Treatment of papermaking water by using reed constructed wetlands

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Abstract: Pilot-scale constructed wetlands planted the reed was constructed to treat papermaking water. The treatment performances of the three wetlands with different operation model for COD, ammonia nitrogen, total phosphorous, BOD\textsubscript{5} were investigated. The results show that the removal efficiency of all kinds of pollution indicators for the sequencing batch wetland of alternating dry and wet is better than that of the continuous wetland, and the performance of systems achieved the best in September and October and declined from November. When effective area of wetlands was 30hm\textsuperscript{2}, irrigation water depth 8cm, pollutants surface loading 2cm/d, and continuous 8d and intermittent 2d at every year in September, the removal efficiency of COD, ammonia nitrogen, total phosphorous and BOD\textsubscript{5} was reached to 34%, 28%, 25% and 46%, respectively. The quality of the outlet water met the requirement of recycle water and discharge standard.

Introduction

Papermaking wastewater has specialities of high concentration of contaminations, complex components and large wastewater quantity\textsuperscript{[1]}. Resource comprehensive utilization of papermaking wastewater has been a hot area of research\textsuperscript{[2-4]}. The settlement-biochemical method is a primary method in wastewater purification at home and abroad, but the papermaking wastewater after treatment method of effluent cannot meet the requirement of discharge standard of "the national standard of water pollutant discharge for pulp and paper industry"(GB3544-2008)\textsuperscript{[5]}. Unless further deep processing technology is used to solve the above problems, but this will increase the cost of processing. Compared with conventional treatment system, the technology of constructed wetland which is viewed as "natural purifier" is easily operated, simple process, low treatment cost, good stability and good ecological effect\textsuperscript{[6-9]}. Reed wetland, which is powerful stain resistance, salt-tolerance and evaporation capacity, has been widely used in wastewater treatment. The inland saline areas in the Yellow River delta have larger area of inland saline reed wetlands, which provides an opportunity for reed wetland to treat papermaking wastewater. Reed wetland treatment of papermaking wastewater not only can make the papermaking wastewater met discharge standard, and can realize the recycle economic pattern of "papermaking wastewater-reed-paper ". Using papermaking wastewater processing SBR as treatment object, and using three pieces of a total of 100 hm\textsuperscript{2} reed wetland to carry out experimental study, the removal effects on COD, ammonia nitrogen, total phosphorus and BOD\textsubscript{5} were investigated. The research offers a foundation for the popularization and application of reed wetland in papermaking wastewater treatment technology.

I. Experiment

1.1 The experimental site

The experimental site was selected in the eastern native reed land covering an area of 100 hm\textsuperscript{2} near the Tuhai River in the Yellow River delta, Soil in the area belong to the coastal tide soil, and configuration has more thick sticky layer, its distribution is in the altitude from 5 m along the Tuhai River and the east of Qin mouth river Midstream. The region belongs to the East Asia sub-humid warm temperate continental monsoon climate, the average annual temperature is 12.5\textdegree C, average precipitation is 600 mm annually, and the yearly evaporation quantitatively is 1800-2000 mm. The mass fraction of soil soluble-salt is from 0.4% to 2.5%, the pH decreased from 7.8 to 8.9 gradually.
1.1.1 The wetland graphic design

We choose the native reed plots which growth uniform to carry out the research. In order to reduce the cost, the system was consisted of three-stage batch surface flow constructed wetlands. The design surface of experimental plots should look something like Fig. 1.

![Fig.1 Schematic diagram of the reed wetlands](image)

1.1.2 The irrigation design of wetland

The influent water of Reed wetland was papermaking wastewater after SBR treatment which stored in the pond. For the realization of the wastewater circulatory flow in the wetland, and make full use of wastewater treatment function of wet land, we designed to the frame and water distribution system of wetland, and control wastewater level and fill order of wetlands. The irrigation technology conditions were shown in Tab.1. First, experiment of wetland treatment of papermaking wastewater was started at low concentration and startup time was 30 d. For increase the biomass and activity of the microorganisms, wetland was constructed by continuous injection with 2 cm/d hydraulic loading rate. Pool1 ran continuously under the same irrigation depth and surface hydraulic loading rate. Pool2 was implemented by dry-wet rotation and intermittent duty, continuous running 8 d, intermittent 2 d. Pool 3 was implemented by dry-wet rotation and intermittent duty, continuous running 8 d, intermittent 2 d, running time was from August to November.

