Study on the Effect of Constructed Wetland in Treating Rural Domestic Sewage

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Abstract. With the progress of modern science and technology, people's living standard is getting higher and higher. The free discharge of production and domestic sewage has caused more and more serious water pollution. The focus of sewage treatment is generally in the city, the rural sewage treatment is often neglected. According to the results of the first national pollution census, the discharge of pollutants in rural areas has a serious impact on the water environment, with COD, nitrogen and phosphorus accounting for 43.7%, 57.2% and 67.4% of the total. China produces about 80 billion tons of rural sewage every year. In rural sewage, 90% of domestic sewage is directly discharged without effective treatment, causing serious water pollution, and sewage treatment is urgent. In this paper, the situation of sewage treatment in rural A of Fujian Province is analyzed, and a constructed wetland is designed according to the actual situation. The constructed wetland has the advantages of simple sewage treatment and maintenance, low operating cost and relatively small consumption. It can also save land resources, can be widely transported to sewage treatment, and can better protect the water environment and aquatic ecosystem.

1. Function introduction of constructed wetland
Constructed wetland has a strong role in degradation and purification of organic pollutants in sewage. As nutrients, some organic pollutants can be directly absorbed by plants. The main body of the constructed wetland system is a series of physical, chemical and biological degradation reactions through the synergy between the wetland matrix, wetland plants and wetland microorganisms, using matrix precipitation, filtration, adsorption and ion exchange, plant absorption, microbial degradation and metabolism, To achieve the purification of pollutants in water[1].

2. Design of constructed wetland sewage treatment system
This paper selects A rural area in Fujian Province as the research object. The rural domestic sewage is discharged arbitrarily without treatment. The domestic washing water, such as washing clothes, vegetables and bath, discharged by the farmers, flows along the ditch to the nearby farmland, canal or trench around the village. Untreated domestic sewage contains a large number of organic compounds, N, P and other nutrient elements, which will directly enter the water and cause water pollution and eutrophication, resulting in the deterioration of water quality and great damage to the ecological environment[2]. There is a large amount of unused land in this rural area, and it is feasible to establish a compound constructed wetland in this area to treat domestic sewage. It is estimated that the treated effluent can meet the first-grade standard of rural domestic sewage discharge in Fujian Province.
Table 1. Discharge standard of rural domestic sewage.

| Control project name | First-class standard | Secondary standard | Tertiary standard |
|----------------------|----------------------|--------------------|-------------------|
|                      | A standard           | B standard         |                   |
| COD(mg/L)            | 50                   | 60                 | 100               | 150               |
| BOD5(mg/L)           | 10                   | 20                 | 30                | 60                |
| NH4-N(mg/L)          | 5                    | 8                  | 25                | 150               |
| TP(mg/L)             | 0.5                  | 1                  | 3                 | 5                 |
| SS(mg/L)             | 10                   | 20                 | 70                | 150               |

2.1. The process flow
In view of the characteristics of relatively concentrated water use and drainage in the rural area, extremely uneven discharge and large instantaneous discharge, the main technological process of the rural domestic sewage treatment is determined by the influent quality and the designed water quality as shown in figure 1.

![Figure 1. Process flow chart.](image)

2.2. Design of water
To ensure more efficient sewage disposal, the displacement is calculated based on the number of permanent residents (PE=450) in the village. Sewage quantity quota (q0) is 120L/(person•d). According to the Code for Outdoor Drainage, the rain recurrence period in rural areas is set as 0.5 years, the total change coefficient of water volume (η) is set as 5.0, and the waste water transport loss is set as 11%.

\[ Q_{\text{max}} = PE \times q_0 \times \eta = 450 \times 0.12 \times 5 = 270 \text{ m}^3/\text{d} \] (1)

Therefore, the water volume of the constructed wetland is 300 m³/d.

2.3. Grille design
The artificial wetland in the forefront preprocessor facilities set up a set of grid, to intercept in sewage such as fiber, broken skin, hair, fruit, vegetables, plastic products, such as the larger suspension and impurities, so as to reduce the follow-up treatment structures of the load, and make it normal individual pollutants, considering the construction and operation cost, using small grid as intercept decontamination facilities, artificial qing tao on a regular basis. The grid adopts steel wire with a diameter of 4mm, which is fixed and installed at an incline of 50° in the open channel before the sand sink pool, and the grid spacing is 1.5cm×1.5cm[3].

2.4. Design of sand settling tank
The effective water depth of the sand settling tank is 2.5m and the designed effective volume is 26.5m³. The sand settling tank uses gravity or centrifugal force to precipitate the inorganic particles with high density in the sewage, and the flow only takes away the organic suspended particles with low density, so as to remove the sediment in the sewage. The sand settling tank is arranged behind the grille to further remove the inorganic particles in the sewage. Sand settling ponds should be cleaned regularly, especially when the effluent of wetlands becomes turbid and after heavy rain, or when the sediment volume is 1/4, the sand settling ponds should be cleaned immediately.

