Modular Eco -Percolation Tank R & D and Engineering Application

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Abstract. The dispersed sewage in some areas which are far from the city's municipal pipelines has not been treated properly. That the effluents are directly discharged without treatment can cause adverse effects on the surrounding environments. In order to treat the dispersed sewage, which has characteristic of high concentration of BOD_5 or NH_3-N, the designers have developed an ecological treatment technology for sewage, which is called Modular Eco-Percolation Tank Process and applied to a highway service area in Shandong Province. The statistics of treated sewage has shown that the Modular Eco-Percolation Tank Process has good applicability for the sewage treatment in the service area. The treated effluents have a stable quality which has reached the water quality standard and can be directly discharged into the environment.

1. Introduction

The scattered drainage area is far away from the urban areas thus its drainage system is usually not in the city municipal sewage pipe network coverage If not handled directly, the discharge of sewage could cause pollution to the surrounding environment [1]. Although the laying of sewage pipe network could be transported to the city sewage treatment plant, the high cost is not realistic. Therefore, decentralized treatment of decentralized sewage is very necessary. What's more, with the improvement on people's living standards, the demand for domestic miscellaneous water (such as urban greenbelt water use and flushing, etc.) is also growing [2]. It will result in a waste of water resources if we all use tap water, which could lead to a fact that the current shortage of water supply situation becomes more serious. Accordingly, under the current shortage of water resources, the research and development for decentralized sewage treatment and reuse technology are even more meaningful.

Dispersed sewage treatment and reuse have the dual meaning of protecting the environment and conserving water resources. It can not only provide new "water source" for resource-strained areas but also to prevent and control pollution even in water-rich areas [3]. Meanwhile, it reduces the burden of urban sewage pipe network and sewage treatment plant and truly realizes the protection of the environment and save the unity of resources, which is in line with China's current advocacy of the

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"energy-saving emission reduction" and building "resource-saving and environment-friendly" society [4].
Designers have analyzed processing facilities of the decentralized domestic sewage (such as expressway service area, remote neighborhoods), the selection of technology, equipment operation, treatment effects and developed a running low energy consumption, which has characteristics of resisting the anti-load change, low construction and operation costs of sewage treatment and reusing decentralized sewage [5].
The application of Modular Eco-Percolation Tank Process provides technical support for the disposal of dispersal wastewater in China, which has important practical significance.

1.1. Research at home and abroad

Decentralized sewage treatment technology is developed relatively early in foreign countries. They generally use decentralized treatment and some small sewage treatment system for processing with particular emphasis on water reuse, the most representative of which is the United States and Japan. The application of a wide range of processing technologies includes membrane bioreactor and artificial wetland treatment process [6]. The water is mainly used for green irrigation, flushing toilets and so on.
China's research on decentralized wastewater treatment and reuse is not systematic enough comparing with foreign countries. The current decentralized sewage treatment process for urban residents mainly uses buried biochemical treatment equipment, SBR, membrane bioreactor, ecological infiltration deep treatment, artificial wetlands, soil infiltration and so on. However, the corresponding research is less in decentralized sewage due to the characteristics of it [7].The water quality, operation cost, management control and so on are not satisfactory which have affected the use of the enthusiasm of the operator and the sewage treatment effect.

2. Interpretation

2.1. Research and development

The principle of Modular Eco-Percolation Tank Process comes from soil infiltration system. The soil infiltration system belongs to the land treatment system and is a practical and inexpensive engineering measure for the decentralized sewage treatment. It makes full use of the microbes, animals, plants, and soil physical and chemical properties of the soil, and can effectively remove the pollution from the sewage substance. Soil infiltration system has many advantages in treating sewage, but the researchers have been researching and developing the corresponding improvement process because of the shortcomings of the system [8]. For example, the system is easy to plug; the treatment load is low; the denitrification effects are not good and the backwashing is not easy.
Among domestic researchers, the majority is to study the removal of pollutants in the sewage effect of the best filler. To accept more sewage treatment with less areas and have the good effect are indeed very few in the research [9]. In view of this defect, researchers developed a set of the treatment process of the recycled water, which is easy to construct and simple to manage---Modular Eco-Percolation Tank Process. The Modular Eco-Percolation Tank Process is based on the soil infiltration system. Modular ecological soil infiltration system based on percolation tank process, treatment structures filled with porous media, using ecological engineering principle by means of engineering [10]. Through arranging the distributing and collecting pipes in the filler, the sewage doses to the filler under the control and being collected effectively. Using the physical and chemical characteristics of Filler-Plant-Microbe composite system to recycle the fertilizer resources of the sewage, and purify the water. Modular Eco-Percolation Tank Process can integrate different number of processing unit modules according to actual sewage quantity and sewage load. This process shortens the time of ecosystem establishment and stabilization, and has better effect on pollutant removal in sewage.

