

Full Length Research Paper

Research on biological aerated filter with volcanic filler for pretreatment of micro-polluted source water in lower temperature

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A pilot-scale research on dealing with micro-polluted source water of 4.2 m³/h by biological aerated filter (BAF) with volcanic filler for pretreatment was carried out. Under the experimental condition of air/water ratio 1:1, and the ammonia nitrogen of raw water 1.57 to 2.72 mg/L, the ammonia nitrogen average removal rate was 95.8%, when water temperature was above 10°C; and the removal rate was still above 70%, when water temperature ranged from 5.5 to 10°C. At the same time, there was no accumulation of nitrite nitrogen in the reactor. Moreover, the removal rate of Mn, COD_{Mn} and UV₂₅₄ was 66.3, 14.1 and 3.2%, respectively. Backwashing process of the BAF had little influence on the biofilm, which could be recovered within 1 to 2 h after the backwashing. The experimental result show that the removal effect of ammonia nitrogen and organic matter was very significant in BAF, even in lower temperature, which could guarantee the treatment effect of the follow-up processing unit.

Key words: Volcanic filler, biological aerated filter, biological pretreatment, micro-polluted water, lower temperature.

INTRODUCTION

With the development of industry and their drastic growth, drinking water sources are polluted heavily. Most sources cannot meet the standard of drinking quality in China, especially in south China. The pollutant of micro-polluted source water was very complicated and serious, especially ammonia nitrogen (NH₄⁺-N) and organic matter, which could not be effectively removed by conventional process, and the effluent of conventional process could hardly reach the drinking water standards in China (GB/T5750-2006).

Biological pretreatment technology had been the research focus of the water treatment (Yu et al., 2003; Li et al., 2006, 2007; Xu et al., 2002), since conventional process could not remove ammonia nitrogen and organic matter sufficiently. Water treatment by biological methods were known to be environment friendly and be demonstrated with little byproduct. Therefore, pretreatment

of polluted source water by biological methods should be a trend for drinking water treatment. Biological aerated filter (BAF) was one of the favorite biological methods in the field of water treatment, and could effectively reduce ammonium and organic matter through microbe mechanisms (Han et al., 2012). BAF has many advantages, such as small volume, little covering earth and hydraulic retention time (HRT), high treatment efficiency and effluent water quality, low investment and running cost etc. Today, BAF has been widely studied and applied in wastewater treatment, and some other biological filtration methods had been successfully researched for drinking water treatment, but limited studies were reported to lend BAF as a pre-treatment method for drinking water production.

In this paper, a pilot-scale research on dealing with micro-polluted source water of 4.2 m³/h by biological aera-

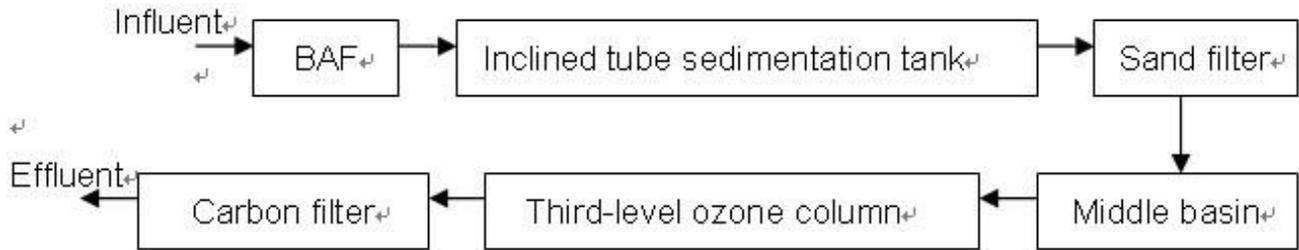


Figure 1. The pilot system process.

