a coagulant into and agitating the ballast water; and

a separation/removal apparatus which separates and removes aggregates which occurs in the coagulation apparatus.

3. The ballast water treatment system according to claim 2, wherein

the control apparatus controls the coagulation apparatus based on the monitoring result of the monitoring apparatus to adjust an injection amount of the coagulant.

4. The ballast water treatment system according to claim 2 or 3, wherein

the separation/removal apparatus is configured as a combination of a magnetic separation and a filter separation.

5. The ballast water treatment system according to any one of claims 1 to 4, wherein

the monitoring apparatus monitors the ballast water by measuring at least one of a turbidity and a chromaticity of the ballast water.

6. The ballast water treatment system according to any one of claims 1 to 4, wherein

the monitoring apparatus monitors the ballast water by performing an image analysis of the ballast water.

7. The ballast water treatment system according to any one of claims 1 to 6, wherein

the control apparatus controls a treatment volume that is treated by the water treatment apparatus per unit time.

8. The ballast water treatment system according to any one of claims 1 to 7, wherein

the monitoring apparatus monitors the water quality of the ballast water at an inlet part of the water treatment apparatus, at an outlet part of the water treatment apparatus, and/or in the ballast tank.

9. The ballast water treatment system according to any one of claims 1 to 8, wherein

the ballast water treatment system comprises a line for returning the ballast water in the ballast tank or the ballast water to be discharged from the ballast tank to the outside to the water treatment apparatus, and the ballast water is retreated by the water treatment apparatus.