

Experimental Study on Start-up Process of Ceramic-Volcanic Rock BAF and Volcanic Rock-Ceramic BAF

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Abstract. In order to improve the treatment efficiency and capacity of resisting impact load in nitrogen removal process of the biological aerated filter (BAF), and effectively reduce cost of investment and operation, volcanic rocks and ceramics were used to construct two systems with different fillers combinations of pre denitrification BAF process for nitrogen removal: Ceramics - volcanic rocks BAF (C-V BAF) and volcanic rocks - ceramics BAF (V-C BAF). Compared the process characteristics of two kinds of filler combinations during the start-up stage. And ,at the same time, nitrogen removal mechanism of two kinds of filler combinations was explored preliminarily. The results of start-up process of C-V BAF and V-C BAF indicated that the ammonia of start-up. The conclusion was obtained by determining the distribution of nitrogen forms in the effluent that the removal efficiency of ammonia nitrogen was maintained a high level mainly through the adsorption of volcanic during the initial stage of start-up process of two kinds of filler combinations. During the middle and late stage of the start-up process, ammonia nitrogen was removed mainly by nitrification, and the biofilm formation rate of nitrification bacteria in V-C BAF was faster than that of C-V BAF.

Keywords: biological aerated filter (BAF), ceramic, volcanic, combinations.

1. Test Equipment and Analysis Methods

1.1. Raw water Quality and Physical & Chemical Properties of Packing

Raw water is taken from drainage of university's student apartment. Inlet water quality during the test process was shown in Table 1. Physical & chemical properties of packing were shown in Table 2.

Table 1: Raw water quality during the test process

Index	COD (mg/L)	NH ₃ -N(mg/L)	TN(mg/L)	pH	temperature(°C)
Range value	39-263	7.12-38.42	9.10-39.74	6.60-7.68	22.1-32.9
Mean value	103	12.50	14.80	7.50	26.4

Table 2: Physical & chemical properties of packing

Packing category	Main chemical components					specific surface area m ² /g	specific gravity	compressive strength Mpa	Bulk density kg/m ³
	SiO ₂	CaO	MgO	Fe ₂ O ₃	Al ₂ O ₃				
volcanic rocks	SiO ₂	CaO	MgO	Fe ₂ O ₃	Al ₂ O ₃	3.005	1.40	5.52	850
	43.27	9.86	1.49	11.86	14.71				
Ceramics	SiO ₂	CaO	MgO	Fe ₂ O ₃	Al ₂ O ₃	3.950	1.40	5.37	830
	68.12	3.51	2.14	0.96	13.38				

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1.2. Analysis Methods

The test focuses on the physical and chemical properties of water samples. The indicators include: total phosphorus (TP), ammonia nitrogen ($\text{NH}_3\text{-N}$), nitrate nitrogen ($\text{NO}_3^-\text{-N}$), nitrite nitrogen ($\text{NO}_2\text{-N}$), total nitrogen (TN), COD_{cr}, pH, temperature, DO, MLSS, MLVSS, biomass, SV, SVI.

1.3. Test Equipment and Process Flow

The experimental device is composed of an anoxic filter and an aerobic filter [1], and the A/O-BAF process is adopted, as shown in fig.1.

The test equipment is composed of two parallel systems. One of the systems is added with the volcanic fillers, and the other with the ceramic fillers. The volume of fillers is 10L.

Two reactors are made of transparent organic glass cylinder with an emptying valve at the bottom [2]. The total volume of the reactor is 20L (H=1.2m, D=15cm). The working volume is 19L, and full water level height is 110cm, the water level height is 40cm after draining. Inlet / drainage water volume is about 10L of each cycle, and water exchange ratio is 1:2. Two reactor was operated exactly the same as three cycles per day and eight hours per cycle. Each cycle consists of water inlet (8 min) , anaerobic section (1.5h), aerobic section (3.5h), sludge discharge (5 min), carbon source for denitrification added (30 min), anoxic (1.5h), water decanting (1.2h) and the stagnation of the section.

