

BIOLOGICAL TREATMENT APPARATUS, BIOLOGICAL TREATMENT METHOD,
AND PROGRAM

BACKGROUND OF THE INVENTION

5 Field of the Invention

[0001]

The present invention relates to a biological treatment apparatus, a biological treatment method, and a program.

10 Description of Related Art

[0002]

When organic wastewater such as excreta is treated, membrane separation such as microfiltration (MF) or ultrafiltration (UF) is mainly used for liquid separation.

There is a membrane separation device, which includes a casing and a plurality of tubular filtration membranes (hollow fiber membranes) accommodated in the casing, and performs filtration while circulating supply water inside the tubular filtration membranes is known (for example, refer to Patent Document 1). In a biological treatment apparatus which includes such a membrane separation apparatus and performs biological treatment of organic wastewater, permeate water which has permeated the tubular filtration membrane is sucked by a suction pump, and stored in, for example, a storage tank to be appropriately used.

[Patent Documents]

[0003]

[Patent Document 1] Japanese Unexamined Patent Application First Publication

25 No. 2013-052338

SUMMARY OF THE INVENTION

[0004]

Fouling, in which fine particles adhere to a membrane surface, progresses when filtration is continuously performed in a membrane separation apparatus using a tubular
5 filtration membrane. In a conventional biological treatment apparatus, since a flow rate of permeate water decreases with the progress of fouling, there is a problem in that it is difficult to stably ensure the flow rate of permeate water.

[0005]

An object of the present invention is to provide a biological treatment apparatus,
10 a biological treatment method, and a program which can stably ensure a flow rate of permeate water even when fouling has proceeded on a tubular filtration membrane.

[0006]

According to a first aspect of the present invention, a biological treatment apparatus includes a biological treatment tank configured to process organic substances
15 contained in water to be treated, a membrane separation apparatus which has a casing and a tubular filtration membrane that partitions the casing into a concentration side space to which supply water flowing out from the biological treatment tank is supplied and a permeation side space in which permeate water separated from the supply water is contained, and has a monolayer structure in which hydrophilic monomers are
20 copolymerized, a booster pump configured to supply the supply water to the concentration side space, a suction pump configured to suck the permeate water from the permeation side space, a back pressure-regulating device configured to regulate the back pressure of the permeation side space, a return line configured to return concentrated water discharged from the membrane separation apparatus to the biological treatment
25 tank, an inter-membrane differential pressure-measuring device configured to measure an

inter-membrane differential pressure between the concentration side space and the permeation side space, and a control device configured to control the booster pump, the suction pump, and the back pressure-regulating device on the basis of the

inter-membrane differential pressure, in which the control device includes a back

- 5 pressure-regulating unit configured to decrease the back pressure by controlling the back pressure-regulating device when the inter-membrane differential pressure increases to a predetermined value or more, and a setting change unit configured to increase at least one of the pressurizing force of the booster pump and the suction force of the suction pump by controlling at least one of the booster pump and the suction pump, and to increase the
- 10 back pressure by controlling the back pressure-regulating device when the regulation range of the back pressure-regulating device has reached the limit.

[0007]

According to the configuration, it is possible to regulate the flow rate of permeate water using the movable range of the back pressure-regulating device by

- 15 reducing the back pressure of the tubular filtration membrane on the basis of the inter-membrane differential pressure even when an inter-membrane differential pressure has risen due to fouling.

In addition, when the regulation range of the back pressure-regulating device has reached the limit, it is possible to regulate the flow rate of the permeate water using the

20 movable range of the back pressure-regulating device again by increasing at least one of the pressurizing force and the suction force and increasing the back pressure.

Moreover, the tubular filtration membrane has hydrophilicity, and thereby it is possible to withdraw the permeate water even when the membrane surface flow velocity of the supply water supplied to the concentration side space is low and the pressure of the

25 supply water is low.

[0008]

In the biological treatment apparatus, the setting change unit may perform control to increase the suction force of the suction pump after the pressurizing force of the booster pump is controlled to increase to and reach the upper limit.

5 [0009]

With such a configuration, it is possible to cause the cleaning effect of the tubular filtration membrane by increasing the pressurizing force of the booster pump and raising a membrane surface flow velocity.

[0010]

10 In the biological treatment apparatus, the control device may include a cleaning control unit which performs the cleaning of the tubular filtration membrane after the suction force of the suction pump is controlled to increase to and reach the upper limit.

[0011]

15 With such a configuration, it is possible to decrease the pressurizing force and the suction force again by performing cleaning on the tubular filtration membrane. In addition, it is possible to reduce the number of times cleaning is performed by performing cleaning after both the pressurizing force and the suction force are controlled to increase to the upper limits.

[0012]

20 In the biological treatment apparatus described above, the return line may include a branch line which supplies the concentrated water to a space between the biological treatment tank and the membrane separation apparatus, and a second flow-regulating valve which is provided on the downstream side of the branch line and regulates the flow rate of the concentrated water flowing through the return line.

25 [0013]

With such a configuration, it is possible to regulate the flow rate of concentrated water introduced into the biological treatment tank.

[0014]

According to a second aspect of the present invention, a biological treatment method includes a pressurization process of pressurizing and supplying supply water flowing out from a biological treatment tank to a concentration side space which is one side of a tubular filtration membrane having a monolayer structure in which hydrophilic monomers are copolymerized, a suction process of sucking permeate water from a permeation side space which is the other side of the tubular filtration membrane, a return process of returning concentrated water discharged from the concentration side space to the biological treatment tank, a back pressure regulation process of decreasing the back pressure of the permeation side space when the inter-membrane differential pressure between the concentration side space and the permeation side space increases to a predetermined value or more, and a setting change process of increasing at least one of the pressurizing force of the supply water and the suction force of the permeate water and increasing the back pressure when the regulation range of the back pressure reaches the limit.

[0015]

According to a third aspect of the present invention, a program causes a computer of the control device of a biological treatment apparatus including a biological treatment tank which processes organic substances contained in water to be treated, a membrane separation apparatus which has a casing and a tubular filtration membrane which partitions the casing into a concentration side space to which supply water flowing out from the biological treatment tank is supplied and a permeation side space in which permeate water separated from the supply water is contained, and has a monolayer

structure in which hydrophilic monomers are copolymerized, a booster pump configured to supply the supply water to the concentration side space, a suction pump configured to suck the permeate water from the permeation side space, a back pressure-regulating device configured to regulate the back pressure of the permeation side space, a return line

5 configured to return concentrated water discharged from the membrane separation apparatus to the biological treatment tank, and an inter-membrane differential pressure-measuring device configured to measure an inter-membrane differential pressure between the concentration side space and the permeation side space to execute decreasing the back pressure by controlling the back pressure-regulating device when the

10 inter-membrane differential pressure increases to and reach a predetermined value or more, and increasing at least one of the pressurizing force of the booster pump and the suction force of the suction pump by controlling at least one of the booster pump and the suction pump, and increasing the back pressure by controlling the back pressure-regulating device when the regulation range of the back pressure-regulating

15 device has reached the limit.

[0016]

According to the present invention, it is possible to regulate the flow rate of permeate water using the movable range of a back pressure-regulating device by decreasing the back pressure of a tubular filtration membrane on the basis of an

20 inter-membrane differential pressure even when inter-membrane differential pressure has risen due to fouling.

In addition, when the movable range of a back pressure-regulating device has reached the upper limit, it is possible to regulate the flow rate of permeate water using the movable range of a back pressure-regulating device again by increasing at least one

25 of a pressurizing force and a suction force and increasing a back pressure.

BRIEF DESCRIPTION OF THE DRAWINGS

[0017]

FIG. 1 is a schematic block diagram of a biological treatment apparatus
5 according to a first embodiment of the present invention.

FIG. 2 is a schematic sectional view of a membrane separation apparatus
according to the first embodiment of the present invention.