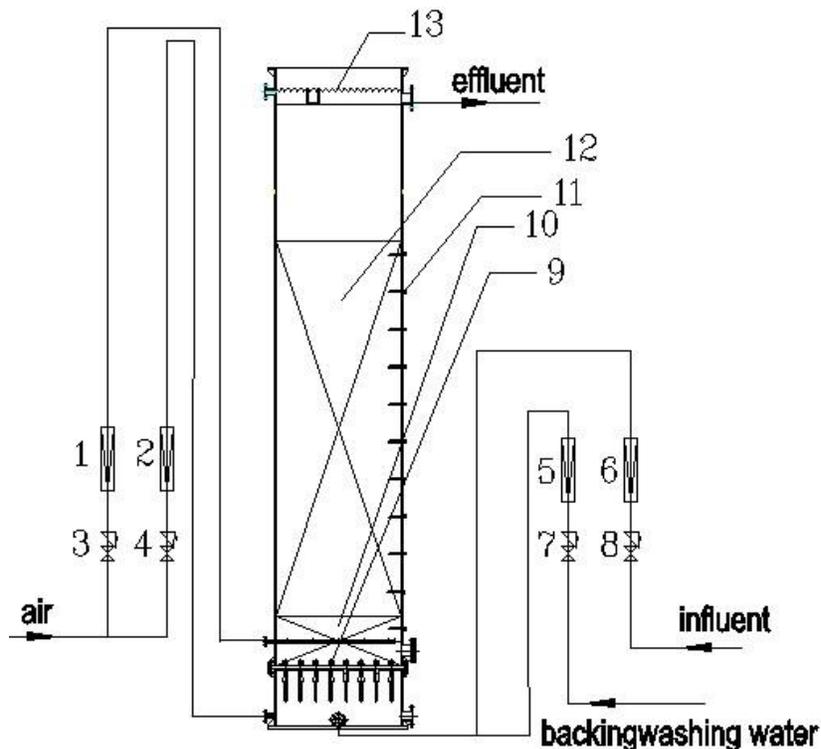


Figure 2. Schematic diagram of the experimental procedure of BAF.1. Backwashing air glass rotameter; 2. Aeration rotameter; 3-4. Solenoid valve; 5. Backwashing water rotameter; 6. Influent electromagnetic flowmeter; 7. Pneumatic valve; 8. Ball valve; 9. Long-handled filter head; 10. Graded gravel layer; 11. Sampling port; 12. filter layer; 13. Sink.

ted filter (BAF) with volcanic filler for pretreatment was carried out in Guanjinggang Water Supply Plant in Jiaying, China. The experimental data showed that biological aerated filter (BAF) with volcanic filler was a promising means to pretreat ammonia nitrogen and organic matter in micro-polluted source water, even in lower temperature.

MATERIALS AND METHODS

The pilot system process

The pilot system process is shown in Figure 1. The biological pretreatment and the conventional treatment process and deep

processing of the water treatment was carried out in the pilot, dealing with micro-polluted source water of 4.2 m³/h. The role of BAF as pretreatment unit was mainly studied in this paper.

BAF experimental device

The testing device is shown in Figure 2.

Raw water

The experimental raw water was sampled from the influent of Guanjinggang Water Supply Plant in Jiaying, China. Table 1 summarizes the main parameters of the raw water.

Table 1. Raw Water Quality and Parameter.

Item (unit)	Variation range	Mean
Turbidity (NTU)	14.2-51.2	28.5
COD _{Mn} (mg/L)	4.69-6.27	5.58
NH ₄ ⁺ -N(mg/L)	0.77-4.13	2.11
nitrite(mg/L)	0.091-0.31	0.16
nitrate(mg/L)	1.52-3.38	2.67
Fe(mg/L)	0.52-2.98	1.73
Mn(mg/L)	0.201-0.608	0.327

Table 2. Analytical Methods.

Item	Analytical method
Temperature (°C)	Thermometer
Turbidity (NTU)	Portable turbidity meter
NH ₄ ⁺ -N (mg/L)	Spectrophotometry
COD _{Mn} (mg/L)	Acid potassium permanganate titration method
Fe (mg/L)	Spectrophotometry
Mn (mg/L)	Spectrophotometric
Nitrate (mg/L)	Spectrophotometry
Nitrite (mg/L)	Spectrophotometry
UV ₂₅₄ (mg/L)	UV spectrophotometer

The main test items and analytical methods

The water quality analysis method was the Standard Examination Methods for Drinking Water (GB/T5750-2006), and specific methods are shown in Table 2.

