

Modelling PFAS leaching across the vadose zone under contrasting climatic conditions

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Modelling PFAS leaching across the vadose zone under contrasting climatic conditions

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Abstract

Concern over per- and polyfluoroalkyl substances (PFAS) has grown steadily as this large family of compounds has become better studied. While widely used for their unique physico-chemical properties, PFAS are now detected across the environment at a global scale. The most significant releases originate from firefighting foams applied on industrial and airport sites, leading to widespread soil and groundwater contamination. The vadose zone, located between the polluted surface and underlying groundwater, is the first zone affected and plays an important role in regulating PFAS migration. Its position makes it a particularly sensitive zone, where retention and transport processes directly determine the concentrations reaching aquifers.

The overall objective of this thesis is to gain a better understanding of the transport processes governing PFAS contamination in the vadose zone. Specifically, the extent to which retention in the vadose zone can significantly reduce the concentrations reaching groundwater is assessed. To achieve this, the work is primarily based on the study by Wallis et al. (2022), which highlights several factors influencing PFAS transport in the unsaturated zone under dry Australian climatic conditions. It was therefore decided to investigate whether these parameters remain equally important in a meteorological context representative of Belgium, i.e., a more temperate environment.

Results obtained under both Mediterranean (Australian) and temperate (Belgian) climatic conditions highlight that physical processes such as precipitation and evapotranspiration exert a strong control on PFAS migration through the vadose zone. In the Australian case, evapotranspiration contributes to retaining most of the PFAS mass within the first two metres of soil for decades, whereas under Belgian temperate conditions it plays a smaller, though still significant, role. At this silty-clayey site, the air-water interface has comparatively greater influence under Belgian conditions, whereas under Australian conditions evapotranspiration dominates PFAS retention. When evapotranspiration is excluded, however, the differences between the two climates largely disappear, confirming its central role. In both settings, PFAS retention occurs mainly in clay-rich horizons, likely due to the larger air-water interfacial area. Finally, interannual climatic variability significantly affects PFAS leaching, underscoring the need for representative climatic records when modelling PFAS transport from the source zone to groundwater.

Keywords: Soil and groundwater pollution, PFAS, vadose zone, leaching, modelling, climate.
