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Introduction to special section: Characterization and monitoring of subsurface contamination

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Subsurface contamination is a significant problem worldwide that directly affects human health, ecosystems, and property. It also can impact valuable resources (e.g., groundwater, surface water, soils). Contaminated sites exist in a variety of sizes and locations, from a leaking underground storage tank to mega sites that stretch across several industrial facilities. Although contamination is primarily the result of anthropogenic activities such as manufacturing, mining, and improper waste disposal, some natural processes can also contribute. This can result in a wide variety of contaminants across a range of concentrations and different media. Subsurface contamination characterization can be challenging because it can occur across a variety of depths, often with no surface footprint. To efficiently address subsurface contamination problems, accurate and high-resolution characterization and monitoring of the contaminant domain is needed.

Subsurface contamination characterization is an inherently difficult task due to the almost endless list of contaminants in a variety of host media and depths. Continuous advances of characterization methods, changes in regulatory standards, and the development of remediation systems further complicate this task. In recent years, novel applications of near surface geophysical methods showed the potential that exists for enhancing subsurface characterization. Electrical geophysical methods have been used in many recent field applications such as hydrocarbon mapping and delineation (Flores Orozco et al., 2012), monitoring enhanced remediation (Williams et al., 2009; Flores Orozco et al., 2011) and natural attenuation (Heenan et al., 2015). A few review papers try to attract attention on methods used as robust monitoring tools (e.g., Slater, 2007; Snieder et al., 2007; Revil et al., 2012) but none have focused on contamination. With this special section we highlight some of the recent advances in the use of geophysical methods for contaminant characterization and monitoring in the subsurface.

The next two manuscripts focus on the use of ground-penetrating radar (GPR). **Babcock et al.** use GPR, in parallel with conventional geotechnical tools, to investigate the transport mechanism of a subsurface hydrocarbon contaminant in an alluvial depositional environment. The authors demonstrate the potential viability of these tools at contaminated sites, which have complex stratigraphy and therefore may pose problems for other methods used in contaminated site investigations.

The very important problem of ultrathin layers of dense nonaqueous phase liquids (DNAPLs) is investigated by **Babcock and Bradford**. They use numerical and physical models to examine the suitability of GPR to characterize ultrathin layers of DNAPL trapped at a sand/clay interface. The numerical and physical models are in good agreement, and both show an increase in reflection strength of 10% or more with partially DNAPL-saturated layer thicknesses as low as $1/50^{th}\lambda$.

The following two manuscripts are focused on common electrical methods, including resistivity, induced polarization (IP) and self potential (SP). **Mendonça et al.** use resistivity and IP, supported by geochemical and microbiological data, for enhanced site characterization; the synergistic interpretation of the geophysical data, with the geochemical and metagenomic data allowed the detailed characterization of gas fluxes in the subsurface. The conceptual model developed suggests that biogas trapped in the subsurface can rapidly travel to the surface.

Doherty et al. use the promising SP method to monitor natural attenuation of gasworks contamination in groundwater. Large SP anomalies are linked to electro-

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chemical and redox processes at the edge of the groundwater plume that are dominated by microbially mediated reactions.

The next manuscript utilizes magnetic methods for environmental investigations. **Kokinou** studies the magnetic properties (magnetic susceptibility [MS] and temperature dependence of the MS) of near-surface soils in an environmental protected area. The differences in the spatial distribution of the magnetic properties identified the potential suggesting anthropogenic and natural sources for contamination in the Natura (EU, 2015) (environmentally protected) study area.

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