

Near-Zero Carbon Sewage Ecological Treatment System and Method

Technical Field

The present application falls within the technical field of sewage treatment, and specifically relates to a near-zero carbon sewage ecological treatment system and method.

Background Art

With the continuous development of the urbanization process, the rapid development of the construction industry, transportation industry, and manufacturing industry leads to the generation of greenhouse gas, sewage, and industrial waste in urban areas, thereby bringing some pressure to the urban bearing capacity. Among them, the direct impact of the greenhouse gas (GHG) represented by CO₂ on the global climate deterioration has become increasingly prominent, such as the frequent occurrence of extreme rainstorms, rising sea level, polar glacier melting, frequent occurrence of extremely cold weather, etc. and the production of greenhouse gases is closely related to industrial production, daily transportation, residents' lives, etc.

The traditional sewage treatment technology needs to consume the electric energy generated by fossil energy in the aeration and dosing, and the electric energy manufacturing process produces carbon dioxide, which belongs to a carbon emission process. The electric energy consumed by the aeration in the whole sewage treatment process is also mainly produced by fossil fuel production, and a large number of greenhouse gases and harmful gases is produced in this process. According to the existing research by scholars, by using engineering SBR, An/O^b, pre-anoxia+A²/O, and other processes, treating every cubic meter of sewage produces the direct gas of 150-500g CO₂, indirect gas of 200-320g CO₂ and total gas releasing amount of 380-830g CO₂. When the ecological surface flow constructed wetland technology and horizontal subsurface flow constructed wetland technology are used, treating every cubic meter of the sewage produces direct gas 340-350g CO₂, indirect gas 99g CO₂, and total gas releasing amount of 440-450g CO₂. From the above carbon emission analysis, the existing sewage treatment technology is a carbon emission process generated by CO₂.

To sum up, when the existing sewage treatment methods are used to treat the sewage, a large number of carbon dioxide, methane, and other greenhouse gases

will be discharged, which aggravates the greenhouse gas effect on the bioclimatic environment. At the same time, the existing municipal sewage treatment plants use a lot of machinery and equipment and thus have high energy consumption. Therefore, the existing constructed wetland technology occupies a large area, and the treatment efficiency is low.

Summary of the Invention

In view of the above analysis, the present invention aims at providing a near-zero carbon sewage ecological treatment system and method for solving the problem that the existing sewage treatment methods emit a large number of greenhouse gases, exacerbating the impact of the greenhouse gas effect on the climate and environment. The object of the invention is achieved as follows.

In one aspect, a near-zero carbon sewage ecological treatment system is provided, comprising:

a solar power supply system for supplying electric energy for system operation; and a sewage ecological treatment system, comprising a sewage ecological treating tank, a plant carbon-sequestrating purification tank, and a recycling tank; wherein the sewage ecological treating tank comprises a water distribution layer, a filtering and purifying layer, a water storage layer, and a sludge discharge layer arranged from top to bottom, the water distribution layer is connected to a sewage source via a water distribution device, and the water storage layer is connected to the recycling tank via a draining device; a plant carbon-sequestrating layer is provided in the plant carbon-sequestrating purification tank, the plant carbon-sequestrating layer is provided above the water distribution layer, a light-transmitting cover is provided above the plant carbon-sequestrating layer, and a net carbon plant is planted in an enclosed space formed by the light-transmitting cover.

Further, the near-zero carbon sewage ecological treatment system further comprises an air interchanging device and an exhaust gas collecting device, wherein both the air interchanging device and the exhaust gas collecting device are in communication with the enclosed space of the light-transmitting cover, and an oxygen concentration sensor is provided in the enclosed space of the light-transmitting cover; the air interchanging device is used for supplying air into the enclosed space of the light-transmitting cover when the enclosed space has a low oxygen concentration; the

exhaust gas collecting device is used for discharging and collecting exhaust gas generated in the plant carbon-sequestrating purification tank.

Further, the near-zero carbon sewage ecological treatment system further comprises a control and display system configured to control the water distribution device to supplement a water level in the water distribution layer to H1 within time T2 when the water level of the water distribution layer decreases from H1 to H2 within time T1; wherein $H2=H1-V/S$, $T2=0.13\sim0.16T3$;

in the above formula: H1 is a maximum water-distribution water level (m);

H2 is a minimum water-distribution water level (m);

V is a volume of sewage treated in a single purifying treatment cycle of a system (m^3);

S is a water distribution area of the system (m^2);

T1 is the running time of a single purifying treatment cycle of the system;

T2 is the water distribution time of a single purifying treatment cycle of the system;

T3 is the total time of the water level of the water distribution layer from when reaching moment H1 to the time when the oxygen concentration in the plant carbon sequestration tank reaches C1, wherein C1 is 13% vol~14.8% vol.

Further, T1 is 8~12h and T2 is 1~2h.

Further, the bulk of the sewage ecological treating tank is 3-5 times of the volume V of the sewage treated in a single purifying treatment cycle of the system, and the hydraulic loading is $0.53\sim1.06\ m^3/(m^2\cdot d)$.

Further, the control and display system is further configured to operate the air interchanging device when the oxygen concentration in the plant carbon sequestration purification tank reaches C1, pass air into the plant carbon-sequestrating layer through an air outputting pipe of the air interchanging device, and discharge and collect exhaust gas from the plant carbon-sequestrating layer via an exhaust gas exhaust pipe of the exhaust gas collecting device; when an oxygen concentration value in the plant carbon-sequestrating layer is C2, the air interchanging device stops working, wherein $C2=1.3\sim1.7\ C1$.

Further, the filtering and purifying layer includes a primary purifying layer and a secondary purifying layer arranged from top to bottom; the primary purifying layer is filled with shale ceramsite, and the secondary purifying layer is filled with composite activated alumina particles.

Further, the drainage device comprises a draining pipe and a draining pump provided thereon, a liquid inlet of the draining pipe is located in the water storage layer, and a

liquid outlet of the draining pipe is connected to the recycling tank.

