New Solution To Apply Constructed Wetland Technology In Cold Climate

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Abstract. Due to the influence of low temperature in winter, the removal effect of pollutants in constructed wetlands in winter is greatly reduced. In order to improve the removal effect of wetland on pollutants such as nitrogen and phosphorus, this paper proposes a new insulation method that uses the residual heat of bathroom bath waste water to supply heat to the constructed wetland. In the proposed new wetland system, the average removal rates of TN, TP and NH4+-N in wetlands reached 61.09%, 85.03% and 33.85%, respectively. The application of residual heat energy to the construction of constructed wetland can realize the recovery and utilization of energy, which is conducive to the promotion and application of constructed wetland in the cold regions of the north.

1. Introduction

Constructed wetland is a wastewater treatment technology widely used in the world, with the advantages of low cost, high efficiency and easy maintenance [1, 2]. However, the mechanism of purification of wastewater by constructed wetlands mainly relies on the combination of filtration of substrates, absorption of plants and transformation of microorganisms, and these pathways are greatly limited by temperature [3]. Studies have shown that in low temperature environments in winter, the treatment of nitrogen, phosphorus and other pollutants in constructed wetlands is extremely poor, and it is difficult to effectively treat wastewater [4]. In order to promote the widespread application of constructed wetlands in cold regions in winter, researchers have conducted a lot of researches on wetland insulation methods in winter, and proposed ice sealing method, film method, greenhouse method, pig manure composting method, etc. [5, 6]. However, the ice sealing method is difficult to maintain, the cost of the film method and the greenhouse method is too high, and the pig manure compost heat has a short duration of heat, which is difficult to widely use [5, 7]. To this end, this paper proposes a new insulation method of constructed wetland using residual heat energy.

Residual heat energy refers to the heat energy that can be recycled, which is an emerging concept that can realize energy recovery and utilization, reduce energy consumption in production and life, and improve energy utilization [8]. In this paper, taking the domestic wastewater treatment of the bathhouse as an example, a new method of applying residual heat energy to the winter heat preservation of constructed wetland is proposed.

2. Materials and Methods

2.1. Wetland Structure
The study area is located in Jinan, Shandong Province, of which the average temperature in December and February is below 0 °C, under this circumstance the common wetland is in a frozen state and is almost inoperable. In order to make the wetland operate normally in winter, this paper proposes the following wetland structure (as shown in Figure 1). The wetland is a horizontal subsurface wetland with a length of 10m, a width of 5m and a depth of 0.7m. It is rectangular and the buried pipe is laid at the bottom. According to the actual investigation, the bathroom bath water is 42~45°C, the bathroom drain is 25~27°C, and the wastewater reaches 17~20°C when the pipeline reaches the constructed wetland. During the experiment, the domestic wastewater discharged from some of the bathrooms was intercepted and introduced into the buried pipe. The residual heat of the wastewater was used to heat the wetland through the pipeline (as shown in Figure 2) to achieve the purpose of heat preservation, thereby improving the removal of pollutants. After the wastewater flows out of the buried pipe, the temperature is 5~7 °C, and then it is sent to the wetland for treatment.

2.2. Substrate Layer
The wetland is divided into three layers from top to bottom: a gravel layer (0.2 m), a zeolite layer (0.2 m), and a steel slag layer (0.3 m). The steel plate is laid at the bottom of the wetland to prevent the wastewater from infiltrating and improve the heat preservation effect. The buried pipe is laid on the steel plate and is made of polyurethane buried pipe with a diameter of DN100, a thickness of 20 mm, and a thermal conductivity of 0.022 kcal/m. h. °C.

2.3. Experimental Water Quality and Hydraulic Parameters
The wetland adopts the method of continuous water inflow, the hydraulic retention time is 3d, and the hydraulic load is controlled at 0.1m/d~0.15m/d. The water quality of wetland influent is shown in Table 1:

| Parameters | BOD (mg/L) | TN (mg/L) | TP (mg/L) | NH$_4^+$-N (mg/L) |
|------------|------------|-----------|-----------|------------------|
| Value      | 79.6~87.5  | 19.58~21.36 | 4.42~4.88 | 8.93~9.83        |

Fig.1 wetland structure

Fig.2 Pipe loop heating top view

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3. Results and Analysis

3.1. Removal of TP
Phosphorus removal is a very complex process, but relies primarily on plant uptake and matrix adsorption. As shown in Figure 3 below, the TP concentration range of wetland influent and effluent was 4.42~4.88mg/L and 0.53~0.78mg/L, respectively, and the average removal rate was 85.03%, which was not affected by temperature.

![Fig.3 Removal effect of TP](image)

In the wetland system, because the outside temperature is too low, the plants cannot grow, and the removal of phosphorus mainly depends on the adsorption of the substrate and the transformation of microorganisms. Studies have shown that the proportion of parts converted by microorganisms during phosphorus removal is small [9]. Adsorption of the matrix is the main route of phosphorus removal. Under the circulating heat supply of the residual heat energy pipeline, the matrix is less affected by the external temperature, the internal temperature is basically maintained at about 10~15℃, and the wetland running time is not long, and the phosphorus desorption amount is small. Therefore, the wetland system removes TP. The effect is good, and the average removal rate reaches 85.03%.

3.2. Removal of TN
As is shown in Fig.4 below, the TN concentrations of wetland influent and effluent were 19.58~21.36mg/L and 7.27~8.97mg/L, respectively. The removal rate was between 58.01%~63.49%, and the average removal rate was 61.09%.

![Fig.4 Removal effect of TN](image)

Numerous studies have shown that the removal of TN is affected by many factors, such as HRT, temperature, DO, plants, etc., where temperature is one of the main factors affecting TN removal.
Studies have shown that in low temperature environments, the activity of nitrifying bacteria and denitrifying bacteria is reduced, and the nitrification and denitrification reaction is weakened, resulting in a decrease in the removal rate of TN [5]. In the wetland system, the residual heat energy pipeline is used for circulating heat supply. The internal temperature of the wetland system is high, and the nitrification and denitrification process is less affected by the external low temperature. The removal effect on TN is good, the average removal rate is over 60%, and the TN effluent concentration is meet the first-class the pollutant discharge standard of urban wastewater treatment plant.

3.3. Removal of NH$_4^+$-N

As shown in Fig. 5, the influent concentration and the effluent concentration range of NH$_4^+$-N are 8.93–9.83mg/L and 5.85–6.70mg/L, respectively, and the removal rate is between 29.49%–37.52%, the average removal rate is 33.85%.

The removal of NH$_4^+$-N mainly depends on three pathways, namely nitrification and denitrification, matrix adsorption and plant absorption [12]. Song et al. (2005) found that the NH$_4^+$-N removal rate was significantly lower in winter than in summer, mainly due to the decrease in temperature and the growth of plants [13]. Under the circulating heat supply of the residual heat energy pipeline, the wetland system has a high internal temperature, which effectively improves the removal effect of the wetland system on NH$_4^+$-N.

4. Conclusions

This paper proposes a new type of winter constructed wetland insulation method, which uses the residual heat energy pipeline to heat the wetland, thereby improving the removal efficiency of pollutants. By this method, the average removal rates of TN, TP, and NH$_4^+$-N in the wetland reached 61.09%, 85.03%, and 33.85%, respectively, and the removal effect was good. The use of residual heat to heat the constructed wetlands can maximize the use of energy and facilitate the promotion and application of constructed wetlands in cold regions of the north.

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