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Viewpoint

PFAS Are Widespread, Not Ubiquitous: Clarifying Misconceptions About the Prevalence of "Forever Chemicals"

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Within the past decade, per- and polyfluoroalkyl substances (PFAS) have become well-known as "forever chemicals". Along with the explosion of research interest in PFAS, there is growing recognition that these compounds are widely detected in the environment. The term "ubiquitous" is commonly associated with PFAS: in fact, a Google Scholar search of the exact phrase "PFAS are ubiquitous" returns 438 results and a search of the exact phrase "PFAS are ubiquitous in the environment" returns 127 results.[1] However, the word "ubiquitous" means that something is found everywhere all of the time,[2] which the larger body of work on PFAS does not support. Although "ubiquitous" is often used with some amount of poetic license, its use in this way can be a disservice to the public and fields of study that seek to understand the occurrence, fate, transport, exposure, and effects of PFAS. In the environment, PFAS are not found in Pleistocene-age groundwater, in glacial ice layers formed thousands of years ago, deep within the earth, or in locations where there has been no direct or indirect interaction with the atmosphere since the development of PFAS, regardless of how excellent a laboratory's detection limits may be. Of these, it is particularly important to note that groundwater does not ubiquitously contain PFAS, given its use as a major source of drinking water supply. The term "ubiquitous" has caused confusion among researchers, leading to the common misconception that if a laboratory were able to measure at a level of parts per quadrillion (ppq) or lower, PFAS would be detectable in any environmental sample worldwide. Worse, it misinforms the public and needlessly overexaggerates an already complex issue. We instead encourage more accurate terms like "widespread", which means that something is widely found[2] and allows for the possibility of nondetect occurrences of PFAS in environmental samples.

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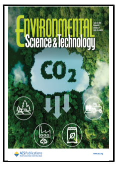

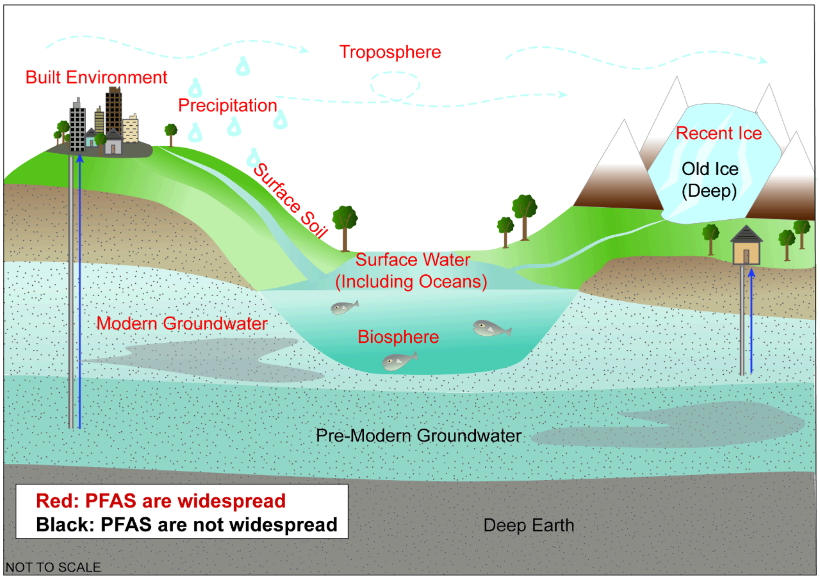

Figure 1. Conceptual diagram of where per- and polyfluoroalkyl substances (PFAS) are widespread (red text) and where they are not widespread (black text). The built environment includes artificial structures such as buildings, landscaping, and roads. Figure modified from ref 5. This figure was created by Federal employees as part of their official duties, constitutes a "U.S. government work", and is in the public domain.

WHEN MIGHT THE TERM "UBIQUITOUS" BE APPROPRIATE WHEN DISCUSSING PFAS IN THE ENVIRONMENT?