FIG. 3 is a flowchart which describes control I of a biological treatment method
according to the first embodiment of the present invention.

10 FIG. 4 is a flowchart which describes control II of the biological treatment
method according to the first embodiment of the present invention.

FIG. 5 is a flowchart which describes control III of the biological treatment
method according to the first embodiment of the present invention.

15 FIG. 6 is a schematic sectional view of a membrane separation apparatus of a
modification of the first embodiment of the present invention.

FIG. 7 is a schematic perspective view of a membrane separation apparatus
according to a second embodiment of the present invention.

FIG. 8 is a schematic sectional view of the membrane separation apparatus
according to the second embodiment of the present invention.

20 FIG. 9 is a perspective view of a reinforcing member according to the second
embodiment of the present invention.

FIG. 10 is a side view of the reinforcing member according to the second
embodiment of the present invention as seen in an axial direction of the reinforcing
member.

25 FIG. 11 is a perspective view of a reinforcing member according to a third

embodiment of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

[0018]

5 (First embodiment)

Hereinafter, a biological treatment apparatus, a biological treatment method, and a program according to a first embodiment of the present invention will be described in detail with reference to the drawings.

As shown in FIG. 1, a biological treatment apparatus 100 of the present
10 invention includes a biological treatment tank 11 for processing organic substances included in water to be treated W1 (organic wastewater including excreta and septic tank sludge), a raw water tank 12 containing supply water W2 flowing out from the biological treatment tank 11, a membrane separation apparatus 1 which separates supply water W3 supplied from the raw water tank 12 into permeate water PW and concentrated water W4,
15 a first flow-regulating valve 23 (a back pressure-regulating device) which regulates a flow rate (flow path resistance) of the permeate water PW, a storage tank 20 which stores the permeate water PW, a return line 19 which returns the concentrated water W4 to the biological treatment tank 11, and a control device 13.

[0019]

20 The control device 13 controls each unit of the biological treatment apparatus 100 and executes various types of functions. The control device 13 is constituted by, for example, a central processing unit (CPU), which is included in the biological treatment apparatus 100, reading a program from a storage unit and executing the program.

[0020]

25 As shown in FIG. 2, the membrane separation apparatus 1 includes a casing 2,

and a tubular filtration membrane 3 which partitions the casing 2 into a concentration side space S on one side of the tubular filtration membrane 3 and a permeation side space P on the other side of the tubular filtration membrane 3. The supply water W3 is supplied to the concentration side space S, and the permeate water PW separated from the supply water W3 is contained in the permeation side space P.

The membrane separation apparatus 1 is a device for extracting permeate water PW from the supply water W3 using a method of performing filtration while circulating the supply water W3 inside a plurality of tubular filtration membranes 3.

[0021]

As shown in FIG. 1, the biological treatment apparatus 100 includes a booster pump 21 which pressurizes the supply water W3 supplied from the raw water tank 12 (the supply water W2 flowing from the biological treatment tank 11), and supplies it to the concentration side space S of the membrane separation apparatus 1, and includes a suction pump 22 which sucks the permeation side space P of the membrane separation apparatus 1.

[0022]

The booster pump 21 has a function of changing the pressurizing force by controlling the number of rotations and changing the membrane surface flow velocity (a velocity at which the supply water W3 flows in the tubular filtration membrane 3). A movable range of the booster pump 21 of the present embodiment converted into the membrane surface flow velocity is 0.15 m/s to 0.60 m/s. It is not preferable with respect to the specification of the tubular filtration membrane 3 of the present embodiment to operate the booster pump 21 out of the movable range.

[0023]

The suction pump 22 has a function of changing the suction force from the

permeation side space P by controlling the number of rotations. The lower limit frequency of the suction pump 22 of the present embodiment is 6 Hz, and the upper limit frequency is 60 Hz. As a result, the suction pump 22 can arbitrarily change the pressure of the permeation side space P.

5 [0024]

The biological treatment tank 11 decomposes and removes BOD, nitrogen compounds, and the like in liquid by operations of nitrifying bacteria and denitrifying bacteria. The water to be treated W1 is supplied to the biological treatment tank 11 via a first line 15. The biological treatment tank 11 and the raw water tank 12 are
10 connected by a second line 16.

[0025]

The raw water tank 12 and the membrane separation apparatus 1 are connected via a supply line 17. The booster pump 21 is provided in the supply line 17. The supply water W3 discharged from the raw water tank 12 is pressurized by the booster
15 pump 21 and is supplied to the concentration side space S of the membrane separation apparatus 1.

A first flow meter 25 which measures a flow rate of the supply water W3 flowing through the supply line 17 and a first pressure gauge 26 which measures the pressure of the supply water W3 flowing through the supply line 17 are provided in the
20 supply line 17.

[0026]

The permeate water PW separated from the membrane separation apparatus 1 is introduced into a permeate water line 18. The permeate water line 18 is connected to the storage tank 20. The first flow-regulating valve 23 and the suction pump 22 are
25 provided in the permeate water line 18. The first flow-regulating valve 23 of the

present embodiment is provided on a downstream side of the suction pump 22, but it is not limited thereto. The first flow-regulating valve 23 may also be provided on an upstream side of the suction pump 22.

[0027]

5 The first flow-regulating valve 23 functions as a back pressure-regulating device which regulates flow path resistance of the permeate water PW flowing through the permeate water line 18 and regulates a back pressure of the permeation side space P of the tubular filtration membrane 3. For example, a back pressure of the permeation side space P increases when an opening degree of the first flow-regulating valve 23 is set to
10 20%, and the back pressure of the permeation side space P decreases when the opening degree of the first flow-regulating valve 23 is set to 100%. It is possible to increase the back pressure of the permeation side space P by performing control in a direction in which the opening degree of the first flow-regulating valve 23 decreases. It is possible to decrease the back pressure of the permeation side space P by performing control in a
15 direction in which the opening degree of the first flow-regulating valve 23 increases.

[0028]

A second flow meter 27 which measures the flow rate of the permeate water PW flowing through the permeate water line 18 and a second pressure gauge 28 which measures the pressure of the permeate water PW flowing through the permeate water line
20 18 are provided in the permeate water line 18.

[0029]

For the concentrated water W4 which is separated from the permeate water PW and discharged from the membrane separation apparatus 1, the total amount except for excess sludge is introduced into the return line 19, and at least a portion thereof is
25 returned to the biological treatment tank 11. The supply water W2 flowing out from the

biological treatment tank 11 returns to the biological treatment tank 11 via the raw water tank 12 and the membrane separation apparatus 1. That is, the supply water W2 flowing out from the biological treatment tank 11 circulates lines constituting the biological treatment apparatus 100.

5 [0030]

A siphon breaker 40 is provided in the return line 19. The siphon breaker 40 includes a branch pipe 41 and a valve 42.

A third pressure gauge 44 which measures the pressure of the concentrated water W4 flowing through the return line 19 is provided between the membrane separation
10 apparatus 1 and the siphon breaker 40 on the return line 19.

[0031]

The return line 19 includes a branch line 45 which branches off from the middle of the return line 19 and supplies the concentrated water W4 to the raw water tank 12. The raw water tank 12 is not necessarily provided. When the raw water tank 12 is not
15 provided, the branch line 45 is connected to a line between the biological treatment tank 11 and the booster pump 21.

[0032]

A second flow-regulating valve 24 which regulates a flow rate of the concentrated water W4 supplied to the biological treatment tank 11 and a third flow
20 meter 43 which measures the flow rate of the concentrated water W4 supplied to the biological treatment tank 11 are provided on a downstream side of a branch point D of the branch line 45 on the return line 19. The third flow meter 43 is provided on a downstream side of the second flow-regulating valve 24 (between the second flow-regulating valve 24 and the biological treatment tank 11).

25 [0033]

The pressure gauges 26, 28, and 44 and the flow meters 25, 27, and 43 are connected to the control device 13 via an electric signal cable.

