Korean J. Limnol. 37 (4): 431~435 (2004)

Hydrogeochemical Environmental Research in Nitrate Contamination in Alluvial Fan Area Groundwater in Tsukui, Central Japan

Ham, Young-Sik[1,2]* and Masanori Okazaki[1]

([1]*Graduate School of Bio-Applications and Systems Engineering, Tokyo University of Agriculture and Technology, 2-24-16, Nakacho, Koganei, Tokyo, 184-8588 Japan*
[2](*Present Address*) *Faculty of Environmental and Information Studies, The Musashi Insutitute of Technology, 3-3-1 Ushikubo-nishi, Tsuzuki-ku, Yokohama, 224-0015, Japan*)

A nitrate-contaminated groundwater was hydrogeochemically investigated to estimate the factors controlling groundwater quality in an alluvial fan area. Even though monthly groundwater levels increased with monthly rainfalls, the monthly NO_3^--N concentrations in groundwater showed a small variation, mostly exceeding a maximum contaminant level of 10 mg L^{-1} in environmental quality standards for groundwater during 2003. The 2003 annual groundwater recharge was 1,730 mm = 20,056 mm - 18,326 mm. Where 20,056 mm and 18,326 mm are annual sum of daily increase and decrease in ground water level. However, the annual sum of increase in ground water level (20,056 mm) was approximately 10 times higher than annual rainfall. Moreover, the annual sum of daily ground water level decrease (-18,326 mm) showed that a large amount of groundwater was discharged with NO_3^--contamination. Hydrogeochemically, a large amount of groundwater input and output through the alluvial fan area were observed after rainfall with a considerably high concentration of NO_3^-. Consequently, this alluvial fan area including forest area reflects on the evidence under the condition of '*nitrogen excess*' or '*nitrogen saturation*'. In addition, such a large amount of groundwater outflow can cause environmental damage in surface water, associated with NO_3^--contamination. This study also expects that this hydrogeochemical data will be useful for water management.

Key words: nitrate-contaminated groundwater, groundwater recharge, rainfall

INTRODUCTION

The Ministry of the Environment of Japan has reported that nitrate nitrogen (NO_3^--N) plus nitrite nitrogen (NO_2^--N) were found in levels exceeding the environmental quality standard for groundwater in 5.9% of the 4,207 wells in Japan in 2002 (Ministry of the Environment of Japan, 2004). Moreover, urban areas in Japan have faced more serious NO_3^--contamination in groundwater, e.g., 60% of 1,179 well water samples in the Nakano area in Tokyo exceeded 10 mg L^{-1} in environmental quality standard for groundwater during 1983-1988 (Miyazaki and Besho, 1990, 1991). It was often established that the NO_3^--contamination in groundwater was caused by atmospheric N input and N fertilizer with NO_3^- leaching through the soil (Singh and Sekhon, 1979; Ritter, 1989; Iqbal *et al*., 1997). However, the hyd-

* Corresponding Author: Tel: +81-45-910-2562, Fax: +81-45-910-2563, E-mail: hamy007@yc.musashi-tech.ac.jp

rogeological information for groundwater systems is still limited. The objective of the study is to hydrogeologically interpret a groundwater system with NO_3^--contamination in an alluvial fun area.

MATERIAL AND METHODS

NO_3^--N concentration (every month), groundwater level (every day) and rainfall (every month) were monitored during 2003 in an alluvial fan area in the Field Science Center Tokyo University of Agriculture and Technology, 3657-1, Nagatakeshidaguchi, Tsukui, Kanagawa Prefecture, Japan at a latitude of 35° 32′58.57″ N and a longitude of 139° 16′18.77″ E. The annual precipitation and annual mean temperature in the study site were 1,669 mm and 13.6°C respectively from 1992 to 1999 (Kurokawa, personal communication). Topographically, this area is an alluvial fan with the main slope direction of west at a slope of 3-5°, ranging from the elevation of 310 m (farm area) to 230 m (residential area) with the relatively high elevation of 372 m in forest mountain area. Nitrogen fertilizer has been applied to the farm area, and the other area has experienced no N fertilizer use, predominantly depending on atmospheric N input.

