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(81) **Designated States** *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, JP, KE, KG, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) **Designated States** *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

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(54) Title: METHOD AND SYSTEM FOR WASTEWATER TREATMENT USING MEMBRANE BIOREACTOR

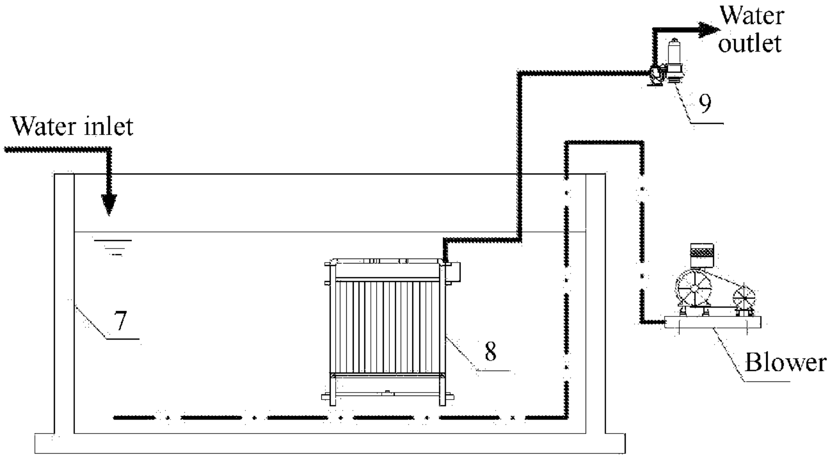

FIG. 8

(57) Abstract: A wastewater treatment system by the membrane bioreactor without physical area division includes a reaction vessel (7), a membrane separation system, a water production system and an aeration system. The membrane separation system is disposed inside the reaction vessel (7). The water production system communicates with the membrane separation system to pump filtrate out of the membrane separation system. The aeration system is employed to aerate the reaction vessel (7) and the membrane separation system. Also provided is a method of wastewater treatment using a membrane bioreactor by controlling aeration to enable a dissolved oxygen concentration to be 0 to 1.5 mg/L, so that the integrated reaction vessel (7) is kept under a facultative environment. The method and the wastewater treatment system by the membrane bioreactor without physical area division existing only under facultative environment, are easy to control and consume less dissolved oxygen.

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METHOD AND SYSTEM FOR WASTEWATER TREATMENT USING MEMBRANE BIOREACTOR

TECHNICAL FIELD

[0001] The invention relates to the field of wastewater treatment, and more particularly to a method and a system for wastewater treatment using a membrane bioreactor.

BACKGROUND OF THE INVENTION

[0002] As shown in FIG **1**, conventional biochemical methods for wastewater treatment require various dissolved oxygen environments including anaerobic environment, aerobic environment, and facultative anaerobic/anoxic environment. The pollutants are degraded according to the following equations:

$C_{10}H_{19}O_3N + CO_2+SO_4 \rightarrow$ R-COOH $+CH_4+NH_3+H_2S+ H_2O$ (producing odor at anaerobic stage)

$C_{10}H_{19}O_3N + NO^{3-} \rightarrow CO_2+N_2 +H_2O$ (anoxic stage)

$C_{10}H_{19}O_3N + O_2 \rightarrow CO_2+NO3- +H_2O$ (aerobic stage)

$NH_3 + O_2 \rightarrow NO^{3-} +H_2O$ (aerobic stage)

[0003] The molecular formula $C_{10}H_{19}O_3N$ represents an organic compound, and it can be understood that the organic compound can have other molecular structures.

[0004] For conventional wastewater treatment methods with or without membrane bioreactor (MBR), areas of different dissolved oxygen environments are disposed in one reaction system, as shown in FIGS. 2 and 4. That is to say, solid structures must be constructed to provide different dissolved oxygen environments for the degradation of pollutants. As a result, the wastewater treatment system has complex structure, multiple control points, high energy consumption, difficult maintenance and unstable operation.

SUMMARY OF THE INVENTION

[0005] In view of the above-described problems, it is one objective of the invention to provide a method and a system for wastewater treatment using a membrane bioreactor.

[0006] To achieve the above objective, in accordance with one embodiment of the invention, there is provided a method of wastewater treatment using a membrane bioreactor, the membrane bioreactor comprising a reaction vessel and an aeration system, the method comprising: controlling an aeration rate of the aeration system to enable a dissolved oxygen concentration in the reaction vessel to be larger than 0 and smaller than 1.5 mg/L, so that the reaction vessel is maintained at a facultative-organism-adapted environment. The membrane bioreactor further comprises a membrane separation system, a dissolved oxygen concentration in the membrane separation system is larger than 0 and smaller than 1.5 mg/L, and the reaction vessel excluding the membrane separation system is larger than 0 and smaller than 0.5 mg/L, and the dissolved oxygen concentration in the membrane separation system is higher than the dissolved oxygen concentration in the reaction vessel excluding the membrane separation system.

[0007] The degradation process of phosphorus in the pollutants is as follows:

Organisms + Phosphate + Facultative organisms → Microbial cells (organophosphorus)

Microbial cells (organophosphorus) + Facultative organisms → P_2H_4/PH_3

[0008] The degradation process of nitrogen in the pollutants is as follows:

$1/2NH_4^+$ (ammonia nitrogen) + $1/2H_2O$ + $1/4O_2$ + facultative organisms → $1/2NO_2^-$ + 2e

$+ 3H^+$

$1/2NH_4^+$ (ammonia nitrogen) + $1/2NO_2^-$ + facultative organisms $\rightarrow 1/2N_2 + H_2O$

[0009] As nitrogen concentration in inlet water changes, a nitrogen degradation process in the reaction system is accompanied by short-cut nitrification and denitrification and the like reactions.