2.2. Technological advantages

Compared with the complex construction process of the traditional soil infiltration system, modular modules of the various modules have been assembled in the factory; only need to locate the

combination and the construction is simple and fast. Modular equipment processing is more durable and has a high degree of standardization and strength compared to the traditional construction of the soil impermeable membrane and will not create a problem due to the traditional way which could format the cracks in the foundation of the leakage and result in groundwater pollution.
The Modular Eco-Percolation Tank Process has the advantages of low investment, low running energy consumption and high efficiency of pollutant removal, and it is beneficial to be used in small and medium-sized sewage treatment. Modular Eco-Percolation Tank Process can really be energy-saving emission reduction, flexible design and can be integrated with the surrounding landscape environment. While doing the sewage treatment, it is also regarded as the role of landscape and ecological protection; truly respects and protects nature.

2.3. Structural diagram
The structural diagram of the process are as shown in the Figure 1, 2 and 3.

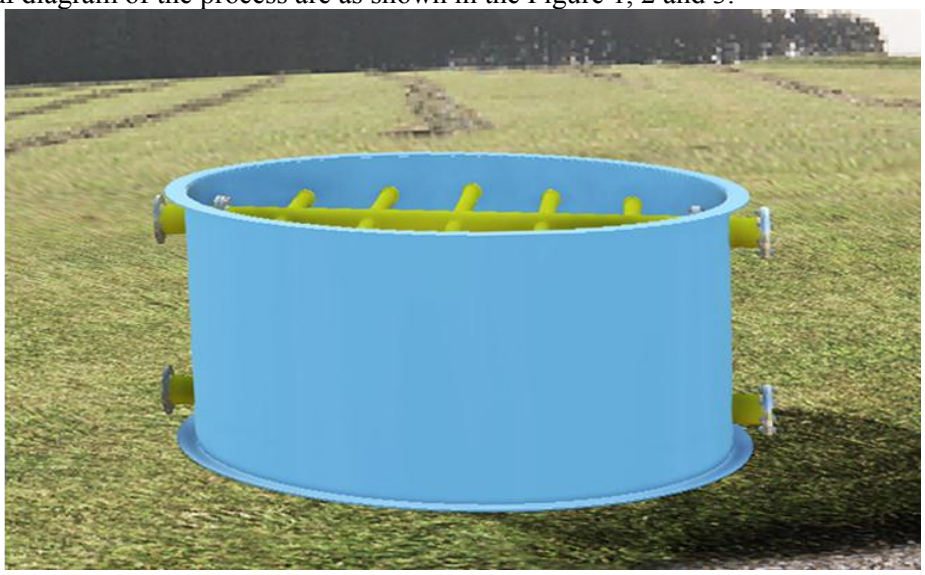

Figure 1. Front view of modular ecological flotation tank.

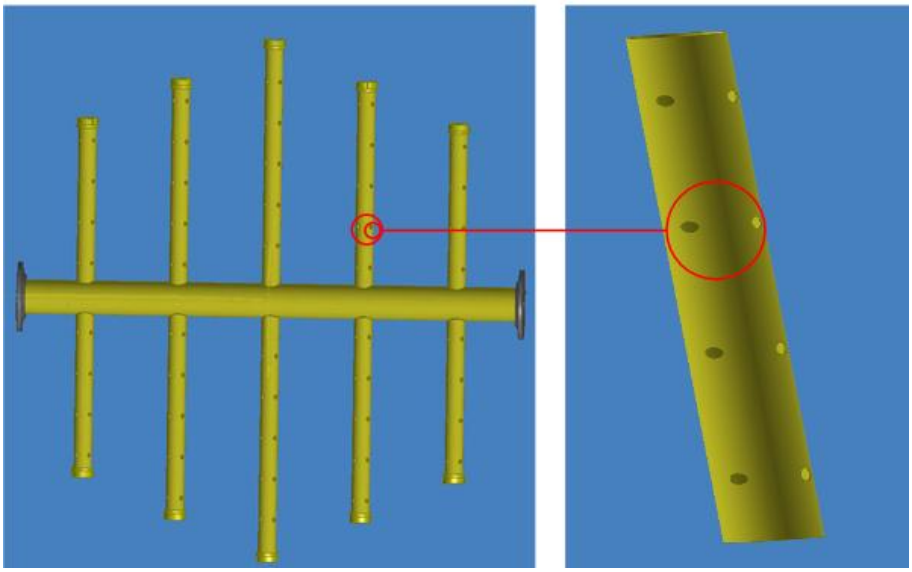

Figure 2. Internal pipe network diagram.