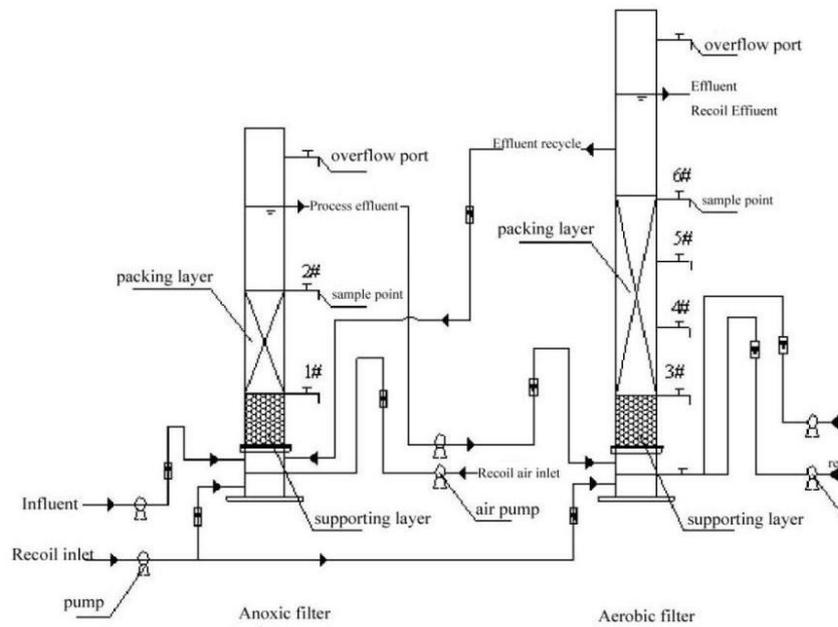


Fig. 1: Experimental device design print

In addition, the pilot system also includes water distribution tank [3], elevated tank, denitrification carbon source inlet barrel, electromagnetic valve, peristaltic pumps and stirrers. In order to ensure that system operates correctly according to the setting conditions, all devices are automatically timed by the time controller.

The effective volume of the water distribution tank is 125L, and the actual working volume is 120L, which is the treatment water volume of one day for two reaction columns shared. The reaction column is provided with a elevated tank to ensure the constant inlet water volume of each cycle. An overflow port is arranged on the elevated tank, and the overflow water is returned to the inlet water tank through the overflow pipe. The effective volume of the elevated tank is adjusted to 45L in this experiment. Prior to the start of each cycle, the peristaltic pump for the water inlet of the reaction column is automatically opened in order to the excessive influent pumped to the elevated tank to obtain constant 45L of influent water, which was prepared for this cycle.

At the end of each cycle and at the beginning of the next cycle, stagnation of the whole system for 1 minute in order to prevent the conflict between water inlet and outlet.

At the beginning of each cycle, the normally closed water inlet valve at the bottom of the elevated tank is opened, and the sewage in the elevated tank enters the reaction column under gravity. This process can be completed less than 5 minutes. After that, the inlet valve is closed for water storage of next cycle.

A diaphragm type aeration head is arranged at the bottom of the reaction column. At the end of anaerobic section and at the beginning of the aerobic section, the normally closed intake valve is opened, air supply system (blower) provides oxygen through the diaphragm type aeration head. In this process, the air input of the two reaction columns is controlled and adjusted respectively through two gas rotameters.

At the end of aerobic section, intake valve is closed. The whole system is stagnant for 1 minutes.

A water distribution bucket of denitrification carbon source of 10 liters as working volume is prepared for providing denitrification carbon source for two days of two reaction columns. The influent denitrification carbon source in each system was 1 litres per cycle. Anhydrous sodium acetate is selected as denitrification carbon source. The dosage of the reagent is calculated according to inlet water volume at the beginning of each cycle. The denitrification carbon source is provided by two peristaltic pumps for the reaction column.

At the end of anoxic section, water decanted stage is started. After 12 minutes, the drain peristaltic pump is turned on, and 10L supernatant was discharged from the reaction column. Thus, a reaction cycle is completed.

2. Study on the Start-up Performance of C-V BAF and V-C BAF

The start-up process of BAF system refers to the processing of microbe multiplication on the surface of the fillers, that is, the enrichment process of microorganisms in the reactor. Generally, which is a sign of the end of BAF start-up period, that the removal rate of COD and $\text{NH}_3\text{-N}$ is stable at the same time. However, because of the ion exchange and adsorption properties of the volcanic rocks, the total removal rate of $\text{NH}_3\text{-N}$ can not be a sign of the end of BAF start-up period. It should use the stability of $\text{NH}_3\text{-N}$ nitrification rate instead, that is, the stability of $\text{NO}_3\text{-N}$ in the effluent should be observed. Discussion on the removal laws of each pollutant during BAF start-up process by comparing outlet water qualities between C-V BAF and V-C BAF.