Further, a sludge discharge device is connected to the sludge discharge layer in preparation for discharging the sludge; the sludge discharge device comprises a sludge discharge pipe and a sludge discharge pump provided thereon.

- 5 Further, the net carbon plant is modular vegetation previously grown in a flower pot or a flower box.

Further, the adjusting tank is connected to a sewage source treated by multiple pretreating tanks, and a stirring device and a liquid level sensor are provided in the adjusting tank.

- 10 Further, a water permeable partition is provided between two adjacent layers of the plant carbon-sequestrating layer, the water distribution layer, the primary purifying layer, the secondary purifying layer, the water storage layer, and the sludge discharge layer.

- 15 Further, both the primary purifying layer and the secondary purifying layer adopt a modular structure.

- Further, the sewage ecological treatment system further comprises a pretreating tank and an adjusting tank, wherein the adjusting tank is provided upstream of the sewage ecological pretreating tank via a pipeline, the pretreating tank is provided upstream of the adjusting tank via a pipeline, the treating tank is connected to an upstream sediment tank via a pipeline, and the sediment tank is connected to an upstream sewage source.
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- Further, the water distribution device comprises a water distribution pump, the liquid inlet of the water distribution pump is in communication with the adjusting tank via a water inlet pipe, and the liquid outlet of the water distribution pump is in communication with the water distribution layer via a water distribution pipe.
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Further, the water distribution pipe is connected to multiple water distribution branch pipes, and the multiple water distribution branch pipes are uniformly arranged in the water distribution layer; a liquid level sensor is provided in the water distribution layer.

- In another aspect, there is provided a near-zero carbon sewage ecological treatment method using the above-mentioned near-zero carbon sewage ecological treatment system.
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Further, the method comprises the steps:

constructing a solar power supply system and a sewage ecological treatment system; and

supplying the domestic sewage to the sediment tank and then to the sewage ecological treatment system for purification treatment, and discharging purified sewage into the recycling tank for use at a water consuming point;

wherein the domestic sewage entering the sewage ecological treatment system firstly enters the sediment tank, settles large particle impurities under the action of gravity, then enters a pretreating tank, and overflows into the adjusting tank after being filtered by a filter assembly in the pretreating tank;

when the adjusting tank reaches a pre-set water level, a water distribution pump is started to supply the sewage in the adjusting tank into the water distribution layer via a water distribution pipe, and the sewage distributes water to the sewage ecological

treating tank from top to bottom in the water distribution layer; the sewage in the water distribution layer successively enters the primary purifying layer and the secondary purifying layer, the sewage ecological treating tank is added with *Pseudomonas stutzeri*, and the sewage treated by the secondary purifying layer enters the water storage layer, and is fed into the recycling tank via the draining device for use at the water consuming point;

in a process of sewage purification treatment, a net carbon plant adsorbs nitrogen, phosphorus, and other organic matters in the sewage, and at the same time, absorbs CO₂ gas generated during sewage treatment through photosynthesis.

Further, the oxygen concentration sensor monitors the oxygen concentration in the sealed space above the plant carbon-sequestrating layer in real time. When the oxygen concentration in the plant carbon-sequestrating layer reaches a C1 value, the air interchanging pump starts to work to pass the air into the plant carbon-sequestrating layer through the air output pipe, and discharge the exhaust gas into the lime water filtering tank through the exhaust gas exhaust pipe; when the oxygen concentration value in the plant carbon-sequestrating layer is C2, the air interchanging pump stops working.

Further, the energy required for the operation of the entire sewage ecological treatment system is provided by a solar power supply system.

Compared with the prior art, the present invention can achieve at least one of the following advantageous effects.

a) The solar power supply system is used to replace the traditional power supply system to supply energy for the whole sewage ecological treatment system. Compared with the traditional sewage treatment process, the carbon emission is

reduced by 10.00%. The sewage ecological treatment system realizes the low-carbonization ecological treatment of the sewage, which could avoid the generation of a large amount of carbon-containing gas and realize large-scale reduction. Compared with the traditional sewage treatment process, the carbon emission is reduced by 78.57%. Aquatic plants with strong adsorption, good nitrogen removal effect, and high photosynthetic efficiency are planted in the plant carbon-sequestrating purification tank. In the process of sewage treatment, the plant root solidifies the carbon in the sewage, and the low concentration of carbon dioxide produced is absorbed by plants through photosynthesis to achieve the maximum degradation. Compared with the traditional sewage treatment process, 8.57% carbon emission is reduced. The near-zero carbon sewage treatment system of the present invention can cumulatively achieve a reduction in carbon emissions of about 97.14%.

b) A suitable gas composition is maintained in the enclosed space above the plant carbon-sequestrating layer by the air interchanging device and the exhaust gas collecting device, so as to achieve the continuous and stable operation of the system.

c) The present invention reduces the emission of greenhouse gases from the source, reduces the generation of carbon, reduces carbon transmission, realizes low-carbon sewage ecological treatment on the carbon emission of the sewage, and is of great significance to assist in the realization of the carbon peaking and carbon neutrality goals.

Brief Description of the Drawings

In order to illustrate the embodiments of the present description or the technical solutions in the prior art more clearly, the following will briefly introduce the drawings that need to be used in the description of the embodiments or the prior art. It is obvious that the drawings in the following description are only some embodiments described in the embodiments of the present description. For those of ordinary skills in the art, other drawings can be obtained according to these drawings.

Fig. 1 is a schematic view illustrating a structure of a near-zero carbon sewage ecological treatment system according to the present invention;

Fig. 2 is a schematic view illustrating a structure of a sewage ecological treatment system according to the present invention;

Fig. 3 is a schematic cross-sectional view of a sewage ecological treatment system according to the present invention;

Fig. 4 is a schematic view illustrating a structure of a modular purifying layer of a sewage ecological treatment system according to the present invention;

Fig. 5 is a schematic view of the control logic of a sewage ecological treatment method according to the present invention.