[0010] In accordance with another embodiment of the invention, there is provided a system for wastewater treatment using a membrane bioreactor, comprising: a reaction vessel, the membrane separation system, a water production system, and an aeration system. The membrane separation system is disposed in the reaction vessel. The water production system communicates with the membrane separation system for pumping a filtrate out of the membrane separation system. The aeration system is employed to aerate the reaction vessel and the membrane separation system. The aeration system is adapted to enable a dissolved oxygen concentration in the reaction vessel to be larger than 0 and smaller than 1.5 mg/L, so that the reaction vessel is maintained at a facultative-organism -adapted environment. A dissolved oxygen concentration in the membrane separation system is larger than 0 and smaller than 1.5 mg/L, and the reaction vessel excluding the membrane separation system is larger than 0 and smaller than 0.5 mg/L, and the dissolved oxygen concentration in the membrane separation system is higher than the dissolved oxygen concentration in the reaction vessel excluding the membrane separation system.

[0011] In a class of this embodiment, the membrane separation system employs a microfiltration membrane or an ultrafiltration membrane.

[0012] In a class of this embodiment, the aeration system employs microporous aeration, perforated aeration, or a combination thereof.

[0013] In a class of this embodiment, the membrane separation system is flushed by concentrating an aeration rate at the membrane separation system by the aeration system.

[0014] In a class of this embodiment, the membrane separation system is concentratedly aerated by increasing an amount of holes or bore size of a perforated aeration pipe corresponding to the membrane separation system.

[0015] In a class of this embodiment, the membrane separation system is concentratedly aerated by increasing an amount of microporous aeration disks corresponding to the membrane separation system.

[0016] Compared with existing technologies, advantages of the method and system of wastewater treatment using the membrane bioreactor without physical area division are as follows: the reaction vessel is maintained at a facultative-organism-adapted environment, which is easy to control and consume less dissolved oxygen. The dissolved oxygen concentration in the membrane separation system is higher for the convenience of scouring.

BRIEF DESCRIPTION OF THE DRAWINGS

[0017] FIG **1** is a flow chart of a conventional biochemical method of wastewater treatment;

[0018] FIG **2** is a flow chart of a conventional wastewater treatment method using a membrane bioreactor;

[0019] FIG **3** is a flow chart of a wastewater treatment method of the invention;

[0020] FIG **4** is dissolved oxygen concentrations of a conventional biochemical method of wastewater treatment;

[0021] FIG **5** is a dissolved oxygen concentration of a wastewater treatment method of the invention;

[0022] FIG **6** is a schematic diagram of a perforated aeration pipe of a wastewater treatment system comprising a membrane bioreactor in accordance with one exemplary embodiment of the invention;

[0023] FIG **7** is a schematic diagram of a microporous aeration structure of a wastewater treatment system comprising a membrane bioreactor in accordance with one exemplary embodiment of the invention;

[0024] FIG **8** is a schematic diagram of a wastewater treatment system comprising a membrane bioreactor in example 1;

[0025] FIG **9** is a schematic diagram of a wastewater treatment system comprising a membrane bioreactor in example 2; and

[0026] FIG **10** is a schematic diagram of a wastewater treatment system comprising a membrane bioreactor in example 3.

DETAILED DESCRIPTION OF THE EMBODIMENTS

[0027] For further illustrating the invention, experiments detailing a method and a system for wastewater treatment using a membrane bioreactor are described below. It should be noted that the following examples are intended to describe and not to limit the invention.

[0028] The method of wastewater treatment using a membrane bioreactor comprising a reaction vessel and an aeration system is provided. The method comprises controlling the aeration rate of the aeration system to enable a dissolved oxygen concentration in a reaction vessel to be larger than 0 and smaller than 1.5 mg/L, so that the reaction vessel is maintained at a facultative-organism-adapted environment. Preferably, the dissolved oxygen concentration is below 1.5 mg/L in the membrane separation system, and concentrations are below 0.5 mg/L in other areas. The dissolved oxygen concentration in the membrane separation system is higher than those of other areas so as to guarantee scour intensity, and the concentration difference has no influence on the facultative environment of the reaction system. The wastewater treatment system by the membrane reactor without the area division employs a facultative membrane reactor (FMBR). A flow chart of the method of wastewater treatment by the membrane reactor without physical area division is shown as FIG **3**.

[0029] A dissolved oxygen concentration of a method of wastewater treatment by the membrane bioreactor without physical area division is shown as FIG **5**. Under a facultative environment, characteristic organisms comprise aerobic organisms, anaerobic organisms, and mostly facultative organisms, and the organisms coexist in one reaction zone. Macromolecule pollutants are degraded into micromolecule and are further gasified. Phosphorus in the pollutant is not discharged in the sludge, but is gasified and discharged in the form of phosphine or biphosphine. Nitrogen in the pollutant is not only degraded via nitrification and denitrification or short-cut nitrification and denitrification, but also is gasified and degraded via anaerobic ammonium oxidation bacteria. Dead organisms (organic residual sludge) can be utilized as the nutrient source of the living organisms and are not discharged form the reactor, thereby realizing zero discharge of organic residual sludge during the whole reaction process.

