

DESCRIPTION

WATER TREATMENT APPARATUS AND WATER TREATMENT METHOD

FIELD OF THE INVENTION

[0001]

5 The present invention relates to a water treatment apparatus and a water treatment method, and more specifically a water treatment apparatus and a water treatment method that perform membrane separation of subject water by a membrane unit having a membrane.

RELATED ART

10 [0002]

Hitherto, there is known a water treatment method of the above type, which includes clarifying water containing suspended matters, such as river water, by way of membrane separation by a hollow fiber membrane unit having a microfiltration membrane (MF membrane) to produce permeate, and membrane
15 separating this permeate by a membrane unit having a reverse osmosis membrane (RO membrane) to produce permeate that is purified water (e.g., Patent Document 1).

[0003]

In such a water treatment method, membrane separation is performed by
20 a membrane unit, using, as subject water, free-residual-chlorine-containing subject water, which is produced by mixing subject water with a chemical containing a chlorine component (hereinafter simply referred to as "chlorine-containing chemical") (e.g., Patent Document 2).

Prior Art Documents

25 Patent Documents

[0004]

Patent Document 1: Japanese Patent Application Laid-open No.

Hei-7-60248

Patent Document 2: Japanese Patent Application Laid-open No.
2005-152688

DISCLOSURE OF THE INVENTION

5 PROBLEMS TO BE SOLVED BY THE INVENTION

[0005]

However, when the free residual chlorine concentration of
free-residual-chlorine-containing subject water is low, membrane fouling may not
be satisfactorily prevented.

10 On the other hand, merely increasing the free residual chlorine
concentration of free-residual-chlorine-containing subject water may invite
another problem, such as cost increase, membrane deterioration or increase in
environmental load.

[0006]

15 In consideration of the above problem, it is an object of the present
invention to provide a water treatment apparatus and a water treatment method
that are capable of suppressing membrane fouling by use of a chlorine-containing
chemical, while at the same time suppressing the increase of the
chlorine-containing chemical to be used.

20 MEANS FOR SOLVING PROBLEMS

[0007]

According to one aspect of the present invention, there is provided a water
treatment apparatus including a membrane unit having a membrane to
membrane separate subject water by the membrane unit, wherein the apparatus
25 alternately performs the following steps: a first filtration step of membrane
separating, as subject water, free-residual-chlorine-containing subject water
having a free residual chlorine concentration not higher than a predetermined

value; and any one of a washing step of submerging a membrane inside the membrane unit in washing water having a free residual chlorine concentration higher than the predetermined value and a second filtration step of membrane separating, as subject water, free-residual-chlorine-containing subject water

5 having a free residual chlorine concentration higher than the predetermined value by the membrane unit.

[0008]

According to another aspect of the present invention, there is provided a water treatment method for membrane separating subject water by a membrane

10 unit having a membrane, the method including alternately performing the following steps: a first filtration step of membrane separating, as subject water, free-residual-chlorine-containing subject water that has a free residual chlorine concentration not higher than a predetermined value; and any one of a washing

15 step of submerging a membrane inside the membrane unit in washing water having a free residual chlorine concentration higher than the predetermined value and a second filtration step of membrane separating, as subject water, free-residual-chlorine-containing subject water having a free residual chlorine concentration higher than the predetermined value by the membrane unit.

[0009]

20 According to still another aspect of the present invention, there is provided a water treatment apparatus for membrane separating subject water, which includes:

a spiral clarifier membrane unit that includes at least one of an ultrafiltration membrane and a microfiltration membrane,

25 wherein, at the time of filtration, free-residual-chlorine-containing subject water, which is produced by mixing subject water with a chlorine-containing chemical and has a free residual chlorine concentration within a range of 0.05-2.5

mg/L, is membrane separated, as subject water, by the clarifier membrane unit; and at the time of washing, washing water that has a free residual chlorine concentration within a range of more than 2.5 mg/L and not more than 250 mg/L is supplied to the clarifier membrane unit to thereby submerge a membrane inside the clarifier membrane unit in the washing water.

[0010]

According to yet another aspect of the present invention, there is provided a water treatment method for membrane separating subject water, including:

at the time of filtration, membrane separating, as subject water, free-residual-chlorine-containing subject water, which is produced by mixing subject water with a chlorine-containing chemical and has a free residual chlorine concentration within a range of 0.05-2.5 mg/L, by a spiral clarifier membrane unit that includes at least one of an ultrafiltration membrane and a microfiltration membrane; and at the time of washing, supplying washing water, which has a free residual chlorine concentration within a range of more than 2.5 mg/L and not more than 250 mg/L, to the clarifier membrane unit to thereby submerge a membrane inside the clarifier membrane unit in the washing water.

[0011]

According to the aforesaid water treatment apparatus and water treatment method, it is possible to further suppress fouling of a membrane or fouling of flow channels of subject water by, at the time of filtration, membrane treating free-residual-chlorine-containing subject water that has a free residual chlorine concentration within a range of 0.05-2.5 mg/L, and possible to further suppress fouling of a membrane or fouling of flow channels of subject water by, at the time of washing, washing a membrane inside the clarifier unit by submerging the same in washing water that has a free residual chlorine concentration higher than that at the time of the filtration. Also, it is possible to suppress the amount

of a chlorine-containing chemical to be used, as well as suppress fouling of a membrane or fouling of flow channels of subject water by lowering the free residual chlorine concentration of free-residual-chlorine-containing subject water at the time of filtration than that at the time of washing.

5 Thus, according to the water treatment apparatus and water treatment method, it is possible to make it hard to cause fouling of a membrane or fouling of flow channels of subject water, and suppress the amount of a chlorine-containing chemical to be used.