2.1. BAF Start-up

In order to accelerate the start-up of the reactor, the experiment start to use the vaccination to cultivate tames method. Sludge inoculated was taken from the reaction tank of the sewage treatment plant. The characteristic parameters of sludge were: $\text{SV}_{30}=83\%$, $\text{SVI}=112.2\text{mL/g}$, $\text{MLSS}=7.4\text{g/L}$, $\text{MLVSS}=4.5\text{g/L}$.

Start-up period was divided into two sections: (1) The sewage filled the filter, each reactor was seeded with 15L homogeneous mixed sludge, and aerobic filter exposed for three days, then anoxic filter stewing three days; (2) After three days, the system roned for 20 days by small flow continuous influent for bio-film culturing, operating conditions were: flow capacity 24 L/d, gas water ratio 5:1, reflux ratio 1:1 and empty tower hydraulic retention time 6h. At the end of start-up period, the water-air combined back-flushing method was used in the reverse washing of the filter, with operation steps as follows:

- (1) Air flushing. Back-flushing rate was $10\text{ L/m}^2\text{ s}$, about 5 min;
- (2) Water-air combined back-flushing. Air back-flushing rate was $10\text{ L/m}^2\text{ s}$, water back-flushing rate was $10\text{ L/m}^2\text{ s}$, about 5 min;
- (3) Water flushing. Back-flushing rate was $10\text{ L/m}^2\text{ s}$, about 5 min. In order to avoid the influence to treatment capacity of the filter to recover quickly, the filter effluent water was used as back flushing water.

2.2. COD Removal Effect of C-V BAF and V-C BAF

Fig. 2 and Fig. 3 respectively reflecting the COD removal of C-V BAF and V-C BAF during start-up period. In the early stage of C-V BAF start-up, the effluent COD concentration was relatively high, and the removal rate of COD was about 69%~77%. Over the time, the effluent COD concentration gradually reduced and remained below 10 mg/L. The removal rate of COD was above 80%. In addition, the removal rate of

COD was very stable during the whole start-up process even under the condition of strong COD impact load, which was maintained more than 80%.

