Research on Optimization Model of Rural Domestic Sewage Treatment Based on Control Unit

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Abstract. Most of the current research on rural domestic sewage is dispersal, while the research on unitized centralized domestic sewage treatment is relatively rare. The paper uses the bio-ecological combination technology to combine the constructed wetland as the control unit to carry out the ecological process ABR composite artificial optimization model research. Firstly, phosphorus removal research on five kinds of matrix fillers such as anthracite, coal slag, ceramicists, sandstone and brick slag is carried out, and the sewage at various levels is studied by adjusting the low, medium and high influenced pollutant loads and controlling the hydraulic retention time of pollutants. The processing efficiency of the processing unit during the filming period and the running period. Finally, the surface flow constructed wetland and the subsurface flow constructed wetland were set up as the secondary treatment unit for rural sewage treatment. The deep identification and extemporization of the sewage was carried out, and finally the effluent quality reached the first-level indicator of the Pollutant Discharge Standard of Urban Sewage Treatment Plant.

Keywords: Rural sewage treatment; Constructed wetland combination; Control unit; Nitrogen and phosphorus removal; Composite artificial optimization.

1. Introduction
The amount of domestic sewage produced in rural China is about 8 billion tons per year, and most rural areas do not take any measures to collect and treat domestic sewage. A large amount of untreated domestic sewage is discharged into the river through point source and non-point source, which seriously pollutes various types of water sources and causes many ecological and environmental problems including bacterial and blooms. Compared with traditional urban sewage treatment systems, rural domestic sewage is very different in terms of influenced water quality, changing laws, processing facilities scale, process and operation management strength. Therefore, rural domestic sewage treatment cannot blindly apply urban domestic sewage [1]. Processing mode. The spatial difference of natural geographical conditions, resource and environmental characteristics and social and economic conditions in rural areas determines that the application and promotion of rural domestic sewage treatment technology must be adapted to local conditions and classified. The optimization of rural domestic
sewage treatment technology should not only consider the technical and economic characteristics of rural domestic sewage treatment technology, but also fully consider the suitability of rural domestic sewage treatment technology for specific regions and the technical needs of stakeholders. In this paper, the matrix adsorption and phosphorus removal comparison test, the ABR artificial wetland combination process and the two-stage wetland series system are used to purify the rural domestic sewage.

2. Base layer adsorption and phosphorus removal performance experiment

2.1. Langmuir adsorption isotherm equation

The Langmuir equation is one of the most commonly used adsorption isotherm equations. It was proposed by physical chemist Langmuir in 1916 based on molecular motion theory and some assumptions. Langmuir's research suggests that atoms or molecules on the solid surface exist outward. The remaining price force, it can capture gas molecules. The range of this residual valence force is comparable to the molecular diameter, so that only the mono layer adsorption occurs on the surface of the adsorbent [2].

\[
Q_e = \frac{Q_m \cdot K_a \cdot C_e}{1 + K_a \cdot C_e} 
\]  
(1)

\(Q_e\): Adsorption reaches equilibrium at a certain time, the adsorption amount of matrix is mg/kg; \(C_e\): adsorption reaches equilibrium at a certain time, the concentration of solution is mg/L; \(Q_m\): theoretical saturated adsorption amount of matrix/mg/kg; \(K_a\): constant, reflecting matrix adsorption Energy level; let \(Q_e = Y, C_e = X; Q_m = a, K_a = b\). Then there is an equation as follows.

\[
Y = \frac{a \cdot b \cdot x}{1 + b \cdot x} 
\]  
(2)

2.2. Freundlich adsorption isotherm equation

The Freundlich adsorption isotherm equation was only an empirical formula at the time of its presentation. The theoretical derivation of this formula, although Haryward, Trappnell, Laidler and Oscik have done a systematic summary. However, the interaction between adsorbed molecules was not considered in the derivation process. Experiments have shown that the Freundlich adsorption isotherm is only suitable for medium coverage. Theoretically, the interaction between adsorbed molecules in this range has reached a point that cannot be ignored. Considering the adsorption system model of adsorption interaction between molecules, the Freundlich adsorption isotherm is derived by using the system theory in statistical mechanics.

\[
Q_e = K_f \cdot C_e^n 
\]  
(3)