[0012]

10 According to another aspect of the present invention, there is provided a water treatment apparatus that includes a reverse osmosis membrane unit having a reverse osmosis membrane and membrane separates subject water by the reverse osmosis membrane unit, including:

 a differential pressure measurement device that measures the differential
15 pressure on non-permeation side of the reverse osmosis membrane unit;

 wherein, when the value measured by the differential pressure measurement device is less than a reference value, free-residual-chlorine-containing subject water that has a free residual chlorine concentration within a range of not less than 0.20 mg/L and less than 1.2 mg/L is
20 membrane separated, as subject water, by the reverse osmosis membrane unit; and when the value measured by the differential pressure measurement device is not less than the reference value, free-residual-chlorine-containing subject water that has a free residual chlorine concentration within a range of 1.2-2 mg/L is
25 membrane separated, as subject water, by the reverse osmosis membrane unit.

[0013]

 According to the aforesaid water treatment apparatus, when the measured value is less than the reference value, by membrane separating

free-residual-chlorine-containing subject water having a low free residual chlorine concentration (not less than 0.20 mg/L and less than 1.2 mg/L), it is possible to produce purified water that is permeate, while suppressing fouling of a membrane and at the same time suppressing deterioration of a reverse osmosis membrane (RO membrane). Also, when the measured value is not less than the reference value, by membrane separating free-residual-chlorine-containing subject water having a higher free residual chlorine concentration (1.2-2 mg/L), it is possible to further suppress fouling of a membrane. In a case where the differential pressure starts rising in membrane separation of subject water at a constant flux, this differential pressure keeps rising even by washing a reverse osmosis membrane with chemicals, such as alkali other than free residual chlorine. On the other hand, according to the aforesaid water treatment apparatus, even if the pressure difference rises to some extent, it is possible to lower the same.

Thus, according to the aforesaid water treatment apparatus, it is possible to suppress fouling of a reverse osmosis membrane (RO membrane) by using a chlorine-containing chemical and at the same time make it hard to cause deterioration of a reverse osmosis membrane (RO membrane).

[0014]

According to still another aspect of the present invention, there is provided a water treatment apparatus that includes a reverse osmosis membrane unit having a reverse osmosis membrane and membrane separates subject water by the reverse osmosis membrane unit, including:

a differential pressure measurement device that measures the differential pressure on non-permeation side of the reverse osmosis membrane unit; wherein, when the value measured by the differential pressure measurement device is not more than a reference value, free-residual-chlorine-containing subject water that has a free residual chlorine

concentration within a range of not less than 0.20 mg/L and less than 1.2 mg/L is
membrane separated, as subject water, by the reverse osmosis membrane unit;
and when the value measured by the differential pressure measurement device is
more than the reference value, free-residual-chlorine-containing subject water
5 that has a free residual chlorine concentration within a range of 1.2-2 mg/L is
membrane separated, as subject water, by the reverse osmosis membrane unit.

[0015]

According to yet another aspect of the present invention, there is provided
a water treatment method that membrane separates subject water by a reverse
10 osmosis membrane unit having a reverse osmosis membrane, including:

measuring the differential pressure on non-permeate side of the reverse
osmosis membrane unit by a differential pressure measurement device;

wherein, when the value measured by the differential pressure
measurement device is less than a reference value,

15 free-residual-chlorine-containing subject water that has a free residual chlorine
concentration within a range of not less than 0.20 mg/L and less than 1.2 mg/L is
membrane separated, as subject water, by the reverse osmosis membrane unit;
and when the value measured by the differential pressure measurement device is
not less than the reference value, free-residual-chlorine-containing subject water
20 that has a free residual chlorine concentration within a range of 1.2-2 mg/L is
membrane separated, as subject water, by the reverse osmosis membrane unit.

[0016]

According to another aspect of the present invention, there is provided a
water treatment method that membrane separates subject water by a reverse
25 osmosis membrane unit having a reverse osmosis membrane, including:

measuring the differential pressure on non-permeate side of the reverse
osmosis membrane unit by a differential pressure measurement device;

wherein, when the value measured by the differential pressure measurement device is not more than a reference value, free-residual-chlorine-containing subject water that has a free residual chlorine concentration within a range of not less than 0.20 mg/L and less than 1.2 mg/L is membrane separated, as subject water, by the reverse osmosis membrane unit; and when the value measured by the differential pressure measurement device is more than the reference value, free-residual-chlorine-containing subject water that has a free residual chlorine concentration within a range of 1.2-2 mg/L is membrane separated, as subject water, by the reverse osmosis membrane unit.

ADVANTAGES OF THE INVENTION

[0017]

As described above, according to the present invention, it is possible to suppress fouling of a membrane by using a chlorine-containing chemical, while at the same time suppressing the amount of a chlorine-containing chemical to be used.

BRIEF DESCRIPTION OF THE DRAWINGS

[0018]

Fig. 1 is a schematic diagram of a water treatment apparatus according to one embodiment of the present invention.

Fig. 2 is a diagram showing change with time in the trans membrane pressure and the free residual chlorine concentration of first free-residual-chlorine-containing subject water in Test Example 1.

Fig. 3 is a diagram showing change with time in the free residual chlorine concentration of second free-residual-chlorine-containing subject water and the trans membrane pressure on non-permeate side of a reverse osmosis membrane unit in Test Example 2.

Fig. 4 is a diagram showing change with time in the salt rejection rate of a

reverse osmosis membrane unit in Test Example 2.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

[0019]

Now, the description will be made for an embodiment of the present
5 invention with reference to the drawings attached hereto.

[0020]

First Embodiment

First, the description will be made for a water treatment apparatus and
water treatment method of the first embodiment.

10 [0021]

Hitherto, there is known a method that includes clarifying water
containing suspended matters, such as river water, by way of membrane
separation by a hollow fiber membrane unit having a microfiltration membrane
(MF membrane) to produce permeate, and membrane separating this permeate by
15 a membrane unit having a reverse osmosis membrane (RO membrane) to produce
permeate that is purified water (e.g., Patent Document 1).

[0022]

However, the hollow fiber membrane unit is relatively expensive, and
thus there is a demand for a method, which uses a membrane of not so expensive.

20 In view of the above, it is conceivable that a spiral membrane unit using a
membrane of a relatively low price, such as an ultrafiltration membrane (UF
membrane) or a microfiltration membrane (MF membrane).

