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Study on N-NH_4^+ removal from underground water by MBBR case study in Bach Khoa Ward, Hanoi, Vietnam

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Moving bed biofilm reactor (MBBR) using porous carrier plastic material, Polyurethane (DHY-1) which has high porosity 92% -96%, has been researched and applied in many water treatment systems. The advantage of the material is that it has high surface area of about 6,000-12,000m^2/m^3 thereby increasing the density of biomass. In this research, they were tried to treat ammonium nitrogen (N-NH_4^+) in the ground water. It was found that the treatment efficiency was more than 90% with N-NH_4^+ concentration of 10-12mg/l. Different densities of carrier materials as well as different influent flow rates have significant impacts on the removal efficiency. The study showed that treatment capacity decreased with high influent flow rate while increased with high density of carrier materials.

Introduction

Hanoi groundwater has been seriously polluted with ammonium nitrogen (N-NH4 +) in the past decade. Groundwater quality deterioration tends to go from the North to the South of the city. Especially ammonium nitrogen components (N-NH_4^+) and organic contaminants tend to be higher with the urbanization process. The N-NH_4^+ in some wells in the Southern area of Hanoi were reported quite high as follows: Phap Van wells (N-NH_4^+ = 15.0-30.0 mg/l, Oxidation 4.0-7.6 mg/l O_2) (Cao, 2006); Tuong Mai wells (N-NH_4^+ = 5.6-15.0 mg/l; Oxidation = 2.1-4.8 mg/l O_2); Ha Dinh wells (N-NH_4^+= 8.9-15.0 mg/l; Oxidation = 2.2-4.5 mg/l O_2); Bach Khoa wells (N-NH_4^+ = 10-12 mg/l; Oxidation = 2-5 mg/l O2). (Hanoi Water Limited Co. Report, 2012). Meanwhile, the allowable ammonium nitrogen concentration should be less than 3mg/l as regulated in Vietnam Standards QCVN 01:2009/BYT by Ministry of Health.

At present, most of applied groundwater treatment technologies mainly treated iron and manganese while ignored the nitrogen compounds (Le and Tran, 2005). Even though it can cause a number of dangerous diseases to human beings (Bouchard, et al., 1988); the research on ammonium removal has been very limited (Cao, 2006; Cao and Nguyen, 2000).

Ammonium nitrogen treatment by moving carrier materials has been proved to obtain high efficiency (Richard, 1979). To evaluate the applicability of MBBR with carrier materials DHY-1, this research focuses on evaluating the impact of the density of the carrier materials and loading rates on N-NH_4^+ removal efficiency.

Materials and methods

Feed water characteristics

The groundwater treatment plant in Bach Khoa (Hanoi) was shut down a few years ago because groundwater is contaminated with high ammonium nitrogen (about 10-12mg/l). The research team has restored that closed well, pumped up the groundwater and analyzed the quality. The water was found with low quality: pH = 6.5-6.8; N-NH_4^+ = 10-12mg/l; iron = 7-12mg/l, pH = 140 - 180 mg$CaCO_3$/l; P-PO_4^{3-}=0.5-1.2 mg/l; Oxidation = 2-5mgO_2/l, negligible nitrite and nitrate (Vietnam construction and Environment Joint stock Company VICEN, 2012). Especially, iron and ammonium was quite high.

Microbiological culturing

Microorganisms was obtained from Kim Lien wastewater treatment plant, then isolated and cultured in the laboratory by adding nutrient source for microbial development such as $NaHCO_3$, NH_4Cl, $NaHPO_4$ (Henze et al., 2002) The conditions of pH = 7.5-8.5, alkalinity and nutrients were kept enough to facilitate microbial development of Nitrosomonas and Nitrobacter. Time for microorganisms development was about 4 weeks at 25-30^{0}C or 2-3 months at 15-20^{0}C (Salvetti et al., 2006).

