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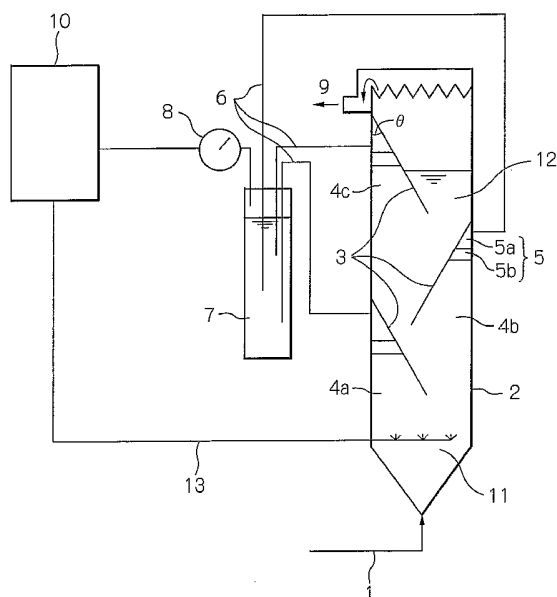
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(54) Title: BIOLOGICAL DENITRIFICATION METHOD AND APPARATUS



(57) Abstract: It is an object to provide a treatment method and treatment apparatus according to which denitrification treatment can be carried out stably even under a high load. The present invention provides a biological denitrification method which comprises introducing waste water containing oxidized nitrogen into an upflow sludge blanket treatment apparatus having a gas/liquid/solid separating portion therein, wherein a denitrifying microorganism and/or a microorganism carrier having a denitrifying microorganism film thereon is charged in the upflow sludge blanket treatment apparatus, and carrying out biological denitrification treatment on the waste water using the denitrifying microorganism.



For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

DESCRIPTION

BIOLOGICAL DENITRIFICATION METHOD AND APPARATUS

TECHNICAL FIELD

5 The present invention relates to biological denitrification treatment of waste water, and in particular relates to a biological denitrification method and apparatus for carrying out denitrification treatment by biologically reducing oxidized nitrogen ($\text{NO}_x\text{-N}$) in waste water discharged from any of various
10 factories, sewage, nightsoil, or the like. Note that in the present application, a gas/liquid/solid separating portion is referred to as a "GSS portion".

BACKGROUND ART

Conventionally, as biological denitrification methods, for
15 example a method in which sludge containing denitrifying bacteria is made to be present in a floating state, a method in which denitrifying bacteria are fixed on a carrier, and an upflow sludge blanket method (hereinafter referred to as "USB method") have been used.

20 In a USB method, an apparatus as shown in Fig. 2 is commonly used. Following is a description of this common USB method. In the following, water to be treated is also referred to as "raw water". Fig. 2 is a schematic diagram showing the constitution of a publicly known biological denitrification apparatus using the USB method.
25 The apparatus of Fig. 2 is constituted from a denitrification tank 22 that has, in a bottom portion thereof, a raw water supply portion

to which is connected a raw water supply pipe 1 through which influent water 21 is supplied, and a denitrifying bacteria sludge layer 23, and has, above the sludge layer 23, a gas colliding portion 24, a gas capturing portion 25, and a treated water 9 outflow portion.

5 In the USB biological denitrification apparatus, denitrification treatment is carried out in the denitrification tank 22, and the denitrifying microorganism is held at a high concentration in the denitrification tank 22 without using a carrier for attaching the denitrifying bacteria. With such an apparatus, an upper portion
10 of the apparatus in which the denitrifying bacteria sludge layer 23 is not built up is constituted as a GSS portion 5 in which gas that has floated up is separated from the sludge, and moreover the sludge is separated from the treated water; a lower portion of the apparatus is constituted as a reaction portion in which the
15 denitrifying bacteria sludge is built up and the denitrification reaction is carried out. Gas (nitrogen gas) 26 captured by the gas capturing portion 25 is discharged via a produced gas recovery pipe 6.

However, there are still problems such as the following with
20 such an upflow sludge blanket method in which the denitrifying bacteria are held at a high concentration. (a) There is a risk of sludge having nitrogen gas produced through the denitrification treatment attached thereto or contained therein floating up and flowing out together with the treated water, leading to a drop in
25 the amount of the denitrifying bacteria sludge in the denitrification tank and a deterioration in the treatment. (b)

The GSS portion occupies 1/3 to 1/2 of the whole apparatus, and hence the space for the reaction portion in which the denitrification reaction is actually carried out is limited, and thus the apparatus as a whole becomes large. (c) Due to (a) and (b) above, treatment
5 with a high load is problematic.

DISCLOSURE OF THE INVENTION

In view of the publicly known art described above, it is an object of the present invention to provide a biological denitrification method and apparatus using the upflow sludge
10 blanket method according to which the amount of denitrifying bacteria-containing sludge held can be increased, and hence denitrification treatment can be carried out stably even under a high load.

To attain the above object, according to the present invention,
15 there is provided A biological denitrification method which comprises introducing waste water containing oxidized nitrogen into an upflow sludge blanket treatment apparatus having a gas/liquid/solid separating portion therein, wherein a denitrifying microorganism and/or a microorganism carrier having
20 a denitrifying microorganism film thereon is charged in the upflow sludge blanket treatment apparatus, and carrying out biological denitrification on the waste water. In the denitrification method according to the present invention, an autotrophic denitrifying microorganism that uses ammonia ions as an electron donor and nitrite
25 ions as an electron acceptor can be used as the denitrifying microorganism. Moreover, a porous medium having an effective

particle diameter of 0.05 to 0.5 mm can be used as the microorganism carrier. Moreover, it is more preferred to use a porous medium having a uniformity coefficient of 1.2 to 2.0. Moreover, in the denitrification treatment according to the present invention, at least some of treated water flowing out from an upper portion of the upflow anaerobic sludge blanket treatment apparatus can be circulated with the water to be treated.

Moreover, according to the present invention, there is provided a biological denitrification apparatus which has an upflow sludge blanket treatment apparatus in which a gas/liquid/solid separating portions are formed in a main body and a denitrifying microorganism and/or a microorganism carrier having a denitrifying microorganism film thereon is charged in the main body, and a pipe for introducing a waste to the upflow sludge blanket treatment apparatus and a pipe for discharging treated water from the upflow sludge blanket treatment apparatus. In the denitrification apparatus according to the present invention, the denitrifying microorganism shall be an autotrophic denitrifying microorganism that uses ammonia ions as an electron donor and nitrite ions as an electron acceptor. Furthermore, the microorganism carrier may be a porous medium having an effective particle diameter of 0.05 to 0.5 mm and more preferably also having a uniformity coefficient of 1.2 to 2.0. Moreover, the upflow sludge blanket treatment apparatus may have a circulating path through which at least some of treated water flowing out from an upper portion of the upflow sludge blanket treatment apparatus is injected into water to be

treated and circulated.

