# PFAS

PER- AND POLY-FLUOROALKYL SUBSTANCES

4th International Congress

## Management of Environmental & Health Risks

**February 4, 2025 – Milan, Italy**

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## Programme

**08:15**
Welcoming participants

**08:45**
Welcome speech & introduction to the congress
• *Dr. Frank Karg, SFSE & ARET, Court Expert, Scientific Director - HPC International (France & Germany)*
• *Dr. Edoardo Slavik, Research & Development Manager - Erica Srl*

**09:00**
Legal Disputes over PFAS in Italy: The Need for Regulatory Framework
*Angelo Merlin, Lawyer, Ateneo School at Ca' Foscari University of Venice, President of Assoreca (Italy)*

**09:30**
Identification and Differentiation of PFAS Contamination Sources in Groundwater and Surface Water for identification of technico-financial Responsibilities
• *Carlo Monti, General Manager - ET&EC SAGL (Switzerland)*
• *Dr. Frank Karg, SFSE & ARET, Court Expert, Scientific Director - HPC International (France & Germany)*

**10:00**
Environmental and human health risk assessment for PFAS management
*Beatrice Cantoni, Junior-Assistant Professor, Department of Civil and Environmental Engineering, Environmental Section - Politecnico di Milano (Italy)*

**10:30** Coffee & Tea break

**11:00**
Toxicological Health Risk Assessment in Case of oral, dermal and Inhalation Exposure of PFAS (TERQ: Toxicological Exposure Risk Quantification and definition of site use specific Remediation Goals – International State-of-the-Art
*Dr. Frank Karg, SFSE & ARET, Court Expert, Scientific Director - HPC International (France & Germany)*

**11:30**
PFAS: A constantly evolving analytical challenge
*Dr. Chem. Francesco Stante, Assoreca PFAS Observatory, Chief of Chemists, CEO and Co-Founder - Laboratori Chimici Stante Srl (Italy)*

**12:00**
Never say forever: unlocking the potential of activated carbon for PFAS removal and destruction
*Dr. Annemie Houben, PhD, R&D Manager - Desotec (Belgium)*

**12:30** Lunch

**13:45**
Advanced oxidation and biological processes for PFAS removal in landfill leachates
• *Claudio Di Iaconi, Research Director, National Research Council, CNR - Water Research Institute, IRSA (Italy)*
• *Silvia Franz, PhD, Associate Professor - Politecnico di Milano Department of Chemistry, Materials and Chemical Engineering "Giulio Natta" (Italy)*

**14:15**
Accelerating transformation for a sustainable future - How TDK leverages technology expertise to tackle the global PFAS pollution challenge
*Nebojsa Ilic, Head of technology - SUIKI, TDK Group (Germany)*

**14:45**
Photoelectrocatalytic advanced oxidation of PFAS in contaminated groundwater of Veneto Region, Italy
• *Silvia Franz, PhD, Associate Professor - Politecnico di Milano Department of Chemistry, Materials and Chemical Engineering "Giulio Natta" (Italy)*
• *Paolo Ronco, PhD, Research & Innovation Manager - Viacqua SpA (Italy)*

**15:15**
The LIFE CASCADE project: treatment technologies for the removal of PFAS and Microplastics from wastewater in textile companies and in centralized wastewater treatment plants
*Cristian Carboni, Business Development Manager - De Nora Water Technologies Italy Srl (Italy)*

**15:45** Coffee & Tea break

**16:15**
Risk assessment of PFAS findings in groundwater: An approach based on data trends from 1500 small industrial sites
*Katerina Tsitonaki, Senior Principal Environmental Engineer - WSP (Denmark)*

**16:45**
Strategy and environmental solution for the effective and sustainable PFAS removal from wastewater. The case of the GEA S.r.l. landfill leachate treatment plant in Sant'Urbano
*Massimo Pezzini, R&D, Engineering Office - Greenhesis SpA (Italy)*

**17:15**
Industrial experiences of removing PFAS directly from landfill leachate
*Julik Zanellato, Business Development Manager - Depura, Tea Group (Italy)*

**17:45**
Discussion & Conclusions

**18:15** End of the Congress


**Editorial**

The International PFAS Congress on 04 February 2025 in Milano – Italy is a very important Scientific and Technical Event for Management Solutions of Environmental and Health Risks and Impacts by PFAS Pollution and Contaminations in Materials, Waste & Waste Waters, Soil, Groundwater, Surface Waters, Drinking Water and Air.

