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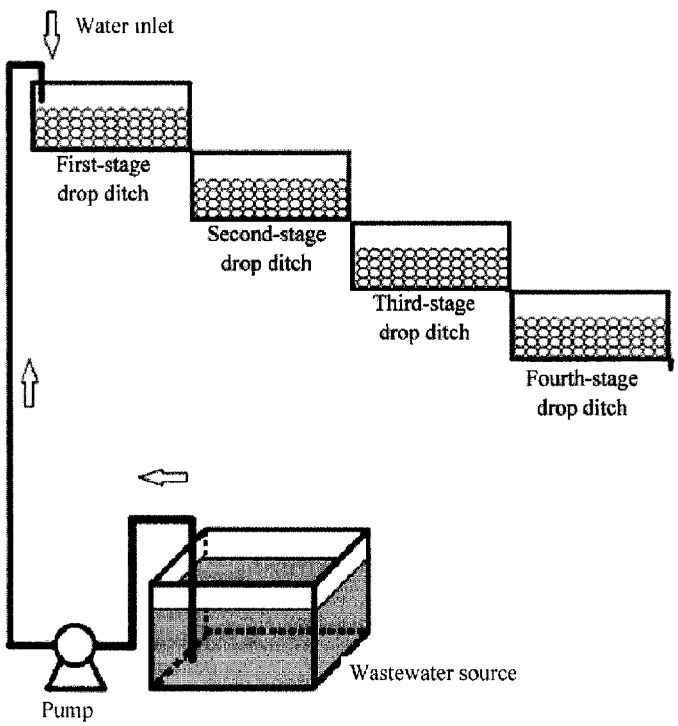
(54) Titre : SYSTEME DE TRAITEMENT DES EAUX USEES COUPLE MODULAIRE
(54) Title: MODULARLY COUPLED WASTEWATER TREATMENT SYSTEM



(57) Abrégé/Abstract:
The present invention relates to the field of wastewater treatment, and provides a modularly coupled wastewater treatment system. Treatment modules of the system include two or three of a multistage ecological pond, a multistage drop aeration ecological ditch

(57) Abrégé(suite)/Abstract(continued):
and a multistage drop dam. The treatment modules are coupled as follows: the multistage ecological pond and the multistage drop aeration ecological ditch are connected in series; or the multistage drop dam, the multistage ecological pond and the multistage drop aeration ecological ditch are connected in series; or the multistage drop aeration ecological ditch, the multistage ecological pond and the multistage drop dam are connected in series. The treatment system provided by the present invention is composed of two or three of the multistage ecological pond, the multistage drop aeration ecological ditch and the multistage drop dam.

ABSTRACT

The present invention relates to the field of wastewater treatment, and provides a modularly coupled wastewater treatment system. Treatment modules of the system include two or three of a multistage ecological pond, a multistage drop aeration ecological ditch and a multistage drop dam. The treatment modules are coupled as follows: the multistage ecological pond and the multistage drop aeration ecological ditch are connected in series; or the multistage drop dam, the multistage ecological pond and the multistage drop aeration ecological ditch are connected in series; or the multistage drop aeration ecological ditch, the multistage ecological pond and the multistage drop dam are connected in series. The treatment system provided by the present invention is composed of two or three of the multistage ecological pond, the multistage drop aeration ecological ditch and the multistage drop dam.

MODULARLY COUPLED WASTEWATER TREATMENT SYSTEM

TECHNICAL FIELD

The present invention relates to the technical field of wastewater treatment, and in particular, to a modularly coupled wastewater treatment system.

BACKGROUND

Agricultural non-point source (NPS) pollution is pollution resulting from many diffuse sources, in direct contrast to point source pollution which results from a single source. Nonpoint source pollution generally results from land runoff, precipitation, atmospheric deposition, drainage, seepage, or hydrological modification (rainfall and snowmelt) where tracing pollution back to a single source is difficult. These pollutants include organic and inorganic substances such as farmland soil particles, nitrogen, phosphorus, pesticides and heavy metals, livestock and poultry manure and domestic wastes. Agricultural NPS pollution has become the main cause of current surface water pollution. Only about 10% of the 120 million tons of nitrogen used worldwide in food production each year are directly consumed by humans. Most of the unused nitrogen is dispersed into a wide range of environments and eventually sinks into surface water bodies, becoming a major source of NPS pollution. Agriculture is the main factor that causes excessive nutrient discharge into water bodies. Studies have shown that about 58% of the total nitrogen and 40% of the total phosphorus in Taihu Lake come from agricultural NPS pollution.

Ecological ditches are used to intercept farmland runoff, which are an important measure for controlling agricultural NPS pollution. They can effectively intercept and remove nitrogen and phosphorus pollutants from farmland drainage, reduce the risk of nitrogen and phosphorus loss from farmland into water bodies, and improve the self-purification capacity of water bodies. Although ecological ditches have become increasingly popular, they have the disadvantages of unstable purification effect and low purification efficiency in the application process.

SUMMARY

In view of this, an objective of the present invention is to provide a modularly coupled wastewater treatment system. This system can adapt to different wastewater water quality and local terrains, and is suitable for the treatment of rural domestic wastewater and agricultural NPS wastewater, ensuring the stability and high efficiency of purification.

To achieve the above purpose, the present invention provides the following technical solution.

A modularly coupled wastewater treatment system is provided, where treatment modules of the system include two or three of a multistage ecological pond, a multistage drop aeration ecological ditch and a multistage drop dam;

the treatment modules are coupled as follows:

the multistage ecological pond and the multistage drop aeration ecological ditch are connected in series; or the multistage drop dam, the multistage ecological pond and the multistage drop aeration ecological ditch are connected in series; or

the multistage drop aeration ecological ditch, the multistage ecological pond and the multistage drop dam are connected in series.

Preferably, the multistage ecological pond includes a contact oxidation pond, a biological stabilization pond and a submerged oxygenation pond which are sequentially communicated with each other.

Preferably, the contact oxidation pond is filled with a modified loofah;

an emergent plant is planted in a box-type ecological floating bed in the biological stabilization pond; the box-type ecological floating bed is filled with a modified loofah;

a submerged plant is planted in the submerged oxygenation pond.