RESULTS AND DISCUSSION

Earlier than this experiment, BAF had operated for about 10 months, so the biofilm was mature. During the experimental period, the conditions were as follows: air/water ratio of 1:1, raw water temperature of 5.5 to 16°C, and the filter velocity of 5.5m/h.

The removal effect of turbidity

As shown in Figure 3, the average removal rate of turbidity was 20.6%, when the raw water turbidity ranged from 14.2 to 51.2 NTU. The turbidity of raw water was removed by physical interception of filter layer and the adsorption and flocculation of biofilm (Yu, 2002; Zhang and Liu, 2005). The experiment data showed that the turbidity removal rate of raw water was lower, because up-flow method was adopted in the experiment, which could not remove turbidity effectively. But removing turbidity was

not the main purpose of BAF, and the turbidity could be removed in coagulation and sedimentation unit. In addition, when the turbidity removal rate was lower, the probability of suspended solids (SS) covering on biofilm would be reduced. In this case, the nitrifying bacteria biofilm was active so that the ammonia nitrogen nitrification was maintained at a high level. Besides, the decline of turbidity removal rate meant lower speed of filtration loss headed to prolong backwashing cycle.

The removal effect of ammonia nitrogen

As shown in Figure 4, when the experimental condition was air/water ratio of 1:1, the ammonia nitrogen of raw water ranged from 1.57 to 2.72 mg/L with an average of 2.11 mg/L, the ammonia nitrogen average removal rate was 95.8%, when water temperature was above 10°C; and the removal rate was still above 70%, when water temperature ranged from 5.5~10°C. Biofilm could be easily formed on the volcanic filter because of its unique features, such as rough surface, large specific surface area and high porosity. The volcanic filter provided an ideal growth and breeding condition for micro-organisms. So the ammonia nitrogen was effectively removed by the oxidation of nitrifying bacteria even in lower temperature due to the volcanic filler providing prodigious biofilm.

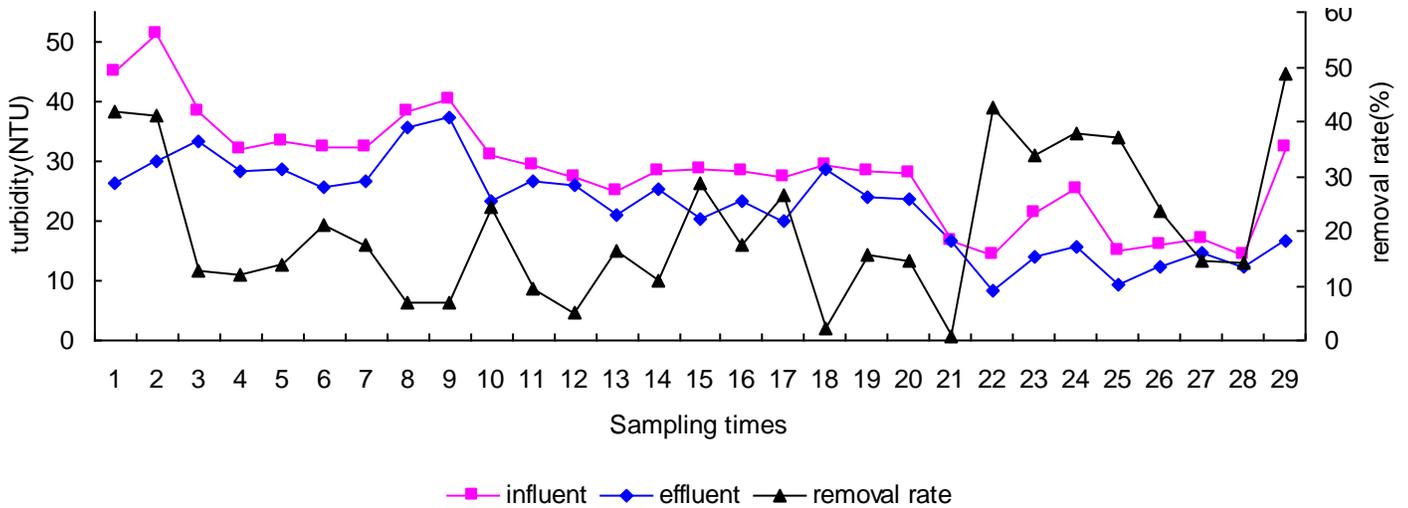


Figure 3. Turbidity removal effect in BAF.