The spiral membrane unit is a membrane unit that has a laminated
structure of a flat filtration membrane and a meshed spacer that acts as flow
25 channels of subject water and maintains the strength of the filtration membrane.

[0023]

In a case where the thus structured spiral membrane unit is used to treat

water (subject water) containing suspended matters equal to or beyond a certain degree, the meshed spacer may be clogged due to these suspended matters.

In view of the above, it is conceivable that subject water is treated by membrane process while suppressing fouling of a membrane or fouling of fluid channels of subject water by residual chlorine resulting from membrane separation of residual-chlorine-containing subject water, which is produced by mixing subject water with a chlorine-containing chemical. However, merely increasing the concentration of the residual chlorine in residual-chlorine-containing subject water may invite a problem, such as cost increase, membrane deterioration or increase in environmental load.

[0024]

In the first embodiment, in consideration of the above problem, an object is to provide a water treatment apparatus and water treatment method that is capable of suppressing fouling of a membrane or fouling of flow channels of subject water and suppressing the amount of a chlorine-containing chemical to be used, even in a case where subject water containing suspended matters equal to or beyond a certain degree is treated by use of a spiral membrane unit.

[0025]

Now, the description will be made for a water treatment apparatus of the first embodiment.

As shown in Fig. 1, a water treatment apparatus 1 of the first embodiment includes a clarifier treatment part 2 that, in turn, includes a clarifier membrane unit 21 to membrane separate subject water A, in which the clarifier membrane unit 21 membrane separates the subject water A containing suspended matters to produce first permeate and first concentrate C; and a reverse osmosis membrane treatment part 3 that, in turn, includes a reverse osmosis membrane unit 31 to membrane separate the first permeate, in which the reverse osmosis

membrane unit membrane 31 membrane separates the first permeate to produce second permeate and second concentrate D. The water treatment apparatus 1 of the first embodiment is configured so that the subject water A is transferred to the clarifier treatment part 2, the first permeate is transferred to the reverse osmosis membrane treatment part 3, the first concentrate C is transferred to a first concentrate storage tank (not shown), the second permeate is transferred as purified water B to a purified water storage tank (not shown), and the second concentrate D is transferred to a second concentrate storage tank (not shown).

[0026]

10 The water treatment apparatus 1 of the first embodiment includes a chlorine aqueous solution storage tank 4 that stores a solution of a chemical containing a chlorine component, such as sodium hypochlorite. The water treatment apparatus 1 of the first embodiment is configured so that a chlorine solution in the chlorine aqueous solution storage tank 4 is transferred to the clarifier treatment part 2, and a chlorine solution in the chlorine aqueous solution storage tank 4 is transferred to the reverse osmosis membrane treatment part 3.

[0027]

The clarifier treatment part 2 includes a mixing part 22 that mixes the subject water A with a chlorine solution to produce first free-residual-chlorine-containing subject water, and is configured so that the first free-residual-chlorine-containing subject water is transferred, as the subject water A, to the clarifier membrane unit 21 for membrane separation.

[0028]

25 The clarifier treatment part 2 includes a first mixing ratio adjustment mechanism (not shown) that adjusts the mixing ratio between the subject water A and a chlorine solution to adjust the free residual chlorine concentration of the produced first free-residual-chlorine-containing subject water.

[0029]

The subject water A, which is mixed with a chlorine solution at the mixing part 22, is not necessarily limited to a specific one, and supernatant water produced by biological treatment and sedimentation separation of organic wastewater, such as human wastewater, sewage water, industrial wastewater (wastewater discharged from, for example, a food factory, a chemical factory, a factory in electronics industry or a pulp plant), river water or lake water may be subjected.

The subject water A is water having suspended matters, and has a turbidity of, for example, 0.1 or more, and more specifically 0.1-50. The turbidity is herein meant a value measured by a laser scattering method.

[0030]

The clarifier treatment part 2 is configured so that, at the time of filtration (first filtration step), the free-residual-chlorine-containing subject water, which is produced by mixing the subject water A with a chlorine solution and has a free residual chlorine concentration in a range of 0.05-2.5 mg/L, is continuously membrane separated, as the subject water A, by the clarifier membrane unit 21; and at the time of washing, washing water, which has a free residual chlorine concentration in a range of more than 2.5 mg/L and not more than 250 mg/L, is supplied to the clarifier membrane unit 21 to allow a membrane inside the clarifier membrane unit 21 to be submerged in the washing water.

[0031]

The water treatment apparatus 1 of the first embodiment is configured so that, at the time of washing, a chlorine solution is transferred, as washing water, from the chlorine aqueous solution storage tank 4 to the clarifier treatment part 2. The water treatment apparatus 1 of the first embodiment is also configured according to needs, so that a chlorine solution transferred from the chlorine

aqueous solution storage tank 4 to the clarifier treatment part 2 is diluted with water to the required concentration and the diluted chlorine solution is used as washing water at the clarifier treatment part 2.

[0032]

5 The clarifier treatment part 2 is configured so that the frequency of washing is preferably once every 10-80 hours, and more preferably once every 20-60 hours.

[0033]

10 The clarifier treatment part 2 is configured so that the membrane submerging time by washing water at the time of washing is 0.2-5 hours.

[0034]

15 The clarifier treatment part 2 is configured so that the permeation flux of the first permeate produced from the clarifier membrane unit 21 is preferably not more than 0.6 m/d, and more preferably in a range of 0.1-0.5 m/d. The clarifier treatment part 2, which is configured to allow the first permeate produced from the clarifier membrane unit 21 to have a permeation flux of not more than 0.6 m/d, produces an advantageous effect that it is possible to further suppress fouling of a membrane or fouling of flow channels of subject water.

[0035]

20 The clarifier membrane unit 21 has at least one of an ultrafiltration membrane and a microfiltration membrane, and is of a spiral type. The spiral membrane unit is a membrane unit that has a laminated structure of a flat filtration membrane and a meshed spacer for maintaining the strength of the filtration membrane.