According to the present invention, there are effects whereby nitrogen gas produced through the denitrification can be recovered rapidly from the GSS portions which are installed in a plurality of tiers, the produced gas/treated water/sludge or carrier separation and recovery performance can be improved, and moreover by attaching the denitrifying bacteria to a microorganism carrier, the amount of denitrifying bacteria held can be increased; treatment with a high load thus becomes possible. According to the present invention, in the case of an upflow anaerobic sludge blanket treatment apparatus that holds sludge containing anaerobic bacteria and has gas/liquid/solid separating portions installed therein in a plurality of tiers, sludge containing denitrifying bacteria supported on a carrier is put in instead of the sludge containing the anaerobic bacteria, and denitrification is made to take place, whereby biological denitrification treatment is carried out.

EFFECTS OF THE INVENTION

According to the present invention, by providing gas/liquid/solid separating portions in a plurality of tiers, and by supporting the denitrifying bacteria on a microorganism carrier, there are effects whereby nitrogen gas produced through the denitrification can be recovered rapidly, the produced gas/treated water/sludge separation and recovery performance can be improved, and the amount of denitrifying bacteria held can be increased. There can thus be provided a biological denitrification method and apparatus according to which treatment can be carried out stably

even under a high oxidized nitrogen load. During operation of the upflow sludge blanket method (USB method) at a high oxidized nitrogen load, stable denitrification treatment results are always obtained, and hence the method and apparatus of the present invention are
5 extremely valuable.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a flow diagram showing the constitution of an embodiment of an upflow denitrification treatment apparatus according to the present invention.

10 Fig. 2 is a schematic diagram showing the constitution of an example of a conventional upflow denitrification treatment apparatus.

Fig. 3 is a schematic diagram showing schematically the constitution of a conventional treatment apparatus used in Example
15 1.

Fig. 4 is a flow diagram showing the constitution of a treatment apparatus according to the present invention used in Example 1.

Fig. 5 consists of graphs showing changes in oxidized nitrogen load, oxidized nitrogen concentration, and removal rate over the
20 course of an experiment of Example 1.

Fig. 6 consists of graphs showing changes in nitrogen load, nitrite nitrogen concentration, and removal rate over the course of an experiment of Example 2.

DETAILED EXPLANATION OF THE INVENTION

25 Following is a description of an embodiment of the present invention with reference to the drawings. Fig. 1 is a flow diagram

showing schematically the constitution of an embodiment using an upflow sludge blanket treatment apparatus preferable for carrying out a biological denitrification treatment method according to the present invention. Note that in all of the drawings for explaining the embodiments and the examples, constituent elements having the same function are shown using the same reference numeral. In the apparatus shown in Fig. 1, there is provided a tubular reactor 2 having the top and bottom thereof stopped up, which has a lower portion thereof communicated with a raw water supply pipe 1. Baffles 3 are provided each of which has one end thereof fixed to either of left and right side walls inside the reactor 2, and has the other end thereof extending toward the side wall on the opposite side while dropping downwards.

In the embodiment shown in Fig. 1, the baffles 3 are provided alternately on the left and right in three places in the vertical direction, whereby acutely angled partitioned sludge zones 4a to 4c are formed between the side walls of the reactor. The angle θ between each baffle 3 and the sidewall of the reactor 2 is preferably an acute angle of not more than 35° , with the baffle 3 pointing downwards, and the area occupied by the baffles 3 is preferably not less than $1/2$ of the cross-sectional area of the apparatus. In the case that θ is an angle greater than 35° , granular sludge will accumulate on the baffle 3 above each of the sludge zones 4a to 4c, and dead spaces will be prone to arising, and hence the fluidity will become insufficient, and thus treatment with a high load may become difficult. Moreover, in the case that the area occupied

by the baffles 3 is less than $1/2$, capturing of the produced gas will become insufficient, and hence problems will arise with the gas/liquid/solid separation. That is, gas will escape upwards from the center of the reactor, and hence it will not longer be possible to sufficiently collect the gas in GSS portions 5, described below.

A GSS portion 5 is formed in an upper portion of each of the partitioned sludge zones 4a to 4c. An outlet to a produced gas recovery pipe 6 which communicates to the outside is provided in a gaseous phase portion 5a of GSS portion 5 in which the produced gas collects upon the reaction commencing. A discharge opening of each produced gas recovery pipe 6 connected from the corresponding gaseous phase portion 5a opens out into water in a water sealing tank 7 that is filled with water. The positions of the openings are at suitable depths at differing water pressures, and a gas meter 8 for measuring the flow rate of the gas discharged from the produced gas recovery pipes 6 is provided on the water sealing tank 7. A gas holder 10 is provided beyond the gas meter 8. Moreover, a treated water pipe 9 through which the supernatant liquid is discharged is connected to an upper end of the reactor 2.

The raw water targeted for treatment in the present invention is waste water containing ammonia nitrogen, organic nitrogen, and oxidized nitrogen. The waste water is subjected to the treatment according to the present invention after some or all of the ammonia nitrogen and organic nitrogen has been converted into oxidized nitrogen through aerobic treatment or the like.

As the denitrification method for the oxidized nitrogen in

the present invention, a method using heterotrophic denitrifying bacteria using organic matter in the raw water or organic matter such as methanol added from the outside as an electron donor, or a method using autotrophic denitrifying bacteria using ammonia nitrogen, sulfur or the like as an electron donor can be used. In the case that ammonia nitrogen is used as an electron donor, the waste water may be subjected to the treatment according to the present invention after some or all of the ammonia nitrogen in the waste water has been converted into mainly nitrite through the above aerobic treatment or the like. Here, it is preferable to submit the waste water to the apparatus with the molar ratio between the ammonia nitrogen and the nitrite nitrogen being 0.5 to 2 of nitrite nitrogen, preferably 1 to 1.5 of nitrite nitrogen, to 1 of ammonia nitrogen.