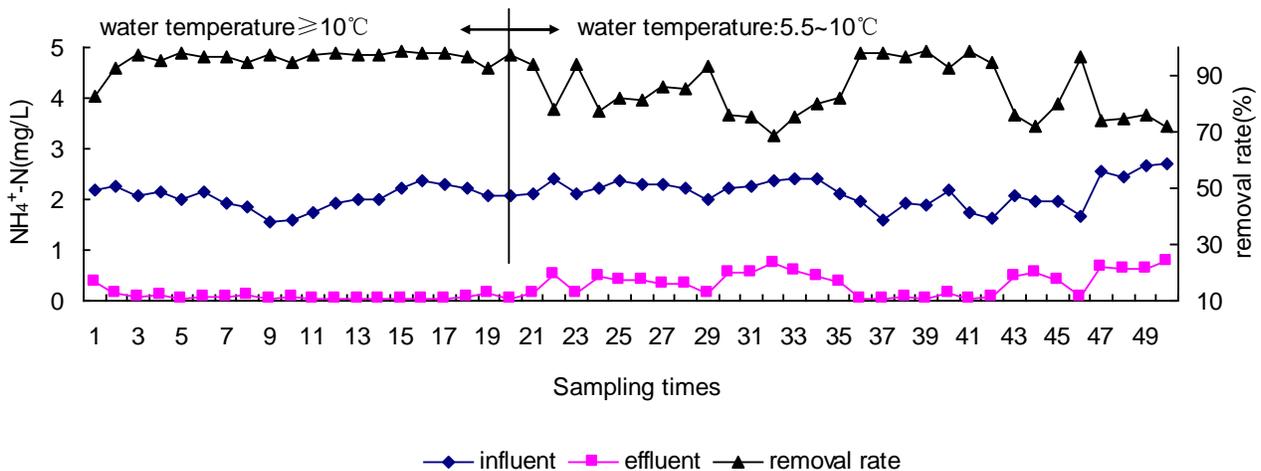


Figure 4. Ammonia nitrogen ($\text{NH}_4^+\text{-N}$) removal effect in BAF.

The removal effect of nitrite

As shown in Figure 5, under the experimental condition that the air/water ratio was 1:1, the raw water nitrite was 0.091 to 0.31 mg/L, and the average removal rate of nitrite nitrogen in BAF was 65.5%, when the temperature ranged from 5.5 to 16°C. There was no accumulation of nitrite in the reactor, so BAF had an excellent ability to remove nitrite. The experimental results show that nitrate nitrogen of the effluent increased to 1.75 mg/L; when ammonia of the raw water ranged from 1.57 to 2.72 mg/L, nitrite of the raw water was 0.091~0.31 mg/L. The experimental data showed that BAF had strong nitrification ability.

The removal effect of COD_{Mn}

As shown in Figure 6, under the experimental condition that the air/water ratio was 1:1, the raw water COD_{Mn}

ranged from 4.69 to 6.27 mg/L with an average of 5.58 mg/L; the average removal rate of COD_{Mn} was 14.13%. The result shows that BAF as pretreatment had positive effect on conventional processing because it not only partly intercepted organic particles but also degraded dissolving organic matter which can hardly be removed by conventional processing.

The removal effect of Mn

As shown in Figure 7, under the experimental condition that the air/water ratio was 1:1, the raw water Mn ranged from 0.201 to 0.327 mg/L, and the average removal rate of Mn was 66.3%, when the water temperature ranged from 5.5~16 °C. The oxidation of Mn was carried out with the catalytic action of bacteria extracellular enzyme, and Mn could be effectively removed when the microbial biomass reached a certain extent. Theoretically, the oxida-

