

DESCRIPTION

POWER GENERATING FACILITY AND POWER GENERATING METHOD

5 CROSS-REFERENCE TO RELATED APPLICATION

[0001]

This application claims priority to Japanese Patent Application No. 2013-128955, the disclosure of which is incorporated herein by reference in its entirety.

10

FIELD

[0002]

The present invention relates to a power generating facility and a power generating method, which generate power using an osmotic pressure generated between two liquids, particularly, using an osmotic pressure generated between seawater and treated water that is treated by a membrane separation activated sludge process.

15

BACKGROUND

20 [0003]

As an example of a power generating facility using an osmotic pressure, a power generating facility including: an osmotic pressure generating unit configured by arranging a high-concentration liquid having a comparatively high concentration of a dissolved component and a low-concentration liquid having a comparatively low concentration of the dissolved component via a semipermeable membrane so as to generate an osmotic pressure from the low-concentration liquid side to the high-concentration liquid side; and a power generating unit configured to generate power by an increase in water volume on the high-concentration liquid side in the osmotic pressure generating unit is known (see Patent Literature 1). In such a power generating facility, continuous generation of the osmotic pressure is required for continuous power

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generation. Therefore, seawater and river water (freshwater) that can be continuously supplied may be used as the high-concentration liquid and the low-concentration liquid in the osmotic pressure generating unit in some cases (see Patent Literature 2).

5 [0004]

Meanwhile, in the field of water treatment, a membrane separation activated sludge process that combines an activated sludge process and a membrane separation process (hereinafter, referred to also as MBR process) is known. In the MBR process, organic matter contained in water to be treated is aerobically or anaerobically decomposed by aeration or circulation of mixed water in which the water to be treated and activated sludge are mixed (purification step). Then, the mixed water after the purification step is filtered through a separation membrane (such as a microfiltration membrane (MF membrane) and an ultrafiltration membrane (UF membrane)) (membrane separation step). Thereby, treated water from which the activated sludge is separated is obtained, and the activated sludge thus separated is returned to the purification step.

[0005]

The MBR process consumes more power than other water treatment processes due to the necessity of performing the aeration and circulation in the purification step, and the aeration or the like in the membrane separation step. Therefore, treated water obtained by the MBR process is proposed to be used in the power generating facility, so as to collect the consumed power. Specifically, there has been proposed a method for generating power by using the treated water obtained by the MBR process as a low-concentration liquid in the osmotic pressure generating unit of the power generating facility described above, and using an osmotic pressure generated between the treated water and seawater.

[0006]

However, in the power generating facility using an osmotic pressure, a water flow caused by the increase in water volume on the high-concentration liquid side due to the osmotic pressure is used to rotate a turbine of a power

generator. Therefore, for example, in the case where the high-concentration liquid has a salt concentration that is lower than an intended concentration (in the case where the difference in concentration between the high-concentration liquid and the low-concentration liquid is small), the water volume on the high-concentration liquid side fails to increase sufficiently, which makes it difficult to rotate the turbine at a sufficient speed. As a result, efficient power generation is difficult. Particularly, in the case of generating power using an osmotic pressure generated between treated water obtained by the MBR process and seawater, it is affected also by the water quality of the treated water. Therefore, a sufficient osmotic pressure cannot be obtained at all, depending on the water quality of the treated water. Thus, efficient power generation is rendered more difficult.

CITATION LIST

Patent Literature

[0007]

Patent Literature 1: JP 2013-013888 A

Patent Literature 2: JP 2009-047012 A

SUMMARY

Technical Problem

[0008]

It is therefore an object of the present invention to provide a power generating facility and a power generating method, which enable efficient power generation, even in the case of using, in power generation using an osmotic pressure, treated water obtained by the MBR process and seawater as liquids to generate the osmotic pressure.

