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ABSTRACTS BOOK

Session 1 – Detection, Modelling and Environmental Behaviour of PFAS

Multiscale site characterisation of a PFAS contaminated Site at Korsør, Denmark

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Abstract

The extensive use of products containing high concentrations of Per- and Polyfluoroalkyl Substances (PFAS) has led to their spreading in soil and groundwater at many places. Risk assessment of contaminated sites rely heavily on calculating or assessing the mass-flux from the source area towards the Vadose zone to the groundwater.

At the national PFAS test Centre at the Firefighting School RESC in Korsør in Denmark, extensive use of aqueous film forming foams (AFFF) has spread into the subsurface and groundwater and has contaminated a large area on and around the site.

In order to perform modelling of the spreading of PFAS to the groundwater, a conceptual 3-D geological model was constructed.

Numerous soil-samples were collected from both boreholes and a small excavation and analysed carefully in order to precisely determine the soil characteristic parameters necessary for modelling PFAS migration in the Vadose zone. Also, the distribution of various soil-types along with potential macropores that may influence the bulk hydraulic properties of the soil was investigated.

At the same time an advanced monitoring system (VMS) was installed for continuous monitoring of water content and precipitation at 6 depths in the Vadose zone along with sampling of water from the same depths, in order to precisely monitor the relation between the PFAS distribution and concentration in soil and pore-water over a period of 2 years. Thus, allowing the observation of the influence of annual variations in precipitation to the migration of PFAS in the soil and groundwater.

The relevance of the soil-types in terms of upscaling procedures and comparison to other areas, was assessed by constructing a large-scale geological model that illustrated the site-specific conditions related to the general geological conditions of Denmark and Northern Europe.

The primary soil types in Northern Europe was deposited during the last glacial period and consists mainly of clay-sandy tills and clayey, sandy, gravelly meltwater deposits. The Korsør site is characterized by meltwater sand with some fine layers of clay and silt, and some sandy till.

Accordingly, most relevant soil-types are present in Korsør except for clay till which covers 40% of Denmark and some marine and organic soils. Accordingly, there is a knowledge gap and further investigations are recommended involving these soil-type.

The main results of the characterization and the monitoring shows that PFAS migration varies quite a lot depending on the water-content in the soil and hence also the precipitation.

Abstract No. 1

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PFAS Transport Dynamics in the Unsaturated Zone

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Abstract

Per- and Polyfluoroalkyl substances (PFAS) are persistent environmental contaminants known for long-term retention in subsurface environments. In this study, the transport dynamics of PFAS compounds were monitored on different scales, from controlled column experiments to field monitoring setups at contaminated sites.

At the lab, simultaneous transport of long- and short-chain PFAS (PFOS, PFOA, PFHxA, and PFPeA) was examined in a large (3 m) column designed to simulate unsaturated flow conditions through episodic infiltration cycles in the unsaturated zone. Similarly, in the field, vadose zone monitoring systems (VMS), which enabled frequent collection of the sediment pore-water and continuous measurement of variation in sediment moisture, were used for tracking PFAS transport at two stations- a decommissioned firefighting training facility (Korsor, Denmark) and a firefighting response site (Ashkelon, Israel).

Column experiment results show that short-chain PFAS compounds (PFHxA and PFPeA) demonstrated high mobility with minimal retardation, closely mirroring the behaviour of the conservative tracer bromide. In contrast, long-chain PFAS (PFOS and PFOA) exhibited strong retention, with their breakthrough curves indicating substantial delays and concentration variability linked to wetting and drainage cycles. Variations in sediment water content, driven by irregular infiltration events, affect PFAS adsorption–desorption processes, primarily through sorption to the solid phase and the air–water interface.

At the two field setups, both short- and long-chain PFAS were found to be in high concentration in the unsaturated profiles. At Korsor, a typical Scandinavian climate, the transport dynamic of both short-chain and long-chain PFAS was attributed to water content variation from infiltration. While short-chain PFAS (PFPeA, PFHxA) were released throughout the monitoring period, long-chain PFAS (PFOA and PFOS) were significantly released during periods of increased water content. Yet, the combined influence of evapotranspiration was observed to reduce the flow-transport dynamics of PFAS, especially in the shallow unsaturated zone during drier seasons. Additionally, sediment analysis from the sites showed high concentrations of both short-chain and long-chain PFAS in macropore areas and clay and organic-rich sediments.

At Ashkelon, a typical Mediterranean climate, similar PFAS transport dynamics were observed, where both short-chain and long-chain PFAS were released throughout the monitoring season. Yet, during periods of increased water content, significant release of long-chain PFAS (PFOA and PFOS) was observed. Long-chain PFOS, a highly retarding PFAS variant, was observed at high concentrations in groundwater, providing likely evidence of the influence of preferential flow-transport dynamics at this site.

These findings show that the dynamics of PFAS transport are a nonlinear water content-dependent process. Likewise, infiltration-driven processes play a critical role in PFAS mobility and are essential for accurately understanding PFAS fate and transport in the subsurface. Soil heterogeneity and climate parameters further complicate the transport of PFAS. As such, an integrated approach incorporating these factors would offer valuable insights for effective remediation strategies at contaminated sites.

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Numerical modeling of PFAS fate in Korsør site

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Abstract

The extensive use of products containing high concentrations of Per- and Polyfluoroalkyl Substances (PFAS) has led to their spreading in soil and groundwater. In certain locations, like Korsør in Denmark, a former firefighting training site, the extensive spreading of aqueous film forming foams (AFFF) in subsurface has led to the detection of measurable PFAS concentrations in the vadose zone. The numerical modelling of the PFAS fate in unsaturated and saturated zones enables us to understand the main PFAS transport mechanisms and quantify the dynamics of PFAS fluxes release toward the aquifer.