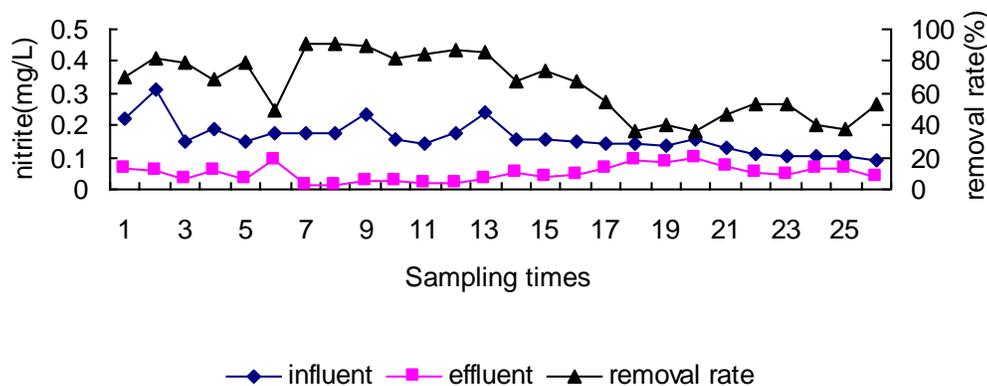


Figure 5. Nitrite removal effect in BAF.

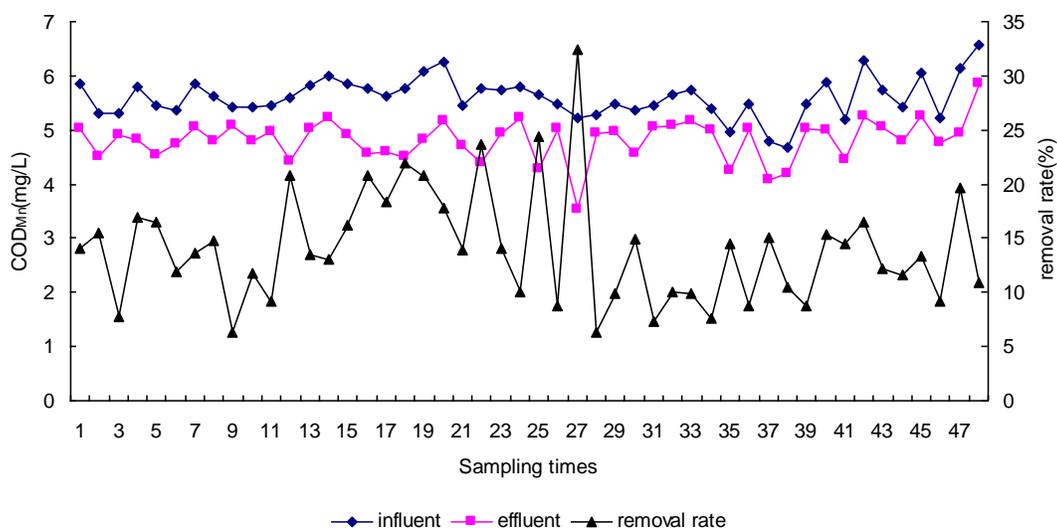


Figure 6. CODMn removal effect in BAF.

tion process of Mn begun after the oxidation process of Fe (Yang et al., 2003). In this experiment, the average removal rate of Fe was 21.9%, and the concentration of Fe of effluent was 1.15 mg/L, therefore, Mn could not be removed completely; maybe the Fe was not oxygenated incompletely.

The removal effect of UV254

The UV254 removal rate ranged from 0 to 8% with an average of 3.42%, when the water temperature ranged from 5.5–16°C. The removal rate of UV₂₅₄ of raw water in BAF was lower, so the removal rate of haloform precursor's elimination of raw water in BAF, which had the good relevance with UV254 was lower.

The influence of backwashing on BAF

Backwashing was carried out when BAF performance began to decline. The backwashing cycle was 7 to 14

days, with air strength of 10 to 15 L/(m²·s) for 10 min, and then with water of the strength of 10 L/(m²·s) for 10 min. After the backwashing, the effluent of BAF was sampled for 1 to 2 h for testing; the removal rate of ammonia was above 80% (Figure 8), and the removal rate of COD_{Mn} was also above 14%. The result shows that the suitable backwash intensity and time would not affect the treatment of BAF.

