Lewatit S100 in Drinking Water Treatment for Ammonia Removal

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Ammonium nitrogen is the most important form of nitrogen that can cause excessive algal growth and stimulate eutrophication in surface water. The purpose of this study is to investigate the possibility of removing ammonium from drinking water by means of an ion exchange process. Polymeric Lewatit S100 material (particle-size 0.3–1.2 mm) was used. The breakthrough capacity was determined by dynamic laboratory investigations and the concentration of regenerant solution (5 and 10 % NaCl) was investigated. The concentration of ammonium ion inputs in the tap water that we used were 10, 5 and 2 mg NH_4^+ l^{-1} and down to levels below 0.5 mg NH_4^+ l^{-1}. The experimental results show that the breakthrough capacity was very small at ammonium concentration 2 mg NH_4^+ l^{-1} compared to its breakthrough capacity at ammonium concentration 10 mg NH_4^+ l^{-1}. There was no difference between regeneration by 10 and 5 % NaCl. We conclude that the use of Lewatit S100 is an attractive and promising method for ammonium concentration greater than 5 mg NH_4^+ l^{-1} and till 10 mg NH_4^+ l^{-1}.

Keywords: Lewatit S100, ion exchange, ammonia removal, drinking water.

1 Introduction

Several nitrogenous compounds, including ammonia, nitrite and nitrate, are frequently present in drinking water and in various types of agricultural, domestic and industrial wastewaters (Metcalf & Eddy, 1991). This necessitates the upgrading of technological schemes, and a search for cost effective and environment friendly methods for removal of ammonia, nitrite, and nitrate. According to the instruction of the European Community Council (CCE) of 15 July 1980, the maximum permissible level of ammonium in drinking water is 0.5 mg/l. Methods for removal of nitrogenous compounds proposed by previous investigators have included air stripping, nitrification/denitrification using fixed or fluidized bed biological reactors and ion exchange. One of the common processes for drinking water treatment applied in recent times is an ion exchange process. Removal of ammonia from water has been investigated by many researchers (Gaspard and Martin, 1983; Hlavay et al., 1983; Vokáčová, et al., 1986; Hódi et al., 1995; Booker et al., 1996; Beler Baykal and Akca Guven, 1997; Cooney et al., 1999). A simple comparison of ammonia removal by both natural and a synthetic material was attempted by (Haralambous et al. 1992). Jörgensen, (1976) wrote in his paper that ammonia removal from wastewater was examined during treatment in a laboratory glass column with a diameter of 20 mm, containing 200 ml of ion exchange material of the following type:

1) a strong acidic cation exchanger on a sodium form (Lewatit 500 A);
2) a strongly acidic cation exchanger on a hydrogen form (Lewatit 500 A);
3) clinoptilolite on a sodium form;
4) an artificial zeolite;
5) sulfonated lignocelluloses on a sodium form;
6) a weak acidic cation exchanger on a sodium form (Lewatit 69 MP);
7) a weak acidic cation exchanger on a hydrogen form (Lewatit 69MP).

The results show that out of ion exchangers 1–7 only 2, 3 and 7, and perhaps also 6 give satisfactory results. The objective of our work is to treat drinking water spiked with NH_4^+ (10±0.5, 5±0.5 and 2±0.5) mg l^{-1}, using Lewatit S100.

2 Materials and methods

Physical description of the system

Fig. 1 shows an experimental apparatus consisting of a column with the following characteristics: Internal diameter = 20 mm, containing approximately 50 ml of exchanger, at a volumetric flow rate of 8.7 ml min^{-1}, which is equivalent to 10.5 bed volumes (BV) per hour, particle-size of material = 0.3–1.2 mm. A glass screen supported the Lewatit in the column.

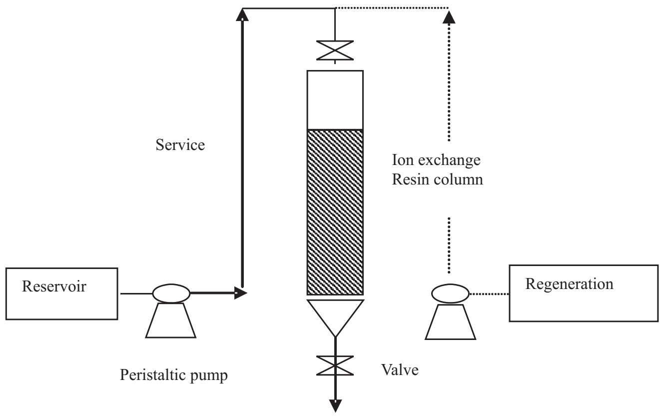

Fig. 1: Laboratory column

Analysis

All analyses were made according to standard methods (APHA, see Greenberg et al., 1992). Ammonia was determined by Nessler methods using a spectrophotometer (Model Hach DR/2000). Calcium and magnesium were determined by the EDTA titrimetric method.