5 Reference numerals:

1, domestic sewage;

2, sediment tank;

3, sewage ecological treatment system; 31, pretreating tank; 32, adjusting tank; 33, sewage ecological treating tank; 331, water inlet pipe; 332, water distribution pump,

10 333, water distribution pipe; 333-1, water distribution branch pipe; 334, water

distribution layer; 335, primary purifying layer; 335-1, primary purification module a;

335-2, primary purification module b; 335-3, primary purification module c; 335-4,

primary purification module d; 335-5, primary purification module e; 336, secondary

purifying layer; 336-1, secondary purification module a; 336-2, secondary purification

15 module b; 336-3, secondary purification module c; 336-4, secondary purification

module d; 336-5, secondary purification module e; 337, water storage layer; 337-1,

draining pipe; 337-2, draining pump; 338, sludge discharge layer; 338-1, sludge

collecting funnel; 338-2, sludge discharge pipe; 338-3, sludge discharge pump; 339,

water permeable partition; 34, recycling tank; 35, plant carbon-sequestrating layer;

20 351, net carbon plant; 352, light-transmitting cover; 36, air interchanging device; 361,

air discharge pipe; 362, air interchanging pump; 363, air intake pipe; 37, exhaust gas

exhaust pipe; 38, lime water filter tank;

4, solar power supply system; 41, solar power; 42, photovoltaic energy storage facility;

and 5, sludge discharge device.

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Detailed Description of the Invention

In order to make the purposes, technical solutions, and advantages of the embodiments of the present application clearer, the technical solutions in the embodiments of the present application will be clearly and completely described

30 below in conjunction with the accompanying drawings in the embodiments of the

present application. Obviously, the described embodiments are a part of the

embodiments of the present application, rather than all the embodiments. Based on

the embodiments of the present application, all other embodiments obtained by one

of ordinary skills in the art without involving any inventive effort are within the scope

of the present application.

In order to facilitate the understanding of the embodiments of the present application, further explanations will be given below with specific embodiments in conjunction with the accompanying drawings, and the embodiments do not constitute limitations to

5 the embodiments of the present application.

In describing the embodiments of the present invention, it needs to be noted that unless otherwise expressly specified and limited, the term "connected" should be interpreted broadly. For example, it can be a fixed connection or a detachable connection, or an integrated connection; it can be a mechanical connection, or an
10 electrical connection; it can be directly connected or indirectly connected through an intermediate medium. For a person of ordinary skills in the art, the specific meaning of the above-mentioned terms in the present invention can be understood according to specific situations.

The terms "top", "bottom", "over", "under", and "on" as used throughout the
15 description are relative positions of the components of a device, e.g. the relative positions of the top substrate and the bottom substrate within the device. It could be understood that the devices are multifunctional regardless of the spatial orientation thereof.

20 Embodiment 1

One specific embodiment of the present invention, as shown in Figs. 1 to 3, discloses a near-zero carbon sewage ecological treatment system, comprising a solar power supply system 4 and a sewage ecological treatment system 3, wherein the solar power supply system 4 provides electric energy for system operation, and the
25 sewage ecological treatment system 3 comprises a sewage ecological treating tank 33, a plant carbon-sequestrating purification tank, and a recycling tank 34;

the sewage ecological treatment system 3 further comprises a pretreating tank 31 and an adjusting tank 32, wherein the adjusting tank 32 is provided upstream of the sewage ecological treating tank 33 via a pipeline, the treating tank 31 is provided
30 upstream of the adjusting tank 32 via a pipeline, the treating tank 31 is connected to the upstream sediment tank 2 via a pipeline, and the sediment tank 2 is connected to at least one sewage source upstream.

The sewage ecological treating tank 33 comprises a water distribution layer 334, a filtering and purifying layer, a water storage layer 337, and a sludge discharge layer

338 arranged from top to bottom, the adjusting tank 32 is in communication with the water distribution layer 334 via a water distribution device, and the sewage preliminarily treated by the pretreating tank 31 and the adjusting tank 32 is fed into the water distribution layer 334 via the water distribution device.

- 5 The water distribution device comprises a water distribution pump 332, and a water inlet pipe 331 and a water distribution pipe 333 connected to the water distribution pump 332; specifically, a liquid inlet of the water distribution pump 332 is connected to the adjusting tank 32 via the water inlet pipe 331, and the liquid outlet of the water distribution pump 332 is in communication with the water distribution layer 334 via
10 the water distribution pipe 333.

Further, in order to achieve uniform water replenishment in the water distribution layer 334, the water distribution pipe 333 connects multiple water distribution branch pipes 333-1, which are uniformly arranged in the water distribution layer 334.

- Further, a liquid level sensor is provided in the water distribution layer 334 for
15 monitoring the liquid level of the water distribution layer 334 in real time. When the water level of the water distribution layer 334 reaches the maximum water-distribution water level H1, the system runs, and the water level in the water distribution layer 334 will gradually decrease; when the water level of the water distribution layer decreases to the minimum water-distribution water level H2 after a running time T1,
20 it is necessary to use the water distribution pump 332 to supplement water into the water distribution layer 334 via the water distribution pipe 333 within time T2 so that the water level in the water distribution layer 334 increases to H1 again; when the liquid level increases to H1, water distribution is stopped.

- The filtering and purifying layer is used for purifying the sewage infiltrated by the
25 water distribution layer 334, and the filtering and purifying layer uses two-stage filtration; specifically, the filtering and purifying layer comprises a primary purifying layer 335 and a secondary purifying layer 336 arranged from top to bottom; among them, the primary purifying layer 335 is filled with shale ceramsite, the particle size of shale ceramsite is 10-15mm, and the layer thickness is 600-800mm; at the same
30 time, the shale ceramsite texture has good adsorption to nitrogen, phosphorus and other pollutants and organic matters in the domestic sewage; the secondary purifying layer 336 is filled with composite activated alumina particles, which have good adsorption for nitrogen, phosphorus and other pollutants and organic matters in the domestic sewage. The size of the composite activated alumina particle is 10-15mm,

and the layer thickness is 600-800mm. The composite activated alumina is an activated alumina layer with the building waste aggregate as the core, the particle size of the building waste aggregate is 5-10mm, and the thickness of the activated alumina layer is 10-5mm. The core unit of an ecological treatment system is constructed by setting a two-stage purifying layer of shale ceramsite + composite activated alumina, and distributing water from top to bottom. Therefore, the purification effect is good.

