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Wetland tourism park ecology and its application in water pollution control

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ABSTRACT

To discuss the wetland ecological environment and its role in water pollution control, the basic components of the wetland ecosystem were analyzed firstly, then it was simulated, and the components of the constructed wetland treatment system were given. The removal principle of the main pollutants in the wetland ecosystem was analyzed, and the design process of the artificial wetland treatment system was given. Taking the waste water in Cui Huashan resort as an example, 300 m^2 two-level wetland treatment systems were designed for waste water treatment. In addition, the treated waste water was conducted with sampling detection. The results showed that the waste water after artificial wetland system treatment could achieve the first level standard of second kind of pollution emission permitted. To sum up, it fully proves the scientific validity of artificial wetland in water pollution control system.

Keywords: Wetland ecosystem; Water pollution control; Artificial wetland treatment system

1. Introduction

The wetland area in China is vast, accounting for 10% of the global wetland area, and all kinds of natural wetlands and constructed wetlands stipulated in the Convention on Wetlands can be found in China. Wetland plays an important role in regulating ecology, maintaining species diversity and protecting the environment, so the wetland is also called "the kidney of the earth" [1]. However, due to the transitional development of human resources and continuous change of global climate, the wetland area in China has been seriously reduced, and the function of wetlands has also declined, which has become a serious factor restricting the economic development of our country [2]. Therefore, it is of great significance to develop the ecological and functional research of wetland for the protection, recovery and rational utilization of wetlands.

Specifically, the function of wetland include many aspects, including providing water resources, resisting flood and other natural disasters, protecting biodiversity, detaining and degrading pollutants and shipping [3]. In view of the cheap and natural decomposition unique advantages of wetland in terms of water pollution degradation [4,5], this paper carries out the simulation study of wetland ecosystem in water pollution control. The composition of artificial wetland system and removal mechanism of various water pollutants are removed, and artificial wetland treatment system planning process is designed. In addition, the waste water in Cui Huashan resort is taken as an example for the water pollution purification verification. Finally, it is proved that the artificial wetland system can effectively control the water pollution, which is scientific and effective in water pollution control.

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2. Wetland ecosystem and water pollution control principles

2.1. Artificial wetland system

Referring to the basic composition of the natural wetland ecosystem, the artificial wetland system consists of the following 5 parts [6].

There is a permeable matrix. Currently, the commonly used permeable matrix is made up of soil, sand and stone. This substrate not only provides attachment for microbial growth, but also provides nutrients for microorganism. When sewage flows through the wetland, the wetland reduces the nutrients in the sewage by physical and chemical reactions.

Microorganism: Microorganism is divided into aerobic microorganisms and anaerobic microorganisms. Aerobic microorganisms mainly live in the plant root surface and the surrounding area. The oxygen of this area comes from plant transport, and organic matter in this area is decomposed by aerobic microbial into carbon dioxide and water by anaerobic respiration. Anaerobic microorganisms live in the anaerobic environment of wetland, and organic matter is decomposed by anaerobic microorganisms through fermentation. For the metal elements in the wetland, the activity of aerobic microorganisms helps the adsorption and enrichment of the metal by the wetland [7].

Aquatic plant: It is required that aquatic plants can grow under water saturation for a long time. The roots of aquatic plants can intercept the suspended solids in the sewage, provide a rich environment for the surrounding areas of the roots by releasing the oxygen through the roots, and ensure the respiratory degradation of aerobic microorganisms. In addition, the root system of aquatic plants is complex, which can effectively intercept the suspended solids in water, and provide dependency for microorganisms and other aquatic animals.

Animal: The animals used in the artificial wetland system contain fish, shellfish, bird and other aquatic animals or near-water animals. The role they play in the wetland system is to maintain the ecological balance of the food chain and nutrition level and to ensure the stability of the whole wetland system [8].

Water body: It provides a living water environment for the whole wetland system, including providing adequate water for the survival of microbes and aquatic plants.

