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Forward geophysical modeling of electrical resistivity anomalies due to groundwater flow and contaminant transport around landfills

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This paper presents theoretical geo-electrical responses associated with polluted groundwater flow in porous media around landfills. Forward computation has proven an important role in all stages of geo-electrical surveys. Previous forward studies have emphasized the space-dependence of electrical conductivity, but largely, they ignored its transient feature resulting from the spreading-out of contaminant plumes in directions transverse to the flow path as well as in the longitudinal flow direction.

In this research, we adopt a novel 'combined' hydrogeological and geo-electrical modeling approach as follows: first using the finite element computer package FEFLOW to simulate contaminant transport and groundwater flow; then establishing the geo-electrical structure based on an empirical relationships between contaminant concentration and water conductivity as well as Archie's law; and finally undertaking the forward computation of geo-electrical anomalies using the finite difference computer packages DCIP2D/DCIP3D. Numerical case studies are conducted for a variety of landfills with different hydrogeological and geological conditions, from which optimal mapping and monitoring configurations are determined.

Methodology

Based on the concentration distribution obtained from hydrogeological modeling and the empirical relationships between concentration of the contaminant and bulk conductivity of the rock, a geo-electrical structure was developed. The resulting geo-electrical anomalies were computed by forward modeling. The entire process was carried out by using the following computer packages:

- Feflow, to simulate contaminant transport and groundwater flow;
- F2D, to build up the input files for the forward geophysical modeling;
- DCIP2D/DCIP3D, to perform the forward computation of the geo-electrical anomalies.

Hydrogeological modeling

A two-dimensional transient ground-water flow model for a hypothetical landfill and vicinity was developed to represent various geological scenarios subject to different hydraulic conditions.

Forward geophysical modeling

Various electrodes configurations have been considered for the geoelectrical model: pole - pole (pp), pole-dipole array with the potential electrodes on the left (pdL), pole-dipole array with the potential electrodes on the right (pdR), dipole-dipole (dd).

Results

The results describe the evolution of the contaminant plumes and electrical responses for various geological models. The geoelectrical response is described in terms of apparent resistivity pseudosections and profiles.

Conclusions and future investigations

Forward modeling indicates electrical resistivity method can be used to delineate the shape of a contaminant plume. The applicability of the geo-electrical technique in locating plumes depends on the size and shape of the targets and the resistivity contrast between the groundwater and the contaminating fluid. At this point of the preliminary investigation, it is difficult to quantify the needed contrast due to a wide range of site conditions and plumes configuration.

Further research will consider different electromagnetic methods (TEM, FEM and MMR) and their ability to delineate the contaminant plumes spreading.