After the first 3 editions held in Paris, WEBS -World Event Business Solution- with the scientific direction of HPC International and Erica Srl, thought it appropriate to organize the event in Italy, a territory with great sensitivity on the topic.

The latest edition of the international congress on PFAS welcomed participants from around twenty European countries and from across the Atlantic. An influx that reflects the keen interest of the global scientific and industrial community in PFAS and the omnipresence of these compounds in the environment, thus raising numerous questions about their toxicity and the strategies to be implemented to mitigate their impact.

Italy has been strongly affected by this issue and PFAS are subject of strong debates due to the widespread pollution, especially of the Po River and in a specific area of the Veneto Region.
In this edition, in addition to the general framework in the regulatory context, diffusion in the territory and impact on health, wide space will be given to technologies, both in terms of studies and pilot projects, as well as case histories of industrial plants built and operating.
The interventions are selected by HPC and Erica.

HPC International all over Europe (HPC AG Group since 1948 with HPC Italia in Milano), has enabled the realization of bold projects: from Site Investigations, Risk Assessments and Remediation of contaminated soils, water & air and the specialization in innovative and cost-effective in-situ-treatment Technologies (microbiological & biochemical Remediation), up to independent governmental and private industry Research Projects (R&D), always with sustainability in mind.
The company develops solutions for soil recycling in environmental consulting and infrastructure planning as an engineering company. It works interdisciplinary, internationally and with engineering precision.

Erica Srl, is an established and reliable company in the management and treatment of industrial waste in Italy. Expertise, optimization, efficiency and savings are the essential points of this reality. Since 2017, Erica has also been involved in research, in particular in the identification of new technologies for the reduction of emerging pollutants and has obtained 3 patents for the PFAS Remover technology, specifically for the reduction of PFAS in landfill leachate.

New Scientific Knowledge and technological Solution Strategies are shared with scientific, technical and legal Experts, as also with Company and Corporate Management Chairs, concerning:

- Legal development in International, European and Italian PFAS and Environmental Regulations,
- Toxicological PFAS up dating and international State-of-the-Art Health Risk Assessments on TERQ Basis (Toxicological Exposure Risk Quantification),
- Site use specific and Pollutant Cocktail specific Definition of Remediation Goals for transparent elimination of non-acceptable toxicological Risks,
- Material, Soil and Water investigation Strategies concerning PFAS Contaminations,
- Identification and Differentiation of PFAS Contamination Sources by use of PVA and MVA-AI (Poly Variant Analysis and Poly Vector Analysis on Artificial Intelligence Basis) for Identification and Differentiation of technical and legal Responsibility and Liabilities,
- Innovative and improved PFAS-Treatments and technical Remediation Strategies and Technologies of Wastewater, Groundwater, Soil etc. under special Focus concerning new approaches and technological approaches from International and Italian Industry and Research Institutes and Corporations,
- Future technological, legal and financial tendencies.

Dr. Frank KARG / HPC INTERNATIONAL SAS & Edoardo SLAVIK / ERICA s.r.l.

Ca' Foscari Challenge School

## Legal disputes over PFAS in Italy: the need for regulatory framework

**ANGELO MERLIN**, Director of the Second-Level University Master's Program in "Sustainable Environmental Remediation and Remediation of Contaminated Sites," University Ca' Foscari of Venice, Criminal Lawyer specializing in Environmental Criminal Law, President of ASSORECA

The most severe groundwater contaminations have historically been caused by industrial activities, particularly discharges from facilities that handle and/or produce chemicals, or by leaching into aquifers from illegal, often buried waste deposits.

This paradigm also applies to groundwater contaminations caused by per- and polyfluoroalkyl substances (PFAS).

In Italy, monitoring conducted by public control bodies revealed in 2013 a serious PFAS pollution affecting surface water bodies and groundwater in the province of Vicenza.

Subsequently, the Public Prosecutor's Office of Vicenza (Veneto Region) launched a criminal investigation into what was labeled "the largest PFAS contamination in Europe".