The first pressure gauge 26, the second pressure gauge 28, and the third pressure gauge 44 function as an inter-membrane differential pressure-measuring device 14,

5 which measures an inter-membrane differential pressure of the membrane separation apparatus 1. The control device 13 calculates the inter-membrane differential pressure of the membrane separation apparatus 1 based on the pressure of the supply water W3 measured by the first pressure gauge 26, the pressure of the permeate water PW measured by the second pressure gauge 28, and the pressure of the concentrated water
10 W4 measured by the third pressure gauge 44.

[0034]

The biological treatment apparatus 100 includes cleaning equipment 29 which performs cleaning on the tubular filtration membrane 3 of the membrane separation apparatus 1. The cleaning equipment 29 may be an apparatus which performs cleaning
15 using a physical cleaning method, an apparatus which performs cleaning using a chemical cleaning method, or an apparatus which performs cleaning using both.

The physical cleaning method is a cleaning method in which cleaning is performed through a physical method such as reverse pressure cleaning, scrubbing, flushing, ball cleaning, and the like. The chemical cleaning method is a cleaning
20 method in which cleaning is performed using an acid, alkali, oxidizing agent, detergent, or the like.

[0035]

The control device 13 controls the booster pump 21, the suction pump 22, the first flow-regulating valve 23, the second flow-regulating valve 24, the cleaning
25 equipment 29, and the like on the basis of the flow rate of the permeate water PW, an

inter-membrane differential pressure, the flow rate of the water to be treated W1, and the like. The control device 13 includes a back pressure-regulating unit 13a which controls the first flow-regulating valve 23 (a back pressure-regulating device) on the basis of the flow rate of the permeate water PW and the inter-membrane differential pressure, a
5 setting change unit 13b which performs a setting change of the booster pump 21 and the like, for example, when a movable range of the first flow-regulating valve 23 reaches the limit, and a cleaning control unit 13c which controls the cleaning equipment 29.

[0036]

In addition, the control device 13 has a function of regulating the flow rate of the
10 concentrated water W4 introduced into the biological treatment tank 11. The control device 13 controls the second flow-regulating valve 24, when the flow rate of the concentrated water W4 measured by the third flow meter 43 has exceeded a predetermined value, so that the flow rate of the concentrated water W4 introduced into the biological treatment tank 11 is equal to or less than the predetermined value. As a
15 result, some of the concentrated water W4 is introduced into the branch line 45.

[0037]

Next, the details of the membrane separation apparatus 1 will be described.

As shown in FIG. 2, the casing 2 includes a casing body 4, a supply water inlet 7
formed below the casing body 4, a concentrated water outlet 8 formed above the casing
20 body 4, and a permeate water outlet 9 formed in the casing body 4.

[0038]

The casing body 4 includes a cylindrical portion 4a having a cylindrical shape, a first conical portion 5 which closes an upper end of the cylindrical portion 4a, and a second conical portion 6 which closes a lower end of the cylindrical portion 4a. The
25 first conical portion 5 is formed in a tapered shape which gradually decreases in diameter

as it goes upward. The second conical portion 6 is formed in a tapered shape which gradually decreases in diameter as it goes downward.

The membrane separation apparatus 1 of the present embodiment has a configuration in which the supply water W3 introduced into the tubular filtration membrane 3 from below flows upward in the tubular filtration membrane 3.

[0039]

The membrane separation apparatus 1 includes a first bulkhead 30 and a second bulkhead 31 which partition the inside of the casing 2 into three spaces. A plurality of insertion holes 32 are formed in the first bulkhead 30 and the second bulkhead 31. The insertion holes 32 are holes penetrating in a plate thickness direction of the first bulkhead 30 and the second bulkhead 31. An inner diameter of the insertion hole 32 is slightly larger than an outer diameter of the tubular filtration membrane 3.

The plurality of tubular filtration membranes 3 extend in a direction of an axis A (a vertical direction in the present embodiment) inside the casing 2, one end thereof is connected to the first bulkhead 30, and the other end is connected to the second bulkhead 31.

[0040]

The first bulkhead 30 is a member formed in a plate shape, and is fixed to an upper part of the casing 2 in an extending direction (a side of the first conical portion 5). A space surrounded by the casing body 4, the first bulkhead 30, and the first conical portion 5 is a first header space S1. The first header space S1 is a space above the first bulkhead 30 in an internal space of the casing 2.

The second bulkhead 31 is a member formed in a plate shape, and is fixed to a lower part of the casing 2 in the extending direction (a side of the second conical portion 6). A space surrounded by the casing body 4, the second bulkhead 31, and the second

conical portion 6 is a second header space S2. The second header space S2 is a space below the second bulkhead 31 in the internal space of the casing 2.

[0041]

A space surrounded by the casing body 4, the first bulkhead 30, and the second bulkhead 31, and on an outer circumferential side of the tubular filtration membrane 3 is the permeation side space P. The permeate water PW extracted from the plurality of tubular filtration membranes 3 is discharged to the permeation side space P and introduced into the permeate water line 18 via the permeate water outlet 9.

[0042]

The supply water inlet 7 is an opening which communicates the outside of the casing 2 with the second header space S2. The supply water inlet 7 is formed in the second conical portion 6 of the casing body 4.

The concentrated water outlet 8 is an opening which communicates the outside of the casing 2 with the first header space S1. The concentrated water outlet 8 is formed in the first conical portion 5 of the casing body 4.

[0043]

The permeate water outlet 9 is an opening which communicates the outside of the casing 2 with the permeation side space P. The permeate water outlet 9 is provided at an upper portion of the cylindrical portion 4a of the casing body 4.

[0044]

The concentration side space S is a space into which the supply water W3 is introduced, and is the first header space S1, a space S3 in a filtration membrane which is a space on an inner circumferential side of the tubular filtration membrane 3, and the second header space S2.

The permeation side space P is a space in which the permeate water PW

separated from the supply water W3 is contained.

[0045]

One end of each of the tubular filtration membranes 3 is inserted into the insertion hole 32 of the first bulkhead 30, and is fixed to an inner circumferential surface of the insertion hole 32. A gap between the inner circumferential surface of the insertion hole 32 and the outer circumferential surface of the tubular filtration membrane 3 is sealed by a sealing material (not shown). The sealing material is preferably a material which initially has viscosity and is cured with time such as an epoxy resin and a urethane resin.

The other end of each of the tubular filtration membranes 3 is fixed to the insertion hole 32 of the second bulkhead 31 in the same manner as one end of the tubular filtration membrane 3.

[0046]

The tubular filtration membrane 3 has a polymer filtration membrane which is in a cylindrical shape and has a monolayer structure in which a hydrophilic monomer is copolymerized in a single main constituent material.

That is, a main material of the polymer filtration membrane is formed from one type of material. Formation of the main material from one type of material means that one type of resin occupies 50 mass% or more of a material (for example, a resin) forming the polymer filtration membrane.

In addition, formation of the main material from one type of material means that the property of the one type of material dominates the property of the constituent material. Specifically, this means a material having 50 to 99 mass% of one type of resin. However, when there is a support supporting the membrane, the support may be the same material as or a different material from the polymer membrane.

[0047]

Polymer materials such as a vinyl chloride resin, a polysulfone (PS) type, a polyvinylidene fluoride (PVDF) type, a polyolefin type such as polyethylene (PE), a polyacrylonitrile (PAN) type, a polyethersulfone type, a polyvinyl alcohol (PVA) type, a polyimide (PI) type, and the like can be used as the main material constituting the polymer filtration membrane.

[0048]

As a main material constituting the tubular filtration membrane 3, a vinyl chloride resin is particularly preferable. Examples of the vinyl chloride resin include a vinyl chloride homopolymer (vinyl chloride homopolymer), a copolymer of a monomer having an unsaturated bond which can be copolymerized with a vinyl chloride monomer and a vinyl chloride monomer, a graft copolymer obtained by copolymerizing a vinyl chloride monomer with a polymer, a (co)polymer made of these chlorinated vinyl chloride monomer units, and the like.

