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Simulation of Underground Microbiological Methanation in a Conceptional Well Doublet System

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Abstract

Underground methanation as a potential conversion part for a hydrogen-based energy infrastructure, is gaining more attention within the last years. The process is driven by microorganisms present in the subsurface producing methane and water by consuming hydrogen, produced from renewable resources, and carbon dioxide, captured from power plants or factories. In the past, the process has been observed as a side effect during underground hydrogen storage (UHS) and town gas storage, but may be also interesting for the development of a designed underground bio-reactor system.

To investigate and predict the potential of underground methanation, a numerical model, recently developed for the prediction of UHS operations, is used. The focus is the implementation of a gas flow cycle in the subsurface by utilizing the open-source simulator DuMux. As storage reservoir, a synthetic rectangular geological model is used. In order to achieve a gas cycle, a rate-controlled injection well and a bottom-hole flowing pressure controlled production well are placed in a distance of 500 m. The storage reservoir was initialized with a gas saturation of 80 %. The injected gas was composed of hydrogen and carbon dioxide in stoichiometric relation. First, a reference simulation was performed neglecting the effects of microbiological gas conversion while in a second step the effects of the microbiological activity in the storage reservoir are considered. The sensitivity to different injection rates and its effect on microbial metabolism and the resulting growth of the microbial population were studied.

The results of the simulations are presented by visualizing the presence and growth of the microbial population and evaluating the composition of the withdrawn gas stream from the production well. By investigating the global behavior of the microorganisms, the build-up of an afterwards static region populated by a high density of microorganisms can be observed. This trend is expectable and can be explained by the life cycle of a microbial population and the sufficient substrate supply. Due to this favorable effect, the methane concentration in the withdrawn gas is increased.

The present work shows that underground methanation has an excellent capability converting hydrogen and carbon dioxide into methane. Microbial populations lead to an altered gas composition in the reservoir and consequently in the withdrawn gas. The implemented gas cycle allows a continuous conversion due to the build-up of a stable microbial population. Further, the simulation model shows an excellent capability to mimic the flow and coupled biochemical processes in the subsurface on field scale.