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Fate and behaviour of PFAS in natural resources: towards a safe circular economy

Julie Lions[1], Anne Togola[1], Hans Groot[2], Martine Bakker[3], Eric D. van Hullebusch[4], Ulf Miehe[5], Veronika Zhiteneva[5], Valeria Dulio[6], Pierre Boucard[6], Julia Hartmann[3], Nicole Heine[7], Thomas Track[7], Alexander Sperlich[8], Matthias Zessner[9], Carme Bosch[10], Massimiliano Sgroi[11], Francesco Fatone[11], Sonia Jou Claus[10], Stefan Colombano[1], and the H2020 PROMISCES project partners*
[1]French Geological Survey (BRGM), DEPA/EVE, Orléans, France (j.lions@brgm.fr)
[2]DELTARES, Boussinesqweg 1, 2629HV Delft, Netherlands
[3]Dutch National Institute for Public Health and the Environment (RIVM); Antonie van Leeuwenhoeklaan 9, 3721 MA Bilthoven, The Netherlands
[4]Université Paris Cité, Institut de Physique du Globe de Paris, CNRS, 75005 Paris, France
[5]Kompetenzzentrum Wasser Berlin gGmbH (KWB), Cicerostrasse 24, 10709 Berlin, Germany
[6]Institut national de l'environnement industriel et des risques (INERIS), rue Jacques Taffanel, 60550 Verneuil-en-Halatte, France
[7]DECHEMA e.V., Theodor-Heuss-Allee 25, 60486 Frankfurt/Main, Germany
[8]Berliner Wasserbetriebe (BWB), Neue Jüdenstrasse 1, 10179 Berlin, Germany
[9]TU Wien, Institut for Water Quality and Resources Management, Karlsplatz 13, 1040 Vienna, Austria
[10]EURECAT, Centre Tecnològic de Catalunya, Plaça de la Ciència, 2, 08242, Manresa, Spain
[11]Universita' Politecnica delle Marche (UNIVPM), Department SIMAU, , Via Brecce Bianche 12, 60121, Ancona, Italy
*A full list of authors appears at the end of the abstract

Resource scarcity has increased interest in the circular economy (CE) for environmental, economic, and social sustainability. The goal is to minimize waste generation and efficiently incorporate waste back into production processes without adversely impacting human health or the environment.

By recognising the importance of assessing the potential accumulation of chemicals and associated risks within the CE, the Horizon 2020 project PROMISCES focuses specifically on the so-called "forever chemicals" such as per- and polyfluoroalkyl substances (PFAS) in five CE routes, including semi-closed water cycles for drinking water (DW), wastewater reuse in agriculture, nutrient recovery from sewage sludge, material recovery from dredged sediments, and groundwater and land remediation for safe reuse.

Based on the results from literature reviews, experiments and case studies, the project addresses the fate and transfer of PFAS across these CE routes. Despite the challenge of analysing PFAS in complex matrices such as sludge and wastewater, robust and sensitive methods have been developed and the following conclusions can be obtained:

Wastewater treatment provides a limited removal efficiency, especially when wastewater

treatment plants receive large contributions from industrial wastewater streams. Advanced wastewater treatment technologies implemented for micro-pollutant removal are not fully effective for all PFAS. Additionally, degradation of precursors can result in increased PFAS concentrations in the effluent. Consequently, until new treatment solutions are implemented, PFAS hotspots may not be able to implement wastewater reuse (e.g. for irrigation).

Riverbank filtration, as a first DW treatment stage, demonstrates limited removal of PFAS. Accordingly, in the presence of an upstream emission source, DW providers may need to implement advanced water treatment technologies.

During wastewater and landfill leachate treatment, particularly long-chain PFAS may accumulate in sludge. Although low level of targeted PFAS compounds were quantified, the presence of precursors in sludge is suspected and may present a barrier to its agronomic valorization. To date, PFAS content in sewage sludge is not regulated and depending on the country, sludge may be spread on agricultural land, incinerated, or disposed in landfills.

Valorisation of dredged sediment as secondary raw material has the advantage of limiting the cost of management and limiting the use of raw materials. Depending on the nature of the sediment (in particular organic matter content) and on the PFAS loads, different treatments result in different removal efficiencies. Moreover, treatments can result in the formation of new persistent PFAS from precursors. When initial loads are low, it seems possible to eliminate PFAS from the solid fraction. Nevertheless, the destruction of residual PFAS in the washing solution is necessary.

In situ and on-site treatments of water and soil are confronted with environmental realities. Even if treatment trains can help overcome the complexity of PFAS treatment, the process efficiency is highly dependent on the alkyl chain length and the functional groups. As for sediment, although various treatment techniques exist, such as PFAS immobilisation, these do not result in complete degradation or removal of PFAS. This stands in the way of achieving a CE, as only after full removal of PFAS, safe reuse of resources can be guaranteed.

H2020 PROMISCES project partners: Bureau de Recherches Géologiques et Minières; Kompetenzzentrum Wasser Berlin gGmbH; Institut national de l'environnement industriel et des risques; Institut de Physique du Globe de Paris; QSAR Lab spolka z ograniczona odpowiedzialnoscia; Umweltbundesamt; Berliner Wasserbetriebe; BioDetection Systems ; Fundacio EURECAT; COLAS Environnement; Gesellschaft für Chemische Technik und Biotechnologie e.V.; Rijksinstituut voor Volksgezondheid en Milieu; Agencia Estatal Consejo Superior de Investigaciones Científicas; Deltares; TU Wien; Bundesanstalt fuer Gewaesserkunde; UNIVERSITA' POLITECNICA DELLE MARCHE ; Consorci Besòs Tordera; HOOGHEEMRAADSCHAP VAN DELFLAND ; ESOLVE Consultoria e ingenieria medioambiental ; ACEA ; SOFIA UNIVERSITY ST KLIMENT OHRIDSKI; SIMAM ; MicroLife Solutions; SINAPTEC; Budapest Waterworks.