The groundwater (well water in depth of -22 m) was collected once a month using a bucket with a rope (Fig. 1). The groundwater sample was taken to a 250 mL plastic bottle (made of polypropylene) with a screw cap. After filtration with a Millipore filter of 0.45 μm in pore size, all of the samples were kept in a freezer at -20°C until determination. The nitrite (NO_2^-) and nitrate (NO_3^-) concentrations were determined using a capillary electrophoresis system (Waters, Quanta 4000E) (Sasaki and Yonekubo, 1997). The NO_2^- concentration was negligible with less than the detection limit. The groundwater level was measured every day with a barometric pressure sensor and water pressure sensor (Van Essen Instruments, DIK-610A) (Fig. 1). The monthly rainfall was measured with an open bulk precipitation collector (rainfall collector) and 1 L plastic graduated cylinder (made of polypropylene) (Hayashi and Okazaki, 2002).

RESULTS

It was estimated that water geologically flowed from the higher elevation areas (forest mountain area) to the lower elevation areas (groundwater)

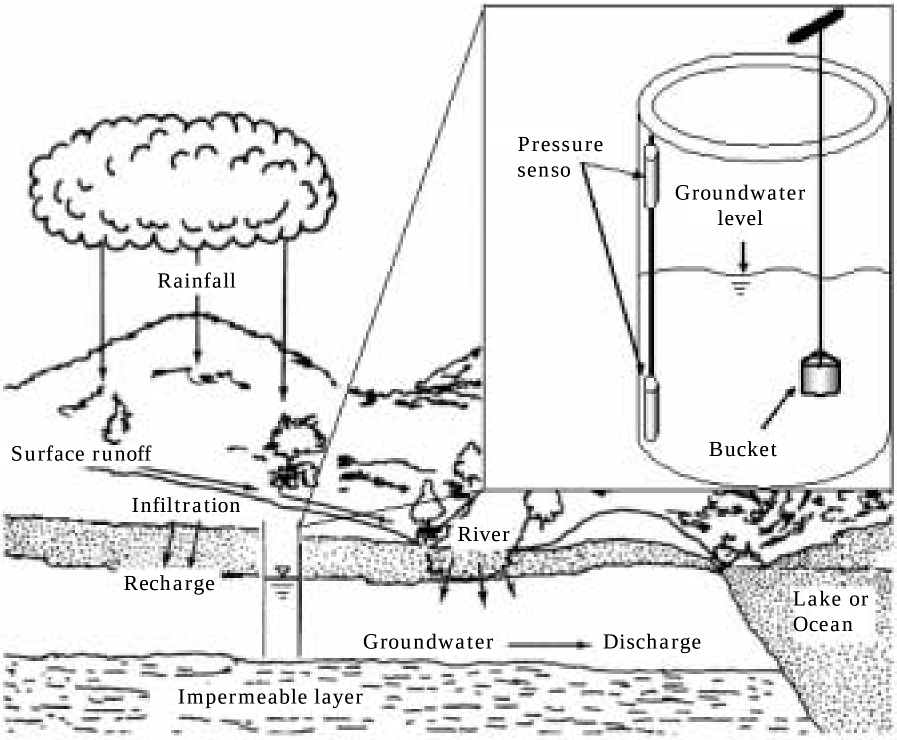

Fig. 1. Hydrologic cycle in groundwater system and monitoring methods.

in this study area, which is located in an alluvial fan area. Consequently, after rainfall the fan area groundwater system may receive much more water flowing with the recharge of groundwater under the condition of such a geological characteristic, compared with a flat area. Even though monthly groundwater levels (average in 28−31 days) increased with monthly rainfalls, the monthly NO_3^-−N concentrations in groundwater showed a small variation, mostly exceeding a maximum contaminant level of 10 mg L^{-1} in environmental quality standards for groundwater (Fig. 2). Historically, this groundwater has not been used for drinking water for 20 years. Also, Kanagawa Prefecture has been recommending the residents not to use the groundwater in this area for drinking. On the other hand, variation in monthly groundwater levels was depending on the monthly rainfall. We found an optimum correlation for a lag time of 1 month between them (r = 0.84).

