Direct measurement of VOC diffusivities in tree tissues: Impacts on tree-based phytoremediation and plant contamination

Recent discoveries in the phytoremediation of volatile organic compounds (VOCs) show that vapor-phase transport into roots leads to VOC removal from the vadose zone and diffusion and volatilization out of plants is an important fate following uptake. Volatilization to the atmosphere constitutes one fundamental terminal fate processes for VOCs that have been translocated from contaminated soil or groundwater, and diffusion constitutes the mass transfer mechanism to the plant–atmosphere interface. Therefore, VOC diffusion through woody plant tissues, that is, xylem, has a direct impact on contaminant fate in numerous vegetation–VOC interactions, including the phytoremediation of soil vapors and dissolved aqueous-phase contaminants. The diffusion of VOCs through freshly excised tree tissue was directly measured for common groundwater contaminants, chlorinated compounds such as trichloroethylene, perchloroethene, and tetrachloroethene and aromatic hydrocarbons such as benzene, toluene, and methyl tert-butyl ether. All compounds tested are currently being treated at full scale with tree-based phytoremediation. Diffusivities were determined by modeling the diffusive transport data with a one-dimensional diffusive flux model, developed to mimic the experimental arrangement. Wood–water partition coefficients were also determined as needed for the model application. Diffusivities in xylem tissues were found to be inversely related to molecular weight, and values determined herein were compared to previous modeling on the basis of a tortuous diffusion path in woody tissues. The comparison validates the predictive model for the first time and allows prediction for other compounds on the basis of chemical molecular weight and specific plant properties such as water, lignin, and gas contents. This research provides new insight into phytoremediation efforts and into potential fruit contamination for fruit-bearing trees, specifically establishing diffusion rates from the transpiration stream and modeling volatilization along the transpiration path, including the trunk and branches. This work also has importance in other plant–VOC interactions, such as potential uptake from the atmosphere for hydrophobic compounds and also uptake from vapor-phase soil contaminants.