15 [0049]

Examples of the hydrophilic monomer include

(1) a vinyl monomer and/or a salt thereof containing a cationic group such as an amino group, an ammonium group, a pyridyl group, an imino group, and a betaine structure,

20 (2) a vinyl monomer containing a hydrophilic non-ionic group such as a hydroxyl group, an amide group, an ester structure, and an ether structure,

(3) a vinyl monomer and/or a salt thereof containing an anionic group such as a carboxyl group, a sulfonic acid group, or a phosphoric acid group, and

(4) other monomers and the like.

25 [0050]

The tube diameter of the tubular filtration membrane 3 can be appropriately selected according to the properties of the supply water W3. For example, the inner diameter of the tubular filtration membrane 3 can be set to 5 mm or less when an amount of crude fibers α for the supply water W3 is 200 mg/liter or less, the inner diameter of the tubular filtration membrane 3 can be set to 5 mm to 10 mm when the amount of crude fibers α is greater than 200 mg/liter and less than 500 mg/liter, and the inner diameter of the tubular filtration membrane 3 can be set to 10 mm or more when the amount of crude fibers α is equal to or greater than 500 mg/liter. It is possible to suppress blocking of the tubular filtration membrane 3 due to the crude fibers by selecting a pipe diameter.

10 [0051]

Next, an operation of the biological treatment apparatus 100 of the present embodiment will be described.

The water to be treated W1 such as excreta is subjected to pre-treatment in a pre-processing facility (not shown), and is sent to the biological treatment tank 11 via the first line 15. The water to be treated W1 is processed in the biological treatment tank 11. Specifically, organic substances contained in the water to be treated W1 are decomposed by microorganisms.

Then, the supply water W2 flowing out from the biological treatment tank 11 is stored in the raw water tank 12, and is supplied to the membrane separation apparatus 1 via the booster pump 21. The supply water W3 supplied to the membrane separation apparatus 1 is sent into the tubular filtration membrane 3 of the membrane separation apparatus 1. An operation of the booster pump 21 is controlled by the control device 13 as described below.

[0052]

25 On the other hand, the permeation side space P in the casing 2 of the membrane

separation apparatus 1 becomes negative pressure due to an operation of the suction pump 22. The suction pump 22 sucks the permeate water PW from the permeation side space P in a direction substantially orthogonal to the flow of the supply water W3 flowing through the tubular filtration membrane 3 through the permeate water outlet 9.

- 5 The operation of the suction pump 22 is controlled by the control device 13 as will be described below. The permeate water PW permeated from the tubular filtration membrane 3 is stored in the storage tank 20 via the permeate water outlet 9 and the permeate water line 18.

[0053]

- 10 For the concentrated water W4 (return sludge) discharged from the membrane separation apparatus 1, the total amount except for excess sludge is introduced into the return line 19. At least a portion of the concentrated water W4 is returned to the biological treatment tank 11, and processing is performed again.

[0054]

- 15 Next, a control method (a biological treatment method) of the biological treatment apparatus 100 of the present embodiment which is a detailed control method of the booster pump 21, the suction pump 22, and the first flow-regulating valve 23 will be described. The control device 13 of the biological treatment apparatus 100 of the present embodiment performs control of the biological treatment apparatus 100, in particular, the flow rate of the permeate water PW, by sequentially executing the following control I, control II, and control III.

[0055]

- The membrane separation apparatus 1 of the present embodiment includes the tubular filtration membrane 3 having a monolayer structure in which a hydrophilic monomer is copolymerized, and can withdraw the permeate water PW at a low flow rate
- 25

(membrane surface flow velocity: 0.15 m/s to 0.60 m/s) and low pressure (pressure of supply water W3: 0.1 MPa or less) based on the properties of materials having a hydrophilic function. The control device 13 of the biological treatment apparatus 100 performs control in consideration of the progress of fouling of the tubular filtration membrane 3 while using the properties.

[0056]

[Control I]

As shown in FIG. 3, control I in the biological treatment method using the biological treatment apparatus 100 of the present embodiment includes an operation process S11, an inter-membrane differential pressure determination process S12, a back pressure regulation process S13, and a regulation range determination process S14 to regulate the flow rate of the permeate water PW.

[0057]

The operation process S11 is a process of setting operation conditions and controlling the booster pump 21, the suction pump 22, and the first flow-regulating valve 23. The operation process S11 includes a pressurization process S11a of controlling the booster pump 21, pressurizing and supplying supply water to the membrane separation apparatus 1, a suction process S11b of controlling the suction pump 22 and sucking the permeate water PW from the permeation side space P of the membrane separation apparatus 1, an opening degree-setting process S11c of setting the opening degree of the first flow-regulating valve 23 to 20%, a return process S11d of returning the concentrated water W4 to the biological treatment tank 11.

[0058]

The operation conditions can be appropriately determined on the basis of specifications of the biological treatment apparatus 100 and the like. In the

pressurization process S11a, the control device 13 controls the booster pump 21 such that a membrane surface flow velocity is 0.15 m/s, on the basis of a value of the flow rate of the supply water W3 received from the first flow meter 25. In the suction process S11b, the control device 13 controls the suction pump 22 such that the suction pump 22 operates in a low frequency range from 6 Hz to 20 Hz. In the opening degree-setting process S11c, the control device 13 controls the first flow-regulating valve 23 such that the opening degree becomes 20%. In addition, the concentrated water W4 is returned to the biological treatment tank 11 via the return line 19 due to these controls (the return process S11d).

10 [0059]

With the settings described above, the supply water W3 has a low flow rate and the permeate water PW is sucked at a low pressure. In addition, an outflow of the permeate water PW (FLUX) is controlled within a range to satisfy a planned value by reducing the opening degree of the first flow-regulating valve 23.

15 [0060]

The inter-membrane differential pressure determination process S12 is a process of determining whether an inter-membrane differential pressure of the membrane separation apparatus 1 is equal to or greater than a first predetermined value. In the inter-membrane differential pressure determination process S12, the control device 13 determines whether an inter-membrane differential pressure measured by the inter-membrane differential pressure-measuring device 14 (the first pressure gauge 26, the second pressure gauge 28, and the third pressure gauge 44) has reached the first predetermined value or more. That is, the control device 13 determines whether an inter-membrane differential pressure rises as fouling progresses in the tubular filtration membrane 3 to satisfy a flow rate planned value of the permeate water PW.

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As a result of the determination, when it is determined that the inter-membrane differential pressure is smaller than the first predetermined value (“No” in S12), pressurization and suction are continuously performed. That is, operation continues without changing the operation conditions when it is determined that the progress of fouling is within an allowable range.

[0061]

In addition, when it is determined that the inter-membrane differential pressure is equal to or greater than a predetermined value (“Yes” in S12), the back pressure regulation process S13 is executed. In the back pressure regulation process S13, the back pressure-regulating unit 13a of the control device 13 gradually opens the first flow-regulating valve 23 and decreases the back pressure of the permeation side space P. That is, the flow rate of the permeate water PW is ensured by increasing the opening degree of the first flow-regulating valve 23.

[0062]

The regulation range determination process S14 is a process of determining whether a regulation range of the first flow-regulating valve 23 (a back pressure-regulating device) has reached a limit (100%) to satisfy the flow rate planned value of the permeate water PW. In the regulation range determination process S14, the control device 13 determines whether the regulation range (movable range) of the first flow-regulating valve 23 which functions as a back pressure-regulating device has reached the upper limit (the opening degree 100%). As a result of the determination, when it is determined that the regulating range of the first flow-regulating valve 23 does not reach the limit (“No” in S14), control is performed in such a way that the first flow-regulating valve 23 continues to gradually open.