[0030] The pollutant degradation process of the method of wastewater treatment by the membrane bioreactor without physical area division is shown as follows:

[0031] Organisms + Phosphate + Facultative organisms → Microbial cells (organophosphorus)

[0032] Microbial cells (organophosphorus) + Facultative organisms → P_2H_4/PH_3

[0033] $1/2NH_4^+$ (Ammonia nitrogen) + $1/2H_2O$ + $1/4O_2$ + Facultative organisms → $1/2NO_2^-$ + 2e + $3H^+$

[0034] $1/2NH_4^+$ (Ammonia nitrogen) + $1/2NO_2^-$ + Facultative organisms → $1/2N_2$ + H_2O

Example 1

[0035] As shown in FIG **8**, a wastewater treatment system comprising a membrane bioreactor employed an integrated wastewater processor using membrane technology, comprising a reaction vessel **7**, a membrane separation system, a water production system, and an aeration system. Areas in the reaction vessel **7** are not divided via separators. The membrane separation system adopted an ultrafiltration membrane assembly **8**. The water production system pumped water via a water production pump **9**. A blower and an aeration pipe were adopted to aerate in the aeration system. Domestic wastewater passed through the reaction vessel **7**, and the blower **3** or **4** controlled aeration to offer oxygen. As shown in FIG **6**, a perforated aeration pipe **2** was employed to aerate beneath the ultrafiltration membrane assembly **1**, and microporous aeration disks **5** and aeration pipes **6** and were employed to aerate at other areas as shown in FIG **7**, thereby forming a facultative reaction zone in the processor. A dissolved oxygen concentration at the membrane was controlled at 0.8-1.2 mg/L, and the dissolved oxygen concentration at other regions was controlled at 0.5-1 mg/L. The pollutants were degraded and removed via a high-efficiency degradation of high-concentration characteristic organism, and finally the pollutants were filtrated via the ultrafiltration membrane assembly disposed on the reaction zone, thereby realizing zero discharge of organic residual sludge during the whole reaction process.

Example 2

[0036] As shown in FIG **9**, a wastewater treatment system comprising a membrane bioreactor employed an integrated wastewater processor using membrane technology, comprises a reaction vessel **10**, a membrane separation system, a water production system, and an aeration system. Areas in the reaction vessel **10** were divided into two, three, or more reaction zones via separators **11**. The membrane separation system adopted an ultrafiltration membrane assembly **12**. The water production system pumped water via a water production pump **13**. A blower and an aeration pipe were adopted to aerate in the aeration system. Domestic wastewater passed through the processor, and the blower offered oxygen for the integrated reaction zone, or each reaction zone was aerated by a plurality of blowers with a similar aeration rate. As shown in FIG. **6**, a perforated aeration system was employed to aerate, and the holes of a perforated pipe per unit area beneath the membrane assembly were more than those of other areas, thereby forming a facultative reaction zone in the processor. A dissolved oxygen concentration at the membrane was controlled at 0.9-1.4 mg/L, and the dissolved oxygen concentration at other regions was controlled at 0.2-0.5 mg/L. The pollutants were degraded and removed via a high-efficiency degradation of high-concentration characteristic organism, and finally the pollutants were filtrated via the ultrafiltration membrane assembly disposed on the reaction zone, thereby realizing zero discharge of organic residual sludge during the whole reaction process.

Example 3

[0037] As shown in FIG. **10**, a wastewater treatment system comprising a membrane bioreactor employed an integrated wastewater processor using membrane technology, comprising a reaction vessel, a membrane separation system, a water production system, and an aeration system. The reaction vessel employed a civil pool construction, comprising a reaction pool **14** which was a water inlet and a reaction pool **15** which was a water outlet, and the two pools were connected via a pipe. The membrane separation system employed an ultrafiltration membrane assembly **16**, and the ultrafiltration membrane assembly **16** was disposed on the reaction pool **15** alone. The water production system pumped water via a water production pump **17**. A blower and an aeration pipe were adopted to aerate in the aeration system. Domestic wastewater passed through the reaction system, and the blower offered oxygen for the two reaction pools, or each reaction pool was aerated by two blowers with a similar aeration. As shown in FIG **7**, a microporous aeration structure was employed to aerate, and microporous aeration disks beneath the membrane assembly were more than those of other areas, thereby forming a facultative reaction zone in the processor. A dissolved oxygen concentration at the reaction pool with the membrane assembly was controlled at 0.9-1.3 mg/L, and the dissolved oxygen concentration at other areas is controlled at 0.2-0.5 mg/L. The pollutants were degraded and removed via a high-efficiency degradation of high-concentration characteristic organism, and finally the pollutants were filtrated via the ultrafiltration membrane assembly disposed on the reaction zone, thereby realizing zero discharge of organic residual sludge during the whole reaction process.

CLAIMS

1. A method of wastewater treatment using a membrane bioreactor, the membrane bioreactor comprising a reaction vessel and an aeration system, the method comprising: controlling an aeration rate of the aeration system to enable a dissolved oxygen concentration in the reaction vessel to be larger than 0 and smaller than 1.5 mg/L, so that the reaction vessel is maintained at a facultative-organism-adapted environment.

2. The method of claim 1, wherein the membrane bioreactor further comprises a membrane separation system, a dissolved oxygen concentration in the membrane separation system is larger than 0 and smaller than 1.5 mg/L, and the reaction vessel excluding the membrane separation system is larger than 0 and smaller than 0.5 mg/L, and the dissolved oxygen concentration in the membrane separation system is higher than the dissolved oxygen concentration in the reaction vessel excluding the membrane separation system.

