MODULAR TOOLBOX FOR ASSESSING THE IMPACTS OF CO_2 LEAKING FROM A GEOLOGICAL STORAGE RESERVOIR INTO A BUILDING

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Text

CO2 capture and storage (CCS) is now recognized as a promising solution within others to tackle greenhouse gas emissions and mitigate climate change. Key issues associated with CCS are linked with the integrity of the reservoir and the containment effectiveness. This is obviously required for the intended purpose of reducing CO_2 emissions, but also to ensure harmlessness to humans and to the environment. However, leakage may occur via existing faults, via an abandoned well or via a sealing deficiency of the cap rock and impact surface elements. This paper focuses on the assessment of these impacts on surface targets, especially on humans.

The objective of our study is to provide an efficient tool for decision support based on simple modeling, which enables to assess the most critical and plausible scenarios concerning human exposure to leaking CO_2. This approach is based on detailed studies of the transport phenomena of CO_2 from the reservoir to the target.
We chose a hypothetical reference scenario corresponding to a leakage through a fault or a well just a few meters below an occupied building. This scenario can be divided in different steps that correspond to different spatial zones:

- Firstly, leakage from the reservoir and migration in the saturated zone through a fault or a well;
- Secondly, migration in the vadose zone and the basements of the building;
- Thirdly, accumulation in the building.

Each of these steps has its own physical properties and consequently its own models. Then, there is necessity to compile the different knowledge and to establish a global tool for decision support. This can be achieved thanks to an adequate and relevant modular approach.
The segmentation in "saturated zone", "vadose zone" and "building" may appear obvious given the fact that specific models exist for these different parts. However the relevance of such segmentation had to be validated and the most appropriate inputs and outputs needed to be determined.
Detailed work was then carried out to develop each module:

- **Module 1:** At the bottom, the first module requires as input the knowledge of pressure in the reservoir, and the characteristics of the leakage pathway (permeability, horizontal section). The leakage rate at the bottom of the vadose zone is obtained with an analytical model treating the migration along the pathway (either fault or well) as Darcy flow.
- **Module 2:** This module aims at obtaining the leakage rate into the building given a punctual leakage rate a few meters deep below the building. No appropriate model for this problem has been found in literature, even though many papers deal with related issues (vapor pollutant VOC transport in vadose zone, intrusion of radon in buildings, predictive simulations of CO_2 injection into the shallow subsurface). Multiphase flow transport numerical simulations accounting for the properties of CO_2 at shallow surface and modeling the vadose zone (unsaturated zone) and two slacked slabs of gravel and concrete (representing the basement of the building) were carried out. Sensitivity analyses on the properties of the vadose and the basement zone show that: (1) Whatever the situation, the vadose zone plays a substantial role in the attenuation of CO_2 flow rate from the subsurface intrusion point to the building, so that this flow rate is reduced by a factor up to 60 % in the worst case situation; (2) Most influential parameters are, in the order: leakage rate, thickness of the vadose zone and permeability of vadose zone. Charts were drawn delivering the attenuation rate due to the vadose zone and the basements as a function of those influential parameters.
- **Module 3:** The third module aims at translating the leakage rate into the building into a CO_2 concentration exposure through an analytical model of mass balance, considering the geometry of the building and its natural ventilation (air exchanges between the indoor and the outdoor environment).
- **Module 4:** The fourth module concerns impurities. Thanks to a basic model of dilution rate, we obtain an estimation of gases concentration in the building as a result of the whole modular toolbox.
- An additional interface enables the user to set the maximum acceptable concentrations (corresponding to national legislation for instance).

Aggregating these 4 modules in a global toolbox provides an efficient, quick and easy-to-use tool for decision support, which enables to assess the impact of CO_2 leakage on human health. The current development of the toolbox takes the form of a spreadsheet, which instantaneously generates the outcomes of the impact assessment (concentration beyond threshold or not for CO_2 and impurities) when the user fills in the input cells.

Beyond the current toolbox, the approach enables a quick and efficient impact assessment for a scenario which can be considered plausible and critical among scenarios resulting from leakage. The current version of this toolbox is still under development. In particular, concerning the existing modules, some phenomena such as intrusion by cracks in the concrete slab are not yet taken into consideration. Besides, other modules, such as a dispersion module to assess exposition in open areas, should be created and integrated in the toolbox. These improvements will be necessary to develop a comprehensive and robust tool that would be useful for decision-makers in preliminary risk analyses.