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Salinization of freshwater aquifers due to subsurface fluid injection quantified by species transport simulations

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Abstract

Potable groundwater resources could be affected by salinization as result of subsurface utilization like CO_2 injection. We examine the potential of freshwater impairment for shallow aquifers and a drinking water well due to upward displacement of saline formation water along an erosional channel and a fault for a prospective storage site in the Northeast German Basin. Location and degree of salinization is governed by the hydrogeological properties of the migration pathways, while the initial local groundwater flow has only a minor impact. Moreover, an early warning is possible within the time frame of a few months.

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Keywords: shallow aquifer; erosion channel; fault; brine displacement; early warning; drinking water well

1. Introduction

The quality of potable groundwater is of high importance for freshwater resources, especially in regions where the vast bulk of drinking water is gained from groundwater, as in the study area where this concerns 99% of the drinking water [1]. Subsurface activities like CO_2 injection could lead to salinization of shallow groundwater resources due to upwards displaced saline formation water along permeable migration pathways. Therefore it is

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crucial to investigate the main influencing factors on distribution of salinization as well as to determine if and in which time frame early warning is possible. Our study is based on the work of Tillner et al. [2,3] who investigated the influence of permeable fault systems on brine displacement for the prospective storage site Beeskow-Birkholz in the Northeast German Basin. With a 3D regional scale model considering the saline groundwater system, they demonstrated that the existence of hydraulically conductive faults is not necessarily an exclusion criterion for potential injection sites, because salinization of shallower aquifers strongly depended on the effective damage zone volume, the initial salinity distribution and overlying reservoirs [2], while permeability of fault zones did not influence salinization of shallower aquifers significantly [3].

Here, 2D species transport simulations are used to examine salinization of the shallow freshwater system due to inflow of saline water through a fault at the base of the model. This is of particular relevance because within the study area an initial geogenic salinization above the salt-freshwater interface is present already [4] and a fault zone as well as an erosional channel exists, representing both potential pathways for upward brine migration. The intrusion rates of saline formation water as well as the permeability of the fault are varied. Also, the influence of the regional groundwater flow and an active drinking water well on the salinization potential of the shallow freshwater aquifers is examined. Hence, for different hypothetical monitoring wells the time frame is determined within which early warning of freshwater impairment is feasible for the study area and if it is possible before extensive salinization arise.

2. Study area, model set up and investigated scenarios

2.1. Study area

The prospective storage site Beeskow-Birkholz is located 80 km SE of Berlin in the Northeast German Basin (NEGB), see Fig. 1a. The storage formation within Middle Buntsandstein, where it was planned to inject 35 Mt CO_2 over a period of 20 years, is overlaid by a multi-barrier system consisting of the common sediment successions from the NEGB [5]. These exclusively saline aquifers are separated by a regionally distributed aquitard, the Rupelian clay, from the freshwater bearing layers above (Fig. 1b). The overlying quaternary sediments were particularly formed due to glacial and interglacial periods and are characterized by a frequent change of facies and variations in sediment thickness [1]. Porous layers of sand and gravel forming freshwater aquifers interlayered by aquitards consisting of silt and marly till.

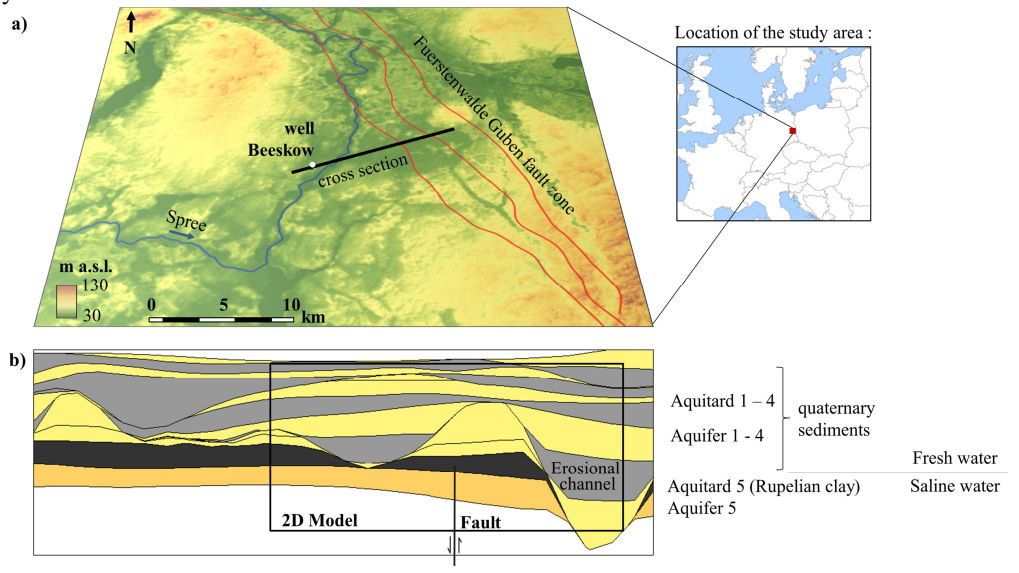

Fig. 1. (a) Overview of the study area displaying the river Spree, the drinking water well Beeskow and the Fuerstenwalde Guben fault zone; (b) the selected cross-section comprise the fault as well as the erosional channel as potential migration pathways.