Preferably, the filling volume of the modified loofah in the contact oxidation pond is 40-60% the volume of the contact oxidation pond.

Preferably, the modified loofah is prepared by the following steps:

immersing a loofah into an alkaline solution for 20-40 min, taking the loofah out, and washing to neutrality to obtain the modified loofah.

Preferably, the multistage drop aeration ecological ditch includes a plurality of ecological ditches connected in a stepwise manner from high to low; each ecological ditch is nested with the next ecological ditch through a snap at the bottom.

Preferably, the multistage drop aeration ecological ditch is covered with a cobblestone; the cobblestone laid in a single ecological ditch is 4-6 cm in thickness, and the cobblestone is 2-5 cm in diameter.

Preferably, the multistage drop dam includes a plurality of drop steps, and each step is 200-300 mm in height.

Preferably, the system further includes a wastewater holding tank and a constant flow pump, wherein wastewater in the wastewater holding tank enters into the treatment modules through the constant flow pump.

The present invention provides a modularly coupled wastewater treatment system. Treatment modules of the system include two or three of a multistage drop aeration ecological ditch, a multistage ecological pond and a multistage drop dam. The treatment modules are coupled as follows: the multistage ecological pond and the multistage drop aeration ecological ditch are connected in series; or the multistage drop dam, the multistage ecological pond and the multistage drop aeration ecological ditch are connected in series; or the multistage drop aeration ecological ditch, the multistage ecological pond and the multistage drop dam are connected in series. The treatment system provided by the present invention is composed of two or three of the multistage drop aeration ecological ditch, the multistage ecological pond and the multistage drop dam. They are coupled according to rural terrains and wastewater water quality in practical applications. With the system, there is no need to add aeration, stirring and other equipment, thus reducing wastewater treatment equipment and operating costs. The system provided by the present invention has simple operation and easy management, and is very suitable for rural wastewater treatment. The system provided by the present invention has stable water treatment effects and high purification efficiency. The system is suitable for the treatment of rural domestic wastewater and agricultural NPS wastewater, and is expected to be used in the restoration and treatment of urban wastewater and eutrophic water bodies such as lakes in the future, having broad application prospects. The results of the examples show that the system of the present invention had a high removal rate of chemical oxygen demand (COD), ammonia nitrogen (NH_4^+-N), total nitrogen (TN) and total phosphorus (TP) in the effluent of rural wastewater.

BRIEF DESCRIPTION OF DRAWINGS

FIG. 1 is a structural diagram of a multistage ecological pond according to the present invention.

FIG. 2 is a structural diagram of a multistage drop aeration ecological ditch according to the present invention.

FIG. 3 is a structural diagram of a four-stage drop aeration ecological ditch according to the present invention.

FIG. 4 is a structural diagram of a multistage drop dam according to the present invention.

FIG. 5 is a structural diagram of a coupled system of a multistage ecological pond and a multistage drop aeration ecological ditch according to the present invention.

FIG. 6 is a structural diagram of a coupled system of a multistage drop dam, a multistage ecological pond and a multistage drop aeration ecological ditch according to the present invention.

FIG. 7 is a structural diagram of a coupled system of a multistage drop aeration ecological ditch, a multistage ecological pond and a multistage drop dam according to the present invention.

In FIG. 5 to FIG. 7, 1. multistage ecological pond, 2. multistage drop aeration ecological ditch, 3. multistage drop dam, 4. wastewater holding tank, and 5. constant flow pump.

DETAILED DESCRIPTION

The present invention provides a modularly coupled wastewater treatment system. Treatment modules of the system include two or three of a multistage ecological pond, a multistage drop aeration ecological ditch and a multistage drop dam.

The treatment modules are coupled as follows:

the multistage ecological pond and the multistage drop aeration ecological ditch are connected in series; or

the multistage drop dam, the multistage ecological pond and the multistage drop aeration ecological ditch are connected in series; or the multistage drop aeration ecological ditch, the multistage ecological pond and the multistage drop dam are connected in series.

The treatment module of the system in the present invention includes a multistage ecological pond. In the present invention, the multistage ecological pond preferably includes a contact oxidation pond, a biological stabilization pond and a submerged oxygenation pond which are sequentially communicated with each other. The contact oxidation pond is preferably filled with a modified loofah. The filling volume of the modified loofah in the contact oxidation pond is preferably 40-60%, and more preferably 50% the volume of the contact oxidation pond.

In the present invention, the modified loofah is preferably prepared by: immerse a loofah into an alkaline solution for 20-40 min, take the loofah out, and wash to neutrality to obtain the modified loofah. In the present invention, the alkaline solution is preferably a sodium hydroxide solution. The present invention has no special requirement for the amount of the alkaline solution, as long as the loofah can be fully immersed. The alkaline solution has a mass fraction of preferably 2-10%, and specifically, 2%, 5% or 10%. The immersion temperature is preferably 25°C, and the time is preferably 20-40 min, more preferably 30 min. In a specific example of the present invention, the immersion is preferably performed under a constant-temperature water bath condition (25°C). If the loofah floats up, a weight can be placed to press the loofah down to completely immerse the loofah. After the immersion is completed, the loofah is taken out, and first rinsed with plenty of tap water and then with deionized water until a rinse solution becomes neutral.

The loofah is a natural slow-release filler widely found in nature. In the present invention, the loofah is prepared into a super-hydrophobic material through a modification treatment, which reduces a hydroxyl group so as to reduce hydrophilicity. The modified loofah can continuously supply a carbon source. The modified loofah has a prolonged service life in water, and is easy to form a biofilm. The modified loofah adsorbs microorganisms and provides a carbon source for removing nitrogen by denitrification. The modified loofah effectively solves the problem of insufficient carbon source in the process of removing nitrogen and phosphorus from rural domestic wastewater and non-point pollutants. The modified loofah filler serves both as an excellent carrier for water microorganisms and a highly efficient adsorption material for nitrogen, phosphorus and other pollutants in water. The degradation of the microorganisms and the adsorption of the modified loofah achieve a dynamic adsorption-desorption mode, which effectively solves the problem that ordinary adsorption materials are unable to effectively intercept pollutants after saturated adsorption. In addition, the modified loofah filler used in the present invention has the characteristics of convenient material selection, low price and environmental protection.