Generally, the term is appropriate when discussing the uppermost surface of the earth's crust (1) where the matrix under consideration has interacted directly or indirectly with the atmosphere (troposphere) since the widespread manufacturing, use, and resulting atmospheric emissions of PFAS circa the 1950s[3] or (2) where there have been releases of PFAS to the environment and subsequent transport away from sources, such as at sites where PFAS-containing aqueous film-forming foam was released or underground injection of PFAS-containing fluids. PFAS have been widely detected in the atmosphere, rain, surface waters, oceans, biota (including humans), and surface soils (Figure 1).[4] Because of this, one can reasonably hypothesize that if laboratories were able to measure to levels of ppq or lower, one would see PFAS detections in all of these matrices for which one of the above two conditions is met. There are cases in which PFAS may not be found in these matrices, however, such as in locations where old groundwater (recharged before PFAS were developed) is discharged to surface water. Other examples include shallow clay-rich soil where diffusion is limited and there has been no interaction with the atmosphere since the development of PFAS, or iron ore for steel or other building materials mined from the earth. Although these scenarios likely represent a minor fraction of these matrices, one must therefore be cautious when applying the term "ubiquitous" broadly across these environments, and terms like "widespread" and "frequently detected" are more appropriate.

WHEN IS THE TERM "UBIQUITOUS" NOT APPROPRIATE WHEN DISCUSSING PFAS IN THE ENVIRONMENT?

PFAS are not ubiquitous in deeper layers of the earth's crust, in old ice layers formed in glaciers cut off from atmospheric exchange prior to the 1950s, in groundwater that was recharged before PFAS were developed (Figure 1), or in any surface matrix in which the above two criteria are not met, such as springs consisting of old groundwater recharged before the development of PFAS.

Of these, groundwater is the most relevant to public health given its use as a drinking water resource worldwide. Within the United States, groundwater used for public drinking water supply is estimated to be 28% Pleistocene aged (>11 800 years ago) and 34% Holocene aged (~75−11 800 years ago), with the remaining 38% younger than ~75 years old ("modern" or recharged since 1953).[6] This modern groundwater coincides with the time frame in which PFAS were manufactured and used more broadly and is most likely to contain PFAS. However, PFAS will not be found in Pleistocene and older Holocene groundwater, regardless of how low laboratory detection limits are, unless contamination was introduced during drilling or water extraction or if the groundwater is mixed with younger sources.[6] In a study of groundwater in the eastern United States, 99% of PFAS detections were within water classified as modern (groundwater recharged in 1953 or later) or mixed modern/premodern groundwater, illustrating quantitatively the lack of PFAS in premodern groundwater.[7] Globally, it is estimated that <6% of groundwater within the top 2 km of the Earth's crust is less than 50 years old.[8] Over time, the fraction of groundwater recharged since the widespread use of PFAS will increase, which will increase the proportion of water potentially contaminated with PFAS. Currently, however, the notion that PFAS are ubiquitous in groundwater is an incorrect and misleading assumption.

Additionally, standard detection limits can complicate the assessment of the presence of PFAS in environmental matrices. For example, a recent study of surface water in Pennsylvania had reporting levels of <1 ng/L for perfluorooctanoate (PFOA) and perfluorooctane sulfonate (PFOS), yet only a 76% detection frequency for samples containing at least one PFAS,[9] suggesting that PFAS are not "ubiquitous" at these low reporting levels. Conversely, the search for lower detection limits is essential for accurately identifying PFAS, but it can also confound PFAS assessment. Specifically, when detection limits are at levels in equilibrium with the atmosphere, it becomes challenging to

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differentiate between the genuine presence of PFAS and contamination with PFAS that may arise from sampling or laboratory procedures. Such inadvertent introductions of PFAS into environmental matrices can distort the understanding of their actual prevalence, making the term “ubiquitous” misleading in this context.

WHY DOES THIS MATTER?

Because there is a heightened sense of public concern over PFAS, using terms like “ubiquitous”, particularly when discussing drinking water supplies, only increases panic and unease. The situation with PFAS contamination is already exceedingly difficult for regulators, policy makers, and water resource managers without needlessly adding unfounded concerns. As a scientific community, we should strive to be accurate and precise in the language we use. We hope that terms like “widespread” and “commonly detected” will replace the word “ubiquitous” when broadly discussing PFAS in the environment.

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Notes

The authors declare no competing financial interest.

Biography

Andrea Tokranov is a Research Hydrologist at the U.S. Geological Survey (USGS) where her research focuses on the environmental exposure, fate, and transport of contaminants of emerging concern utilizing a combination of field, laboratory, and modeling approaches. She manages a research laboratory at the USGS Eastern Ecological Science Center, where high-resolution mass spectrometry is used for targeted and nontargeted analysis of PFAS in environmental samples. She also co-leads the PFAS Core Technology Team within the Environmental Health Program of the Ecosystems Mission Area of the USGS. Andrea earned her Bachelor of Science degree from Brown University in 2012 and her Ph.D. from the Harvard University School of Engineering and Applied Sciences in 2019.

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