Advances in Engineering Research (AER), volume 143
6th International Conference on Energy and Environmental Protection (ICEEP 2017)

Study on Operation Parameters Optimization and Denitrification Efficiency of Deep-Bed Denitrification Filter

Xianzhang Zhao [1,a], Hongjie Wang [1,2,b],

Wenyi Dong [1,2,c], Shilong Jiang [3,d]

1. Harbin Institute of Technology Shenzhen Graduate School, Shenzhen, China

2. Shenzhen Key Laboratory of Water Resource Application and Environmental Pollution Control, Shenzhen, China

3. China Electronics Innovation Environmental Technology CO., LTD., Jiangsu, China

[a]362971355@qq.com, [b]whj1533@qq.com,

[c]dwy1967@qq.com, [d]825744355@qq.com

Keywords: denitrification filter; denitrification; C/N; HRT

Abstract. Some areas have raised discharge standards for effluent total nitrogen (TN) concentration in China. However, the main component of effluent TN in the wastewater treatment plant is nitrate nitrogen (NO_3^--N). This research focuses on TN removal using deep-bed denitrification filter, the hydraulic retention time (HRT) and influent C/N ratio are optimized at 25 °C and 10 °C. The optimum influent C/N of denitrification filter is 3:1 at 25 °C and 10 °C. The optimum HRT is 0.25 h at 25 °C and 1 h at 10 °C. Under the optimum conditions, the average concentration of effluent TN is 6.76 mg/L at 25 °C and 8.76 mg/L at 10 °C. The minimum carbon source addition and shortest HRT of deep-bed denitrification filter at room and low temperature were optimized, which has a practical significance in environmental engineering.

Introduction

With the increasing attention to environmental protection, the discharge standard of wastewater treatment has been continuously improved in China. In some areas, the effluent total nitrogen (TN) discharge standard has been raised from integrated discharge standard class A (15 mg/L) to the local standard A (10 mg/L) [1]. The high concentration of nitrate nitrogen (NO_3^--N) was in the effluent results in a fact that the effluent TN concentration is difficult to meet this standard [2]. In order to reduce the effluent TN concentration, it is necessary to control the concentration of NO_3^--N.

Recently, the advanced treatment unit has been gradually applied to the upgrading of wastewater treatment plants [3]. The commonly methods include biological activated carbon technology, Membrane Bioreactor (MBR) and deep-bed denitrification filter. The biological activated carbon technology and MBR method have a good ability to remove pollutants, but they have the problem of easy plugging and difficult to be cleaned [4, 5]. Deep-bed denitrification filter owns high treatment efficiency, small footprint, and easy to clean [6, 7]. It is gradually applied for advanced NO_3^--N removal [8]. Hydraulic retention time (HRT) and influent C/N are important parameters for the deep-bed denitrification filter. Some studies show that HRT had a great influence on the effluent TN concentration of deep-bed denitrification filter [9, 10]. The efficiency of TN could increase by 30% and the effluent TN was less than 6 mg/L by means of additional carbon source [11].

Meanwhile, some studies have shown that the denitrification was inhibited under low temperature condition [12].

In this paper, the removal efficiency of TN and NO_3^--N was compared at the room temperature (25 °C) and low temperature (10 °C). HRT and influent C/N of deep-bed denitrification filter are optimized at 25 °C and 10 °C. The removal of TN and COD along the route also be analyzed.

Materials and methods

Deep-bed denitrification filter device. The structure of the deep-bed denitrification filter is shown in Fig. 1. The total height of the filter column is 1.8m, the inner diameter is 0.08 m, and the effective volume is 5.53 L. The filter material is quartz sand, the height of filter layer is 1.1 m. The supporting layer is filled with coarse grit, the height of column supporting layer is 0.3 m. The influent is transported quantitatively by peristaltic pump. The filter was washed once every 24 h. At first, deep-bed denitrification filter was washed 8min by air-water, and then washed 8 min by water. After completing the test at room temperature, the equipment is moved into a low temperature cold storage.

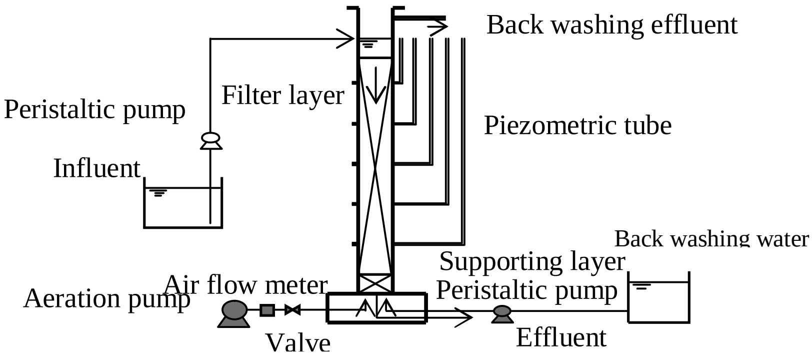

Fig.1 Flow chart of deep-bed denitrification filter

Raw water characteristics.

