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Variation of Organic Matter Decomposition in Constructed Wetlands with Enhancing Aeration

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ABSTRACT

Two different constructed wetlands were applied to remove organic matter of micro-polluted wastewater from a wastewater treatment plant. In this research, organic matter removal showed a favourable effect in two constructed wetlands. Moreover, the aeration device added to the wetlands' bottom could obviously increase the removal rates of chemical oxygen demand (COD) in micro-polluted wastewater under this operational condition. In addition, the optimal operational condition for COD removal was evaluated by three dimensional (2D and 3D) contour plots while the bottom aeration device was added. The results showed that in horizontal zeolite subsurface constructed wetland (HZSW), the optimal removal rates of COD, which could reach above 95.56%, were obtained when the average daily aeration time was about 17~21h and hydraulic loadings were 0.16~0.24m^3/(m^2·d). In contrast, in horizontal limestone subsurface constructed wetland (HLSW), the optimal removal rates of COD, namely, 93.54~94.95%, could be obtained when the average daily aeration time was more than 16h and hydraulic loadings were about 0.13~0.32m^3/(m^2·d). In summary, the removal effects of COD increased obviously after the bottom aeration device was added in the two constructed wetlands.

INTRODUCTION

In recent years, constructed wetlands (CWs) have been turned out to be an efficient ecological technology for the treatment of various kinds of polluted waters (Fu et al. 2009, Liu et al. 2012, Precup et al. 2011, Zhu et al. 2011). The advantages of CWs over other conventional treatment systems are lower costs and easy to operate and maintain (Greenway 2003, Summers et al. 1993). Constructed wetlands treatment technology had been given the measure of standard method in a multitude of countries because of the requirement for low-carbon, environment-friendly technologies (Kaya et al. 2009, Vohla et al. 2011).

However, the wastewater removal effect of major pollution in constructed wetland would decrease at quite a few cold districts (Prochaska et al. 2006, Drizo et al. 2006). Therefore, some methods have been applied for solving the bottleneck problems (Zhao et al. 2009). Artificial enhanced aeration went a good way to increase the dissolved oxygen (DO) in the interior of constructed wetlands, as a consequence increased the removal effect for major pollution (Guo et al. 2010, Tao et al. 2009, Yang et al. 2010). Artificially aerated CWs (AACW) can increase oxygen transfer rate of 160 g m^{-2} d^{-1} by compressing air from the atmosphere into the wetland bed with the use of a blower (Wen et al. 2010). Most conventional CWs fail to fulfil this first step due to insufficient oxygen supply. Hence, oxygen supply is the key issue to enhance nitrogen removal in CWs, and artificial aeration is the most effective alternative to guarantee sufficient oxygen supply. In particular, when dealing with high strength wastewater, artificial aeration seems to be the only option to achieve complete nitrification. Meanwhile, the primary purpose of the current study was to achieve high rate organic matter removal from high strength wastewater with two horizontal subsurface constructed wetlands. In this study, the oxygen aeration tubes were fixed up at the bottom of the constructed wetland, and the changed trends of COD and operational parameters in constructed wetlands were analysed under intermittent aeration and optimum aeration conditions, respectively.

MATERIALS AND METHODS

Subsurface wetland systems: In this experiment, the horizontal subsurface wetland systems consisted of two 1m^2 wetland mesocosms (1.6m length × 0. 6m width × 0.6m depth). Gravel, with a particle diameter of 15-25mm, was laid at the bottom of the two systems, and the depth was 0.10m. Zeolite and limestone were laid respectively in the

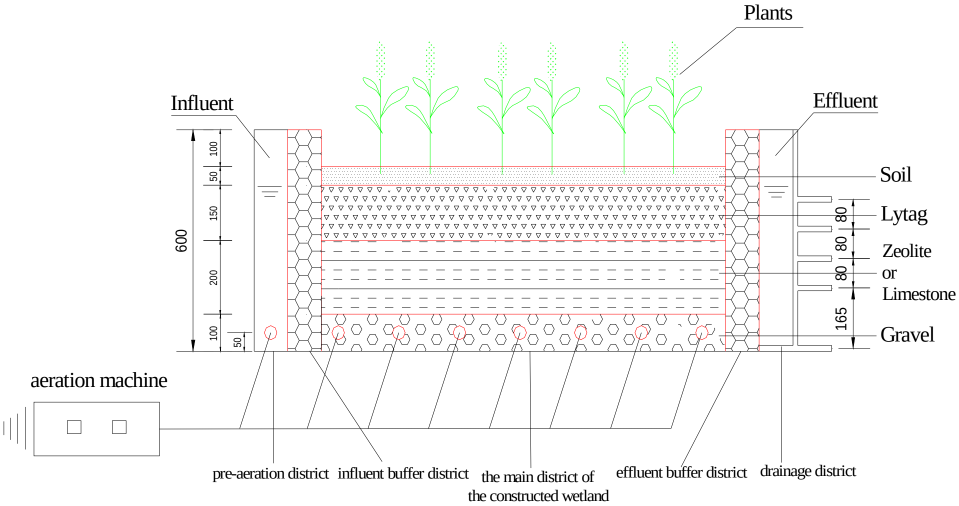


Fig.1: The schematic diagram of the main apparatus.

