



Effects of CO₂ mineral sequestration in saline aquifers of the Upper Silesian Coal Basin - Experimental and modeling studies

Krzysztof Labus

Silesian University of Technology, Institute for Applied Geology, Gliwice, Poland (klabus@o2.pl)

Saline aquifers of Tertiary and of Carboniferous productive formation of the Upper Silesian Coal Basin (USCB), on the borderland of Poland and Czech Republic are considered as possible localities for CO₂ sequestration. For the purpose of CO₂ sequestration capacity assessment of the aquifers - a hydrochemical modeling study was performed, basing on the petrophysical and mineralogical characteristics of the formations, pore water composition, pressure and temperature values, and kinetic reaction rate constants of minerals. The first stage of modeling was focused on immediate changes to occur in the aquifer in beginning of CO₂ injection, the second – simulated long-term effects of sequestration.

Mineral trapping capacity values for the analyzed formations were calculated for the storage period of 20 000 years. The calculations are based on the balance of CO₂ contained in the carbonate minerals (mainly dawsonite) that precipitate or dissolve in the model. Mineral trapping capacity, for the sandstone aquifers varies between 1,2 and over 6,6 kgCO₂/m³, and for confining cap rocks between 0,89 and 1,42 kgCO₂/m³. The quantity of gas trapped in the form of solution, assessed basing on modeled chemical constitution of pore water reaches 4,07 kgCO₂/m³.

In order to track the effects of gas-rock-water interactions an experimental study was carried out. The representative rock samples were placed in the reaction chamber of the RK1 autoclave, built for the purpose of the work. The chamber was filled with brine, and CO₂ injected to the desired at appropriate temperature. The experiment was carried on for 75 days. Dynamic conditions of the system are ensured by twice-daily change of the position of the vessel. Continuous pH logging, and analyses of fluids sampled from device's chambers enabled monitoring of the reactions. Analysis of reacted samples, by means of scanning electron microscope, revealed significant changes in mineral constitution and structure. The analysis verified the process of dissolution of skeletal grains, observed in all of the samples; corroded feldspars were frequently covered with secondary clay minerals. Dissolution of K-feldspar was apparent in the samples where the potassic lamellae within the crystals were etched relative to the sodic ones. Regular or hollow crystals of dawsonite were found to be formed in the pore space between framework grains and within the clay mineral blades.

The coupled modeling and experimental works revealed that for the analyzed rocks the mineral trapping mechanism is controlled by dissolution of calcite and kaolinite (or muscovite), and dawsonite and chalcedony precipitation. With increasing time and reaction progress, the K-feldspar (if present in the aquifer material) was also dissolved. For the samples containing illite, close to the termination of modeling period (20 000 years), the dissolution of illite enables precipitation of dolomite and muscovite recrystallization. Additional portion of SiO₂ is then released and quartz is able to precipitate. Consumption of hydrogen ions in this reaction supports the rise of pH. In the case of samples in which carbonate minerals are absent, during the CO₂ injection into the pore space – the hydrolysis of kaolinite was responsible for the production of chalcedony.

Western part of the Tertiary aquifer is suitable to play a role of specific natural analogue for the case of the USCB, helping to understand the impact of slow flux of CO₂ on such a hydrogeological environment. One-dimensional advective-dispersive-reactive transport model was applied to reconstruct the processes of forming groundwater chemistry in effect of primary pore fluid dilution by infiltrating precipitation waters, accompanied by: geogenic CO₂ flux. It was found that the transformations of primary groundwater chemistry proceed accordingly to the string of water type evolution: Cl-Na - HCO₃-Na-Mg, which was confirmed by the results of field survey.