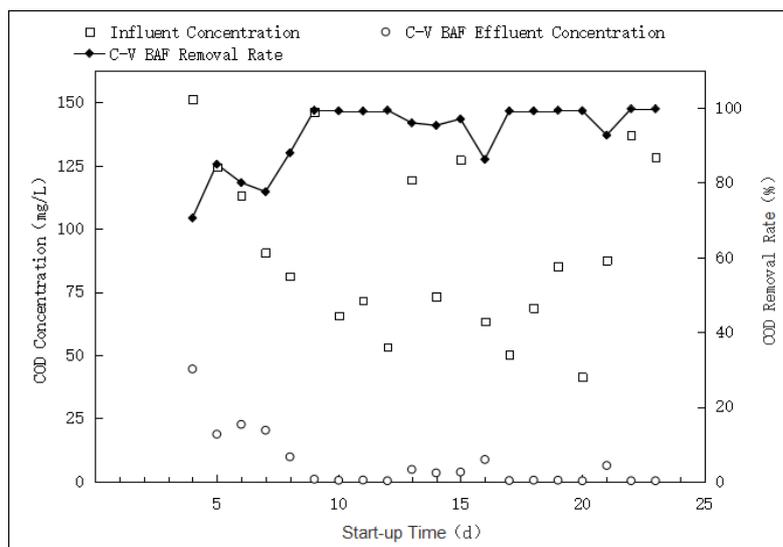


Fig. 2: COD removal effect of C-V BAF during start-up process

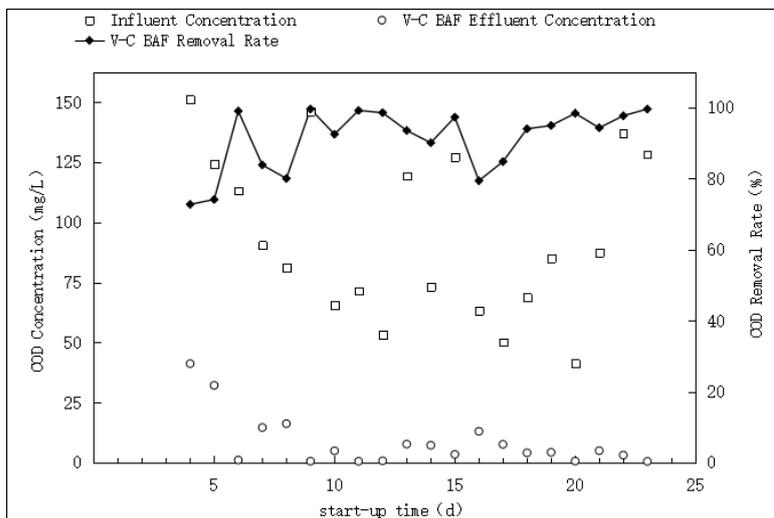


Fig. 3: COD removal effect of V-C BAF during start-up process

In the early stage of V-C BAF start-up, the effluent COD removal rate was relatively low, which was about 70%. Till the mid to late of the start-up period, the removal rate of COD was also above 80%. Compared with C-V BAF, V-C BAF also had strong ability against shock loading, but the stability of the COD removal efficiency was relatively poor.

In the early stage of start-up, BAF system mainly oxidized COD through the free microorganism within the gap of fillers, and the ability against shock loading was weak. The removal rate of COD presented a continuous small fluctuation. Until the mid to late of the start-up period, biofilms on the surface of the fillers gradually matured, the ability against shock loading has also been significantly improved, and the water quality of the effluent tended to be stable. In addition, the total porosity of volcanic fillers slightly higher than that of ceramic fillers, its adsorption retention capacity is better than that of the ceramic fillers, so C-V BAF exhibited a more stable COD removal rate.

2.3. Effect of V-C BAF and C-V BAF on the Removal of Ammonia Nitrogen

Effect of V-C BAF and C-V BAF on the removal of ammonia nitrogen was shown in Fig.4 and Fig.5.

Before 7th d of the start-up process, NH₃-N removal rate of C-V BAF system had a slight decline in the trend. But, NH₃-N removal rate in the whole start-up process was stable at more than 95%. NH₃-N

concentration of the effluent maintained below 0.32mg/L Before 7th d of the start-up process, NH₃-N removal rate of V-C BAF system showed a significant downward trend. NH₃-N concentration of the effluent in this stage reached 1.6mg/L~2.3mg/L. NH₃-N removal rate was only 74%~84%. NH₃-N removal rate of the system started to rise rapidly after 7th D of the start-up process. NH₃-N removal rate of the system was stabilized at more than 95% after 10th D of the start-up process.

