Bayesian statistical interpretation of hydrochemistry data to delineate the groundwater vulnerability to nitrate contamination

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Nitrate contamination of groundwater is a serious environmental problem in South Korea and elsewhere. Better understanding of the source(s) and spatial land use control of groundwater nitrate pollution is required to manage nitrate contamination. In this context, we used a GIS technique integrated with a Bayesian statistical approach to interpret hydrochemistry data of groundwater, in order to produce a spatial map reliably showing groundwater vulnerability to nitrate contamination. For this purpose, we used the hydrochemistry data of 45 groundwater samples from the Pyosun Watershed located on Jeju volcanic island, Korea. The studied groundwater system is considered to be highly susceptible to non-point contamination sources such as agricultural pollutants because of the short residence time in the permeable basaltic aquifer.

The vulnerability (i.e., pollution probability) was initially predicted using a logistic model on the relationship between observed nitrate concentrations and the distribution of agricultural fields within a land use map. However, the initial results on vulnerability prediction were not satisfactory yielding a few unreliable results. This is likely due to inherent uncertainties of the adopted statistical model (i.e., model error) and the land use classification obtained from the GIS technique (i.e., data error). To assess such uncertainties, we re-evaluated the spatial information with the membership probability in relation to the extent of agricultural lands, using a fuzzy algorithm on a remote sensed image. In the next step, the results estimating data error were compared with the improved spatial map showing the probability of the nitrate concentrations to exceed a natural background (2.5 mg/L in the studied area). Finally, we compared the results of two probability maps for each GIS grid cell using the Bayesian regression, in order to assess the model uncertainty. As a result of these steps, the obtained results on groundwater vulnerability were significantly improved to yield a significant correlation between predicted nitrate concentrations and observed nitrate concentrations. Therefore, our technique developed in this study can be successfully used for evaluating groundwater vulnerability to nitrate contamination based on the hydrochemistry and land use data in agricultural areas.

Interaction of supercritical CO_2 with bentonite

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Physical properties (e.g., porosity and permeability) of caprocks may be altered by interaction between Supercritical (SC) CO_2 and caprock. Caprocks in potential geological carbon sequestration sites can have clay minerals, which is mainly affected by SC CO_2. In this study, interaction between SC CO_2 and clay minerals was evaluated at various conditions. Bentonite was used in this study because bentonite mainly consists of montmorillonite, which is the expandable clay mineral.

SC CO_2/bentonite/water interaction kinetic tests were conducted in a stainless steel autoclave reactor at various conditions for a week to investigate how bentonite is altered in saline water when contacted with SC CO_2. The tests were conducted at 50℃ and 12 MPa. Two reaction systems (SC CO_2/bentonite and SC CO_2/water/bentonite) were used to mimic the geologic CO_2 sequestration environment. The water/bentonite system without addition of SC CO_2 was also used as a reference system. 1N NaCl, $MgCl_2$, and $CaCl_2$ solutions and sea water were used to investigate the effect of salts on the bentonite alteration in the presence of SC CO_2.

In the SC CO_2/bentonite system without water, the mass and volume of bentonite sample decreased probably due to pore water in bentonite gradually dissolved in SC CO_2. In the SC CO_2/water/bentonite system, blue and greenish mineral precipitation was observed on surface of bentonite samples. In addition, the bentonite samples swelled during the interaction. The bentonite samples swelled in the presence of salts, even though the degree of swelling was less than that without salts. These results implies that salinity and water content can affect the extent of bentonite alteration in the presence of SC CO_2. Further evaluation of the effect of precipitation and dissolution of minerals on the physical properties of bentonite when contacted SC CO_2 is needed.