Solution to Problem

[0009]

A power generating facility according to the present invention includes:

an osmotic pressure generating unit including a treated water supply unit that supplies treated water treated by a membrane separation activated sludge process and a seawater supply unit that supplies seawater, the osmotic pressure generating unit being configured to generate an osmotic pressure from the treated water side to the seawater side by contact between the treated water and the seawater via a semipermeable membrane; a high-osmotic pressure generating agent adding unit configured to add a high-osmotic pressure generating agent that increases the osmotic pressure in the osmotic pressure generating unit to the seawater; and a power generating unit configured to be actuated by an increase in water volume in the seawater supply unit due to the osmotic pressure.

[0010]

It is preferable that the power generating facility further include a high-osmotic pressure generating agent recovery unit configured to collect the high-osmotic pressure generating agent from the seawater discharged from the osmotic pressure generating unit.

[0011]

A method for generating power according to the present invention includes: an osmotic pressure generating step of making contact between treated water that is treated by a membrane separation activated sludge process and seawater via a semipermeable membrane to generate an osmotic pressure from the treated water side to the seawater side; a high-osmotic pressure generating agent adding step of adding a high-osmotic pressure generating agent that increases the osmotic pressure in the osmotic pressure generating step to the seawater; and a power generation step of generating power using a power generator that is actuated by an increase in water volume on the seawater side due to the osmotic pressure.

[0012]

It is preferable that the method for generating power further include: a high-osmotic pressure generating agent collecting step of collecting the high-osmotic pressure generating agent from the seawater after the osmotic

pressure generating step.

BRIEF DESCRIPTION OF DRAWING

[0013]

5 Fig. 1 is a schematic view showing a water treatment apparatus according to the present embodiment.

DESCRIPTION OF EMBODIMENTS

[0014]

10 Hereinafter, embodiments of the present invention are described with reference to Fig. 1. In the following figure, the same or corresponding portions are denoted by the same reference numerals, and the description thereof is not repeated.

[0015]

15 A power generating facility 1 according to this embodiment is configured to generate power using an osmotic pressure generated between two liquids. As the two liquids used for generating the osmotic pressure, treated water (hereinafter, referred to also as MBR treated water) that is obtained by treating water to be treated containing organic matter by a membrane
20 separation activated sludge process (hereinafter, referred to also as MBR process) and seawater are used. The water to be treated is not specifically limited, and sewage such as domestic wastewater and industrial wastewater can be used, for example.

[0016]

25 The power generating facility 1 includes an osmotic pressure generating unit 2 that generates an osmotic pressure, and a power generating unit (power generator) 3 that is actuated by water flow generated by the osmotic pressure. The power generating facility 1 further includes a high-osmotic pressure generating agent adding unit 4 that adds a high-osmotic pressure generating
30 agent for increasing the osmotic pressure between the two liquids in the osmotic pressure generating unit 2 to the seawater, and a high-osmotic

pressure generating agent recovery unit 5 that collects the high-osmotic pressure generating agent from the seawater containing the high-osmotic pressure generating agent.

[0017]

5 The osmotic pressure generating unit 2 includes an internal space partitioned by a semipermeable membrane 2a. Thus, the osmotic pressure generating unit 2 includes a treated water supply unit 2b having an internal space to which the MBR treated water is supplied, and a seawater supply unit 2c having an internal space to which the seawater is supplied. The osmotic pressure generating unit 2 is configured so that the MBR treated water and the seawater to be supplied are in contact with each other via the semipermeable membrane 2a. In this way, the osmotic pressure generating unit 2 is configured to generate an osmotic pressure by penetration of moisture from the MBR treated water side to the seawater side via the semipermeable membrane 2a. The semipermeable membrane 2a is not specifically limited, and a common forward osmosis membrane or reverse osmosis membrane can be used therefor.