The reactor 2 is used with a carrier and sludge charged therein. The carrier and the sludge may be charged in either order. Alternatively, the carrier and the sludge may be charged in after having been mixed together. As the sludge used, it is preferable to charge in granular sludge comprising denitrifying bacteria, but the sludge does not have to be granular. As the denitrifying bacteria, either heterotrophic denitrifying bacteria or autotrophic denitrifying bacteria as described above can be used. The carrier is preferably an abiotic porous medium, preferably having an effective particle diameter of 0.05 to 0.5 mm. Of such carriers, one having an average specific gravity of 1.05 to 2.0 is preferable. Examples include activated charcoal, zeolite, silica sand,

diatomaceous earth, fired ceramics, and ion exchange resins. The amount of the carrier packed into the denitrification tank can be made to be 10 to 75 vol%.

The raw water is introduced into the reactor 2 from the raw water supply pipe 1. The raw water is suitably diluted as required with some of the treated water circulated, diluting water supplied in from the outside, or the like, and the flow rate of the influent water in the reactor 2 may be adjusted to 0.01 to 5 m/h, whereby the state of flow of the sludge layer inside the reactor becomes good. If the flow rate of the influent water in the reactor 2 is made to be 6 m/h or more, then the denitrifying bacteria-attached carrier will be prone to flowing out together with the treated water, and hence this flow rate is preferably made to be not more than 5 m/h.

Oxidized nitrogen is decomposed by the denitrifying bacteria in the reactor 2, thus producing nitrogen gas. It was experimentally confirmed by the present inventors that the denitrifying bacteria may be granulated spontaneously by production of the gas and flow rate of a liquid in the reactor. It was also experimentally confirmed that, when using the carrier, the denitrifying bacteria may become fluidized and be substantially fixed on the surface of the carrier. The produced gas is separated off and collects in the GSS portion 5 at the upper end of each the partitioned sludge zones 4a to 4c, thus forming a gaseous phase portion 5a in each GSS portion 5, and is then lead through the produced gas recovery pipe 6 into the water sealing tank 7. The amount of the produced gas discharged is recorded

by the gas meter 8, before the produced gas is fed into the gas holder 10. Some of the produced gas becomes attached to the microorganism-supporting carrier in each of the partitioned sludge zones 4a to 4c, thus reducing the apparent specific gravity of the microorganism-supporting carrier, and hence accompanied by the microorganism-supporting carrier, this produced gas reaches the water surface in the GSS portion 5. The produced gas then forms bubbles, and stops temporarily in a water surface bubble portion 5b. The bubbles gathered in the water surface bubble portion 5b eventually burst, whereby the produced gas and the microorganism-supporting carrier separate from one another, the carrier returning to its original specific gravity and thus settling downwards, and the produced gas being discharged from the produced gas recovery pipe 6 through the water sealing tank 7 to the outside of the system. The water that has been clarified through the decomposition of the oxidized nitrogen is discharged from the upper end of the reactor through the treated water pipe 9 to the outside of the system.

The gas pressure in the gaseous phase portion 5a differs between the GSS portions 5, and hence this pressure difference is preferably adjusted using the water sealing tank 7. The closer to the location from which the raw water is fed in, the higher the water sealing pressure must be kept. Other than using such a water sealing tank 7, there are many methods for adjusting the pressure of the recovered gas. For example, pressure valves or the like may be used. According to the upflow sludge blanket treatment

method of the present invention, the produced gas can be recovered separately from each of the partitioned sludge zones, and hence the amount of produced gas per unit cross-sectional area of the reactor is reduced. In particular, the amount of gas per unit cross-sectional area of the reactor is reduced in the location closest to the treated water pipe 9 through which the treated water flows out. The amount of the sludge and the carrier flowing out from the system can thus be greatly reduced.

In the case of treating foaming raw water, the gaseous phase portions 5a in the GSS portions 5 and the produced gas recovery pipes 6 will become blocked up, and hence recovery of the produced gas will become difficult. In such a case, foaming in the GSS portions 5 can be suppressed by adding an antifoaming agent to the water flowing into the reactor 2 in advance. Compared with a method in which the antifoaming agent is dripped or sprayed into the GSS portions 5, this method is more effective in preventing foaming in a closed space. As the antifoaming agent, an antifoaming agent having an antifoaming effect in accordance with the properties of the raw water can be used. Regarding the type of the antifoaming agent, either a silicone type antifoaming agent or an alcohol type antifoaming agent can be used.

In the case that scum is prone to forming due to the raw water having high SS or the like, scum will form inside or on the surface of the bubble portions 5b in the GSS portions 5, and hence recovery of the produced gas will become difficult. In such a case, it is possible to connect a produced gas blowing pipe 13 to a gas diffusing

pipe 11, and supply produced gas from the gas holder 10 into the GSS portions 5, thus breaking up or preventing formation of the scum. The scum is broken up by the gas bubbles blown in from the gas diffusing pipe 11, and the broken up scum flows with the liquid
5 through the reactor 2 and is thus discharged with the treated water.

In the present embodiment, the blown gas can be recovered in each GSS portion, and hence the amount of the produced gas per unit cross-sectional area of the reactor is low, particularly in the location closest to the treated water pipe through which the
10 treated water flows out, and hence the function of it being possible to greatly reduce the amount of the sludge and the carrier flowing out from the system is not impaired. A gas diffusing pipe 11 can be disposed in the lower portion of the reactor 2, or in the lower portion of each GSS portion. The carrier layer is agitated by the
15 gas blown in, and hence contact between the denitrifying bacteria and the influent waste water is improved; in particular, in the case that the oxidized nitrogen load flowing into the main body of the reactor is low, the amount of gas produced therefrom is low, and hence the effect of agitation by the gas blown in is great.

20 The gas blown into the GSS portions 5 to break up and remove scum in the GSS portions 5 is preferably a gas that does not contain oxygen and does not have an effect on the denitrification treatment; it is particularly preferable to use the produced nitrogen gas. Note that in the case of using heterotrophic denitrifying bacteria,
25 the bacteria will be facultative anaerobic bacteria, and hence so long as the ORP of the treated water is maintained at not more than

-100 mV and the conditions are such that there is no effect on the denitrification treatment, a gas containing oxygen such as air may be used. The frequency of blowing in the gas depends on the properties of the waste water, but there is an effect of breaking
5 up and removing scum in the GSS portions if this frequency is between once per day and once per week. Moreover, the effect of agitating the sludge layer can be further improved by making the frequency of blowing in the gas be greater than once per day.

Several embodiments of the present invention are as follows.

10 1. A biological denitrification method which comprises introducing waste water containing oxidized nitrogen into an upflow sludge blanket treatment apparatus having a gas/liquid/solid separating portion therein, wherein a denitrifying microorganism and/or a microorganism carrier having a denitrifying microorganism
15 film thereon is charged in the upflow sludge blanket treatment apparatus, and carrying out biological denitrification treatment on the waste water using the denitrifying microorganism.