2.2. Mechanism of water pollution removal

The principle of removing organic matter: Organic matter can be divided into soluble organic matter and suspended organic matter. For suspended organic matter, precipitation and filtration can quickly intercept in waste water for microorganisms decomposition [9]; while soluble organic matter is removed by biofilm adsorption and microbial metabolism. There are many kinds of organic matters. In the case of aerobic respiration of carbohydrate organic matter, the equation of microbial metabolism is given.

$$C_6H_{12}O_6 + 6H_2O + 6O_2 \xrightarrow{\text{enzyme}} 6CO_2 + 12H_2O \quad (1)$$

The enzymes in the formula are provided by microorganisms. From the upper formula, it can be seen that carbohydrate organic matter is decomposed into CO_2 and water after aerobic respiration, and they are all pollution-free substances.

The principle of removing suspended solids: The solid suspended matter is mainly removed by sedimentation and filtration. The flow rate in the wetland is slow and shallow and the obstruction of the rhizomes of aquatic plants leads to almost all 20% area of the suspended solids being removed [10].

The principle of removing nitrogen: There are two ways to remove nitrogen in water, one is nitrification/de-nitrification, and the other is plant absorption. Inorganic nitrogen produced by inorganic nitrogen in water and nitrification/de-nitrification can be absorbed by plant roots, but the nitrogen consumption of this part is only 8~16% of the total amount. Because of the transport of oxygen to plants, the substrate is rich in oxygen, anoxic and anaerobic. In the meanwhile, nitrification and de-nitrification occur simultaneously in wetlands. The nitrification and de-nitrification equation is

$$A - H + HNO_3 \rightarrow A - NO_2 + H_2O \quad (2)$$

$$2NO_3^- + 10e^- + 12H^+ \rightarrow N_2 + 6H_2O \quad (3)$$

The principle of removing phosphorus: The removal of phosphorus includes three ways of plant absorption, microbial removal, and chemical reaction. The soluble phosphorus in the waste water is absorbed by plants, and through assimilation, transformed into organic components; microbial phosphorus removal includes normal assimilation and excessive accumulation of phosphorus; chemical phosphorus removal is different because of filler difference. Iron or calcium filler is mainly generating iron phosphate or calcium phosphate and forming the precipitation. The chemical formula is:

$$F_e^{3+} + PO_4^{3-} \rightarrow F_ePO_4 \downarrow \quad (4)$$

$$C_a^{3+} + PO_4^{3-} \rightarrow C_aPO_4 \downarrow \quad (5)$$

The principle of removing heavy metals: The removal mechanism of heavy metals in wetlands includes the absorption of clay colloid and the organic layer on the surface of the soil, and the selective absorption of heavy metals by plants.

3. Water pollution control test based on artificial wetland system

3.1. Design of artificial wetland system

To design an artificial wetland system, first of all, we should choose the type of wetland. According to the different flow patterns, the wetland can be divided into surface flow wetland, subsurface flow wetland and vertical flow wetland. The characteristics of various types of wetlands are shown in Table 1.

Because different wetland types have different sewage treatment capacities, we must first of all choose the wetland types according to the sewage quality (mainly the

Table 1
Characteristics of various types of wetlands

Wetland type	Characteristics
Surface flow wetland	Sewage slowly flows from the wetland surface, which has the advantages of less investment, simple operation and low operation cost; the disadvantage is wide area, small hydraulic load, weak purification ability and easy generation of mosquitoes.
Subsurface flow wetland	Subsurface flow wetland consists of one or more packed bed, the bed body filling medium and bed waterproofing layer. It has the advantages of great hydraulic load, good processing effect on the organic matter, suspended solids and heavy metals, and less mosquitoes. The disadvantage is that the control is complex and the effect of nitrogen and phosphorus treatment is poor.
Vertical flow wetland	The sewage vertically flows from the wetland surface to the filler bed. It has the advantages that oxygen is transmitted through plant transfer and atmosphere diffusion two ways, so that the nitrification ability is strong and the treatment effect on nitrogen and phosphorus is excellent; the disadvantage is poor organic matter removal ability, complex control and easy generation of mosquitoes and flies.

concentration of pollutants in water), features of each type of wetland (mainly treatment capacity of different types of wetlands for different pollutants) and features of land where the project is. Then, according to different plants tolerance and decontamination ability and growth in water saturated state, the locally advantageous aquatic plants are selected. The bed structure is designed according to the organic load and hydraulic load; finally, the test run is carried out, and the problems in the process of trial operation are solved, to make the system continuously improved. The design flow chart of the artificial wetland treatment system is shown in Fig. 1.