3. A wastewater treatment system comprising a membrane bioreactor, the membrane bioreactor comprising:

   a) a reaction vessel;

   b) a membrane separation system;

   c) a water production system; and

   d) an aeration system;

   wherein

   the membrane separation system is disposed in the reaction vessel;

the water production system communicates with the membrane separation system to pump filtrate out of the membrane separation system;

the aeration system is employed to aerate the reaction vessel and the membrane separation system;

the aeration system is adapted to enable a dissolved oxygen concentration in the reaction vessel to be larger than 0 and smaller than 1.5 mg/L, so that the reaction vessel is maintained at a facultative-organism-adapted environment.

4. The wastewater treatment system of claim 3, wherein a dissolved oxygen concentration in the membrane separation system is larger than 0 and smaller than 1.5 mg/L, and the reaction vessel excluding the membrane separation system is larger than 0 and smaller than 0.5 mg/L, and the dissolved oxygen concentration in the membrane separation system is higher than the dissolved oxygen concentration in the reaction vessel excluding the membrane separation system.

5. The wastewater treatment system of claim 3, wherein the membrane separation system employs a microfiltration membrane or an ultrafiltration membrane, and the aeration system employs microporous aeration, perforated aeration, or a combination thereof.

6. The wastewater treatment system of claim 5, the membrane separation system is flushed by concentrating an aeration rate at the membrane separation system by the aeration system.

7. The wastewater treatment system of claim 6, wherein the membrane separation system is concentratedly aerated by increasing an amount of holes or bore size of a perforated

aeration pipe corresponding to the membrane separation system.

8. The wastewater treatment system of claim 6, wherein the membrane separation system is concentratedly aerated by increasing an amount of microporous aeration disks corresponding to the membrane separation system.

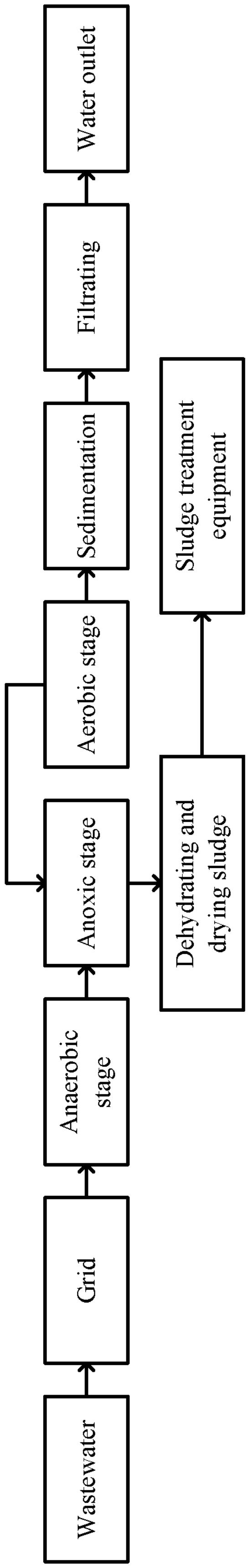
Wastewater
Grid
Anaerobic stage
Anoxic stage
Aerobic stage
Sedimentation
Filtrating
Water outlet
Dehydrating and drying sludge
Sludge treatment equipment

FIG. 1

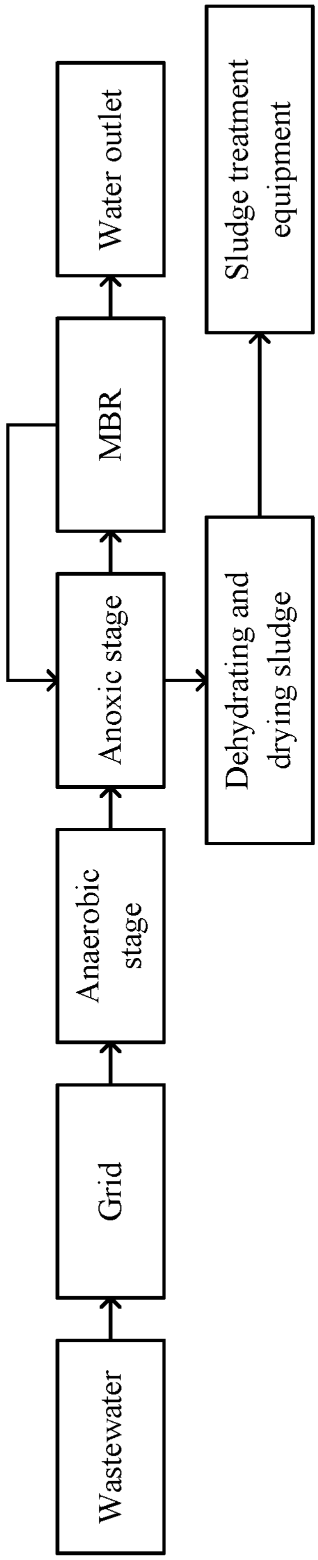
Wastewater
Grid
Anaerobic stage
Anoxic stage
MBR
Water outlet
Dehydrating and drying sludge
Sludge treatment equipment

FIG. 2

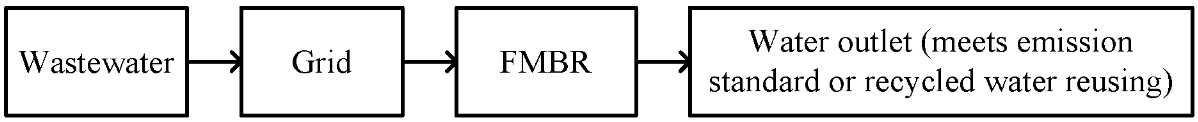
Wastewater
Grid
FMBR
Water outlet (meets emission standard or recycled water reusing)