Carrier material DHY-1

Carrier materials are cubic in shape, dimension of 1x1 cm; apparent specific volume of 33 g/l; apparent specific weight 0.97 g/l; surface area of about 6000-12000m^2/m^3. Polyurethane is very durable and non-toxic for drinking water. The carrier materials were added into the reaction tank until target density was achieved, normally in the range of 10-30% of volume of water in reactor tank in this study.

Photograph 1. DHY-1 carrier material (left: carrier materials with microorganism; right: carrier materials without microorganism)

Experimental diagram

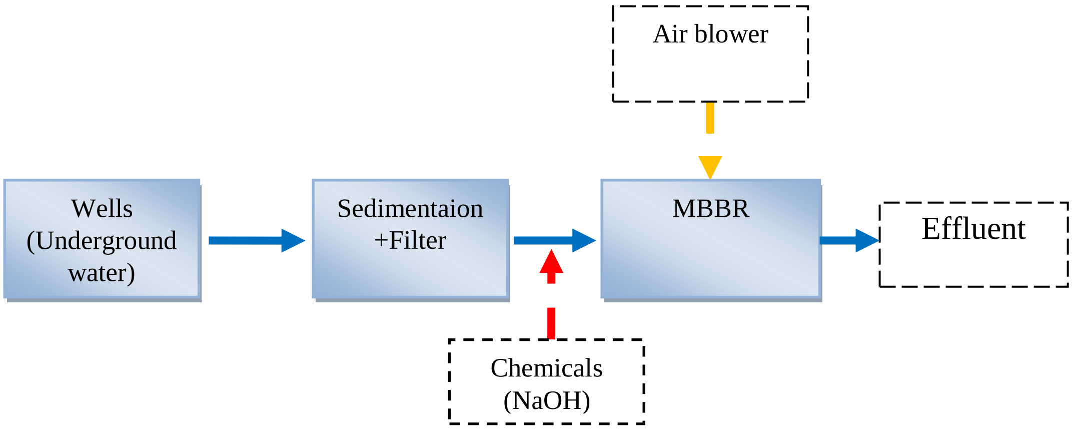

Figure 1: Experimental diagram at Bach Khoa treatment plant (Hanoi)