By accounting for the main hydrogeological and physicochemical parameters, a simplified 3D numerical model of Korsør site was considered in the platform of COMSOL, and two PFAS contamination scenarios were simulated for PFOA, PFDA, PFOS, PFBA: (1) focusing only on the unsaturated zone, applying a one-day PFAS pulse covering a broad area of the top, the fate of PFAS was detected during a period of 2 years (short-term); (2) looking at both the unsaturated and saturated zone, applying periodic 1-day PFAS pulses every 60 days over a narrow area of the ground surface, the fate of PFAS was detected during a period of 32 years (long-term). Three alternative case studies were simulated with regard to the mechanism of PFAS migration downwards: (a) convective and dispersive mass-transfer; (b) mass-transfer coupled with linear equilibrium sorption on soil surface; (c) mass-transfer coupled with soil sorption and interfacial sorption.

Regarding the short-term simulations, compared to the pure convective / dispersive PFAS transport, the soil sorption retains the PFAS in the upper layers and delays their spreading toward the groundwater, while the interfacial PFAS sorption results in a reduction of the PFAS concentration dissolved in aqueous phase of unsaturated zone. Regarding the long-term simulations, the delayed PFAS migration, due to sorption on soil or sorption on soil and air/water interfaces lead to longer arrival times at water table in relation to the convective/dispersive PFAS mass-transfer. This is also reflected in the higher values of PFAS mass flux (negative values indicate flow downwards) entering the water-table, through pure mass-transfer compared to the sorption cases.

Abstract No. 3

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Monitoring PFAS Migration Trends in Municipal Landfills

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Abstract

Landfills play a vital role in municipal solid waste management (MSW), but they pose challenges such as groundwater contamination from leachate transport to the groundwater, and greenhouse gas emissions, creating various long-term environmental impacts. Per- and Polyfluoroalkyl substances (PFAS) are persistent environmental contaminants detected in landfills among many other sources.

In our study, we examined two municipal solid waste (MSW) landfills with distinct environmental characteristics. The first site is a closed, unlined landfill located near Rishon LeZion, Israel, previously used for domestic waste disposal. It features a 16-meter-high waste mound and a 14-meter-thick unsaturated soil layer separating the waste from the underlying water table. The second site is a 5-meter deep, unlined landfill in Trelleborg, Sweden, initially used for domestic and industrial waste and later repurposed as a firefighting training facility. The Vadose Zone Monitoring System (VMS) was installed at both sites to monitor real-time water percolation along the landfill waste profile and the unsaturated zone, allowing for the leachate pore water sampling.

At the Rishon site, multiple PFAS compounds were detected. Notably, PFBA was found at high concentrations near the bottom lining of the waste mound, indicating preferential mobility. In contrast, other PFAS variants exhibited elevated concentrations closer to the surface, suggesting retardation within the aerobic layers of the landfill. The lower concentrations observed in the deeper anoxic zones may indicate potential transformation processes occurring under anaerobic conditions. Overall, the findings confirm that domestic waste landfills can be significant sources of PFAS release.

At the Trelleborg site, variability in water content across the waste body closely followed seasonal precipitation trends. During periods of low rainfall, elevated levels of pH, dissolved organic carbon (DOC), and dissolved nitrogen (DN) were observed. Both DOC and DN increased along the waste profile, from the aerobic upper layers to the anoxic lower zones. Multiple PFAS compounds were detected throughout the monitoring period. Short-chain PFAS appeared in high concentrations, likely linked to recurrent firefighting activities at the site. Interestingly, long-chain compounds such as PFOA and PFOS—banned from use at the site for over a decade—were still detected at elevated levels, particularly in the aerobic zones. Their persistence highlights the long-term retention of legacy PFAS in landfills and underscores the ongoing risk they pose for groundwater contamination.

These findings underscore the complexity of PFAS behaviour in landfill environments, influenced by waste composition, redox conditions, hydrological dynamics, and historical site activities. The contrasting patterns observed between the Rishon and Trelleborg sites highlight how local environmental conditions and landfill histories shape PFAS mobility, retention, and transformation. Notably, both sites demonstrate that even legacy PFAS compounds, long discontinued in use, can persist and migrate within the waste body, posing a continued threat to underlying groundwater systems. This emphasizes the need for long-term monitoring and site-specific risk assessments to inform remediation strategies and protect water resources.

Abstract No. 4

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Empowering water safety with a sensitive and optimized online SPE-UHPLC-HRMS method for broad spectrum PFAS monitoring

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Abstract

Per- and poly- fluoroalkyl substances (PFAS) are a large group of synthetic chemicals, which represent an important class of emerging contaminants [1]. In the last fifty years, they have been used in the production of surfactants, lubricants, food packaging, fire-retardant foams, cosmetics and personal care products. Currently, over 9000 compounds belong to this class, including both the so-called Legacy and Emerging PFAS. Due to their unique physicochemical properties, they are generally characterized by high persistence in the environment, making PFAS contamination a serious environmental problem. Nowadays, PFAS are widespread in the global environment, including wildlife and humans: they have now been detected at trace levels in both the environment and biota, including water [2]. Dietary intake (from drinking water and food) is considered the main pathway of human exposure to these substances, and it can lead to immune, fertility and endocrine dysfunctions. For this reason, it is extremely important to assess the degree of PFAS contamination of waters. This work presents a highly sensitive new approach for the accurate quantification of 34 PFAS in water, using online solid-phase extraction (SPE) combined with ultra-high performance liquid chromatography coupled to high resolution mass spectrometry. The instrumental method was optimized exhaustively, including mass spectrometric parameters, chromatographic conditions, and online SPE settings. It was validated in accordance with ISO/IEC 17025 and demonstrated excellent linearity ($R^2 = 0.986$-0.999), with low limits of detection (LOD ranging from 0.77 to 16.0 ng/L) and quantification (LOQ from 1.2 to 24.0 ng/L). The method's precision and accuracy were robust, with intraday relative standard deviation (RSD) ranging from 1.7 to 14%, intraday RSDs ranging from 3.5 to 14%, and recoveries from 74.4 to 120%. The method was successfully used in an interlaboratory comparison involving 35 laboratories to analyse 20 PFAS in drinking water and groundwater, and provided satisfactory results. Furthermore, it was used to analyse three ground water samples from a firefighting training site in Denmark, five river water samples from the south-eastern Piedmont region of Italy, and ten snow samples from the Monte-Bianco area, further confirming its effectiveness for the determination of PFAS in diverse aquatic environments. Among the analysed samples, PFAS were consistently detected in groundwater and river samples. Groundwater samples showed particularly high concentrations, with compounds like PFHxA, PFHxS, and PFOA reaching up to 36.9 µg/L. In river water, PFOA, PFHxA, and PFHpA were found in all samples, with PFOA reaching concentrations up to 114 ng/L, indicating widespread contamination. In contrast, no PFAS were detected in snow samples, likely due to dilution from heavy precipitation during the sampling period.