2. The biological denitrification method according to above item 1, further comprising introducing gas generated in the
20 denitrifying treatment into a water sealing tank, and discharging the gas to the outside of the apparatus.

3. The biological denitrification method according to above item 1 or 2, wherein said denitrifying microorganism is an autotrophic denitrifying microorganism that uses ammonia ions as
25 an electron donor and nitrite ions as an electron acceptor.

4. The biological denitrification method according to any

one of above items 1-3, wherein said microorganism carrier is a porous medium having an effective particle diameter of 0.05 to 0.5 mm.

5 5. The biological denitrification method according to any one of above items 1-4, wherein in said denitrification treatment, at least some of treated water flowing out from an upper portion of said upflow sludge blanket treatment apparatus is circulated with water to be treated.

10 6. A biological denitrification apparatus which has an upflow sludge blanket treatment apparatus in which a gas/liquid/solid separating portions are formed in a main body and a denitrifying microorganism and/or a microorganism carrier having a denitrifying microorganism film thereon is charged in the main body, and a pipe for introducing a waste to the upflow sludge blanket
15 treatment apparatus and a pipe for discharging treated water from the upflow sludge blanket treatment apparatus..

20 7. The biological denitrification apparatus according to above item 6, further comprising a pipe for discharging gas generated in the upflow sludge blanket treatment apparatus and a water sealing tank connected to the pipe.

25 8. The biological denitrification apparatus according to above item 6 or 7, wherein the upflow sludge blanket treatment apparatus is a tubular reactor, and a baffle is provided in the reactor, the baffle having one end fixed to a side wall inside the reactor and the other end extending toward the side wall on the opposite inside the reactor while dropping downwards wherein the

angle between the baffle and the side wall of the tubular reactor is not more than 35°.

9. The biological denitrification apparatus according to any one of above items 6-8, wherein said denitrifying microorganism is an autotrophic denitrifying microorganism that uses ammonia ions as an electron donor and nitrite ions as an electron acceptor.

10. The biological denitrification apparatus according to any one of above items 6-9, wherein said microorganism carrier is a porous medium having an effective particle diameter of 0.05 to 0.5 mm.

11. The biological denitrification apparatus according to any one of above items 6-10, wherein said upflow sludge blanket treatment apparatus has a circulating path through which at least some of treated water flowing out from an upper portion of said upflow sludge blanket treatment apparatus is injected into water to be treated and circulated.

EXAMPLES

Following is a more specific description of the present invention through examples.

Example 1

Figs. 3 and 4 show schematically apparatuses used in a multi-stage denitrification treatment experiment. System A uses a conventional upflow sludge blanket method; as shown in Fig. 3, methanol 15 was injected into the raw water supply pipe 1 of Fig.

2. System B and system C are systems in which three inclined baffles

3 were installed, the angle between each baffle and a side wall of the apparatus was made to be 30° , with the baffle pointing downwards, and a gas diffusing pipe 11 was installed and produced gas was blown in therefrom, this being shown in Fig. 4. System B is a system in which only granular sludge was charged into the apparatus. System C is a system according to the present invention; a denitrifying microorganism supported on a carrier was used.

As shown in Fig. 4, raw water was introduced into the apparatus from the raw water supply pipe 1 connected to the lower end of the reactor 2, and treated water was obtained from the treated water pipe 9 in the upper portion of the reactor 2. GSS portions 5 in which was collected gas produced through decomposition of organic matter and purification were formed in the reactor 2, and the outlet of a produced gas recovery pipe 6 communicating to the outside was provided at the upper end of each GSS portion 5. Methanol 14 was injected in as an electron donor for the denitrification treatment.

The volume of a liquid layer portion was 1m^3 , and the water temperature in the reactor was made to be 20 to 25°C . Waste water (oxidized nitrogen 100 mg/L) discharged from a chemical plant to which inorganic nutrient salts (phosphorus etc.) were added was used as the raw water. Methanol was injected in such that the BOD was 300 mg/L . As the carrier for system C, activated charcoal of particle diameter 0.1 to 0.2 mm was charged in such that the volume when left to stand would be 0.5 m^3 . Treated water was circulated, expanding the microorganism carrier layer to approximately 0.85 m^3 . For system B and system C, blowing in of produced gas was carried

out once per hour.

Fig. 5 shows changes in the denitrification treatment results over the course of the experiment. For all of the systems, the oxidized nitrogen load of the treated water was gradually increased. Up to approximately 80 days of the experiment elapsing, it was possible to carry out the treatment with approximately the same load for all of the systems. After approximately 80 days, upon the oxidized nitrogen load becoming greater than $3 \text{ kg/m}^3/\text{d}$, for system A, the oxidized nitrogen concentration of the treated water increased, and after 90 days, the oxidized nitrogen removal rate had dropped to 50%. For system A, upon the load increasing, granular sludge having produced nitrogen gas attached thereto or contained therein floated up and flowed out together with the treated water, and hence the amount of denitrifying bacteria granular sludge in the denitrification tank dropped, and the treatment performance dropped. On the other hand, with system B and system C in which GSS portions were provided in a plurality of tiers, even at an oxidized nitrogen load of $5 \text{ kg/m}^3/\text{d}$, treatment could be carried out with a treated water oxidized nitrogen concentration of not more than 5 mg/L, and an oxidized nitrogen removal rate of not less than 95%. However, once the oxidized nitrogen load was further increased and this load became $6 \text{ kg/m}^3/\text{d}$, for system B, VSS of the treated water increased, the amount of granular sludge in the denitrification tank dropped, and the treatment performance dropped. Table 1 shows a comparison of the treatment results in a steady state.

Table 1

Comparison of treatment results in steady state

	System A (Conv. method 1)	System B (Conv. method 2)	System C (Method of present invention)
Oxidized nitrogen volume load (kg/m ³ ·d)	2.5	5.0	6.0
Oxidized nitrogen removal rate (%)	95	95	95
VSS of treated water (mg/L)	40-80	40-80	40-80

With system C according to the present invention, the oxidized nitrogen load was 6 kg/m³/d, the oxidized nitrogen removal rate 95%, and the VSS of the treated water 40 to 80 mg/L. On the other hand, with conventional method 2 of system B, the oxidized nitrogen load was 5 kg/m³/d, the oxidized nitrogen removal rate 95%, and the VSS of the treated water 40 to 80 mg/L. In this way, with the method of system C according to the present invention, the denitrification treatment results were stable even when operation was carried out at a high oxidized nitrogen load. Moreover, the VSS concentration of the treated water was approximately the same as with the conventional method.

