Per-and polyfluoroalkyl substances (PFAS): an emerging contaminant

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Abstract
PFAS compounds are ubiquitous in the environment and in consumer products. Unlike other emergent contaminants this is a family of compounds with, literally, thousands members. Our knowledge of toxicological and environmental fate and transport properties is an evolving field. On the other hand, regulatory limits (when they exist) are extremely low and address only a limited handful of compounds. Because of their physical-chemical properties there are unconventional migration pathways, such as sewer exfiltration and biosolids residuals, that complicate site assessment and site closure. Surveys to date in Greece are fragmented and very limited in scope and focus. The objective of this study is to discuss how professional judgement should be used to collect appropriate data to both define the nature and extent of impact and to assess whether receptors may be adversely impacted and how to select an appropriate remedy, if mitigation of those impacts is warranted.

Keywords: Drinking water, PFAS, conceptual site model (CSM), Greece

1. Introduction and Methodology

Per- and polyfluoroalkyl substances (PFAS) are a complex family of more than 3,000 manmade aliphatic compounds having at least one carbon–fluorine (C-F) bond and containing a charged functional group head attached at one end. The charged group can be anionic, cationic, zwitterionic or nonionic. Because of their chemical structure, they have unique physical and chemical properties (for example, surfactant, oil-repelling, water-repelling, high thermal stability, high water solubility). As a result, PFAS have been extensively manufactured and used worldwide, in numerous commercial and industrial applications such as in military bases, fire training schools, airports, landfills, known contaminated sites, metal industries etc.

Generally, PFAS are persistent, bioaccumulative and toxic (PBT). Because of their PBT properties and high mobility, many regulatory jurisdictions have or are planning to develop regulatory standards. Some regulators have chosen to regulate specific compounds individually, while others have chosen to address both individual compounds and totals. For the most part, regulations are limited to drinking water, but other medial have occasionally been regulated as well. By-and-large, holistic development of multi-media standards has been lagging. These efforts are complicated by the vast universe of PFAS compounds and the lack of appropriate toxicologic information for the majority of them. However, lack of regulatory standards greatly hinders characterization and remediation.

PFAS hydrophobic, lipophobic, and surfactant properties combine to confer unique fate and transport characteristics. They are very soluble and do not form a separate phase, even at high concentrations. As a result, they will migrate rapidly. The ionic properties of the charged head control sorption to the soil or rock matrix. The ionic state of the matrix minerals (e.g. surface charge of clays and micas) will attract or repel PFAS, depending on the nature of the functional group head. Groundwater pH will also affect PFAS ability to sorb. Studies indicate that even the type of organic carbon present in the subsurface can contribute to differences in sorptive behavior. As a result, fate and transport of PFAS is highly dependent upon ambient geologic and geochemical conditions.

In addition to the absence of regulatory standards, investigation and remediation of PFAS impacted media are complicated by a number of unique factors: a) lack of validated and universally acceptable analytical methods for all targeted media; b) ubiquitous presence of PFAS in the environment creates an anthropogenic background; c) PFAS contaminated water is used in industrial processes and discharged to the environment after use; and d) processes such as wastewater treatment and conveyance result in unintended discharges.

In light of the constantly shifting and evolving regulatory and technical framework, it is critical to approach site investigations for PFAS in a deliberate and organized manner. Key in that, is the development of conceptual site model (CSM) and considers the unique properties of PFAS.

The CSM provides a description of relevant site features and the surface and subsurface conditions that help visualize the extent of identified contaminants of concern and the risk they pose to receptors. The CSM is an iterative tool that should be developed and refined as information is obtained during review of the site history and continues throughout the site and/or remedial investigation. Generally, the CSM should be striving to describe and put in perspective the following: nature and behavior of source(s); the site hydrogeologic model, with attention to the expected PFAS sorption behavior, past or current site activities that might affect contaminant behavior; relation of site to known or suspected ambient PFAS sources, data gaps.

In Greece water supply comes either from surface water bodies (mainly in big cities) or groundwater. The Aegean islands are partly supplied by local groundwater sources. Another very important factor of water supply in Greece is the numerous, mostly, unpermitted agricultural groundwater wells. The aim of this study is to prepare a preliminary characterization framework suitable to be used by the Greek water supply authorities for PFAS-contaminated site identification and management that has been prepared and presented herein.

2. A systematic approach for Greece

The research on PFAS in Greece is still very limited and no standards have been promulgated in the country so far. Zafeiraki et al. (2015) studied the presence of PFAS in some tap waters in Greece showing that PFAS concentration is generally low (<5.9 ng/L). Moreover, there are no PFAS monitoring data for surface water in Greece.

A preliminary framework suitable to be used by Greek water supply authorities for PFAS-contaminated sites identification and management is proposed and presented herein. The recommended framework consists of a series of stages as shown below:

- potential PFAS sources identification;
- potential PFAS receptors identification;
- CSM construction with most vulnerable PFAS water supply sources;
- confirmatory water sampling campaigns; and
- PFAS remediation technologies identification and evaluation.

For potential PFAS sources identification (e.g., military bases, fire training schools, airports, landfills, contaminated sites, metal plating industries etc.) all the available geospatial data sources in Greece would be identified and used (e.g., River Basin Management Plans, Google Earth maps, EIAs).

All available geospatial data for cities and settlements, authorized water supply sources (e.g. National Register of Water Abstraction) and geological background (e.g., Institution of Geology and Mineral Exploration) would be used to prioritize potential PFAS receptors based on risk assessment principles. Based on the above criteria, a CSM would be constructed where the most vulnerable PFAS affected water supply sources are identified.

In these water supply sources, sampling campaigns should be carried out to confirm or exclude the PFAS presence and thus optimize the initial CSM. Therefore, a detailed sampling protocol would be prepared based on the available international experience. A significant part of this protocol is to set the main principles based on which the Greek laboratories should be evaluated for reliable PFAS analysis.

Finally, the available remediation technologies for PFAS-contaminated sites would be identified and evaluated taking into account criteria such as performance, simplicity, capital cost, O&M cost, sustainability etc. that may be used even by small Greek water supply authorities.

References

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