The present invention uses the modified loofah filler as a carrier for adsorbing microorganisms from the contact oxidation pond, which achieves efficient interception of organic pollutants in the wastewater and microbial degradation.

In the present invention, an emergent plant is preferably planted in a box-type ecological floating bed in the biological stabilization pond. The box-type ecological floating bed is preferably filled with a modified loofah with a filling volume of 50%. The preparation method of the modified loofah is the same as the method described in the above solution, and will not be repeated here. The present invention has no special requirement for the box-type ecological floating bed, and a box-type ecological floating bed well known to those skilled in the art can be used. The present invention has no special requirement for the type of the emergent plant, and an emergent plant suitable for local conditions can be planted. In a specific example of the present invention, a waterfowl suitable for local conditions can also be cultured in the biological stabilization pond. The present invention uses the modified loofah and the aquatic plant in combination in the biological stabilization pond to overcome the shortcomings of using only a single means of plant purification and the seasonal problems of the plant, ensuring a stable wastewater treatment effect. The present invention forms an artificial ecosystem in the biological stabilization pond. With solar energy (energy provided by solar radiation) as the initial energy, the organic pollutants in the wastewater entering into the pond are degraded and transformed through the material migration, transformation, and stepwise transfer and conversion of energy in multiple food chains in the biological stabilization pond.

In the present invention, a submerged plant is planted in the submerged oxygenation pond. The present invention has no special requirement for the type of the submerged plant, and a submerged plant suitable for local conditions can be planted. An ecological food chain system is constructed in the submerged oxygenation pond by the photosynthesis and respiration of the submerged plant to achieve deep water purification.

In the present invention, the contact oxidation pond, the biological stabilization pond and the submerged oxygenation pond are mutually communicated. In a specific example of the present invention, the contact oxidation pond, the biological stabilization pond and the submerged oxygenation pond are preferably separated by a partition. An upper part of a partition between the contact oxidation pond and the biological stabilization pond is flush with a circumferential height of the multistage ecological pond. The partition is provided with an opening at the bottom to pass the wastewater. This ensures that the slow-release filler and the aquatic plant in the box-type floating bed in the contact oxidation pond and the biological stabilization pond are in full contact with the polluted water. The opening is preferably 20-30 cm in height. A partition between the biological stabilization pond and the submerged oxygenation pond is lower than the circumferential height of the multistage ecological pond by 10-20 cm. In this way, water in the biological stabilization pond can pass through the partition into the submerged oxygenation pond, thereby reducing an impurity such as a particle entering into the submerged oxygenation pond. The present invention has no special requirement for the specific dimensions of the contact oxidation pond, the biological stabilization pond and the submerged oxygenation pond, and the dimensions are preferably adjusted according to the water treatment capacity and the geographical location. In a specific example of the present invention, the dimensions and structure of the multistage ecological pond are shown in FIG. 1. In FIG. 1, the contact oxidation pond, the biological stabilization pond and the submerged oxygenation pond are arranged from left to right in turn, and the arrows in the figure indicate the direction of water flow.

The treatment module of the system in the present invention includes a multistage drop aeration ecological ditch. In the present invention, the multistage drop aeration ecological ditch includes a plurality of ecological ditches connected in a stepwise manner from high to low. Each ecological ditch is specifically an open rectangular parallelepiped, and is provided with a snap at the bottom thereof for nesting with the next ecological ditch. Specifically, the right bottom of a first-stage ecological ditch is connected to the left top of a second-stage ecological ditch through a snap, and the right bottom of the second-stage ecological ditch is connected to the left top of the third-stage ecological ditch through a snap, and so on. The slope of a single ecological ditch is 0°, which means that the ecological ditch is placed horizontally. In the present invention, the multistage drop aeration ecological ditch is preferably covered with a cobblestone. The thickness of the cobblestone laid in a single ecological ditch is preferably 4-6 cm, and more preferably 5 cm. The diameter of the cobblestone is preferably 2-5 cm, and more preferably 3-4 cm. In the present invention, the multistage drop aeration facilitates the growth of a biofilm on the cobblestone. In the present invention, an aquatic plant is preferably planted at a junction of two ecological ditches and where the water flows slowly. The aquatic plant enhances the purification effect, beautifies the environment, and increases economic benefits.

In the present invention, the multistage drop aeration ecological ditch is preferably made of a stainless steel plate. The present invention has no special requirement for the length, width and height of each ecological ditch, and the number of stages of the multistage drop aeration ecological ditch, and they can be designed according to the water treatment capacity and water quality. In a specific example of the present invention, the specific dimensions of the multistage drop aeration ecological ditch are shown in FIG. 2. In FIG. 2, the length of a single ecological ditch is 1000 mm, width is 800 mm, and height is 500 mm. The ecological ditch is an open rectangular parallelepiped. The height of a stainless steel plate at the junction of two ecological ditches is preferably lower than the other three stainless steel plates to facilitate the flow of water. In a specific example of the present invention, a Fr number (Froude number) is preferably used for scaling and correcting water flow conditions based on the dimensions in FIG. 2. FIG. 3 shows the structure of a four-stage drop aeration ecological ditch.

Conventional ecological ditches follow the law of an oxygen sag curve along the water flow direction. The multistage drop aeration ecological ditch of the present invention is a non-powered aeration system, which can realize the supply of dissolved oxygen (DO) in different downstream sections without relying on a water flow force. This helps to remove pollutants, enhances the growth and metabolism of the plant in the ditch, strengthens the removal, infiltration and interception of N and P, and greatly reduces energy consumption.