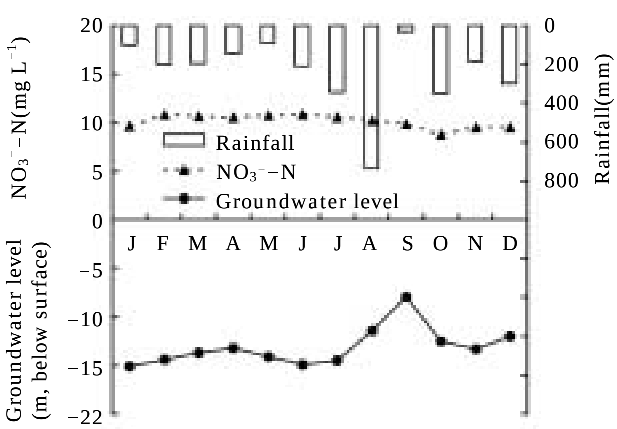

Fig. 2. Monthly rainfalls (white bars), groundwater levels (closed circles) and NO_3^-−N concentrations (closed trigon) in groundwater during 2003.

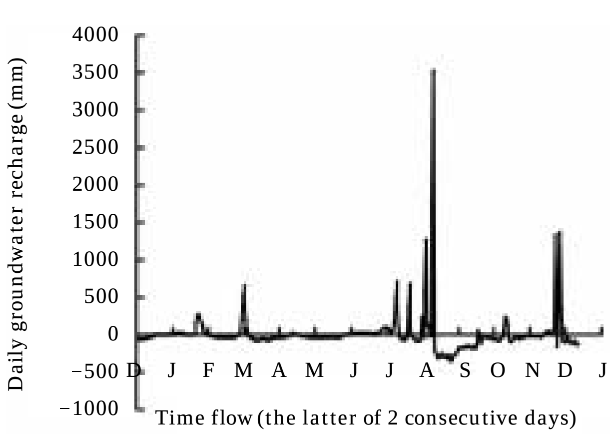

Fig. 3. Daily groundwater recharge during 2003. The groundwater recharge indicates the difference in groundwater level between 2 consecutive days.

Daily groundwater recharges were represented by the difference in the groundwater level between 2 consecutive days (Fig. 3). The positive values indicate the daily increases in groundwater levels. Besides, the negative values showed the daily decreases in groundwater levels. The 2003 annual groundwater recharge was 1,730 mm = 20,056 mm−18,326 mm. Where 20,056 mm and 18,326 mm are annual sum of daily increase and decrease in ground water level, respectively. The annual sum of daily increases in groundwater level (20,056 mm) was approximately 10 times higher than annual rainfall. This result shows that this groundwater system has a wide recharge area. Consequently, this alluvial fan area groundwater received a large amount of infiltration water through the upland and forest area topographically and geologically. Moreover, the annual sum of daily decreases in groundwater level (−18,326 mm) showed that a large amount of groundwater outflowed with NO_3^-−contamination.

DISCUSSION

Hydrogeochemically, it was concluded that a large amount of groundwater input and output through the alluvial fan area occurred after rainfall with a considerably high concentration of NO_3^-. Consequently, this result supports the evidence that the alluvial fan area including forest area was under the condition of '*nitrogen excess*' or '*nitrogen saturation*'. Furthermore, such a large amount of groundwater output can adversely affect other surface water quality, associated with NO_3^-−contamination. This study also expects that this hydrogeochemical data will be useful for water management.

ACKNOWLEDGMENT

I would like to say my appreciation to Dr. Hiromi Kobori and Dr. Bushell Brenda (Professor in Faculty of Environmental and Information Studies, The Musashi Institute of Technology) for checking my English. And I am grateful to Mrs. Naito, the late Mr. Naito (resident in Tsukui) and

Dr. Yuzo Kurokawa (Associate Professor in Field Museum Tsukui, Field Science Center Tokyo University of Agriculture and Technology) for their cooperation with collecting the groundwater sample (well water). Also I would like to thank Mr. Tomonori Saito and his company, Daiki Rika Kogyo Co., Ltd., for supporting a set of pressure sensor.