Specification of the material

Lewatit S100 was the material used for the investigation. Lewatit S100 is a synthetic resin ion exchanger of the Na-type. It is a strongly acid cationic ion exchange resin.

System operation parameters

The first experiment was carried out to see the exhaustion performance of Lewatit S100 using distilled water spiked at 10 mg NH_4^+ l^{-1} concentration. Then we applied tap water containing $Ca^{+2} = 60$ mg l^{-1} and $Mg^{+2} = 12$ mg l^{-1}. The concentrations of ammonium input were 10, 5 and 2 mg NH_4^+ l^{-1} as (NH_4Cl) and down to levels below 0.5 mg l^{-1}.

In the regeneration phase, we used 5.0% NaCl at a volumetric flow rate of 8.7ml min^{-1}, which is equivalent to 10.5 bed volumes (BV) per hour and then 10% NaCl. After regeneration, the excess Cl^- was removed from the Lewatit S100 by distilled water. This washing was repeated until visual tests with $AgNO_3$ revealed zero chloride.

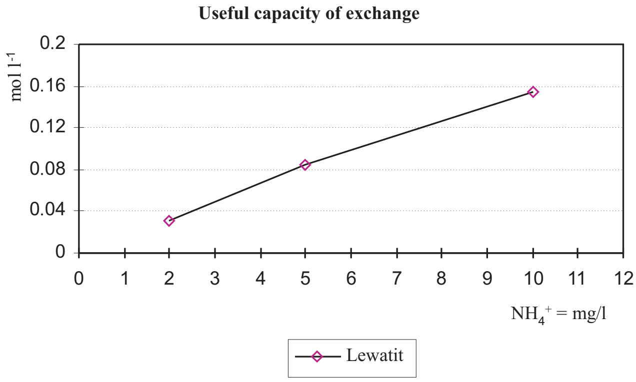

Fig. 3: Exchange capacity

3 Results and discussion

Breakthrough capacity

Within the scope of this work, the results from the first experiment using distilled water indicated that the volume of water treated till breakthrough, defined as 0.5 mg l^{-1} in

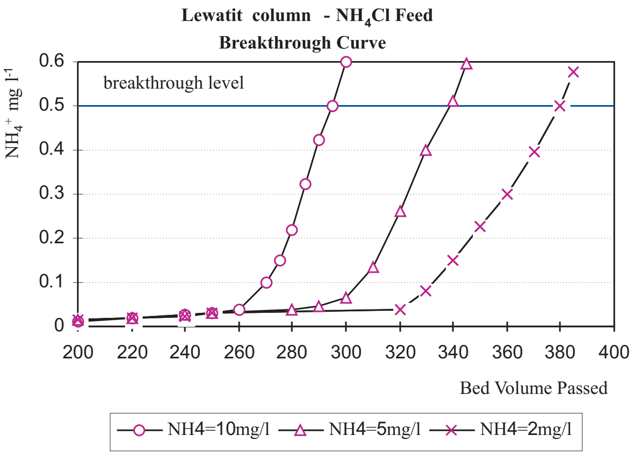

Fig. 2: Results from column study

NH_4^+, was 2570 BV (128.5 l), and the breakthrough capacity was 1.356 mol l^{-1} for $NH_4^+ = 10$ mg l^{-1}.

Fig. 2 shows that for tap water containing calcium and magnesium ions, the breakthrough capacity and the volume of water treated till NH_4^+ breakthrough were 0.156, 0.085, 0.0317 mol l^{-1} and 295 BV (14.75 l), 340 BV (17 l), 380 BV (19 l), respectively. These values indicate that tap water produces a lower breakthrough capacity than distilled water, due to the presence of other ions, especially ions with a polyvalent charge in water, such as Ca^{+2} and Mg^{+2}.

Fig. 3 shows that, for tap water, the evaluation of practical capacity exchange is a function of the entering concentration of NH_4^+. These results reveal that the breakthrough capacity is lower by approximately 0.55 and 0.2 times at $NH_4^+ = 5$ and 2 mg l^{-1}, respectively, than the breakthrough capacity at $NH_4^+ = 10$ mg l^{-1}. Thus, Lewatit S100 can remove ammonium ions very quickly with a higher breakthrough capacity at initial ammonia concentration of more than 5 mg l^{-1}.

Comparing the results summarized in Table 1, it can be seen that the calcium elimination from solution of 10 mg l^{-1} NH_4^+ was higher than the other solution of 5 mg l^{-1} and 2 mg l^{-1}. Magnesium was elimination from all ammonium solution with the same rate.

Regeneration effects

The elution curves (Fig. 4) indicate no difference between regeneration by (10 and 5%) NaCl solution. Table 2 shows that 29 BV (1.45 l) of on NaCl solution is sufficient for ammonium elution using Lewatit S100. These results reveal that Lewatit S100 is slightly more economical when using 5% NaCl for regeneration.