The treatment module of the system in the present invention includes a multistage drop dam. The multistage drop dam includes a plurality of drop steps. The height of each step is preferably 200-300 mm, more preferably 250 mm, and the width of each step is preferably 1000 mm. A baffle is preferably provided on both sides of the drop step. The present invention has no special requirement for the height of the baffle on both sides of the multistage drop dam, as long as the water does not flow out. In the present invention, the total number of stages of the multistage drop dam is preferably calculated by Formula I:

$$n^2 = (C_0 - C_n) / C_x, \text{ Formula I.}$$

In Formula I, C_0 is a pollutant concentration of an untreated water body, C_n is an expected concentration after purification, C_x is a removal rate of a single-stage drop step, and n is a number of stages of the drop dam.

In the present invention, the multistage drop dam is preferably made of a stainless steel plate. In a specific example of the present invention, preferably, a plurality of drop units are made with a stainless steel plate, and each drop unit includes 3-4 drop steps. The plurality of drop units are nested in a vertical direction by a steep ground or a ground support through a snap to form a drop dam with a desired number of stages. This reduces the difficulty of construction and transportation. In a specific example of the present invention, the multistage drop dam is constructed according to a rural terrain, and the wastewater flows through the drop steps by gravity to achieve multistage drop aeration. In a specific example of the present invention, the dimensions of the multistage drop dam are shown in FIG. 4.

The treatment modules of the system provided by the present invention include two or three of a multistage ecological pond, a multistage drop aeration ecological ditch and a multistage drop dam. The treatment modules are coupled in three modes, specifically:

In a first mode, the multistage ecological pond and the multistage drop aeration ecological ditch are connected in series, that is, the multistage ecological pond is placed in front of the multistage drop aeration ecological ditch, as shown in FIG. 5. In this coupling mode, the submerged oxygenation pond of the multistage ecological pond is communicated with the multistage drop aeration ecological ditch. A water outlet is provided on a side surface of the submerged oxygenation pond, which allows the water to flow downstream along the multistage drop aeration ecological ditch. In this coupling mode, the multistage ecological pond efficiently purifies the water and intercepts part of nitrogen and phosphorus. The multistage ecological pond also beautifies the rural ecological environment and improves the circulating water quality in rural areas. The multistage

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ecological pond can also serve as a regulating pond to regulate the water volume, which solves the problems of conventional ecological ditch systems in modern villages. Since the conventional ecological ditch systems lack a regulating pond, the wastewater volume fluctuates greatly, the precipitation leads to an increase in the surface runoff, and nitrogen, phosphorus and other nutrients overflows into different sections of the ecological ditch, resulting in poor treatment results. In the present invention, this coupling mode is suitable for eutrophic water (which falls within surface water Class V) with large fluctuations in water quantity.

In a second mode, the multistage drop dam, the multistage ecological pond and the multistage drop aeration ecological ditch are connected in series, that is, the multistage drop dam is placed in front of the multistage ecological pond and the multistage drop aeration ecological ditch, as shown in FIG. 6. In this coupling mode, the multistage drop dam is communicated with the contact oxidation pond of the multistage ecological pond. The water flows down from the multistage drop dam by gravity for sufficient aeration, and flows into the multistage ecological pond for nitrogen and phosphorus removal. Finally, the water flows out of the multistage ecological pond and enters into the multistage drop aeration ecological ditch for further contact oxidation, so as to deeply remove the organic matter in the wastewater. In the present invention, this coupling mode is suitable for steep mountainous countryside. The water flows up and down into the ecological ditch, which increases the DO in the water body. After the interception and degradation by the multistage ecological pond, the water is directed by the multistage drop aeration ecological ditch.

In a third mode, the multistage drop aeration ecological ditch, the multistage ecological pond and the multistage drop dam are sequentially connected in series, as shown in FIG. 7. In this coupling mode, the multistage drop aeration ecological ditch is communicated with the contact oxidation pond of the multistage ecological pond, and the submerged oxygenation pond of the multistage ecological pond is communicated with the multistage drop dam. The water flows through the multistage drop aeration ecological ditch for contact oxidation to remove the organic matter in the wastewater, and then flows into the multistage ecological pond for nitrogen and phosphorus removal. Finally, the water flows from the multistage ecological pond into the multistage drop dam for further oxygen enrichment and organic matter removal. In the present invention, this coupling mode is suitable for places where the amount of water changes little and the site is limited. The ecological ditch first directs the water to flow for primary purification. Then, the multistage ecological pond intercepts and degrades the water. Finally, the multistage drop dam drops the water to increase the DO in the water body and improve the visual aesthetics.

In the above solution, when the modules are connected in series, adjacent modules are preferably connected by a snap. The present invention has no special requirement for the structure of the snap, as long as the connection can be realized.

The present invention provides three coupling modes. They are selected according to rural terrains and wastewater water quality in practical applications. The system provided by the present invention avoids the need to add aeration, stirring and other equipment, and thus reduces wastewater treatment equipment and operating costs. The system provided by the present invention has simple operation and easy management, and is very suitable for rural wastewater treatment.

In the present invention, the system preferably further includes a wastewater holding tank and a constant flow pump. The wastewater in the wastewater holding tank enters into the treatment modules through the constant flow pump.

In the present invention, the wastewater is stored in the wastewater holding tank, and is sent to the system by the constant flow pump, so that the wastewater passes through the above-mentioned treatment modules in order. The present invention has no special requirement for the specific application method of the system described in the above solution. In a specific example of the present invention, the system is preferably operated in a continuous operation mode. The present invention has no special requirement for the hydraulic retention time (HRT) and daily treatment capacity of wastewater in the system, and they are adjusted according to the wastewater water quality and the dimensions of each module in the specific example.

The technical solutions provided by the present invention are described in detail below with reference to the examples, but the technical solutions cannot be understood as limiting the protection scope of the present invention.

Example 1

A multistage ecological pond and a multistage drop aeration ecological ditch are connected in series for wastewater treatment, as shown in FIG. 5. The multifunctional ecological pond includes a contact oxidation pond, a biological stabilization pond and a submerged oxygenation pond in order, each being 1.0 m high × 1.0 m wide × 1.0 m long. A partition between the contact oxidation pond and the biological stabilization pond is flush with a circumferential height of the multistage ecological pond. An opening with a height of 25 cm is provided at the bottom of the partition. A partition between the biological stabilization pond and the submerged oxygenation pond is as high as 90 cm. The specific dimensions are shown in FIG. 1.