This investigation initiated a criminal trial in which fifteen defendants faced serious charges related to public health endangerment and environmental damage.

The trial is expected to conclude with a verdict by the beginning of summer 2025.

A similar investigation was carried out by the Public Prosecutor's Office of Alessandria (Piemonte Region), involving two executives of a major multinational company for environmental disaster due to negligence. They allegedly failed to comply with the obligation to remediate previous PFAS pollution of the aquifer under their production site.

This contamination worsened over time due to the company's failure to contain the release of these substances into the environment.

The Italian judicial controversies have not been limited to criminal charges and have also involved administrative justice.

Administrative courts have evaluated the legitimacy of certain regulations imposed by a regional authority, including those aimed at establishing PFAS discharge limit values and procedures for identifying responsible parties in the case of PFAS-contaminated sites.

These judicial proceedings clearly highlight the absence of specific regulations in Italian law regarding the environmental impacts that companies may cause by releasing PFAS substances.

This regulatory gap concerns both the management of industrial wastewater discharges and the remediation of contaminated sites, creating significant confusion among public and private operators who instead need to work within a context of legal certainty.

While awaiting legislative action on emissions of per- and polyfluoroalkyl substances into the environment through discharges, it is crucial for politics and

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science to reestablish the relationships necessary for creating effective “technical regulations” on environmental and ecosystem protection.
These relationships, as is often the case, must not be left to chance dynamics or contingent approaches to solving problems that garner significant media or emotional attention. Worse, they should not be subjected to the power dynamics that may arise within the realms of science or politics.
Determining quantitative risk levels associated with the use and exposure to PFAS substances must be addressed from a global and shared perspective. For example, this could involve promoting the European-level development of "best available techniques" to reduce PFAS in discharges.
This issue involves the broader problem of acceptability and, fundamentally, how we aim to achieve the community goal of a "high level of environmental protection" within the framework of the overarching objective of "sustainable development".

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# Identification and Differentiation of PFAS Contamination Sources in Groundwater and Surface Water for identification of technico-financial Responsibilities

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• *Dr. Frank Karg, SFSE & ARET, Court Expert, Scientific Director - HPC International (France & Germany)*
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## Abstract:

In cases of large-scale groundwater contamination with PFAS, several different PFAS sources are often involved, which have mixed together in contamination plumes. In order to determine the respective contamination proportion of the various **PFAS sources**, these sources **must be identified and differentiated**. With the help of specific target analyses, based on an **AI-MVA** (Multi-Vector Analysis with artificial intelligence) and **PVA** (Poly Variance Analysis), it is determined which PFAS products are involved (AFFF firefighting foams from fire incidents, fire training zones, airports, hydraulic oils, surfactants from fluoropolymer production, galvanization, landfills, etc.).