FIG. 3

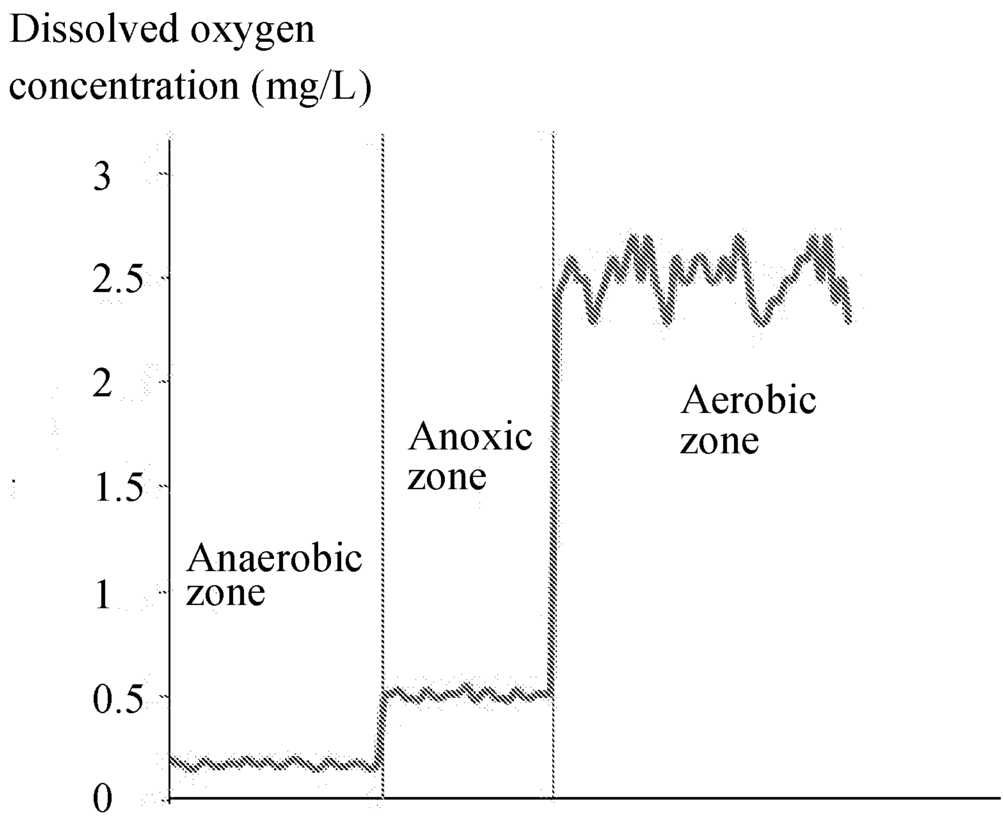
Dissolved oxygen concentration (mg/L)
3
2.5
2
1.5
1
0.5
0
Anaerobic zone
Anoxic zone
Aerobic zone

FIG. 4

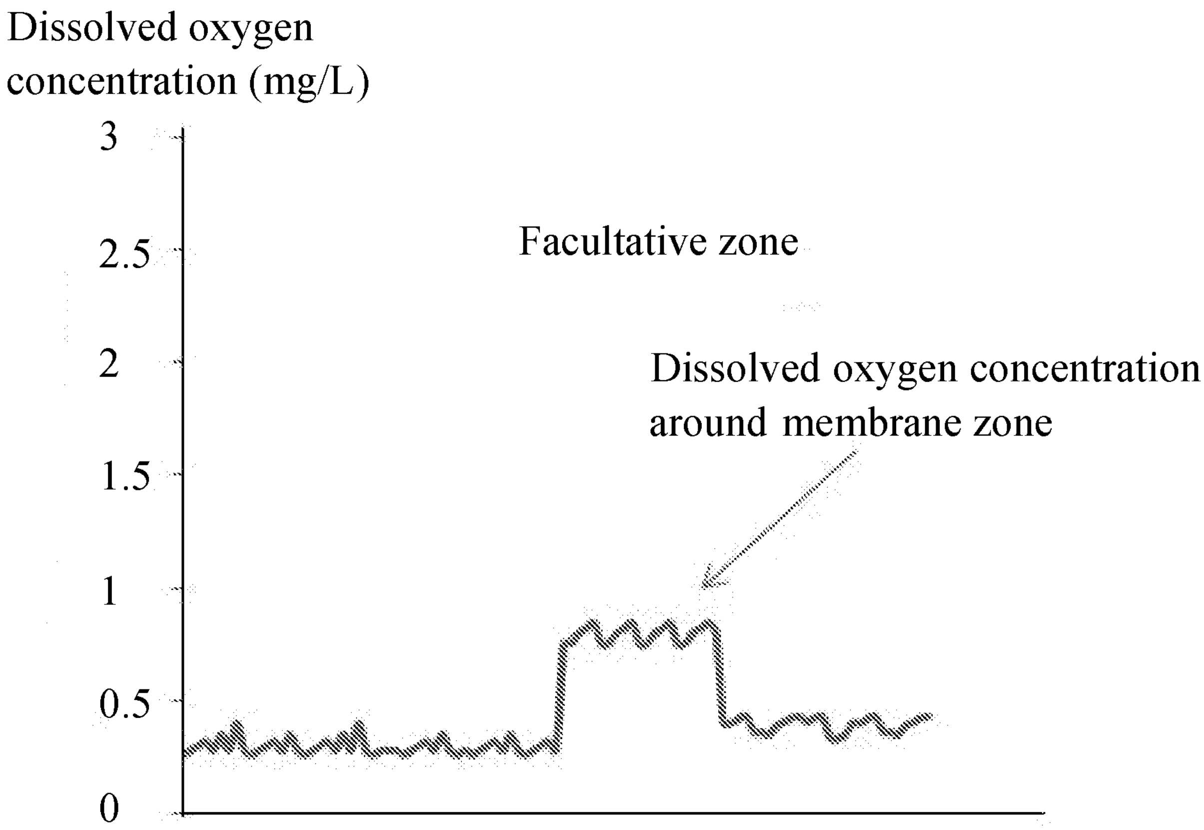
Dissolved oxygen concentration (mg/L)
3
2.5
2
1.5
1
0.5
0
Facultative zone
Dissolved oxygen concentration around membrane zone