<table>
<thead>
<tr>
<th>Wetland</th>
<th>Effective area (hm²)</th>
<th>Irrigation depth (cm)</th>
<th>Hydraulic load (cm/d)</th>
<th>runtime (month)</th>
<th>Operation description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>40</td>
<td>8</td>
<td>2</td>
<td>4</td>
<td>the same depth and load</td>
</tr>
<tr>
<td>2</td>
<td>30</td>
<td>8</td>
<td>2</td>
<td>4</td>
<td>8d+2d</td>
</tr>
<tr>
<td>3</td>
<td>30</td>
<td>8</td>
<td>2</td>
<td>4</td>
<td>6d+4d</td>
</tr>
</tbody>
</table>

1.2 Materials

All reagent used were of AR grade. The used papermaking wastewater which by intensified micro-electrolysis-hydrolysis-acidification-SBR technology was from a local papermaking plant in Shandong. The COD of water averaged 85 mg/L, the mass concentration of ammonia nitrogen was 1.42 mg/L, the mass concentration of total phosphorus average 0.1 mg/L, BOD₅ averaged 30 mg/L.

1.3 Analytical methods

The article utilized the potassium dichromate method (GB/T11914-1989) to measure COD in the experimental conditions. The measure method of BOD₅ is the dilution and seeding method dilution (HJ505-2009). Ammonia nitrogen, Nessler's reagent Spectrophotometry was adapted to the ammonia nitrogen determination of wastewater samples (HJ535-2009). AMo-Sb spectrophotometric method (GB/T11893-1989) has been applied to determining total phosphorus in water.

2. Results and discussion

2.1 The removal of COD in waste water by Reed wetland

When the reed wetland operated stably after the operation, it continuously ran for 7 days. Meanwhile, we analyzed the change of COD in wastewater taken from the channels of different pools every day. The result is shown in Fig. 2.

The result shows that thereed wetland can decontaminate certain pollutants in the papermaking wastewater, and COD removal rates of the wastewater after treated in the pools of 1, 2, 3 were 28%, 34% and 34.5%, respectively. The approaches for removal of COD were the absorption by the reedwetland, and the degradation by the rhizosphere microorganism[10, 11].
The result shows that No. 2 and No. 3 of pools using dry-wet rotation and intermittent operation in the way of the combination had a higher removal rate of COD than continuous-time-rated pool (No. 1). The reason is that using dry-wet rotation and intermittent operation in the way of the combination can greatly increase the oxygen supply in the soil, improve the quantity and activity of soil microbe, and promote the decomposition of organic pollutants. Meanwhile, it can avoid the emergence of plant root rot. With continuous running, the wetland was continuously exposed in polluted water over time, the adsorption of the soil reach saturation, so reduce the ability to degrade many kinds of contaminant [12, 13].

2.2 The removal of ammonia nitrogen in wastewater by Reed wetland

When the reed wetland operated stably after the operation, it continuously ran for 7 days. Meanwhile, we analyzed the change of ammonia nitrogen in wastewater taken from the channels of different pools every day. The result is shown in Fig. 3.

The Fig. 3 shows that the reed wetland could certainly remove ammonia nitrogen from the wastewater like COD. The removal rate of ammonia nitrogen in No. 2 and No. 3 of dry-wet alternation pools come up to 28% and 29% respectively. The ammonia nitrogen was removed mainly by adsorption, nitrification/denitrification and plant/microorganism absorption. The degradation of ammonia nitrogen in the wastewater also mainly relied on reed wetland plants and microorganisms, but the biodegradation of ammonia nitrogen is more complicated. Because of the intermittent operation mode existed the alternation of aerobic-anoxic environments, more nitrogen was decomposed by stronger microbial activity. So the removal rate of nitrogen of No. 2 and No. 3 pools is higher than that of the No. 1 pool.

2.3 The removal of total phosphorus in wastewater by Reed wetland

As mentioned above conditions, the change of total phosphorus in wastewater as shown in Fig. 4.
As showed in Fig. 4 the total phosphorus removal rate of No. 1 pool continuously operating was 19%, the removal rate of total phosphorus by No. 2 and No. 3 pools treatment came up to 25% and 27% respectively. The total phosphorus was removed mainly by reed wetland adsorption /plant /microorganism absorption. There are evidence shows that about 28%-59% of organic matter forming the plant photosynthesis transferred to the underground, 4%-70% of the organic matter through root secretion into the soil. The roots secretion created a good condition for the survival of microorganisms, and promoted the rhizosphere biodegradation [14, 15]. Research shows reed wetland dry-wet alternation process makes the soil in the alternating phase of aerobic-anoxic-anaerobic, which is of benefit to phosphate removal and increase the phosphate sorption capacity of the soils [16, 17].