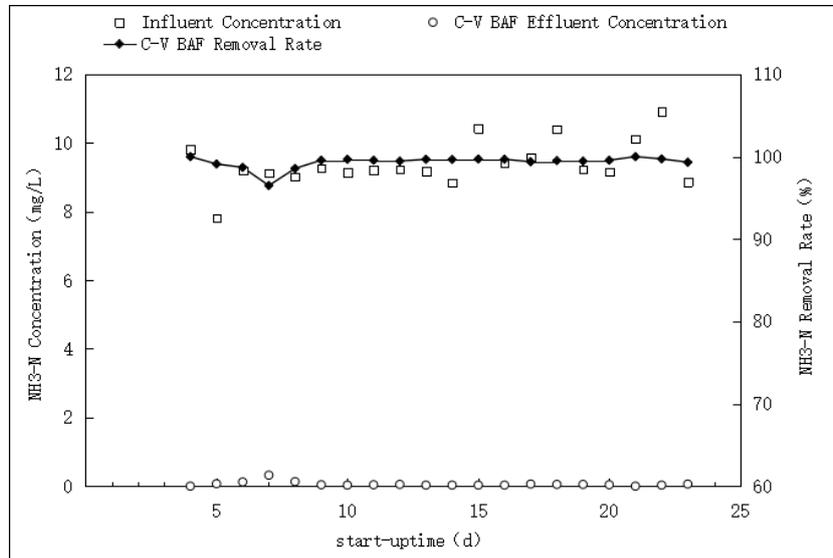


Fig. 4: NH₃⁻N removal effect of C-V BAF during the start-up process

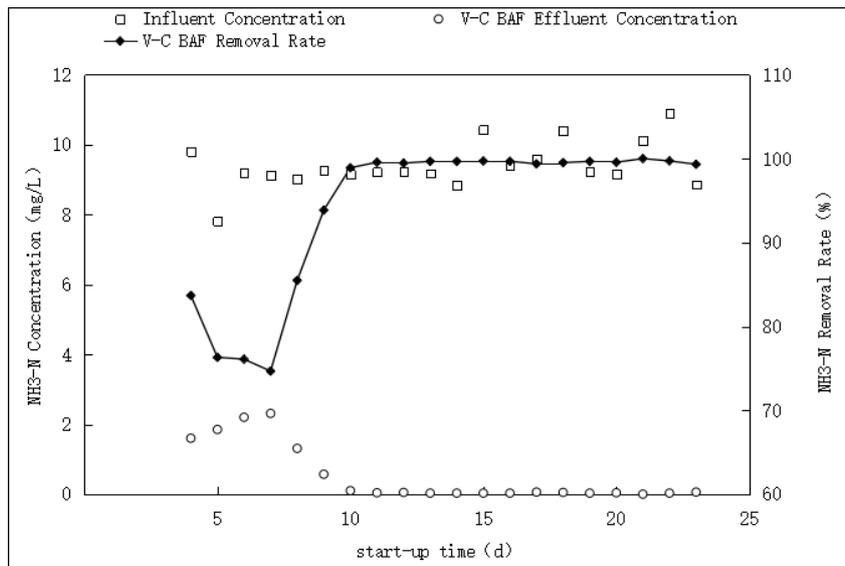


Fig. 5: NH₃⁻N removal effect of V-C BAF during the start-up process

The above phenomena may be due to the strong ammonium ion exchange function of the volcanic rocks. The fresh volcanic rocks in the early stage of the start-up process had a large amount of ammonium ion exchange capacity, which could adsorb a large amount of ammonia nitrogen in a short time. As a result, the removal rate of ammonia nitrogen in the initial stage of two kinds of combinations was "virtual high". With the gradual balance of the adsorption of volcanic rocks, the ion exchange function was weakened, and the surface of the biofilm has not been formed. A large number of ammonia nitrogen could not be nitrification and ammonia nitrogen concentration of the effluent gradually increased. Compared with C-V BAF, V-C BAF system has less volcanic rock capacity, and the buffer function of ammonia nitrogen was weak, so the ammonia nitrogen concentration of the effluent on the initial stage of start-up process was higher. In the middle and late stage of start-up process, the formation of mature biofilm on the surface of the filling materials was completed. Even without the adsorption buffer function of volcanic rocks, the removal rate of

ammonia nitrogen could also be kept at a high level.

2.4. Removal Efficiency of Total Nitrogen by C-V BAF and V-C BAF

The C-V BAF and V-C BAF are all filled with the volcanic rock filter. $\text{NH}_3\text{-N}$ removal of BAF containing volcanic rock filter included microbial nitrification and the ion exchange of volcanic rocks. Therefore, it is necessary to exam total nitrogen removal of the effluent of two kinds of combination, observe the nitrogen distribution of the effluent, and determine ammonia nitrogen nitratio degrees of two kinds of combination. Results as shown in Fig. 6 and Fig. 7.