Example 2

In the present example, an experiment was carried out using the multi-stage denitrification treatment apparatuses shown in Figs. 1 and 2. System D used a conventional upflow sludge blanket method, using the apparatus shown in Fig. 2. System E and system F are systems in which three inclined baffles 3 were installed, the angle between each baffle and a side wall of the apparatus was made to

be 30°, and a gas diffusing pipe was installed and produced gas was blown in therefrom, this being using the apparatus shown in Fig. 1. System E is a system in which only granular sludge was charged into the apparatus. System F is a system according to the present invention; a denitrifying microorganism supported on a carrier was used.

As shown in Fig. 1, raw water was introduced into the apparatus from the raw water supply pipe 1 connected to the lower end of the reactor 2, and treated water was obtained from the treated water pipe 9 in the upper portion of the reactor 2. GSS portions 5 in which was collected gas produced through decomposition of ammonia nitrogen and nitrite nitrogen and purification were formed in the reactor 2, and the outlet of a produced gas recovery pipe 6 communicating to the outside was provided at the upper end of each GSS portion 5.

The volume of a liquid layer portion was 1m³, and the water temperature in the reactor was made to be 30 to 35°C. Waste water discharged from an anaerobic sludge digestion tank (liquid eliminated from digestion: containing 500 mg/L of ammonia nitrogen) to which inorganic nutrient salts (phosphorus etc.) were added was subjected to digestion treatment such that the ammonia nitrogen to nitrite nitrogen ratio became approximately 1:1, and the resulting nitrified water was used as the raw water. As the carrier for system F, activated charcoal of particle diameter 0.1 to 0.2 mm was charged in such that the volume when left to stand would be 0.5 m³. Treated water was circulated, expanding the

microorganism carrier layer to approximately 0.85 m^3 . For system E and system F, blowing in of produced gas was carried out once per hour.

Fig. 6 shows changes in the denitrification treatment results over the course of the experiment. For all three systems, the nitrogen load was gradually increased while observing the oxidized nitrogen concentration of the treated water. Up to approximately 100 days of the experiment elapsing, it was possible to carry out the treatment with approximately the same load for all of the systems. After approximately 100 days, upon the nitrogen load becoming greater than $2 \text{ kg/m}^3/\text{d}$, for system D, the oxidized nitrogen concentration of the treated water increased, and after 115 days, the nitrogen removal rate had dropped to 50%. For system D, upon the load increasing, granular sludge having produced nitrogen gas attached thereto or contained therein floated up and flowed out together with the treated water, and hence the amount of denitrifying bacteria granular sludge in the denitrification tank dropped, and the treatment performance dropped.

On the other hand, with system E and system F in which GSS portions were provided in a plurality of tiers, even at an oxidized nitrogen load of $4 \text{ kg/m}^3/\text{d}$, treatment could be carried out with a treated water nitrite nitrogen concentration of not more than 5 mg/L , and an nitrogen removal rate of not less than 80%. However, once the oxidized nitrogen load was further increased and this load became $5 \text{ kg/m}^3/\text{d}$, for system E, VSS of the treated water increased, the amount of granular sludge in the denitrification tank dropped,

and the treatment performance dropped. Table 2 shows a comparison of the treatment results in a steady state.

Table 2

Comparison of treatment results in steady state

	System D (Conv. method 1)	System E (Conv. method 2)	System F (Method of present invention)
Oxidized nitrogen volume load ($\text{kg}/\text{m}^3 \cdot \text{d}$)	2.0	4.0	5.0
Nitrogen removal rate (%)	83	83	83
VSS of treated water (mg/L)	40-80	40-80	40-80

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With system F according to the present invention, the nitrogen load was $5 \text{ kg}/\text{m}^3/\text{d}$, the nitrogen removal rate 83%, and the VSS of the treated water 40 to 80 mg/L . On the other hand, with conventional method 2 of system E, the nitrogen load was $4 \text{ kg}/\text{m}^3/\text{d}$, the nitrogen removal rate 83%, and the VSS of the treated water 40 to 80 mg/L . In this way, with the method of system F according to the present invention, the denitrification treatment results were stable even when operation was carried out at a high nitrogen load. Moreover, the VSS concentration of the treated water was approximately the same as with the conventional method.

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CLAIMS

1. A biological denitrification method which comprises introducing waste water containing oxidized nitrogen into an upflow
5 sludge blanket treatment apparatus having a gas/liquid/solid separating portion therein, wherein a denitrifying microorganism and/or a microorganism carrier having a denitrifying microorganism film thereon is charged in the upflow sludge blanket treatment apparatus, and carrying out biological denitrification treatment
10 on the waste water using the denitrifying microorganism.

2. The biological denitrification method according to claim 1, further comprising introducing gas generated in the denitrifying treatment into a water sealing tank, and discharging the gas to the outside of the apparatus.

15 3. The biological denitrification method according to claim 1 or 2, wherein said denitrifying microorganism is an autotrophic denitrifying microorganism that uses ammonia ions as an electron donor and nitrite ions as an electron acceptor.

20 4. The biological denitrification method according to any one of claims 1-3, wherein said microorganism carrier is a porous medium having an effective particle diameter of 0.05 to 0.5 mm.

5. The biological denitrification method according to any one of claims 1-4, wherein in said denitrification treatment, at least some of treated water flowing out from an upper portion of
25 said upflow treatment apparatus is circulated with water to be treated.

6. A biological denitrification apparatus which has an upflow treatment apparatus in which a gas/liquid/solid separating portions are formed in a main body and a denitrifying microorganism and/or a microorganism carrier having a denitrifying microorganism film thereon is charged in the main body, and a pipe for introducing a waste to the upflow sludge blanket treatment apparatus and a pipe for discharging treated water from the upflow sludge blanket treatment apparatus..

7. The biological denitrification apparatus according to claim 6, further comprising a pipe for discharging gas generated in the upflow sludge blanket treatment apparatus and a water sealing tank connected to the pipe.

8. The biological denitrification apparatus according to claim 6 or 7, wherein the upflow sludge blanket treatment apparatus is a tubular reactor, and a baffle is provided in the reactor, the baffle having one end fixed to a side wall inside the reactor and the other end extending toward the side wall on the opposite inside the reactor while dropping downwards wherein the angle between the baffle and the side wall of the tubular reactor is not more than 35°.

9. The biological denitrification apparatus according to any one of claims 6-8, wherein said denitrifying microorganism is an autotrophic denitrifying microorganism that uses ammonia ions as an electron donor and nitrite ions as an electron acceptor.