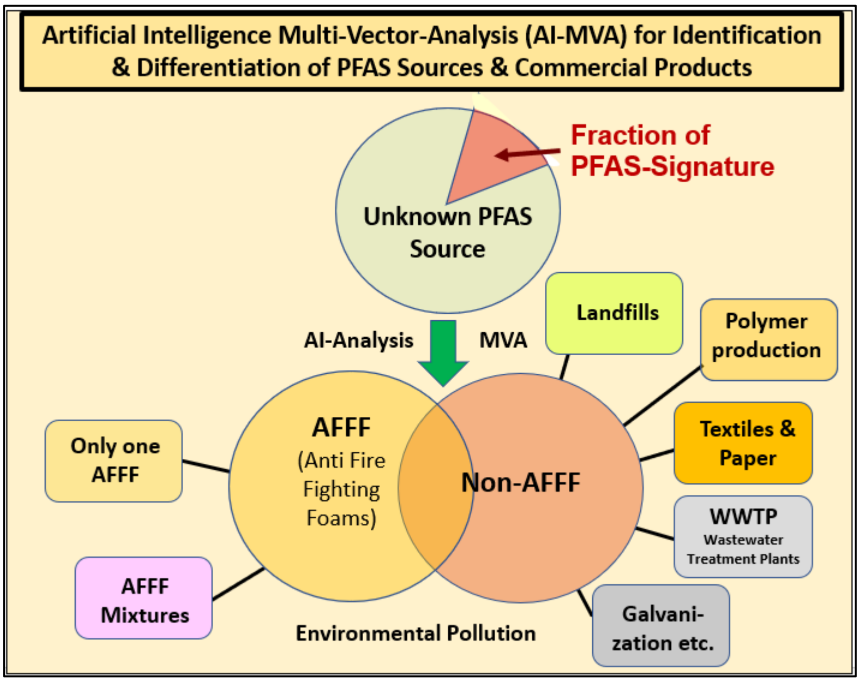


Fig. 1: Principles of PFAS Source Differentiation between AFFF and non-AFFF Sources.

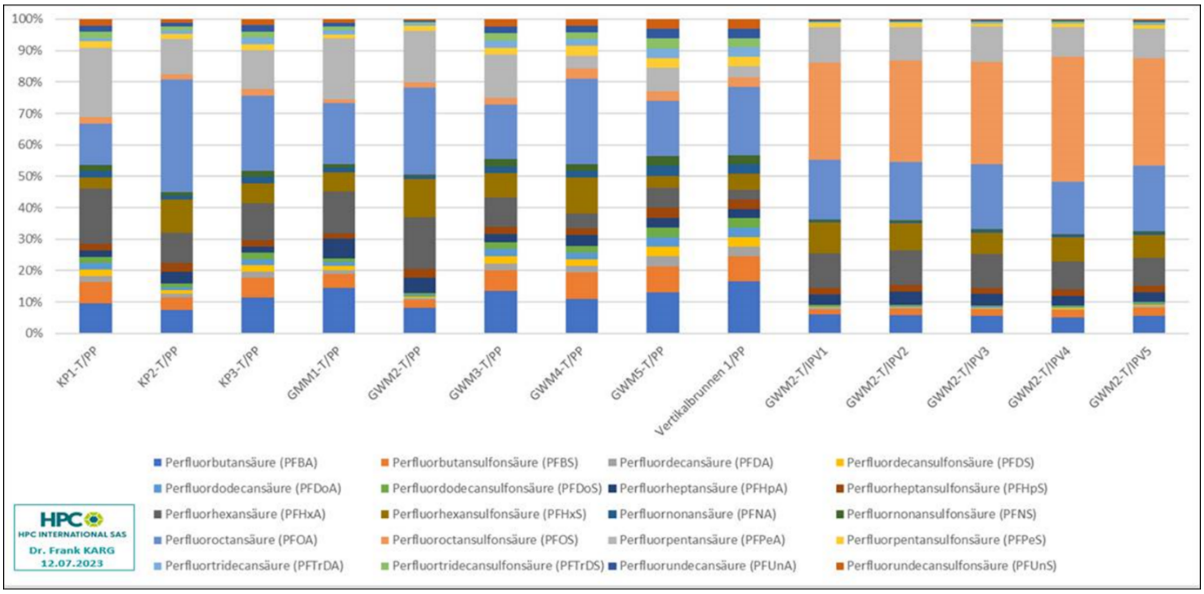


Fig. 2: Typical PFAS Contamination Source Clusters in different Groundwater Samples