The water storage layer 337 is used to store purified water purified by the filtration through the filtering and purifying layer, and the water storage layer 337 is connected to the recycling tank 34 through a draining device. Specifically, the drainage device comprises a draining pipe 337-1 and a draining pump 337-2. As an example, a water draining pipe 337-1 is provided in the water storage layer 337, a water draining pump 337-2 is provided on the water draining pipe 337-1, the water in the water storage layer 337 is drained to the recycling tank 34 via the draining pump 337-2 and the draining pipe 337-1, a medicament is added to the recycling tank 34 via a dosing pump, and a lift pump in the recycling tank 34 supplies purified water in the recycling tank 34 to a water consuming point after the quartz sand filter treatment.

The sludge discharge layer 338 is used to contain the accumulated suspended particles generated in the purification and filtration process, and the sludge discharge device 5 is connected to the sludge discharge layer 338 for discharging the sludge. The sludge discharge device 5 comprises a sludge discharge pipe 338-2, a sludge collecting funnel 338-1, and a sludge discharge pump 338-3. Specifically, the sludge discharge pipe 338-2 is provided in the sludge discharge layer 338, the sludge collecting funnel 338-1 is further provided in the sludge discharge layer 338, the sludge discharge pump 338-3 is provided on the sludge discharge pipe 338-2, and the slope of the bottom surface of the sludge discharge layer is 1%, the slope direction being to the sludge discharge pipe 338-2. The sludge in the sludge discharge layer 338 is discharged via the sludge discharge pump 338-3 and the sludge discharge pipe 338-2.

The plant carbon-sequestrating purification tank is a part of a sewage ecological treatment system, a plant carbon-sequestrating layer 35 is provided in the plant carbon-sequestrating purification tank, the plant carbon-sequestrating layer 35 comprises a biological ceramsite layer and a net carbon plant 351 planted on the biological ceramsite layer, a light-transmitting cover 352, such as a glass cover or a

plastic canopy, is covered on the plant carbon-sequestering layer 35, and the net carbon plant 351 grows in an enclosed space formed by the light-transmitting cover 352; the plant with good carbon sequestration performance is used to perform circulated purification on the sewage, and the plant photosynthesis could effectively absorb the carbon dioxide generated during the sewage treatment so as to achieve the role of carbon reduction. Among them, the biological ceramsite has the advantages of light weight, large specific surface area, strong adsorption capacity, etc. as biomembrane carrier filter material.

The sewage ecological treating tank 33 is provided in the underground space below the plant carbon-sequestering layer 35 located above the water distribution layer 334. This structure design helps to realize the integrated arrangement of the sewage ecological treating tank 33 and the plant carbon-sequestering purification tank.

Alternatively, in the present embodiment, the net carbon plant 351 is selected as a plant having an efficient carbon sequestration and oxygen releasing capacity, and the planting pattern is hydroponic cultivation. The net carbon plant 351 is placed in a flower pot or flower box with a depth of about 100-150mm, multiple through holes are provided at the bottom of the flowerpot or flower box, the root of the net carbon plant 351 passes through the through holes into the water distribution layer 334, and the biological ceramsite with a particle size of 20-30mm is used to carry out filling. See Table 1 for details.

Table 1 Net Carbon Plant Selection and Capacity Analysis Table

Serial Number	Name	Carbon sequestration capacity (g/m ² ·d)	Oxygen releasing capacity (g/m ² ·d)	Planting density (number/m ²)	Planting pattern
1	Reed	19.00	13.38	16	Hydroponic cultivation
2	Polygonum hydropiper Linn	14.56	10.26	16	Hydroponic cultivation

3	Typha	10.16	7.16	16	Hydroponic cultivation
4	Acorus calamus	14.32	7.56	16	Hydroponic cultivation
5	Salix integra	1.93	1.34	18	Hydroponic cultivation
6	Nitraria	16.75	12.27	18	Hydroponic cultivation
7	Tamarix	17.52	13.89	18	Hydroponic cultivation
8	Juncaceae	10.29	7.86	20	Hydroponic cultivation
9	Iris pseudacorus L	10.78	8.15	20	Hydroponic cultivation
10	Lythrum salicaria	12.65	9.96	20	Hydroponic cultivation
11	Cyperus alternifolius	11.96	8.79	22	Hydroponic cultivation
12	Scindapsus aureus	10.17	8.05	22	Hydroponic cultivation
13	Aspidistra elatior	12.53	9.68	22	Hydroponic cultivation

14	Canna	20.24	14.16	10	Hydroponic cultivation
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Further, the net carbon plant 351 is pre-cultivated in a flower pot or a flower box to form modular vegetation, the pot body of the flower pot or the box body of the flower box are both made of a water permeable material, and the modular vegetation is directly planted in the biological ceramsite layer of the plant carbon-sequestrating layer 35 when the plant carbon-sequestrating purification tank is constructed. By making the net carbon plants 351 into modular vegetation in advance, it is not only convenient for the construction and cultivation, but also convenient for replacing the modular vegetation directly when it is needed.

In the present embodiment, the near-zero carbon sewage treatment system further comprises an air interchanging device 36 and an exhaust gas collecting device. The air interchanging device 36 is in communication with the enclosed space of the light-transmitting cover 352 for supplying air into the enclosed space of the light-transmitting cover 352 when the enclosed space has a low oxygen concentration; the exhaust gas collecting device is in communication with the enclosed space of the light-transmitting cover 352 for discharging and collecting the excessive acid exhaust gas such as CO₂ gas, hydrogen sulfide, etc., other than those required for the growth of plant photosynthesis in the plant carbon-sequestrating purification tank.

