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Evaluation of Trichloroethylene vapour fluxes using measurements at the soil-air interface and in the atmosphere close to the soil surface

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Industrialization during the 19^{th} and 20^{th} century led to the use of chemical products such as chlorinated solvents, e.g., trichloroethylene (TCE). At locations where volatile organic compounds were accidentally spilled on the soil during transport or leaked from their storage places, they could have migrated vertically through the unsaturated zone towards the underlying groundwater. As a result of their high volatility a large vapour plume is consequently formed. Understanding when, at which concentrations and how long, these pollutants will be present in soil, groundwater, atmosphere or indoor air, still remains a challenge up to date.

This study was conducted as part of a broader experiment of TCE multiphase mass transfer in a large (25m×12m×3m) well-instrumented artificial basin. TCE was injected as liquid phase in the vadose zone and experiments were conducted during several months. Firstly, TCE vapour fluxes were experimentally determined in two different ways: (a) direct measurements at the soil-air interface using a flux chamber and (b) evaluations based on measurements of TCE concentrations in the air above the soil surface using a modular experimental flume (5m×1m×1m) with a fixed air flow. Secondly, numerical simulations were conducted to analyse the differences between these two types of fluxes.

Several positions of the flume on the soil surface were tested. Based on the TCE concentrations measured in the air, vapour fluxes were determined with the aerodynamic method using the modified Thornthwaite-Holzmann equation. It assumes that the concentrations and velocities are temporally and spatially constant in horizontal planes and requires data on the gradients of concentration, horizontal wind velocity and temperature.

TCE vapour fluxes measured at the soil-air interface decrease with distance from the source zone. However, this decrease was either high, at the first stage of experiment (120μg/(m^{2}s) near the source zone compared to 1,1μg/(m^{2}s) 2m away) or low, 3 weeks later (38μg/(m^{2}s) near the source zone compared to 29μg/(m^{2}s) 2m away) depending on the flume position on the basin. In the measuring sections of the flume, a turbulent air velocity profile was established. TCE concentrations were correctly measured despite their low values and the derived profiles were close to logarithmic ones. In the case where the measured TCE vapour fluxes at the soil-air interface did not vary significantly in air flow direction, the concentration profiles obtained in the different modules were quite the same. Conversely, when vapour fluxes were strongly decreasing in flow direction, the measured concentration profiles were significantly different. Calculated vapour fluxes indicate the same trend as the vapour fluxes measured at the soil-air interface: strongly decreasing fluxes (31μg/(m^{2}s) near the source zone compared to 9μg/(m^{2}s) 2m away) or nearly constant fluxes (2,3μg/(m^{2}s) near the source zone compared to 2,2μg/(m^{2}s) 2m away). There is still one order of magnitude between the measured and calculated fluxes. This can be due to concentration profiles which are not necessarily in equilibrium conditions with TCE vapour fluxes from the vadose zone regardless of the flume position on the basin. Numerical simulations were used to illustrate this phenomenon.