FIG. 5

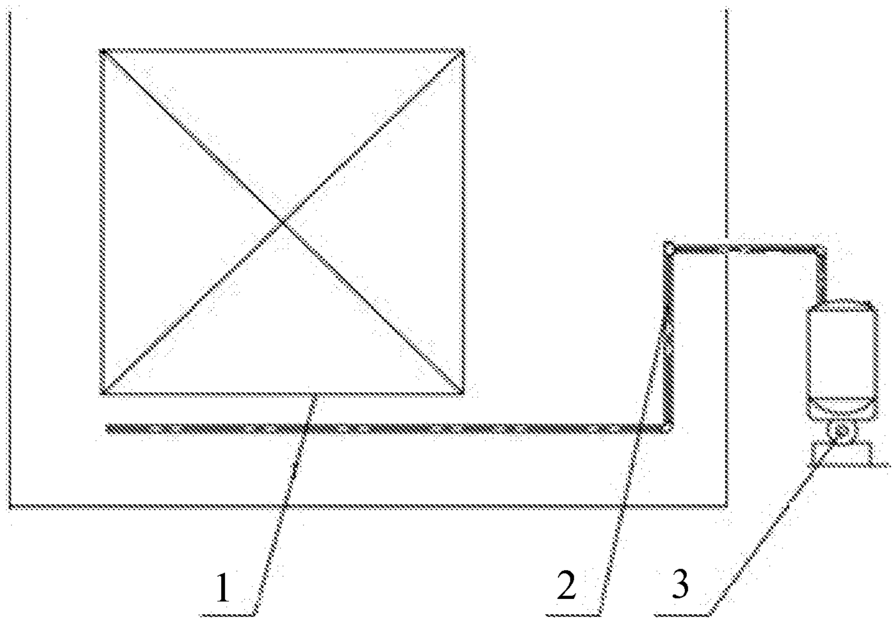
1
2
3

FIG. 6

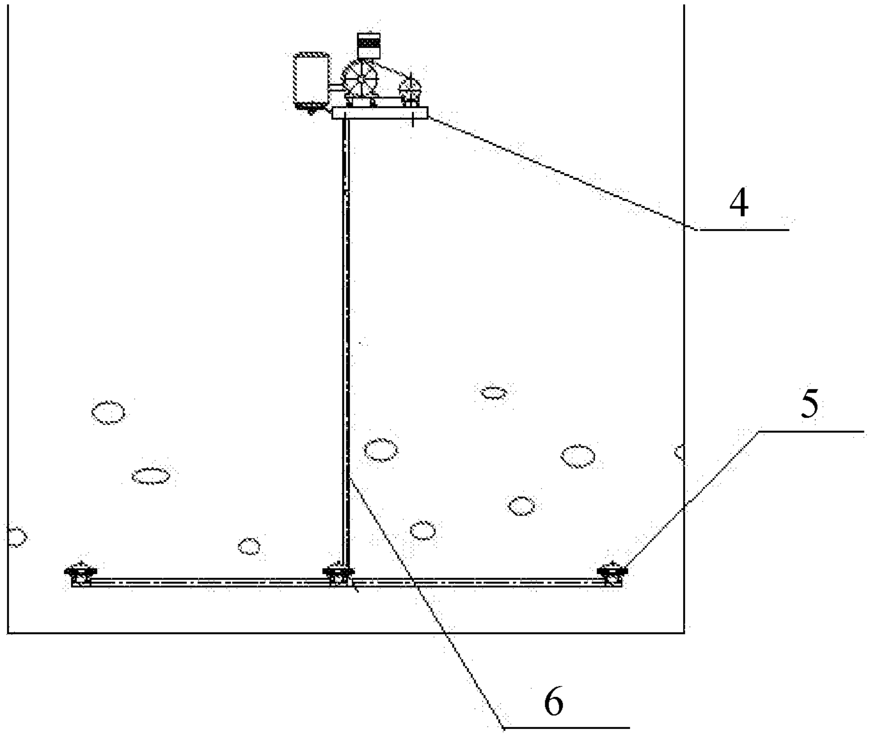

FIG. 7