The air interchanging device 36 comprises an air interchanging pump 362, an air outlet of the air interchanging pump 362 is in communication with an enclosed space of the light-transmitting cover 352 via the air discharge pipe 361, the air inlet of the air interchanging pump 362 is connected to an air intake pipe 363, and a valve and a flowmeter are provided on the air discharge pipe 361 so as to achieve a precise ventilation volume; an oxygen concentration sensor is provided in the sealed space above the plant carbon-sequestrating layer 35 for monitoring the oxygen concentration in the sealed space above the plant carbon-sequestrating layer, and the air interchanging pump 362 is started or closed according to the monitored oxygen concentration value so as to maintain the oxygen content in the sealed space within a suitable range.

The exhaust gas collecting device comprises a lime water filter tank 38, wherein the lime water filter tank 38 is in communication with the enclosed space of the light-

transmitting cover 352 via an exhaust gas exhaust pipe 37, the lime-water filtering medium can remove the acidic exhaust gas such as carbon dioxide, hydrogen sulfide, etc. in the exhaust gas, and an exhaust pump, a valve, and a flowmeter can be provided on the exhaust gas exhaust pipe 37 to achieve accurate exhaust gas displacement.

The solar power supply system 4 uses the building roof, building curtain wall, outdoor greenbelt, and like sites and spaces to lay out the photovoltaic energy storage facility 42 such that the absorbed solar power 41 is converted into electric energy and stored in the photovoltaic energy storage facility 42 for the use by the electrical facilities in the system. Since solar power is affected by the limitations of the solar illumination time, the illumination angle, the illumination intensity, etc., it is flexibly arranged in residential buildings and public buildings in combination with the shape of the building, such as using building roofs, building curtain walls, outdoor greenbelt and like sites and space to lay out the photovoltaic power generating facilities such that the absorbed solar power is converted into the electric energy and stored for use, so as to achieve energy self-sufficiency in local areas, thereby effectively reducing the use of fossil energy.

In this embodiment, the treating tank 31 is provided with a filter assembly and an overflow pipe for filtering sewage fed from the sediment tank 2, and the filtered sewage overflows into the adjusting tank 32 via the overflow pipe. The filter assembly comprises a grid material-filtering device, a hair collector, and an oil and sewage separator.

In this embodiment, the adjusting tank 32 can regulate multiple sewage sources such that the sewage from different sources can all be fed into the adjusting tank 32, a stirring device is provided in the adjusting tank 32, and the sewage from different sources can be uniformly mixed in the adjusting tank 32 via the stirring device. A liquid level sensor is also provided in the adjusting tank 32 for monitoring the height of the water level of the sewage in the adjusting tank 32.

In this embodiment, a horizontally arranged water permeable partition 339 is provided between two adjacent layers of the plant carbon-sequestrating layer 35, the water distribution layer 334, the primary purifying layer 335, the secondary purifying layer 336, the water storage layer 337, and the sludge discharge layer 338. In order to realize the modular construction of the sewage ecological treating tank 33, multiple vertically parallel water permeable partitions 339 are longitudinally arranged in the

interior of the sewage ecological treating tank 33 to separate and fix the modular facilities of the primary purifying layer 335 and the secondary purifying layer 336, so as to facilitate the replacement of fillers.

Further, both the primary purifying layer 335 and the secondary purifying layer 336 adopt a modular structure, facilitating the installation and construction, and improving the construction efficiency. Illustratively, as shown in Fig. 4, the primary purifying layer 335 comprises a primary purification module a 335-1, a primary purification module b 335-2, a primary purification module c 335-3, a primary purification module d 335-4 and a primary purification module e 335-5 arranged in parallel; the secondary purifying layer 336 includes a secondary purification module a 336-1, a secondary purification module b 336-2, a secondary purification module c 336-3, a secondary purification module d 336-4, and a secondary purification module e 336-5 arranged in parallel.

The near-zero carbon sewage ecological treatment system of the present embodiment further includes a control and display system for controlling the operation of the near-zero carbon sewage ecological treatment system and for displaying the operation state and operation parameters of the near-zero carbon sewage ecological treatment system. The control and display system is configured to control the water distribution device to replenish the water level in the water distribution layer to H1 within time T2 when the water level of the water distribution layer decreases from H1 to H2 within time T1. That is to say, when the water level of the water distribution layer reaches the maximum water-distribution water level H1, the water level of the water distribution layer decreases to the minimum water-distribution water level H2 after the system purifies the sewage running for T1 time. The water is replenished into the water distribution layer 334 again by using the water distribution device, the water level in the water distribution layer 334 is replenished to the maximum water-distribution water level H1 within T2 time, the running is continued for T1 time, and the above-mentioned running operations are repeated to achieve the sewage purifying treatment.

The control and display system is further configured such that when the oxygen concentration in the plant carbon-sequestrating purification tank reaches C1, the air interchanging device starts to work. The air enters the plant carbon-sequestrating layer through an air outputting pipe, and the exhaust gas in it is discharged into the lime water filter tank 38 through an exhaust gas exhaust pipe; when the oxygen

concentration value in the plant carbon-sequestering layer 35 is C_2 , the air interchanging device ceases to operate, wherein $C_2=1.3\sim 1.7 C_1$.

This embodiment also discloses a near-zero carbon sewage ecological treatment method using the above-mentioned near-zero carbon sewage ecological treatment system of this embodiment.

Fig. 5 shows the control logic of a sewage ecological treatment method of the present embodiment.

The near-zero carbon sewage ecological treatment method comprises the following steps:

step 1: constructing a solar power supply system 4 and a sewage ecological treatment system 3.

Specifically, when the sewage ecological treating tank 33 and the plant carbon-sequestering purification tank are constructed, a pit is excavated on the ground, a sludge discharge layer 338, a water storage layer 337, a secondary purifying layer 336, a primary purifying layer 335, a water distribution layer 334, and a plant carbon-sequestering layer 35 are laid from bottom to top, a net carbon plant 351 is planted on the plant carbon-sequestering layer 35, the plant carbon-sequestering layer 35 is covered with a light-transmitting cover 352, and the net carbon plant 351 is located in the inner space of the light-transmitting cover 352. The pretreating tank 31 and the adjusting tank 32 are constructed at a certain distance from the sewage ecological treating tank 33, the pipeline is laid, and various equipment required for the operation is installed. According to the position of the sewage ecological treatment system 3, the photovoltaic energy storage facilities 42 are arranged on nearby building roofs, building curtain walls, outdoor greenbelt, and like sites and spaces such that the absorbed solar power 41 is converted into electric energy and stored in the photovoltaic energy storage facilities 42, and the photovoltaic energy storage facility 42 is electrically connected to the electric facilities in the system.

