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Editorial

Some Advanced Technologies for DNAPLs Source Identification and Characterization

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Chlorinated aliphatic and aromatic compounds have been often used as solvents since the early 1940s. Due to their limited but significant aqueous phase solubility, spills of these compounds typically result in the migration and formation of a separate organic phase that, if it is denser than water, it is known as DNAPL (Dense Non Aqueous Phase Liquid). It moves through the subsurface contaminating large volumes of saturated porous media; it can persist as a source of widespread and long-term contamination for decades, slowly dissolving into the water phase.

In a general sense, transport of chlorinated hydrocarbons can be divided into three stages:

1) Migration as a separate immiscible phase.

2) Stabilization as an immobile phase that acts as a source of dissolving organic contaminant.

3) Migration as a dissolved contaminant in groundwater.

Thus, because of these peculiarities, groundwater remediation regarding industrial organic contaminants requires a detailed knowledge of the subsurface distribution of the contaminant and a complete understanding of the flow processes involved.

Over the last decades a great research effort was conducted in order to comprehend the mechanisms of infiltration and redistribution of DNAPLs in water-saturated porous media. Most of the studies demonstrated the importance of subsurface heterogeneity on the migration and final distribution of DNAPLs. Indeed, heterogeneities cause mechanisms like the unstable behaviour of downward DNAPL flow, no uniform distribution of entrapped DNAPL and formation of pools on top of fine-grained layers.

Due to the crucial importance of soil properties distribution in pollutant transport in porous media, a lot of attention has been dedicated in the past decades by researchers to incorporate into mathematical models a realistic description of spatial variability of hydrological formations. Stochastic modelling is usually invoked in this case; this approach recognizes that hydrological properties of the porous formations are affected by uncertainty and considers them as a spatial random function. In order to describe the soil properties variability, such as hydraulic conductivity, multi-Gaussian models have been commonly adopted with the justification that they are consistent with field data at a few experimental sites. However, more detailed studies of the structure of sedimentary formations suggest that many sites have a hierarchical structure in which several modes and correlation lengths combine to create a much complex and heterogeneous structure. Such a complexity is created by the arrangement of lithofacies units, which have size, granulometric and textural properties dependent upon the energy of the depositional environment. A way to model such complexity is by multi-indicator geostatistical models. Significant advances in understanding the correlation between the variability of medium properties and the lithofacies distribution were made so far. Indeed, several works appeared in literature confirming the strict relationship between the hydraulic conductivity variability and the facies distribution in sedimentary structures. For example Ritzi et al. [1] investigated the conductivity variability in glaciofluvial aquifers through a facies-based approach.

Clearly a full, though stochastic, description of soil properties spatial distribution is needed to investigate relevance of heterogeneity into mechanisms and processes underlying DNAPL (or other non-wetting fluids) migration, fingering and entrapment (mechanism also known as “DNAPL invasion” [2]).

Even if the relation between spatially variable soil properties and spreading or irregular distribution of entrapped NAPLs is well established [3], few numerical studies applied multiphase models to heterogeneous porous formations. These studies revealed the fundamental influence of spatial variability of the medium properties, such as conductivity, porosity and capillary pressure saturation on fate of immiscible flow path and organic pollutant spreading; the authors observed an increased DNAPL spreading into the aquifer as the heterogeneity of the medium was more relevant. This trend was also detected both at field and laboratory scale with experimental tests conducted in order to investigate the influence of aquifer heterogeneities on the movement and subsequent distribution of immiscible contaminant after a spill. However it is very difficult to experimentally simulate the shape of strata and lenses that are usually much more irregular; some approaches are laboratory models where sloping and irregularly shaped soil layers represent barriers to DNAPL migration or laboratory tests [4,5] where simplified analogues of random field-site sedimentary structure are characterized by an approximated log-normal distribution of the conductivity field with assigned statistical properties. It has been observed that in granular aquifers the soil properties distribution is related to lithofacies distribution and most of the variability comes from the contrast between different facies instead of inside the lithofacies itself. The properties contrast between facies could be also of several orders of magnitude, i.e. clay inclusions embedded in a sandy aquifer. Aquifers with these properties have been recognized at a site located in the neighborhood of Milan (Italy). We studied and characterized the site (Research project founded

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by Italian Ministry of Research and University) by both laboratory experimental models [6,7] and numerical simulation. Experiments performed on one realization of the stochastic process representing the soil properties variability of the aquifer, provided a reliable data source with which the results obtained through the stochastic approach were compared.

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