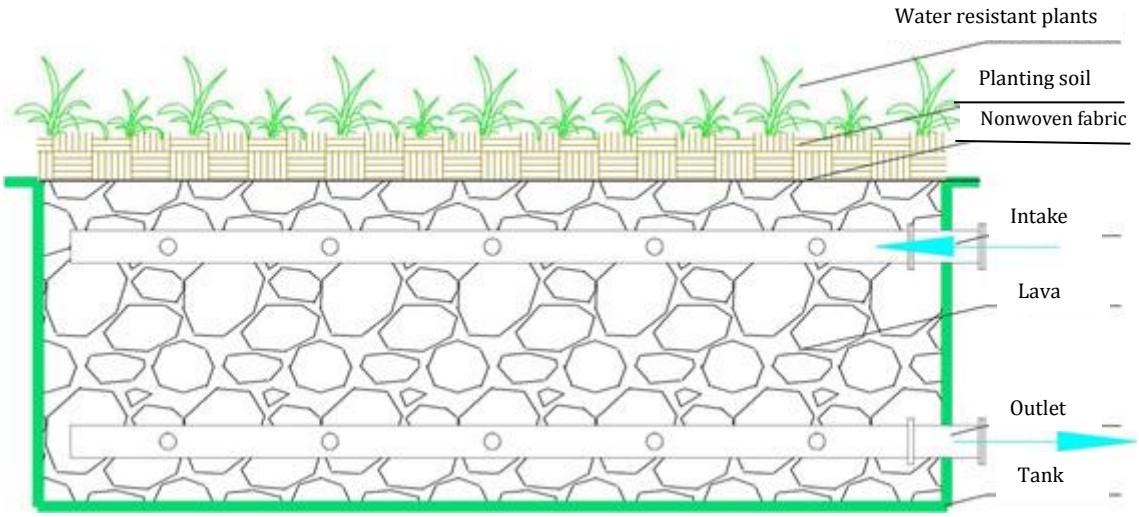

Figure 3. Section of the modular ecological flotation tank system.

2.4. The principle of modular ecological flotation tank

Ecological infiltration tank uses an impermeable material and the filler is filled with the whole ecological infiltration tank. Ecological infiltration tank is buried in the set, covered with non-woven fabrics, and then backfilled planted soil; the surface is planted moisture-resistant plants. The ecological leaching tank relies on the combined action of microorganisms, aquatic plants and fillers to remove the pollutants such as suspended solids, organic matter, nitrogen, and phosphorus. The main removal principles of pollutants are as followed:

(1) From the bottom of the ecological infiltration tank to the top, the filler in the microbial is in the anaerobic, anoxic and aerobic state step by step. The researchers use the metabolic activity of microorganisms to oxidize organic compounds in sewage into inorganic substances so as to purify the water.

(2) Water-tolerant plants absorb some nutrients by themselves. Leaves and branches can transport oxygen from the atmosphere to the root in order to provide dissolved oxygen for the microbial growth. The roots of the water-resistant plants extend vertically downward and have very strong penetrability. Thus the ability to transmit oxygen is strong. The uptake of the surface plant and the decomposition of the underground microbial are an artificial strengthening on natural ecological processes.

(3) After allocating the sewage, the filler can remove nitrogen and phosphorus and other pollutants through physical and chemical pathways such as absorption, filtration, ion exchange, complex reaction. The selected filler has characteristics such as inert, corrosion resistance, strong surface hydrophilic, rough and porous. The attached biofilm's growth speed is fast and there's no inhibitory effect for the immobilized microbial elements therefore it does not affect the activity of micro-organisms. Consequently, it is easy to format a stable micro-ecological balance system in the tank. Even if the packing is caused by improper use, the filler can be used for backfilling after cleaning.

