Design and construction of groundwater monitoring network at shallow-depth CO\textsubscript{2} injection and leak test site, Korea

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Abstract

The effectiveness of CO\textsubscript{2} leakage characterization is highly dependent on reasonable monitoring network designs for detecting the CO\textsubscript{2} leakage under various hydrogeological conditions. Also, the migration of CO\textsubscript{2} through heterogeneous subsurface is very difficult to predict because small differences in material properties may result in vastly different migration patterns. Therefore, like other environmental contaminants, it is necessary to design optimized groundwater monitoring network to effectively characterize the migration of the CO\textsubscript{2}. Main objectives of this study is to construct optimized groundwater monitoring network considering hydrogeological characteristics in field-scale transport of CO\textsubscript{2} originated from artificially-injected CO\textsubscript{2} at the environmental impact monitoring test site in Eumseong, Korea (K-COSEM). 13 monitoring wells were installed at the site aligned with the regional groundwater flow direction. Various hydraulic tests were performed to estimate the hydraulic characteristics such as hydraulic conductivity, effective porosity, and groundwater velocity. Firstly, borehole electromagnetic flowmeter tests, pumping and slug tests were carried out. The value of hydraulic conductivity ranged between 1.72e-5 and 1.86e-5 m/sec. Borehole electromagnetic flowmeter tests were performed to figure out groundwater flow direction and it showed was not identical to the topographic gradient. From the results of flowmeter test, most of the monitoring wells showed that groundwater was flowing toward the pumping well. However, in some monitoring wells, groundwater flow direction indicated a direction along the regional flow direction in spite of pumping action at surrounding wells. Push-drift-pull tracer test was conducted to acquire site hydrogeological information and characteristics. Multiple tracers (SF\textsubscript{6} and chloride) were applied to evaluate applicability of volatile and non-volatile tracers for preliminary CO\textsubscript{2} injection and leak test. Effective porosity, regional groundwater velocity, and recovery percentage of each tracer for total 3 specific depth zones (zone 1: 15-18 m depth from the ground surface; zone 2: 21-24m depth; zone 3: 27-30 m depth) were calculated by analysing data from the push-drift-pull tests. Volatile and non-volatile tracers showed different mass recovery percentage. Most of salt mass was recovered but less than half of SF\textsubscript{6} mass was recovered. However, breakthrough curves of both tracers indicated similar peak time, effective porosity, and regional groundwater velocity. The values of effective porosity showed a range of between 0.05 and 0.23. The value of regional groundwater velocity was estimated to be between 0.06 and 0.25 m/d. The estimated effective porosities at zone 1 and regional groundwater velocity at zone 3 were the highest values compared with those of other zones.
heterogeneity understood through the various field tests. Three multi-depth monitoring well nests each of them was composed of four monitoring well units drilled with different depths (each 18, 22, 26, 30 m deep) have been installed along the groundwater flow direction and dedicated to depth-discrete water quality monitoring in saturated zone (Fig. 1). Additional, four multi-depth monitoring well nests each of them was composed of four unsaturated-zone monitoring well units drilled with different depths (each 5, 8, 11, 14 m deep) were also installed with a distance of 1.25 m away between saturated zone monitoring wells and were dedicated to depth-discrete gas monitoring in unsaturated zone (Fig. 1). By these efforts, effective groundwater monitoring network for temporal and spatial CO₂ leakage detection and groundwater safety management have been designed and constructed at the test site (Fig. 2).

Figure 1. Cross-sectional view of multi-level monitoring wells installed at unsaturated and saturated zone for CO₂ injection and leak test (vertical section)
Figure 2. CO$_2$ injection and multi-level monitoring well arrangement for effective groundwater monitoring