The multistage drop aeration ecological ditch has four ditches. Each ditch is an open rectangular parallelepiped with a length of 1000 mm, a width of 800 mm and a height of 500 mm, and is made of a stainless steel plate. The four ditches are nested from top to bottom to form a four-stage drop aeration ecological ditch. The specific dimensions are shown in FIG. 2.

The above system is used to treat rural domestic wastewater. The wastewater is stored in a wastewater holding tank, and a constant flow pump is used to lift the wastewater into the multistage ecological pond. The wastewater flows into the multistage drop aeration ecological ditch through the contact oxidation pond, the biological stabilization pond and the submerged oxygenation pond in order.

The coupled system was operated in a continuous operation mode. The influent water included 186 mg•L^{-1} COD, 54.53 mg•L^{-1} TN, 33.37 mg•L^{-1} NH_4^+-N, and 11.20 mg•L^{-1} TP. The influent water load was 3000 L/h. The effluent water was analyzed after 7 days, and the results are shown in Table 1. Through the treatment of the system in this example, the removal rate of COD in the wastewater was 82.44%, the removal rate of TN was 81.42%, the removal rate of NH_4^+-N was 74.83%, and the removal rate of TP was 81.25%.

Table 1 Influent and effluent water quality test results in the "pond-ditch" coupled system

	COD	TN	NH_4^+-N	TP
Water inlet	186±3.61	54.53±0.83	33.37±1.17	11.20±0.17
Water outlet	32.67±1.53	10.13±0.49	8.40±0.26	2.10±0.10
Removal rate	82.44.	81.42.	74.83.	81.25.

The coupled system was operated in a continuous operation mode. The influent water included 207.67 mg•L^{-1} COD, 60.80 mg•L^{-1} TN, 45.23 mg•L^{-1} NH_4^+-N, and 14.87 mg•L^{-1} TP. The influent water load was 6000 L/h. The effluent water was analyzed after 7 days, and the results are shown in Table 2. Through the treatment of the system in this example, the removal rate of COD in the wastewater was 79.45%, the removal rate of TN was 79.44%, the removal rate of NH_4^+-N was 73.77%, and the removal rate of TP was 80.04%.

Table 2 Influent and effluent water quality test results in the "pond-ditch" coupled system

	COD	TN	NH_4^+-N	TP
Water inlet	207.67±3.79	60.80±1.05	45.23±1.15	14.87±0.06
Water outlet	42.67±1.15	12.50±0.36	11.87±0.25	2.97±0.12
Removal rate	79.45.	79.44.	73.77.	80.04.

Example 2

A multistage drop dam, a multistage ecological pond and a multistage drop aeration ecological ditch are connected in series for wastewater treatment, as shown in FIG. 6. The multistage drop dam has three stages. Each step has a height of 200 mm and a width of 1000 mm. The total height of the multistage drop dam is 600 mm. The specific dimensions are shown in FIG. 4. The dimensions and other settings of the multistage ecological pond and the multistage drop aeration ecological ditch are the same as those in Example 1.

The above system is used to treat rural domestic wastewater. The wastewater is stored in a wastewater holding tank, and a constant flow pump is used to lift the wastewater into the multistage drop dam. The wastewater flows into the multistage drop aeration ecological ditch through a contact oxidation pond, a biological stabilization pond and a submerged oxygenation pond of the multistage ecological pond in order.

The coupled system was operated in a continuous operation mode. The influent water included

211.33•L^{-1} COD, 56.13 mg•L^{-1} TN, 39.67 mg•L^{-1} NH_4^+-N, and 18.00 mg•L^{-1} TP. The influent water load was 3000 L/h. The effluent water was analyzed after 7 days, and the results are shown in Table 3. Through the treatment of the system in this example, the removal rate of COD in the wastewater was 90.22%, the removal rate of TN was 82.07%, the removal rate of NH_4^+-N was 91.60%, and the removal rate of TP was 81.48%.

Table 3 Water quality test results of water inlet and outlet in the "dam-pond-ditch" coupled system

	COD	TN	NH_4^+-N	TP
Water inlet	211.33±6.11	56.13±2.87	39.67±1.80	18.00±0.26
Water outlet	20.67±1.53	10.07±0.35	3.33±0.32	3.33±0.15
Removal rate	90.22.	82.07.	91.60.	81.48.

The coupled system was operated in a continuous operation mode. The influent water included 192.00•L^{-1} COD, 47.30 mg•L^{-1} TN, 35.43 mg•L^{-1} NH_4^+-N, and 17.27 mg•L^{-1} TP. The influent water load was 6000 L/h. The effluent water was analyzed after 7 days, and the results are shown in Table 4. Through the treatment of the system in this example, the removal rate of COD in the wastewater was 89.06%, the removal rate of TN was 80.06%, the removal rate of NH_4^+-N was 90.31%, and the removal rate of TP was 80.70%.

Table 4 Water quality test results of water inlet and outlet in the "dam-pond-ditch" coupled system

	COD	TN	NH_4^+-N	TP
Water inlet	192.00±4.36	47.30±2.49	35.43±1.68	17.27±0.15
Water outlet	21.00±1.00	9.43±0.30	3.43±0.15	3.33±0.12
Removal rate	89.06.	80.06.	90.31.	80.70.

Example 3

A multistage drop aeration ecological ditch, a multistage ecological pond and a multistage drop dam are connected in series for wastewater treatment, as shown in FIG. 7. The dimensions and other setting parameters of the multistage drop aeration ecological ditch, the multistage ecological pond and the multistage drop dam are the same as those in Example 2.

The above system is used to treat rural domestic wastewater. The wastewater is stored in a wastewater holding tank, and a constant flow pump is used to lift the wastewater into the multistage drop aeration ecological ditch. The wastewater flows into the multistage drop dam through a contact oxidation pond, a biological stabilization pond and a submerged oxygenation pond of the multistage ecological pond in order.