Step 2: precipitating the domestic sewage 1 via a sediment tank 2 and then feeding the same into a sewage ecological treatment system 3 for purification treatment, wherein the purified sewage is discharged into a recycling tank 34 for use at a water consuming point.

Specifically, the domestic sewage 1 is discharged into the sediment tank 2, and the domestic sewage 1 is collected via the sediment tank 2 and then discharged into the sewage ecological treatment system 3; the domestic sewage in the sewage

ecological treatment system 3 firstly enters a pretreating tank 31, and then after being filtered by a filter assembly in the pretreating tank 31, overflows into an adjusting tank 32; the adjusting tank 32 can uniformly mix sewage from different sources, and the sewage in the adjusting tank 32 gradually rises;

5 when the adjusting tank 32 reaches a preset water level, the water distribution pump 332 is started to supply the sewage in the adjusting tank 32 into the water distribution layer 334 of the sewage ecological treating tank 33 via the water distribution pipe 333, and the sewage distributes water to the sewage ecological treating tank from top to bottom in the water distribution layer 334; the sewage in the water distribution layer
10 334 firstly enters the primary purifying layer 335, then enters the secondary purifying layer 336 under the action of its own gravity, and is subjected to the secondary purifying layer treatment; the sewage after the adsorption, filtration, and biological decomposition of the biological filter material enters the water storage layer 337; the purified sewage in the water storage layer 337 enters the recycling tank 34 via the
15 water draining pipe 337-1; large suspended particles gather and then settle into the sludge discharge layer 338, then are discharged into the sludge collecting funnel 338-1 under the action of gravity, and are discharged via the sludge discharge pipe 338-2. The purified sewage in the water storage layer 337 can be periodically fed into the plant carbon-sequestrating layer 35 for watering the net carbon plant 351, and after
20 being filtered by the plant carbon-sequestrating layer 35, enters the recycling tank 34 again. The secondary purifying layer treatment is performed again, thereby improving the sewage treatment effect.

At the same time, the net carbon plant 351 in the plant carbon-sequestrating layer 35 adsorbs organic matters such as nitrogen and phosphorus in the sewage, and at the
25 same time, the photosynthesis of the net carbon plant 351 absorbs CO₂ gas generated in the sewage treatment process to promote the photosynthesis and help plant growth. The oxygen concentration sensor in the plant carbon-sequestrating purification tank monitors the oxygen concentration of the gas in the sealed space above the plant carbon-sequestrating layer in real time; when the oxygen
30 concentration in the plant carbon-sequestrating layer 35 reaches a C1 value, the air interchanging pump 362 starts to work, the air enters the plant carbon-sequestrating layer 35 through the air output pipe 361, the exhaust gas in it is discharged into the lime water filter tank 38 through the exhaust gas exhaust pipe 37, and the lime-water solution in the lime water filter tank 38 removes gases such as carbon dioxide and

hydrogen sulfide in the exhaust gas; when the oxygen concentration value in the plant carbon-sequestrating layer 35 is C2, the air interchanging pump 362 stops operating, wherein $C2=1.3\sim 1.7 C1$. Alternatively, $C1 < 15\% \text{ vol}$, $C2 \geq 21\% \text{ vol}$.

In the process of sewage purification, the liquid level sensor in the water distribution layer 334 monitors the water level in the water distribution layer 334 in real time; when the water level of the water distribution layer reaches the maximum water-distribution water level H1, the water level of the water distribution layer decreases to the minimum water-distribution water level H2 after the system purifies the sewage running for T1 time. Then water is distributed into the water distribution layer 334 again, the water level in the water distribution layer 334 is replenished to the maximum water-distribution water level H1 within T2 time, the running is continued for T1 time, and the above-mentioned running operations are repeated to achieve the sewage purifying treatment. Sewage treatment in this process goes through the following stages: instantaneous inflow-treatment period T1-instantaneous drainage-water distribution period T2. Such alternation is beneficial to alleviate the problems of easy clogging and insufficient oxygen supply in traditionally constructed wetlands, etc. Meanwhile, the running time and the water distribution time are related to the plant's carbon treatment intensity. The stronger the carbon sequestration capacity of the plant is, the shorter the water distribution time is; the weaker the carbon sequestration capacity of the plant is, the longer the water distribution time is. By controlling the system and the sensor to monitor in real-time, the whole process can achieve intelligent control.

Further, $H2=H1-V/S$;

Wherein: H1--maximum water-distribution water level (m);

H2--minimum water-distribution water level (m);

V--the volume of the sewage treated in a single purifying treatment cycle of the system (m^3);

S--the water distribution area of the system (m^2).

Further, the bulk of the sewage ecological treating tank 33 is 3-5 times of the volume V of the sewage treated in a single purifying treatment cycle of the system, and the hydraulic loading is $0.53\sim 1.06 \text{ m}^3/(\text{m}^2\cdot\text{d})$.

It is verified that the running time T1 of a single purifying treatment cycle of the system is 8-12h, and the water distribution time T2 of a single purifying treatment cycle of the

system is 1-2h. The time parameters not only make the sewage purification treatment effect of the system good, but also make the growth environment of the net carbon plant 351 suitable, which can make the system run continuously and closer to zero carbon emission.