25 [0036]

 The reverse osmosis membrane treatment part 3 includes a first permeate storage part 32 that stores the first permeate containing free residual chlorine,

and is configured so that the first permeate that is a second free-residual-chlorine-containing subject water is transferred, as the subject water A, to a reverse osmosis membrane unit 31 for membrane separation. Also, the reverse osmosis membrane treatment part 3 is configured so that a chlorine solution is added to the first permeate storage part 32 in order to adjust the free residual chlorine concentration of the first permeate.

[0037]

The reverse osmosis membrane treatment part 3 further includes a second mixing ratio adjustment mechanism (not shown) that adjusts the mixing ratio between the first permeate and a chlorine solution to thereby adjust the free residual chlorine concentration of the first permeate that is the second free-residual-chlorine-containing subject water.

[0038]

The reverse osmosis membrane treatment part 3 includes a differential pressure measurement device (not shown) that measures the differential pressure (pressure loss in flow channels) on the non-permeate side of the reverse osmosis membrane unit 31.

By the differential pressure (pressure loss in flow channels) on the non-permeate side is herein meant the difference in pressure calculated by subtracting the pressure value of concentrate produced without permeation through the reverse osmosis membrane from the pressure value of supply water supplied to a reverse osmosis membrane of the reverse osmosis membrane unit 31, and more specifically meant the difference in pressure calculated by subtracting the pressure value of concentrate at a concentrate outlet of the membrane module from the pressure value of supply water at a supply water inlet of a membrane module of the reverse osmosis membrane unit 31.

[0039]

Furthermore, the reverse osmosis membrane treatment part 3 is configured so that second free-residual-chlorine-containing subject water, which has a free residual chlorine concentration in a range of not less than 0.20 mg/L and less than 1.2 mg/L, preferably in a range of more than 0.25 mg/L and less than 1.2 mg/L, and more preferably in a range of 0.3-1.0 mg/L when the value measured by the differential pressure measurement device (not shown) is less than a reference value, is continuously membrane separated, as the subject water A, by the reverse osmosis membrane unit 31; and the second free-residual-chlorine-containing subject water, which has a free residual chlorine concentration in a range of 1.2-2 mg/L and preferably in a range of 1.4-1.8 mg/L when the value measured by the differential pressure measurement device (not shown) is not less than the reference value, is continuously membrane separated, as the subject water A, by the reverse osmosis membrane unit 31.

[0040]

The reverse osmosis membrane treatment part 3 is also configured so that the free residual chlorine concentration of first permeate, which is second free-residual-chlorine-containing subject water, is adjusted by the second mixing ratio adjustment mechanism (not shown) on the basis of the measured value obtained by the differential pressure measurement device (not shown).

[0041]

The reference value per reverse osmosis membrane unit is preferably in a range of 0.01-0.1 MPa, and more preferably in a range of 0.02-0.09 MPa.

[0042]

The reverse osmosis membrane unit 31 has a reverse osmosis membrane (RO membrane) and is a hollow fiber membrane unit.

The reverse osmosis membrane (RO membrane) is a reverse osmosis membrane (RO membrane) made of cellulose acetate.

[0043]

The water treatment apparatus of the first embodiment is thus configured and now the description will be made for a water treatment method of the first embodiment.

5 [0044]

The water treatment method of the first embodiment is a method that includes membrane separating, as the subject water A, first free-residual-chlorine-containing subject water produced by mixing the subject water A with a chlorine solution and having a free residual chlorine concentration of 0.05-2.5 mg/L at the time of filtration; and supplying washing water having a free residual chlorine concentration in a range of more than 2.5 mg/L and not more than 250 mg/L to the clarifier membrane unit 21 to thereby submerge a membrane inside the clarifier membrane unit 21 in the washing water at the time of washing.

[0045]

15 The thus configured water treatment apparatus and water treatment method of the first embodiment produces the following advantageous effects.

[0046]

For example, the water treatment apparatus 1 of the first embodiment is configured so that second free-residual-chlorine-containing subject water, which has a free residual chlorine concentration in a range of not less than 0.20 mg/L and less than 1.2 mg/L, preferably in a range of more than 0.25 mg/L and less than 1.2 mg/L, and more preferably in a range of 0.3-1.0 mg/L when the value measured by the differential pressure measurement device (not shown) is less than a reference value, is continuously membrane separated, as the subject water A, by the reverse osmosis membrane unit 31; as well as being configured so that second free-residual-chlorine-containing subject water, which has a free residual chlorine concentration in a range of 1.2-2 mg/L and preferably 1.4-1.8 mg/L when the value

measured by the differential pressure measurement device (not shown) is not less than the reference value is continuously membrane separated, as the subject water A, by the reverse osmosis membrane unit 31. The thus configured water treatment apparatus 1 produces the following advantageous effects.

5 According to the water treatment apparatus 1, it is possible to produce purified water that is second permeate, while suppressing fouling of a membrane and deterioration of a reverse osmosis membrane (RO membrane) by membrane separating second free-residual-chlorine-containing subject water that has a low free residual chlorine concentration (not less than 0.2 mg/L and less than 1.2
10 mg/L) when the measured value is less than a reference value. It is possible to further suppress fouling of a membrane by membrane separating second free-residual-chlorine-containing subject water that has a higher free residual chlorine concentration (1.2-2 mg/L) when the measured value is not less than the reference value. In a case where the differential pressure starts rising in
15 membrane separation of the subject water A at a constant flux, this differential pressure keeps rising even by washing a reverse osmosis membrane (RO membrane) with chemicals, such as alkali other than free residual chlorine. On the other hand, according to the water treatment apparatus 1, even if the pressure difference rises, it is possible to lower the same.

20 [0047]

 Although the thus configured water treatment apparatus and water treatment method of the first embodiment produces the above advantageous effects, the water treatment apparatus and water treatment method of the present invention is not necessarily limited to the above configuration, and may be
25 subjected to modification, if any.

