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Comparison of hydrochemical informations of groundwater obtained from two different underground storage systems_

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Abstract

Statistical- based, principal component analysis (PCA) was applied to chemical data from two underground storage systems containing LPG to assess the usefulness of such technique at the initial stage (Pyeongtaek) or middle stage (Ulsan) of hydrochemical studies. For the first case, both natural and anthropogenic contamination characterize regional groundwater. Saline water buffered by Namyang lake affects as a natural factor, whereas cement grouting influence as an artificial factor. For the second study area, contaminations due to operation of LPG caverns, such as disinfection activity and cement grouting effect, deteriorate groundwater quality. This study indicates that principal component analysis would be particularly useful for summarizing large data set for the purpose of subsurface characterization, assessing their vulnerability to contamination and protecting recharge zones.

key word : principal component analysis (PCA), underground storage system, saline water influence, cement grouting effect, disinfection activity

1. Introduction

Many variables are important for the understanding of the processes taking place in the groundwater system. The information gathered in many variables can best be handled using multivariate technique (Laaksoharju and others 1999). Multivariate methods are essential tools for organizing, grouping, evaluating and reducing the dimension of the observed environmental data (Duffy and Brandes 2001). The multivariate statistical technique of principal component analysis (PCA) has recently been applied to distinguishing different processes of pollution (Giménez and Morrell 1997), calculating the effect of the groundwater mixing on the obtained groundwater composition (Laaksoharju and others 1999) and tracing groundwater circulation (Join and others 1997). This paper concerns the integration of hydrochemical observations of groundwater from two underground LPG storage cavern sites and describes how hydrochemical data sets of two LPG terminals were analyzed with the aim of obtaining comprehensive view of the processes that control the groundwater variability and the natural and the human- induced relationships. Traditional geochemical studies were tried

initially, but met with limited success, due to the large number of sets of data, which are often difficult to interpret. The objective of this study is to establish, interpret and compare of the hydrochemical composition of the groundwater of two underground storage systems containing LPG.

2. Results and Discussions

General hydrochemistry

Based on pH and Na concentration, groundwater boreholes around Pyeongtaek LPG storage facility are divided into two chemical groups (Fig. 1). Group A has Na concentration greater than almost 200 mg/L and pH range less than 9. Group B has ranges less than 200 mg/L and range greater than almost 10. Therefore, Group A represents values indicative of seawater intrusion and Group B represents values indicative of cement grout contamination. Some samples fall into category A and B, suggesting mixing between A and B. Range of pH and Na concentration in these samples generally plot middle area; therefore, samples are defined transition zone between seawater intrusion and cement grout effect.

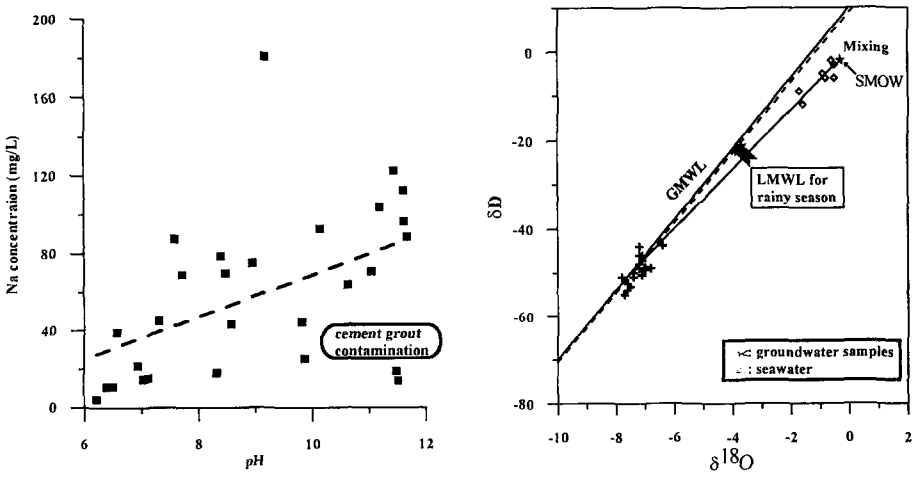

Figure 1. Characteristics of H and O isotopic compositions of the groundwater in Ulsan LPG terminal

Principal component analysis

Variables that depend on similar intrinsic properties may be described by a principal property represented by a single new variable. Fig. 8 shows graphs derived from the principal component analysis (PCA) applied to the physical and chemical variables determined in two LPG terminals. Principal components 1 and 2 explain 48% (Pyeongtaek) and 46% (Ulsan) of the total variance of the data population, respectively. We present the results of only the first two principal components for each analysis because they explain the majority of the variance in the original data. This statistical treatment assists in understanding the origin of the hydrochemistry and in inferring the existence of certain hydrochemical processes which have affected them.

