

Evaluation of geochemical processes affecting groundwater chemistry in Namwon, Korea

Kangjoo Kim, Natarajan Rajmohan, Hyung Jung Kim, Suk Hwi Kim,
Gab-Soo Hwang, Min Joe Cho*, Sang-Ho Lee**

*School of Civil and Environmental Engineering, Kunsan National University, Kunsan, Jeonbuk 573-701, Korea., *Korea Institute of Geology and Mineral Resources, Yuseong-ku, Daejeon, 305-350, Korea*
***Department of Ocean Information Science, Kunsan National University, Jeonbuk 573-701, (Koreakangjoo@kunsan.ac.kr)*

Abstract

Groundwater chemistry in Namwon area, Korea, was investigated to understand the contribution of geochemical processes on groundwater chemistry. For this study, a total of 279 groundwater samples were collected from 93 wells distributed over the study area. Higher concentrations of major ions are generally encountered in the shallow alluvial wells, suggesting that these chemicals are originated from the surface contamination sources. Mass balance analysis based on reaction stoichiometry reveals that the water chemistry is regulated by three major chemical processes: weathering of silicate/carbonate minerals, input of Cl/SO₄ salts, and nitrate generating processes. The results show that mineral weathering is the most dominating factor regulating the groundwater chemistry. However, the groundwaters with the higher salt concentration indicate the larger mineral weathering effect, suggesting that some part of the mineral weathering effect is also associated with the anthropogenic activities such as limes applied to the cultivated lands, carbonates (CaCO₃) in the cement materials.

Key words : mineral weathering, nitrification, chlorides, sulfates, mass balance, Namwon

1. Introduction

The chemical composition of groundwater is regulated by various factors, which include atmospheric input, mineral weathering through rock-water interaction, and anthropogenic activities. Hence, understanding of geochemical processes affecting the chemical character of groundwater is difficult, especially, in the areas having complicated land-use characteristics. In this study, a simple mass balance approach is applied to understand the role of various geochemical processes in regulating groundwater chemistry in Namwon, Korea. Land use of Namwon is mainly forest (65 %) and agricultural (23 %). The bedrocks of the study area are Triassic to Jurassic plutonic rocks (leucocratic

granite, biotite granite, granodiorite, two-mica granite, diorite, gabbro, etc.), age-unknown meta-sedimentary rocks (quartzite and schist), and Precambrian metamorphic rocks (granitic gneiss, biotite gneiss, migmatite gneiss, etc.). These bedrocks are unconformably overlain by alluviums formed along the stream courses. Groundwater samplings were carried out three times: March 2002, August 2002, and February 2003. Groundwater samples were collected from both bedrock (43 wells) and alluvium wells (49 wells). In total, 279 groundwater samples were collected over the duration of the study. Electrical conductivity (EC), dissolved oxygen (DO) and pH were measured directly in the field. Major ions, NO_3 and dissolved silica were analysed in the laboratory.

2. Result and discussion

The results of the chemical analysis indicate that 7 wells out of the total wells investigated ($n=93$) show nitrate concentrations exceeding the Korean drinking water standard (44.3 mg/L). Likewise, 59 wells out of the total wells investigated show chloride concentrations higher than 10 mg/L, indicating that the groundwaters are significantly affected by the anthropogenic activities because chloride in the inland essentially originates from the surface sources such as domestic waste waters, septic tanks, fertilizers, and CaCl_2 used to de-ice roads during winter (Lowrance et al., 1997; Thunqvist, 2004). The sulfate is likely to be originated from the land surface as in the forms of fertilizers (MgSO_4 , K_2SO_4) and CaSO_4 in cement materials, thus, also can be used as an indicator for the anthropogenic activity like chloride.

