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# Hydro-geochemical impact of $CO_2$ leakage from geological storage on shallow potable aquifers: A field scale pilot experiment.

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In order to assess the environmental implications of leakage of $CO_2$ from a geological sequestration site into overlying shallow potable aquifers, a 3 month field release experiment is planned to commence in spring 2012 at Vrøgum plantation, Western Denmark. To test the injection and sampling methodologies and as a study of short term effects, a pilot experiment was conducted at the field site: 45 kg of food grade $CO_2$ was injected at 10 m depth over 48 hours into an unconfined, aeolian/glacial sand aquifer and the effects on water chemistry studied. The $CO_2$ was injected through an inclined well installed with a 1 m length of porous polyethylene well screen (20 $\mu$m pore size) initially at a rate of 5 litres per minute increasing to 10 litres per minute after 24 hours. Water samples were taken from a network of multi-level sample points (8, 4 and 2.4m depth) before, during and after the injection and measured for physico-chemical parameters and major/trace element composition. Although the site possesses a relatively high hydraulic conductivity (12-16 m/day), due to the small hydraulic gradient (0.0039) 6 days elapsed before effects of $CO_2$ on the ground water were detected in the first sampling point located 0.5 m down flow from the injection well. The dissolved plume of $CO_2$ was observed only in the 8 m depth sample points and moved with flow (approximately 0.10 – 0.12 m/day). The plume spread laterally to 2m width as little as 1 m from the injection screen after 26 days, indicating that $CO_2$ bubbles change the hydraulics of the medium. Dissolved $CO_2$ was not detected in sample points at 4 or 2.4 m depth at any time during the experiment, suggesting gas could not move into the slightly finer grained upper sand. Effects of $CO_2$ dissolution at 8 m depth were manifest as a clear and stable increase in electrical conductivity (approximately 160 to 300 $\mu$S/cm), a relatively small increase in total dissolved ions (approximately 30 to 50 mg/l) and an unstable depression of pH (approximately 5.8 to 4.73). The dissolved $CO_2$ plume evolved with a distinct maximal front observed to pass through sample points followed by a slowly dissipating tail. After 56 days the $CO_2$ plume reached the end of the monitoring network and was at its greatest extent (5 m length by 1 m width) however still appeared to be increasing in size suggesting residual gas phase $CO_2$ trapped within the pore space continuously dissolving. Water quality did not significantly deteriorate and only small increases in major and trace elements were observed. Overall, groundwater chemistry results indicate that for an aquifer composed primarily of slowly reacting silicate sediments, such as Vrøgum, the risks to water resources from a short term leak from CCS into shallow overlying aquifers are minimal. However, a potential accumulation effect within the plume front as it moves through the formation was observed inferring a large scale leak may develop a $CO_2$ charged plume exceeding guideline values for major and trace elements.