2022 MCM/ICM

How much CO_2 can we store within the subsurface ?

Background

Humans have had an unprecedented impact on Earth's climate system since the mid-20th century, causing undesired global warming of the Earth system. Emission of gases, in particular, carbon dioxide (CO_2) is the major driver of this global warming. Carbon emission reduction and carbon sequestration techniques have been proposed to address the negative impacts of carbon emission on climate change. In September 2020, Chinese government has declared that China would strive to peak carbon dioxide emissions before 2030 and achieve carbon neutrality before 2060. Carbon neutrality of a country means that the carbon emissions by this country have been balanced out directly, or indirectly, by carbon saving measures such as replacing fossil fuels with renewable energy, planting trees, energy-saving and carbon reduction. Even though it is important to develop and apply carbon emission reduction and clean energy technologies such as natural gas hydrate, geothermal, hot dry rock, nuclear energy, hydropower, wind energy, solar energy, and hydrogen energy, carbon sequestration technologies are also crucial.

In subsurface carbon sequestration, CO_2 is stored in depleted oil and gas reservoirs, deep saline aquifers, and/or unmineable coal seams (Figure 1). Saline aquifers are not typically useful as a source of water for either drinking or agriculture, and thus they are considered for carbon sequestration. In addition, deep saline aquifers are believed to have the greatest storage potential world-wide. Saline aquifers suitable for storage are plentiful in many parts of the world (Figure 2).

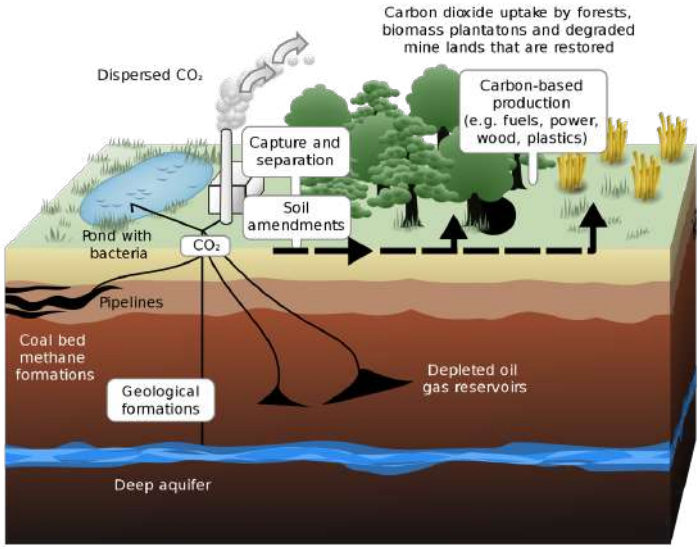

Figure 1. Schematic showing both terrestrial and geological subsurface sequestration of carbon dioxide (adapated from the website https://en.wikipedia.org/wiki/Carbon_sequestration)