Several points need to be emphasized: in the choice of the region, considering the economic factors, we should try to choose the wasteland with a certain slope depression or low economic value; the water inlet device of waste water should be as uniform as possible, and we can use the porous tube, and in view of the north cold winter, it is generally buried underground, but also bring the problem of water diversion inconvenience; the selection of filler generally uses the large stone with the size of 60–100 mm. At the same time, in order to increase the phosphorus removal capacity, the stones with high calcium can be used. As there will be some sinking of filler after immersion in water, in the construction, we should build with a degree. In order to prevent the wetland system polluted by groundwater due to infiltration, we need to set impervious layer in the original soil layer. We can use clay, asphalt and other low cost materials; in the plant selection, we should increase the diversity of species as far as possible, which not only can improve the overall ecological viability, but also can enhance the decontamination ability of the system. In the meanwhile, we should also take into account the pollution resistance of plants, the development of the roots and the requirements of beauty.

3.2. An application example of artificial wetland system

Cui Huashan is located in the south of Xi'an Dayukou, with beautiful scenery. Especially the unique landslide landscape attracted a large number of tourists, so that Cui Huashan has a large amount of water utilization. The water comes from the upstream spring. If the sewage is directly discharged after being used, it will affect the water utilization of downstream residents and universities such as Xi'an FanYi University. In consequence, we must deal with the waste water after treatment and the goal is to reach the first level emission standards.

The first step is to divide the waste water. The domestic sewage of Cui Huashan resort includes toilet water, oily water in restaurants, bath water, and amusement park drainage. The main pollution of waste water includes organic matter, solid suspension, oil, detergent, TP, NH_4–N, bacteria and so on. Among them, CODcr, BOD, nitrogen and phosphorus, bacteria and so on exceed the standard, and they need to be discharged after treatment. In reference to the first class standard of second types of pollutants, the highest concentration of pollutants allowed to be discharged is shown in Table 2.

The second step is to estimate the amount of water. According to the daily consumption of 150 L water per person, the average daily number is 100–150 people. Considering the weekends and holidays, the daily consumption of tourists is 150 and then the daily consumption of water is 22.5 m^3. In order to reserve the surplus, the water will be finally recognized as 25 m^3.

The third step is to deal with the process. The processing system covers an area of about 300 square meters and is irregular. Considering that there are great differences in the reception volume of the villa in different seasons and different periods, the wetland treatment system is divided into three groups. The control valves are set up in each group, and the number of the groups is determined according to the quantity of tourists. The flow chart of the sewage treatment is shown in Fig. 2.

The residence time of sewage is 3–5 d at 20 DEG C, and the temperature is low and delayed to 9–12 d in winter.

The fourth step is the process and description of artificial wetland treatment system. Each artificial wetland system is composed of 3 subsystems, which are the subsurface and the surface flow pattern two kinds. The filler of the three beds is exactly the same as that of the aquatic plants. The filler is gravel bed and fly ash mixture, the first sections aquatic plants are reed, Canna and so on and the latter sections aquatic plants contain duckweed, schleid and typha.