The secondary effluent is the influent of deep-bed denitrification filter**.** Methanol was added to the raw water to provide the carbon source for denitrification.

Table 1 Deep Bed Filter Raw Water Quality

Unit: (mg/L)

Water quality	COD	TN	NO_3^--N
Ranging	20~60	12~14	10~12

Analytical methods. NO_3^--N and TN citrate were measured by spectrophotometer (UV-2450, Shimadzu, Kyoto). COD was measured by potentiometric titration (905, Metrohm, Switzerland) [13].

Results and discussion

Optimization HRT. The influent of the deep-bed denitrification filter C/N ratio was 3:1, and the HRT of deep bed filter was optimized at 25 °C and 10 °C.

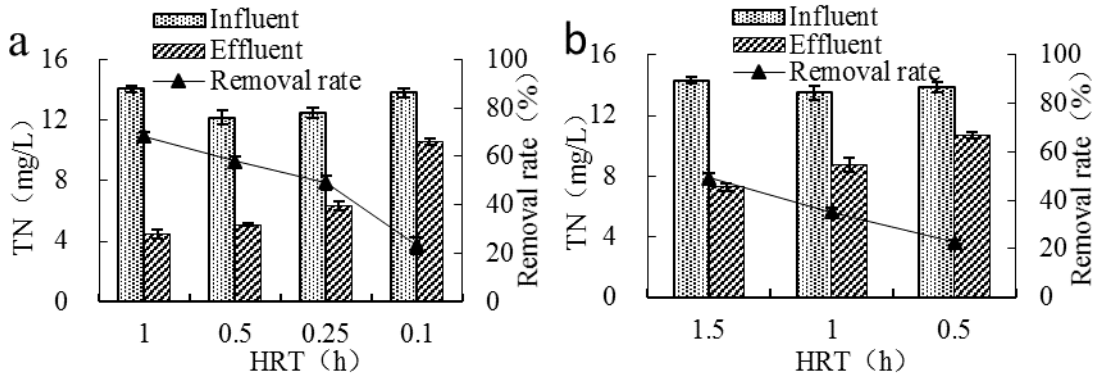

Fig.2 TN removal under different HRT (a) 25 °C, (b) 10 °C

When the HRT was 0.25 h and the influent temperature was 25 °C, the effluent TN concentration is 6.32 mg/L, which was lower than 10 mg/L (refer with: Fig. 2a), it met the discharge standard. When the HRT is 0.1 h, it did not meet the discharge standard. Therefore, the shortest HRT was 0.25 h. The TN concentration in effluent was lower than 10 mg/L when the HRT was 1 h at 10 °C (refer with: Fig. 2b). When the HRT was shortened to half an hour, the effluent TN concentration was 10.7 mg/L. Therefore, the optimal HRT was 1 h at 10 °C.

When HRT was 1 h, the concentrations of effluent TN was 4.47 mg/L at 25 °C and 8.76 mg/L at 10 °C (refer with: Fig. 2). The efficiency of TN reduced from 68.3% to 35.2%. Denitrification efficiency was inhibited at low temperature，which led to nitrogen removal capacity of the deep bed denitrification filter decreased [14]. With the decreasing of HRT, the effluent TN concentration increased gradually at both 25°C and 10 °C，it is because that the pollutant loading increase [15].

Optimization C/N. The influent C/N was optimized under the optimal HRT, the HRT is 0.25 h at 25 °C, and HRT is 1 h at 10 °C. The removal efficiency of TN at different influent C/N ratios is shown in Fig. 3.

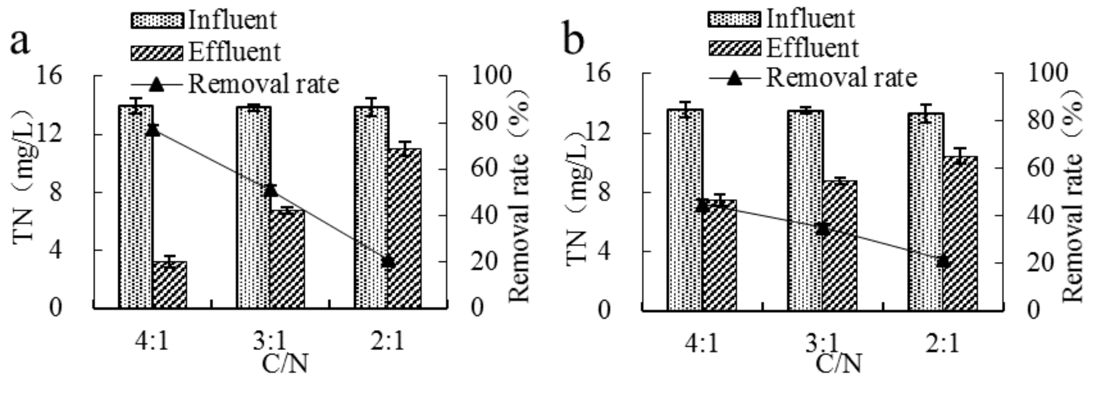

Fig.3 TN removal under different influent C/N (a) 25 °C, (b) 10 °C

It can be seen that the effluent concentration of TN decreased gradually with influent C/N ratios decreased. When influent C/N was 3:1, with the HRT was 0.25 h, the effluent concentration of TN 6.76 mg/L at 25 °C (refer with: Fig. 3a), and with the HRT was 1 h, the effluent concentration of TN was 8.76 mg/L at 10 °C (refer with: Fig. 3b). The effluent both can meet the discharge standard of deep denitrification at C/N ratio 3:1.