\(Q_e\): At some point, the adsorption reaches equilibrium, the adsorption amount of the substrate is mg/kg; \(C_e\): the adsorption reaches equilibrium at a certain time, the concentration of the solution is mg/L; \(K_f\): constant, the partition coefficient of the adsorbed substance between the solid and liquid phases; \(n\): constant, reflecting the strength of matrix adsorption, between 0 and 1; let \(Q_e = Y, C_e = X; Q_m = a, K = b\). The above formula can be simplified:

\[
Y = a \cdot X^b 
\]  
(4)
2.3. Matrix geothermal adsorption conditions and parameters

The Langmuir isotherm adsorption curve is suitable for describing cinder and ceramicists, while the Freundlich isotherm adsorption curve is suitable for describing anthracite, sandstone and shale brick slag. In addition, according to the fitting curve and the following table, it is also known that the theoretical saturated adsorption amount of cinder and ceramicists reaches 1212.34 and 405.00 mg/kg, respectively, and the actual adsorption amount of the matrix is generally larger than the theoretical saturated adsorption amount of the matrix. The adsorption concentration can be used to determine the solution concentration \( C_e \) during adsorption equilibrium and the substrate adsorption amount \( Q_e \) during adsorption equilibrium, so that the fitting curve corresponding to each matrix can be fitted and the corresponding fitting equation can be obtained [3]. According to the coefficients in the fitting equation, the theoretical saturated adsorption amount \( Q_m \) of each matrix, the constant \( K_a \) of the adsorption potential of the reaction matrix, the partition coefficient between the solid and liquid phases of the adsorbed material-constant \( K_f \), and the constant reflecting the adsorption strength of the matrix can be known. \( \frac{1}{n} \), between 0 and 1. As shown in the table below.

| Packing type      | Langmuir isotherm adsorption curve | Freundlich isotherm adsorption curve |
|-------------------|------------------------------------|-------------------------------------|
|                   | \( Q_m \)  | \( K_a \)  | \( Q_m \)  | \( K_a \)  | \( K_f \)  | \( \frac{1}{n} \) |
| anthracite        | 526.10   | 0.67×10^{-2} | 2.56      | 221.21   | 0.26      |
| cinder            | 1212.24  | 1.02×10^{-2} | 12.22     | 59.21    | 0.60      |
| Bio-ceramic       | 405.00   | 0.20×10^{-2} | 0.92      | 1296.52  | 0.11      |
| sandstone         | 551.64   | 24.41×10^{-2} | 124.67    | 172.62   | 0.22      |
| Shale brick slag  | 520.40   | 22.44×10^{-2} | 119.04    | 196.95   | 0.26      |

3. Experiment on the effect of related parameter setting on the phosphorus removal performance of the substrate

3.1. Effect of Different Matrix Dosage Gradient on Phosphorus Removal Performance of Substrate

The amount of phosphorus removal by matrix is closely related to the parameters such as matrix type and particle size, and the amount of matrix is also the key factor affecting the amount of phosphorus removal. Although the amount of the substrate is small, there is a certain economic benefit, but the phosphorus in the solution cannot be well removed; although the amount of the matrix is large, the phosphorus in the solution can be well removed, but it is not suitable in terms of economic efficiency and cost input. So find the right amount of matrix to meet economic benefits and good removal rate.

The figure below shows the relationship between the solution concentration and the matrix dosage gradient when the adsorption process reaches equilibrium. It can be seen from the figure that when different types of substrates are used and the dosage is consistent, the solution concentration relationship is sandstone, anthracite, cinder, shale brick slag and ceramicists. However, the difference in the amount of matrix can clearly distinguish the relationship between the adsorption and removal rate of phosphorus on the substrate. It can be seen from the figure that when the amount of the matrix reaches 2g/50mL, the solution concentration of the ceramicists, shale brick slag and coal slag reaches the adsorption equilibrium, and the solution concentration is obviously smaller than that of the anthracite and sandstone [4]. At the same time, according to the removal rate curve of adsorption and phosphorus removal, it can be clearly seen that the removal rates of ceramicists, shale brick slag and coal slag at 2g/50mL are 85%, 74%, and 72%, respectively. The removal rate of adsorbed phosphorus removal from anthracite and sandstone is only 41% and 33%. Based on this, it is obvious that the difference in matrix type is also one of the important factors affecting the effect of matrix adsorption and phosphorus removal. When the dosage of the substrate was controlled at 4g/50mL, the difference was more obvious. The removal rates of the first three were about 95%, and the removal rates of the latter two substrates also rose to 55%.
3.2. Influence of different pH on the performance of matrix adsorption and phosphorus removal

The form of phosphorus in the solution includes several kinds of $H_3PO_4$, $H_2PO_4^-$, $HPO_4^{2-}$, and $PO_4^{3-}$, and various substrates include physical adsorption and chemical adsorption for phosphorus adsorption, and physical adsorption is a physical force between an adsorb molecule and an adsorbent surface atom or molecule. Adsorption; absorptive refers to the chemical interaction between the adsorbent and the adsorbed material. The pH of the solution indicates the negative value of the logarithm of the hydrogen ion ($H^+$) concentration in the solution, $\left(-\log_{10} [H^+]\right)$. The pH of pure water at constant temperature and constant pressure = 7, which means that the hydrogen ion concentration $[H^+]$ and the hydroxide concentration $[OH^-]$ in the aqueous solution remain equal.