- 5 Further, the water distribution time is related to the oxygen concentration, and the total time of the water level of the water distribution layer 334 from when reaching moment H1 to the time when the oxygen concentration in the plant carbon sequestration tank reaches C1 is T3, $T_2=0.13\sim0.16T_3$, wherein C1 is 13% vol ~14.8% vol.
- 10 In this embodiment, the *Pseudomonas stutzeri* is added to the sewage ecological treating tank 33, and the *Pseudomonas stutzeri* can be added to one or more layers of the water storage layer 337, the secondary purifying layer 336, or the primary purifying layer 335 during the construction of the sewage ecological treatment system in step 1; when the sewage is supplied to the sewage ecological treating tank 33 in
- 15 step two, the *pseudomonas stutzeri* can also be added to the supplied sewage, and the sewage mixed with the *Pseudomonas stutzeri* can be supplied to the water distribution layer 334 to be infiltrated step by step to fill the entire sewage ecological treating tank 33.

- In this embodiment, the organic pollutants in a dissolved and colloidal state in the
- 20 sewage are degraded and converted into harmless substances by the metabolic function of microorganisms, so that the sewage is purified. When the sewage is fed into the water distribution layer 334, the sewage successively passes through the primary purifying layer 335 and the secondary purifying layer 336 from the top to the bottom. After the long-term filtration and purification of porous filter material substrate
- 25 by the sewage, one layer of biomembrane is formed on the outer layer of the filter material substrate, and it extends from the outer layer of biomembrane to form an anaerobic zone, facultative zone, and aerobic zone from the inside to the outside, where nitrifying bacteria and denitrifying bacteria grow respectively. These microorganisms decompose the organic matters and colloids in the sewage. At the
- 30 same time, the *Pseudomonas stutzeri* is added to the sewage in the sewage ecological treating tank 33, thereby making it have a good denitrification effect. According to the experimental analysis, when the OD value₆₀₀ of the concentration of the bacteria solution added, is selected to be equal to 1.0, the adding proportion is

$V_{\text{bacteria solution}} : V_{\text{sewage to be treated}} = 1:200 \sim 1:300$, and the addition is carried out for continuously 10 days. When each time it is the same, the bacteria solution has the best effect on nitrogen in the sewage. After that, there is no need to add the bacteria solution, and the system can run automatically, realizing the absorption and conversion of N element, achieving the purpose of removing nitrogen and purifying the sewage, and reducing the carbon-containing greenhouse gas emission.

Compared with the prior art, the near-zero carbon sewage ecological treatment system and method provided in the present embodiment have at least one of the following beneficial effects.

1. The sewage ecological treatment system adopts the ecological treatment process constructed by shale ceramsite-composite activated alumina two-stage purifying layer, which realizes the physical-chemical-biological synergistic degradation of organic matters, nitrogen, and phosphorus in the sewage, does not rely on the traditional mechanical aeration facilities, and minimizes the energy consumption of the sewage treatment. The energy consumption used in the sewage treatment operation is powered-up by the solar power supply system. The plant carbon-sequestering layer is placed in a relatively sealed space, and plants with good carbon sequestration performance are used for cyclic purification of the sewage. At the same time, the plant photosynthesis can effectively absorb the carbon dioxide generated in the process of sewage treatment, or a suitable gas composition is maintained in the enclosed space on the plant carbon-sequestering layer through an air interchanging device and an exhaust gas collecting device so that the near-zero carbon emission of the sewage treatment is achieved by combining the above-mentioned numerous emission reduction measures.

2. According to the existing research results, the gas emission generated by the traditional sewage treatment method is $350\text{g CO}_2/\text{m}^3$, while the gas emission generated by the sewage purification treatment process in the sewage ecological treating tank in the embodiment is $75\text{g CO}_2/\text{m}^3$, which reduces by 78.57% compared with the gas emission of the traditional sewage treatment technology. In the present embodiment, in the sewage ecological treatment, the electric energy consumed is powered by solar power, and the gas equivalent generated by the energy consumed by treating per 1 cubic meter of sewage is 35g CO_2 , which is equivalent to 10.00% of the gas emission of the traditional sewage treatment technology. The gas absorbed

by per square meter of plant carbon sequestration and photosynthesis is 30g CO₂, which is equivalent to 8.57% of the gas emission of traditional sewage treatment technology. Compared with the traditional sewage treatment technology, the present embodiment achieves the carbon emission reduction of 97.14%, basically reaching the target of near-zero carbon, by using the sewage ecological treatment system, the solar power supply system, etc.

3. By improving and optimizing the water distribution mode, hydraulic loading, and treatment process, the dissolved oxygen level of the substrate is effectively controlled, the periodic change of the oxygen rich-anoxic-anaerobic environment in a treatment unit is realized, the synchronous nitrification and denitrification efficiency is improved, and at the same time, the stable and persistent removal of phosphorus is promoted; the biomembrane growth on the substrate surface is reasonably controlled to avoid clogging, the synchronous denitrification and phosphorus removal efficiency of the system is further improved, and the stable operation of the ecological treatment process is ensured.

4. The air interchanging pump can be adjusted according to the oxygen concentration in the light-transmitting cover, so as to control the carbon emission in the plant tank. Further, combined with the oxygen content, the timing of different stages of sewage treatment in the filtering and purifying layer is controlled to achieve near zero emission in an optimal way; at the same time, the solar power system is a power system with zero emission, thereby achieving near-zero emission.

The specific implementation modes described above further describe in detail the purpose, technical solutions, and beneficial effects of the present application. It should be understood that the above descriptions are only specific implementation modes of the present application, and are not intended to limit the scope of the present application. Any modification, equivalent replacement, improvement, etc. made within the spirit and principle of this application shall be included within the scope of this application.

