Evaluation of the CO_2 leakage risk along abandoned wells in the French context

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Keywords: Risk analysis, CO_2 leakage, abandoned wells

Three types of geological formations capable of retaining CO_2 are favoured: deep saline aquifers, depleted or declining oil and natural gas reservoirs and deep unmineable coal seams. Deep aquifers offer the most substantial CO_2 storage capacities, and their wide geographical distribution favours a shortening of the distance between CO_2 sources and storage sites. For this this kind of storage, which is generally considered as the main storage target, abandoned wells are considered as a potential leakage vector. Indeed, the injected CO_2 will be in contact with abandoned wellbores penetrating the aquifers. The state of the encountered wellbore may vary within a significant range. For instance, depending on the quality of the cementing job, or on the type of abandonment procedure or on the external solicitation that have stressed the well, wells can either be considered as a sustainable barrier to CO_2 leakage or as a preferential leakage pathway to upper fresh water aquifers or to the atmosphere.
The elaboration of a classification, based on data that can be easily found in official reports is to be the best option to have a first estimation of the leakage risk associated to a large number of wells. Indeed, deterministic approaches will be confronted to the lack of available data and to the lack of knowledge on the physical processes that occur, while the direct estimation of wellbore integrity from in-situ measurement is not possible for a large number of wells. Moreover, the results of a classification approach can easily be imported into a GIS based tool that can be used as a decision making help for the site selection management.

The aim of the present study is to develop a classification that takes into account both the characteristics of the wellbore and its near environment (e.g. reservoir fluid chemistry, caprock…).
To reach this goal, we have used, as a starting point, the classification developed by Watson and Bachu in 2007 (shallow leakage criteria) and 2008 (deep leakage criteria) for the sedimentary basin of Alberta (T.L. Watson, S. Bachu, SPE 106817, 2007 and T.L. Watson, S. Bachu, SPE 112924, 2008). The first work was to adapt this classification to the French context. Indeed, number of criteria of the shallow leakage classification depends on Alberta specificities such as regulations, drilling/abandonment procedures …, while the most of the data needed for the deep leakage classification are hardly available in France.
The selected criteria are the wellbore type (with/without casing that intercepts the aquifer where the storage will take place), the abandonment date (before/after 2000 which corresponds to a significant improvement in the French wellbore abandonment regulation), the top level of primary cementation, the deviation of the wellbore, and the drilling date (before/after 1980).

The second task was to add new environmental criteria, such as the chemistry of aquifer pore space fluid, the kind of surrounding rock and the in-situ temperature, pressure and stress fields. These criteria allow then to take into account the evolution of the leakage risk between the abandonment date and the time when the wellbore is effectively in contact with the CO_2 plume. The quantification of their impact on wellbore leakage risk and threshold values set-up are estimated from the simulation of cement chemical alteration and calculation of the mechanical integrity of the casing-cement and cement-rock interfaces under variations of in-situ stress, temperature and pressure fields.

The next step was to evaluate if this classification can be applied in the French context. In other terms, if the chosen criteria can be easily checked from the available data of wellbore reports. To carry on this work, we used the data base carried out under an agreement between BRGM and the French Water agency (J. F. Vernoux, BRGM Report, 2003). This data base is composed of 2590 oil wells, 119 geothermal wells, 435 natural gas wells and 338 water wells. The criteria were verified through SLQ request, and then the risk category was computed and integrated into a Geographical Information System.

The input data necessary to establish the classification are mostly available. When a data is lacking, we have considered either: 1) a more prejudicial option assuming that the value of the criterion linked to this data is maximum; 2) or a less prejudicial option where the criterion is not taken into account in the computation of the risk category. For the most prejudicial case, the results show that 55% of the wellbores that reached the selected deep saline aquifer (i.e. the Calcareous Dogger of the Paris Basin) are in the worst risk category. This high risk level can be explained by the fact that 56.5% of the selected wellbore have a casing that intercepts the aquifer, 84% are cemented to the ground level and 95% were abandoned before 2000. On the contrary, if we consider the least prejudicial case, only 25% of the studied wellbore are in the worst risk category. This emphasizes that the data lack management is of primary importance in this kind of study. Thus, without any additional information, the evaluation of the CO2 leakage risk along the abandoned wells should at least exhibit the two extreme values that respectively correspond to the least and the most prejudicial options.