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Remediation of water from per-/poly-fluoroalkyl substances (PFAS) – Challenges and perspectives

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ABSTRACT

Per-/poly-fluoroalkyl substances (PFAS) are an emerging class of environmental contaminants used as additives to either enhance the thermo-chemical stability of products or alter the properties of surfaces. PFAS are amphiphilic molecules, composed of fluoro-alkyl chains terminated by specialized functional groups such as carboxylic, sulphonic acids, phosphates, sulphonamides, and betaines; offering surfactant-like behavior, and making them highly persistent and mobile across all environmental compartments. The treatment of PFAS contaminated water remains very complex due to the typically low concentrations and because of the complexity of the wastewater matrix in which PFAS are present. Exposure to trace amounts of PFAS can cause severe health impacts across all life forms. Trains of treatment or removal techniques must be employed to achieve higher removal rates. This review assesses existing methods for PFAS capture, concentration, and degradation from wastewaters. The performance and selectivity, as well as scalability and cost-effectiveness, of these techniques are critically compared while operating limitations, as well as emerging solutions, are presented to evaluate the combinatorial benefits of tandem operations for successful PFAS remediation. The discussion is then focused on

Abbreviations: ACs, Activated Carbons; AFFF, Aqueous Film-Forming Foams; AFPO, Ammonium Perfluorooctanoate; ASH, Air Sparged Hydrocyclon; BCF, Bio-accumulation Factor; BDD, Boron-Doped Diamond; $BiFeO_3$, Bismuth Ferrite; BiOCl, Bismuth Oxychloride; C.D., Current Density; $CaCl_2$, Calcium Chloride; CaF_2, Calcium Fluoride; CBCs, Coconut-Based Carbons; CNTs, Carbon Nanotubes; DCMD, Direct Contact Membrane Distillation; DMAPAA-Q, (N-[3-(Dimethylamino) Propyl]Acrylamide Methyl Chloride Quaternary;; EO, Electro-Oxidation; FTCAs, Fluorotelomer Carboxylic Acid; FTOH, Fluorotelomer Alcohol; FTS, Fluorotelomer sulfonate; Ga_2O_3, Gallium Trioxide; GAC, Granular Activated Carbon; GO, Graphene Oxide; H_2O_2, Hydrogen Peroxide; HCl, Hydrochloric acid; HF, Hydrogen fluoride; In_2O_3, Indium Trioxide; IrO_2, Iridium Dioxide; K_{OC}, Organic-Carbon Partition Coefficient; K_{OW}, Octanol-Water Partition Coefficient; LCMS, Liquid Chromatography Mass Spectroscopy; LDH, Layered Double Hydroxides; LOQ, Limit of Quantification; MF, Microfiltration; MIPs, Molecularly Imprinted Polymers; MnO_x, Manganese Oxides; MQL, Method Quantification Limit; MWCNTs, Multi-Walled Carbon Nanotubes; Na_2SO_4, Sodium Sulfate; NaCl, Sodium Chloride; NaOH, Sodium hydroxide; NF, Nanofiltration; O_3, Ozone; OEP, Oxygen Evolution Potential; OH^-, Hydroxyl Ion; PAC, Powdered Activated Carbon; PbO_2, Lead Oxide; PC, Photo-Catalysis; PDFA, Perfluorodecanoic Acid; PEC, Photo-Electrocatalytic; PFAAs, Perfluoroalkyl Acids; PFAS, Per-/Poly-Fluoroalkyl Substances; PFBA C_3F_7COOH, Perfluorobutanoic Acid; PFBS, Perfluorobutane Sulfonate; PFCAs, Perfluoro Carboxylic Acids; PFCs, Perfluorinated Compounds; PFDA, Perfluorodecanoic acid; PFDoDA, Perfluorododecanate; PFHpA $C_6F_{13}COOH$, Perfluoroheptanoic Acid; PFHpS, Perfluoroheptanesulfonic Acid; PFHxA $C_5F_{11}COOH$, Perfluorohexanoic Acid; PFHxS, Perfluorohexane sulfonate; PFNA, Perfluorononanoic Acid; PFOA $C_7F_{15}COOH$, Perfluorooctanoic Acid; PFOS, Perfluorooctane Sulphonic Acid; PFOSA, Perfluorooctane Sulfonamide; PFPeA C_4F_9COOH, Perfluoropentanoic Acid; PFPrA C_2F_5COOH, Perfluoropropionic Acid; PFSAs, Perfluoro Sulphonic Acids; PFTDA PFTeDA, Perfluorotetradecanoic Acid; PFTrDA, Perfluorotridecanoic Acid; PFUnDA, Perfluoroundecanoic Acid; polyDADMAC, Polydiallyldimethyl Ammonium Chloride; POPs, Persistent Organic Pollutants; POSA, Perfluorooctane sulfonamide; POSF, Perfluorooctane Sulfonyl Fluoride; rGO, Reduced Graphene Oxide; RO, Reverse Osmosis; RuO_2, Ruthenium oxide; $S_2O_8^{2-}$, Persulfate; SnO_2, Tin dioxide; SWCNTs, Single Walled Carbon Nanotubes; TFA CF_3COOH, Trifluoroacetic Acid; TiO_2, Titanium dioxide; UF, Ultrafiltration; U.S. EPA, United States Environmental Protection Agency; WTPs, Water Treatment Plants; WWTPs, Wastewater Treatment Plants; ZVI, Zero Valent Iron.

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