PFAS Re-Foamed

A Challenge and A Treatment Solution

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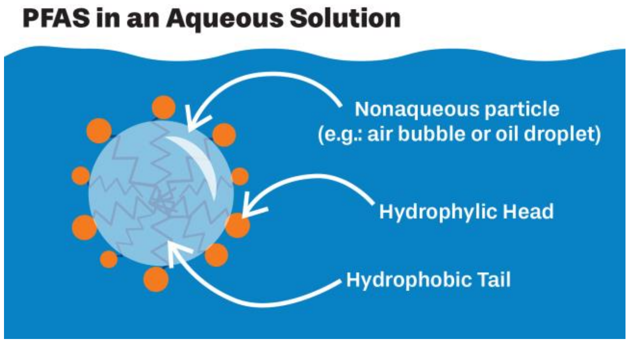
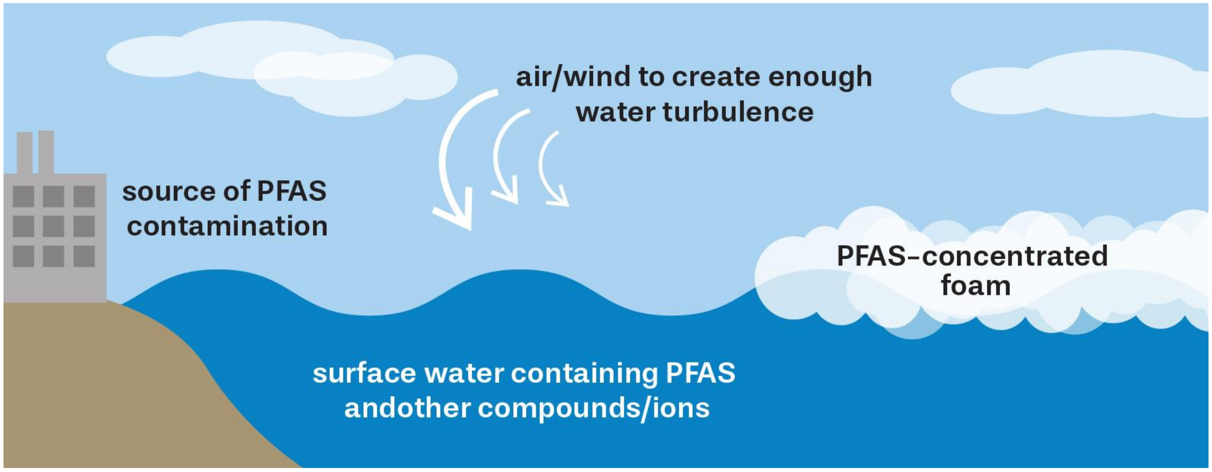
PFAS are surfactants



Each individual compound in the PFAS family has a fluorinated "tail" and a hydrophilic "head" and, thus, is a surfactant or a so-called "fluorosurfactant."

*Wikipedia's description of PFAS properties: "Fluorosurfactants can reduce the surface tension of water down to a value half of what is attainable by using hydrocarbon surfactants. This ability is due to the lipophobic nature of fluorocarbons, as **fluorosurfactants tend to concentrate at the liquid-air interface**….Fluorosurfactants are more stable and fit for harsh conditions than hydrocarbon surfactants because of the stability of the carbon–fluorine bond. Likewise, perfluorinated surfactants persist in the environment for that reason."*

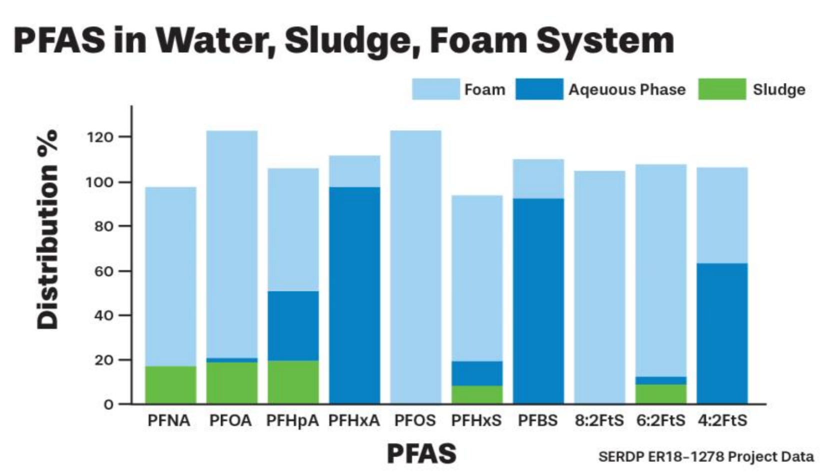
Discharged PFAS can be re-foamed in the environment



While PFAS foam can be observed directly from PFAS-foam discharges (e.g., AFFF), as well as other applications or accidental spills, in some cases the dissolved PFAS in surface water can be re-foamed under natural conditions due to its surfactant properties. The State of Michigan has recommended their residents to avoid contact with the foam on lakes and rivers if a community is impacted by a known or suspected PFAS contamination site. "***Foam on these lakes and rivers can have much higher amounts of PFAS than the water. Swallowing foam with PFAS could be a risk to your health***." Michigan's guidance document, "Foam: a Naturally-Occurrence Phenomenon," suggests that "if these materials are released to a water body in large quantities, they can cause foaming. In addition, the presence of silt in water, such as from a construction site, can cause foam".