3. Application example

3.1. Project overview

A highway service area in Shandong Province covers an area of 100 acres. Housing construction area is more than 5500 square meters. It is a comprehensive service area with parking, refueling, car maintenance, restaurants, shopping malls, toilets, guest rooms, leisure and so on. The peak daily discharge of sewage in the north and south part of service area reaches 200 tons. The treatment process used in original sewage treatment plant was "contact oxidation + precipitation + filtration". Not only it required a higher management, but also the water was difficult to reach a stable A Standard. Therefore, it resulted in that sewage station had been abandoned because of long-term idle. After abandoning the sewage treatment station, the sewage in the service area is treated by suction truck.

The project covers an area of about 216m^2 ; regional service population is about 8,000; the maximum daily sewage volume is 200t/d; the maximum sewage flow is 8.5t/h. After about 15 days of construction, the project has been successfully completed on March 20, 2017, and began to commission the operation of the system in early April. After a month of debugging operation, the water quality can be achieved "urban sewage treatment plant pollutant discharge standards" (GB18918-2002) In the A-level emission standards. The water quality of the project is shown in the following Table 1.

Table 1. Engineering water quality.

Project	pH	COD_{Cr}(mg/L)	BOD_5(mg/L)	NH_3-N(mg/L)	SS(mg/L)	Colority
Water in	6～9	≤350	220	≤30	≤150	≤70
Water out	6～9	≤50	≤10	≤5	≤10	≤30

3.2. Treatment process

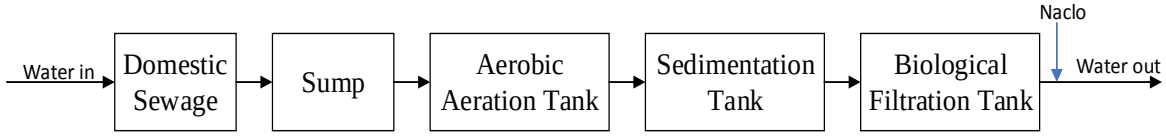

Figure 4. Process flow chart.

The sewage in north and south service areas of which is collected by the service area drainage network flows into the sump by gravity. The process of the treatment process is shown in the Figure 4. Sewage lifting pump is installed in sump and sewage pumps through the water pipe lift the sewage into the 4 pretreatment tanks (3 aerobic aeration tanks, 1 vertical flow sedimentation tank). Pre-treated sewage is distributed by gravity into 20 ecological infiltration tanks and disposed in the ecological infiltration tank through the complex biochemical decomposition and diafiltration process. The way of water disinfection is to release chlorine regularly. The chematic diagram is shown in the Figure 5.

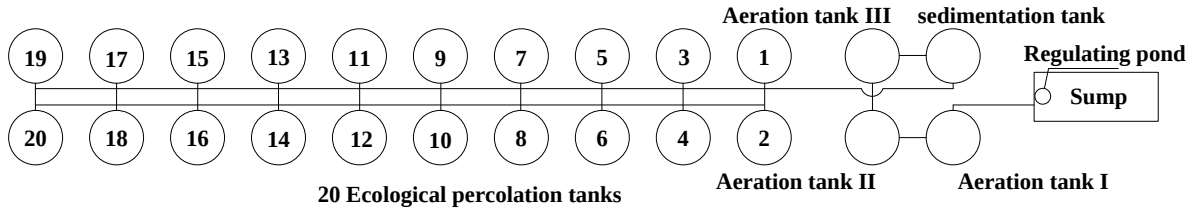

Figure 5. Schematic diagram of the plane layout.

3.3. Composition and parameters

Sump: taking anti-seepage measures and using the service area northeast side of the reservoir to dredge and for its masonry. The size of the sump is 30 m × 6 m × 1.5 m, and the sump collects the sewage in the service area and adjusts the water quality and water quantity effectively, and plays the role of regulating the pool to ensure the stable operation of the follow-up process. The regulation pool with steel structure is set in the sump; the effective volume is 150m^3; the sludge flows back to the regulator pool by gravity then lifted back to the aeration tank through the pump.

Aerobic aeration tank: the main materials use anti-corrosion steel plate, part of it buried in the ground; the diameter is 2.8m; the height is 5.6m; total of 3 are in series. Aerobic aeration tank pretreats the sewage with hypoxia/ aerobi; ation tank aeration uses the underwater aerator. Researchers use steel ring to fix three aerobic aeration tank and sedimentation tank together to prevent the subsidence of the pool body.

Sedimentation tank: the materials and specifications are same with aeration tank; sedimentation tank uses the method of vertical precipitation.

Ecological infiltration tank: The main body of the flotation tank is made of glass fiber reinforced plastic; the diameter is 2.8m; the height is 1.4m; the perforated pipe is used to distribute and drain water. The filler uses 3~5 cm massive volcanic rocks.
Water resistant plants: the project obtains materials locally, choosing iris or reed for moisture-resistant plants.