On the other hand, when it is determined that the regulation range of the first

flow-regulating valve 23 has reached the limit (“Yes” in S14), since no further increase in flow rate of the permeate water PW is expected, the procedure proceeds to control II.

[0063]

[Control II]

5 As shown in FIG. 4, the control II of the biological treatment method includes a first setting change process S21, a first inter-membrane differential pressure determination process S22, a first back pressure regulation process S23, a first regulation range determination process S24, a second setting change process S25, a second inter-membrane differential pressure determination process S26, a second back pressure
10 regulation process S27, and a second regulation range determination process S28 to satisfy the flow rate planned value of the permeate water PW.

[0064]

 The first setting change process S21 is a process of performing a setting change in the operation conditions when the regulation range of the first flow-regulating valve
15 23 has reached the limit in the regulation range determination process S14 of the control I. In the first setting change process S21, the control device 13 performs a setting change of the booster pump 21 such that the membrane surface flow velocity is 0.30 m/s. That is, a pressurizing force of the booster pump 21 is increased. A setting change of the suction pump 22 is not performed.

20 [0065]

 As the pressurizing force of the booster pump 21 is increased, the membrane surface flow velocity and the flow rate of the supply water W3 increase and the cleaning effect of a membrane surface increases. In addition, the flow rate of the permeate water PW increases as the pressure of the supply water W3 increases.

25 The control device 13 controls the first flow-regulating valve 23 such that the

opening degree is 20%, which is an initial set value. As a result, the outflow of the permeate water PW is controlled within the range to satisfy a planned value.

[0066]

In the first inter-membrane differential pressure determination process S22, the control device 13 determines whether an inter-membrane differential pressure measured by the inter-membrane differential pressure-measuring device 14 has reached a second predetermined value (an inter-membrane differential pressure higher than the first predetermined value) or more.

As a result of the determination, when it is determined that the inter-membrane differential pressure is smaller than the second predetermined value (“No” in S22), pressurization and suction are continuously performed.

[0067]

In addition, when it is determined that the inter-membrane differential pressure is equal to or larger than the second predetermined value (“Yes” in S22), the first back pressure regulation process S23 is executed. The back pressure-regulating unit 13a of the control device 13 gradually opens the first flow-regulating valve 23 and decreases the back pressure of the permeation side space P.

[0068]

In the first regulation range determination process S24, the control device 13 determines whether the regulation range of the first flow-regulating valve 23 has reached the limit (100%). As a result of the determination, when it is determined that the regulation range of the first flow-regulating valve 23 does not reach the limit, control is performed in such a way that the first flow-regulating valve 23 continues to gradually open.

On the other hand, when it is determined that the regulation range of the first

flow-regulating valve 23 has reached the limit, since no further increase in flow rate of the permeate water PW is expected, a setting change of the booster pump 21 is performed.

[0069]

5 The second setting change process S25 is a process of performing a setting change in the operation conditions again when the regulation range of the first flow-regulating valve 23 has reached the limit. In the second setting change process S25, the control device 13 performs a setting change of the booster pump 21 such that the membrane surface flow velocity is 0.60 m/s. That is, the control device 13 performs a
10 setting change such that the supply water W3 supplied by the booster pump 21 has a large flow rate.

In addition, the control device 13 controls the first flow-regulating valve 23 such that the opening degree is 20%, which is an initial set value. As a result, the outflow of the permeate water PW is controlled within the range to satisfy a planned value.

15 [0070]

Hereinafter, the second inter-membrane differential pressure determination process S26, the second back pressure regulation process S27, and the second regulation range determination process S28 are executed in the same manner as the first inter-membrane differential pressure determination process S22, the first back pressure
20 regulation process S23, and the first regulation range determination process S24.

In the second regulation range determination process S28, when it is determined that the regulation range of the first flow-regulating valve 23 has reached the limit, since no further increase in the flow rate of the permeate water PW is expected, the procedure proceeds to control III.

25 [0071]

Moreover, since the concentrated water W4 increases with an increase in the supply water W3 particularly in the control II, the control device 13 controls the second flow-regulating valve 24 on the basis of the flow rate of the concentrated water W4 measured by the third flow meter 43. As a result, the flow rate of the concentrated water W4 introduced into the biological treatment tank 11 is regulated.

[0072]

[Control III]

As shown in FIG. 5, the control III of the biological treatment method includes a setting change process S31, an inter-membrane differential pressure determination process S32, a back pressure regulation process S33, a regulation range determination process S34, and a cleaning process S35 to satisfy the flow rate planned value of the permeate water PW.

[0073]

The setting change process S31 is a process of performing a setting change in the operation conditions when the regulation range of the first flow-regulating valve 23 has reached the limit in the second regulation range determination process S28 of the control II.

In the setting change process S31, the control device 13 performs a setting change of the suction pump 22 such that the suction pump 22 operates at 20 Hz to 40 Hz. A setting change of the booster pump 21 is not performed. Due to an increase in suction force by the suction pump 22, the flow rate of the permeate water PW increases.

The control device 13 controls the first flow-regulating valve 23 such that the opening degree is 20%, which is an initial set value. As a result, the outflow of the permeate water PW is controlled within the range to satisfy a planned value.

[0074]

In the inter-membrane differential pressure determination process S32, the control device 13 determines whether an inter-membrane differential pressure measured by the inter-membrane differential pressure-measuring device 14 has reached a third predetermined value (an inter-membrane differential pressure higher than the second predetermined value) or more.

As a result of the determination, when it is determined that the inter-membrane differential pressure is smaller than the third predetermined value (“No” in S32), pressurization and suction are continuously performed.

[0075]

In addition, when it is determined that the inter-membrane differential pressure is equal to or larger than the third predetermined value (“Yes” in S32), the control device 13 executes the back pressure regulation process S33. The back pressure regulation process S33 is a process of reducing the back pressure of the permeation side space P and increasing the suction force of the suction pump 22 when the inter-membrane differential pressure is increased to be equal to or larger than the third predetermined value.

The back pressure regulation process S33 includes a process S33a of regulating the first flow-regulating valve and a process S33b of regulating the suction pump.

In the process S33a of regulating the first flow-regulating valve, the back pressure-regulating unit 13a of the control device 13 gradually opens the first flow-regulating valve 23 and reduces the back pressure of the permeation side space P. In the process S33b of regulating the suction pump, the control device 13 gradually increases the suction force of the suction pump 22. That is, the control device 13 gradually increases a frequency of the suction pump 22 from 40 Hz.

[0076]

The regulation range determination process S34 is a process of determining

whether the suction pump 22 reaches a maximum frequency and whether the regulation range of the first flow-regulating valve 23 has reached the limit.

In the regulation range determination process S34, the control device 13 determines whether the regulation range of the first flow-regulating valve 23 and the regulation range of the suction pump 22 have reached the limits. As a result of the determination, when it is determined that limits of the regulation ranges are not reached, control is performed in such a way that the first flow-regulating valve 23 is gradually opened and the suction force of the suction pump 22 continues to be increased.

[0077]

On the other hand, when it is determined that the regulation ranges of the first flow-regulating valve 23 and the suction pump 22 have reached the limits, since no further increase in the flow rate of the permeate water PW is expected, cleaning of the tubular filtration membrane 3 is performed.

In the cleaning process S35, the cleaning control unit 13c of the control device 13 performs cleaning of the tubular filtration membrane 3 by controlling the cleaning equipment 29.

After the cleaning process S35, when it is determined that the inter-membrane differential pressure is restored by the control device 13, the procedure returns to the control I.

[0078]

According to the embodiment described above, the flow rate of the permeate water PW can be regulated using the movable range of the first flow-regulating valve 23 (the back pressure-regulating device) even when the inter-membrane differential pressure has risen due to fouling by reducing the back pressure of the tubular filtration membrane 3 on the basis of the inter-membrane differential pressure.