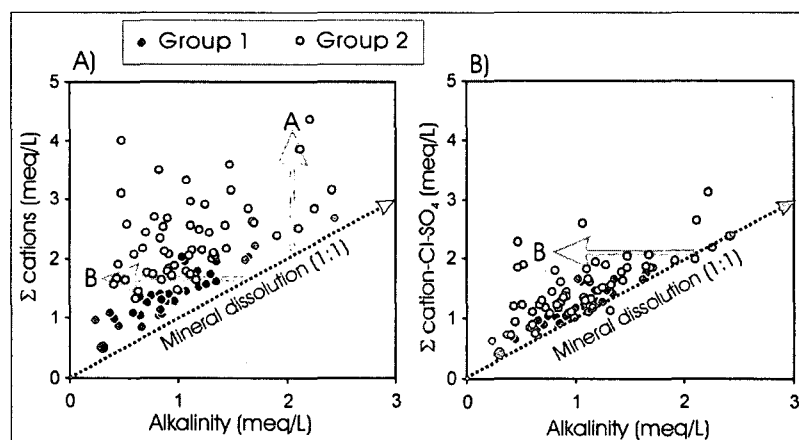


Fig. 1. Relations between Scation and alkalinity (A) and between Scation corrected for $\text{Cl}+\text{SO}_4$ salts and alkalinity (B). Arrows 'A' and 'B' represent the reaction pathways for $\text{Cl}+\text{SO}_4$ salt input and nitrate generating processes, respectively.

The wells used in this study are classified into two groups based on $\text{Cl}+\text{SO}_4$ levels and the effects of various chemical processes on those groups were evaluated. The threshold value for this classification is $\text{Cl}+\text{SO}_4=0.4$ meq/L. Relation between total cation and alkalinity (1:1 relation) is used to check the contribution of mineral dissolution in the observed water chemistry, which shows that only a few samples plotted on the 1:1 mineral dissolution and most of them have higher ratio (Fig. 1). This strongly suggests the influence of other chemical processes such as Cl/SO_4 -salt input and nitrate generating processes, on groundwater chemistry. To evaluate the role of the various processes

affecting the observed water chemistry, a correction was made for the total cation because each process affects water chemistry differently: (i) weathering of silicate or carbonate minerals affects both alkalinity and total major cations with 1:1 relation (Kim, 2003), (ii) input of Cl and SO₄ salts increases the concentration of total major cations without changing alkalinity, and (iii) the nitrate generating processes (oxidation of ammonium and/or organic matters) affect only alkalinity with no or little change in cation concentrations. After the successive corrections for Cl/SO₄-salt input and nitrate generating processes, 1:1 relation between total cation and alkalinity were observed. Hence, mineral weathering, Cl/SO₄-salt input, and nitrate generating processes mostly explains the observed water chemistry. A mass balance approach is used to assess the contribution of these processes on water chemistry. The total cation balanced by chloride and sulfate can be considered as an influence of Cl/SO₄ salts and the total cation unbalanced by chloride and sulfate can be considered as a mineral-weathering origin. However, above assumption cannot show the role of the nitrate generating processes in regulating water chemistry, because the total cation is not or little influenced by those processes. Therefore, the similar considerations were applied to the alkalinity using following equations: Alkalinity consumed by nitrate generation (NG) = Alkalinity from mineral