 For example, according to the water treatment apparatus of the first embodiment, the reverse osmosis membrane treatment part 3 is configured so that

second free-residual-chlorine-containing subject water, which has a free residual chlorine concentration in a range of not less than 0.20 mg/L and less than 1.2 mg/L when the value measured by the differential pressure measurement device (not shown) is less than a reference value, is continuously membrane separated, as the
5 subject water A, by the reverse osmosis membrane unit 31; as well as being configured so that second free-residual-chlorine-containing subject water, which has a free residual chlorine concentration in a range of 1.2-2 mg/L when the value measured by the differential pressure measurement device (not shown) is not less than the reference value is continuously membrane separated, as the subject
10 water A, by the reverse osmosis membrane unit 31. However, according to the water treatment apparatus of the present invention, the reverse osmosis membrane treatment part 3 may be configured so that second free-residual-chlorine-containing subject water, which has a free residual chlorine concentration in a range of not less than 0.20 mg/L and less than 1.2 mg/L when
15 the value measured by the differential pressure measurement device (not shown) is not more than a reference value, is continuously membrane separated, as the subject water A, by the reverse osmosis membrane unit 31; as well as being configured so that second free-residual-chlorine-containing subject water, which has a free residual chlorine concentration in a range of 1.2-2 mg/L when the value
20 measured by the differential pressure measurement device (not shown) is more than the reference value is continuously membrane separated, as the subject water A, by the reverse osmosis membrane unit 31.

[0048]

Second Embodiment

25 Now, the description will be made for a water treatment apparatus and water treatment method of a second embodiment.

[0049]

Hitherto, there is known a water treatment method that includes mixing subject water with a chlorine-containing chemical to produce free-residual-chlorine-containing subject water having a free residual chlorine concentration in a range of 0.1-1 mg/L, and membrane separating the free-residual-chlorine-containing subject water, as subject water, by a reverse osmosis membrane unit (e.g., Patent Document 2).

[0050]

However, according to the aforesaid method, it is not possible to satisfactorily suppress fouling of the reverse osmosis membrane (RO membrane).

[0051]

On the other hand, when an attempt is made to satisfactorily suppress fouling of a reverse osmosis membrane (RO membrane) by merely increasing the free residual chlorine concentration of the free-residual-chlorine-containing subject water, the reverse osmosis membrane (RO membrane) may be deteriorated due to free residual chlorine of the free-residual-chlorine-containing subject water.

[0052]

In consideration of the above problem, an object of the second embodiment is to provide a water treatment apparatus and water treatment method that is capable of preventing a reverse osmosis membrane (RO membrane) from being easily deteriorated while at the same time suppressing fouling of the reverse osmosis membrane (RO membrane) by use of a chlorine-containing chemical.

[0053]

First, the description will be made for the water treatment apparatus of the second embodiment.

As shown in Fig. 1, a water treatment apparatus 1 of the second embodiment includes a clarifier treatment part 2 that, in turn, includes a clarifier membrane unit 21 to membrane separate subject water A, in which the clarifier

membrane unit 21 membrane separates the subject water A to produce first permeate and first concentrate C; and a reverse osmosis membrane treatment part 3 that, in turn, includes a reverse osmosis membrane unit 31 to membrane separate the first permeate, in which the reverse osmosis membrane unit 31
5 membrane separates the first permeate to produce second permeate and second concentrate D. The water treatment apparatus 1 of the second embodiment is configured so that the subject water A is transferred to the clarifier treatment part 2, the first permeate is transferred to the reverse osmosis membrane treatment part 3, the first concentrate C is transferred to a first concentrate storage tank
10 (not shown), the second permeate is transferred as purified water B to a purified water storage tank (not shown), and the second concentrate D is transferred to a second concentrate storage tank (not shown).

By the clarifying is herein meant coarse filtration compared with a reverse osmosis membrane filtration, that is, filtration of impurities (e.g., solid
15 matters, etc.) coarser than those separated by a reverse osmosis membrane (RO membrane), which is performed prior to the filtration process by the reverse osmosis membrane (RO membrane).

[0054]

The water treatment apparatus 1 of the second embodiment includes a
20 chlorine aqueous solution storage tank 4 that stores a chlorine solution of chemicals containing a chlorine component, such as sodium hypochlorite. The water treatment apparatus 1 of the second embodiment is configured so that a chlorine solution in the chlorine aqueous solution storage tank 4 is transferred to the clarifier treatment part 2, and a chlorine aqueous solution in the chlorine
25 aqueous solution storage tank 4 is transferred to the reverse osmosis membrane treatment part 3.

[0055]

The clarifier treatment part 2 includes a mixing part 22 that mixes the subject water A with a chlorine solution to produce first free-residual-chlorine-containing subject water, and is configured so that the first free-residual-chlorine-containing subject water is transferred, as the subject water
5 A, to the clarifier membrane unit 21 for membrane separation.

[0056]

The clarifier treatment part 2 includes a first mixing ratio adjustment mechanism (not shown) that adjusts the mixing ratio between the subject water A and a chlorine solution to adjust the free residual chlorine concentration of the
10 produced first free-residual-chlorine-containing subject water.

[0057]

The subject water A, which is mixed with a chlorine solution at the mixing part 22, is not necessarily limited to a specific one, and supernatant water produced by biological treatment and sedimentation separation of organic
15 wastewater, such as human wastewater, sewage water, industrial wastewater (wastewater discharged from, for example, a food factory, a chemical factory, a factory in electronics industry and a pulp plant), river water or lake water may be subjected.

The subject water A is water having suspended matters, and has a
20 turbidity of, for example, 0.1 or more, and more specifically 0.1-50. The turbidity is herein meant a value measured by a laser scattering method.

[0058]

The clarifier membrane unit 21 has at least one of an ultrafiltration membrane and a microfiltration membrane. The clarifier membrane unit 21 is a
25 spiral membrane unit. The spiral membrane unit is a membrane unit that has a laminated structure of a flat filtration membrane and a meshed spacer for maintaining the strength of the filtration membrane.

