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2D modeling of unsaturated flow dynamics in urban heterogeneous fills

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Contaminated land is generally recognized as a significant hindrance to the economic development of urban areas. These brownfields, as they are called, are usually the legacy of former industrial activities and they can usually be found in or around almost every city as abandoned and unused stretches of land. In Canada, 30 000 brownfields have been reported while in the US, the EPA reports numbers between 0.5M and 1M.

The environmental or public health risk posed by brownfields is not well understood. Most of these sites contain heterogeneous fills of contaminated soil, construction debris, and various wastes, which can be hazardous. The contamination of these fills is generally a mixture of organic compounds and metals. Furthermore, these fills are usually located in the vadose zone, thereby greatly complicating the flow dynamics of the infiltrating water. Because of such severe physical and chemical heterogeneity, it becomes very difficult to assess and predict the mobilisation of contaminants in these fills without an appropriate conceptualisation and quantification of the flow of the infiltrating water at the scale of the urban field.

This study was conducted to establish a conceptual representation of the unsaturated flow dynamics in an urban heterogeneous fill located in downtown Montreal (Canada). Work was performed in three stages:

1. Field work was conducted by geophysical investigation and trench excavation to identify the principal units of materials found in the fill. Samples were then taken from each unit;

2. Grain-size analyses were performed on samples from each unit. Using the grain-size distributions, we produced a soil moisture characteristic curve for each unit based on the physicoempirical model developed by Arya and Paris (1981, 1999). These soil moisture characteristic curves were fitted with the van Genuchten model (1980) to obtain parameters for unsaturated flow modelling using HYDRUS 2D;

3. A 2D vertical cut of the fill was represented in finite elements and was used for modeling the infiltration of water. The latter was conducted for various initial conditions of precipitation flux. The influence of various parameters on water flow was assessed, namely the degree of physical heterogeneity, hysteresis in the characteristic curves, the presence of coarse particles in some materials (e.g. gravels and larger).

Modeling results enabled us to identify specific units which had a significant influence of the dynamics of the infiltrating water. For instance, coarser units combined with underground impervious structures (e.g. old concrete slabs) served as preferential pathways. In some parts of the fills, this preferential flow reached quickly contaminated materials thereby increasing the risk of contaminant mobilisation.

Our results provide a schematic representation of unsaturated flow dynamics in a heterogeneous fill and as such are a means to underline the importance of accounting for heterogeneity at a the scale of the urban field when making an assessment of the potential for contaminant mobilisation by water from brownfields.