Editorial Corner

Poly- and Per-fluoroalkyl Substances (PFAS) in Water Environment

Debraj Bhattacharyya*
Departments of Civil Engineering and Climate Change, Indian Institute of Technology Hyderabad, Telangana, India

Malinee Sriariyanun
Department of Chemical and Process Engineering, The Sirindhorn International Thai-German Graduate School of Engineering (TGGS), King Mongkut's University of Technology North Bangkok, Bangkok, Thailand

* Corresponding author. E-mail: debrajb@ce.iith.ac.in, macintous@gmail.com DOI: 10.14416/j.asep.2021.08.001

Poly- and per-fluoroalkyl substances (PFAS, C_nF_{2n+1}-R) are a group of ubiquitous man-made emerging contaminants that are being used in a wide range of applications since the 1950s. PFAS have been detected in most environmental compartments including water, wastewater, soil, and atmospheric dust. PFAS have a non-polar hydrophobic alkyl chain attached to a polar hydrophilic charged functional group such as carboxylate, sulfonate, or phosphonate. PFAS are generally less water-soluble, however, these compounds can be degraded into per-fluoroalkyl carboxylic acids and per-fluoroalkyl sulfonic acids in the environment under aerobic conditions. These PFAS derivatives are highly water-soluble due to charged functional groups. Since some PFAS are aqueous solubility, concerns have been raised about PFAS being transmitted to humans through contaminated drinking water. PFAS are highly resistant to thermal, chemical, and biological degradation and are highly accumulative in nature. PFAS have been observed to bio-magnify through the trophic web and have long half-life (3–8 years) depending on the length of the carbon chain present in the compounds.

Studies have found that PFAS primarily enter surface and groundwater sources through discharge of untreated or partially treated sewage and industrial effluents. Effluents from allied-PFAS product manufacturing are considered as the primary sources. Army training centers, fire-fighting camps, airports where aqueous film-forming foams are used are also notable sources of PFAS. Other possible sources of PFAS include urban run-off, dry or wet atmospheric deposition, and infiltration of leachate into groundwater from municipal and hazardous waste landfill sites.

Clinical studies have proved that exposure to PFAS results in multiple ill-effects on immune systems during the early stage of pregnancy, pre- and post-natal stages, and on the growth period of children. PFAS can cross the placental barrier and their exposure during pregnancy can affect birth size and brain development. Neonatal exposures of PFAS cause pneumonia, respiratory syncytial virus infection, wheezing, asthma, eczema and also stimulate chickenpox and otitis media. PFAS exposure affects functions of liver, kidney, and thyroid. Long-chain PFAS accumulate in the liver as it is the primary target organ. These compounds cause toxicity to humans by increasing the lipid and uric acid levels in human blood, and reducing glomerular filtration, resulting in chronic kidney disease. PFAS accumulations in humans can cause testicular, ovarian, and breast cancer. In women, PFAS exposure delays menarche, disrupts the menstruation cycle, alters sex hormone levels, and affects estrogen secretion.

For the past few decades, PFAS contamination has grown into a serious health threat. Countries like the United States, Australia, the European Union, and China have formulated guidelines and implementation strategies to combat PFAS. Some PFAS have been included in the candidate list of regulatory substances, in the watch list of priority substances under water framework directive of the EU, and in the list of persistent organic pollutant (POP) at the Stockholm Convention on POP in 2009. Subsequently, emphasis has also been given to replace long-chain PFAS with short-chain and ultra-short-chain PFAS. However, their performance was observed to be less when compared with that of the long-chain PFAS. As a result, relatively high quantities of short-chain PFAS were used to achieve a comparable efficiency. At the same time, uncertainty about the toxicity of short-chain PFAS existed. It was also observed that the continuous release of short-chain PFAS may also harm human health and the environment in the long run, although they are said to be less bio-accumulative than the long-chain PFAS. Through participation in the EPA Stewardship Program, major PFAS manufacturers from North America and Europe have voluntarily committed to eliminate the use of long-chain PFAS by developing alternative short-chain PFAS. However, long-chain PFAS can still be detected in environment due to their persistent nature and also because of the fact that not all participated in the EPA Stewardship Program still produce long-chain PFAS.

PFAS are resistant to degradation due to strong C−F bond. It is difficult to eliminate these compounds with traditional treatment methods, thereby potentially exposing humans to drinking water polluted with PFAS. Coagulation, flocculation, and sedimentation, as well as rapid sand filtration are not effective methods for eliminating PFAS from water and wastewater. Most PFAS were not oxidized by oxidation or advanced oxidation processes in conventional drinking water treatment plants. UV irradiation is often ineffective at normal or higher doses for PFAS removal. Granular activated carbon (GAC) has the potential to make drinking water free of PFAS. Longer-chain PFAS adsorb well onto sorbents than short-chain PFAS. The short-chain compounds on the other hand, easily achieve a breakthrough. The effectiveness of GAC is reduced in the presence of other organic matter. Therefore, pretreatment and regular filter reactivation are required. Although Anion Exchange resins are effective at removing PFAS, they are not commonly used in drinking water treatment plants. More information is required on resin effectiveness and water characteristics. The relevant factors to consider before implementing resins are resin regeneration and brine disposal. The majority of PFAS will be rejected by Nanofiltration/Reverse Osmosis membranes. However, lower molecular weight and neutral PFAS may not be removed by some NF membranes. Conscious efforts should be made to eliminate or minimize the PFAS exposure. Also, PFAS often co-exist with other pollutants in water and are difficult to remove in conventional treatment plants. Therefore, a combination of different approaches is required for its treatment. Choosing the best remediation strategy be challenging and will depend on several factors, such as site location, water quality, PFAS levels, treatment targets, hydrogeology, etc.

Assoc. Prof. Dr. Debraj Bhattacharyya

Assoc. Prof. Dr. Malinee Sriariyanun
Editorial Board