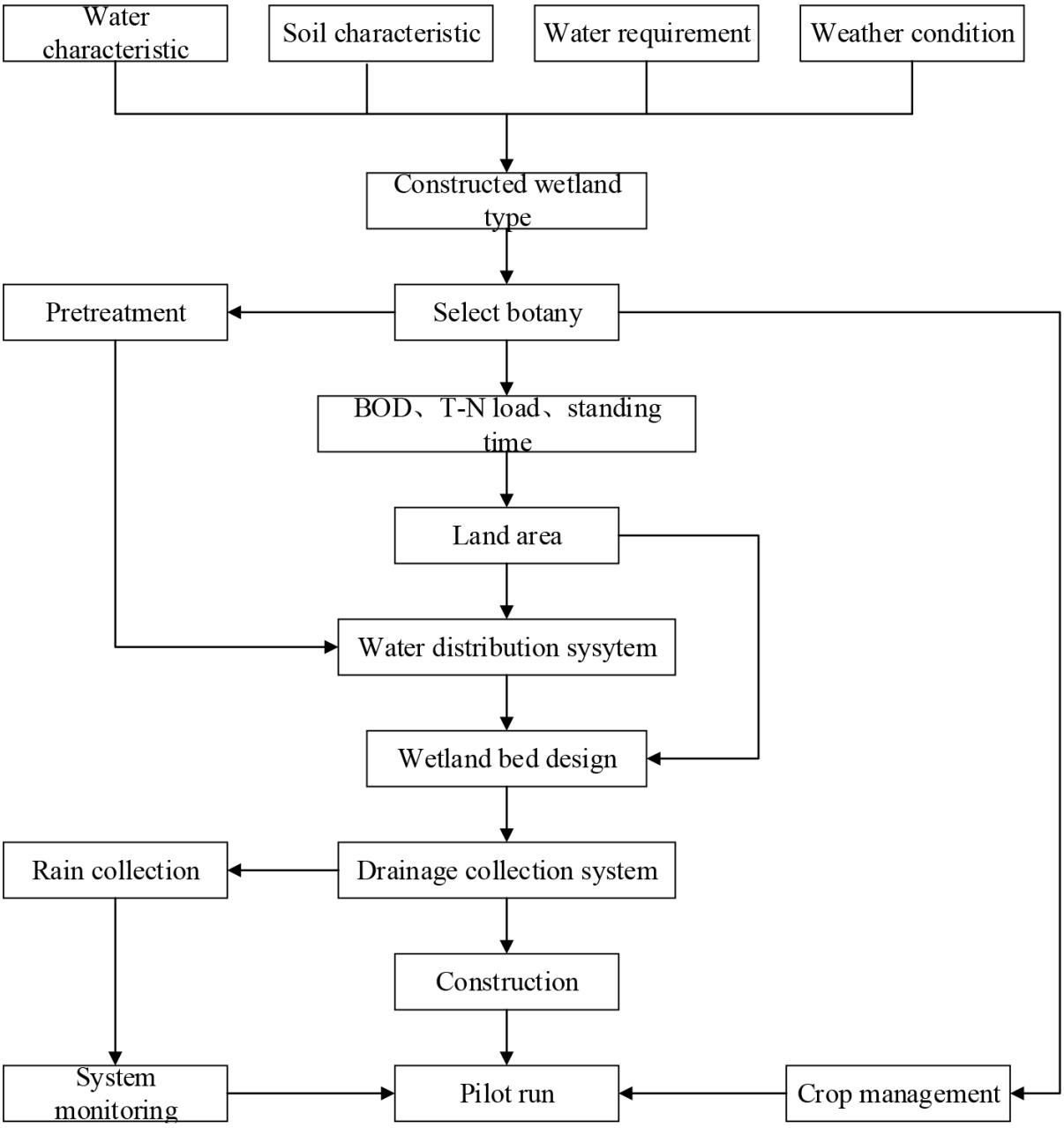

Fig. 1. Design flow chart of artificial wetland

Table 2
Maximum concentration of pollutants allowed discharging

Components	Concentration
Color, mg/L	50
CODcr, mg/L	60
BOD_5, mg/L	20
Total phosphorus, mg/L	0.5
NH_4-N, mg/L	15
pH value	6–9
Solid suspensions, mg/L	30

The first area is a pebble water area, with PVC perforated tube water, a double row of holes, 45 degrees below the oblique, and a hole distance of about 10 cm. In order to prevent the severe freezing of water in winter, the PVC tube is buried 10 cm under the surface of the pebble. The size of the Pebble Grain in the water distribution area is between 60~100 mm, which requires that the pebbles to be hard, and thus it is difficult to be pulverized.

