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Technology and practice of rural sewage treatment based on unpowered biochemical project

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Abstract. Quantity, quality, features of **s**ewage and problems of sewage treatment in X town, Yunhe county are analyzed. The unpowered biochemical treatment combined with artificial wetland sewage treatment is proposed. The combination of the decentralized and centralized treatment of rural sewage in this town is recommended. Effect of the sewage treatment of rural and application prospect is also discussed, and the running result showed that this technology processed performed well. Low investment in construction, low cost in operation, and easy management make this technology applicable to the less developed areas of the rural.

1. Introduction

With the constant improvement of rural life level and industry, quatity of waste water increased rapidly. Discharging of wastewater directly into rivers and lakes without treating will inevitably lead to water pollution, and the development of the reckless does not conform to the trend of today's development. Therefore, it is essential in our morden county to recognize that strengthen the rural sewage treatment has become an important content of socialist new rural construction.

Under the condition of Chinese huge land area, social organization structure, economic development status and living habits are various as the distribution of villages and towns is extremely scattered. All these factors not only resulted in the complex characteristics of village wastewater, such as wide surface, dispersal, but also the complexity of choice of treatment process, construction, investment, operation and management. The development of rural areas in China is relatively deficient because of the shortage of funds and resources. By the end of 2014, administrative villages, whose domestic sewage was treated before discharge, made up only 13% in China. The characteristics of rural domestic sewage are very different from that of the city, but its technical system and management system are not perfect. The environmental burden of domestic sewage in rural areas has exceeded the city's. In the formulation and implementation of the 13th five-year plan, sewage treatment in rural areas has become an important issue in China's water environment governance. [1]

Therefore, how to control and manage rural sewage problem, still need to be constantly practiced and discussed. The source of rural sewage was various, containing domestic sewage, farmland storm runoff, livestock sewage and so on. So it has the characteristics of wide varieties of sources, intermittent discharge, diversity of water quality, high organic concentration, small pollution load of unit area, etc. [2] Practical technology with less cost, low energy consumption, stable operation, should be adopted combined with the actual situation. The methods of rural sewage collection and treatment are divided into three types according to the degree of centralized treatment: urban sewage treatment, collected and processed of village units through small pipe networks (village group for short), and in-situ wastewater treatment. The key point to reduce the cost of sewage treatment in rural

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areas is to choose the suitable sewage collection and treatment methods.[3] The model of "classification in household, collection system in village, transporting and processing in town" is generally adopted in areas around town and places of sensitive environment. However, in villages with scattered layout, underdeveloped economy and inconvenient transportation, the mode of "classification in household, collection system and processing in village" is preferred.

Engineering technical measures and technical schemes have been compared and analyzed in the case of X town in Yunhe country. Various treatment technologies and artificial wetland systems in rural areas was focused on to provide a certain reference to the overall reduction of rural environment less developed.

2. Project Summary

Yunhe county X town covers 5.96 km^2, contains 19 village groups, 415 households, and a design service population of 1,026. The original sewage system is transformed as some of the sewage in the village is discharged through the ditches, which seriously affects the appearance of the village at present. According to the *Technical guide for the individual project of lishui rural environmental serial remediation*, this village was regarded as the key demonstration village, and its sewage treatment rate must reach more than 75%. According to this guide and on-the-spot investigation, the water used per person (consumption per head) was 120 litres per day, production rate of sewage was 85%, the collection rate was 85%. Storm water sewers and sewage systems were separated. Sanitory waste, such as kitchen sewage, toilet flushing and washing wastewater, collected by building sewers, then drained to branch by gravity and to the sewage treatment facilities finally. The total sewage treatment scale of the village is 105 m^3/d considering of the growth of foreign tourists during the peak season.

On the actual reconnaissance, the dwellings are scattered except four concentrated settlements. A combination of centralized and decentralized sewage treatment mode is adopted and each village processing scale is shown in table 1.

Table 1. Scale of Sewage Treatment in Different Regions

Project		Size ($m^{3/}$d)	Processing facility quantity (a)
Administrative village	A Village	55	2
	B Village	15	1
	C Village	20	1
	D Village	15	1

According to the actual water quality sampling datas, considering the village life level and the water quality of the same kind of village in this region, the water quality of the village sewage treatment station should achieve level 1 B standards prescribed by *Pollution discharge standards for urban sewage treatment the plants (GB18918-2002).* The principal datas of influent and effluent is shown in Table 2.