References

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Abstract No. 5

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Ion-pair assisted SERS method for ultra-sensitive detection of PFAS in aqueous media

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Abstract

Per- and polyfluoroalkyl substances (PFAS) are environmentally persistent and toxic compounds frequently detected in water sources. Due to their widespread use, mobility, and bio accumulative nature, detecting PFAS at ultra-trace levels—especially in the parts-per-trillion (ppt) range—is essential for regulatory compliance and, hence, human health protection. Traditional techniques, like LC-MS/MS, offer high accuracy but are costly, complex, and not ideal for field-based or large-scale monitoring. This study introduces a rapid, cost-effective method for detecting both short- and long-chain PFAS using Surface-Enhanced Raman Scattering (SERS), adapted from the U.S. EPA's MBAS protocol.

The method utilizes a cationic dye, the methylene blue (MB), as a molecular probe forming ion pairs with PFAS anionic surfactants, which are first extracted into chloroform and then dissociated back into water. This step enables MB to "interact" efficiently with silver nanoparticles in aqueous media, significantly enhancing the SERS signal. The characteristic Raman peak of MB at 1620 cm^{-1}, assigned to the C -C ring stretching, serves as the detection marker. The approach allows indirect quantification of PFAS by measuring MB after dissociation, confirmed via their 1:1 stoichiometric correlation. Further optimization using improved optical configurations, such as CCD quantum efficiency, CCD pixel binning, short focal length spectrographs and optimized collection geometry components will enable even lower detection thresholds, potentially making sub-ppt detection feasible with a portable setup. This opens the way for on-site environmental diagnostics without costly instrumentation. With current research-grade set-up, detection limits reached 5 ppt for PFBA.

The method's simplicity, and non-reliance on complex substrates, distinguish it from existing SERS approaches. It provides fast, selective PFAS detection with minimal sample handling, making it promising for scalable water quality monitoring and real-world applications. Ongoing work explores the method's extension to a broader range of PFAS, including sulfonated variants or ultra short entities such as trifluoroacetic acid (TFA), that may form partial ion pairs, influencing extraction behaviour and detection efficiency. These studies aim to evaluate ion-pair extraction-accuracy, detection limits, and method validation parameters, and contribute to the method's full analytical validation across PFAS classes.

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Elastin-Like Peptides-Modified Electrochemical Sensor for PFSA

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Abstract

The persistent industrial pollutants, perfluoroalkyl and polyfluoroalkyl substances (PFASs), pose a significant health hazard because of their bioaccumulative and toxic effects on human health. Standard analytical techniques, such as liquid chromatography-mass spectrometry, hinder the PFASs' rapid analysis due to a laborious and expensive workflow and the requirement for a centralized facility. Here, we developed a portable and sustainable sensor for a rapid in-field detection of the PFAS subtype perfluoro sulphonic acid (PFOS) in water. The sensor is based on an array of electrodes modified with elastin-like peptides (ELPs) of different hydrophobic and fluorophilic properties. The array generates cross-reactive electrochemical signals in the presence of PFOS and a redox mediator that are then analysed using chemometrics. The PFOS sensing mechanism relies on obstructing electron transfer between the modified electrode and the redox mediator (Fig. 1a). Electrochemical impedance spectrographs (5-500 nM PFOS) show increased charge transfer resistance (Figs. 1b&1c). The calculated sensitivity was 4.03 ± 0.25 ppb/Ohm and 22.7 ± 2.7 ppb/Ohm for either the fluorophilic or the hydrophobic electrodes, respectively, with no significant interference from humic acid ($p > 0.05$). We trained a partial least squares regression (PLSR) chemometric model to predict PFOS levels in simulated (Fig. 1d) and spiked groundwater samples (Fig. 1e) with corresponding limit of detection of 50 ± 3 nM and 113 ± 13 nM, respectively. Integrating the proposed sensor in a portable microfluidic device will enable rapid and on-site assessment of PFAS in contaminated water sources.

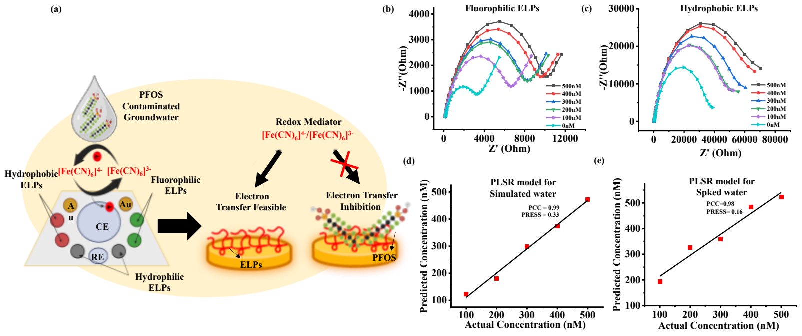

Fig. 1. *(a) Scheme of our approach to detect perfluoro sulphonic acid (PFOS). We use an electrode array modified with elastin-like peptides (ELPs) that generate a set of cross-reactive electrochemical signals in the presence of PFOS and a redox mediator and are analysed using chemometrics. Electrochemical impedance spectrographs recorded in the presence of PFOS using either (b) fluorophilic or (c) hydrophobic ELPs-modified electrodes. (d&e) PLSR-based calibration model for PFOS detection.*

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Integrated QSAR Framework for Predicting PFAS Albumin Binding and Half-life in Humans

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Abstract

Per- and Polyfluoroalkyl substances (PFAS) represent a class of synthetic chemicals whose widespread industrial use and emerging safety risks have driven researchers to investigate their detrimental environmental effects. The key challenge with PFAS lies in their prolonged biological persistence, primarily due to their strong affinity for various protein targets. Albumin, the predominant protein in human and animal blood serum, exhibits particularly strong interactions with PFAS compounds. This study aims to develop a computational framework for estimating PFAS half-lives through the integration of serum albumin binding predictions, while simultaneously elucidating structural features that govern their biological persistence.

