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Hydrogeochemical interpretation of South Korean groundwater monitoring data using Self-Organizing Maps

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ABSTRACT

The National Groundwater Monitoring Network (NGMN) of South Korea provides data since 1995 to monitor the water level and quality of groundwater on a national scale. Major ions such as Ca, Mg, Na, K, HCO_3, Cl, SO_4 and NO_3 have been monitored since 2008 to assess groundwater quality. Hydrochemical data of bedrock groundwater samples collected from 299 monitoring stations in 2009 were examined using the Self-Organizing Map (SOM) approach. Based on hydrochemical characteristics, bedrock groundwater is clustered into two groups and six subgroups. Group I containing 70.2% of groundwater samples (and monitoring stations) is characterized by lower TDS values and NO_3 concentrations than Group II, indicating that Group I waters are less affected by contamination. Subgroup I-1 (39.1%) represents Ca–HCO_3-type groundwater with relatively low pH, TDS and concentrations of most ions compared with groundwater of Subgroups I-2-1 (26.1%) and I-2-2 (5.0%). Subgroup I-2-2 represents a moderately alkaline, F-rich, Na–HCO_3-type groundwater. Group II records either anthropogenic or natural processes. Subgroup II-1 (16.1%) contains groundwater with low values of TDS, HCO_3 and pH, and moderately high NO_3 concentrations due to nitrification, while groundwater of Subgroups II-2-1 and II-2-2 is characteristically high in Ca and Mg. Subgroup II-2-1 is also very high in SO_4 and HCO_3 but very low in NO_3, while Subgroup II-2-2 is substantially enriched in Cl and NO_3. The hydrochemistry of groundwater of Subgroup II-2-1 likely results from dissolution of carbonates and gypsum in clastic sedimentary rocks and is affected by dissolution of pyrite and/or S-bearing fertilizers in crystalline rocks. The enrichment of NO_3, Cl, Ca and Mg in groundwater of Subgroup II-2-2 is the result of substantial contamination from agrochemicals and manure. Thus, about 20.5% (Subgroups II-1 and II-2-2) of bedrock groundwater in South Korea records anthropogenic contamination. This study shows that the SOM approach can be successfully used to classify and characterize the groundwater in terms of hydrochemistry and quality on a regional scale.

1. Introduction

In many countries, groundwater is the main source of safe drinking water and is also crucial for agricultural and industrial uses. Groundwater is considered as a separate ecosystem affecting groundwater-dependent ecosystems such as rivers, lakes and wetlands (Danielopol et al., 2003; Hinsby et al., 2008; Hose, 2005; Kløve et al., 2011; Quevauviller, 2005). However, the sustainable use of groundwater is threatened by the deterioration of groundwater quality resulting from natural and/or anthropogenic contamination as well as improper or insufficient management. Thus, it is urgently needed to assess the geochemical status of groundwater and to evaluate the impact of anthropogenic contamination. For these purposes, regional- or national-scale groundwater quality monitoring is conducted in most countries (Jousma and Roelofsen, 2004).

In South Korea, the National Groundwater Monitoring Network (NGMN) has been operating since 1995. At each monitoring station, groundwater depth, electrical conductivity (EC) and water temperature are automatically measured at an hourly interval and are transmitted to the host web server at *K-Water* (formerly *Korea Water Resources*). In addition, groundwater quality parameters are monitored twice per year including pH, chemical oxygen demand (COD), total coliforms, NO_3, Cl, and some other harmful substances such as Cd, As, CN, Hg, organic P, phenol, Pb, Cr^{6+}, TCE and PCE. The monitoring of major cations (Ca, Mg, Na and K) and anions (Cl, HCO_3 and SO_4) began in 2008.

Hydrogeochemical processes including water-rock interaction and anthropogenic contamination control the variability of major dissolved ions (Dalton and Upchurch, 1978; Dinelli et al., 2012; Frengstad et al.,