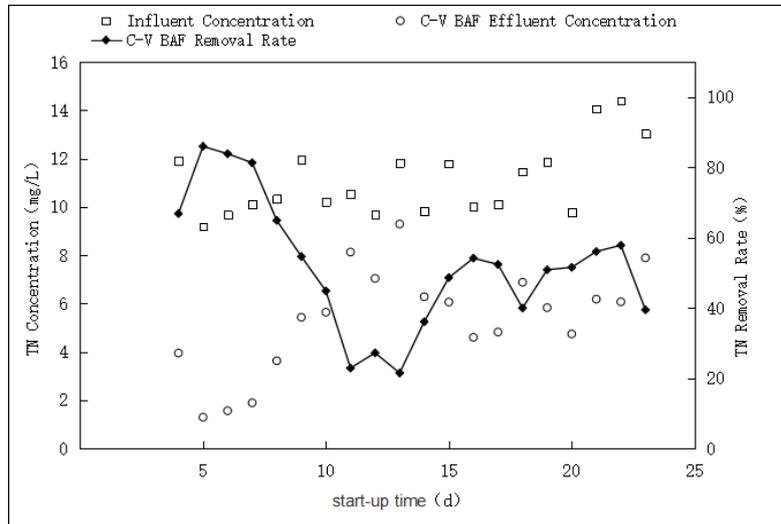


Fig. 6: TN removal effect of C-V BAF during starting process

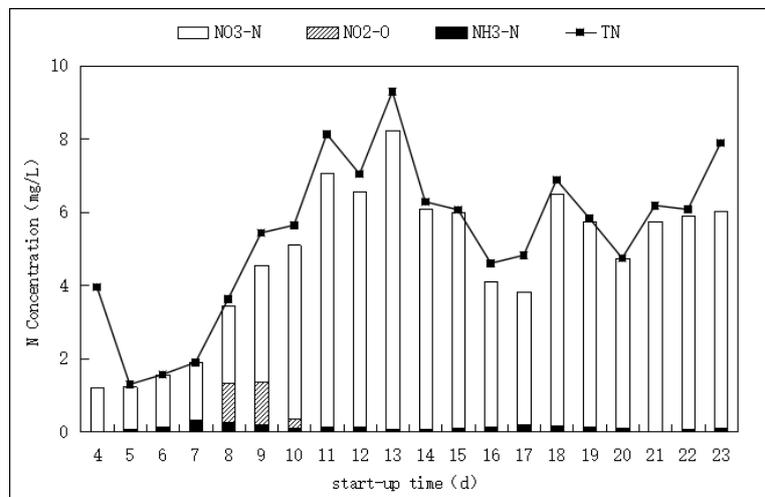


Fig. 7: The nitrogen distribution of the effluent during starting process of C-V BAF

The total nitrogen removal rate of C-V BAF had the trend of first increased and then decreased at the early stage of starting process. And then, total nitrogen removal rate gradually stabilized at around 50%, and the effluent total nitrogen was about 5~8 mg/L at the late stage of starting process. As shown in the figure, on 8-10d of the starting process, $\text{NO}_2\text{-N}$ appeared transient accumulation in C-V BAF. At this time, $\text{NO}_3\text{-N}$ in the effluent also began to rise sharply. It suggested that the nitrifying bacteria has been adapted to new environment and begun to multiply. On 10 days after the start, TN in the effluent was almost all nitrate. It could be speculated that nitrifying bacteria has been initially formed on the filler surface.

In the early stage of starting process, the large amounts of ammonia nitrogen in system was adsorbed by volcanic rock. The substrate which could be used by nitrifying bacteria was also rarely. Less amount of $\text{NO}_2\text{-N}$ were produced by nitrite bacteria, thus all of them were transformed to $\text{NO}_3\text{-N}$. The phenomenon of $\text{NO}_2\text{-N}$ accumulation could not be observed. When the adsorption capacity of volcanic rocks was saturated

in the system, ammonia nitrogen in the adsorption of volcanic rocks began massive release to the aqueous phase. At this time, the substrate which could be used by nitrifying bacteria increased. Along with nitrite bacteria multiply, the concentration of NO_2^- -N also increased. But nitrate bacteria had a generation cycle longer than nitrite bacteria, would not be able to oxidize NO_2^- -N which was produced by nitrite bacteria synchronized. So, the transient accumulation of NO_2^- -N was observed.

When C-V BAF was early stage of start-up, nitrifying bacteria on the filler surface has not yet formed. C-V BAF maintained higher ammonia nitrogen removal efficiency mainly by adsorption on volcanic rock. With the enrichment and growth of nitrification bacteria, C-V BAF mainly removed ammonia nitrogen by nitrification after 10d of start-up.