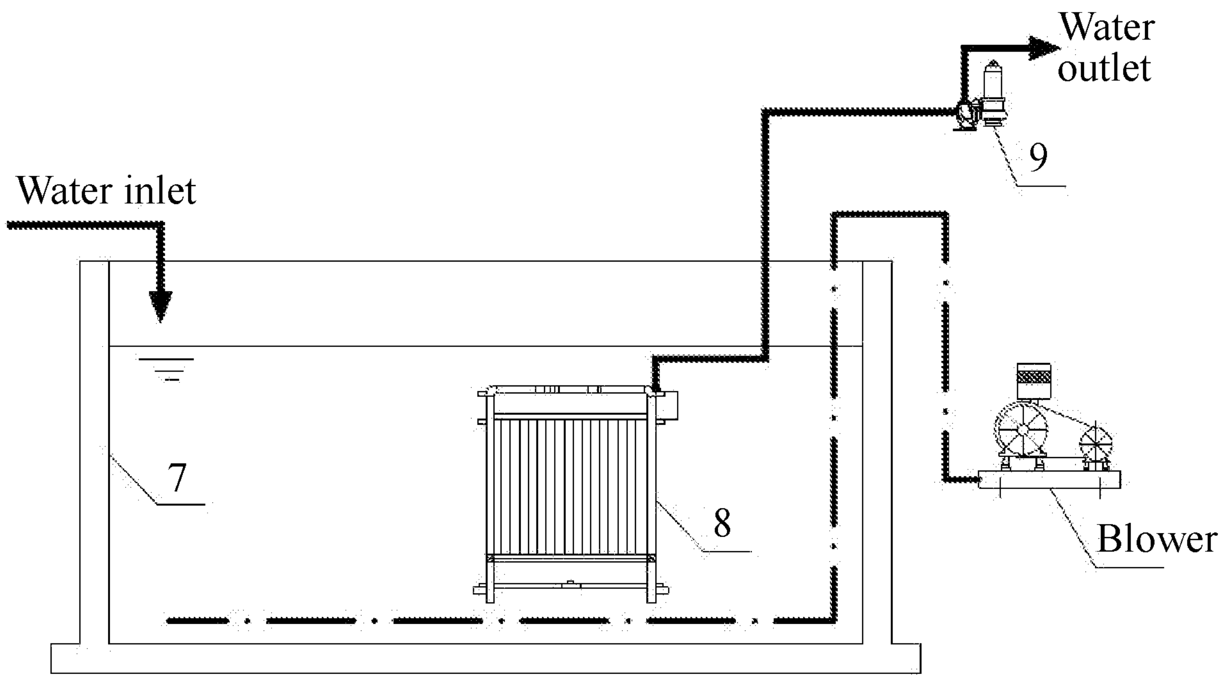

FIG. 8

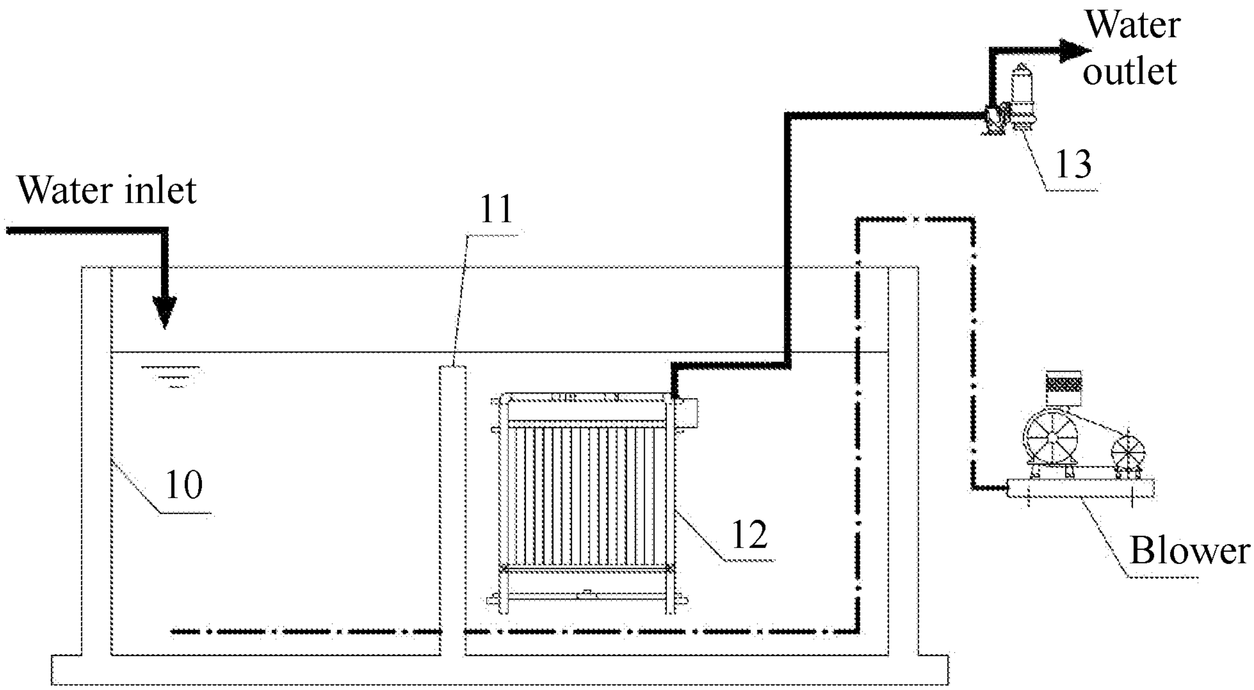
Water outlet
Water inlet
11
13
10
12
Blower