3.4. Structure of ecological infiltration system
The ecological infiltration tank uses FRP as its material, filled with volcanic rocks. Ecological infiltration tank is buried in the set, covered with non-woven fabrics then backfilled planted soil with the thickness of 100 ~ 150 mm, planting water resistant plant on the surface such as yellow iris or reed. Firstly, sewage is pretreated by flowing through the pool, then aeration tank and the sedimentation tank. The sewage flows to the ecological drainage tank water pipe buried in the underground, and then infiltrate the surrounding volcanic rock from top to bottom, finally to the next ecological infiltration tank through the bottom of the porous collection tube. The comparion diagrams of the front and rear effect are as shown in the Figure 6.

Figure 6. Before and after the works of soil cover.

3.5. System construction cost and benefit analysis
The costs statistics of the treatment construction in the Geran high-speed service area are shown in the table below. 1 ton of water investment is about 3,500 yuan. The construction costs are shown in the Table 2.

Table 2. Construction costs.

Serial number	project name	Total price (million Yuan)
1	Civil part	0.14
2	Plant part	0.06
3	Supporting facilities	0.5
	Total	0.7

Direct operating costs:
Electricity: The total installed capacity of the project is 3kW; the starting time is 24 h, the power factor is 0.7; the electric charge is 1 yuan/kW·h then:
Electricity charges: $3 \times 24 \times 0.7 \times 1 = 50.4$ yuan/day
Labor cost: The function of ecological diafiltration is a maintenance-free process, no need for management, only with a small amount of mechanical and electrical equipment in the pretreatment stage. The equipment is all automatic. The property management personnel can do the patrol inspection job thus it will not incur additional costs.
Per ton of water direct operating costs:

(Electricity + labor costs)/daily treatment of water = 50.4/200 = 0.252 yuan/ per ton

4. Benefit analysis

1) Sewage treatment costs

Under the premise that the project does not take the cost of labor into account, the direct operation of water costs 0.252 yuan per ton. Compared to the costs of the sewage to the municipal drainage, the fee of municipal sewage treatment is 1.0 yuan per ton. The sewage treatment capacity considered in accordance is about 200 yuan per ton for a day, and the daily processing fee is 150 yuan for a day. Therefore it can save sewage commission processing costs more than 50,000 yuan for a year.

2) Cost of self-contained wells

Under normal operating conditions, the process can be used for service areas of greening, spraying and other use. The cost of self-provided wells is about 2 to 3 yuan per ton if water costs, sewage charges, management fees and equipment maintenance costs are considered in it. If used daily 200 tons of recycled water to replace these high-quality water, it could save 70,000 tons of groundwater resources per year and reduce water costs more than 100,000 yuan.

3) Environmental benefits

It can fully improve the service area and the surrounding environmental health through the implementation of this project. Annual COD emissions are reduced by 35 tons; BOD emissions are reduced by 20 tons, and total nitrogen emissions are reduced by 2 tons. The project adopts the way of ecological treatment to reduce pollution and integrate into nature.

4) Social benefits

The regional environment has been improved through the implementation of the project. The social problems caused by sewage pollution have been eliminated. The image has been established for the development of service area, and the conditions for sustainable development have also been established.

5. Innovative features

(1) The theme of the wastewater treatment design and application is "Energy saving and emission reduction". In the practical application, the ecological management can be used to reduce the investment cost and the pollutant discharge, also save energy. The water quality is better, and it is more respectful for nature and protects the ecological environment.

(2) The pretreatment equipment and the ecological percolating tank can be combined flexibly and conveniently according to the water treatment capacity.

(3) Compared with the rectangular box structure, the round tank structure has reasonable force structure, uniform hydraulic conditions, and avoids the common distribution dead angle of the structure to ensure the stability of the treatment effect.

(4) Commercial production is more favorable.

6. Conclusion

The research and development are mainly used for the highway service area away from the municipal facilities, remote villages, towns and other scattered domestic sewage treatment; it has the characteristics of low investment cost, convenient operation and management and low maintenance cost in the later stage. The research and development of this project are of great significance to speed up the construction of "resource-saving and environment-friendly" society and to improve the efficiency of water resources utilization and respond to the "13th Five-Year Plan" of energy conservation and emission reduction issued by the State Council. At the same time, the reuse of sewage treatment technology can effectively alleviate the current situation of water resources and provide strong support for the construction of ecological civilization.

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