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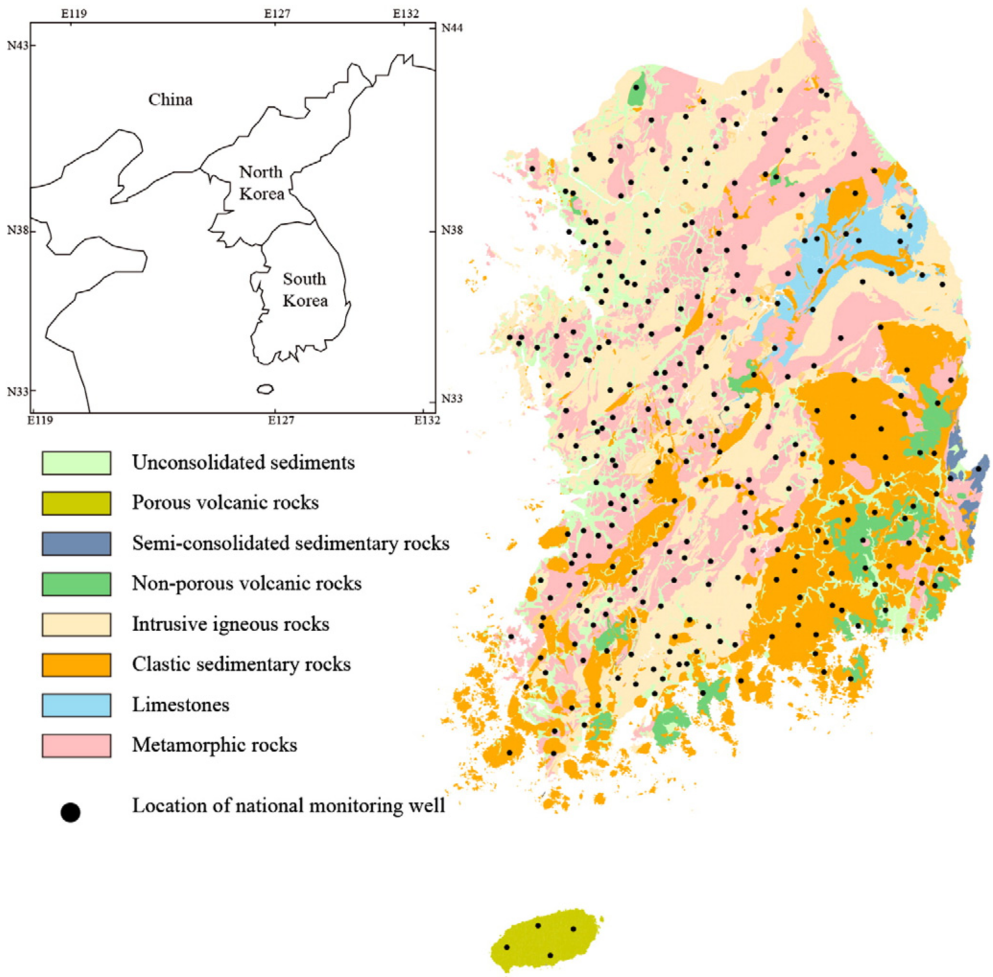

Fig. 1. Simplified geological map of South Korea, showing the locations of groundwater wells of National Groundwater Monitoring Network.

2010; Güler and Thyne, 2004; Sung et al., 2012). Previous studies using NGMN data in South Korea have focused on the interpretation of variations of water level, temperature and EC (Lee, 2011; Lee and Hahn, 2006; Lee et al., 2007; Moon et al., 2004; Park et al., 2011), while hydrochemical data have not been evaluated.

Regional or national-scale groundwater quality monitoring provides high dimensional data. In order to extract useful information from the monitoring data, it is necessary to reduce a high dimensional data into a lower dimensional space with a minimum loss of information. The dimensionality reduction can reveal unknown patterns or structures

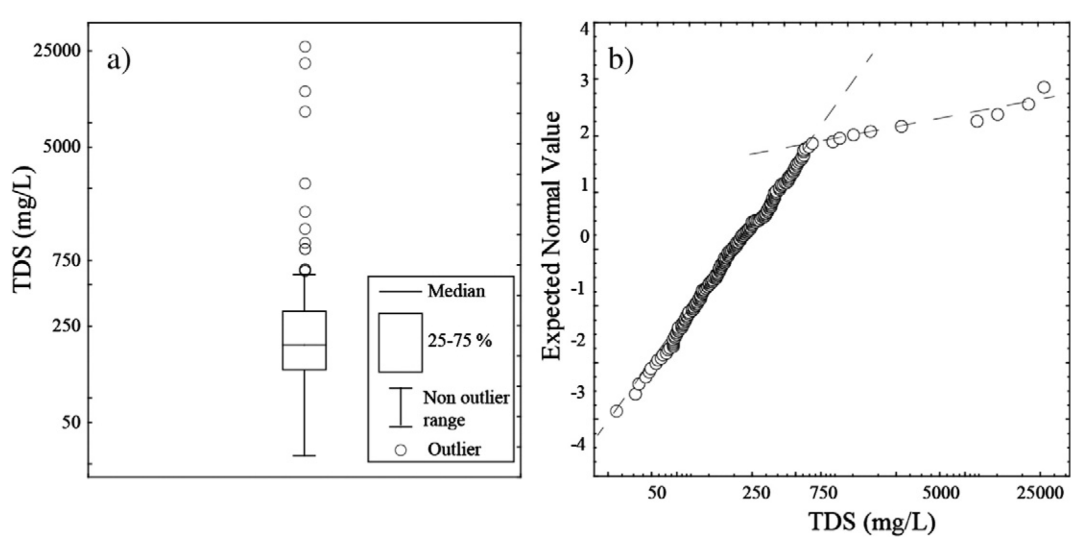

Fig. 2. Statistical distribution of TDS values in a) box plot and b) probability plot. Outliers are clearly shown in both plots.