10. The biological denitrification apparatus according to

any one of claims 6-9, wherein said microorganism carrier is a porous medium having an effective particle diameter of 0.05 to 0.5 mm.

11. The biological denitrification apparatus according to any one of claims 6-10, wherein said upflow treatment apparatus
5 has a circulating path through which at least some of treated water flowing out from an upper portion of said upflow treatment apparatus is injected into water to be treated and circulated.

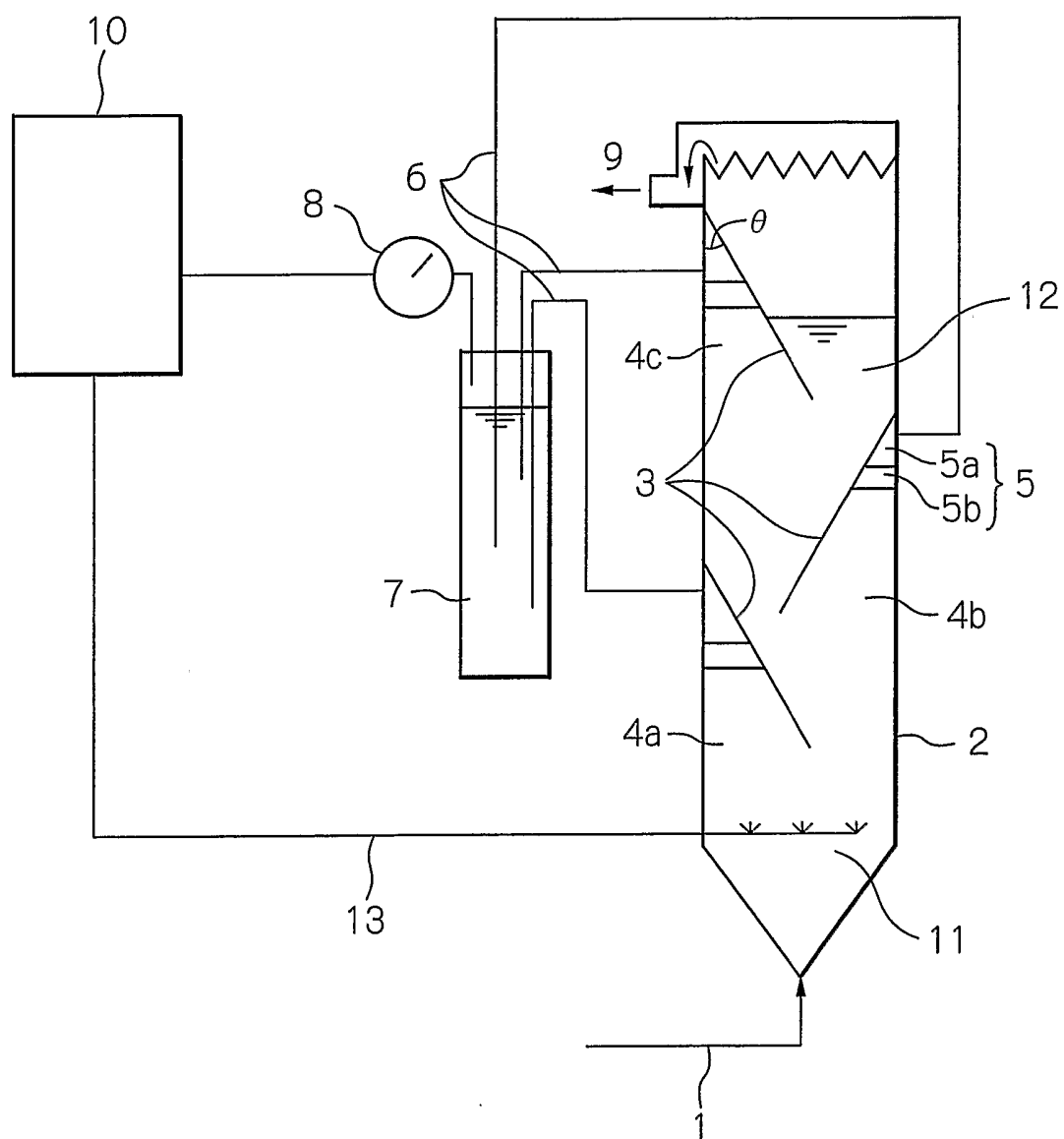
Fig. 1

Fig. 2

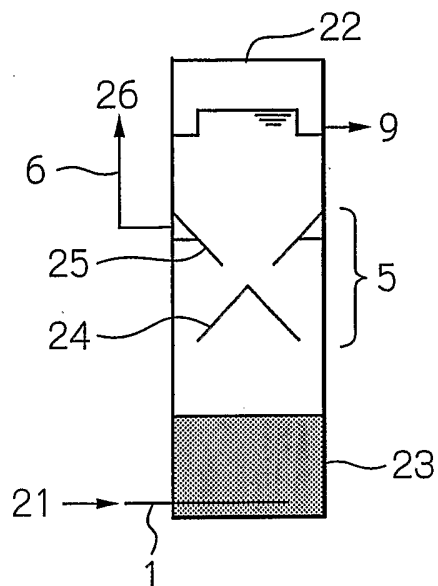


Fig. 3

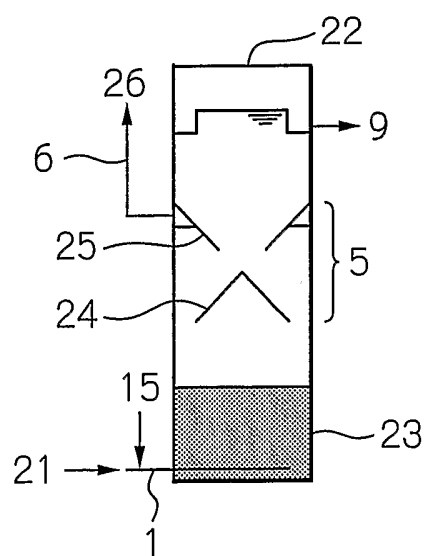