Table 2. Water Quality Requirement of Influent and Effluentt

Project	PH	COD_{cr}(mg/L)	BOD_5(mg/L)	SS(mg/L)	NH_3-N(mg/L)	T-P(mg/L)
Influent	6~9	≤200	≤120	≤100	≤20	≤1
Effluent	6~9	≤60	≤20	≤20	≤15	≤1

3. Sewage Treatment Process

3.1. Process Comparison

Over the years, a variety of methods have been developed for the treatment of wastewater. There are four mainly treatment methods for urban sewage in our country, A/O membrane-bioreactor, integrate sewage ecological treatment system, artificial wetland and land percolation treatment. More information can be found in next discussions.

A/O membrane bioreactor is a new technology, combined membrane separation technology and waste water biological treatment technology. This process is able to replace the secondary sedimentation in traditional secondary biological treatment.[4] Due to the introduction of the membrane separation unit, and the higher sludge concentration in the membrane bioreactor exist, the denitrification performance in the membrane bioreactor can be strengthened to some extent.[5]

The integrated wastewater treatment system, also known as A/O biochemical process, has a built-in precipitation and sludge return system. The shell of the machine is made of mechanical winding glass fiber reinforced plastics tank and is buried under the land. It has a long service life, which has been proven that the system can work for 15 years, stain and stable water quality so that it's suitable for sewage treatment in rural areas. Furthermore, this system is equipped with soil deodorization facilities, automatic electrical control system and alarm system. The shortage of this system is also obvious, revealing in a bit high cost in initial construction investment.

The artificial wetland sewage treatment technology is designed to remove nitrogen and phosphorus from domestic sewage via the action of nitrogen and phosphorus uptake by plants and soil organisms by regularly harvesting wetland plant.[6] However, there are some problems in the operation of artificial wetlands as it is greatly affected by temperature. Studies have showed that nitrification in wetland tends to stop below 4 °C. Although there is no good solution to the above problems, artificial wetland has achieved rapid growth in recent years in China because of its low cost, high degree of automation, convenient management and maintenance, obvious nitrogen and phosphorus removal efficiency and beautification effect on environment.

Table 3. Comparison of Decentralized Sewage Treatment Technologies

Project	Processing scale/($m^3 \cdot d^{-1}$)	Water quality standard	Technical and economic analysis		
			Floor area/($m^2 \cdot m^{-3}$)	tons of water investment / 10,000 yuan	Operating cost/(yuan $\cdot m^3 \cdot d^{-1}$)
A/O plate membrane - bioreactor	10~50	GB 18918-2002 level B standard	0.64~0.91	1.0	0.25~0.3
The integrated sewerage ecological treatment system	10~30	GB 18918-2002 level B standard	1	1.0	0.27~0.32
Artificial wetland	10~50 and above	GB 18918-2002 level B standard	10	0.6	0.2
Land seepage system	10~50 and above	GB 18918-2002 level B standard	10	0.76	0.2

Infiltration land treatment system, belonging to small wastewater land treatment system, is a kind of artificial strengthen sewage ecological engineering treatment technology. Under the condition of artificial control, the sewage is distributed to the land, soil animals. Soil microbe, plant roots under the surface of soil and the properties of the soil itself are fully utilized in this system to purify the wastewater through a series of physical, chemical, physical- biochemical purification. Due to the large amount of organic matter in the sewage, the microorganisms and plant roots in the soil can adsorb the nutrients and grow better, and the water is purified at the same time. Though it has the advantages of stable, less cost, easy management, good treatment effect, this technique is widely used abroad[7] but not at home for the affect of different factors.

Comparison between various decentralized sewage treatment technologies is shown in Table 3. From the data in the table, it can be seen that both land infiltration and artificial wetland occupy large area but have the relatively low investment. A/O flat membrane - bioreactor and integrated wastewater ecosystem have a slightly higher investment cost and a small footprint. There is little difference in the cost of running management in these water treatment systems. By comparison, artificial wetland

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treatment technology is undoubtedly a good sewage treatment technology for areas lacking of capital and technology as it has advantages of low cost, low energy consumption, simple and effective operation[8]. In addition, artificial wetland ecosystem has ecological landscape effect, which can also be used as "natural observation park" or local "ecological education base".

3.2. Scheme Selection
Considering the above factors, the sewage treatment process scheme of the village is shown in Figure 1.

