Geoelectrical Remote System for Monitoring Shallow Subsurface CO₂ Migration

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Abstract

The implementation of the first CO₂ MMV field lab in Brazil, located in Florianópolis, Santa Catarina state, offered an excellent opportunity for running controlled release experiments in a real open air environment. After three CO₂-controlled release experiments run from 2011 up to 2015, PETROBRAS, the national oil company that is sponsoring the project, has launched a new challenge. The company stimulated the implementation of a new Brazilian experimental site located in a geologically more complex conditions and more challenging from a technological point of view. The choice of an area inside PUCRS campus, in Viamão - Rio Grande do Sul state, was motivated by a predominantly clay subsoil and the privileged location of the site in terms of logistics and security, as the project houses high-tech equipments with significant cost. The purpose of this work is to present the results obtained by the geoelectrical remote time lapse using 3D electrical imaging technique to the monitoring of CO₂ migration in both saturated and unsaturated clay-rich sediments in Viamão site, which is lithologically different from the Florianópolis field lab, composed of sand-rich sediments. The CO₂-controlled release occurred in 2016, covering an subsurface area of approximately 2.925 m². The CO₂ was continuously injected through an injection well, at 3 m deep, in a period of 31 days (24 hours/day), at a rate ranging from 5 to 20 kg / day, totalizing 346 kg of injected CO₂. While the CO₂ was been injected, 3D electrical images using dipole-dipole array, were acquired in a daily base, totaling 46 consecutive days (including periods before and after injection have been suspended). 3D (tridimensional) and 4D (time-lapsed) electrical imaging produced images up to 17 m below the surface. Remote monitoring has been used for the continuous characterization of the soil/sediment geoelectric responses, significantly increasing the accuracy with respect to the external effects that interfere in the geoelectric responses, such as excessive precipitation and changes in the injection rate. Comparison of post-injection electrical imaging results with pre-injection images.
shows changes in resistivity values consistent with released CO₂ migration pathways. A pronounced increase in resistivity (up to ~ 1,900 ohm.m), with respect to the pre-injection values, have been noticed to the southeast of the injection well, in a shallow depth (0.50 m - deep). Background values of 75 ohm.m have changed to 2,000 ohm.m, right after injection. On the same day that resistivity raised increased CO₂ flux from soil, measured using accumulation chambers, were also observed, reaching values 20 times greater than those observed during baseline measurements (7 mmol/m²/s). The increased CO₂ concentration in the atmosphere compared to background-measured concentrations using-carbon caps, also coincides with the results of the subsurface resistivity, due to CO₂ migration. Geoelectrical remote monitoring has also shown that significant changes in resistivity values occur in differentiated portions of the area. Probably due to the heterogeneous nature of the area’s lithology. If we consider the existence of a hanging aquifer in the area, CO₂ will have a trend to flow into the unsaturated zone, since it is easier to displace air than water.