[0018]

 The treated water supply unit 2b is fluidically connected to a biological treatment apparatus M that treats the water to be treated by the MBR process. Specifically, the treated water supply unit 2b and the biological treatment apparatus M are fluidically connected to each other by a treated water flow path L1 that allows the MBR treated water discharged from the biological treatment apparatus M to circulate toward the treated water supply unit 2b, and the treated water supply unit 2b and the biological treatment apparatus M are fluidically connected to each other by a return water flow path L2 that allows the MBR treated water discharged from the treated water supply unit 2b to return to the biological treatment apparatus M.

[0019]

 The seawater supply unit 2c is connected fluidically (specifically, by a seawater flow path L3 that allows the seawater to circulate toward the

seawater supply unit 2c) to a supply source (specifically, an ocean S) of the seawater. The seawater flow path L3 is provided with a pump (not shown) for drawing the seawater. Further, the seawater supply unit 2c is connected fluidically (specifically, by a dilution water flow path L4 that allows diluted seawater discharged from the seawater supply unit 2c to circulate toward the power generating unit 3) to a power generating unit 3.

[0020]

The power generating unit 3 is connected fluidically (specifically, by the dilution water flow path L4) to the osmotic pressure generating unit 2 (specifically, to the seawater supply unit 2c). Further, the power generating unit 3 is configured to be actuated by the flow of the diluted seawater (hereinafter, referred to also as dilution water) discharged from the osmotic pressure generating unit 2 (specifically, the seawater supply unit 2c) to generate power. The power generating unit 3 including a turbine that is rotated by the flow of dilution water can be used, for example. Further, the power generating unit 3 is connected fluidically (specifically, by a dilution water flow path L5 that allows the dilution water discharged from the power generating unit 3 to circulate toward the high-osmotic pressure generating agent recovery unit 5) to the high-osmotic pressure generating agent recovery unit 5, which will be described below.

[0021]

The high-osmotic pressure generating agent adding unit 4 is configured to be capable of adding the high-osmotic pressure generating agent to the seawater before being supplied to the osmotic pressure generating unit 2.

Further, the high-osmotic pressure generating agent adding unit 4 is connected fluidically (specifically, by a high-osmotic pressure generating agent return flow path L6 that allows the high-osmotic pressure generating agent after being collected to return) to the high-osmotic pressure generating agent recovery unit 5, which will be described below. The high-osmotic pressure generating agent is not specifically limited as long as it is capable of increasing the osmotic pressure generated between the seawater and the MBR treated water by being

added to the seawater. However, the high-osmotic pressure generating agent preferably has properties that allow the collection of the high-osmotic pressure generating agent from the seawater.

[0022]

Further, the high-osmotic pressure generating agent may be soluble in the seawater, or may be dispersible in the seawater. Examples of the high-osmotic pressure generating agent that is soluble in the seawater include inorganic salts, saccharides, and soluble gases (such as ammonia). On the other hand, the high-osmotic pressure generating agent that is dispersible in the seawater only needs to be uniformly dispersible in the seawater, and examples thereof include organic solvents and nanoparticles. Further, the high-osmotic pressure generating agent to be used may be seawater having a salt concentration higher than that of the target seawater to which the high-osmotic pressure generating agent is added.

[0023]

In particular, because of ease of collection from the seawater, nanoparticles are preferably made of a material having magnetic properties (hereinafter, nanoparticles having magnetic properties may be referred to also as "magnetic particles"). The magnetic particles are preferably made of a metal compound or the like. Further, examples of the magnetic particles include carrier particles having magnetic properties with their surfaces coated with a hydrophilic polymer. Specifically, nanoparticles of acetyl acetone iron (III) coated with polyacrylic acid, for example, can be mentioned.

[0024]

The high-osmotic pressure generating agent recovery unit 5 is connected fluidically (specifically, by the dilution water flow path L5) to the power generating unit 3, and is connected fluidically (specifically, by the high-osmotic pressure generating agent return flow path L6) to the high-osmotic pressure generating agent adding unit 4. The high-osmotic pressure generating agent recovery unit 5 is configured to be capable of collecting the high-osmotic pressure generating agent from the dilution water

discharged from the power generating unit 3, and is configured to be capable of returning the collected high-osmotic pressure generating agent to the high-osmotic pressure generating agent adding unit 4.