Positive or negative loadings of each constituent on principal components can be found in Fig. 2. Based on the patterns of loadings, each variable can be interpreted as a specific hydrochemical process or multiple hydrochemical processes. In Pyeongtak area, principal component 1 characterized by higher positive loadings in EC, Si, Ca, Mg, K, Sr, Li, Cl- and SO_4^{2-} and lowering of NO3-. Principal component 1 seems to be related to processes caused by the seawater effect as previous correlation matrix indicated. And PC 2 explains 15% of the eigenvalue and is related to Mg, Na, HCO_3 , NO_3 (positive), pH, Ca, K, Al (negative). Unlike Pyeongtaek area, the first set of PCA loadings explains 33% of the variance and is highly related to pH, TDS, Na and K. These variables are strongly linked with disinfection activity. On the other hand, PC2 account for 13% of the eigenvalue and is linked with Ca, Mg, Cl and CO_3^{2-}. Such variables could be explained by cement pollution and dissolution effect like Pyeongtaek area.

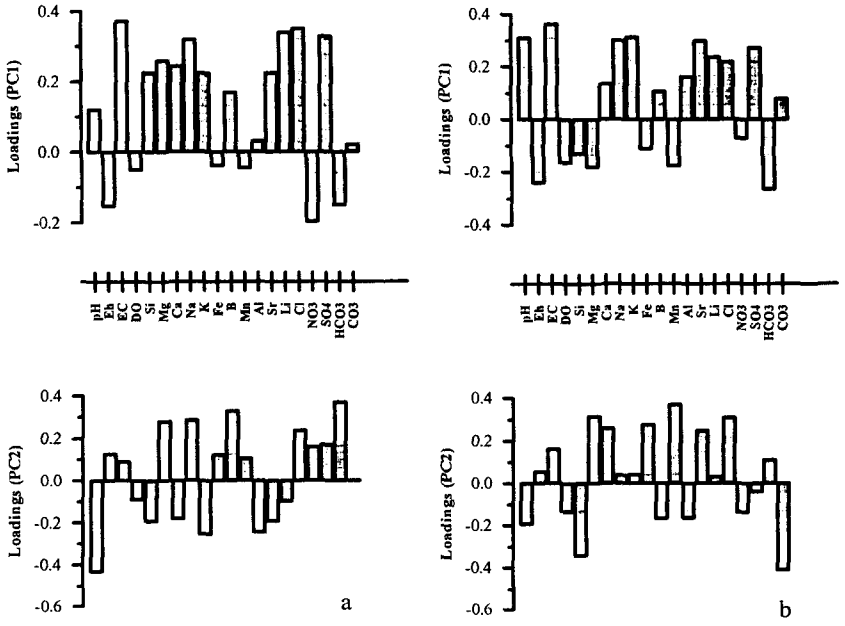

Figure 2. Loadings of 20 physico- chemical variables on two significant p components for groundwater samples **a** Pyeongtaek and **b** Ulsan

3. Summary and Conclusions

The results of the statistical analyses, as applied to the hydrochemical data set, provide insight into the regional factors and processes controlling groundwater recharge and discharge and composition of the study areas. An interpretation of the chemical composition and statistical results of the groundwater is complicated by the characteristics of contaminants. The effect of each contaminant is inclined to mask hydrochemical processes and characteristics occurring in the subsurface.

As referred to Pyeongtaek area, the results of previous study indicate that two types of contaminant are present, the first type characterized the influence of Namyang lake, buffering seawater, and the second type was cement grout effect when observed

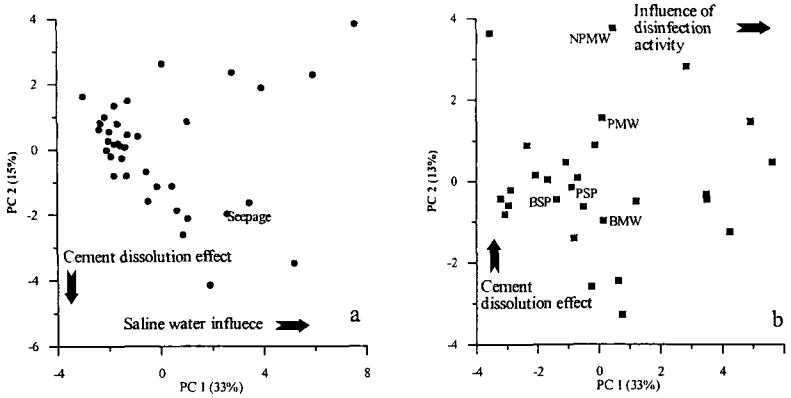

Figure 3. Bivariate plot of the scores of PC 1 and PC 2 according to su Pyeongtaek and **b** Ulsan

in newly constructed facility due to stability. Unlike Pyeongtaek area, although similar case study, groundwater boleholes in Ulsan LPG storage facility were affected disinfection activity and cement dissolution.

We have used a limited number of stable isotope compositions of the groundwater. For reliable and confirmed grouping of groundwater and identification of possible underlying geochemical heterogeneity within the study area, more stable isotope data, especially Pyeongtaek area, are needed.

4. Reference

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