We present an integrated computational workflow built upon two interconnected QSAR models. The initial model estimates PFAS-albumin association constants, with these outputs subsequently incorporated as descriptors, together with additional molecular features, into the second model for half-life estimation. Training and validation datasets incorporated molecular descriptors calculated from SMILES notation of PFAS structures. Comprehensive literature mining and data compilation were performed to capture the broadest possible range of PFAS compounds, thereby maximizing the predictive scope for previously uncharacterized substances.

Feature selection procedures were applied to optimize descriptor sets while maintaining model interpretability. Low-variance descriptors were excluded, and forward selection combined with K-fold cross validation was used to identify the most informative predictors for each endpoint. Through systematic algorithm comparison, optimal machine learning approaches were chosen for each prediction task. Random forest regression was implemented for the albumin binding association constant model, while heteroscedastic Gaussian process regression was selected for half-life prediction to explicitly capture dataset uncertainty.

Model performance was quantified using R^2 metrics across both cross-validation and external test sets. The albumin binding predictor achieved R^2 values of 0.645 and 0.641 respectively, whereas the half-life predictor demonstrated R^2 scores of 0.715 and 0.679. Feature interpretation was conducted using SHapley Additive exPlanations (SHAP) analysis to quantify individual descriptor contributions to binding and half-life predictions. SHAP analysis revealed critical insights regarding feature relevance and the mechanistic relationships between molecular structure and predicted outcomes.

The final implementation involved model deployment through a web-accessible platform. Both QSAR models were incorporated into the Jaqpot cloud-based ecosystem, providing researchers with prediction capabilities through both interactive web interfaces and programmatic API access. This integrated framework represents a significant advancement in computational toxicology tools for PFAS risk assessment, offering researchers and regulatory agencies enhanced capabilities for evaluating the environmental and human health impacts of emerging PFAS compounds.

Abstract No. 8

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Session 2 – Removal and Destruction of PFAS, from Technologies to Case Studies

Surface Active Foam Fractionation (SAFF®) for Regulatory-Grade PFAS Removal: Insights from the SCENARIOS Italian Demonstration

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Abstract

Per- and polyfluoroalkyl substances (PFAS) are increasingly regulated due to their persistence, mobility and human and ecological toxicity, with regional legislation in Piedmont (L.R. 25/2021) already mandating discharge concentrations as low as 0.65 ppt for PFOS. Within the Horizon Europe SCENARIOS project (scenarios-project.eu), Surface Active Foam Fractionation (SAFF®) has been advanced as a media-free, low-energy technology that exploits PFAS amphiphilicity and biodegradable co-surfactants to abate both long- and short-chain PFAS. Early pilot and full-scale trials in Denmark, Spain and Sweden have demonstrated scalability and compliance with EU drinking water standards (Directive 2020/2184), achieving > 99 % removal of Σ20 PFAS and near-complete abatement of problematic short-chain congeners when co-surfactants are applied.

Building on these foundations, the Marazzato Group is currently hosting the first Italian SAFF® demonstration at its liquid-waste treatment facility in Villastellone (Metropolitan City of Turin, Piedmont). A 20 $m^3 h^{-1}$ modular skid upgraded under SCENARIOS is being tested in combination with coagulation–flocculation and sand filtration over a 10-week prospective campaign. Performance will be evaluated with and without biodegradable co-surfactant dosing, with targets of > 99 % removal of long-chain PFAS (C7–C14), > 95 % removal of short-chain PFAS (C4–C6), consistent compliance with regional regulatory thresholds, energy consumption below 0.3 kWh m^{-3}, and foam-concentrate yields < 0.01 % for downstream destructive treatment. This deployment—SAFF®'s first fully embedded in an Italian legal framework—will provide a decisive validation of its plug-and-play, media-free credentials under real industrial conditions. Beyond enabling cost-effective compliance for industry, the demonstration is expected to reduce environmental PFAS loads and human exposure, generate data for digital-twin development and operator training, and inform hybrid treatment trains integrating foam fractionation with plasma destruction. Together, these outcomes contribute to the EU ambition of zero-emission PFAS management within a circular-economy water-safety framework.

Abstract No. 9

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First Application of SAFF® for PFAS Abatement in Drinking Water: Complete Removal of PFBS and Compliance with EU 2020/2184

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Abstract

Per- and polyfluoroalkyl substances (PFAS) in drinking water represent a major regulatory challenge due to their persistence, mobility, and toxicity. The EU Drinking Water Directive (2020/2184/EC), fully enforceable from January 2026, sets a threshold of 100 ng L^{-1} for the sum of 20 PFAS. Analysis of underground well water in Spain revealed a Σ20 PFAS concentration of 178 ng L^{-1}, exceeding this limit, with perfluorobutane sulfonate (PFBS, 75 ng L^{-1}) as the dominant congener.

To address this, we validated a mini-Surface Active Foam Fractionation (mini-SAFF®) system for the first time in a drinking water context, using quaternary nitrogen detergents as co-surfactants. At 1 mg L^{-1} detergent dosing, all PFAS congeners ≤ C6 fell below the analytical limit of detection, with total Σ20 PFAS removal of 93.5 %. Increasing the co-surfactant to 5 mg L^{-1} reduced all targeted PFAS below detection except for residual PFBA (5.7 ng L^{-1}, 64 % removal), corresponding to a total Σ20 PFAS concentration of 5.7 ng L^{-1}. At 10 mg L^{-1} dosing, PFBA removal increased to 90 % (1.6 ng L^{-1} remaining), achieving an overall Σ20 PFAS removal of 99.4 %. Mass balance analysis showed that ≥ 99.9 % of the detergent consistently partitioned into the PFAS-concentrated stream, with only 0.1 % detectable in treated effluent at doses ≥ 5 mg L^{-1}.

