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# Detection of $CO_2$ leakage by the surface-soil $CO_2$-concentration monitoring (SCM) system in a small scale $CO_2$ release test

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Monitoring of $CO_2$ release through the ground surface is essential to testify the safety of $CO_2$ storage projects. We conducted a feasibility study of the multi-channel surface-soil $CO_2$-concentration monitoring (SCM) system as a soil $CO_2$ monitoring tool with a small scale injection. In the system, chambers are attached onto the ground surface, and NDIR sensors installed in each chamber detect $CO_2$ in soil gas released through the soil surface. Before injection, the background $CO_2$ concentrations were measured. They showed the distinct diurnal variation, and were positively related with relative humidity, but negatively with temperature. The negative relation of $CO_2$ measurements with temperature and the low $CO_2$ concentrations during the day imply that $CO_2$ depends on respiration. The daily variation of $CO_2$ concentrations was damped with precipitation, which can be explained by dissolution of $CO_2$ and gas release out of pores through the ground surface with recharge. For the injection test, 4.2 kg of $CO_2$ was injected 1 m below the ground for about 30 minutes. In result, $CO_2$ concentrations increased in all five chambers, which were located less than 2.5 m of distance from an injection point. The Chamber 1, which is closest to the injection point, showed the largest increase of $CO_2$ concentrations; while Chamber 2, 3, and 4 showed the peak which is 2 times higher than the average of background $CO_2$. The $CO_2$ concentrations increased back after decreasing from the peak around 4 hours after the injection ended in Chamber 2, 4, and 5, which indicated that $CO_2$ concentrations seem to be recovered to the background around 4 hours after the injection ended. To determine the leakage, the data in Chamber 2 and 5, which had low increase rates in the $CO_2$ injection test, were used for statistical analysis. The result shows that the coefficient of variation (CV) of $CO_2$ measurements for 30 minutes is efficient to determine a leakage signal, with reflecting the abnormal change in $CO_2$ concentrations. The CV of $CO_2$ measurements for 30 minutes exceeded 5% about 5 minutes before the maximum $CO_2$ concentration was detected. The contributions of this work are as follows: (1) SCM is an efficient monitoring tool to detect the $CO_2$ release through the ground surface. (2) The statistical analysis method to determine the leakage and a monitoring frequency are provided, with analyzing background concentrations and $CO_2$ increases in a small-scale injection test. (3) The 5% CV of $CO_2$ measurements for 30 minutes can be used for the early warning in $CO_2$ storage sites.