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Nitrate by Nanofiltrations in Very Small Drinking Water Systems

[1]*Meea Kang,* [1]*Tae-Kyung Jeong and* [2]*In-Ho Hwang*

[1]Department of Environmental Engineering andong National University,
388, Songchon andong, Gyungbuk, Korea
[2]Hankook Jungsoo Industries Co., Ltd, 1281-2, Jeongwang, Shihung, Gyeonggi, Korea

Abstract: Groundwater is an essential drinking water source in gyeongbuk, Korea. Population of water consumption has exposed to NO_3-N which is one of the important water quality parameters for a long time. NO_3-N concentration is varied with the season change and is increased with the passage of time. To evaluate the availability of nanofiltration membrane (NF) systems, the NO_3-N removal by UTC-70UB and UTC-20 was performed. In both UTC-70UB and UTC-20, NO_3-N removal is affected strongly by groundwater characteristics. UTC-70UB is a suitable system for the removal of a wide range of NO_3-N from groundwaters in a view of the drinking water production. For the application of NF to small drinking water treatment systems, the water supply law must pay due regard to the state of rural areas.

Key words: Groundwater · Nitrate · Nanofiltration · Drinking water · Rural area

INTRODUCTION

Nitrate concentration in water resources, particularly in groundwater, has increased to a level that potentially causes a public health threat in many regions of the world [1-3]. Recently a very big problem caused by NO_3-N in small drinking water plants (small drinking water plant: water production is lesser than 10^4 m^3/day) with groundwaters has occurred in Korea.

In the case of small drinking water plants, the quality, quantity and availability of drinking water are one of the most important and social issues at rural areas. Monitoring of water quality on the basis of data is necessary to supply safe drinking waters. The regulatory limit for nitrate (as nitrogen) in drinking water proposed by KEM(The Korean Environmental Ministry) as 10 mg/L. Even when the concentration of nitrate nitrogen was detected over the drinking water quality standard, the residents of that country have no chance to change the drinking water immediately. KEM began to improve small drinking water plants for providing the safe drinking water actively. Since groundwater is associated with an agricultural irrigation, its quality becomes worse with each passing day. Especially groundwater is polluted by nitrates responding a risk for human health [4-6]. The studied area, located in gyeongbuk, Korea, encompasses irrigated agricultural fields.

NF has shown its effectiveness in the removal of a great variety of undesirable components from water [7-8]. Its separation mechanisms combine sieving effect, differences in diffusivity and solubility of solutes and electrostatic interactions between the membrane surface groups and the ions. In the case of negatively charged membranes, anions like nitrates can be effectively removed [9]. A suitable NF membrane for nitrate removal must have tight porous structures and be negatively charged.

The present work studied the rejection of the UTC-70UB and UTC-20 with synthetic water and groundwater. The influence of nitrate rejection and groundwater quality was studied using nitrate concentration changes.

The following points were taken into account:

- Investigation of nitrate pollution level in groundwater;
- Concentration effect on nitrate removal;
- NF feasibility in very small drinking water systems.

MATERIALS AND METHODS

Taking contamination levels of nitrate into consideration, one small drinking water plant using

Corresponding Author: Dr. Meea Kang, Department of Environmental Engineering andong National University, 388, Songchon andong, Gyungbuk, Korea
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groundwater was selected in the gyeongbuk area of Korea. Nitrate contamination in the plant caused by intensive land-use and the employment of N-based for fertilizer in agriculture was considered to be a serious environmental problem, which affects on the human health.

Groundwater samples for drinking water were used analyzed from January to July, 2008 and we used the official data produced by KEM(the Korean Environmental Ministry) for water quality information. To assess the possibility of nanifiltration on groundwater qualities, we used two membranes such as UTC-70UB and UTC-20 and five types of groundwaters. All experiments with membranes were carried out with C40-B cell model conducted by Nitto Denko Corp. in our previous study.

For UTC-70UB and UTC-20, NaCl rejection by our experiments is shown 90% and 54% (with 50 mg/L as NaCl, 1MPa), respectively. While NaCl rejection by UTC-70UB and UTC-20 in the catalog produced by Toray Corp. is shown 95% and 60%, respectively.

For five types of groundwater, NO_3-N concentration ranges from 0.3 mg/L to 18.4 mg/L. In the case of serious nitrate contamination of groundwater can result in poor drinking water quality, loss of water supply, high clean-up costs, high costs for alternative water supplies and potential health problems.

RESULTS AND DISCUSSION

NO_3-N Concentration in Groundwater A (GWA): NO_3-N concentrations in GWA from 2002 to present are shown in Fig.1. From 2002 NO_3-N concentrations in GWA is increased and its concentrations is shown higher than the drinking water quality standard of 10 mg/L from 2004. Once NO_3-N concentration is detected high levels, the detection possibility of high levels is increased suddenly.

