A 2-D numerical model with strong coupling of subsurface and indoor air for vapour intrusion: influence of lithologies and concrete properties

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1- Background/Objectives

Chlorinated solvents are among the most common soil and groundwater contaminants due to their widespread use as dry-cleaning solvents and as degreasing agents. Due to their physicochemical properties, they produce large scale plumes of pollution in the groundwater. In the densely populated regions, these pollution plumes are located under residential and urban development areas and therefore difficultly accessible. Vapours can migrate through building slabs into indoor air (like shows on Figure 1.1). Soil vapor migration into house, with subsequent inhalation, is often the main exposure pathway to humans at sites contaminated with Volatile Organic Compounds (VOCs). Two approaches are commonly used for quantification of indoor concentrations: indoor gas measurement or transfer modeling from the source.

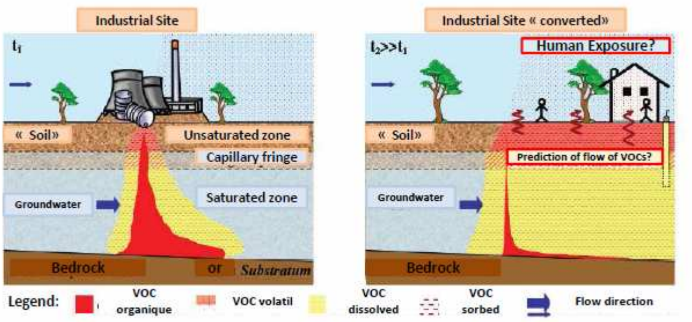

Figure 1.1 : exposure scenario [Cotel, 2008]

Analytical 1-D model (Johnson & Ettinger, 1991 and VOLASOIL, 2008 models) development is relatively well advanced but measurements for model calibration and "validation" hardly exist in the literature. Furthermore, predictions of indoor gas concentrations from different models may vary by several orders of magnitude, depending on the application. With picture 1.2, we can say that to be realistic, the phenomenon have to be modeled in 3-D or at least in 2-D if there is a symmetry.

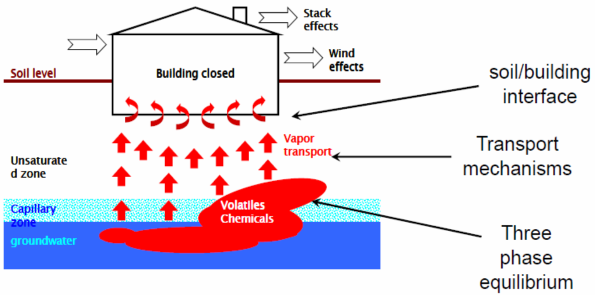

Figure 1.2 : phenomena involved in the vapour intrusion

The work presented here consists in building a numerical 2-D model for vapour intrusion. Specifically, we study the influence of lithologies (multilayer, thickness, soil properties) and the influence of concrete properties on the vapor intrusion into dwellings for several scenarios. Also, our model takes into account the indoor air phenomenon, therefore it can overlap with indoor air measures.

2- Approach/Activities:

This numerical modeling was performed with COMSOL Multiphysics. COMSOL is a finite element analysis for various physics and engineering applications, especially coupled phenomena or multiphysics.

The assumptions made here are: 2-D geometry, turbulence in indoor and outdoor air, constant water content profile, permeable homogeneous slab, soil and groundwater infinite source, only gas phase is mobile, two-components (Air-Perchloroethylene), isothermal conditions, water table is fixed.

Our model takes into account the phenomena in soil, indoor air and outdoor air (strong coupling). The flow equations are: Brinkman equations for porous media, k-ε model for indoor air. The transport equation is Convection-Diffusion equation.

Many scenarios were studied considering the soil: monolayer, multilayer (with slightly permeable layer), various thicknesses, various water content profiles, several source locations. Also for the concrete, we look after: various thicknesses, various permeabilities. For each scenario, we follow the indoor concentration in three points, in addition to the concentration profiles in the soil.

For inputs, soil data were gathered from US-EPA database. For this example, we have chosen the perchlorethylene as pollutant and its characteristics were taken from INERIS database.

3- Results/Lessons Learned:

The comparison of the concentration shows how much thickness is important on vapor intrusion. The impact of concrete permeability was highlight, also the influence of water content.

This study shows 2 things:

1- our model can translate the phenomena involved in vapor intrusion model, in a coupled way (subsurface and indoor air) with the possibility to have the concentration in soil and indoor for comparison with fields measurements.
2- these characteristics (soil, slab) impact the results to attach great importance for next step : field measurements for a study case.

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