2.5. Design of compound constructed wetland
A rural area has a humid climate and a lot of Rain Water. According to the specific conditions of the countryside, it is proposed to build two-level wetlands. The first stage is a surface undercurrent integrated wetland, and the second stage is a facultative wetland. When the amount of water is too
large, the subsurface flow wetland changes to surface flow operation under the action of large amount of water, and the sediment is trapped on the surface of the constructed wetland to reduce the risk of matrix bed blockage in the lower part of the subsurface flow wetland. The surface flow wetland at the front end plays the role of filtering, sedimentation and river closure, which reduces the blockage problem of the follow-up subsurface flow wetland [4]. On the other hand, in view of the weak effect of the sand settling tank caused by the untimely cleaning of the sand settling tank, the surface flow wetland strengthens the removal of particulate impurities which are easy to clog the wetland. The surface layer of the wetland is composed of sandy soil, the matrix layer is composed of 2~5mm coarse sand and phosphorus removal filler, and the impervious cloth is PE membrane double-sided geotextile.

| Table 2. Classification and structural composition of wetlands. |
|---------------------------------------------------------------|
| **Surface flow** | **Subsurface flow** | **Integrated wetland** | **Facultative wetland** |
| The thickness of the surface (m) | 0.05 | 0.05 |
| Thickness of matrix layer (m) | 0.10 | 0.55 |
| Thickness of impervious layer (m) | Not counted | Not counted |
| Total thickness (m) | 0.15 | 0.60 |

The wetland area is calculated according to the surface hydraulic load: the surface hydraulic load of the constructed wetland refers to the amount of sewage that can be accepted by the constructed wetland per square meter per unit time, and the value range is generally 0.05~0.3 m$^3$/m$^2$·d. When the surface hydraulic load is $q_{hs} = 0.2$ m$^3$/ (m$^2$·d), the wetland area is 1500 m$^2$.

$$A = \frac{Q}{q_{hs}} = \frac{300}{0.2} = 1500m^2$$  \hspace{1cm} (2)

Where

- $A$ = Constructed wetland area (m$^2$)
- $Q$ = Design water volume of constructed wetland (m$^3$/d)
- $q_{hs}$ = Surface hydraulic load (m$^3$/m$^2$·d)

The total area of the rural constructed wetland is 1500 m$^2$ and the designed water volume is 300 m$^3$. The aspect ratio of the constructed wetland unit should be controlled below 3:1. The plane dimension is 60 m long and 25 m wide. The integrated wetland of the first stage subsurface flow is 25 m long and 25 m wide, and the second stage facultative wetland is 35 m long and 25 m wide. The plants selected in the wetland are Reed, cattail, rice grass, beauty coke, water peanut and so on. The wetland species collocation is reasonable, taking into account the dual goals of sewage purification and landscape effect [5].

Figure 2. Side profile of two-stage composite wetland.
3. Study on purification effect of domestic sewage treatment by constructed wetland

3.1. Sample collection and processing
Water samples were collected from August to December respectively. 500ml of water samples were collected each time, and the pH value of water samples was tested on site. Acid was added to the water samples, and the pH value of water samples was adjusted to about 2. Continuous monitoring shall be conducted every 7 days every month for 3 days each time to compare the designed effluent water quality concentration of the project and determine whether the actual operation effect of the project is consistent with the design expectation.

Table 3. Methods for detection and analysis of water quality.

| Detection index | Analytical methods | The main instrument |
|-----------------|--------------------|---------------------|
| Temperature     | Thermometer method | Thermometer          |
| PH              | Convenient PH method | Portable PH meter  |
| COD             | Dichromate titration | Reflux device, burette |
| TP              | Ammonium molybdate spectrophotometry | Visible spectrophotometer |
| NH₄-N           | Nessler's reagent spectrophotometry | Visible spectrophotometer |

3.2. Analysis of purification effect of constructed wetland system

Through sampling investigation, it is found that the average concentration of COD in the domestic sewage entering the constructed wetland every month is 100mg/L, NH₄-N is 30mg/L, TP is 3.4mg/L, the concentration of COD discharged is generally stable around 44mg/L, the concentration of NH₄-N is generally stable around 5mg/L, the concentration of TP is generally stable around 0.8mg/L, and the monitoring time is 5 months. The removal rates of COD, NH₄-N and TP in the constructed wetland system are about 60%, 80% and 70% respectively. The concentration of COD, NH₄-N and TP in the effluent all stably reached the first-class standard of the Rural domestic sewage discharge Standard in Fujian Province, which proved that the constructed wetland has good application value[6].

With the decrease of air temperature, the purification effect of the constructed wetland also decreased, indicating that the operation effect of the constructed wetland system in summer and autumn is better than that in winter. In order to ensure the use effect of the constructed wetland, the wetland plants with good cold tolerance and rich root zone can be replaced in winter, and the insulation layer can be covered in the outer layer of the wetland. Generally speaking, the constructed wetland system has a good ability to purify the pollutants in rural domestic sewage[7].

4. Conclusion
People mainly use physical and chemical methods and biological methods to treat domestic sewage, while constructed wetlands, as a sewage treatment method, belong to biological methods, and have
many high-quality characteristics, such as low investment, low operating cost, easy to operate, not easy to produce secondary pollution and so on. The innovation of this article is that, according to the topography, climate, hydrology and other conditions of rural area A in Fujian Province, the dominant microbial and plant communities are integrated to build a stable composite artificial wetland system. The system has the advantages of low energy consumption, simple operation, low capital construction cost and low energy consumption. The operating cost of domestic traditional treatment technology is 1.0 yuan per ton, but the operating cost of the combined system is estimated to be 0.2 yuan per ton[8]. And the quality of the treated effluent can be ensured to a great extent. The results of the combined model of constructed wetlands can be used for sewage treatment in township communities, as well as tourism, vacation and other scenic development areas. It can also be used in areas where freshwater resources are scarce. The foundation and scale of water conservancy in China is still in the initial stage, so it is of great significance to develop a sewage treatment technology system suitable for our national conditions.

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