[0025]

5 Next, a method for generating power using the power generating facility 1 configured as above is described.

[0026]

Water to be treated is treated by the biological treatment apparatus M, which allows MBR treated water to be obtained. The MBR treated water is
10 supplied to the osmotic pressure generating unit 2 (specifically, the treated water supply unit 2b) via the treated water flow path L1. Accordingly, the seawater to which the high-osmotic pressure generating agent has been added by the high-osmotic pressure generating agent adding unit 4 is supplied to the osmotic pressure generating unit 2 (specifically, the seawater supply unit 2c)
15 via the seawater flow path L3. The amount of the high-osmotic pressure generating agent to be added to the seawater is not specifically limited. However, the high-osmotic pressure generating agent is preferably added to the seawater so that the osmotic pressure in the osmotic pressure generating unit 2 is equal to or more than a specific value. Specifically, the high-osmotic
20 pressure generating agent is added to the seawater so as to give an osmotic pressure of preferably 2.5 MPa or more and 5.0 MPa or less, more preferably 2.5 MPa or more and 7.5 MPa or less.

[0027]

In this way, the MBR treated water is supplied to the treated water
25 supply unit 2b, and the seawater is supplied to the seawater supply unit 2c, thereby allowing the MBR treated water and the seawater to be in contact with each other via the semipermeable membrane 2a. Thus, the moisture of the MBR treated water penetrates through the semipermeable membrane 2a to the seawater side (forward osmosis). The osmotic pressure herein is higher than
30 the osmotic pressure when the high-osmotic pressure generating agent is not added to the seawater. That is, the amount of moisture to be moved from the

MBR treated water to the seawater is larger than that in the case where the high-osmotic pressure generating agent is not added to the seawater.

[0028]

Then, the osmotic pressure is generated as described above, which
5 causes a reduction in water volume in the treated water supply unit 2b due to the MBR treated water being concentrated, resulting in a negative pressure state within the treated water supply unit 2b. This generates a force drawing the MBR treated water from the biological treatment apparatus M into the treated water supply unit 2b, so that the MBR treated water is efficiently
10 supplied to the treated water supply unit 2b. Further, the concentrated MBR treated water is returned to the biological treatment apparatus M via the return water flow path L2.

[0029]

On the other hand, the seawater is diluted due to the penetration of
15 moisture from the MBR treated water in the seawater supply unit 2c, which causes an increase in water volume. Then, the increased volume of the seawater (that is, dilution water) is discharged from the seawater supply unit 2c, and is supplied to the power generating unit 3 via the dilution water flow path L4. That is, the increase in water volume in the seawater supply unit 2c
20 generates a flow of the dilution water toward the power generating unit 3. Then, the turbine is rotated in the power generating unit 3 by the flow of the dilution water discharged from the seawater supply unit 2c, thereby generating power.

[0030]

25 The dilution water used in the power generating unit 3 contains the high-osmotic pressure generating agent, and therefore the high-osmotic pressure generating agent is collected therefrom by the high-osmotic pressure generating agent recovery unit 5. The unit (method) for collecting the high-osmotic pressure generating agent is not specifically limited, and can be
30 appropriately selected depending on the properties of the high-osmotic pressure generating agent. For example, in the case where the high-osmotic pressure

generating agent is an inorganic salt, a saccharide, or an organic solvent, the high-osmotic pressure generating agent is collected at high concentration by removal of moisture from the dilution water by a reverse osmosis method using a reverse osmosis membrane (that is, by concentrating the dilution water).