FIG. 9

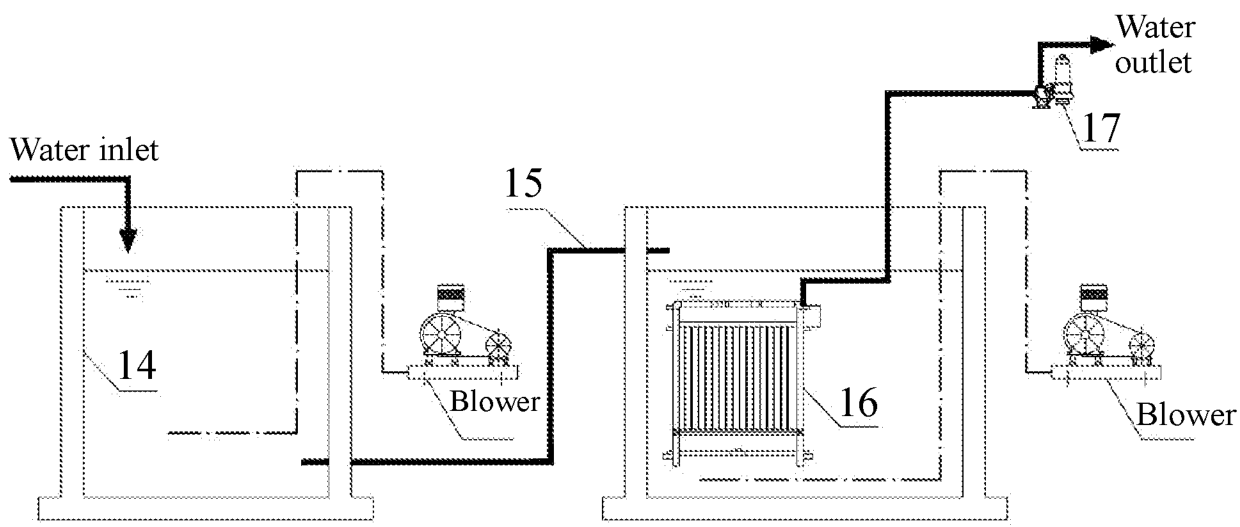
Water outlet
Water inlet
17
15
14
Blower
16
Blower

FIG. 10

INTERNATIONAL SEARCH REPORT

International application No.
PCT/CN2015/091153

A. CLASSIFICATION OF SUBJECT MATTER

C02F 3/30(2006.01)i

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 practicable, search terms used)

CNABS; CNPAT; EPODOC; WPI; CNKI; Elsevier Sciencedirect: MBR, membrane, bioreactor, facultative, DO, dissolved, oxygen, ORP, redox, potential, oxidation, reduction, aeration

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
E	CN 205061691 U (JIANGXI JDL ENVIROMENTAL PROT RES AND DEV CT CO.， LTD.) 02 March 2016 (2016-03-02) claims 1-6	3-7
X	CN 101885537 A (JIANGXI JDL ENVIROMENTAL PROT RES AND DEV CT CO.， LTD.) 17 November 2010 (2010-11-17) claim 1	1-8
X	US 2010288697 A1 (SHENZHEN JDL ENVIRONMENTAL PROT) 18 November 2010 (2010-11-18) claims 1 and 2	1-8
X	US 2010288698 A1 (JIANGXI JDL ENVIROMENTAL PROT RES LTD) 18 November 2010 (2010-11-18) description， paragraphs [0022]-[0024]， and figure 1	1-8
X	CN 102730914 A (JIANGXI JDL ENVIROMENTAL PROT RES LTD) 17 October 2012 (2012-10-17) claims 1 and 3	1-8

☑ Further documents are listed in the continuation of Box C. ☑ See patent family annex.

* Special categories of cited documents:

- "A" document defining the general state of the art which is not considered to be of particular relevance
- "E" earlier application or patent but published on or after the international filing date
- "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
- "O" document referring to an oral disclosure, use, exhibition or other means
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- "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
- "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
- "&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
17 May 2016	**07 June 2016**

Name and mailing address of the ISA/CN	Authorized officer
STATE INTELLECTUAL PROPERTY OFFICE OF THE P.R.CHINA **6, Xitucheng Rd., Jimen Bridge, Haidian District, Beijing 100088, China**	**CAO,Meng**
Facsimile No. **(86-10)62019451**	Telephone No. **(86-10)62084995**

INTERNATIONAL SEARCH REPORT

International application No.
PCT/CN2015/091153

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	EP 2251307 A1 (SHENZEN JDL ENVIRONMENTAL PROT) 17 November 2010 (2010-11-17) claims 1 and 3	1-8
X	LIAO，Zhimin et al. "A new process of aerobic membrane bioreactor for treatment of biogas slurry" *Journal of Jiangxi University of science and technology,* Vol. 34, No. 3, 30 June 2013 (2013-06-30), ISSN: 1007-1229, sections 1.2 and 2.1，and figure 1	1-8

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/CN2015/091153

Patent document cited in search report			Publication date (day/month/year)	Patent family member(s)			Publication date (day/month/year)
CN	205061691	U	02 March 2016	None			
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				JP	2010264435	A	25 November 2010
				EP	2251309	A1	17 November 2010
				JP	5864831	B2	17 February 2016
				CN	101885539	B	20 June 2012
				US	8173019	B2	08 May 2012
				INCHE	200902301	A	26 November 2010
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				EP	2253596	A1	24 November 2010
				JP	5352528	B2	27 November 2013
				JP	2010264444	A	25 November 2010
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CN	102730914	A	17 October 2012	CN	102730914	B	02 April 2014
EP	2251307	A1	17 November 2010	US	2010288696	A1	18 November 2010
				JP	5596949	B2	24 September 2014
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				CN	101885570	B	04 April 2012
				CN	101885570	A	17 November 2010
				US	8262911	B2	11 September 2012
				INCHE	200902299	A	26 November 2010