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# Carbon-dioxide Storage in Geological Media

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Each day more $CO_2$ is discharged into atmosphere and the projections do not refer to the considerable decreases for the emissions in the near future, as the fossil fuel have been expected to remain the main energy resource for its approximately 150 years of life even by the more conservative estimations. This case leads to two alternatives as i) accomplishing lower carbon emissions or ii) switching to cleaner energy resources not emitting $CO_2$. However, currently these two alternatives are far from the reality since there is any successful solution by each of these alternatives. So the most promising solution is to capture, sequester and store $CO_2$ in a sink area or media.

$CO_2$ can be stored in geological formations either under the ocean floor or in the terrestrial areas. Storage under the ocean floor does not be seen as applicable since the transport and the storage processes are extremely costly and difficult. In the terrestrial areas $CO_2$ can be stored in low rank coal deposits, saline aquifers depleted oil reservoirs and deep massive rock masses. In these media storage is performed basically as the injection of $CO_2$ in a supercritical fluid form. The success of these type *in-situ* geological storage methods is dependent on an impermeable layer preventing upright movement of gas. Otherwise, as a result of the upright movement, it transforms again its gas form.

As a geological storage alternative the mineral carbonation method has been considered as a promising method in $CO_2$ storage. After the storage process $CO_2$ is transformed into different minerals. The method can principally be considered as a dissolution process and as a result of the chemical reactions between $CO_2$ and the minerals containing Mg and Ca, geologically stable and environmentally safe carbonate minerals (calcite and magnesite) are formed. The method can be applied as *in-situ* and *ex-situ*. One of a couple of pioneering work (CarbFix Project) have been conducted at Iceland. As an *in-situ* storage process $CO_2$ charged water is injected deep into basalt rock. However, *in-situ* processes has a basic disadvantage as the distribution of $CO_2$ in whole body of rock underground is difficult and requires extensive logging.

*Ex-situ* storage of $CO_2$ requires to process rock outside the main rock. Researches on this type of storage method are on the lab scale currently. After a comminution process the rock material is processed in a pressure and temperature controlled acid-water solution. $CO_2$ is injected into a process medium at a suitable pressure and flow rate. $CO_2$ interacting with the minerals in the solution performs carbonation process. This is an exothermic reaction and as a result thermodynamically stable carbonates are formed. High rates of Mg and Ca containing minerals carbonated as a result of $CO_2$ effect. Main reaction is as follows.

$$CaO + CO_2 \rightarrow CaCO_3 + 179\ \text{kJ/mol}$$

$$MgO + CO_2 \rightarrow MgCO_3 + 118\ \text{kJ/mol}$$

Pure Ca and Mg oxides are not abundant in nature. However, high amount of minerals containing chemical combinations of these oxides are found. Peridotite, serpentine and dunite rocks contain high rates of Mg oxides. Amounts of these rock groups exceed far beyond the total reserves of the fossil fuels.

Industrial carbonation processes can be performed as gas-solid, gas-liquid or a combination these two. Gas-solid process base the direct contact of $CO_2$ to fine grained minerals and has advantage over the solution process as it requires low energy. Gas-solid processes occur at room temperature and by lower process speeds.

Higher process speeds can be obtained by gas-liquid processes. Speed of the process is dependent mainly on the dissolution rate of the Mg under high pressure and temperature. By most used solution method, the fine grained Ca and Mg containing silicate minerals taken into a solution using suitable reactive and then $CO_2$ is injected into solution. Acceptable process rates are possible. Output of this process depends basically on the temperature and the pressure of process medium. Experiments showed that the higher temperatures resulted in the higher dissolution rates of Ca or Mg.

As they offer more stable and environmentally safe alternative of storage for $CO_2$, more attention and effort needs to be directed to the mineral carbonation (either *in-situ* or *ex-situ*). Both methods need more research in the future. Efficient distribution/injection of the $CO_2$ in deep rock mass is the most important challenge for *in-situ* carbonation method. Main barrier over the current *ex-situ* carbonation method can be seen as the efficiency and the cost of the process. Therefore, the research efforts focused mainly on the process kinetics (reactives, pressure, temperature etc.) and the material properties (type of rock, mineral content, grain size etc.), to define the most effective process.

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