This study provides the first demonstration that SAFF®, when applied to drinking water sources and combined with quaternary N detergents, can reliably abate both long- and short-chain PFAS to well below forthcoming EU regulatory thresholds. The findings position mini-SAFF® as a modular, media-free technology capable of supporting utilities in achieving compliance with the 2026 standards.

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Energy Efficient Destruction of PFAS in Water by Cold Atmospheric Plasma

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Abstract

Per- and polyfluoroalkyl substances (PFAS) are a group of man-made chemicals, widely used for the manufacture of industrial and commercial products [1]. Despite their unique properties, there is considerable and growing concern over PFAS due to their persistent and bioaccumulative nature [2]. Given the detection of PFAS in waterbodies, such as groundwater and tap water, numerous conventional water remediation methods have been devoted in degrading them from water. However, the effectiveness of these methods is limited due to their long treatment time, required secondary treatment and high energy consumption [3]. Recent researches have proved that plasma technology is a promising water remediation process, demonstrating effective removal of PFAS in different water matrices (e.g. lab prepared water, landfill leachate, groundwater). Specifically, cold atmospheric plasma (CAP) combines in situ generation of reactive oxygen and nitrogen species with high oxidative and reductive potential, UV radiation and hydrated electrons, resulting in highly efficient PFAS destruction [4].

In this study, lab prepared PFAS contaminated water solutions were treated using two different plasma reactors: a gas-liquid dielectric barrier discharge (DBD) and a plasma bubble reactor. The effectiveness of each plasma reactor was investigated, while other crucial parameters (e.g. treatment time, pulsed-plasma waveform, plasma gas, water matrix, initial PFAS concentration) were also explored. In addition, the overall effectiveness of the plasma system was evaluated in terms of defluorination efficiency and energy requirements. This study provides valuable insights into the effective and cost-efficient treatment of PFAS-contaminated water using cold plasma technology.

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A comparative study of PFCA decomposition by photocatalysis, ozonation, and sonolysis

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Abstract

The detection of polyfluoroalkyl substances (PFAS) in relatively high levels in surface / ground water and living beings stimulated the testing of a variety of water remediation technologies, ranging from physical methods, like nanofiltration, adsorption, and air fractionation to advanced oxidation processes (AOPs).

In the present work, the potential to reduce the concentration of several PFCAs (PFDA, PFOA, PFHpA, PFHxA, PFPeA) in water is studied at lab-scale with the application of three scalable AOPs: (i) photocatalysis in a photo-reactor equipped with a UV-C lamp of 6W, and a recirculation tank; (ii) ozonation in a semi-batch bubble flow reactor; (iii) ultrasonication in a batch reactor. ZnO and Fe-doped-ZnO photocatalytic nanoparticles were synthesized, and immobilized on two non-porous substrates (Duranit and soda lime beads) which were packed in the photoreactor. Ozonation was carried out in a stainless steel column, where the ozone was produced from a high voltage corona discharge plasma by regulating the flow rate of gas (oxygen or air) at 0.1 L/min. An ultrasound probe operating at constant frequency 25 kHz and variable power (25-180 W) was used for sonolysis in a jacketed batch reactor, with the continuous injection of cooling water in the jacket to keep the temperature constant. Both photocatalysis and sonolysis were tested without and with the injection of air. Aqueous solutions of volume 250-450 mL and initial PFCA concentration 10 mg/L were used in all tests. Occasionally, 4mL of water samples were collected and the PFCA concentration was measured with methylene blue active substances method coupled with UV-Vis spectrophotometry (MBAS-UV-Vis).

A one-dimensional advection-dispersion-reaction model, with time-dependent kinetic constant and pseudo-1st order reaction rate, was used to estimate the kinetic parameters governing the rate of the photocatalytic PFOA degradation. A modified tank-in-series model with backflow was used to estimate the kinetic parameters of the direct and indirect PFOA degradation by ozonation. The kinetic parameters of sonolysis were estimated by using a phenomenological 1st order reaction rate model. The performance of the three methods was evaluated for each PFCA, in terms of the PFCA removal efficiency, and the energy consumption per unit mass of decomposed PFCA. The conditions maximizing the effectiveness of each method with the minimum energy expenditure are determined and guidelines for scaling-up at the large scale are provided.

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Destruction of concentrated PFAS in groundwater using cold atmospheric plasma after SAFF pre-treatment

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Abstract

The last few decades per- and polyfluoroalkyl substances (PFASs) have been designated as persistent organic pollutants (POPs). These fluorinated organic compounds, so called “forever chemicals”, are characterized by remarkable persistency and their ability to diffuse through long-distances from the point source of release, via air, soil or water [1]. Due to their presence in different environmental compartments, PFAS have been frequently detected in drinking water, surface water and groundwater, posing in danger both humans and wildlife [2]. Although, physical, chemical, and biological methods have been used to remove PFAS from water, they commonly present drawbacks such as non-effective destruction, secondary pollution and high-energy consumption [3]. Currently, cold atmospheric plasma (CAP) has emerged as a fast, green and energy-efficient technique for degrading PFAS in water. CAP is based on the simultaneous production of reducing and oxidizing reactive oxygen and nitrogen species (RONS), in addition to UV radiation and high-energy electrons which have been proved key-role players in PFAS destruction [4].

This study aimed to assess the destruction of concentrated PFAS in groundwater after surface-active foam fractionation (SAFF) -using cold atmospheric plasma. A multiparameter optimization of the system was conducted by investigating the influence of pulsed-plasma waveform, reactor configuration and plasma gas. Therefore, the hyperconcentrated wastes were treated in gas-liquid dielectric barrier discharge (DBD) or plasma bubble reactor energized by HV nanopulses or micropulses, under both air and argon gas.

The results showed that plasma bubble system under argon gas, powered by HV nanopulses demonstrated the most effective performance. Specifically, after 3 hours of argon-plasma bubble treatment the total PFAS degradation efficiency was equal to ~99%. Among the long-chain PFAS; PFHxA was degraded by ~62%, whereas PFOA, PFHxS, PFHpS and PFOS were degraded by ~100%. Regarding short-chain PFAS; PFHpA and 6:2FTS were almost completely degraded (~100%), while the degradation efficiency of PFBS and PFPeS was ~44% and and ~97%, respectively. The results of the present work highlights the potential of cold plasma technology for treating effectively real PFAS contaminated wastewater.