Microscopic observation of the media

We removed the carrier samples from the filter layer at the different depths along the flow direction, respectively. After the samples were pretreated according to the requirements, they were observed by scanning electron microscope (SEM). The samples were taken from the inflow 0.3, 1.6, 2.4m, respectively. Scanning electron microscopy showed that the biomass of the carrier decreased significantly with the filter layer depth. On the carrier of filter layer 30 cm (Figure 9b), there were growth

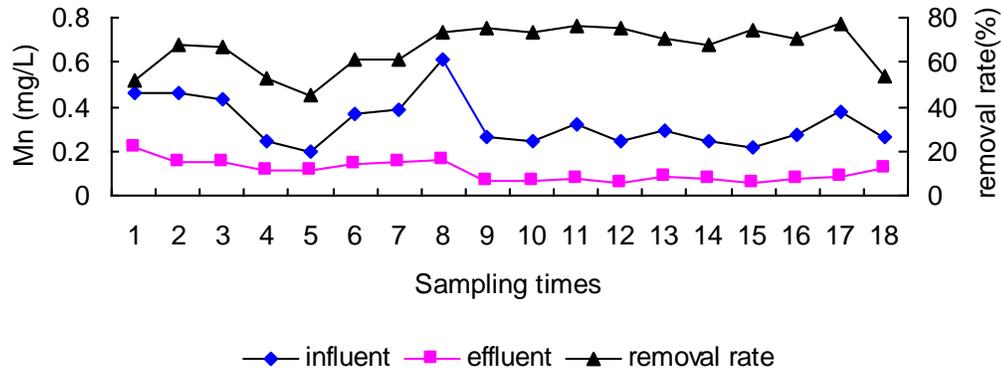


Figure 7. Mn removal effect in BAF.

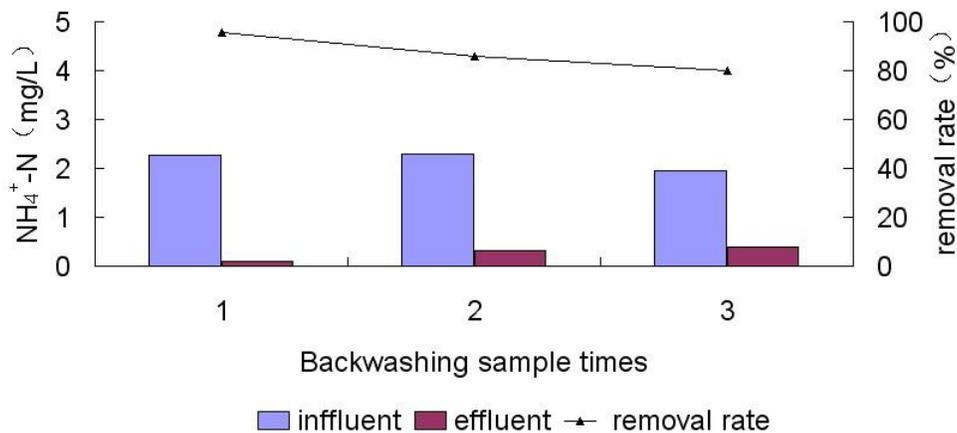


Figure 8. The influence of backwashing on BAF.

of more microorganisms on the carrier sunken place, and it was covered by a large number of filamentous fungi, filamentous fungi crisscross, forming biofilm skeleton, such as aureus and bacillus inclusion in it, and in addition, there were a few very fine filamentous cell secretion. Bacterial surface adsorbed a great number of inorganic or organic debris due to the reason that the test source water turbidity was higher; so many filamentous fungi, bacteria and bacilli were coated. The biofilm structure was not dense, there are many large gaps, and this was conducive to the matrix and dissolved oxygen mass transfer. The filamentous fungi at carrier of filter layer 160 cm was significantly reduced (Figure 9c) and there was a few filamentous fungi in the 240cm outflow (Figure 9d). This shows that the microbial groups and quantity were reduced as the filter layer depth increased. Biofilm could not completely cover the surface of the carrier when observed by scanning electron microscope. There was usually only scattered individual cell or a few cells together in the carrier surface trunk and smooth place, on the contrary, a great number of microorganisms grew in the sunken place or holes; the growth thickness highly

correlated the depth of the sag. This shows that surface depression and holes were easy adherent microbes by microorganisms. Carrier surface roughness had great influence with biomass and the biofilm formation velocity. Unlike wastewater treatment, the biofilm at carriers was very thin in BAF in poor nutrient micro-polluted source water treatment.