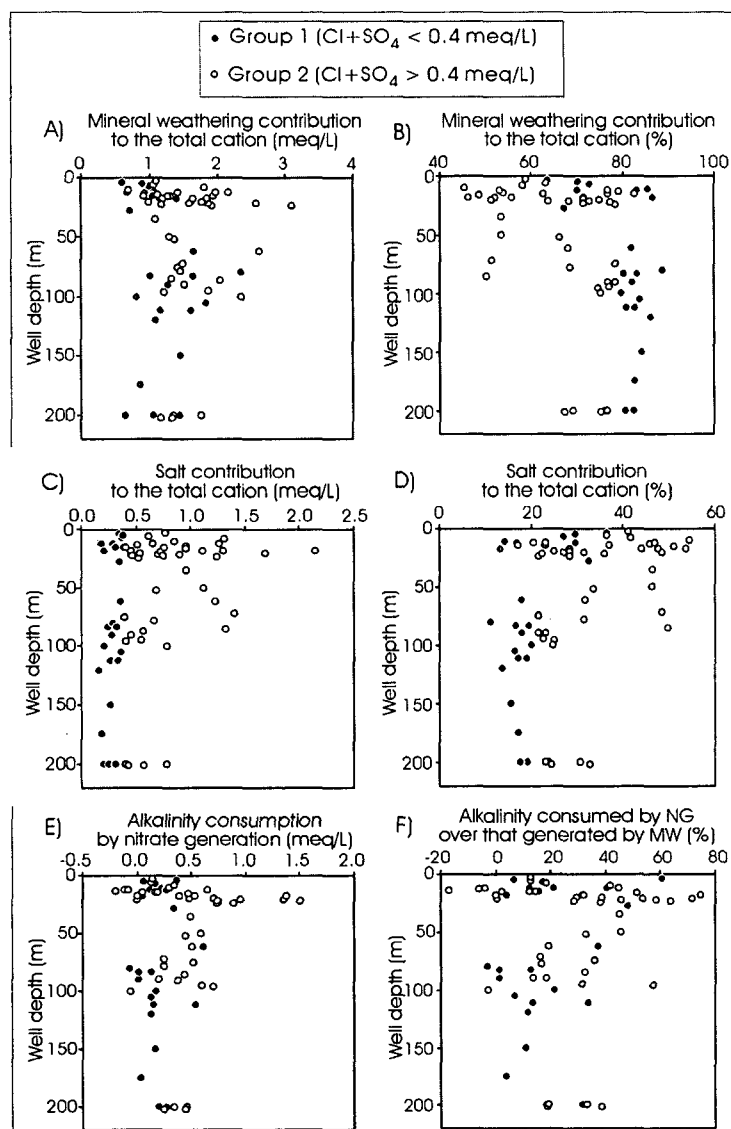


Fig. 2. Contributions of various geochemical processes on water chemistry as a function of well depth.

weathering (MW) - alkalinity (meq/L). The calculation results are shown in Fig. 2. The results show that mineral weathering contributes 1.39 ± 0.50 meq/L (mean \pm standard deviation) of the total cations dissolved in the groundwater (1.98 ± 0.75 meq/L), while Cl+SO₄-salt input explains 0.59 ± 0.39 meq/L of the observed total cation concentration, in overall (Fig. 2).

As we expected, the contributions of Cl+SO₄ salt to the total cation in the alluvial wells ($31 \pm 11\%$) and in Group 2 wells ($34 \pm 10\%$) are generally higher than those in the bedrock wells ($26 \pm 10\%$) and in the Group 1 wells ($20 \pm 6\%$), respectively. Like the results for salt contributions to the total cation, the alkalinity consumptions by nitrate generation are generally higher in alluvial wells (0.38 meq/L) or in Group 2 wells (0.44 meq/L) than in bedrock wells (0.29 meq/L) or in Group 1 wells (0.18 meq/L), respectively. However, contrary to our expectation, the cation contribution from mineral weathering is somewhat more significant in the groundwaters highly affected by anthropogenic activities (1.55 ± 0.49 meq/L, Group 2) than the Group 1 wells (1.14 ± 0.40 meq/L; Fig. 2), which seems to be the result of anthropogenic activities: (1) enhanced mineral weathering by acidification due to nitrate generating processes (Zilberbrand et al., 2001), and (2) lime application (Chae et al., 2004), and/or dissolution of CaCO₃ originated from cement materials.

Acknowledgements

This study was financially supported by the Saemankeum Environmental Research Center of Kunsan National University.

References

- Chae GT, Kim K, Yun ST, Kim KH, Kim SO, ChoiBY, Kim HS, Rhee CW. Hydrogeochemistry of alluvial groundwaters in an agricultural area: an implication for groundwater contamination susceptibility. *Chemosphere* 2004; 55: 369-378.
- KIGAM (Korea Institute of Geology and Mineral Resources). A technical investigation report on groundwaters in Namwon area, 2004 (in Korean, title translated).
- Kim K. Long-term disturbance of ground water chemistry following well installation. *Ground Water* 2003; 41: 780-789.
- Lowrance R, Altier LS, Newbold JD, Schnabel RR, Groffman PM, Denver JM, Correll DL, Gilliam JW, Robinson JL, Brinsfield RB, Staver KW, Lucas W, Todd AH. Water quality functions of riparian forest buffers in Chesapeake Bay watersheds. *Environ Management* 1997; 21: 687-712.
- Thunqvist E. Regional increase of mean chloride concentration in water due to the application of deicing salt. *Sci Total Environ* 2004; 325: 29-37.
- Zilberbrand M, Rosenthal E, Shachnai E. Impact of urbanization on hydrochemical evolution of groundwater and on unsaturated-zone gas composition in the coastal city of Tel Aviv, Israel. *J Contam Hydrol* 2001; 50:175-208.