Abstract No. 13

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Biochar-Amended Vermicompost: An Environmentally Sustainable Option

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Abstract

Per- and polyfluoroalkyl substances (PFAS) exhibit resistance to chemical, physical, and biological degradation within the environment. Consequently, the incorporation of environmentally safe organic amendments, such as biochar, into croplands is emerging as a viable remediation strategy for mitigating the potential accumulation of PFAS in crops. The scope of this study was to investigate the potential of biochar-amended vermicompost (vermichar) to enhance the quality of soils that may experience substantial PFAS input. To this end, arid soil from abandoned agricultural land in the Canary Islands (Spain) was experimentally contaminated with a mixture of PFAS (25 ng/g dry soil each), including short-chain (perfluoropentanoic acid [PFPeA]), long-chain (perfluorooctanesulfonic acid [PFOS], and perfluorooctanoic acid [PFOA]), and emerging congeners (6:2 fluorotelomer sulfonic acid [6:2FTSA]). The soil had previously received 5%, 10%, and 20% (dry mass) of vermichar. Subsamples of each treatment were placed into pots (500 g), and lettuce (Lactuce sativa) and chickpeas (Cicer arietinum) were cultivated for 2 months. Morphometric parameters of the plants (root and shoot weight, shoot height, leaf number), soil exoenzyme activities, microbial activity, and available macronutrients (inorganic P, NO_3^-, and NH_4^+) were measured following the harvesting.

The application vermichar resulted in a progressive increase in soil enzyme activities, which can be attributed to the substantial load of enzymes contained within this carbonaceous material. Nevertheless, a significant increase in N- and P-acquiring enzyme activities was observed in PFAS-spiked soils treated with vermichar when compared to their PFAS-free counterparts. This finding suggested that PFAS were immobilized by vermichar, minimizing their interaction with soil microorganisms and exoenzymes. Nonetheless, doses lower than 20% w/w are recommended due to the notable detrimental effects on chickpea development at this vermichar level. A significant decrease in NH_4^+ concentrations was found across all treatments, regardless of the plant species. Conversely, the concentrations of available NO_3^- increased by an order of magnitude in all vermichar-treated soils, although this increase was markedly more pronounced in PFAS-free soils. The chemical analysis of PFAS indicated a significant impact of vermichar on limiting plant uptake. Our results suggest that the application of vermichar at doses <10% w/w provides dual benefits for PFAS-contaminated soils, enhancing their fertility potential while simultaneously reducing PFAS bioavailability.

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Session 3 – Environmental Performance and Societal Impacts

Integrated monitoring and toxicological assessment of PFAS in aquatic ecosystems: Human exposure risks in UK and Spanish populations and insights from cellular bioenergetic profiling

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Per- and polyfluoroalkyl substances (PFAS) are persistent, bioaccumulative and potentially toxic contaminants increasingly detected in coastal and marine ecosystems. This study combines extensive monitoring of PFAS in aquatic environments and biota with mechanistic toxicity assessments to better understand environmental exposure pathways and human health risks.

Comprehensive field campaigns were conducted between 2020 and 2024 across the United Kingdom (UK) and Spain, analysing PFAS concentrations in over 10,000 freshwater, groundwater and saline water samples, and 288 edible fish specimens from 16 species. Water samples were sourced from the UK Environment Agency's Monitoring Programme, while fish were selected to reflect local dietary habits. PFOS and PFOA emerged as dominant compounds, with regional variation: Spanish fish showed higher levels of long-chain and emerging PFAS (e.g., PFNA, 6:2 FTS), whereas UK fish had elevated PFOS. Average dietary intake in Spain exceeded EFSA's threshold by over fivefold, highlighting the urgency of mitigation in high-consumption regions. In the UK, freshwater hotspots such as Moreton-in-Marsh underscored the need for targeted remediation.

To complement field data, *in vitro* toxicological profiling was conducted using zebrafish embryo fibroblast (ZF4) cells exposed to 19 PFAS, assessed via Seahorse XF extracellular flux analysis and CCK-8 viability assays. Mid- and long-chain PFAS - particularly PFOA, PFDA, and Nafion BP1 - caused significant mitochondrial dysfunction and glycolytic shifts at concentrations as low as 250 - 600 µM. Effects were dose-dependent and followed known chain-length toxicity trends, confirming mechanistic links between PFAS structure and bioenergetic disruption.

By integrating environmental monitoring with New Approach Methodologies (NAMs), this research provides a multidimensional evaluation of PFAS risks. These findings inform ecotoxicological models and regulatory strategies, while supporting the shift toward non-animal, mechanistic testing frameworks for complex contaminants.

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Per- and polyfluoroalkyl substances (PFAS) and antimicrobial resistance

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Abstract

Per- and polyfluoroalkyl substances (PFAS), a class of persistent man-made chemicals known as 'forever chemicals' due to their extreme environmental longevity, have been widely utilized in industrial applications since the 1940s. Emerging evidence suggests a significant impact of these compounds on the biodiversity, composition, and activity of microbial communities. In this respect, PFAS-contaminated soil samples collected from the Albäck fire drill site in Trelleborg (Sweden) were analyzed in Winogradsky columns to investigate the response of the soil microbial community to PFAS exposure. The columns were treated with high concentrations of perfluorooctanoic acid (PFOA) and, over time, the aqueous phase of these columns revealed selective growth of two facultative anaerobic human opportunistic pathogens: Klebsiella grimontii and Citrobacter braakii. Whole-genome sequencing of the two isolated strains unveiled extensive arrays of antibiotic resistance genes (ARGs), notably those conferring resistance to fluoroquinolones. Furthermore, both isolates possessed genes encoding sophisticated multidrug efflux systems (e.g., AcrAB-TolC, EmrAB-TolC, oqxAB, AdeFGH), critical for expelling a wide range of toxic compounds, including various antibiotics, and potentially PFAS. A pivotal finding was that direct exposure of K. grimontii and C. braakii isolates to PFOA significantly enhanced their resistance to specific aminoglycosides, fluoroquinolones, and macrolides. This elevated resistance correlated with a dose-dependent upregulation of key ARGs, including kpnF, kpnG, adeF, and oqxA in K. grimontii, with acrA also upregulated at lower PFOA concentrations. These results strongly suggest that PFOA acts as a direct modulator, amplifying antibiotic resistance through transcriptional activation of ARGs. Beyond transcriptional effects, the study considers how PFAS might indirectly promote resistance. PFAS can induce oxidative stress and increase bacterial cell membrane permeability, potentially facilitating the horizontal gene transfer of antibiotic resistance plasmids and the uptake of exogenous DNA—processes crucial for the dissemination of ARGs. Given the fluorine content in both PFAS and fluoroquinolones, a potential cross-resistance mechanism involving fluoride was explored. The presence of the crcB gene, encoding a fluoride ion transporter, in both isolates suggests a mechanism for fluoride detoxification, enabling survival in these contaminated, fluorine-rich environments.