middle layers of the two wetlands, both with particle diameters of 6-10mm and depth of 0.20m. The upper beds consisted of lytag with a depth of 0.15m and particle diameter of 3-5mm. The sieving soils were laid at the uppermost layers, the depth of which was 0.05m. *Phragmites* sp. and cattail sps. were planted in the soils with interplanting ratio of 1:1, and the plant densities of them were 48 plants/m^2 and 50 plants/m^2, respectively. The horizontal zeolite subsurface wetland would be represented by HZSW and horizontal limestone subsurface wetland by HLSW in the following parts of this paper. The schematic diagram of the main apparatus is shown in Fig. 1.

In the horizontal direction, constructed wetland was divided into pre-aeration district, influent buffer district, the main district of the constructed wetland, effluent buffer district and drainage district. Large size zeolites were filled in influent and effluent buffer district (particle size of 10~15mm), accordingly ensured uniform inlet and outlet. Raw water flowed into pre-aeration buffer district from the top of the influent buffer district, the main flow flowed through the main district of the constructed wetland, afterwards flowed out from the bottom of the effluent buffer district, and eventually into the drainage district. In addition, aeration tubes were installed in the pre-aeration district with a height of 0.05m. In the gravel layer of the main district of the constructed wetland, the aeration tubes were also evenly distributed with a height of 0.05m in the same way and aeration tube diameter was about 10mm.

Influent quality: Raw wastewater was obtained from wastewater treatment plant in Tangshan, P.R. China. The composition of the influent used in all experiments is given in Table 1.

Methodology: In the experiment, samples were collected intermittently. During the aeration phase, system operation time was divided into five periods according to the daily aeration time, and every period was of five days. Meanwhile, the average daily aeration time was 4h, 8h, 12h, 18h and 24h, respectively. In addition, the two and three dimensional (2D and 3D) contour plots were carried out by OriginPro 8.0.

In case of atmospheric temperature decrease, the removal of various pollutants has declined in the constructed wetlands. At this time, according to wetland simulation system design features, the bottom aeration device was added in the two constructed wetlands, which was consisted of aeration machine, aeration connector tubes, control valves and preinstalled aeration ports. The model number of aerator was LP-40, and aeration rate was of 50L/min. Meanwhile, aeration connector tubes were made of plastic with a diameter of 10mm having the plastic control valves. Preinstalled aeration ports were installed when the constructed wetlands were built, and which connected a few plexiglass tubes across the width of the constructed wetlands. For the purpose of uniform aeration, many pores, each with a diameter of 3mm, were evenly distributed on every across tube.

Table 1: Characteristics of the wastewater sample used in the experiments.

Parameter	Unit	Concentration
pH	-	6.5~8.0
Chemical Oxygen Demand (COD)	mgL^{-1}	31.6~81.1
Ammonia Nitrogen (NH3-N)	mgL^{-1}	9.5~11.7
Total Nitrogen (TN)	mgL^{-1}	15.7~21.1
Total Phosphorus (TP)	mgL^{-1}	0.89~1.22

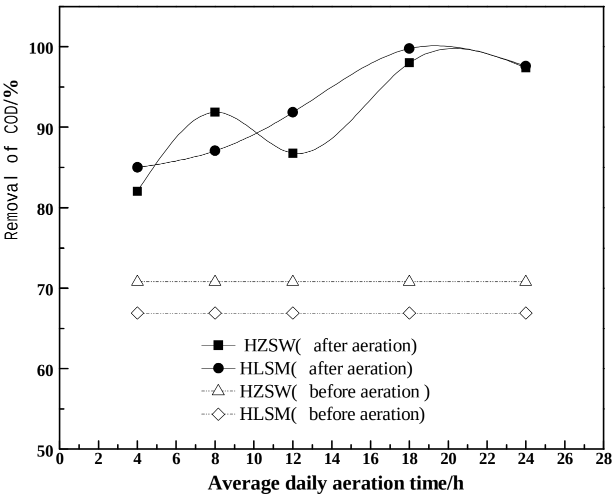


Fig. 2: Aeration effects in related to removing COD in horizontal subsurface wetlands.