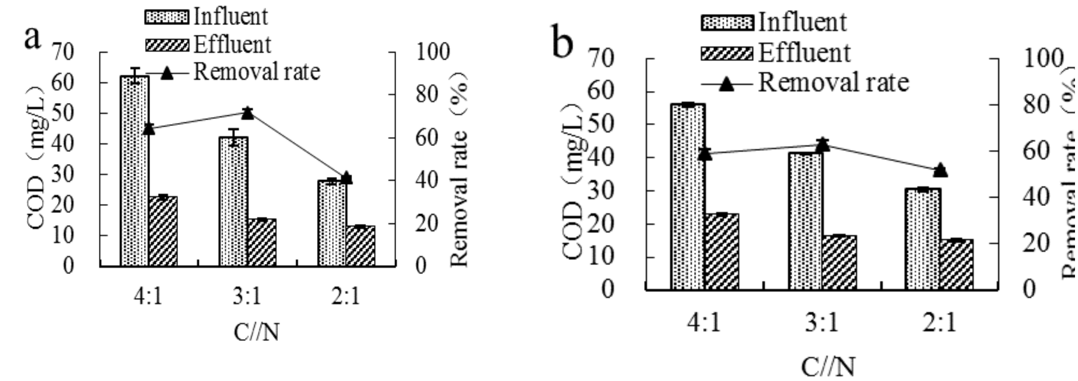

Fig. 4 COD removal under different influent C/N (a) 25 °C, (b) 10 °C

With the decreasing of C/N, the effluent concentration of COD decreased, and then reached a smooth. When influent C/N were 4:1, 3:1 and 2:1 the effluent concentration of COD were 23 mg/L, 15 mg/L and 13 mg/L at 25 °C, (refer with: Fig. 4a), and the COD concentration were 23 mg/L, 16 mg/L and 15 mg/L at 10 °C (refer with: Fig. 4b). The results showed that the concentration of effluent COD did not present markedly different when C/N were 3:1 and 2:1. Because the influent of the deep-bed denitrification filter is the effluent after biological treatment, a portion of the carbon source in the effluent is not available. While C/N was 4:1, part of the carbon sources were not consumed. TN could reach the discharge standard when the lowest C/N was 3:1. Therefore, the optimum influent C/N was 3:1 at 25 °C and 10 °C.

Contaminants removal along the route. The concentrations of COD and TN were investigated at the optimized HRT and C/N ratio.

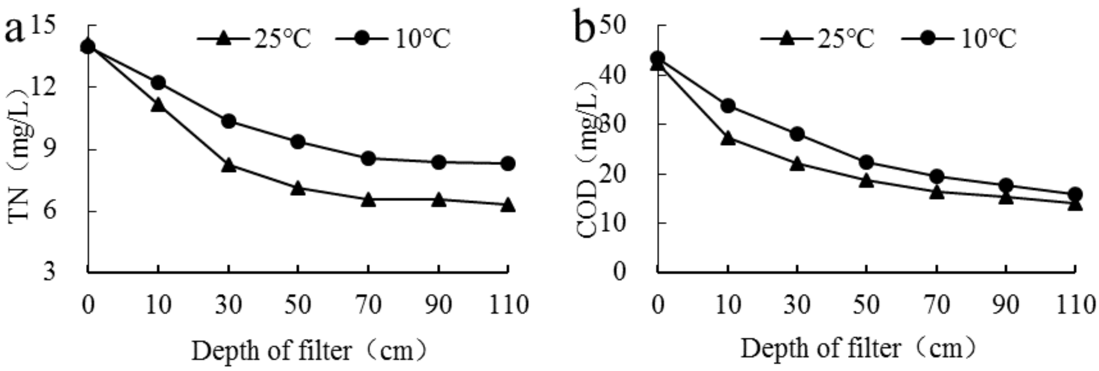

Fig. 5 The change of TN and COD concentration

The results showed that the removal of TN and COD mainly focused on the top of the filter column within 50 cm, there was no obvious change at the bottom of the 50~110 cm (refer with: Fig. 5). In the former 50 cm, the remaining organic can hardly be consumed. So denitrification process occurred in the former 50 cm.

Conclusions

The optimum HRT was 0.25 h at 25 °C and 1 h at 10 °C. The optimum influent C/N ratio was 3:1 at 25 °C and 10 °C. The concentration of TN was 6.76 mg/L at 25 °C and 8.76 mg/L at 10 °C under the optimized HRT and C/N ratio. Denitrification is mainly in the top of the filter within 50 cm.

Acknowledgements

This work was financially supported by the major scientific and technological project for water pollution control.（2015ZX07306001-04）.

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