Modeling of Source to Building Exclusion Distances at Petroleum-Contaminated Sites

Iason Verginelli (verginelli@ing.uniroma2.it) and Renato Baciocchi (baciocchi@ing.uniroma2.it)
(University of Rome Tor Vergata, Italy)

Background/Objectives. The role of biodegradation in attenuating petroleum hydrocarbon vapors migrating into indoor environments has been the subject of several papers in the last decade. Despite this, due to the overly conservative character of the screening models generally used in the risk analysis framework, vapor intrusion still results a critical pathway in several petroleum-contaminated sites. To overcome this limitation, in the last decades more detailed models accounting for biodegradation were developed. More recently, a big effort was also made to identify source to building separation screening distances, beyond which the potential for vapor intrusion can be considered negligible. This was mainly made by carrying out statistical analysis of large soil vapor datasets collected from the field. However, these empirical screening distances are associated to a certain probability percentage (e.g., 95% of cases) that for a given type and source concentration (e.g., dissolved-phase or LNAPL source) the contaminant of concern will be attenuated below a target soil-gas screening level. To support and further justify these empirical analyses, mathematical modelling can be certainly of help.

Approach/Activities. In this work, we present two simple analytical models that allow to directly estimate, on a site-specific basis, the risk-based screening distance for petroleum hydrocarbons. The proposed solutions rely on a 1-D vapor intrusion model that incorporates a steady-state subsurface vapor source, diffusion-dominated vapor transport in a homogeneous soil, aerobic biodegradation limited by oxygen availability, diffusive and convective mass transfer across the building foundation and mixing within the indoor environment. In addition, the models account for the transport of oxygen due to diffusion and its consumption to sustain the aerobic reaction.

Results/Lessons Learned. In nearly all simulated conditions, source to building vertical separation distances greater than 2 m or 5 m were found to be sufficient to attenuate to acceptable risk-based levels petroleum hydrocarbon vapors from dissolved-phase or LNAPL sources, respectively. These results are consistent with the empirical screening criteria of 1.8 m (6 feet) for dissolved contamination and 4.6 m (15 feet) for LNAPL sources suggested by U.S.EPA (2015). On the other hand, it was found that the lateral exclusion distance for petroleum vapor intrusion can be set equal to 6 m for groundwater sources and to 9 m for soil sources, regardless of the source concentration and depth. These exclusion criteria can be significantly reduced for low to moderate source concentration. For instance, from low to moderate source concentrations (e.g., for benzene concentrations lower than 5 mg/L in groundwater and 0.1 mg/kg in soils) and deep sources (e.g., deeper than 5 m) the simulations carried out suggested that the lateral screening distances in principle may be set equal to zero. Indeed, for such scenarios a source to building vertical separation of few meters is already enough to attenuate petroleum vapors below acceptable levels.