In Fig.2 we can find the seasonal variation of NO_3-N concentrations in GWA. The highest NO_3-N concentration is found in dry season (the rate of total rainfall is less than 10% a year), while the lowest NO_3-N concentration is found in rainy season season (the rate of total rainfall is over than 50% a year). Variations were attributed to agricultural activities and rainfall distribution. The NO_3-N concentrations in the rainy season were lower that those in the dry season. This could be attributed to rainfall recharge and resulting dilution effects on the NO_3-N.

Effect of NO_3-N Concentrations on Membrane Performance: In order to be considered the use of membranes for groundwater, the permeated flux and rejection has to satisfy the quality and quantity for drinking water. The experiments were performed for feeds at three levels of NO_3-N, 25, 50 and 500mg/L. Table 1 shows the permeated flux of two membranes as a function of NO_3-N concentration at 1 MPa.

In the case of UTC-70UB, the permeated flux has no significant difference in both distilled water and NO_3-N solution. In the case of UTC-20, the permeated flux in distilled water shows slightly higher than that in NO_3-N solution, while the permeated flux in all NO_3-N solutions has almost the same flux levels. As shown in Table1, NO_3-N rejection by UTC-70UB shows higher than that by UTC-20. In addition, NO_3-N rejection by UTC-70UB is not

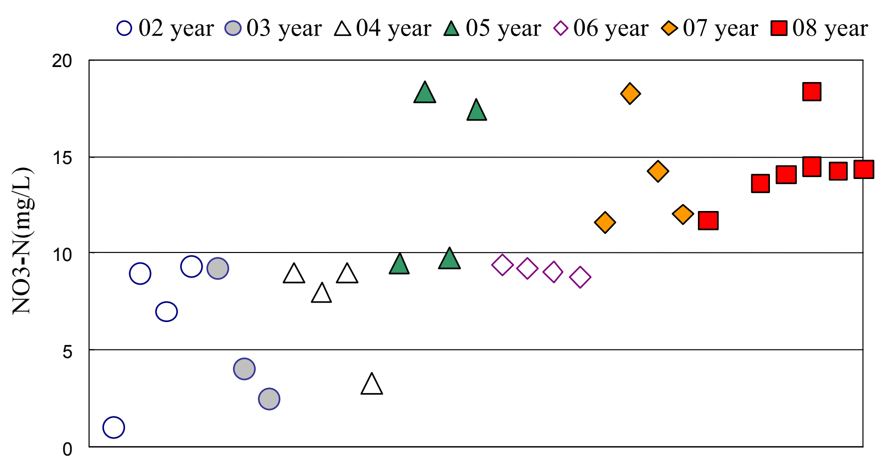

Fig. 1: NO_3-N concentration in groundwater A (GWA) from 2002 to 2008

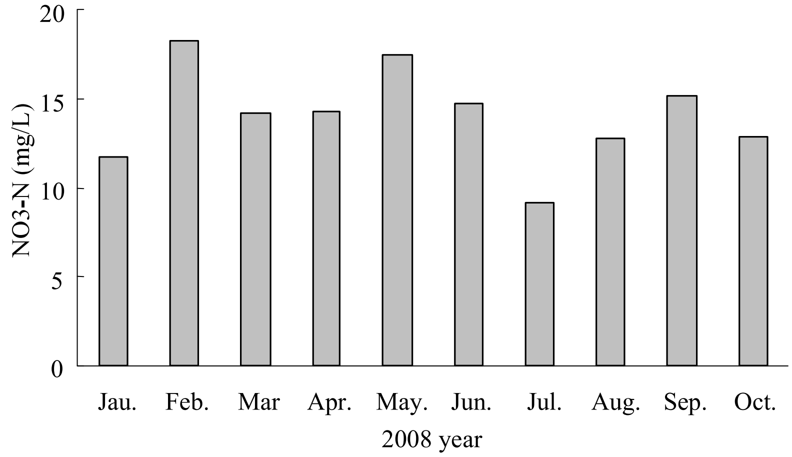

Fig. 2: NO_3-N concentration in groundwater A (GWA) from Jan. to Oct., 2008

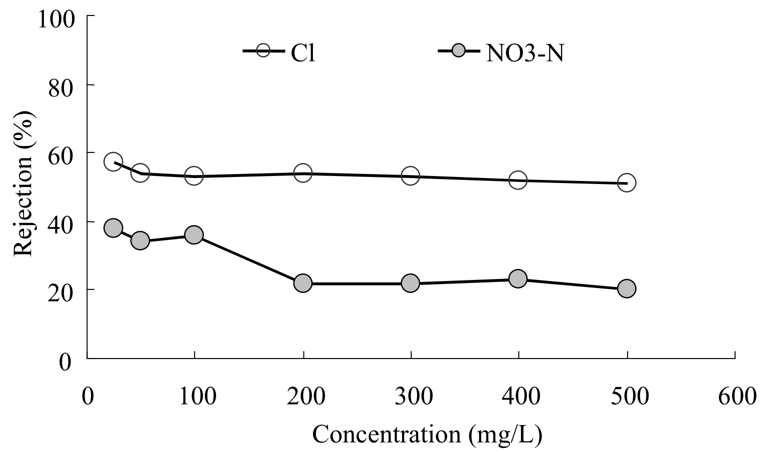

Fig. 3: Rejection of chloride ion and NO_3-N by UTC-20 as a function of concentration