Fig. 4

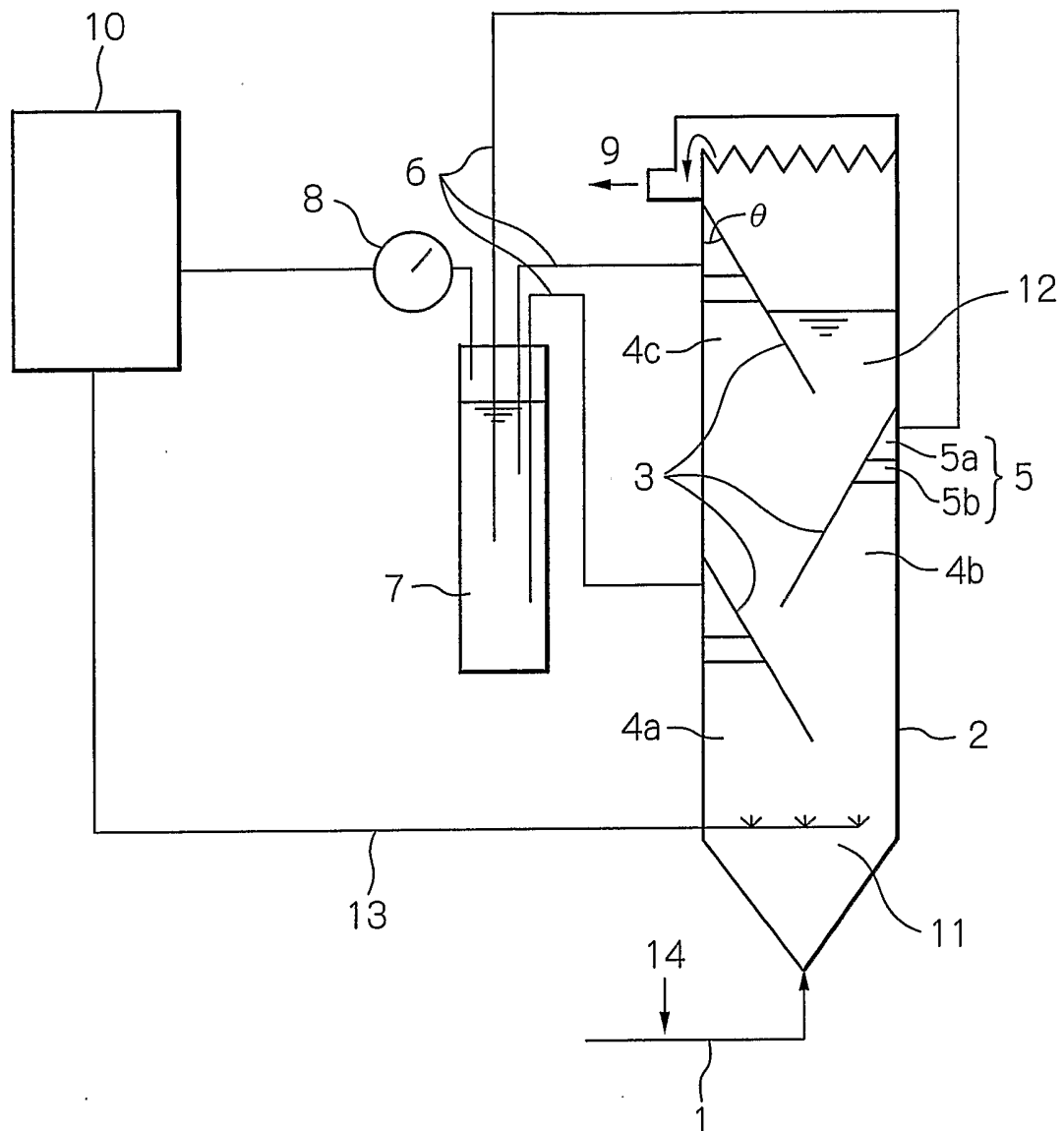


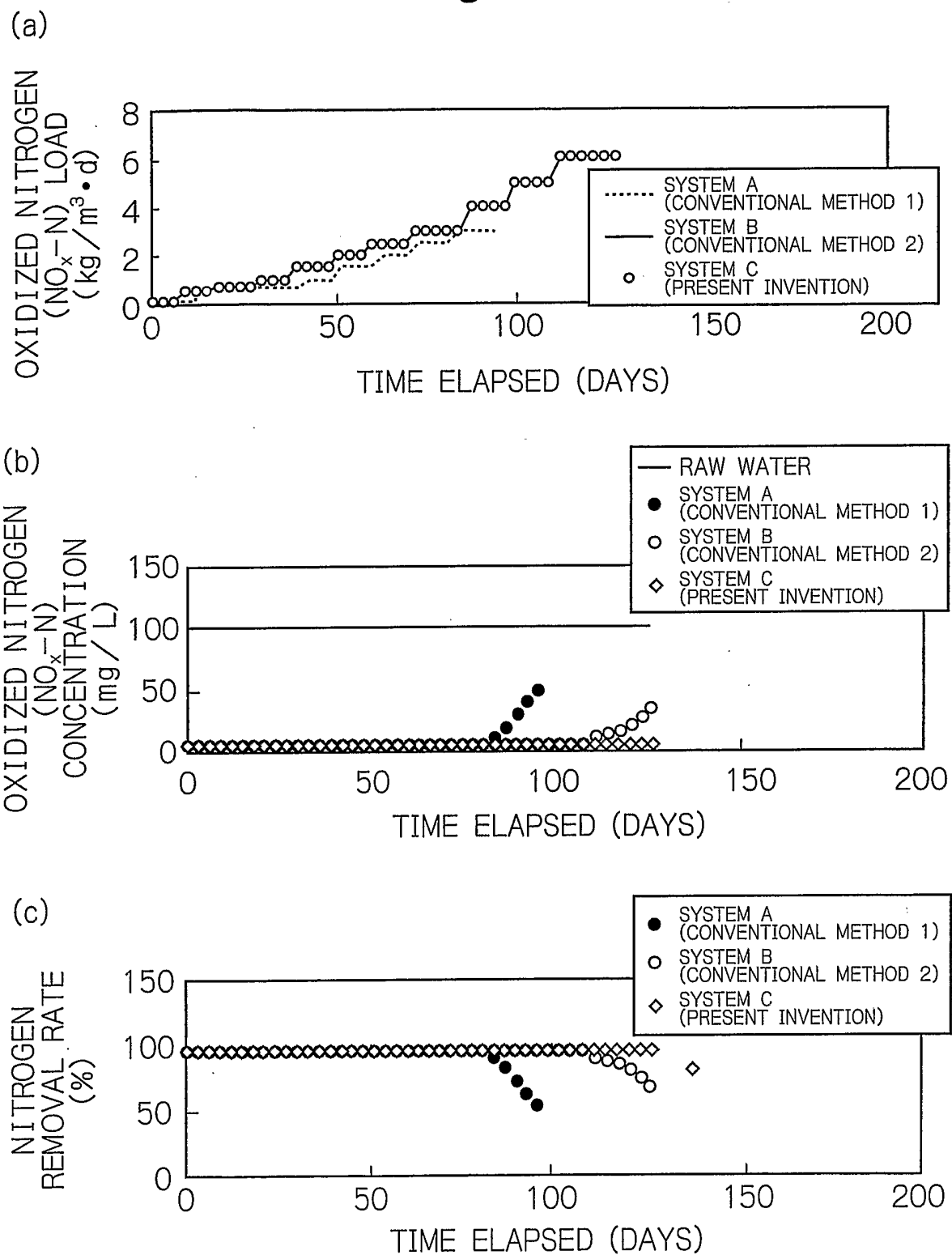
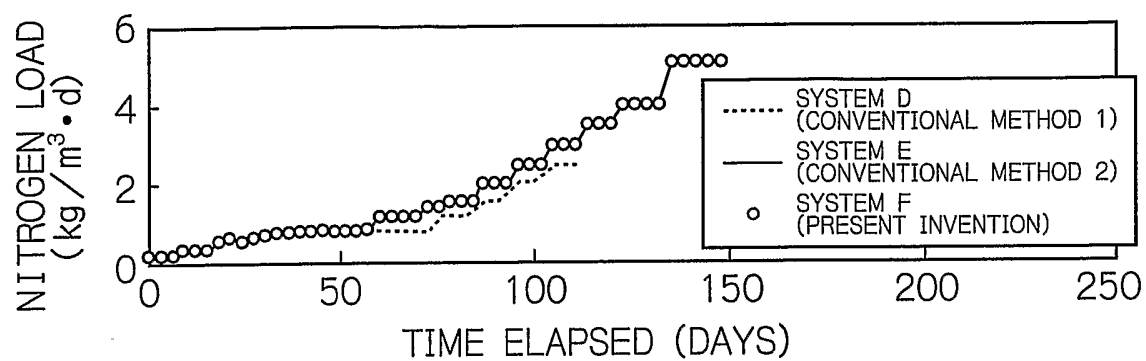
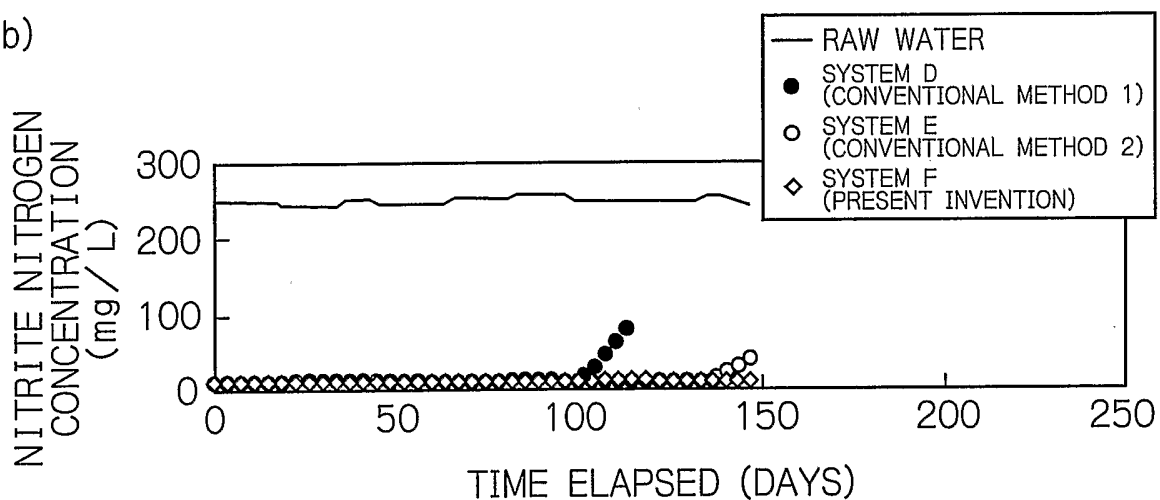
Fig. 5

Fig. 6

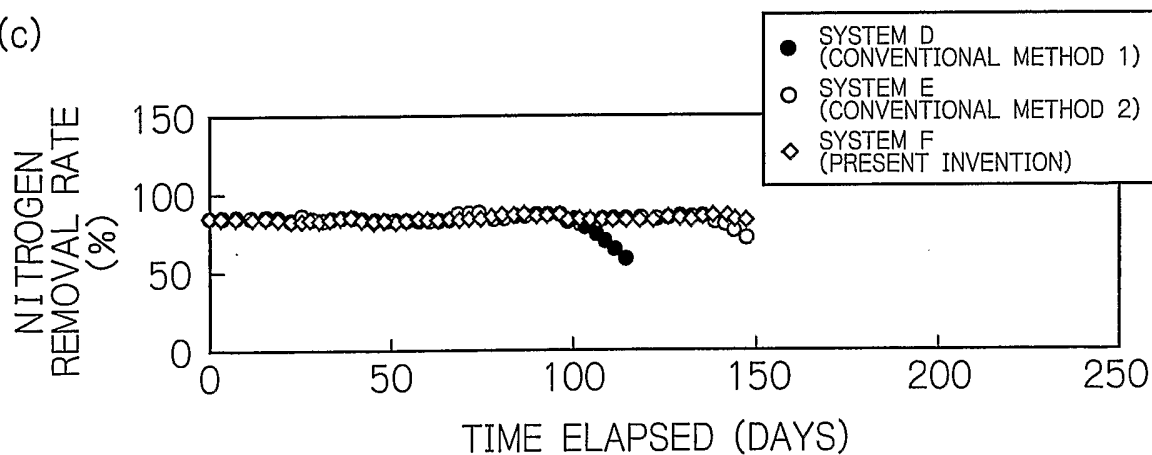
(a)



(b)



(c)



INTERNATIONAL SEARCH REPORT

Inter	nal Application No
PC	P2005/020662

A. CLASSIFICATION OF SUBJECT MATTER
C02F3/28 C02F3/30

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
C02F

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, PAJ, WPI Data, BIOSIS, COMPENDEX

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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Y	abstract	1-11
X	DATABASE WPI Section Ch, Week 200349 Derwent Publications Ltd., London, GB; Class D15, AN 2003-516614 XP002362300 & JP 2003 047990 A (KURITA WATER IND LTD) 18 February 2003 (2003-02-18)	1,3-6, 9-11
Y	abstract	1-11

☒ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

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Date of the actual completion of the international search

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INTERNATIONAL SEARCH REPORT

Inter	nal Application No
PC	P2005/020662

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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