In addition, when the regulation range of the first flow-regulating valve 23 has reached the limit, the flow rate of the permeate water PW can be regulated using the movable range of the first flow-regulating valve 23 again by increasing the pressurizing force and increasing (closing the first flow-regulating valve 23) the back pressure.

5 Moreover, the tubular filtration membrane 3 has hydrophilicity, and thereby it is possible to withdraw the permeate water PW even when the membrane surface flow velocity of the supply water W3 supplied to the concentration side space S is low and the pressure of the supply water W3 is low.

[0079]

10 Moreover, a sludge concentration (a concentration ratio) of the concentrated water W4 returning to the biological treatment tank 11 can be regulated by controlling the booster pump 21 and the suction pump 22 in combination. When the sludge concentration increases, the suction force increases and the pressurizing force decreases. When the sludge concentration decreases, the suction force decreases and the
15 pressurizing force increases.

[0080]

 Moreover, the pressurizing force of the booster pump 21 is controlled to increase to the upper limit, and thereby it is possible to cause the cleaning effect of the tubular filtration membrane 3 in the control II by increasing the pressurizing force of the booster
20 pump 21 and raising the membrane surface flow velocity.

 In addition, it is possible to decrease the pressurizing force and the suction force again by performing the cleaning of the tubular filtration membrane 3 after the control to increase suction force of the suction pump 22 to the upper limit in the control III. Moreover, it is possible to reduce the number of times of cleaning after both the
25 pressurizing force and the suction force are controlled to the upper limits.

[0081]

Moreover, since the membrane surface flow velocity can be lowered in the biological treatment apparatus 100 of the present embodiment, a circulation flow rate can be reduced. As a result, it is possible to reduce the operation of the booster pump 21.

- 5 In addition, it is possible to decrease the diameter of pipes by reducing a flow rate of circulation water.

[0082]

Moreover, it is possible to suppress the tubular filtration membrane 3 from being blocked by a crude fiber component by selecting an inner diameter of the tubular
10 filtration membrane 3 in accordance with an amount of crude fibers of the supply water W3.

[0083]

- In addition, it is possible to prevent crude fiber materials and the like from being deposited on the header spaces S1 and S2 or from becoming granular by setting the upper
15 part and the lower part of the casing 2 to be a tapered shape. That is, when the casing 2 has a cylindrical shape, a corner portion of the end portion becomes a dead space, but it is possible to eliminate the dead space and suppress retention of the crude fiber materials and the like by setting the upper part and the lower part of the casing 2 to be a tapered shape.

20 [0084]

- Moreover, when the biological treatment tank 11 is at a position lower than the membrane separation apparatus 1, a total amount of the liquid in the membrane separation apparatus 1, including the permeate water PW, is pulled out at the time of a stoppage of the booster pump 21 due to a siphon effect. When the permeate water PW
25 is pulled out, the suction pump 22 continues to operate unnecessarily until filled with the

permeate water PW, and thus this may cause a failure. The biological treatment apparatus 100 of the present embodiment can prevent pulling out of liquid due to the siphon effect at the time of a device stoppage by providing the siphon breaker 40 in the return line 19.

5 [0085]

In the embodiment described above, the siphon breaker 40 is provided in the return line 19, but the present invention is not limited thereto. For example, a pressure open tank may be provided in the return line 19.

[0086]

10 In the embodiment described above, control to increase the suction force of the suction pump 22 in the control III is performed after the pressurizing force of the booster pump 21 is increased in the control II, but the order is not limited thereto. For example, the control to increase the suction force of the suction pump 22 in the control III may be performed after the control I, and the control II may be performed after the control III.

15 In addition, the control to increase the pressurizing force of the booster pump 21 and the control to increase the suction force of the suction pump 22 may be performed alternately or may also be performed at the same time.

That is, at least one of the booster pump and the suction pump may be controlled after the regulating device of the first flow-regulating valve 23 has reached the limit in
20 the control I.

[0087]

In the embodiment described above, the suction force of the suction pump 22 is increased to the upper limit of the regulation range of the suction pump 22 in the back pressure regulation process S33 of the control III, but the suction force may be increased
25 by two steps in the same manner as the control of the booster pump 21 in the control II.

[0088]

In the embodiment described above, the first flow-regulating valve 23 has been used as a back pressure-regulating device which regulates the back pressure of the permeation side space P in the embodiment described above, but the present invention is not limited thereto. For example, the back pressure may be changed by extending a line on the downstream side of the membrane separation apparatus 1 upward and providing a plurality of open valves to change water pressure of the permeate water PW.

[0089]

In the embodiment described above, the membrane separation apparatus 1 in which the tubular filtration membranes 3 are arranged in parallel has been adopted as the membrane separation apparatus 1, but the present invention is not limited thereto. For example, as shown in FIG. 6, the plurality of tubular filtration membranes 3 may also be connected in series. That is, the membrane separation apparatus 1 may also have a plurality of U-shaped first connection members 46 which connect one ends of the plurality of tubular filtration membranes 3 and the other ends of the plurality of tubular filtration membranes 3 such that the plurality of tubular filtration membranes 3 are connected in series.

[0090]

At this time, the plurality of tubular filtration membranes 3 connected in series and an effluent water inlet may be directly connected by a tubular second connection member 59, and the plurality of tubular filtration membranes 3 connected in series and the concentrated water outlet 8 may be directly connected by a tubular third connection member 60. In this case, the first header space S1 and the second header space S2 may be omitted. In addition, the configuration of the casing 2 may be changed by eliminating the first conical portion 5 and the second conical portion 6, and the like.

[0091]

Moreover, the supply water W3 introduced into the tubular filtration membrane 3 from the lower side flows upward in the tubular filtration membrane 3 in the membrane separation apparatus 1 of the embodiment described above, but the present invention is not limited thereto. The concentrated water outlet 8 may be provided at the lower part of the casing 2 and the supply water W3 may flow downward in the tubular filtration membrane 3.

[0092]

Processing of each unit may be performed by recording a program for realizing all or some functions of a control device on a computer-readable recording medium, and causing a computer system to read and execute the program recorded on the recording medium. The “computer system” herein includes hardware such as an OS and peripheral devices. In addition, the “computer system” includes a homepage-providing environment (or a display environment) if a WWW system is used.

Moreover, the “computer-readable recording medium” refers to a portable medium such as a flexible disc, a magneto-optical disc, a ROM, and a CD-ROM, or a storage device such as a hard disk, and a Solid State Drive embedded in a computer system. Furthermore, the program may be a program for realizing some of the functions described above, and may also be a program which can realize the functions described above in combination with a program which is already recorded in a computer system.

[0093]

[Second embodiment]

Hereinafter, a biological treatment apparatus of a second embodiment of the present invention will be described with reference to drawings. A difference from the first embodiment described above will be mainly described and descriptions of the same

portions will be omitted. The difference between the present embodiment and the first embodiment is that a membrane separation apparatus unit 50 shown in FIG. 7 is adopted in the biological treatment apparatus 100 of the first embodiment.

As shown in FIG. 7, a plurality of membrane separation apparatuses 1B are
5 laterally arranged in a housing 51 of the membrane separation apparatus unit 50 in the membrane separation apparatus unit 50 of the present embodiment. That is, an axis A (refer to FIG. 8) of a cylindrical shaped casing 2 of the membrane separation apparatus 1B, unlike in the first embodiment, extends in a horizontal direction.

[0094]

10 As shown in FIG. 8, the membrane separation apparatus 1B includes the cylindrical shaped casing 2, a plurality of tubular filtration membranes 3, and a reinforcing member 34 which reinforces the tubular filtration membranes 3.

[0095]

The membrane separation apparatus 1B of the present embodiment includes the
15 reinforcing member 34 which reinforces each of the tubular filtration membranes 3.

The reinforcing member 34 is a tubular member covering each of the tubular filtration membranes 3 from the outer circumferential side. The tubular filtration membrane 3 is inserted on the inner circumferential side of the reinforcing member 34.