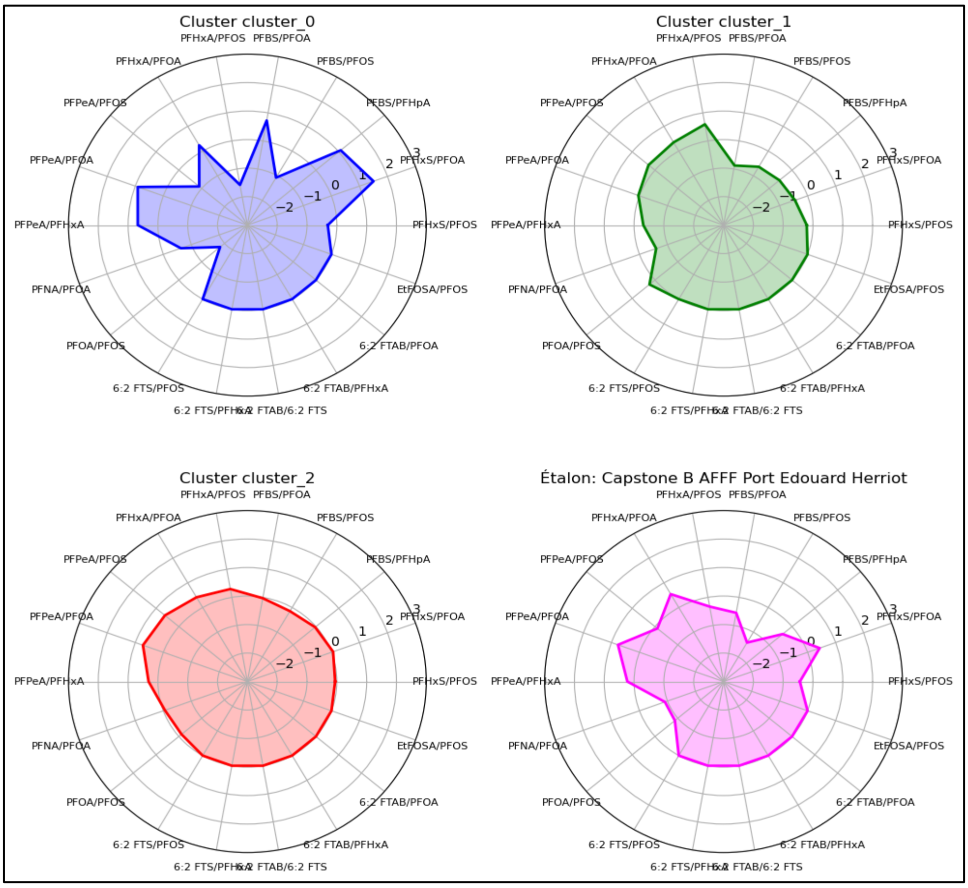


Fig. 3: Different PFAS Standard Chemical Spectrums (Cluster Radars) of commercial PFAS Products.

The AI-MVA or PVA is based on the experience of over 800,000 PFAS analyses from Western Europe and the USA, the multi-mathematical considerations of chemical PFAS analysis and a constantly growing database of the individual monomer spectra of commercial PFAS products.

