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Integration of geochemical and geophysical data at a NAPL-contaminated site

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Due to their non-invasive nature, geoelectrical methods offer an excellent opportunity to aid characterization of NAPL contaminated sites. We tested this applying a series of cross-hole geo-electrical measurements, together with monitoring campaigns of chemico-physical parameters at a hydrocarbon-contaminated site in the North-West of Italy. The contamination is due to a blow-out of a well that discharged a great amount of crude oil over a large area in 1994. The contamination is still present in soils and groundwater in residual form in the vadose zone, which is mainly characterized by alternating silt, sand and gravel Groundwater fluctuates by several meters, with higher levels at the end of summer due to recharge from the agricultural irrigation.(8 m +/- 2 m). A small scale test-site has been set up in 2008 within the most contaminated area. Two boreholes (called B-S3 and B-S4), spaced 6 m apart, were equipped with electrodes to perform cross-hole geo-electrical measurements both in vadose- and saturated zone. One meter apart from the boreholes, a multilevel sampling system was installed in October 2009.
We focus on vertical resistivity and induced polarisation logs (IP), comparing the geophysical results with the values of chemico-physical parameters on samples collected at the sampling ports of the multilevel system. Referring to the time series of Autumn 2010 and Spring 2011, the electrical logs show a gradual decrease of apparent resistivity values below the groundwater level (from 600 to 150 ohm m) in borehole B-S3, and a marked increase of normalized apparent chargeability (NM) values, within the depth range of 8 to 14 m, with a peak at 11 m. This behaviour of the IP response was detected in borehole B-S3 only, indicating a great spatial heterogeneity at the site. The NM parameter is mainly related to the surface electrical properties around the solid grains of the soil and thus to bio-degradation processes of the organic matter available at the site (NAPL).
The IP anomaly is well related to the peak of concentration of hydrocarbon contaminants; high values of TOC (both in soil and groundwater) and DOC were detected in the depth range between 8 to 12 m; this states a high NAPL concentration as organic substrate. Moreover, values of Fe++, manganese, hydrogen carbonate exceeding background values by far, and low redox potentials were detected, indicating that a degradation activity is still in progress.
The joint use of borehole geo-electrical measurements and the chemico-physical monitoring of the permitted in the specific case to locate the zone characterized by a more intense bio-degradation activity, demonstrating the effectiveness of the integrated approach.