[0096]

20 As shown in FIG. 9, the reinforcing member 34 includes a tubular body portion 35 disposed on the outer circumferential side of the tubular filtration membrane 3, a plurality of support portions 36 provided on the inner circumferential surface 35a of the tubular body portion 35, and a plurality of through-holes 37 formed in the tubular body portion 35.

25 The tubular body portion 35 has a cylindrical shape. As shown in FIG. 10, the

inner diameter (a diameter of the inner circumferential surface 35a) of the tubular body portion 35 is larger than the outer diameter of the tubular filtration membrane 3. A gap G is formed between the inner circumferential surface 35a of the tubular body portion 35 and the outer circumferential surface of the tubular filtration membrane 3. The outer diameter of the tubular filtration membrane 3 can be set to, for example, 5 mm, and the inner diameter of the tubular body portion 35 can be set to, for example, 7 mm. In this case, the gap G between the inner circumferential surface 35a of the tubular body portion 35 and the outer circumferential surface of the tubular filtration membrane 3 is 2 mm. The tubular body portion 35 is formed such that the gap G between the tubular body portion 35 and the tubular filtration membrane 3 is constant.

[0097]

The length of the tubular body portion 35 is the same as an interval between the first bulkhead 30 and the second bulkhead 31. That is, the length of the tubular body portion 35 is the same as the length of the tubular filtration membrane 3 exposed in the permeation side space P.

The tubular body portion 35 is made of light metal such as titanium or aluminum, or plastic such as polyacetal resin. It is preferable that the plate thickness of the tubular body portion 35 be as thin as possible to the extent that the strength of the reinforcing member 34 is not impaired.

[0098]

The support portion 36 is a protrusion extending in an axial direction Da (an extending direction) of the tubular body portion 35. A plurality of (eight in the present embodiment) the support portions 36 are formed in the circumferential direction of the tubular body portion 35 at intervals. The height of each of the support portions 36 is substantially the same as the width of the gap G between the inner circumferential

surface 35a of the tubular body portion 35 and the outer circumferential surface of the tubular filtration membrane 3.

[0099]

The reinforcing member 34 of the present embodiment has eight support
5 portions 36, but the present invention is not limited thereto and any portions which can support the tubular filtration membranes 3 may be the support portion. It is preferable to set the number of the support portions 36 to as few as possible, such as three, to secure a space between the tubular body portion 35 and the tubular filtration membranes 3, that is, a space to which the permeate water PW is discharged, more widely.

10 In addition, the support portions 36 are continuously formed in the axial direction Da of the tubular body portion 35 in the present embodiment, but the present invention is not limited thereto. The support portion 36 may support the tubular filtration membranes 3 while securing this space as much as possible without filling the space between the tubular body portion 35 and the tubular filtration membranes 3. For
15 example, the support portion 36 may be intermittently formed in the axial direction Da. In addition, the tubular filtration membranes 3 may also be point-supported by a plurality of support protrusions which space the tubular filtration membranes 3 apart from each other.

[0100]

20 A through-hole 37 is an opening for communicating the outer circumferential side of the tubular body portion 35 and the inner circumferential side of the tubular body portion 35. A plurality of through-holes 37 are regularly (evenly) arranged on the entire outer surface of the tubular body portion 35. It is preferable that as many of the through-holes 37 as possible be formed to the extent that the strength of the reinforcing
25 member 34 is not impaired. It is preferable that the positions of the through-holes 37

in the circumferential direction of the tubular body portion 35 are different from the support portions 36.

[0101]

According to the embodiment described above, the membrane separation
5 apparatus 1B is horizontally placed, that is, disposed such that the casing 2 extends in a horizontal direction, and thereby it is possible to perform the replacement of the membrane separation apparatus 1B easily even when the plurality of membrane separation apparatuses 1B are disposed. Accordingly, the maintenance of the membrane separation apparatus unit 50 made of the plurality of membrane separation apparatuses
10 1B can be easily performed.

[0102]

Moreover, the plurality of tubular filtration membranes 3 are reinforced by the reinforcing member 34, and thereby it is possible to prevent the tubular filtration membrane 3 from bending even when the tubular filtration membrane 3 is disposed to
15 extend in a horizontal direction.

In addition, the gap G is formed between the inner circumferential surface 35a of the tubular body portion 35 and the outer circumferential surface of the tubular filtration membrane 3 by the support portion 36 of the reinforcing member 34, and thereby it is possible to support the tubular filtration membrane 3 so as not to bend
20 without impeding the flow of the permeate water PW permeated from the tubular filtration membrane 3.

[0103]

Moreover, when the membrane separation apparatus is vertically placed, the head difference (resistance) increases between one end and the other end of the tubular
25 filtration membrane 3. The membrane separation apparatus 1B is horizontally placed,

and thereby it is possible to decrease the head difference and the FLUX (the outflow amount) distribution as compared with the case in which the membrane separation apparatus is vertically placed.

[0104]

5 In addition, the membrane separation apparatus 1B is horizontally placed, and thereby membrane separation apparatuses 1B are easily connected to each other in series. This can be easily applied even when the plurality of membrane separation apparatuses 1B constituting the membrane separation apparatus unit 50 are arranged in series.

[0105]

10 The length of the reinforcing member 34 is made the same as the interval between the first bulkhead 30 and the second bulkhead 31 in the embodiment described above, but the present invention is not limited thereto. For example, the length of the reinforcing member 34 may be made longer than the interval between the first bulkhead 30 and the second bulkhead 31, and the reinforcing member 34 may be inserted into the
15 insertion hole 32 of the first bulkhead 30 and the second bulkhead 31. By adopting such a form, it is possible to further reduce a burden on the tubular filtration membrane 3.

[0106]

 Moreover, the reinforcing member 34 is in a cylindrical shape and may have a mesh shaped network structure disposed so as to be in contact with the tubular filtration
20 membrane 3 on the outer circumferential side of the tubular filtration membrane 3. The network structure can be, for example, a plastic tube formed by combining a plurality of linear plastics with each other in a lattice shape.

[0107]

 As an alternative of the linear plastic, for example, a wire formed of a metal
25 such as stainless steel can be adopted. In addition, a wire covered with vinyl or the like

may also be adopted.

Moreover, a combining method of the plurality of linear plastics is not limited to the lattice shape, and the plurality of linear plastics may also be knitted into a hexagon.

[0108]

5 [Third embodiment]

Hereinafter, a reinforcing member used in a membrane separation apparatus of a third embodiment of the present invention will be described with reference to drawings.

A difference from the second embodiment described above will be mainly described and descriptions of the same portions will be omitted in the present embodiment. The

10 difference between the present embodiment and the second embodiment is that not only the membrane separation apparatus unit 50 shown in FIG. 7 is adopted in the biological treatment apparatus 100 of the first embodiment but also a reinforcing member 34C of FIG. 11 is adopted instead of the reinforcing member 34 of the membrane separation apparatus unit 50.

15 As shown in FIG. 11, the reinforcing member 34C of the present embodiment includes a plate-like body portion 48 in a circular plate shape, and a plurality of membrane insertion holes 49 formed in the plate-like body portion 48. The tubular filtration membranes 3 are inserted into the plurality of membrane insertion holes 49, respectively. Three reinforcing members 34C are provided at intervals in the axial

20 direction Da of the casing 2.

[0109]

The outer circumferential surface 48a of the plate-like body portion 48 of the reinforcing member 34C is in contact with the inner circumferential surface of the casing

2. The reinforcing member 34C is supported by the lower part of the reinforcing

25 member 34C being in contact with the inner circumferential surface of the casing 2.

The outer circumferential surface 48a of the lower part of the reinforcing member 34C functions as a reinforcing member support portion which supports the reinforcing member 34C. In addition, it is desirable that a notch 55 exist, for example, in a portion of the reinforcing member 34C such that the permeate water PW circulates in the permeation side space P.