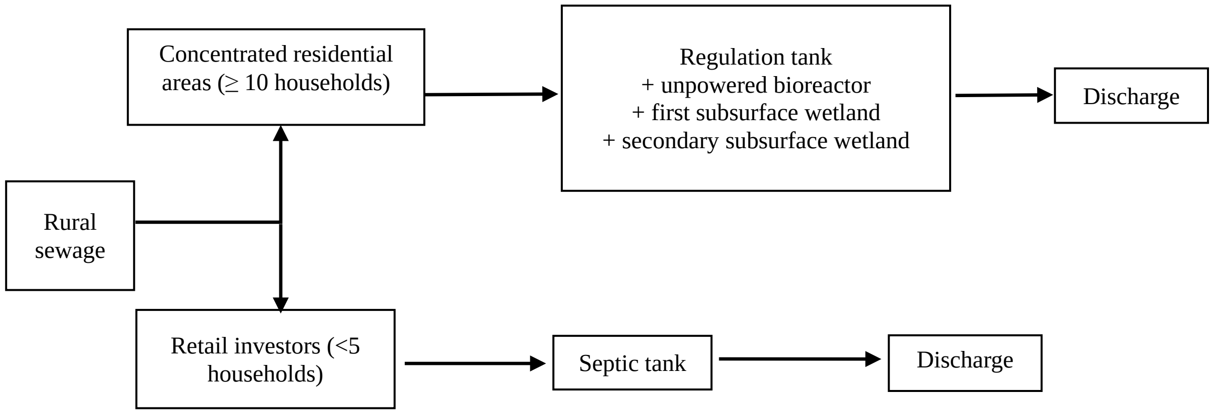

Figure 1. Sewage Treatment Process Scheme of X Town

The sewage pipe network is built to collect the household sewage collected into the small sewage treatment station in the centralized area of the user. To design the network properly, suitable material, size and location of pipes and manholes should be available for the areas to be served. In this project, pipes were made of high density polyethylene (HDPE), and the trunk sewers' diameter ranged from 250~300 mm. Manholes, one of the principal appurtenances, with the size of 400 mm×400 mm, made of concrete, should be constructed every 40m in trunk. In addition, the height from the surface to the bottom of manholes should be determined according to the buried depth of the pipe. Sequence of methods, regulation tank—unpowered bioreactor—first subsurface wetland—secondary subsurface wetland were selected in this project. The folding plate reactor with floating balls internal, which can make a good contact between sewage and microbial was adopted in the unpowered bioreactor process. The secondary subsurface flow artificial wetland is constructed under the primary by the vertical flow form, which is connected by water. There was at least one vertical guide wall arranged in each wetland of the vertical flow subsurface wetland group. The multi-level aerobic and anoxic-aerobic biological reaction of wastewater can be promoted as the flow of the water above the current flows passed in turn of aquatic plant growed in media, various substrates filled in, aquatic plant and so on[9].

For dispersed users, septic tanks are used to treat sewage as the septic tank process is more mature and easily accepted in rural applications. When the tank is mixed with raw wastewater, numerous bacteria and other microorganisms are used to decompose the organic solids under anaerobic condition, promote coagulation and flocculation, and convert the colloidal and suspended solids into settle able solids. As a result, wastewater was modified after precipitation, and provided fertilizer for farmers by installing feces collection channel.

3.3. Parameters of Process
1) Regulating tank

Hydraulic retention time: HRT=10h; Structural: reinforced concrete /bricked.

2) Unpowered bioreactor

COD volume load: 0.25kgCOD/m^{3}d; Hydraulic retention time: HRT=20h; Effective water depth:1.5m; Packing quantity:80%; Packing thickness: 1.0m; Structure: steel+Fiberglass-Reinforced Plastics(FRP) +anticorrosive materia.

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3) Submerged artificial wetland

Hydraulic load: $0.4m^3/m^2 \cdot d$; Hydraulic retention time: HRT=1.5d; Length-width ratio: ≤3:1; Effective depth: 0.8m; Water distribution manner: perforated diversion wall; Packing matrix (from the bottom): pebble, 150 mm in thickness, 80-100 mm in diameter; round limestone, 150 mm in thickness, 50 to 60 mm in diameter; pebble, 150 mm in thickness, 10-30 mm in diameter; sand, 150 mm in thickness, 2-5 mm in diameter; aquatic plants (emergent plants) : reeds, calamus, scirpus, and bog rushes (ratio of 4:3:2:1), planting density: 20-25 plants $/m^2$; structure of wetland bed : reinforced concrete.