REFERENCES

Hayashi, K. and M. Okazaki. 2002. Effect of volcanic fumes from Mt. Oyama, Miyakejima Island, on atmospheric deposition, soil solution, and soil properties in Kumagaya, Central Japan. *Soil Sci. Plant Nutr.* **48**: 401−411.

Iqbal, M.Z., N.C. Krothe and R.F. Spalding. 1997. Nitrogen isotope indicators of seasonal source variability to groundwater. *Environmental Geology* **32**: 210−218.

Ministry of the Environment of Japan. 2004. Conservation of the Water, Soil and Ground Environments (Section 3 of Part Two). *In*: Annual White Paper on the Environment 2004, p. 89−108, Gyosei, Tokyo. (in Japanese)

Miyazaki, T. and O. Besho. 1990. Analysis of water quality for groundwater in Nakano area in Tokyo (1). Nakano Institute of Public Health, Tokyo. (in Japanese)

Miyazaki, T. and O. Besho. 1990. Analysis of water quality for groundwater in Nakano area in Tokyo (2). Nakano Institute of Public Health, Tokyo. (in Japanese)

Ritter, W.F. 1989. Nitrate leaching under irrigation in the United States. *J. Environ. Sci. Health* **A24**: 349−378.

Sasaki, H. and J. Yonekubo. 1997. Optimization of electromigrative sample introduction in capillary electrophoresis. *Bunseki Kagaku* **46**: 429−437.

Singh, B. and G.S. Sekhon. 1979. Nitrate pollution of groundwater from farm use of nitrogen fertilizers. *Agric. Envirn.* **4**: 207−225.

(Manuscript received 19 May 2004,
Revision accepted 24 November 2004)

<**국문적요**>

일본 츠꾸이 선상지 지하수의 질산성 질소 오염에 대한 수문지구화학적 연구

Ham, Young-Sik[1,2]* **and Masanori Okazaki**[1]

([1]*Graduate School of Bio-Applications and Systems Engineering, Tokyo University of Agriculture and Technology, 2-24-16, Nakacho, Koganei, Tokyo, 184-8588 Japan*
[2](*Present Address*) *Faculty of Environmental and Information Studies, The Musashi Insutitute of Technology, 3-3-1 Ushikubo-nishi, Tsuzuki-ku, Yokohama, 224-0015, Japan*)

이 연구는 일본의 카나가와현 츠꾸이에 위치하고 있는 선상지에서 지하수 수질을 조절하는 요인들을 평가하기 위해 질산성 질소에 의해 오염된 지하수를 수문지구화학적으로 조사하였다. 2003년 월별 지하수의 수위는 강우에 의해 크게 증감하였지만, 지하수 내의 질산성 질소 농도는 약간의 변화만을 보여주었다. 뿐만아니라 년중 대부분 지하수 수질 기준의 최고 오염 수준 10 mg L^{-1}을 초과하였다. 2003년 1년간 지하수의 재충전량은 1,730 mm (지하수 수위의 일 증가의 년간 총합인 20,056 mm와 일별 감소량의 년간 총합인 18,326 mm의 차이)로 나타났다. 그러나 지하수 수위의 일별 증가량의 년간 총합(20,056 mm)은 년간 강우량보다 약 10배 이상 높았다. 더욱이 일별 감소량의 년간 총합(18,326 mm)은 많은 양의 지하수가 질산성 질소 오염과 함께 방출되었음을 보여주었다. 상당히 높은 질산성 질소를 보유한 강우가 있은 후, 선상지를 통해 많은 양의 지하수 유출입이 관찰되었다. 결과적으로, 산림지대를 포함한 이 선상지에서는 “질소 과잉” 또는 “질소 포화” 라고 하는 상태를 반영하고 있다. 많은 양의 지하수 방출은 지표수에서 질산성 질소의 오염과 같은 환경문제를 야기할 수 있으며, 본 연구를 통해 수문지구화학적 자료가 수질관리에 유용하길 기대한다.