In addition to whole genome sequencing, the bacterial diversity of the Trelleborg soil samples and Winogradsky columns was also assessed using a 16S rRNA metabarcoding approach. In both soil and column samples exposed to PFAS congeners, an increased relative abundance of Proteobacteria (the phylum that includes K. grimontii and C. braakii) was observed, alongside a marked reduction in overall microbial diversity.These comprehensive findings have important implications for public health and environmental policy. They position PFAS as significant environmental drivers of antimicrobial resistance and biodiversity loss, underscoring the urgent need for enhanced microbial monitoring in contaminated ecosystems to mitigate these complex threats.

Abstract No. 16

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Assessment of PFAS Exposure in the Alessandria Area: Rationale and Implementation of Two Pilot Studies within the SCENARIOS Project

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Abstract

Per- and polyfluoroalkyl substances (PFAS), extensively used in industrial processes due to their thermal and chemical stability, are persistent environmental contaminants known to bioaccumulate in living organisms. Their presence in water, soil, and food chains raises concern about chronic exposure and potential long-term health effects. Due to the complexity and cost of analytical techniques required for PFAS detection in biological samples, large-scale assessments in the general population remain limited.

In the locality of Spinetta Marengo, Alessandria (AL), Piedmont, Italy, an industrial complex known as "Polo Chimico of Spinetta" has been operational for the production of fluoropolymers since the 60's.

In May 2020, in the town of Montecastello, situated approximately 10 km from the industrial site, the presence of PFOA (0.13 µg/l) and its replacement C6O4 (0.34 µg/l) was detected in groundwater intended for production of drinking water. As a result, on June 11th, 2020, the well supplying water to the town's aqueduct was closed.

With the aim of validating PFAS detection methods, two pilot studies have been launched within the framework of the EU-funded SCENARIOS project, aiming to assess internal exposure and to validate rapid, cost-effective detection methods, including electrochemical sensors and Raman/SERS spectroscopy, against reference LC-HRMS techniques.

The first study involves 160 residents, randomly selected and equally distributed by gender and across four age groups (<18 years, 18–49 years, 50–65 years, >65 years). Of these, 80 participants are residents of Montecastello (classified as "potentially exposed") and 80 of Frugarolo (classified as "likely non-exposed"). As of June 2025, enrolment in Montecastello has been completed (76 participants), while recruitment in Frugarolo is ongoing (60 enrolled).

The second study, currently in progress, extends the sample to individuals living within increasing distances from the industrial site (≤3 km, 3–6 km, and >6 km), covering the wider Alessandria area. For this study, 37 participants have currently been enrolled, selected using the same stratified random approach based on age and gender. For both studies, participation involves blood sampling for PFAS determination and the evaluation of selected biochemical and clinical parameters, urine collection for PFAS analysis and microalbuminuria assessment, and collection of drinking water samples from participants' households to assess the potential occurrence of these substances in drinking water. In addition, each participant is interviewed by trained personnel using a structured questionnaire, comprising five sections, to collect information on personal data, environmental conditions, occupational history, dietary habits, and water use. Results of biochemical-clinical examinations are communicated to participants, with the recommendation to discuss them with their general practitioner. PFAS concentration data from biological samples will be presented in an aggregated and pseudo-anonymized form, in full compliance with ethical and data protection standards.

Keywords: PFAS, human exposure.

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Soil enzymology for assessing PFAS bioavailability

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Abstract

Agricultural lands in arid, semi-arid, and Mediterranean regions encounter significant challenges due to limited availability of organic matter and water. These issues may be partially mitigated through the application of biosolids, composts, and reclaimed wastewater. However, the implementation of such practices may result in an increased presence of organic contaminants in soils, thereby raising concerns regarding the safety of agricultural products and potential implications for human health. Per- and polyfluoroalkyl substances (PFAS), which are prevalent environmental pollutants found in biosolids, composts, and reclaimed wastewater, have not been thoroughly investigated in terms of their impact on soil functions.

This study seeks to examine the effects of perfluorooctanoic acid or PFOA (a legacy congener) and 6:2 fluorotelomer sulfonic acid or 6:2FTSA (an emerging, precursor congener) on selected soil exoenzymes associated with the carbon, nitrogen, phosphorus, and sulphur cycles. Soil samples obtained from the Canary Islands (Spain), recognized as one of the most arid regions within the European Union, were spiked with varying concentrations (0— 250 ng/g dry mass) of both PFAS and incubated at 25 °C in darkness. Exoenzyme activities were measured periodically over a 210-day period, whereas PFAS concentrations were assessed at both the beginning and the end of the experiment. The findings revealed significant inhibition of certain exoenzymes, with the magnitude and timing of responses differing according to the type of exoenzyme. For instance, β-glucosidase activity was inhibited at concentrations of 50 and 250 ng/g of PFOA and 6:2FTSA during the initial two weeks. Conversely, esterase activity exhibited significant inhibition for a duration of up to 60 days. Furthermore, alkaline phosphatase activity was suppressed at these PFAS concentrations throughout the entire 210-d incubation period. Chemical analyses demonstrated that PFOA concentrations remained constant, while 6:2FTSA concentrations decreased by 60—49.2%, leading to the formation of perfluoroheptanoic acid (1.02—1.89 ng/ dry mass). The extremely low organic matter content of the soils (0.77 % total organic carbon), together with the low microbial activity, may elucidate the long-term responses of soil enzymes to both PFAS, attributable to the limited capacity of the soil to inactivate these chemicals.