3.4. Details of Processing Facilities in Each Region

According to the field investigation, the water purification facilities of Yunhe county X town were investigated and the details are identified in Table 4.

Table 4. Parameters of Pretreatment Facilities

Village name	Scale ($m^3 \cdot d^{-1}$)	Regulating pool Length×width×depth (m)	Anaerobic biological reaction pool Length×width×depth (m)	Remarks
A Village	40	3×4×2.0	3×8×2.0	Co-construct
B Village	15	2×2×2.0	2×4×2.0	Co-construct
C Village	20	2×3×2.0	2×6×2.0	Co-construct
D Village	15	2×2×2.0	2×4×2.0	Co-construct

Table 5. Parameters of Constructed Wetland

Village name	Scale (m3·d-1)	Artificial wetland Length×width ×depth (m)	Aquatic plants (strains)	Remarks
A village	55	23.2×7.4×1.5	2940	Reeds1170 ; Calamus 880; Scirpus 590; Bog rushes 300
B village	15	13.1×3.9×1.5	740	Reeds300 ; Calamus220; Scirpus 150; rushes70
C village	20	13.5×4.5×1.5	1220	Reeds490;Calamus 370;water leek240; Bog rushes 120
D village	15	13.1×3.9×1.5	740	Reeds300 ; Calamus220;Scirpus 150; Bog rushes 70
Total	105		5640	

4. Processing Effect Analysis

Since operated from March 2015, the project has been running well and the water quality indicators are shown in table 6.

Table 6. Average Water Quality of Influent and Effluent in X Town in Lishui City

Project	BOD_5 (mg/L)	COD (mg/L)	SS (mg/L)	NH_3-N (mg/L)	TN (mg/L)	T-P (mg/L)
Influent	212.6	306.7	186.8	39.4	45.9	4.69
Effluent	8.4	38.4	6.3	7.3	12.6	0.43
Removal rate (%)	96.0	87.5	96.6	81.5	72.5	90.8

Water wetland, substrates, aquatic plants and microorganisms constitute the four basic elements of artificial wetland sewage treatment system. Datas showed that the removal performance on N, P was optimized under the interconnected synergy of physical, chemical and biological proces. The main physical action is that it can filter and retain SS in the sewage through the substrate layer and intensive plant work and root system after the sewage enters the wetland. Chemical reactions mainly refer to chemical precipitation, adsorption, ion exchange, antagonism and redox reaction. Biochemical reaction mainly refers to the degradation and removal of pollutants by means of microorganism, which is decomposed into simple and small molecules through open-loop and broken bonds in aerobic, anaerobic and anaerobic conditions.

Cui's studies showed that existence of plants can promote nitrification as removal rate of TN in artificial wetland systems of having plants was obviously higher than that of not[10]. Table 6 showed that this project performed well on the sewage treatment in the town, and the average removal rate of each pollutant is some 87%. A higher removal rate was achieved in SS(96.6%), followed by BOD_5(96%) and T-P(90.8%). All the effluent index meet the A standard of *Pollutant discharge standard of urban sewage treatment plant*(GB18918-2002), indicating that the operation is in good condition.

5. Conclusion

Domestic sewage treatment in rural areas is not easy due to the difficulties in normal operation of treatment facilities, to a certain extent. If the treatment mode of large and medium-sized municipal sewage treatment plants is adopted, it will increase the burden on farmers. On the contrary, unpowered biochemical reactor combined with the artificial wetland treatment has the advantages of low construction investment, low operation and processing cost, easy management and so on. It's suitable for rural areas in underdeveloped areas. After the implementation of the project, the local sewage and other environmental problems can be effectively solved.

The sewage treatment scheme has been effective, but there are still some problems. For the area, sewage treatment is still in the exploratory stage, and it is still relatively weak in the combination of sewage treatment and sewage resources. Due to the realistic factors such as fund management, many supporting facilities have not been put in place and the processing effect has not been optimized. Lacking of basic environmental monitoring and statistical data, relatively weak local residents' participation, also increase the difficulty of future governance and management.

According to the series of problems mentioned above, it is suggested that the relevant departments should combine the actual situation, increase the investment, maintain a high degree of attention, and take active and effective measures to solve problems existed.

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