Conclusions

Under the experimental condition that the air/water ratio was 1:1, the ammonia nitrogen of raw water ranged from 1.57 to 2.72 mg/L, and the ammonia nitrogen average removal rate was 95.8%, when water temperature is above 10 °C; and the removal rate was still above 70%, when water temperature ranged from 5.5 to 10 °C. The data showed that BAF with volcanic filler as pretreatment of micro-polluted source water could effectively remove ammonia nitrogen. The removal rate of Mn, COD_{Mn} and UV_{254} were 66.3, 14.1 and 3.2%, respectively. The suitable backwashing process of the BAF had little influence

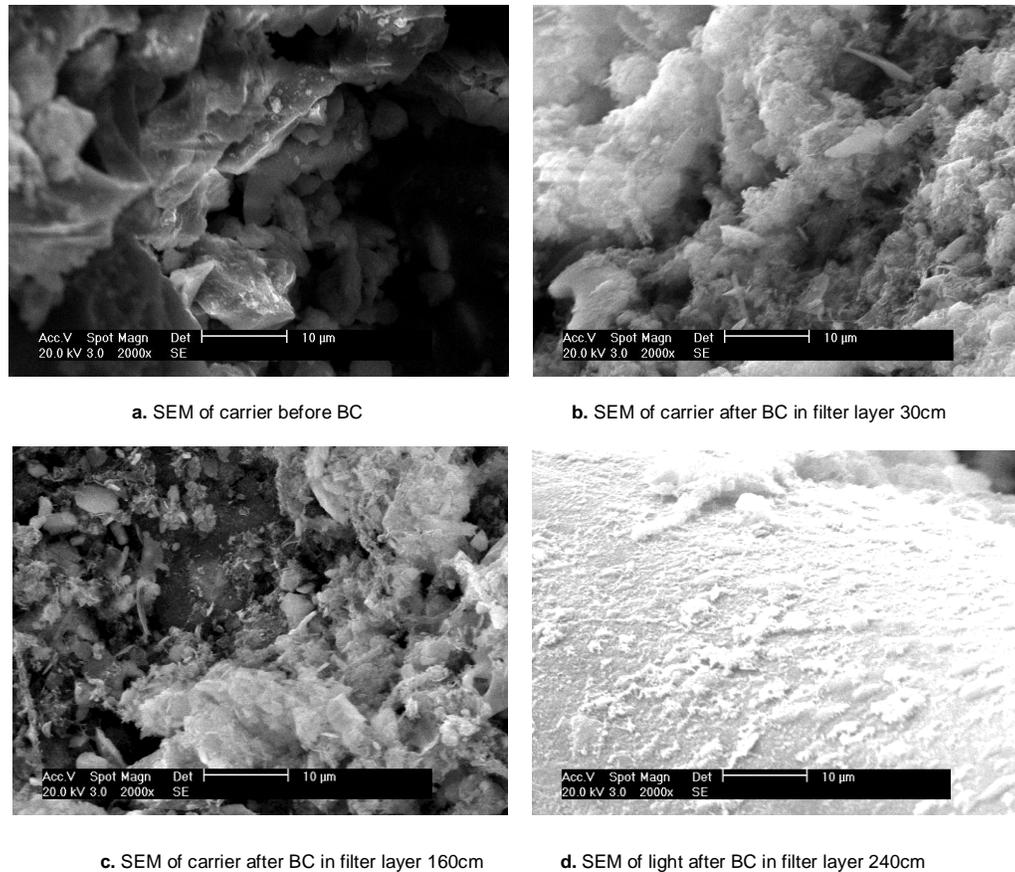


Figure 9. Comparison of the carriers before and after biofilm culturing (BC). A, SEM of carrier before BC; B, SEM of carrier after BC in filter layer 30 cm; C, SEM of carrier after BC in filter layer 160 cm; D, SEM of light after BC in filter layer 240 cm.

on the biofilm, which could be recovered within 1 to 2 h after the backwashing. Biofilm could not completely cover the surface of the carrier, and microorganisms mainly grew in the sunken place or holes. For micro-polluted source water, BAF with volcanic filler was a promising means to pretreat ammonia nitrogen and organic matter, even in lower temperature.

ACKNOWLEDGEMENTS

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