Foam concentrating PFAS in traditional wastewater or leachate treatment processes

PFAS uptake at air-water interfaces have been reported in academic literature (Schaefer et al, 2019; Lyu et al., 2018; Campbell et al., 20019; Goss et al, 2006) and PFAS air-water interface partitioning coefficients have been developed by CDM Smith PFAS expert Dr. Charles Schaefer (Schaefer et al, 2019).



Additionally, empirical data also recognize significant PFAS (particularly long-chain PFAS) uptake by a foam layer when the foam co-exists with water and sludge. During the wastewater and landfill treatment processes, it is not uncommon to generate a layer of foam from naturally-occurring sources and organic surfactants, including organic pollutants with surfactant properties. While PFAS-specific treatment technologies for landfill leachate and wastewater treatment plants are still under development, the PFAS uptake phenomenon by air-water interface (i.e., foam) may shed light on a potential PFAS removal mechanism, if the foam is properly skimmed off and collected.

The PFAS foam fractionation phenomenon was recently studied using PFAS-impacted landfill leachate as the studied matrix (Robey et al., 2020). Researchers aerated the leachate until the foam generation slowed down. Then, the treated leachate samples and the collected foam layer that were coalesced back into liquid (PFAS concentrate) were subsequently analyzed. The study included 10 replicates and a mean removal percentage of 69% and a median removal percentage of 92%. **The treatment appears to be highly effective for all except the smallest and largest PFAS molecules.** The study suggests a high probability that PFAS can be removed via uptake by foam generated during the landfill leachate and WWTP treatment processes.

Using foam fractionation for water treatment

The properties of PFAS uptake by air-water interface have also been engineered into a water treatment process/technology. Through generation of gas bubbles and PFAS uptake by the bubbles, foam fractionation becomes a new option to separate and concentrate PFAS. For instance, OPEC Australia relies on this process for its Surface Active Foam Fractionation (SAFF) technology, which includes multiple processes that remove PFAS from groundwater and then concentrate PFAS into very low volumes of final PFAS concentrate. This SAFF technical has successfully treated 20 million liters of groundwater and only generates 500L of final PFAS concentrate without using chemicals or sorbents (OPEC 2020). Additionally, Evocra and Arcadis partnered on the development of an ozone fractionation process that utilizes ozone for PFAS uptake in industrial wastewater, paired with a separation/destruction solution that relies on plasma and argon gas.

Where else can this foam fractionation technology be applied?

In addition to the groundwater and landfill leachate examples mentioned above, based on the advantages of its low-cost operation and no spent sorbent generation, we consider this alternative technology to have potential applications for the following areas. However, more studies and life cycle assessment need to be conducted to validate the benefits of this technology. There is also the need for a polishing step to achieve stringent PFAS limits.

- Wastewater treatment plant
- In-situ groundwater remediation
- RO Rejects
- Investigation derived waste

Limitations of foam fractionation as a treatment technology

The surfactant properties are not identical among all species of PFAS. Longer-chain PFAS generally have good surfactant properties and can fractionate into bubbles effectively. The shorter-chain PFAS with higher water solubility and lower surfactant abilities generally have poorer removal efficiency compared to longer-chain PFAS.

It has been recommended by the literature that longer aeration time can enhance short-chain PFAS uptake by bubbles. While water with very low total organic carbon (TOC) can limit foam generation, water with higher TOC and higher ionic strength would be easier to generate foams from and improve the PFAS uptake by bubbles/foam.

PFAS foam concentrate destruction

Where can the final PFAS concentrate go? The small volume of PFAS foam concentrates can be incinerated or can be destroyed using destruction technologies previously discussed in another newsletter. The combination of foam fractionation and destruction technologies can certainly break the PFAS cycle without returning PFAS into the environment.

CDM Smith is currently verifying the foam fractionation technology

We believe a technology that is green and sustainable without the use of sorbent or manmade chemical additions should be an option when considering PFAS treatment. While foam fractionation effectiveness can vary—depending on the rate of aeration, water quality, PFAS chain lengths, bubble density and sizes, foam collection effectiveness, and the targeted concentration factor to reduce the foam volume—in general, this foam fractionation technology is an engineering process relatively easy to design, build and operate. At CDM Smith, we are testing different types of waters to determine the PFAS removal efficiency and the effectiveness of PFAS concentrate destruction. This technology is ready to mitigate PFAS at your sites.