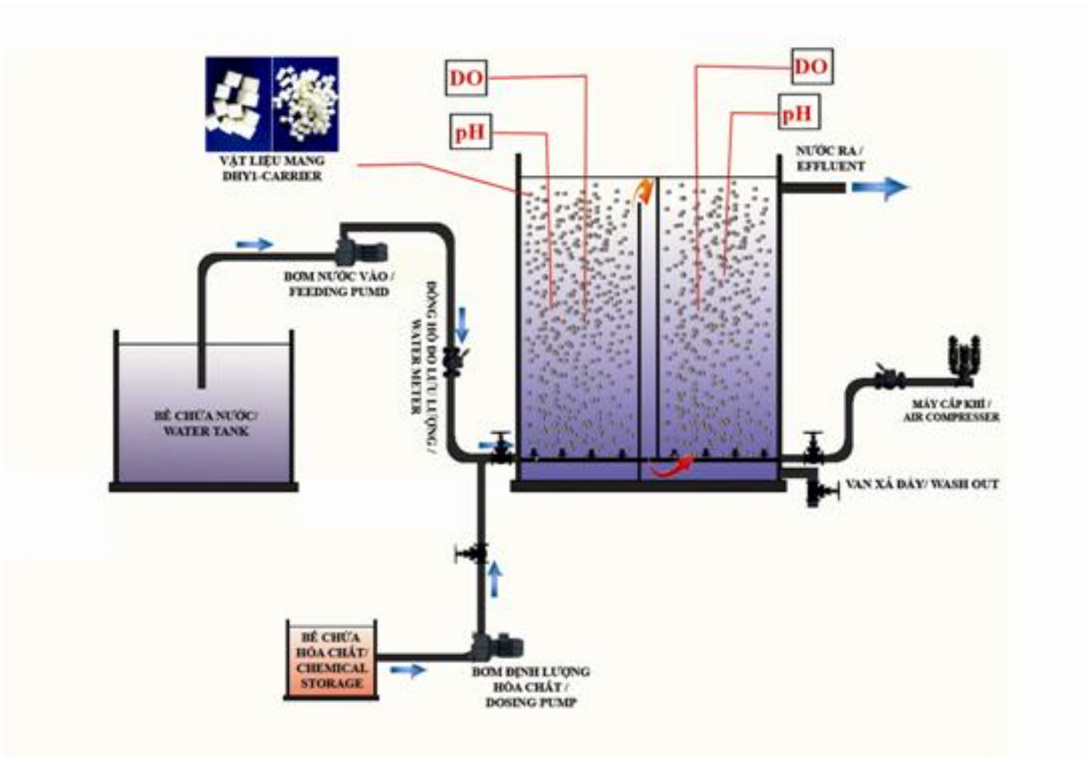

Figure 2. Diagram of experimental equipment system – MBBR tank

Feed water was pumped from the wells to combined sedimentation and media filter unit. After that, it was fed into reaction tank MBBR. The tank with volume of 1,2m^3 made of steel CT3 (Length x width x height = 800x800x1800mm) was integrated with gas distribution system in the bottom of the tank (Figure 2). Different carrier materials of 10%, 15%, 20%, 25%, 30% were tried to evaluate the ammonium oxidation rate, with the aim of choosing the optimal density to apply for the treatment system. Various input flowrates of 0.5; 1; 1.5; 2.0; 2.5 m^3/h were applied to evaluate optimum loading of ammonium nitrogen on the efficiency of nitrification. Experimental conditions are present in Table 1.

During the experiments, samples were collected and analyzed in terms of NH_4^+-N, NO_2^--N, NO_3^--N, DO and alkalinity to evaluate the effectiveness of each different experimental conditions.

Table 1. Experimental conditions

Input flow (m^3/h)	Retention time (h)		
	Compartment 1	Compartment 1	Entire system
0.5	1.2	1.2	2.4
1.0	0.6	0.6	1.2
1.5	0.4	0.4	0.8
2.0	0.3	0.3	0.6
2.5	0.24	0.24	0.48

Results and discussion

The effect of the carrier density and the input flow to the nitrification rate was presented in Tables 2, 3, 4, 5, 6. It was observed that the greater density of the carrier is, the higher ammonium nitrogen treatment rate is.

The efficiency reached 90% at 0.8 h with the carrier density of 30%. For the densities of 10% and 15%, it required 1.5-2 hours to achieve the efficiency of above 80%. In addition, as the input flow increased, the efficiency of ammonium removal decreased and the density of the carriers also affected the nitrification process.

Table 2. Ammonium treatment efficiency with carrier density of 10%(120 l)

Q ($m^{3/}/h$)	Retention time (h)	Co-NH_4^+ (mgN/l)	C-NH_4^+ (mgN/l)	C-NO_3^- (mgN/l)	C-NO_2^- (mgN/l)	Efficiency (%)	NH4+-N Treated load (kgN/m3/day)
0.5	2.4	10.82	2.36	6.58	0.15	78.2	0.846
1	1.2	10.34	4.35	4.65	0.12	57.9	1.198
1.5	0.8	10.25	5.97	3.98	0.08	41.8	1.284
2	0.6	10.71	7.32	2.61	0.09	31.7	1.356
2.5	0.48	11.05	8.31	2.24	0.18	24.8	1.37

Table 3. Ammonium treatment efficiency with the carrier density of 15%(180 l)

