Validation of a New Conceptual Model of TCE Vapor Generation from Dissolved Groundwater Plumes

Carolyn Sauck, Tissa Illangasekare, Toshihiro Sakaki, Benjamin Petri, John Christ
Environmental Science and Engineering Department, Colorado School of Mines

Abstract. Intrusion of chemical vapor into subsurface structures and basements has received recent attention because of the potential health risks posed from inhaling contaminated air for long periods of time. Regulatory drivers require the evaluation of potential vapor intrusion (VI) when volatile chemicals are present in the soil and groundwater. The current approaches of evaluating the risk of VI involve the use of highly simplified screening models that make a number of assumptions with respect to how the processes contributing to mass transfer from entrapped non-aqueous phase liquid (NAPL) sources and from the NAPL dissolved in the groundwater plume are modeled. The need exists to develop conceptual models that describe the vapor generation, attenuation and transport to build better and more accurate prediction models for vapor intrusion risk assessment. With this as a goal, a research study is under way to improve our understanding of basic processes associated with vapor intrusion through experiments conducted at different test scales. The experimentally generated data is used to improve the conceptual understanding of the processes and test hypotheses on how vapor generation occurs. This data will also be used to develop and validate improved models for field applications. This paper focuses on a part of the study dealing with vapor generation from the dissolved groundwater plumes. The new proposed conceptual model under study is based on the observation that a groundwater plume with dissolved organics does not generate a significant organic vapor plume unless the groundwater table is fluctuating. The basic hypothesis is that mass transfer of dissolved organics in the water to organic vapor in the air of the unsaturated zone should be modeled as a rate limited process. An experimental study was conducted in a small two-dimensional test tank with dimensions 40 cm x 30 cm x 5 cm with sampling ports to extract water samples from the saturated zone. Conditions are created to simulate mass transfer from TCE dissolved in the groundwater plume under fluctuating water table conditions. In the first experiment, an aqueous solution of TCE with a dissolved concentration of 500 mg/L was placed in the tank and the water table was raised then lowered to create an unsaturated zone with contaminated residual water. A steady stream of air was passed through the tank and the effluent samples were collected and analyzed for TCE vapor concentration. Aqueous samples were extracted from the saturated zone to determine change in concentration of TCE in the plume. The preliminary data clearly shows that the effective mass transfer behavior is rate limited. The mass transfer is only equivalent to the equilibrium assumption based on Henry’s Law for a short period immediately after the water table drops, at which point the residually saturated soil contains dissolved TCE concentrations equal to those found in the groundwater plume. As the air flows through the tank, this TCE mass is quickly transferred to the vapor phase and purged from the system. Once the TCE mass in the residually saturated pore water is exhausted, a long tail in the effluent TCE vapor concentration is observed. The results suggest that the effective rate limited behavior in the whole test system is not only controlled by the mass transfer that occurs through water/air interfaces in the residually water saturated zone, but it is also a result of slow diffusion that occurs in the capillary fringe and within the stationary groundwater plume, creating the observed tail in effluent TCE vapor concentration. Experiments for different airflow rates and plume concentrations will be conducted to generate a comprehensive data set to validate both the conceptual model and numerical models that will be developed. Preliminary analysis of the small tank data using a multiphysics simulator COMSOL is presented.

1 Department of Civil and Environmental Engineering, United States Air Force Academy, Colorado Springs, CO