Table 1: Effect of NO_3-N concentration on flux and rejection

NF	Flux and Rejection	Distilled water	NO_3-N concentration (mg/L) 25	50	500
UTC-70UB	Flux (m^3/day)	0.0026	0.0026	0.0025	0.0023
	Rejection (%)	-	88	88	87
UTC-20	Flux (m^3/day)	0.0094	0.0079	0.0080	0.0078
	Rejection (%)	-	38	34	20

Where, rejection (%) = (feed conc.-permeated conc.)/feed conc. *100

Table 2: Characteristics of groundwater quality

Items	Unit	GWA	GWB	GWC	GWD	GWE
pH	-	7.6	7.9	8.0	8.2	8.2
E.C.	uS/cm	477	542	255	493	943
Cl^-	mg/L	25	18	8.2	60	11
SO_4^{2-}	mg/L	38	122	20	31	3.2
NO_3-N	mg/L	18.3	2.0	1.2	0.3	3.3
TDS	mg/L	230	263	122	239	463
Hardness	mg/L	210	312	92	178	347

decreased with the increase of NO_3-N concentrations, while that by UTC-20 is decreased with the increase of NO_3-N concentrations when NO_3-N concentrations are varied from 25 to 500 mg/L.

Fig.3 describes the comparison of rejection between chloride ion and NO_3-N by UTC-20.

As illustrated in Fig.3, NO_3-N rejection is affected by concentration levels while the chloride ion is rejected with a stable efficiency and high rejection rats. It means that NO_3-N is not a simple pollutant when NO_3-N is detected with a high concentration in groundwater. If the NO_3-N rejection by UTC-20 is 38%, it can be achieved the drinking water standard of NO_3-N with 9.92 mg/L when NO_3-N concentration is lower than 16 mg/L in the feed water.

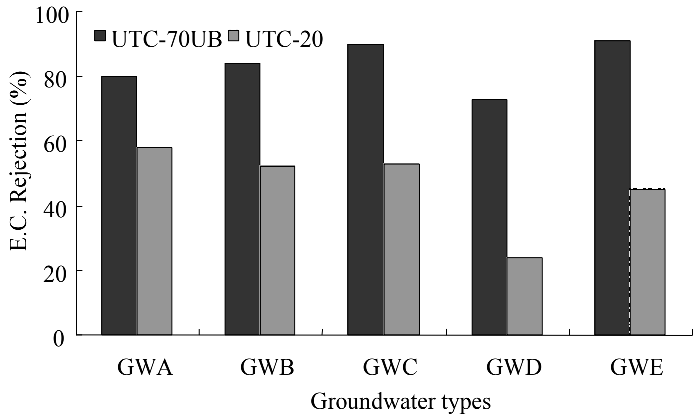

Fig. 4: Effect of groundwater quality on rejection efficiency

Effect of Groundwater Quality on Membrane Performance: To understand water quality effect on membrane performance, the quality of groundwater is measured as shown in Table 2. The population health is exposed by groundwater used for drinking directly. The effect of groundwater qualities on the rejection efficiency by nanofiltration as a function of electric conductivity (E.C.) is shown in Fig. 4. Five types of groundwater are described with GRA, GRB, GRC, GRD and GRE which are used for drinking water without any treatment. As shown in Fig.4, E.C. rejection is very strongly affected by the water quality, especially chloride ion. In the case of GWD, chloride ion is detected much higher than that in other groundwater. Concentration of chloride ion in GWD is 59.8 mg/L while that in other GWs is lower than 20 mg/L.

For UTC-70UB, the rejection of E.C. in GWA, GWB, GWC and GWE is higher than 80% while that in GWD is just 73%. For UTC-20, rejection in GWA, GWB and GWC is higher than 50% while that in GWD is just 24%. Also E.C. rejection is not varied directly as the nanofiltration efficiency in an actual condition of groundwaters. It can be understood according to E.C. rejection in the case of GWE. For GWE, E.C. rejection by UTC-20 shows higher than that of GWD while E.C. rejection by UTC-70B shows highest efficiency. It is demonstrated that NF system with the lower rejection efficiency is required the characteristic of water qualities more carefully to product safe drinking water.

CONCLUSIONS

Recently NO_3-N is detected high levels which are harmful to human in many small drinking water plants in Korea. Once NO_3-N is occurred with a high concentration, the concentration of NO_3-N is rarely reduced. The effect of NO_3-N concentration is significant in the case of UTC-20 while UTC-70UB efficiency on NO_3-N removal is not affected by NO_3-N concentration with the range of 25 to 500 mg/L. In both UTC-70UB and UTC-20, their efficiency of E.C. rejection is strongly affected by groundwater characteristics. However it is demonstrated that UTC-70UB is a suitable system for remove NO_3-N in groundwaters because NO_3-N removal efficiency is high and stable regardless of groundwater qualities.

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