Q ($m^{3/}/h$)	Retention time (h)	Co-NH_4^+ (mgN/l)	C-NH_4^+ (mgN/l)	C-NO_3^- (mgN/l)	C-NO_2^- (mgN/l)	Efficiency (%)	NH4+-N Treated load (kgN/m3/day)
0.5	2.4	10.55	1.88	6.76	0.09	82.2	0.867
1	1.2	10.27	3.01	6.18	0.11	70.7	1.452
1.5	0.8	10.29	4.65	4.23	0.22	54.8	1.692
2	0.6	11.01	6.34	3.48	0.16	42.4	1.868
2.5	0.48	11.32	7.45	2.56	0.06	34.2	1.935

Table 4. Ammonium treatment efficiency with the carrier density of 20%(240 l)

Q ($m^{3/}/h$)	Retention time (h)	Co-NH_4^+ (mgN/l)	C-NH_4^+ (mgN/l)	C-NO_3^- (mgN/l)	C-NO_2^- (mgN/l)	Efficiency (%)	NH4+-N Treated load (kgN/m3/day)
0.5	2.4	10.34	0.85	8.13	0.05	91.8	0.949
1	1.2	10.71	1.72	7.07	0.12	83.9	1.798
1.5	0.8	10.14	2.89	6.21	0.09	71.5	2.175
2	0.6	10.89	5.35	4.39	0.07	50.9	2.216
2.5	0.48	11.5	6.72	3.58	0.14	41.6	2.39

Table 5. Ammonium treatment efficiency with the carrier density of 25%(300 l)

Q (m^3/h)	Retention time (h)	Co-NH_4^+ (mgN/l)	C-NH_4^+ (mgN/l)	C-NO_3^- (mgN/l)	C-NO_2^- (mgN/l)	Efficiency (%)	NH4+-N Treated load (kgN/m3/day)
0.5	2.4	9.34	0.05	8.82	0.09	99.5	0.929
1	1.2	9.97	1.15	7.64	0.13	88.5	1.764
1.5	0.8	9.63	2.05	7.14	0.17	78.7	2.274
2	0.6	10.57	4.82	4.05	0.08	54.4	2.3
2.5	0.48	10.87	6.03	3.18	0.15	44.5	2.42

Table 6. Ammonium treatment efficiency with the carrier density of 30%(360 l)

Q (m^3/h)	Retention time (h)	Co-NH_4^+ (mgN/l)	C-NH_4^+ (mgN/l)	C-NO_3^- (mgN/l)	C-NO_2^- (mgN/l)	Efficiency (%)	NH4+-N Treated load (kgN/m3/day)
0.5	2.4	9.85	0.03	8.15	0.09	99.7	0.982
1	1.2	10.45	0.31	8.56	0.12	97.0	2.028
1.5	0.8	10.61	1.06	7.75	0.09	90.0	2.865
2	0.6	10.56	3.03	6.05	0.05	71.3	3.012
2.5	0.48	10.73	4.77	3.38	0.18	55.5	2.98