5 Further, in the case where the high-osmotic pressure generating agent is ammonia (soluble gas), ammonia gas is collected from the dilution water by ammonia stripping. Furthermore, in the case where the high-osmotic pressure generating agent is magnetic particles, the magnetic particles remain in a magnetic field by passing the dilution water through the magnetic field,
10 and thus the magnetic particles are collected from the dilution water. It should be noted that an electromagnet, for example, can be used for forming the magnetic field. Specifically, dilution water containing magnetic particles is passed through a column filled with steel wool while the column is energized, thereby allowing the steel wool to serve as an electromagnet. Therefore, a
15 difference in flow rate occurs between the liquid and the magnetic particles in the column. That is, the magnetic particles are attracted by the electromagnet, which makes it difficult for the magnetic particles to pass through the column. Thus, the magnetic particles can be separated.

[0031]

20 The high-osmotic pressure generating agent collected by the high-osmotic pressure generating agent recovery unit 5 is again added to the seawater by the high-osmotic pressure generating agent adding unit 4. In the case where the high-osmotic pressure generating agent collected by the high-osmotic pressure generating agent recovery unit 5 is insufficient, the
25 insufficient amount of high-osmotic pressure generating agent is added thereto from the outside. Meanwhile, the dilution water from which the high-osmotic pressure generating agent is collected by the high-osmotic pressure generating agent recovery unit 5 is discharged into the environment without further water treatment if its water quality is adaptable for discharge into the environment
30 such as rivers and oceans. However, the dilution water may be discharged into the environment after it is subjected to further water treatment so as to

have desired water quality.

[0032]

As described above, the power generating facility and the power generating method according to the present invention enable efficient power generation, even in the case of using seawater and treated water obtained by the MBR process as liquids to generate the osmotic pressure in power generation using an osmotic pressure.

[0033]

Specifically, the power generating facility 1 of the above-described embodiment is capable of adding the high-osmotic pressure generating agent to the seawater by being provided with the high-osmotic pressure generating agent adding unit 4, and therefore is capable of increasing the osmotic pressure (in other words, the volume of membrane-permeated water that moves from the treated water supply unit 2b side to the seawater supply unit 2c side) as compared to the osmotic pressure before the addition of the high-osmotic pressure generating agent. Therefore, even in the case where an osmotic pressure (in other words, an increase in volume of membrane-permeated water) necessary for efficient power generation in the power generating unit 3 cannot be obtained between the treated water and the seawater before the addition of the high-osmotic pressure generating agent, the addition of the high-osmotic pressure generating agent allows the osmotic pressure (in other words, the increase in volume of membrane-permeated water) necessary for power generation to be obtained. Therefore, efficient power generation is possible in the power generating unit 3 without being affected by the water quality of the treated water.

[0034]

Further, since the high-osmotic pressure generating agent recovery unit 5 is further provided, the collected high-osmotic pressure generating agent can be used again for increasing the osmotic pressure. Therefore, the high-osmotic pressure generating agent can be circulated for use, and the amount of the high-osmotic pressure generating agent to be newly added can be reduced.

Further, the high-osmotic pressure generating agent is collected from the seawater, which allows the water quality of the seawater to return to the water quality before the addition of the high-osmotic pressure generating agent. Therefore, it is easier to release the seawater after being used in the power generating facility into the ocean.

[0035]

Further, in the power generating method of the above-described embodiment, the high-osmotic pressure generating agent is added to the seawater in the high-osmotic pressure generating agent adding step, which can increase the osmotic pressure (in other words, the volume of membrane-permeated water) as compared to the osmotic pressure before the addition of the high-osmotic pressure generating agent. Therefore, even in the case where an osmotic pressure (in other words, an increase in volume of membrane-permeated water) necessary for efficient power generation in the power generation step cannot be obtained between the treated water and the seawater before the addition of the high-osmotic pressure generating agent, the addition of the high-osmotic pressure generating agent allows the osmotic pressure (in other words, the increase in volume of membrane-permeated water) necessary for power generation to be obtained. Therefore, efficient power generation is possible in the power generation step without being affected by the water quality of the treated water.