Abstract No. 18

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Societal dimensions of PFAS remediation

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Abstract

Effective remediation of per- and polyfluoroalkyl substances (PFAS) contamination is not only a technological challenge but a deeply social one. The SCENARIOS project integrates technical innovation with a structured social assessment to evaluate the societal readiness, barriers, and enabling conditions for the deployment of PFAS remediation strategies across multiple European contexts.

This study presents a transdisciplinary analysis conducted at three demonstration sites—Korsør (Denmark), Trelleborg (Sweden), and Alessandria (Italy)—combining public surveys (n=95), stakeholder interviews, and participatory workshops. The results reveal a widespread concern regarding PFAS-related risks, particularly in drinking water and human health exposure; however, public action and engagement remain inconsistent. Identified barriers include limited regulatory awareness, low trust in public institutions, and perceived complexity and high cost of remediation technologies. Conversely, enablers of social uptake include transparent governance, early stakeholder involvement, and the presence of visible local remediation efforts.

The assessment underscores the need for contextualised risk communication strategies that bridge technical knowledge and public perception. Emphasis is placed on participatory governance models, citizen-inclusive monitoring frameworks, and long-term engagement plans to ensure the legitimacy and durability of remediation interventions. A cost-benefit analysis further supports the argument that integrating societal values into environmental decision-making enhances both implementation feasibility and sustainability outcomes.

The findings also highlight the necessity of complementing environmental impact assessments and regulatory planning with robust social analysis, particularly for PFAS and other emerging contaminants. Embedding social science into remediation initiatives is critical not only to improve public acceptance but also to ensure that environmental interventions advance broader goals of societal resilience, inclusivity, and environmental justice.

Abstract No. 19

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Cost-Benefit Analysis of SCENARIOS PFAS Technologies

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Abstract

Per- and polyfluoroalkyl substances (PFAS) removal from the environment is considered a critical issue due to their persistent, bio-accumulative, mobile, and toxic nature. However, removal comes at an economic cost of remediation technology deployment. The present work uses cost-benefit analysis to assesses the societal benefits of two innovative SCENARIOS technologies for PFAS remediation – Surface Active Foam Fractionation, for PFAS separation; and Cold Atmospheric Plasma, for PFAS destruction.

The cost-benefit analysis monetises avoided health risks related to reduced PFAS exposure and compares them to economic cost of remediation. Health risks are monetised by integrating publicly available contamination data with scientific results on exposure pathways and exposure-response relationships. Technology deployment costs are calculated considering the installation and operational cost provided by technology developers.

Results show that in all SCENARIOS case studies, the benefits of remediation likely outweigh the cost – particularly in densely populated or high-exposure areas. Drinking water and soil treatment are found to be complementary, and shared infrastructure emerged as a cost-efficient strategy.

When extrapolated to the European scale, annual benefits from PFAS remediation are estimated at €21 billion with a substantial uncertainty range of €19–300 billion. Estimated benefits surpass deployment cost by at least a factor of two. Given the large amount of possible remediation sites, a prioritization framework is proposed to support future site selection based on exposure risk and urgency.

This work's findings underline the potential of SCENARIOS technologies to deliver large-scale health and environmental benefits and to inform evidence-based policy development across the EU.

Abstract No. 20

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Environmental Assessment of PFAS Treatment Technologies

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Abstract

This study outlines the methodological approach and preliminary results of the Life Cycle Assessment (LCA) activities carried out within the SCENARIOS project (Horizon Europe, GA No. 101037509), aiming to quantify the environmental performance of both conventional and innovative technologies for the treatment of PFAS-contaminated matrices.

The assessment covers both water-based and soil-based treatment strategies demonstrated at various Technology Readiness Levels (TRLs) across SCENARIOS demonstration sites. The methodology follows ISO 14040 and 14044 standards [1], [2] and integrates inputs from project partners, demonstration data, technical specifications, and laboratory-scale results. System boundaries were defined following a gate-to-gate and gate-to-grave approaches, depending on specific technology, its maturity level and the availability of reliable data [3].

In line with standard LCA procedures, the study begins with the goal and scope definition. The scope outlines the system boundaries, the functional unit (i.e., a measure of the service delivered by the system), and the assumptions and limitations of the assessment. Functional units were tailored to each type of PFAS remediation technology, considering both aqueous matrices (e.g., landfill leachate) and solid matrices (e.g., PFAS-contaminated soils or sludges).

The technologies analysed differ in their operational principles and can be classified into two main categories: destruction technologies (Cold Atmospheric Plasma – CAP, Thermal Destruction – TD) [4], [5] and separation technologies (Surface Active Foam Fractionation – SAFF, Soil Washing – SW, Granular Activated Carbon – GAC) [6], [7]. Among these, CAP and SAFF represent innovative solutions, while the others are conventional approaches. The LCA methodology first involved a detailed mapping of all process steps within the remediation chain. Subsequently, individual technologies were combined to enhance performance, resulting in integrated treatment trains that were also assessed through LCA.

These scenarios were then compared to a no-treatment baseline, serving as a reference to quantify the environmental burden of inaction and to strengthen the rationale for investing in remediation technologies.

The LCA covers the full process implementation across the demonstration sites (DEMOs), which aim to validate soil and water treatment technologies—both in-situ and ex-situ—by benchmarking their environmental impacts and sustainability against traditional approaches.

Primary data collected from the Demo sites were integrated with secondary data related to well-established, harmonized technologies (e.g., using consistent units, time frames, and system boundaries), enabling coherent integration and comparison with primary datasets.

The results support the use of Life Cycle Assessment as a strategic decision-making tool in PFAS policy development and the implementation of sustainable remediation strategies across Europe.

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