[0110]

According to the embodiment described above, the plurality of tubular filtration membranes 3 are mechanically connected by the reinforcing member 34C. As a result, it is possible to prevent the tubular filtration membranes 3 from bending even when the tubular filtration membranes 3 are disposed to extend in a horizontal direction.

In addition, since the reinforcing member 34C of the present embodiment supports the tubular filtration membrane 3 only at three points in an extending direction, the permeate water PW can be further permeated.

[0111]

In the reinforcing member 34C of the embodiment described above, the outer circumferential surface 48a of the reinforcing member 34C is in contact with the inner circumferential surface of the casing 2, but the present invention is not limited thereto. That is, if the reinforcing member 34C is supported by the inner circumferential surface of the casing 2, the upper part of the reinforcing member 34C may not be in contact with the inner circumferential surface of the casing 2. In addition, for example, a portion of the outer circumference such as a polygonal shape may be in contact with the casing 2.

Moreover, the number of the reinforcing members 34C is not limited to three, and may be appropriately increased or decreased in accordance with the strength of the tubular filtration membrane 3.

[0112]

As described above, the embodiments of the present invention have been described in detail, but various modifications can be made in a range not departing from a technical concept of the present invention.

For example, with regard to the number of tubular filtration membranes 3, five tubular filtration membranes 3 are shown in FIG. 2 and the like, but the number of tubular filtration membranes 3 is not limited thereto.

The control device 13 in the control II and the control III has reset the opening degree of the first flow-regulating valve 23 to an initial value of 20%; however, it is not limited to the initial value, and may also be reset to a value changing from the limit value within the regulation range such as 30%.

Moreover, the constituents shown in the modification of the first embodiment may be applied to the second embodiment and the third embodiment.

While preferred embodiments of the invention have been described and illustrated above, it should be understood that these are exemplary of the invention and are not to be considered as limiting. Additions, omissions, substitutions, and other modifications can be made without departing from the spirit or scope of the present invention. Accordingly, the invention is not to be considered as being limited by the foregoing description, and is only limited by the scope of the appended claims.

20

EXPLANATION OF REFERENCES

[0113]

1 Membrane separation apparatus

2 Casing

3 Tubular filtration membrane

25

4 Casing body

	5 First conical portion
	6 Second conical portion
	7 Supply water inlet
	8 Concentrated water outlet
5	9 Permeate water outlet
	11 Biological treatment tank
	12 Raw water tank
	13 Control device
	13a Back pressure-regulating unit
10	13b Setting change unit
	13c Cleaning control unit
	14 Inter-membrane differential pressure-measuring device
	15 First line
	16 Second line
15	17 Supply line
	18 Permeate water line
	19 Return line
	20 Storage tank
	21 Booster pump
20	22 Suction pump
	23 First flow-regulating valve (Back pressure-regulating device)
	24 Second flow-regulating valve
	25 First flow meter
	26 First pressure gauge
25	27 Second flow meter

	28 Second pressure gauge
	29 Cleaning equipment
	30 First bulkhead
	31 Second bulkhead
5	32 Insertion hole
	34 Reinforcing member
	35 Tubular body portion
	36 Support portion
	37 Through-hole
10	40 Siphon breaker
	43 Third flow meter
	44 Third pressure gauge
	45 Branch line
	46 First connection member
15	48 Plate-like body portion
	49 Membrane insertion hole
	50 Membrane separation apparatus unit
	51 Housing
	55 Notch
20	59 Second connection member
	60 Third connection member
	100 Biological treatment apparatus
	P Permeation side space
	PW Permeate water
25	S Concentration side space

S1 First header space

S2 Second head space

S3 Space in a filtration membrane

W1 Water to be treated

5 W2, W3 Supply water

W4 Concentrated water

What is claimed is:

1. A biological treatment apparatus, comprising:

5 a biological treatment tank configured to process organic substances contained in water to be treated;

a membrane separation apparatus which has a casing and a tubular filtration membrane which partitions the casing into a concentration side space to which supply water flowing out from the biological treatment tank is supplied and a permeation side space in which permeate water separated from the supply water is contained, and has a
10 monolayer structure in which hydrophilic monomers are copolymerized;

a booster pump configured to supply the supply water to the concentration side space;

a suction pump configured to suck the permeate water from the permeation side space;

15 a back pressure-regulating device configured to regulate the back pressure of the permeation side space;

a return line configured to return concentrated water discharged from the membrane separation apparatus to the biological treatment tank;

20 an inter-membrane differential pressure-measuring device configured to measure an inter-membrane differential pressure between the concentration side space and the permeation side space; and

a control device configured to control the booster pump, the suction pump, and the back pressure-regulating device on the basis of the inter-membrane differential pressure,

25 wherein the control device includes

a back pressure-regulating unit configured to decrease the back pressure by controlling the back pressure-regulating device when the inter-membrane differential pressure increases to a predetermined value or more, and

5 a setting change unit configured to increase at least one of the pressurizing force of the booster pump and the suction force of the suction pump by controlling at least one of the booster pump and the suction pump, and to increase the back pressure by controlling the back pressure-regulating device when the regulation range of the back pressure-regulating device has reached the limit.

10 2. The biological treatment apparatus according to Claim 1, wherein the setting change unit performs control to increase the suction force of the suction pump after the pressurizing force of the booster pump is controlled to increase to and reach the upper limit.

15 3. The biological treatment apparatus according to Claim 2, wherein the control device includes a cleaning control unit which performs cleaning on the tubular filtration membrane after the suction force of the suction pump is controlled to increase to and reach the upper limit.

20 4. The biological treatment apparatus according to any one of Claims 1 to 3, wherein the return line has a branch line which supplies the concentrated water to a space between the biological treatment tank and the membrane separation apparatus, and a second flow-regulating valve which is provided on the downstream side of the branch line and regulates the flow rate of the concentrated water flowing through the
25 return line.

5. A biological treatment method, comprising:

a pressurization process of pressurizing and supplying supply water flowing out from a biological treatment tank to a concentration side space which is one side of a

5 tubular filtration membrane having a monolayer structure in which hydrophilic monomers are copolymerized;

a suction process of sucking permeate water from a permeation side space which is the other side of the tubular filtration membrane;

a return process of returning concentrated water discharged from the
10 concentration side space to the biological treatment tank;

a back pressure regulation process of decreasing the back pressure of the permeation side space when the inter-membrane differential pressure between the concentration side space and the permeation side space increases to a predetermined value or more; and

15 a setting change process of increasing at least one of the pressurizing force of the supply water and the suction force of the permeate water and increasing the back pressure when the regulation range of the back pressure reaches the limit.

6. A program which causes a computer of a control device of a biological treatment

20 apparatus including a biological treatment tank which processes organic substances contained in water to be treated, a membrane separation apparatus which has a casing and a tubular filtration membrane which partitions the casing into a concentration side space to which supply water flowing out from the biological treatment tank is supplied and a permeation side space in which permeate water separated from the supply water is

25 contained, and has a monolayer structure in which hydrophilic monomers are

copolymerized, a booster pump configured to supply the supply water to the concentration side space, a suction pump configured to suck the permeate water from the permeation side space, a back pressure-regulating device configured to regulate the back pressure of the permeation side space, a return line configured to return concentrated

5 water discharged from the membrane separation apparatus to the biological treatment tank, and an inter-membrane differential pressure-measuring device configured to measure an inter-membrane differential pressure between the concentration side space and the permeation side space to execute:

decreasing the back pressure by controlling the back pressure-regulating device

10 when the inter-membrane differential pressure increases to and reach a predetermined value or more, and

increasing at least one of the pressurizing force of the booster pump and the suction force of the suction pump by controlling at least one of the booster pump and the suction pump, and increasing the back pressure by controlling the back

15 pressure-regulating device when the regulation range of the back pressure-regulating device has reached the limit.