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Environmental geophysics in urban areas

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Urban soil can originate from : 1) anthropogenic deposits (e.g. urban fills), which can constitute a pollution source for the underlying hydrogeological formation and 2) superficial alluvial deposits (i.e. river outwash, glacio-alluvial deposits) underlying urban areas. We will show examples of the use of geophysical methods for the characterization of either type of urban deposit for the purpose of determining heterogeneity patterns which could indicate a residual pollution or pathways for contaminant migration into the subsurface.

Both anthropogenic and alluvial deposits exhibit large physical and chemical heterogeneity, resulting from the presence of various materials (some of which are considered wastes in anthropogenic soils) and the nonuniform structural and chemical organisation of these materials. The environmental assessment of urban soils is difficult using conventional methods of borehole drilling and grab sampling. These methods provide highly localized information about the physical and chemical properties of the deposit with large gaps of information between the data points. It then becomes quite advantageous to use indirect methods of characterization, such as geophysical methods, to bridge the gaps between the conventional data by delineating the physical properties of these soils through the measurement of their electric, electromagnetic, magnetic and dielectric properties. Such delineation may help in investigating zones of potential contamination as well as in obtaining a pattern of the internal structural organisation of the deposit.

To demonstrate the potential of geophysical methods in largely heterogeneous and strongly anthropogenic deposits, geophysical measurements where made on an urban site, located in a former industrial district of downtown Montréal (Québec, Canada). A previous investigation using borehole drilling and sampling had shown that the site was covered with heterogeneous fill down to a few meters. Four geophysical methods were used: electromagnetic induction, magnetic gradiometry, electrical resistivity and ground-penetrating radar. The integrated interpretation of the results from the four methods enabled us to delineate the physical heterogeneity of the fill, i.e. to determine the position of buried structures and potentially contaminated enclaves as well as to locate the interface between the anthropogenic and the natural deposits. Volumetric data were also obtained from the geophysical measurements, namely the volume of the anthropogenic deposit and its main anomalies (e.g. large demolition debris). Geophysical data was validated using in situ observations (e.g. during trench excavation) and geophysical simulation based on a theoretical model representing the different structural units of the fill and their respective electric, magnetic, electromagnetic and dielectric properties.

Geophysical measurements were also performed at the bottom of a stormwater infiltration basin in eastern Lyon (France). The deposit from which the basin was excavated is of glacio-alluvial origin. Two geophysical methods were used for this work, namely ground-penetrating radar and electrical resistivity. The interpretation of the results provided the textural and structural heterogeneity pattern of the deposit. Moreover, a 15-m long by 2.5-m wide trench was excavated for sampling purposes. Stratified sampling was performed following the layering of the formation. More than one hundred samples were taken, which underwent physical and chemical analyses: grain-size distribution, organic matter content, metal (Cu, Pb, Zn) content. Results indicate a correlation between the presence of metals, organic matter and silt-size particles. The distribution of the silt content and the concentrations of metals depend on the stratigraphy of the deposit. Geophysical profiles were calibrated using sedimentological information obtained from the trench face. In this case, geophysical methods could be used to assess zones showing large concentrations in metals.

In conclusion, geophysical methods used on both types of urban deposits provided a more precise delineation of the structural organisation of these deposits which in turn could be used to improve the characterization of the distribution of contaminants. Therefore, such methods could possibly be used as part of the sampling planning process.

Key words: contaminated urban fills, infiltration basin, ground-penetrating radar, electrical resistivity, electromagnetic induction, magnetic gradiometry, urban pollution