[0036]

Further, since the high-osmotic pressure generating agent is collected from the seawater in the high-osmotic pressure generating agent collecting step, the collected high-osmotic pressure generating agent can be used again for increasing the osmotic pressure. Therefore, the high-osmotic pressure generating agent can be circulated for use, and the amount of the high-osmotic pressure generating agent to be newly added can be reduced. Further, the high-osmotic pressure generating agent is collected from the seawater, which allows the water quality of the seawater to return to the water quality before the addition of the high-osmotic pressure generating agent. Therefore, it is

easier to release the seawater used in the power generating facility into the ocean.

[0037]

It should be noted that the power generating facility and the power
generating method according to the present invention are not limited to the
above-described embodiments, and various modifications can be made without
departing from the gist of the present invention. Further, it is a matter of
course that configurations or methods of the above-described plurality of
embodiments may be optionally employed in combination (configurations or
methods according to one of the embodiments may be applied to configurations
or methods according to another embodiment), or configurations or methods
according to the following various modifications may be optionally selected to
be employed for configurations or methods according to the above-described
embodiments.

[0038]

For example, the high-osmotic pressure generating agent is added to
the seawater before being supplied to the seawater supply unit 2c in the
above-described embodiments. However, there is no limitation to this. The
high-osmotic pressure generating agent may be added to the seawater, for
example, in the seawater supply unit 2c as long as the desired osmotic pressure
can be obtained.

[0039]

Further, the high-osmotic pressure generating agent is collected from
the dilution water used in the power generating unit 3 in the above-described
embodiments. However, there is no limitation to this. The high-osmotic
pressure generating agent may be collected from the dilution water, for
example, before being supplied to the power generating unit 3.

REFERENCE SIGNS LIST

[0040]

1: Power generating facility

2: Osmotic pressure generating unit

2a: Semipermeable membrane

2b: Treated water supply unit

2c: Seawater supply unit

5 3: Power generating unit

4: High-osmotic pressure generating agent adding unit

5: High-osmotic pressure generating agent recovery unit

L1: Treated water flow path

L2: Return water flow path

10 L3: Seawater flow path

L4, L5: Dilution water flow path

L6: High-osmotic pressure generating agent return flow path

M: Biological treatment apparatus

S: Ocean

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CLAIMS

1. A power generating facility comprising:

an osmotic pressure generating unit including a treated water supply
unit that supplies treated water treated by a membrane separation activated
sludge process and a seawater supply unit that supplies seawater, the osmotic
pressure generating unit being configured to generate an osmotic pressure from
the treated water side to the seawater side by contact between the treated
water and the seawater via a semipermeable membrane;

a high-osmotic pressure generating agent adding unit configured to add
a high-osmotic pressure generating agent that increases the osmotic pressure
in the osmotic pressure generating unit to the seawater; and

a power generating unit configured to be actuated by an increase in
water volume in the seawater supply unit due to the osmotic pressure.

2. The power generating facility according to claim 1, further comprising:

a high-osmotic pressure generating agent recovery unit configured to
collect the high-osmotic pressure generating agent from the seawater
discharged from the osmotic pressure generating unit.

3. A method for generating power, comprising:

an osmotic pressure generating step of making contact between treated
water that is treated by a membrane separation activated sludge process and
seawater via a semipermeable membrane to generate an osmotic pressure from
the treated water side to the seawater side;

a high-osmotic pressure generating agent adding step of adding a
high-osmotic pressure generating agent that increases the osmotic pressure in
the osmotic pressure generating step to the seawater; and

a power generation step of generating power using a power generator
that is actuated by an increase in water volume on the seawater side due to the
osmotic pressure.

4. The method for generating power according to claim 3, further comprising:

- 5 a high-osmotic pressure generating agent collecting step of collecting the high-osmotic pressure generating agent from the seawater after the osmotic pressure generating step.