

Tool 2.2: Guide to PFAS Fate and Transport in Surface and Groundwater Environments

The following document describes the mechanisms by which PFAS may be transported in surface and groundwater environments and the factors determining its eventual fate.

Per - and Polyfluoroalkyl Substances (PFAS) in Water
Type of Released PFAS
Relevance: Refers to PFAS chemical structure affecting their properties such as dissolution in water and interaction with sediment particles.
Specific factors to be evaluated and their effect on PFAS fate and transport: Solubility – Many commonly reported PFAS have high water solubility, easily dissolve when in contact with water, and may travel long distances. Organic carbon partitioning coefficients (K_{OC}) – The higher the K_{OC} value, the higher the potential for PFAS to partition from groundwater into soil organic carbon fraction and the higher the retardation of transport via groundwater. Since this parameter does not capture any contributions from electrostatic interactions, any estimate based on this value alone may underestimate or overestimate retardation. However, the following general rule should be valid for most PFAS: longer-chain PFAS are less mobile in water as compared to shorter-chain ones since their longer carbon chains have a stronger lipophobic effect and a subsequent higher affinity for the organic carbon fractions in sediments.
Environmental Characteristics
Relevance: Determines the potential for delayed transport and persistence in groundwater due to adsorption to the organic carbon fraction of soils or sediments or diffusion in and out of lower permeability materials.

<p>Per - and Polyfluoroalkyl Substances (PFAS) in Water</p>
<p><i>Specific factors to be evaluated and their effect on PFAS fate and transport:</i></p> <p><u>Soil-sediment organic carbon fraction (f_{oc})</u>– The higher the soil or sediment organic fraction, the higher the potential for retarded groundwater transport of PFAS. This parameter does not capture potential contributions from electrostatic interactions between electrostatically charged PFAS and soil particles, which could either decrease or increase PFAS mobility in groundwater (Interstate Technology and Regulatory Council 2020). Electrostatic interactions should be evaluated for each specific case, considering the charge of studied PFAS and the composition of soils from the saturated zone.</p> <p><u>Diffusion in and out of lower permeability materials</u> may be estimated through diffusion coefficients for released PFAS in various aquifer materials – determines the capacity for long-term PFAS persistence in an aquifer and are a topic of ongoing research (Interstate Technology and Regulatory Council 2022). If lower permeability materials (such as low-permeability soils, bedrock, or even concrete) are present, PFAS may diffuse in such materials and then back-diffuse from them into the groundwater, resulting in long-term persistence of PFAS in groundwater regardless of the original source status. Therefore, the potential for diffusion in and out of low permeability materials should be carefully evaluated since these materials may become secondary PFAS sources.</p>
<p>Micelle Formation Potential</p>
<p><i>Relevance:</i> Determines the potential for forming foams on water surface, affecting PFAS transport via water.</p>
<p><i>Specific factors to be evaluated and their effect on PFAS fate and transport:</i></p> <p><u>Concentration of PFAS in water</u> – At high dissolved concentrations (above critical micelle concentration (CMC)), PFAS would be expected to form micelles. Such concentrations have not been reported at airports and may not be expected. However, dissolved PFAS concentrations that could be 1,000 times lower may still result in the formation of hemimicelles or bilayers. Such lower PFAS concentrations may be encountered at some airport sites and may result in the increase in near-surface PFAS concentrations in surface waters (Yu, et al. 2009).</p>

Per - and Polyfluoroalkyl Substances (PFAS) in Water

Presence of disturbing factors – Winds, waves, or other turbulent forces, may introduce air into surface water bodies, may result in foam formation above the surface water bodies if PFAS dissolved concentration is high enough to form micelles, hemimicelles or bilayers. The presence of natural dissolved organic carbon within the water body can also enhance foam formation and contribute to enrichment of PFAS in these foams even at PFAS concentrations below reported CMCs (Schwichtenberg, et al. 2020). Such PFAS foams above water surface have been reported downgradient of PFAS release areas (AECOM 2021).

Potential for Precursor Transformation into Commonly Monitored PFAS Compounds

Relevance: Determines the potential for PFAS released in water to change in the amounts and composition due to precursor transformation.

Specific factors to be evaluated and their effect on PFAS fate and transport:

Total Oxidizable Precursor (TOP)– Evaluation of the TOP may be done on representative water samples (e.g., closer to the source and at various distances downgradient) to establish the potential of PFAS presence in water to generate higher concentrations and change the signature due to transformation of precursor PFAS (polyfluorinated PFAS) into the measured and reported common PFAS compounds.

Total Organic Fluorine (TOF) - Evaluation of the TOF may be done on representative water samples (for example, closer to the source and at various distances downgradient) in order to confirm the trends observed via TOP analysis and evaluate the real extent of the presence of PFAS that may not be established due to analytical limitations, since only a very small fraction of PFAS potentially present may be measured via common laboratory analytical techniques (between 40-80 individual PFAS out of thousands of PFAS potentially present).

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