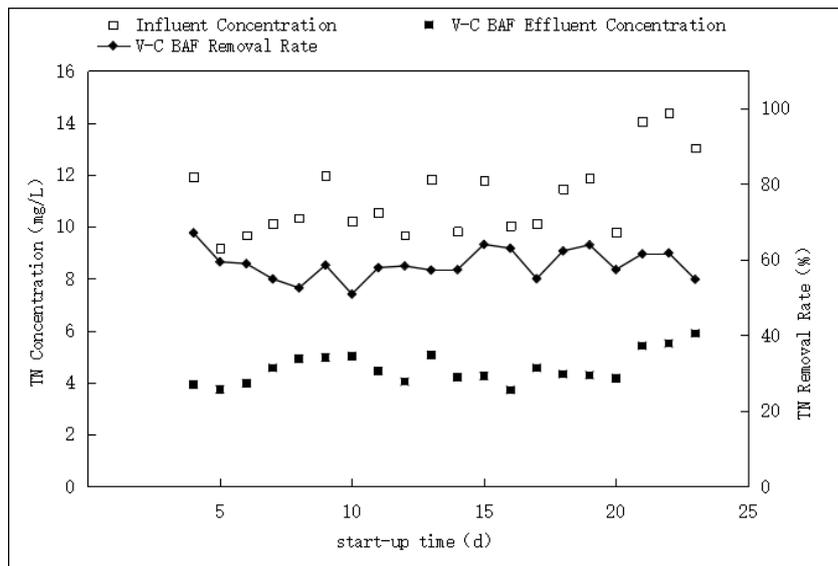


Fig. 8: TN removal effect of V-C BAF during starting process

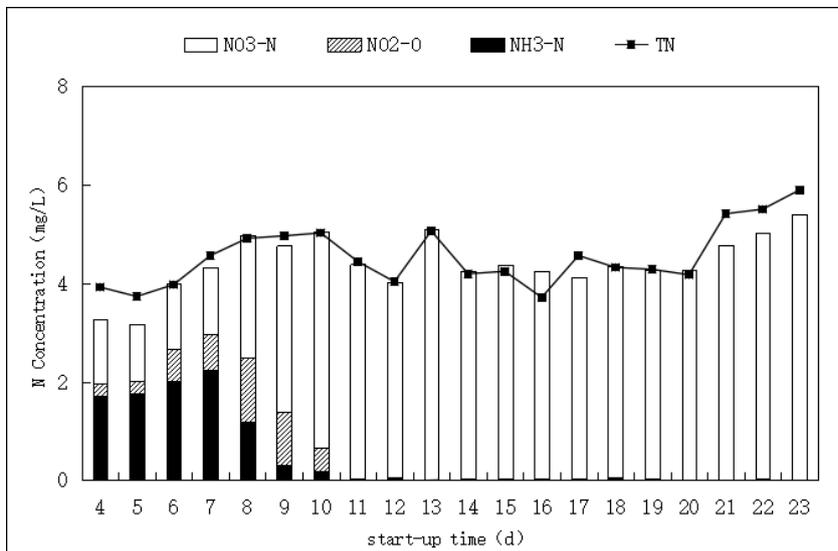


Fig. 9: The nitrogen distribution of the effluent during starting process of V-C BAF

Due to the adsorption and desorption of ammonia nitrogen by the volcanic rocks in the system, the TN removal rate of the early stage system showed a slow downward trend. But in the whole process of start-up, the TN removal rate of V-C BAF was stable to maintain more than 50%. TN concentration of effluent was about 3.8~6mg/L. System in the early start stage of 10 days, there were NO_2^- -N accumulation phenomena also. On 8th D or 9th D, the accumulation reached the peak value. On the 8th day of start-up process, the NO_3^- -N of the system effluent also began to sharply rising with ammonia nitrogen decreased greatly. After 10 days of the start-up process, TN of the effluent was almost composed of NO_3^- -N.

The V-C BAF in volcanic rock filling quantity was only 1/3 of the C-V BAF, so the total adsorption

capacity was lower. The water phase of V-C BAF system had relatively higher substrate concentration of ammonia nitrogen which nitrifying bacteria could make use of, and generation cycle of nitrate bacteria was longer than nitrite bacteria. Therefore, the early start stage of 10d, the system has the phenomenon of NO_2^- -N accumulation. On 8th D of start-up process, the nitrate and nitrite greatly increased in the system, and that the biological membrane of the system had started to propagate largely .

In conclusion, V-C BAF in the early start stage removed ammonia nitrogen mainly by the effect of adsorption by volcanic rocks. In the middle and late stage of start-up process, V-C BAF removed ammonia nitrogen mainly by nitrification. Compared with C-V BAF, the biofilm formation rate in V-C BAF was faster.

3. Acknowledgements

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4. References

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