[0059]

The reverse osmosis membrane treatment part 3 includes a first permeate storage part 32 that stores the first permeate containing free residual chlorine, and is configured so that the first permeate that is a second

5 free-residual-chlorine-containing subject water is transferred, as the subject water A, to a reverse osmosis membrane unit 31 for membrane separation. Also, the reverse osmosis membrane treatment part 3 is configured so that a chlorine solution is added to the first permeate storage part 32 in order to adjust the free residual chlorine concentration of the first permeate.

10 [0060]

The reverse osmosis membrane treatment part 3 further includes a second mixing ratio adjustment mechanism (not shown) that adjusts the mixing ratio between the first permeate and a chlorine solution to thereby adjust the free residual chlorine concentration of the first permeate that is the second

15 free-residual-chlorine-containing subject water.

[0061]

The reverse osmosis membrane treatment part 3 includes a differential pressure measurement device (not shown) that measures the differential pressure (pressure loss in flow channels) on the non-permeate side of the reverse osmosis
20 membrane unit 31.

By the differential pressure (pressure loss in flow channels) on the non-permeate side is herein meant the difference in pressure calculated by subtracting the pressure value of concentrate produced without permeation through the reverse osmosis membrane from the pressure value of supply water
25 supplied to a reverse osmosis membrane of the reverse osmosis membrane unit 31, and more specifically meant the difference in pressure calculated by subtracting the pressure value of concentrate at a concentrate outlet of the membrane module

from the pressure value of supply water at a supply water inlet of a membrane module of the reverse osmosis membrane unit 31.

[0062]

Furthermore, the reverse osmosis membrane treatment part 3 is
5 configured so that second free-residual-chlorine-containing subject water, which has a free residual chlorine concentration in a range of not less than 0.20 mg/L and less than 1.2 mg/L, preferably in a range of more than 0.25 mg/L and less than 1.2 mg/L, and more preferably in a range of 0.3-1.0 mg/L when the value measured by the differential pressure measurement device (not shown) is less than a
10 reference value (in a first filtration step), is continuously membrane separated, as the subject water A, by the reverse osmosis membrane unit 31; and the second free-residual-chlorine-containing subject water, which has a free residual chlorine concentration in a range of 1.2-2 mg/L and preferably in a range of 1.4-1.8 mg/L when the value measured by the differential pressure measurement device (not
15 shown) is not less than the reference value (in a second filtration step), is continuously membrane separated, as the subject water A, by the reverse osmosis membrane unit 31.

[0063]

The reverse osmosis membrane treatment part 3 is also configured so that
20 the free residual chlorine concentration of first permeate, which is second free-residual-chlorine-containing subject water, is adjusted by the second mixing ratio adjustment mechanism (not shown) on the basis of the measured value obtained by the differential pressure measurement device (not shown).

[0064]

25 The reference value per reverse osmosis membrane unit is preferably in a range of 0.01-0.1 MPa, and more preferably in a range of 0.02-0.09 MPa.

[0065]

The reverse osmosis membrane unit 31 has a reverse osmosis membrane (RO membrane) and is a hollow fiber membrane unit.

The reverse osmosis membrane (RO membrane) is a reverse osmosis membrane (RO membrane) made of cellulose acetate.

5 [0066]

The water treatment apparatus of the second embodiment is thus configured and now the description will be made for a water treatment method of the second embodiment.

[0067]

10 The water treatment method of the second embodiment is a method that includes membrane separating, as the subject water A, second free-residual-chlorine-containing subject water, which has a free residual chlorine concentration in a range of not less than 0.20 mg/L and less than 1.2 mg/L when the value measured by the differential pressure measurement device (not shown)
15 is less than a reference value, by the reverse osmosis membrane unit 31; and membrane separating, as the subject water A, second free-residual-chlorine-containing subject water, which has a free residual chlorine concentration in a range of 1.2-2 mg/L when the value measured by the differential pressure measurement device (not shown) is not less than the
20 reference value, by the reverse osmosis membrane unit 31.

[0068]

Although the water treatment apparatus and water treatment method of the second embodiment has the above configuration, the water treatment apparatus and water treatment method of the present invention is not necessarily
25 limited to the above configuration, and may be subjected to modification, if any.

[0069]

For example, according to the water treatment apparatus of the second

embodiment, the reverse osmosis membrane treatment part 3 is configured so that second free-residual-chlorine-containing subject water, which has a free residual chlorine concentration in a range of not less than 0.20 mg/L and less than 1.2 mg/L when the value measured by the differential pressure measurement device (not shown) is less than a reference value, is continuously membrane separated, as the subject water A, by the reverse osmosis membrane unit 31; as well as being configured so that second free-residual-chlorine-containing subject water, which has a free residual chlorine concentration in a range of 1.2-2 mg/L when the value measured by the differential pressure measurement device (not shown) is not less than the reference value is continuously membrane separated, as the subject water A, by the reverse osmosis membrane unit 31. However, according to the water treatment apparatus of the present invention, the reverse osmosis membrane treatment part 3 may be configured so that second free-residual-chlorine-containing subject water, which has a free residual chlorine concentration in a range of not less than 0.20 mg/L and less than 1.2 mg/L when the value measured by the differential pressure measurement device (not shown) is not more than a reference value, is continuously membrane separated, as the subject water A, by the reverse osmosis membrane unit 31; as well as being configured so that second free-residual-chlorine-containing subject water, which has a free residual chlorine concentration in a range of 1.2-2 mg/L when the value measured by the differential pressure measurement device (not shown) is more than the reference value is continuously membrane separated, as the subject water A, by the reverse osmosis membrane unit 31.

Examples

[0070]

Now, more specific description will be made for the present invention with citing test examples.

[0071]

(Test Example 1)

Supernatant, of which turbidity varies within a range of 0.1-50, produced by subjecting sewage water to biological treatment and then sedimentation separation is mixed with a chlorine solution to produce first free-residual-chlorine-containing subject water. The free-residual-chlorine-containing subject water is membrane separated by a spiral clarifier membrane unit (Trade name: RS50-S8, manufactured by Nitto Denko Corporation) having an ultrafiltration membrane (UF membrane). The trans membrane pressure of the clarifier membrane unit, which is being performing membrane separation, is measured by a pressure data logger (Trade name: DAQSTATION DX120, manufactured by Yokogawa Electric Corporation).

