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The Nesjavellir (Iceland) geothermal system: the efficiency and long-term effects of the industrial CO_2 and H_2S storage on reservoir fluid composition

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The Nejsavellir power plant (SW Iceland) with an installed capacity of 120 MW_e and 300 MW_{th} emits annually about 15 and 8 Mt of CO_2 and H_2S. These emissions are significantly lower comparing to the emissions sourced from conventional fossil fuel burning plants, however, their presence disqualify geothermal as a green (carbon and sulfur free) energy source. To minimize the emissions from the geothermal industry in Iceland, the CarbFix method will be implemented at the Nesjavellir as a part of the GECO project. The CO_2 and H_2S gases will be injected together with a mixture of separated water and condensed steam into the basalt hosted geothermal aquifer where their mineralization into carbonate and sulfide minerals is expected. The planned injection rates in the first phase of the project that starts in 2021 are 1 Mt/yr of CO_2 and 0.6 Mt/yr of H_2S.

The Nesjavellir hydrothermal fluid is characterized by temperatures ranging from about 265 to 300°C, neutral pH_T of 7.1-7.7 and CO_2 and H_2S concentrations of 30.1-561 and 60.4-194 ppm, respectively. The injection fluid has lower temperature of ~85°C, acidic pH of ~4.9°C and elevated CO_2 and H_2S concentrations of ~15,000 and ~5,500 ppm, respectively. Geochemical modelling reveals that injection of this fluid enhances leaching of the altered basalt and as the reaction progresses the secondary minerals including sulfides and carbonates precipitate. The mineralization efficiency is temperature dependent, being 80-100% at <150°C for both CO_2 and H_2S but decreasing to <40% for H_2S and 0% for CO_2 at 300°C. Therefore, injection into cooler parts of the hydrothermal system at <200°C e.g., at its periphery, can be an effective industrial CO_2 and H_2S storage method. Carbon, sulfur and helium isotope systematics and abundances reveal a significant passive degassing of CO_2 in the area. If mineralization efficiency in such hydrothermal system is <100% the annual gas emissions will increase with time. Long-term permanent CO_2 and H_2S fixation is, however, evident independent on mineral trapping efficiency.

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