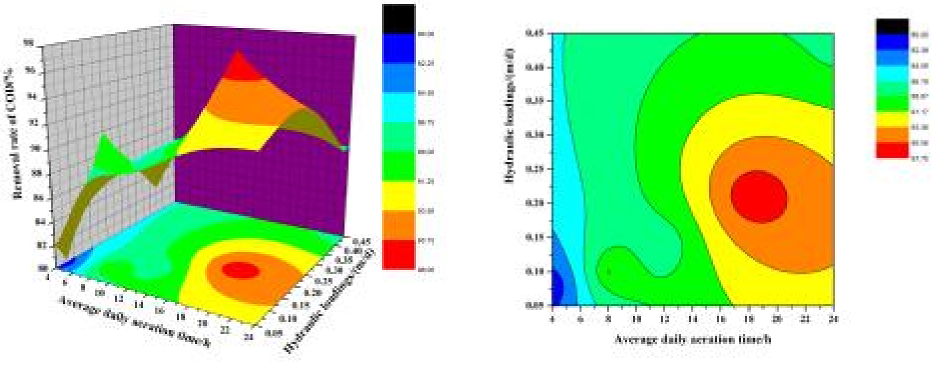
RESULTS AND DISCUSSION

Removal effect of COD before aeration and after aeration: As is shown in Fig. 2, the two horizontal flow constructed wetlands exhibited favourable removal effects of COD under different average daily aeration times, the removal rates maintained more than 82%. The removal of COD gradually increased in two horizontal subsurface constructed wetlands as average daily aeration time went by. Moreover, when average daily aeration time was 18h, the two wetlands exhibited the optimal removal rate with a value of 98.0% and 99.8% for COD, and the HLSW was better. Meanwhile, under the condition of no aeration, the average removal rates for COD were 70.8% at HZSW and 66.9% at HLSW. As could be seen from the above data, adding the bottom aerator has a significant impact on COD removal efficiency of the horizontal flow constructed wetland, and the value of removal rate increased apparently in HLSW. In summary, the removal rates for COD increased in horizontal subsurface constructed wetland after adding the bottom aeration device.

Measurement of optimal operational parameters under aeration condition: In this study, different average daily aeration times and hydraulic loadings were 4h, 8h, 12h, 18h, 24h, and 0.278m/d, 0.139m/d, 0.093m/d, 0.070m/d, 0.056m/d, respectively. Therefore, the objective of this study was to examine the effects of aeration on the removal effects of the horizontal subsurface constructed wetland in different conditions and present the results in two and three dimensional (2D and 3D) contour plots, then the optimal operation condition could be obtained under the aeration condition.

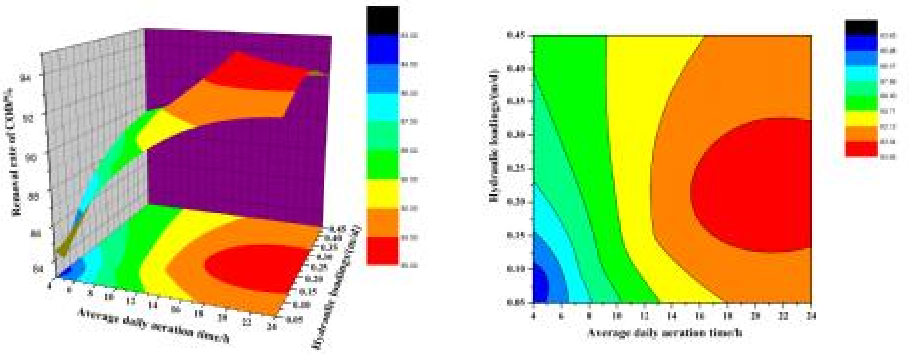
Optimal operational condition in HZSW: As shown in Fig. 3, under different average daily aeration times and hydraulic loadings, the removal effect of COD of wastewater was obvious in HZSW. The optimal removal rates for COD were obtained when the average daily aeration time was about 17~21h and hydraulic loadings was 0.16~0.24m^3/(m2·d), and the removal rates could achieve to more than 95.56%. In addition, the indication colours were gradually changed from deep blue to deep red in the indicated range, namely removal rates for ammonia nitrogen exhibited inverse relation to hydraulic loadings. For an average daily aeration time, the optimal operational condition could also be obtained at a certain range.

Optimal operational condition in HLSW: As shown in Fig. 4, the removal effects of COD of wastewater were obvious in HLSW under different average daily aeration times and hydraulic loadings, however, compared with HZSW, the average removal rates decreased to a certain extent. Meanwhile, the optimal removal rates for COD in HLSW could be obtained when the average daily aeration time was more



(a) (b)

Fig. 3: Simulated diagram of removal effects of COD in related to horizontal-zeolite constructed wetland.



(a)

(b)

Fig. 4: Simulated diagram of removal effects of COD in related to horizontal-limestone constructed wetland.

than 16h and hydraulic loadings were about 0.13~0.32m ^{3}/(m^2·d), and the range of removal rates was about 93.54~94.95%. Contrary to HZLM, the indication colours were gradually changed from deep blue to deep red in the indicated range, namely removal rates for COD exhibited direct proportion relation to hydraulic loadings. For an average daily aeration time, the optimal operational condition could also be obtained at a certain range.

CONCLUSIONS

In this experiment, the bottom aeration device was applied to obtain outstanding removal rates of COD in cold climate. The result showed that the optimal removal rates for organic matter pollutants from micro-polluted wastewater in two horizontal subsurface constructed wetlands could be obtained under certain aeration time and hydraulic loadings. Furthermore, in HZSW and HLSW, the removal rates of COD could achieve 98.0% and 99.8%, respectively. In addition, the removal effects of COD increased obviously after adding the bottom aeration device.

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