A holistic solution for PFAS pollution. Aims, solutions and remediation technologies developed under the H2020 project SCENARIOS

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In the last decade, per- and polyfluoroalkyl substances (PFAS) have been added to the list of pollutants of concern because they are mobile, persistent, bioaccumulative toxic in long term and potentially carcinogenic.. PFASs are detected in numerous environmental matrices, confirming their high persistence and mobility in the environment. In addition, the chemical structure of PFAS and their reactivity pose a technological challenge for remediation efforts. SCENARIOS is an H2020 research and innovation project involving 19 partners from 11 countries. The main objective is to fill knowledge gaps and achieve breakthrough TRL advances in toxicological assessment, congener detection and remediation of PFAS with unprecedented energy balance and virtually no external chemical additives, supporting EU countries in decision-making related to environmental safety and human health. The project will evaluate and develop state-of-the-art technologies and strategies for the detection, quantification, control, and elimination of PFAS in soil, vadose zone, and water by targeting outcomes within the 4 remediation quadrants: In-situ Soil, In-situ Water, Ex-situ Soil, and Ex-situ Water. Likewise, the project is developing a set of solutions to control pollution and remediate PFAS contaminated soils (agricultural and industrial) and groundwater. All these solutions will comply with the principle of green chemistry, zero energy, sustainability and circular economy.mm wide.

In order to choose the best technologies for various conditions and document the efficiency of the remediation actions, it is essential to provide the optimal overview of the geological/hydraulic conditions at the contaminated site. Constructing models with adequate degree of details, dense data coverage with high-quality data is necessary. Many studies rely of few data sources; resulting in relatively sparse data, however, in this study, we demonstrate how multiple different data sources may be combined in order to gain new insight on the geological history, which is central to the subsequent 3D geological modelling. The analyses in this study include (I) GIS analysis (Geomorphology/geology/aerial photos/high resolution elevation models), (II) Detailed borehole analysis (geotechnical, petrographic and textural analyses), (III) Spear auger mapping, (IV) Hydraulic test/analysis, (V) Chemical analysis, (VI) 3-d geological modelling. All data will be incorporated in the GIS platform, GeoAtlasLive, allowing visualization of GIS layers, the geological model and hydraulic, chemical, data related to water and soil sampling points in a 3-D framework, thus allowing the optimal overview of multiple data in order to optimize the design for optimal monitoring and remediating strategies. The model also forms the framework for detailed analysis of multiscale (lab-field scale) studies of contaminant transport/degradation processes in order to evaluate efficiency and risk assessment of various remediation approaches.

One new technology for high-quality data collection is the advanced Vadose zone Monitoring System (VMS). As most water resources pollution start with down percolation of contaminated water from land surface through the unsaturated zone to the underlying groundwater, and from there to related surface water resources such as rivers,lakes and sea oceans. Therefore, real time monitoring of contaminant migration in the unsaturated zone is critical for characterization of pollutants. VMS technology provides real time continuous information on water flow and contaminant migration through the unsaturated zone, from land surface to the water-table, and offer the possibility to analyse unique data on PFAS transport in the subsurface, with respect to the site-specific hydro-geological, chemical and climatic conditions. In the framework of the SCENARIOS project, mobility of PFAS in natural unsaturated zones, as measured in full scale field conditions, will be analysed by combining measurements of their interfacial properties with experiments in porous media models able to describe the fate of PFAS from the pore-scale to aquifer-scale. VMS will be implemented at typical PFAS contaminated sites, landfills and firefighting training zones, and evaluated.

For treatment of PFAS, treatment technologies developed so far include adsorptive and destructive methods. But in 2021 a new PFAS remediation technology was introduced to the market, based on foam fractionation, which is a well-known technology within the food and aquarium industry. The technology is called SAFF – Surface Active Foam Fractionation, and is developed by EPOC Enviro (EPOC), Australia. The SAFF process utilizes the physio-chemical properties of PFAS compounds to attach to fine air bubbles as a result of its hydrophobic and hydrophilic properties. When accurately controlled bubbles are introduced and allowed to rise in a narrow column of water, the bubbles become exceptionally effective in collecting PFAS compounds that are loosely bound to the water molecules. Once at the surface, PFAS can easily be removed by separation and concentration through a passive ”spill over weir” system, and a patented active vacuum system. Treated (aerated) water can then be released to the recipient.

Parameter	Carbon chain length	Removal rates (%) full scale Ground Water Australia, 80 000m3	Removal rates (%) full scale leachate at Telge landfill >100 000 m3	Removal rates (%) full scale leachate at NSR Lanfill >10 000 m3
PFDA	C10	100%	100%	90%
PFNA	C9	100%	100%	97%
6:2 FTS	C8	100%	100%	100%
PFOA	C8	100%	100%	100%
PFOS	C8	100%	100%	100%
PFHpA	C7	80%	98%	99%
PFHxS	C6	99%	100%	100%
PFHxA	C6	20-30%	29%	54%
PFPeA	C5	25-35%	3%	0%
PFBS	C4	10-20%	10%	43%
PFBA	C4	30-40%	1%	8%

The collected PFAS concentrate is passed on to further fractionation steps to become a high concentration liquid of relatively small volume suitable for destruction via permanent destruction techniques such as high temperature thermal combustion, Super Critical Water Oxidation (SCWO) or Electrochemical Oxidation (EO). But all these destruction technologies face important challenges with energy demand and cost due to the recalcitrant nature of PFAS and the C–F bond (1). A promising destructive treatment technology which is well-established for its efficiency to remove a wide range of persistent contaminants in water is Cold Atmospheric Plasma (CAP) exhibiting advantages such as high energy efficiency, effectiveness, rapidness, and green character.[2] In this project, a novel highly energy efficient CAP method is implemented for the degradation of PFOA in water. A nanosecond pulsed (NSP) generator and an in-liquid configuration of the CAP reactor for the direct generation of plasma species in the form of bubbles inside water, were used in order to maximize the energy efficiency of the process. The impact of the most critical parameters including treatment time, pulse voltage/frequency, plasma gas, PFOA initial concentration, etc. will be examined in detail for the method optimization, and the technology will be evaluated to show if this technology can be a sustainable solution for destruction of PFAS contaminated medias such as the concentrate generated by SAFF.
In this talk, the proposed technologies and results obtained will be presented and discussed.