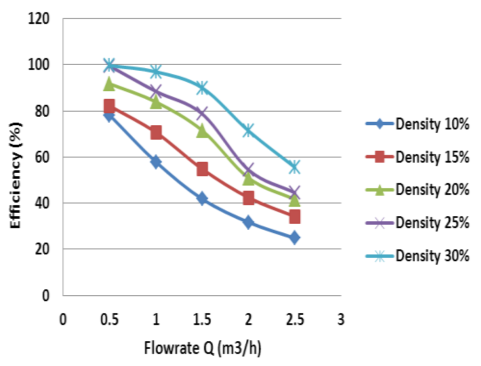

Figure 3. Effect of carrier density on nitrification process

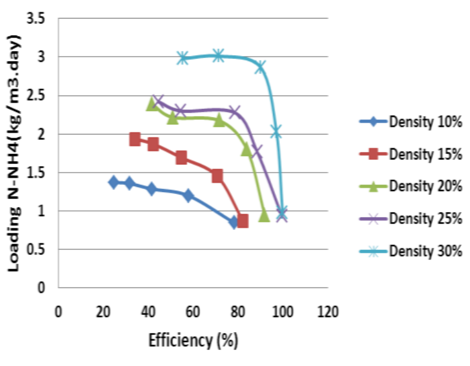

Figure 4. Effect of N-NH_4^+ on nitrification process

In addition, it was found from the above tables and Figure 3 that the higher retention time, the greater treatment performance of ammonium nitrogen. Besides, shorter duration was required with higher density of the carrier materials. For instance, with densities of carrier material 20, 25, 30%, the retention time was only 0.8 hours to be able to lower the contents of ammonium to 1.06-2.89 mgN/l (71.5- 90% removal efficiency). However, with densities of 10% & 15%, it needed over 2 hours to lower N-NH_4^+ to 2mgN/l (85% removal efficiency). Figure 4 showed clearly the effect of ammonium loading rate on nitrification process in which higher N loading was, lower removal capacity was achieved.

The above results may be explained based on the fact that as the contents of ammonium was not so high and there were no competition between autotrophic-bacterium and heterotrophic microorganism during aeration due to not many organic matters in underground water. Thus, oxidation rate was significantly high.

Conclusion

According to this study, by using MBBR, the content of ammonium of 10-12mgN/l can be treated with carrier materials from 20-30% (240-360 liters of materials) with high removal efficiency of 92-95%.

With high density of 20%-30% as well as high load of N-NH_4^+, treatment performance could be achieved up to 80%. With the same retention time of 1.2h, 20%-30% densities of carrier materials could obtain 80% removal efficiency, but it was required more than 2h to be able to obtain similar performance for lower material densities of 10% - 15%.

With content of N- NH_4^+ from 10-12mg/l, denitrification process might not be required. However, in case of treatment higher N- NH_4^+ concentration, it is necessary to supplement the organic matter content and added one compartment for denitrification.

It is concluded via this study that this treatment technology can be applied for treatment of ammonium for domestic water supply. The treated effluent met both Vietnamese and international standards for water quality. The volume of reactor can be saved 20-30%.

Currently, the nitrogen-contaminated groundwater is quite common in Southern area of Ha Noi city, especially for sources close to residential areas. According to the study, the N-NH_4 treatment by MBBR technology is feasible and reliable (high water quality), in particular for small and medium scale plants. In addition, the MBBR system can be designed and modified to adapt with different water sources.

References

Bouchard, D.C., Williams, M.K., and Sarampalli, R.Y (1988). *Nitrate contamination of groundwater*: Sources and potential health effects, J.AWWA 80.

Cao, T. H. (2006). *An evidence for the contribution of anamox process in nitrogen removal from groundwater. The 6th general seminar of the core university program*. Environmental science and technology for sustainability of asia. Kumamoto University, Japan.

Eaton, A. D.; Clesceri L. S., Greenberg A. E., Franson M-A. H. (1999). *Standard Method for the Examination of water and wastewater (20th Edition)*. American Public Health Association, American Water Works Association, Water Environmental Federation.

Hanoi Water Limited Company Annual Report, 2012.

Henze M., Harremoes P., Jansen J., Arvin E (2002). *Wastewater treatment*. 3rded. Springer. pp. 89 - 99 .

Le V. C., Tran, M. P. (2005). *Influence of hardness on the ammonia exchange by cationic resin from groundwater.* Advances in Natural Siences, Vol. 6, No.2 ,159-164.

Nguyen, V. K., Cao, T. H. (2000) *Study and treatment of N-ammonium in underground water,* Water supply, Page 1- 116.

Richard,Y, (1979). *Biological methods for the treatment of groundwater, Oxidation techniques in drinking water treatment,* USEPA.

Salvetti, R.; Azzellino, A.; Canziani, R.; Bonomo L., (2006), *Effects of temperature on tertiary nitrification in moving-bed biofilm reactors*, WATER RESEARCH 40, 2981– 2993.

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