Geophysical Research Abstracts
Vol. 14, EGU2012-1985, 2012
EGU General Assembly 2012

Semi-analytical model of brine leakage through an abandoned plugged well to determine the Area of Review for CO_2 geological storages

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Deep saline aquifers are currently considered for CO_2 storage in different places of the world. Many of these aquifers are located in sedimentary basins that have experienced a past oil and gas prospection and / or production, which has left a quantity of wells with sometimes undetermined plugging history. Despite a careful site selection, a remaining risk of leakage outside the storage reservoir cannot be excluded, and potential leakage pathways have to be reviewed.

Existing semi-analytical models can estimate the leakage flow rate of brine, possibly followed by CO_2, from the storage aquifer to an overlying one (cf. publications by Nordbotten and co-authors, 2004-2009). These models use a time discretization, but do not use any spatial grid. They are consequently very computationally efficient but require considering homogeneous horizontal aquifer models with uniform properties.

In addition, several authors have proposed a definition of the "Area of Review" of CO_2 storage sites as the area where the pressure changes due to the injection can drive the reservoir brine up to a shallower aquifer. This approach relies on a static equilibrium of the denser brine replacing a lighter one, which implies supposing that the wellbore does not present any cement plug or any element that can slow down the leakage.

In the present study, we combine these two approaches by developing a semi-analytical model able to consider the dynamic brine flow from the storage reservoir to an overlying aquifer through a vertical conduit. That leak is composed of an open wellbore and a porous column, whose characteristics are representative of degraded cements of an abandoned well. During the leakage, the saline brine coming from the storage reservoir progressively fills in the leak and replaces the original fluid, which was less saline and therefore less dense. The model computes the transient leakage rate, the progressive filling of the leak and several pressures variations.

For a given injection scenario, we use this model for estimating the Area of Review and prioritizing the regions where potential pathways have to be examined: from the most conservative case where the leak is merely composed of a open wellbore, one can also consider the presence of a cement plug that will slow down the leakage. Considering a given plug characteristics (porous column height and permeability), the Area of Review can be reduced compared to the conservative case (i.e. with no cement plug) in order to focus the review.

We apply this Area of Review delimitation methodology to the Paris basin context, considering the Dogger aquifer as a storage reservoir and the Albien shallower aquifer as a drinking water resource. Both formations are linked through a 820 m long vertical leak made of a cement plug and an "open" wellbore. Sensitivity analysis is carried out on the typical characteristics of the wellbore + cement plug of this region.