The free residual chlorine concentrations of the first free-residual-chlorine-containing subject water at the time of filtration are those set as shown in Fig. 2, and the free residual chlorine concentration of washing water at the time of washing is 125 mg/L.

The time of submerging the membrane in washing water at the time of washing is one hour, and, in each of the sections (periods of time) in Fig. 2, a test is performed with the frequency of washing shown in Table 1.

A test is performed to cause permeation fluxes of the first permeate produced from a clarifier membrane unit to be at values shown in Table 1, in each of the sections (periods of time) in Fig. 2.

[0072]

Table 1

Section No.	Permeation Flux m/d	Washing Frequency
①	0.5	Once every 24 hours
②	0.5	Once every 48 hours
③	0.5	Once every 72 hours
④	0.5	Once every 48 hours
⑤	0.7	Once every 48 hours
⑥	0.7	Once every 24 hours
⑦	0.7	Once every 48 hours

[0073]

As shown in Fig. 2, it has become apparent that the membrane separation by the water treatment apparatus and water treatment method within the scope of the present invention is capable of suppressing fouling of a membrane or fouling of flow channels of subject water, as well as suppressing increase in the amount of a chlorine-containing chemical to be used.

[0074]

(Test Example 2)

The first free-residual-chlorine-containing subject water of Test Example 1 is membrane separated by a spiral clarifier membrane unit (Trade name: RS50-S8, manufactured by Nitto Denko Corporation) having an ultrafiltration membrane (UF membrane) of Test Example 1 to produce first permeate as second free-residual-chlorine-containing subject water. The second free-residual-chlorine-containing subject water is membrane separated by a hollow fiber reverse osmosis membrane unit (Trade name: HB10255FI, manufactured by Toyobo Co., Ltd.) having a reverse osmosis membrane (RO membrane) made of cellulose acetate to produce second permeate. The differential pressure on non-permeate side of a reverse osmosis membrane unit, which is being performing membrane separation, is measured by a pressure data logger (Trade name: DAQSTATION DX120, manufactured by Yokogawa Electric Corporation) as a

differential pressure measurement device. The result is shown in Fig. 3.

As shown in Fig. 3, when the values measured by the differential pressure measurement device is less than a reference value (0.06 MPa), the second free-residual-chlorine-containing subject water is caused to have a free residual chlorine concentration in a range of not less than 0.20 mg/L and less than 1.2 mg/L, which is membrane separated as subject water by the reverse osmosis membrane unit. When the value measured by the differential pressure measurement device is not less than the reference value, the second free-residual-chlorine-containing subject water is caused to have a free residual chlorine concentration in a range of 1.2-2 mg/L, which is membrane separated as subject water by the reverse osmosis membrane unit.

The electric conductivities of the second free-residual-chlorine-containing subject water and the second permeate are measured in order to calculate the salt rejection rate of a reverse osmosis membrane (RO membrane) of the reverse osmosis membrane unit. The electric conductivities are measured according to the electrode method. The result is shown in Fig. 3.

The salt rejection rate of a reverse osmosis membrane (RO membrane) of the reverse osmosis membrane unit is a value calculated by the following equation.

$$\text{Salt rejection rate (\%)} = (1 - C_p/C_f) \times 100$$

Cf: electric conductivity of second free-residual-chlorine-containing subject water, Cp: electric conductivity of second permeate

[0075]

As shown in Fig. 3, it is indicated that the differential pressure is not more than 0.1 MPa, and thus little fouling of flow channels is caused. Further, it is possible to reduce the differential pressure even if it starts rising, by causing the differential pressure to be in a range of more than 0.25 mg/L and less than 1.2 mg/L when the differential pressure has become not less than 0.06 MPa.

As shown in Fig. 4, the salt rejection rate is not less than 97%, and it was indicated that a reverse osmosis membrane (RO membrane) has not been deteriorated due to free residual chlorine.

DESCRIPTION OF THE REFERENCE NUMERALS

5 [0076]

1: water treatment apparatus, 2: clarifier treatment part, 3: reverse osmosis membrane treatment part, 4: chlorine aqueous solution storage tank, 21: clarifier membrane unit, 22: mixing part, 31: reverse osmosis membrane unit, 32: first permeate storage part, A: subject water, B: purified water, C: first concentrate, D: second concentrate

10

CLAIMS

1. A water treatment apparatus comprising: a membrane unit having a membrane to membrane separate subject water by the membrane unit, wherein
5 the apparatus alternately performs the following steps: a first filtration step of membrane separating, as subject water, free-residual-chlorine-containing subject water having a free residual chlorine concentration not higher than a predetermined value; and any one of a washing step of submerging a membrane inside the membrane unit in washing water having a free residual chlorine
10 concentration higher than the predetermined value and a second filtration step of membrane separating, as subject water, free-residual-chlorine-containing subject water having a free residual chlorine concentration higher than the predetermined value by the membrane unit.
- 15 2. A water treatment method for membrane separating subject water by a membrane unit having a membrane, the method comprising alternately performing the following steps: a first filtration step of membrane separating, as subject water, free-residual-chlorine-containing subject water that has a free residual chlorine concentration not higher than a predetermined value; and any
20 one of a washing step of submerging a membrane inside the membrane unit in washing water having a free residual chlorine concentration higher than the predetermined value and a second filtration step of membrane separating, as subject water, free-residual-chlorine-containing subject water having a free residual chlorine concentration higher than the predetermined value by the
25 membrane unit.

3. A water treatment apparatus for membrane separating subject water, comprising:

a spiral clarifier membrane unit that includes at least one of an ultrafiltration membrane and a microfiltration membrane,

5 wherein, at the time of filtration, free-residual-chlorine-containing subject water, which is produced by mixing subject water with a chlorine-containing chemical and has a free residual chlorine concentration within a range of 0.05-2.5 mg/L, is membrane separated, as subject water, by the clarifier membrane unit; and at the time of washing, washing water that has a free residual chlorine
10 concentration within a range of more than 2.5 mg/L and not more than 250 mg/L is supplied to the clarifier membrane unit to thereby submerge a membrane inside the clarifier membrane unit in the washing water.