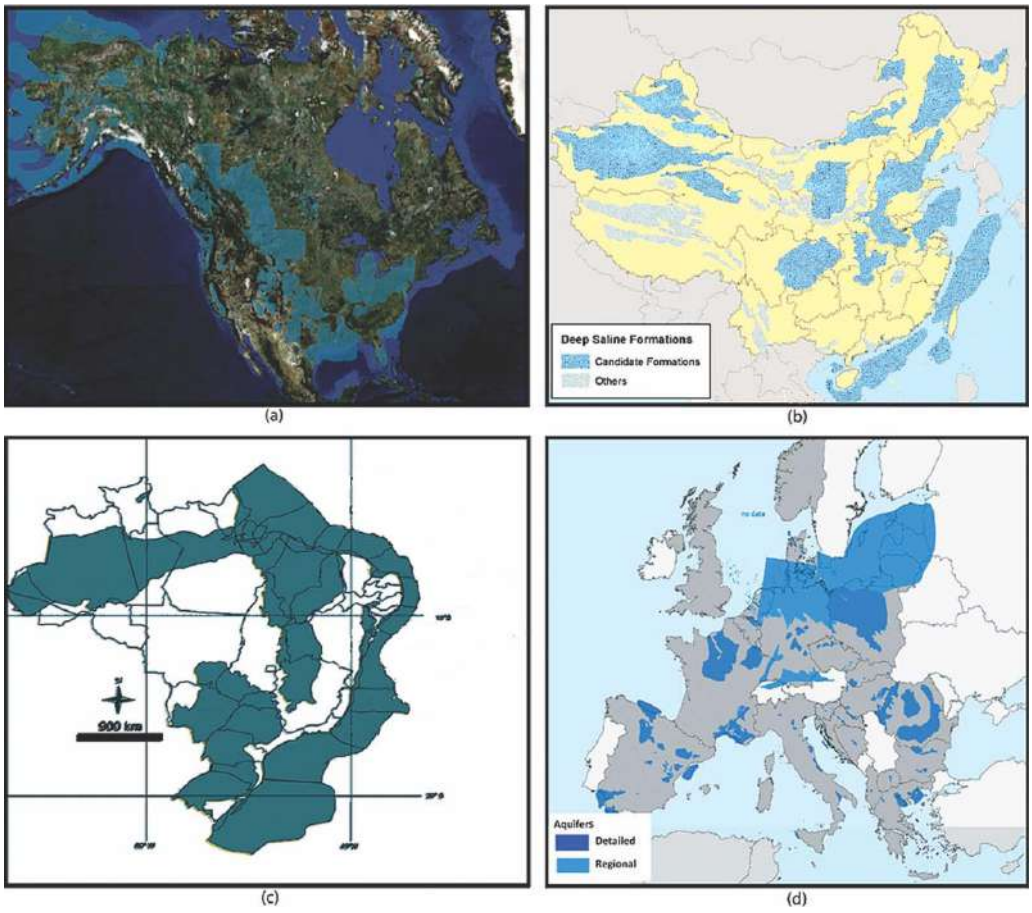

Figure 2: Aquifer distribution in selected regions of the world: (a) USA and Canada, (b) China, (c) Brazil, and (d) the EU
(adapated from the paper "Prospects for Subsurface CO_2 Sequestration" by A. Firoozabadi and P. C. Myint, in AIChE Journal, 2010)

Problem Context

Estimation of CO_2 storage capacity can help us to assess how much CO_2 can be stored in the future and it can also help us to decide whether or not CO_2 storage can provide a feasible method for reducing the levels of CO_2 in the atmosphere.

The volumetric approach to estimate CO_2 storage capacity is natural and also quite straightforward. In this approach, you first estimate the total pore volume of the aquifer, the proportion of the volume which the CO_2 will occupy within the pore volume, and the density of CO_2 (or the density of CO_2-water or the density of CO_2-brine depending on your model). The total pore volume can be calculated from the product of the areal extent, the average thickness and the average porosity of the aquifer. The CO_2 density depends on temperature and pressure, and it can be estimated by searching the corresponding data under a certain pressure and temperature condition typically occurring in the aquifer, or by using an equation of state. The estimation of the proportion of pore

space is trickier and more subjective, sometimes modeled as a product of several factors; but it is clear that the proportion of pore space is positive but less than one if we take account of the fact that CO_2 will not be able to access all of the pore space.

Many deep saline aquifers do not have significant build-up of pressure when injecting CO_2; in this case, the previously-discussed volumetric approach seems to be reasonable. Other (relatively smaller) aquifers might raise the pressure when CO_2 is injected; in this case, the compressibility of the pore space and the brine, and the maximum average pressure build-up in the aquifer might both affect CO_2 storage capacity.

Tasks

1. Construct an evaluation model for CO_2 storage capacity in China. Search the Internet and the literature to obtain relevant data for your model. Estimate the total CO_2 storage capacity within all deep saline aquifers in China.

2. For your estimation in Task 1 above (i.e., your estimation of the total CO_2 storage capacity within all deep saline aquifers in China), how sensitive does this estimation depend on the density of CO_2 (or the density of CO_2-water or the density of CO_2-brine depending on your model)?

3. Based on your model and estimation, please write a popular science essay stating the significance and policy implications of your CO_2 storage model in achieving the goals of "carbon emissions peaking" and "carbon neutrality".

Submission

Your solution paper should include a 1-page Summary Sheet and a piece of short public science essay. The body cannot exceed 20 pages for a maximum of 23 pages with the Summary Sheet and short essay inclusive. The appendices and references should appear at the end of the paper and do not count towards the 23 pages limit.