It can be seen from Fig. 2 that the same type of matrix has different effects on the adsorption and removal of phosphorus under different pH (pH=5, 6, 7, 8, 9, 10). Under different pH, the three kinds of substrates of ceramicists, sandstone and shale brick slag have better adsorption effect on phosphorus than anthracite and cinder. The adsorption removal rate of sandstone at pH=6 shows a rapid change of V type, which indicates that the acidity and alkalinity affects the adsorption removal rate of phosphorus by sandstone to some extent. ceramicists and shale brick residue for phosphorus The adsorption removal rate is always maintained at around 95%. Such a high removal rate may be that the initial concentration of the phosphorus-containing solution is relatively low (15 mg/L) and their porosity and specific surface area are large. In addition, the anthracite matrix is for phosphorus. The removal rate is generally lower.
than 60%. When the pH changes range from 5-8, the adsorption removal rate of phosphorus in the anthracite matrix shows a downward trend, that is, when the pH is 8, the removal rate drops to 53%, which decreases 6 percentage points. When the pH is from 8 to 10, it can be seen that the adsorption of phosphorus on the anthracite matrix gradually rises to about 68%. It can be known that the pH is equal to 9, which is most beneficial to the anthracite matrix for the phosphorus in the solution. The adsorption removal can best exert the adsorption removal performance of anthracite.

4. ABR -- Construction of Vertical Flow Constructed Wetland Combination Process

Fig. 3 ABR artificial wetland combination process construction

First, the raw water entering the system is preheated by grid filtration to block the impurities with larger particle size outside the system; then, the effluent enters the anaerobic baffled reactor through the pipeline for anaerobic treatment, after a certain After the hydraulic retention time, various microorganisms in the system can absorb and convert some pollutants; next, the effluent enters the sewage regulation tank through the pipeline, and at the same time, the sewage is oxidize by using the drop in height; then the sewage is passed through The sewage lifting pump is lifted to the high water distribution tank, and the overflow pipe is arranged in the matching water tank. The sewage entering the high-water distribution tank is evenly sprayed by the water distributor to the top of the vertical flow artificial wetland after passing through the flow meter; the last four types of vertical flow artificial the wetland uses gravity to carry out corresponding biochemical treatment of the infiltrated sewage [5]. The specific processing procedure is shown in Figure 3.

Correlation degree between different pollutant load gradients (low concentration, medium concentration and high concentration) and different types of constructed wetlands and water quality indicators (COD, TN, TP, NH4+-N, N03--N) in the effluent after system treatment. It can be known from the following table that there is a very significant positive correlation between the influenced pollutant load gradient and the chemical oxygen demand, total nitrogen, total phosphorus, nitrogen and nitrate nitrogen in the effluent after system treatment, and different treatments. There was only a significant negative correlation between the type and total phosphorus in the effluent, and there was no significant correlation between pollutant load, chemical oxygen demand, total nitrogen, nitrogen and nitrate nitrogen. However, there is a very significant positive correlation between chemical oxygen demand, total nitrogen, total phosphorus, nitrogen and nitrate nitrogen.

5. Conclusion

In this paper, the factors affecting the adsorption of phosphorus by various substrates (anthracite, cinder, ceramicists, sandstone and shale brick slag) (matrix type, basal plasma grade, initial solution concentration, solution pH, organic matter and its concentration, inorganic anions, The comparison
between continuous oscillating time and temperature), and further control the influence of factors such as hydraulic retention time and influenced pollutant load on the treatment of rural domestic sewage by ABR constructed wetland combined process, and finally combined with two-stage constructed wetland composite system for rural domestic sewage The secondary treatment is carried out so that the water quality indicators of the system effluent can reach the first-class B standard of the Municipal Waste water Treatment Plant Pollutant Emission Standard GB18918-2002, thus providing relevant basic data for the field implementation of the project as a reference.

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