Hydrogeochemical characteristics of shallow groundwater in the western coastal area, Korea: Application of geostatical methods for discrimination of the area affected by seawater intrusion

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1. Introduction

The aquifer in the western coastal area of Korea is affected by salinization process associated with seawater intrusion. By sampling of shallow groundwaters (N = 229) in the area located within 10 km away from the coastline, regional hydrogeochemical survey has been conducted in order to evaluate the salinization problem in the area.

2. General hydrogeochemical characteristics: causes of water chemistry variation

The solute concentrations of 229 shallow groundwaters are graphically shown as the form of box plot (Fig. 1). Of the elements analyzed, HCO_3, Cl, SiO_2, Ca, NO_3, Na, SO_4, Mg and K are dominant. The concentrations of these elements also generally show the log normal distribution.

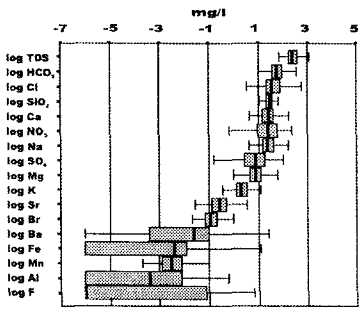

Fig. 1 Box plots showing the chemical composition of shallow groundwater in the western coastal area, Korea.

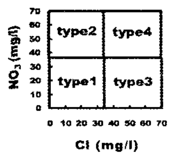

Fig. 2 Four types of shallow grounwaters in the western coastal area, Korea, classified based on the interpretation of cumulative frequency curves(sinclair, 1974) of Cl and NO_3 concentration data (N=229). The threshold values are 34.7mg/l Cl and 37.2mg/l NO_3^-.

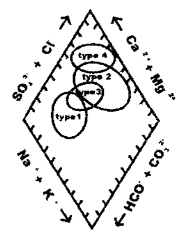

Fig. 3 Piper's diagram

The solute concentrations of coastal groundwaters are controlled by several processes which mainly include water-rock interaction, seawater mixing, and anthropogenic pollution. The graphical method described by Sinclair (1974) was used to separate and discriminate the waters potentially affected by both seawater mixing and anthropogenic contamination from the less-polluted waters of which chemistry was largely controlled by water-rock interaction: by using this method, we have obtained the maximum values of less-polluted background population. The obtained threshold values are 34.7 mg/l chloride and 37.2 mg/l nitrate. Based on this criterion, we have classified the waters into four characteristic types (Fig. 2): type 1 waters represent the non- or less-polluted waters; type 2 waters are largely influenced by seawater mixing; type 3 waters are affected anthropogenically by nitrate; and type 4 waters represent the effects of both seawater mixing and anthropogenic contamination.

The plotting of analytical data on a Piper's diagram also can be used to make a tentative conclusion as to the origin of the water (Fig. 3). Type 1 waters are plotted in the field of the Ca-HCO_3 facies, indicating that they were evolved through water-rock interaction; type 2 waters represent the Ca-Cl and Na-Cl hydrochemical facies, showing the effect of seawater mixing with the contribution of cation exchange reaction; type 3 waters show the Ca-HCO_3 and Ca-Cl facies; and type 4 waters are mainly Ca-Cl facies. The Piper's diagram also shows that both type 2 and type 4 waters are typically influenced strongly by seawater mixing.

Figure 4 shows the relationships among some hydrochemical parameters which are commonly used to identify the mixing of seawater. The ideal seawater mixing line also shown in each diagram. The Br*10^3 versus Cl molar ratio diagram seems to be used as the best geochemical tool for identifying the seawater mixing, likely due to their conservative nature. Most of type 2 waters are plotted along or near the seawater mixing line, evidencing that type 2 waters are strongly influenced by seawater mixing.

3. Discriminant analysis

Discriminant analysis was performed to evaluate the reality of the classification of 4 types of groundwaters (Table 1). The canonical correlation of Function 1 and Function 2 was 0.827 and 0.763, respectively. The Hit Ratio indicating the reality of the classification is very high (86.9%), indicating that the results of our classification of waters are significantly meaningful and therefore the chemistry of each type water well reflects the hydrogeochemical process(es).

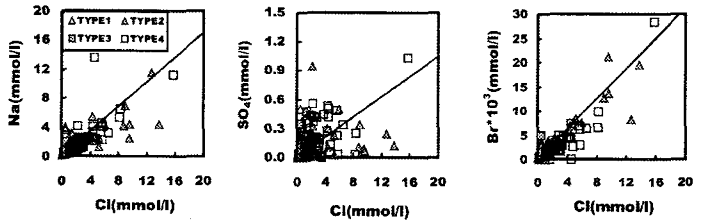

Fig. 4 Relationship between Cl and other elements(Na, So_4 and Br) for four types of groundwaters. Solid line indicate the ideal mixing with sea water .

Table 1. Results of discriminant analysis for shallow groundwaters examined (N = 229, Hit Ratio = 86.9%)

Type*	Count*	Predicted group membership			
		Type 1	Type 2	Type 3	Type 4
1	87	73(83.9%)	2(2.3%)	12(13.8%)	0(0%)
2	48	6(12.5%)	40(83.3%)	1(2.1%)	1(2.1%)
3	25	0(0%)	0(0%)	25(100%)	0(0%)
4	69	0(0%)	1(1.4%)	7(10.1%)	61(88.4%)

* Results from the analysis shown in Fig. 2

4. Summary

The quality of shallow groundwaters in the western coastal area (<10 km away from the coastline) of Korea are affected by water-rock interaction, seawater mixing, and anthropogenic contamination. According to the hydrochemistry the water samples are classified into four types (types 1, 2, 3, and 4). At least 48 waters (about 20%) among 229 waters seem to be more or less affected by salinization process. However, further studies based on stable isotopic and hydrogeologic data are necessary.

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