4. The water treatment apparatus according to claim 3, further comprising a
15 reverse osmosis membrane unit having a reverse osmosis membrane made of cellulose acetate, wherein permeate containing free residual chlorine produced by the clarifier membrane unit is membrane separated by the reverse osmosis membrane unit.

20 5. The water treatment apparatus according to claim 3 or 4, wherein the permeation flux of permeate produced from the clarifier membrane unit is not more than 0.6 m/d.

6. The water treatment apparatus according to claim 3 or 4, wherein the
25 washing frequency is once every 10-80 hours.

7. The water treatment apparatus according to claim 5, wherein the washing frequency is once every 10-80 hours.

8. The water treatment apparatus according to claim 3 or 4, wherein the
5 membrane submerging time by the washing water at the time of washing is 0.2-5 hours.

9. The water treatment apparatus according to claim 5, wherein the
membrane submerging time by the washing water at the time of washing is 0.2-5
10 hours.

10. The water treatment apparatus according to claim 6, wherein the
membrane submerging time by the washing water at the time of washing is 0.2-5
hours.

15

11. The water treatment apparatus according to claim 7, wherein the
membrane submerging time by the washing water at the time of washing is 0.2-5
hours.

20 12. A water treatment method for membrane separating subject water,
comprising:

at the time of filtration, membrane separating, as subject water,
free-residual-chlorine-containing subject water, which is produced by mixing
subject water with a chlorine-containing chemical and has a free residual chlorine
25 concentration within a range of 0.05-2.5 mg/L, by a spiral clarifier membrane unit
that includes at least one of an ultrafiltration membrane and a microfiltration
membrane; and at the time of washing, supplying washing water, which has a free

residual chlorine concentration within a range of more than 2.5 mg/L and not more than 250 mg/L, to the clarifier membrane unit to thereby submerge a membrane inside the clarifier membrane unit in the washing water.

- 5 13. A water treatment apparatus that includes a reverse osmosis membrane unit having a reverse osmosis membrane and membrane separates subject water by the reverse osmosis membrane unit, comprising:

 a differential pressure measurement device that measures the differential pressure on non-permeation side of the reverse osmosis membrane unit;

- 10 wherein, when the value measured by the differential pressure measurement device is less than a reference value,

free-residual-chlorine-containing subject water that has a free residual chlorine concentration within a range of not less than 0.20 mg/L and less than 1.2 mg/L is membrane separated, as subject water, by the reverse osmosis membrane unit;

- 15 and when the value measured by the differential pressure measurement device is not less than the reference value, free-residual-chlorine-containing subject water that has a free residual chlorine concentration within a range of 1.2-2 mg/L is membrane separated, as subject water, by the reverse osmosis membrane unit.

- 20 14. The water treatment apparatus according to claim 13, wherein, when the measured value is less than the reference value, free-residual-chlorine-containing subject water having a free residual chlorine concentration within a range of more than 0.25 mg/L and less than 1.2 mg/L is membrane separated, as subject water, by the reverse osmosis membrane unit.

15. A water treatment apparatus that includes a reverse osmosis membrane unit having a reverse osmosis membrane and membrane separates subject water by the reverse osmosis membrane unit, comprising:

a differential pressure measurement device that measures the differential
5 pressure on non-permeation side of the reverse osmosis membrane unit;

wherein, when the value measured by the differential pressure measurement device is not more than a reference value,

free-residual-chlorine-containing subject water that has a free residual chlorine concentration within a range of not less than 0.20 mg/L and less than 1.2 mg/L is

10 membrane separated, as subject water, by the reverse osmosis membrane unit;

and when the value measured by the differential pressure measurement device is more than the reference value, free-residual-chlorine-containing subject water

that has a free residual chlorine concentration within a range of 1.2-2 mg/L is membrane separated, as subject water, by the reverse osmosis membrane unit.

15 16. The water treatment apparatus according to claim 15, wherein, when the measured value is not more than the reference value,

free-residual-chlorine-containing subject water having a free residual chlorine concentration within a range of more than 0.25 mg/L and less than 1.2 mg/L is

20 membrane separated, as subject water, by the reverse osmosis membrane unit.

17. The water treatment apparatus according to any one of claims 13-16, wherein the reverse osmosis membrane is made of cellulose acetate.

18. A water treatment method that membrane separates subject water by a reverse osmosis membrane unit having a reverse osmosis membrane, comprising:

measuring the differential pressure on non-permeate side of the reverse osmosis membrane unit by a differential pressure measurement device;

5 wherein, when the value measured by the differential pressure measurement device is less than a reference value,

free-residual-chlorine-containing subject water that has a free residual chlorine concentration within a range of not less than 0.20 mg/L and less than 1.2 mg/L is membrane separated, as subject water, by the reverse osmosis membrane unit;

10 and when the value measured by the differential pressure measurement device is not less than the reference value, free-residual-chlorine-containing subject water that has a free residual chlorine concentration within a range of 1.2-2 mg/L is membrane separated, as subject water, by the reverse osmosis membrane unit.

15 19. A water treatment method that membrane separates subject water by a reverse osmosis membrane unit having a reverse osmosis membrane, comprising:

measuring the differential pressure on non-permeate side of the reverse osmosis membrane unit by a differential pressure measurement device;

20 wherein, when the value measured by the differential pressure measurement device is not more than a reference value,

free-residual-chlorine-containing subject water that has a free residual chlorine concentration within a range of not less than 0.20 mg/L and less than 1.2 mg/L is membrane separated, as subject water, by the reverse osmosis membrane unit;

25 and when the value measured by the differential pressure measurement device is more than the reference value, free-residual-chlorine-containing subject water that has a free residual chlorine concentration within a range of 1.2-2 mg/L is membrane separated, as subject water, by the reverse osmosis membrane unit.