The coupled system was operated in a continuous operation mode. The influent water included 175.86•L^{-1} COD, 43.97 mg•L^{-1} TN, 29.63 mg•L^{-1} NH_4^+-N, and 15.30 mg•L^{-1} TP. The influent water load was 3000 L/h. The effluent water was analyzed after 7 days, and the results are shown in Table 5. Through the treatment of the system in this example, the removal rate of COD in the wastewater was 84.41%, the removal rate of TN was 81.42%, the removal rate of NH_4^+-N was 87.74%, and the removal rate of TP was 82.35%.

Table 5 Water quality test results of water inlet and outlet in the "ditch-pond-dam" coupled system

	COD	TN	NH_4^+-N	TP
Water inlet	175.86±5.51	43.97±2.46	29.63±1.62	15.30±0.26
Water outlet	27.33±0.58	8.17±0.57	3.63±0.47	2.70±0.10
Removal rate	84.41.	81.42.	87.74.	82.35.

The coupled system was operated in a continuous operation mode. The influent water included 161.67•L^{-1} COD, 41.39 mg•L^{-1} TN, 28.40 mg•L^{-1} NH_4^+-N, and 15.97 mg•L^{-1} TP. The influent water load was 3000 L/h. The effluent water was analyzed after 7 days, and the results are shown in Table 6. Through the treatment of the system in this example, the removal rate of COD in the wastewater was 83.09 %, the removal rate of TN was 41.39%, the removal rate of NH_4^+-N was 86.03%, and the removal rate of TP was 82.88 %.

Table 6 Water quality test results of water inlet and outlet in the "ditch-pond-dam" coupled system

	COD	TN	NH_4^+-N	TP
Water inlet	161.67±7.02	41.39±1.62	28.40±1.20	15.97±0.30
Water outlet	27.33±1.15	8.33±0.21	3.97±0.06	2.73±0.06
Removal rate	83.09.	79.85.	86.03.	82.88.

The system provided by the present invention avoids the need to add aeration, stirring and other equipment. The system has simple operation and easy management, and is very suitable for rural wastewater treatment. In addition, the system has stable water treatment effects, high purification efficiency and broad application prospects.

The above descriptions are merely preferred implementations of the present invention. It should be noted that a person of ordinary skill in the art may further make several improvements and modifications without departing from the principle of the present invention, but such improvements and modifications shall also be deemed as falling within the protection scope of the present invention.

What is claimed is:

1. A modularly coupled wastewater treatment system, wherein treatment modules of the system comprise two or three of a multistage ecological pond, a multistage drop aeration ecological ditch and a multistage drop dam;

the treatment modules are coupled as follows:

the multistage ecological pond and the multistage drop aeration ecological ditch are connected in series; or

the multistage drop dam, the multistage ecological pond and the multistage drop aeration ecological ditch are connected in series; or

the multistage drop aeration ecological ditch, the multistage ecological pond and the multistage drop dam are connected in series.

2. The system according to claim 1, wherein the multistage ecological pond comprises a contact oxidation pond, a biological stabilization pond and a submerged oxygenation pond which are sequentially communicated with each other.

3. The system according to claim 2, wherein the contact oxidation pond is filled with a modified loofah;

an emergent plant is planted in a box-type ecological floating bed in the biological stabilization pond; the box-type ecological floating bed is filled with a modified loofah;

a submerged plant is planted in the submerged oxygenation pond.

4. The system according to claim 3, wherein the filling volume of the modified loofah in the contact oxidation pond is 40-60% the volume of the contact oxidation pond.

5. The system according to claim 3, wherein the modified loofah is prepared by the following steps:

immersing a loofah into an alkaline solution for 20-40 min, taking the loofah out, and washing to neutrality to obtain the modified loofah.

6. The system according to claim 1, wherein the multistage drop aeration ecological ditch comprises a plurality of ecological ditches connected in a stepwise manner from high to low; each ecological ditch is nested with the next ecological ditch through a snap at the bottom.

7. The system according to claim 6, wherein the multistage drop aeration ecological ditch is covered with a cobblestone; the cobblestone laid in a single ecological ditch is 4-6 cm in thickness, and the cobblestone is 2-5 cm in diameter.

8. The system according to claim 1, wherein the multistage drop dam comprises a plurality of drop steps, and each step is 200-300 mm in height.

9. The system according to claim 1, further comprising a wastewater holding tank and a constant flow pump, wherein wastewater in the wastewater holding tank enters into the treatment modules through the constant flow pump.