Table 1: Results of experiments

Resins	$NH_4^+ = 10$ mg l^{-1}		$NH_4^+ = 5$ mg l^{-1}		$NH_4^+ = 2$ mg l^{-1}	
	Ca^{+2}(mg l^{-1})	Mg^{+2}(mg l^{-1})	Ca^{+2}(mg l^{-1})	Mg^{+2}(mg l^{-1})	Ca^{+2}(mg l^{-1})	Mg^{+2}(mg l^{-1})
Lewatit	2.85	1.29	4.0	1.01	10.02	1.22

Table 2: Elution of ammonia

NaCl = 5%			NaCl = 10%		
Volume (ml)	NH_4^+ (mg l^{-1})	BV	Volume (ml)	NH_4^+ (mg l^{-1})	BV
500	0.65	10	500	1.9	10
1000	0.211	20	1000	0.125	20
1200	0.09	24	1250	0.098	25
1450	0.029	29	1450	0.04	29

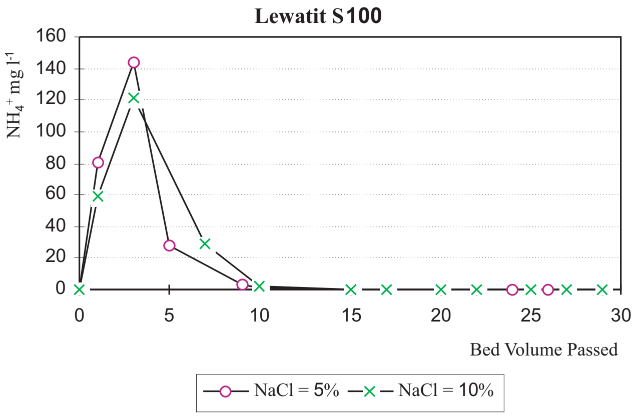

Fig. 4: Elution curves of ammonium ions

4 Conclusions

The experimental results indicate that Lewatit S100 as a cation exchanger can remove ammonium ions very quickly. Higher breakthrough capacity was found at an initial ammonium ion concentration of more than 5 mg/l compared to 2 mg. The calcium elimination was lower at an ammonium ion concentration of 10 mg/l. No difference between regeneration by 10 and 5% NaCl was observed. We conclude that the use of Lewatit S100 is an attractive and promising method for ammonium concentration greater than 5 mg NH_4^+ l^{-1} and till 10 mg NH_4^+ l^{-1}.

References

[1] APHA *Standard methods for examination of water and waste water*. 18th Edition, 1992, Published by American Public Health Association, Washington, USA

[2] Beler Baykal, B. and Akca Guven, D.: *Performance of clinoptilolite alone and in combination with sand filters for the removal of ammonia peaks from domestic wastewater*. Wat. Sci. Technol.,1997, Vol. 35, No. 7, pp. 47–54

[3] Booker, N., Cooney, E. and Priestly, A.: *Ammonia Removal from Sewage Using Natural Australian Zeolite*. Wat. Sci. Technol., 1996, Vol. 34, No. 9, pp. 17–24

[4] Cooney, E., Booker, N., Shallcross, D. and Stevens, G.: *Ammonia Removal from Wastewater Using Natural Australian Zeolite. I. Characterization of the Zeolite*. Sep. Sci. Technol., 1999, Vol. 34, No. 12, pp. 2307–2327

[5] Gaspard, M. and Martin, A.: *Clinoptilolite in Drinking Water treatment for NH_4^+ Removal*. Wat. Res., 1983, Vol. 17, No. 3, pp. 279–288

[6] Hlavay, J., Vigh, Gy., Olaszi, V. and Inczédy, J.: *Ammonia and iron removal from drinking water with clinoptilolite tuff*. Zeolite 3, 1983, pp. 188–190

[7] Hódi, M., Polyák, K. and Hlavay, J.: *Removal of pollutants from drinking water by combined ion exchange and adsorption methods*. Envir. International, 1995, Vol. 21, No. 3, pp. 325–331

[8] Haralambous, A., Maliou, E., and Malamis, M.: *The use of zeolite for ammonia uptake*. Wat. Sci. Technol., 1992, Vol. 25, No. 7, pp. 139–145

[9] Jörgensen, S. E.: *Ammonia removal by use of clinoptilolite*. Wat. Res., 1976, Vol. 10, pp. 213–224

[10] Metcalf and Eddy Inc.: *Wastewater engineering: treatment, disposal, and reuse.* 3rd edn., 1992, McGraw-Hill, New York

[11] Vokáčová, M., Matějka, Z. and Ellášek, J.: *Sorption of Ammonium-Ion by Clinoptilolite and by Strongly Acidic Cation Exchangers*. Acta Hydrochim, 1986, Vol. 14, No. 6, pp. 605–611

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