Claims

1. A near-zero carbon sewage ecological treatment system, characterized by comprising:

5 a solar power supply system for supplying electric energy for system operation;
and a sewage ecological treatment system, comprising a sewage ecological treating tank, a plant carbon-sequestrating purification tank, and a recycling tank;

the sewage ecological treating tank and plant carbon-sequestrating purification tank are built in the pit excavated on the ground; the sewage ecological treating tank is
10 arranged in the underground space below the plant carbon-sequestrating layer, and the sewage ecological treating tank and the plant carbon-sequestrating purification tank are integrated;

wherein the sewage ecological treating tank comprises a water distribution layer, a filtering and purifying layer, a water storage layer, and a sludge discharge layer
15 arranged from top to bottom, the water distribution layer is connected to a sewage source via a water distribution device, and the water storage layer is connected to the recycling tank via a draining device;

a plant carbon-sequestrating layer is provided in the plant carbon-sequestrating purification tank, the plant carbon-sequestrating layer is provided above the water
20 distribution layer, a light-transmitting cover is provided above the plant carbon-sequestrating layer, and a net carbon plant is planted in an enclosed space formed by the light-transmitting cover;

air interchanging device and an exhaust gas collecting device, wherein both the air interchanging device and the exhaust gas collecting device are in communication with
25 the enclosed space of the light-transmitting cover, and an oxygen concentration

sensor is provided in the enclosed space of the light-transmitting cover;

the air interchanging device is used for supplying air into the enclosed space of the light-transmitting cover when the enclosed space has a low oxygen concentration;

the exhaust gas collecting device is used for discharging and collecting exhaust gas generated in the plant carbon-sequestrating purification tank;

setting liquid level sensor in the water distributing layer for real-time monitoring the liquid level of the water distributing layer;

further comprising a control and display system configured to control the water distribution device to supplement a water level in the water distribution layer to H1

within time T2 when the water level of the water distribution layer decreases from H1 to H2 within time T1; the running is continued for T1 time, and the above-mentioned running operations are repeated to achieve the sewage purifying treatment;

wherein $H2 = H1 - V/S$, $T2 = 0.13 \sim 0.16 T3$;

in the above formula: H1 is a maximum water-distribution water level (m);

H2 is a minimum water-distribution water level (m);

V is a volume of sewage treated in a single purifying treatment cycle of a system (m^3);

S is a water distribution area of the system (m^2);

T1 is running time of a single purifying treatment cycle of the system;

T2 is water distribution time of a single purifying treatment cycle of the system;

T3 is a total time of the water level of the water distribution layer from when reaching moment H1 to the time when an oxygen concentration in the plant carbon sequestration tank reaches C1, wherein C1 is 13% vol~14.8% vol;

T1 is 8~12h and T2 is 1~2h;

the bulk of the sewage ecological treating tank is 3-5 times of the volume V of the

sewage treated in a single purifying treatment cycle of the system, and the hydraulic

loading is $0.53\text{--}1.06\text{ m}^3/(\text{m}^2\cdot\text{d})$;

the control and display system is further configured to operate the air interchanging device when the oxygen concentration in the plant carbon sequestration purification tank reaches C1, pass air into the plant carbon-sequestrating layer through an air outputting pipe of the air interchanging device, and discharge and collect exhaust gas from the plant carbon-sequestrating layer via an exhaust gas exhaust pipe of the exhaust gas collecting device; when an oxygen concentration value in the plant carbon-sequestrating layer is C2, the air interchanging device stops working, wherein $C2=1.3\sim 1.7\ C1$.

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2. The near-zero carbon sewage ecological treatment system according to claim 1, characterized in that the filtering and purifying layer comprises a primary purifying layer and a secondary purifying layer arranged from top to bottom;

the primary purifying layer is filled with shale ceramsite, and the secondary purifying layer is filled with composite activated alumina particles.

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3. The near-zero carbon sewage ecological treatment system according to claim 1, characterized in that the drainage device comprises a draining pipe and a draining pump provided thereon, a liquid inlet of the draining pipe is located in the water storage layer, and a liquid outlet of the draining pipe is connected to the recycling tank.

20

4. The near-zero carbon sewage ecological treatment system according to claim 1, characterized in that a sludge discharge device is connected to the sludge discharge layer in preparation for discharging the sludge;

the sludge discharge device comprises a sludge discharge pipe and a sludge

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discharge pump provided thereon.

5. The near-zero carbon sewage ecological treatment system according to claim 1, characterized in that the sewage ecological treatment system further comprises a pretreating tank and an adjusting tank, wherein the adjusting tank is provided upstream of the sewage ecological treating tank via a pipeline, the pretreating tank is provided upstream of the adjusting tank via a pipeline, the pretreating tank is connected to an upstream sediment tank via a pipeline, and the sediment tank is connected to an upstream sewage source.

10

6. A near-zero carbon sewage ecological treatment method, characterized by using the near-zero carbon sewage ecological treatment system to treat sewage according to any one of claims 1 to 8, the method comprises the following steps:

15 constructing a solar power supply system and a sewage ecological treatment system; when the sewage ecological treating tank and the plant carbon-sequestering purification tank are constructed, a pit is excavated on the ground, a sludge discharge layer, a water storage layer, a secondary purifying layer, a primary purifying layer, a water distribution layer, and a plant carbon-sequestering layer are laid from bottom to top, a net carbon plant is planted on the plant carbon-sequestering layer, the plant carbon-sequestering layer is covered with a light-transmitting cover ; and

20 supplying domestic sewage into the sewage ecological treatment system for purification treatment, and discharging purified sewage into the recycling tank for use at a water-consuming point;

25

wherein the domestic sewage entering the sewage ecological treatment system firstly enters the sediment tank, settles large particle impurities under the action of gravity, then enters a pretreating tank, and overflows into the adjusting tank after being filtered by a filter assembly in the pretreating tank;

- 5 when the adjusting tank reaches a pre-set water level, a water distribution pump is started to supply the sewage in the adjusting tank into the water distribution layer via a water distribution pipe, and the sewage distributes water to the sewage ecological treating tank from top to bottom in the water distribution layer; the sewage in the water distribution layer successively enters the primary purifying layer and the secondary
- 10 purifying layer, the sewage ecological treating tank is added with *Pseudomonas stutzeri*, and the sewage treated by the secondary purifying layer enters the water storage layer, and is fed into the recycling tank via the draining device for use at the water consuming point;

- in a process of sewage purification treatment, a net carbon plant adsorbs nitrogen,
- 15 phosphorus, and other organic matters in the sewage, and at the same time, absorbs CO₂ gas generated during sewage treatment through photosynthesis.