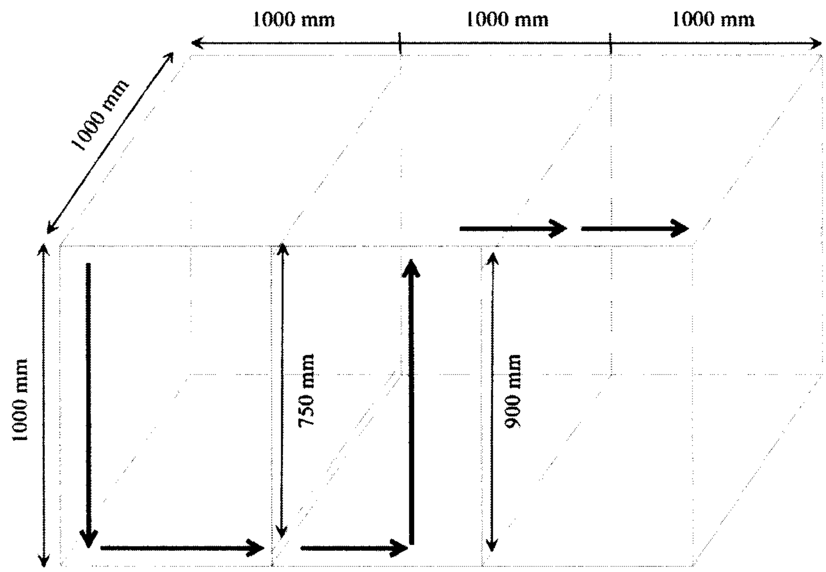

FIG. 1

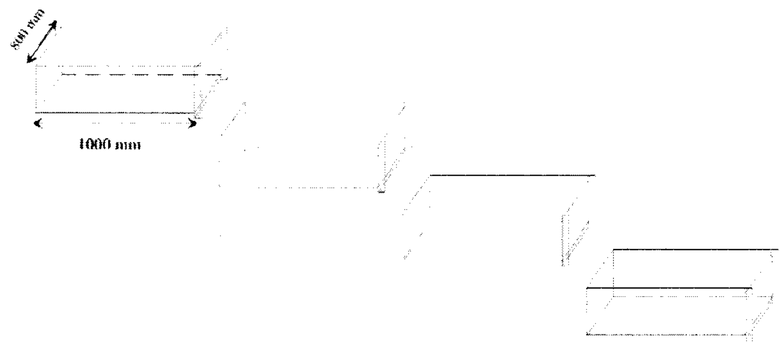

FIG. 2

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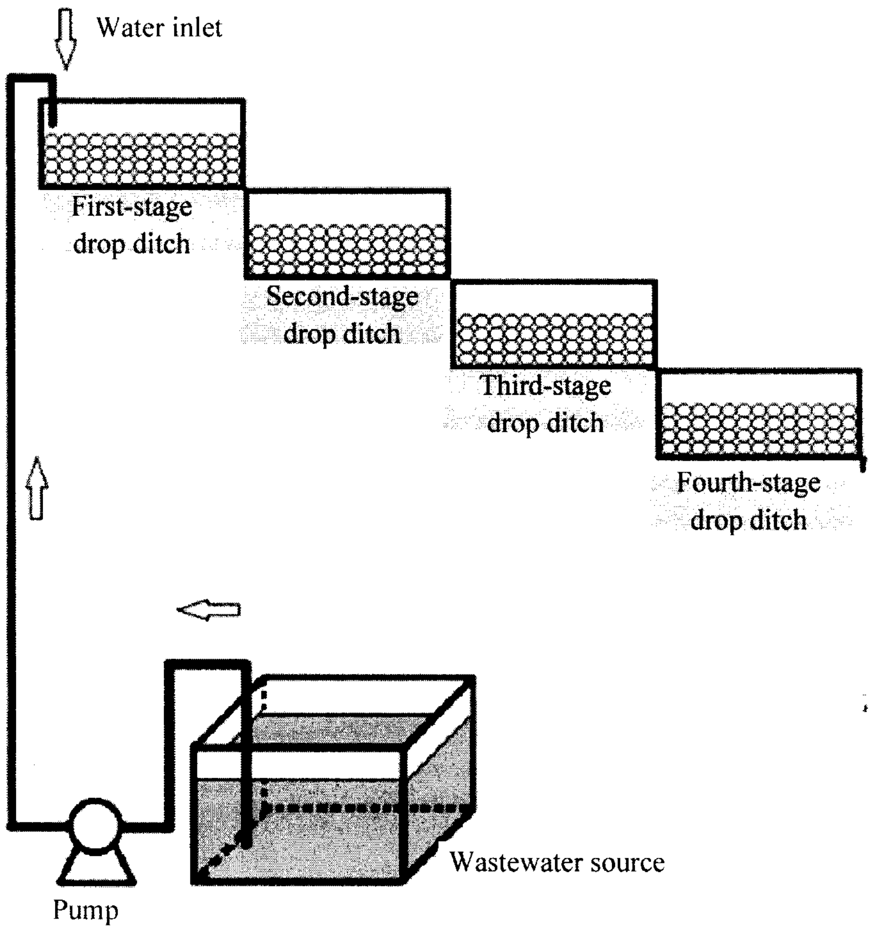

Water inlet
First-stage drop ditch
Second-stage drop ditch
Third-stage drop ditch
Fourth-stage drop ditch
Wastewater source
Pump