2.4 The removal of BOD$_5$ in wastewater by Reed wetland

The Fig. 5 shows that the average BOD$_5$ removal efficiency of No. 1 pool continuously operating was 32%. The removal rate of BOD$_5$ by No. 2 and No. 3 pools treatment came up to 46% and 50%. The BOD$_5$ was removed mainly by biodegradation in wetlands, sediment, and plant/microorganism absorption, and one of the most important influence factors is aerobic effect. Dry-wet alternation process of No. 2 and No. 3 pools makes high aerobic capacity, so the removal rate of BOD$_5$ is higher than that of the No. 1 pool which has poor oxygen condition and less oxygen.

2.5 The running status of reed wetland in summer and fall seasons

Wetland ecosystem run under the following conditions, the depth of irrigation was 8 cm, surface hydraulic loading was 2 cm/d, and four months of continuous operation from August to November in 2014, in other words, it experienced summer, autumn and winter. The result of the COD remove rate was shown in Fig. 6. The removal of COD of three wetlands increased at first and then decreased in the process of from summer to early winter, and remove rate is higher in Sep, and later peaked in Oct. Results by comparison showed that the removal rate of pool 1 was minimum, the removal rate may not vary much between pool 2 and pool 3, and pool 3 removal rate slightly higher than that of pool 2. From August to October, the average temperature increased from 28°C to 35°C. The activity of microorganisms degradation of pollutants and COD removal rate were increased. At the same time, the rise of temperature is beneficial to the reed growth, so the fixed action by plant tissue through adsorption was strengthened. In addition, the microbial film system can help speed the degradation rate of pollutants further [17]. The microbial activity and degradation rate of wetland system were reduced for temperature dropping in winter. Reed plant also gradually...
decline, and their fixation was decreasing. At the same time, there was a decrease in oxygen supply of wetland system\textsuperscript{[18]}, leading to lack enough dissolved oxygen for the aerobic microorganisms in pollutants, and COD removal rate decreased obviously.

![Fig.6 Removal efficiency of COD during operating period](image)

2.6 The quality analysis of papermaking wastewater purified by reed wetland

The experimental results of COD, BOD\textsubscript{5}, ammonia nitrogen and phosphorus by three pieces of wetland in three operation modes showed that No. 2 and No.3. The removal rate of pollution indicators such as COD in intermittent operation wetlands 2, 3 were higher than that of continuous operation wetland 1. Meanwhile, the removal rate of each index of No.3 wetland was slightly higher than that of No. 2 wetland, but the wastewater treatment capacity of No.3 wetland was lower than wetland2. Pollutant removal and the wastewater treatment capacity requirements were analyzed and considered, the design parameters and operation mode of No. 2 wetland treated with papermaking waste water were adopted in experiments. Under the optimum conditions, the average removal rate of COD, ammonia nitrogen, total phosphorus and BOD\textsubscript{5} were 34\%, 28\%, 25\% and 46\%, respectively. The characteristics of influent and effluent wastewaters were shown in Tab. 2.

<table>
<thead>
<tr>
<th>Water sample</th>
<th>COD (mg \cdot L\textsuperscript{-1})</th>
<th>NH\textsubscript{4}+N (mg \cdot L\textsuperscript{-1})</th>
<th>TP (mg \cdot L\textsuperscript{-1})</th>
<th>BOD\textsubscript{5} (mg \cdot L\textsuperscript{-1})</th>
</tr>
</thead>
<tbody>
<tr>
<td>IN</td>
<td>85.00</td>
<td>1.42</td>
<td>0.10</td>
<td>30.00</td>
</tr>
<tr>
<td>OUT</td>
<td>56.00</td>
<td>1.02</td>
<td>0.08</td>
<td>16.00</td>
</tr>
</tbody>
</table>

3. Conclusions

The following conclusions can be drawn from the present work:

(1) Wetlands planted the reed were constructed to treat papermaking wastewater. At every year in September, When effective area of wetlands, irrigation water depth and pollutants surface loading were 30hm\textsuperscript{1}, 8cm, and 2cm/d respectively, and the time of continuous running and shutdown were 8 d and 2 d, the removal efficiencies of COD, ammonia nitrogen, total phosphorus and BOD\textsubscript{5} under principles under those particular conditions were reached to 34\%, 28\%, 25\% and 46\%, respectively. The treated papermaking water met the requirement of recycle water and discharge standard.

(2) Experiment adopted continuous and intermittent operation types. For dry-wet intermittent operation of No. 2 and No. 3 pools, theirs indicators of sewage treatment such as COD removal rate were much higher than that of continuous operation pool (No.1). The removal rate of pool 3 which has long water supply cut-off time was slightly higher than pool 2. The design parameters and operation mode of No. 2 wetland treated with papermaking wastewater were formulated through experiments.

(3) Adopting the combination of flooding-drying alternation and intermittent working fashion can significantly improve the oxygen supply in the soil, provide oxygen and substrate conditions, increase amount and microbial activity of aerobic microorganisms. So the decomposition of organic pollutants in soil was promoted.

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References