The third area sets the water collecting device of the subsurface bed. The water collecting area is used to collect water with PVC perforated pipe, and the arrangement is consistent with the water distribution area. The water collecting tube uses elbow rotary valve and in order to

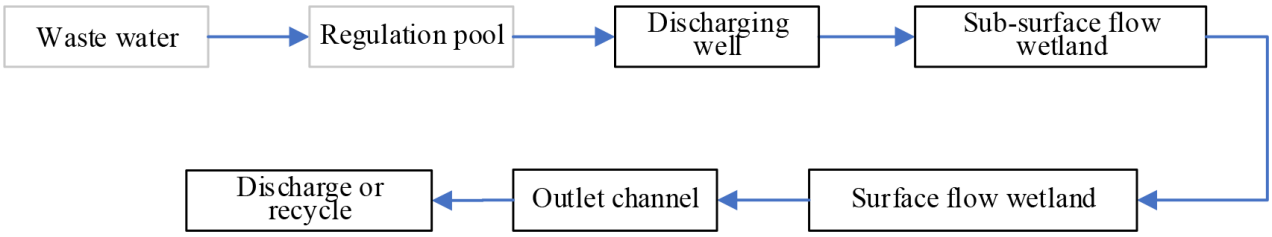

Fig. 2. Sewage treatment process

Table 3
Concentration of treated pollutants

Components	Concentration
Color, mg/L	35.7
CODcr, mg/L	51.2
BOD_5, mg/L	16.7
Total phosphorus, mg/L	0.4
NH_4-N, mg/L	10.2
pH value	8.1
Solid suspensions, mg/L	18.9

adjust the water level in the subsurface flow bed, the water in the collector flows into the second level surface flow bed.

The fifth area sets wide grass strips, plants plant and filters duckweed and dead microorganisms as well as plant and animal waste. It also prevents the outflow and water and reduces water quality.

The sixth area is the surface discharge water sink, and the overflow water is used to enter the sink.

3. Results and discussion

The two level wetland treatment system designed is used to treat the waste water from Cui Huashan resort. The water from the tank is collected as a test object, and the purification effect of the constructed wetland treatment system on sewage is tested. The concentration of pollutants in the water is shown in Table 3.

It can be seen from the table that the concentration of pollutants in the water has reached the first level of the allowable discharge after the treatment of the wetland. The concentration of CODcr and BOD, in a certain extent, reflects the concentration of organic reactions in water and the reduction of the concentration of organic matter in water is mainly the result of microbial decomposition. The reduction of phosphorus concentration is because of the limestone with high content of calcium is selected in the filler layer and the combination of phosphorus and calcium forms the precipitation. The reduction of nitrogen concentration is due to the absorption of aquatic plants and nitrification/de-nitrification of microbial. The reduction of solid suspensions is the results of the layer filtration, so the water contains only a few solid suspensions. Table 3 fully proves that the two-level wetland system designed in this paper has an obvious effect on the pollution control of the waste water from Cui Huashan resort.

4. Conclusion

This paper mainly analyses the basic composition of the wetland ecosystem, and through the simulation of the natural ecological environment of the wetland, designs the artificial wetland treatment system. In addition, the control principle of wetland ecological system of water pollution is analysed, and the decomposition method of organic matter, solid suspensions, nitrogen, phosphorus and heavy metals in wetland is explained. Taking the domestic waste water of Cui Huashan resort as the research object, we design 300 m^2 two-level wetland treatment system. There are two kinds of wetlands in the two sites, namely, the subsurface flow and the surface flow wetland. The two wetlands can play a complementary role in function and superiority. The experimental results showed that the two level wetland treatment system designed could effectively deal with the domestic waste water in Cui Huashan, so that all the pollutants in the final water discharged reach the first level of discharge.

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