FIG. 3

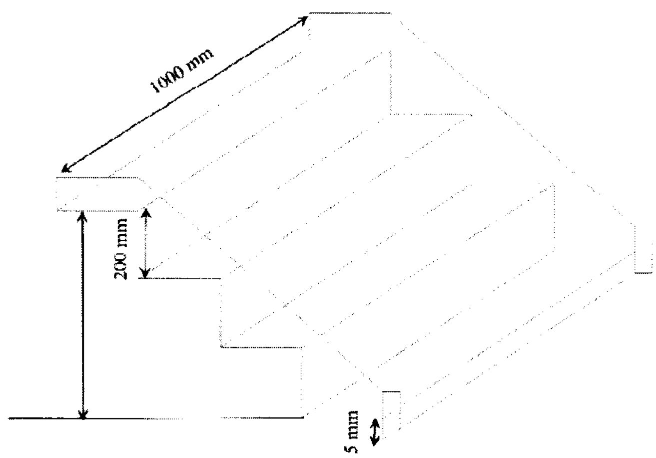

1000 mm
200 mm
5 mm

FIG. 4

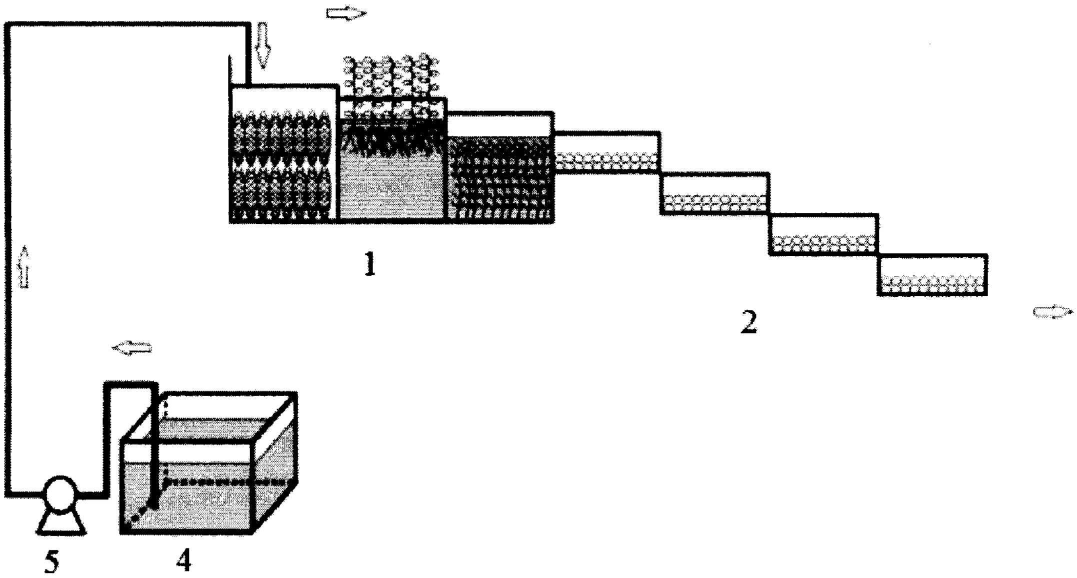


FIG. 5

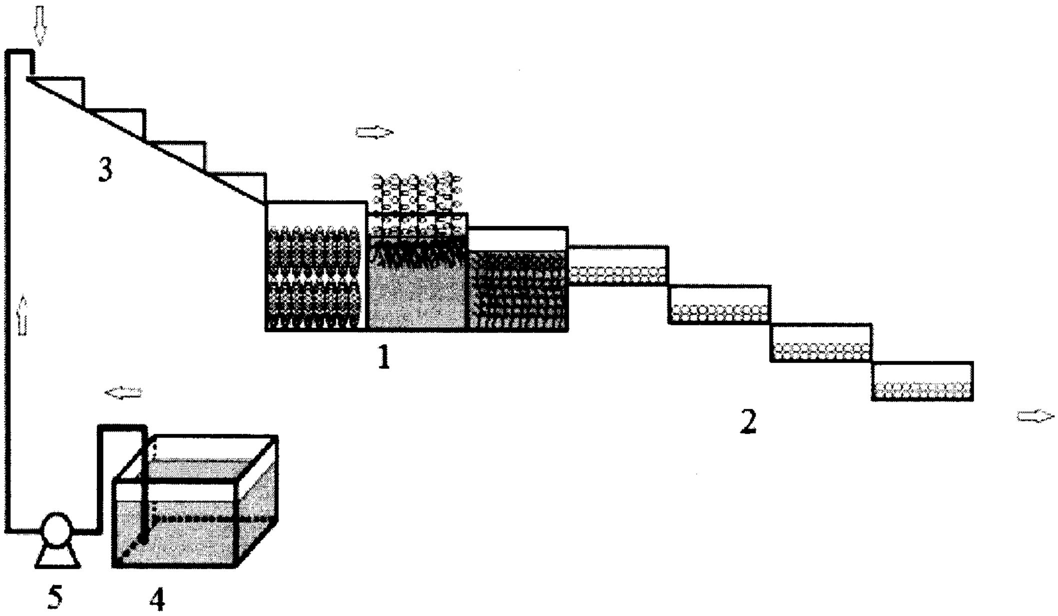


FIG. 6

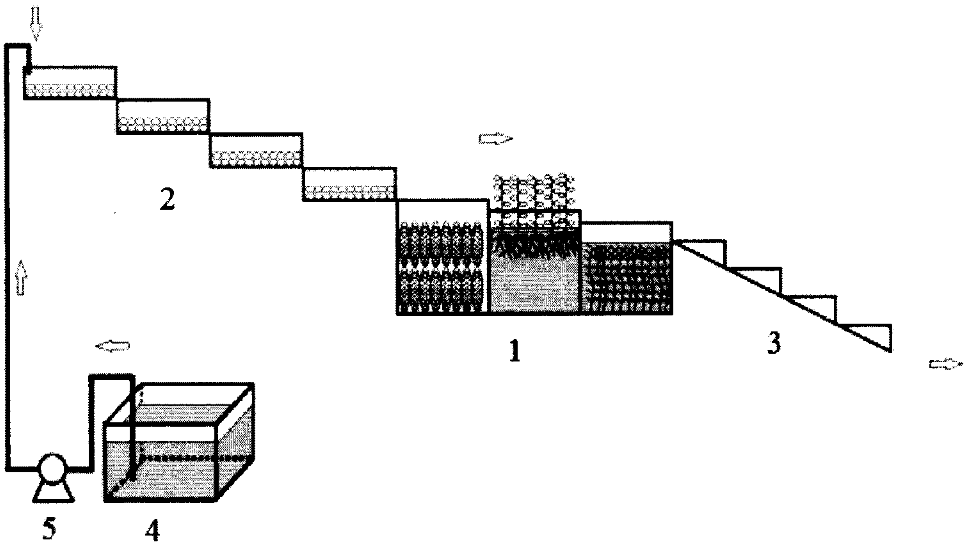
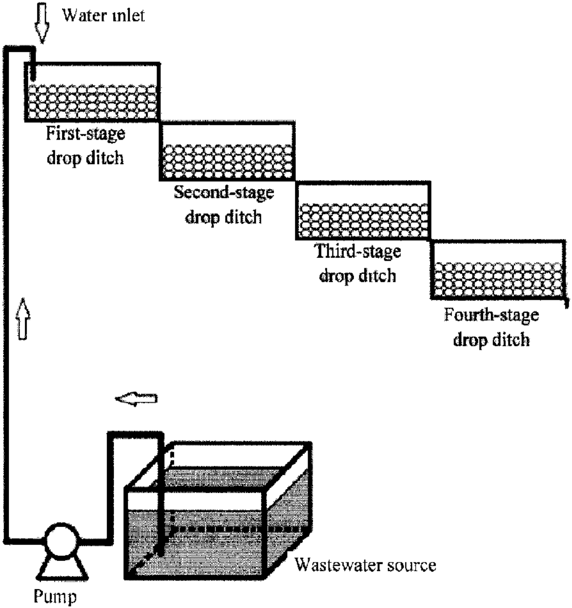


FIG. 7


Water inlet
First-stage
drop ditch
Second-stage
drop ditch
Third-stage
drop ditch
Fourth-stage
drop ditch
Wastewater source
Pump