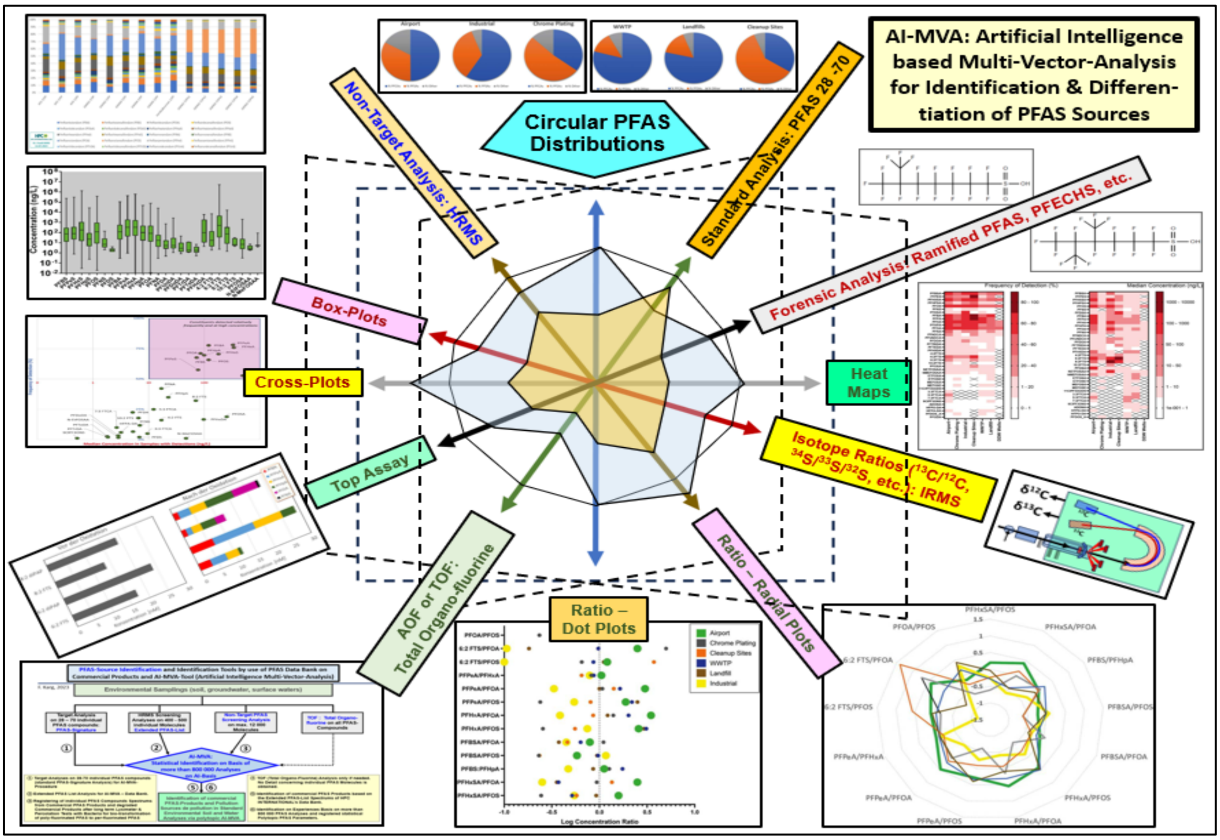


Fig. 4: Parameters for AI-MVA or PVA contamination Source differentiation of PFAS.

This is particularly important in order to identify the various PFAS sources in order to define the necessary cost distribution of management and remediation costs in accordance with the share of responsibility. This approach is **particularly important for Court expertise, for authorities, for Insurance Companies and for Industries** in order to be able to remediate groundwater (and soil) PFAS contamination in a transparent, fair and sustainable manner and **to allocate the necessary financial resources to the various responsible parties**. Examples of this come from the USA, Switzerland, Germany and France (south of Lyon in the Rhône Valley and at airports).

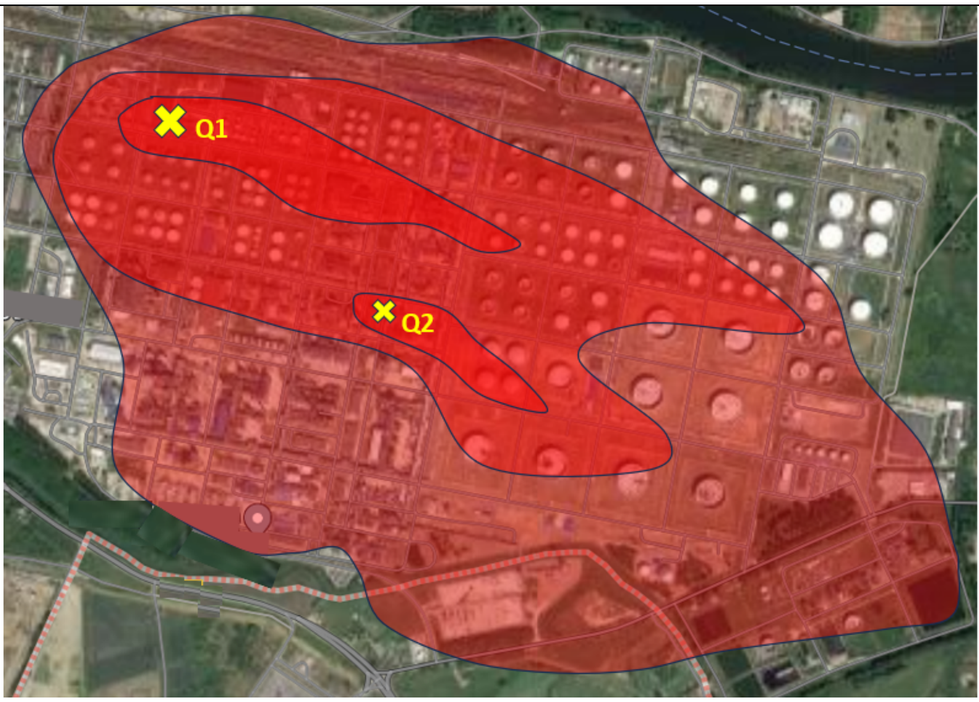


Fig 5a: PFAS Iso-concentration mapping of groundwater contamination.

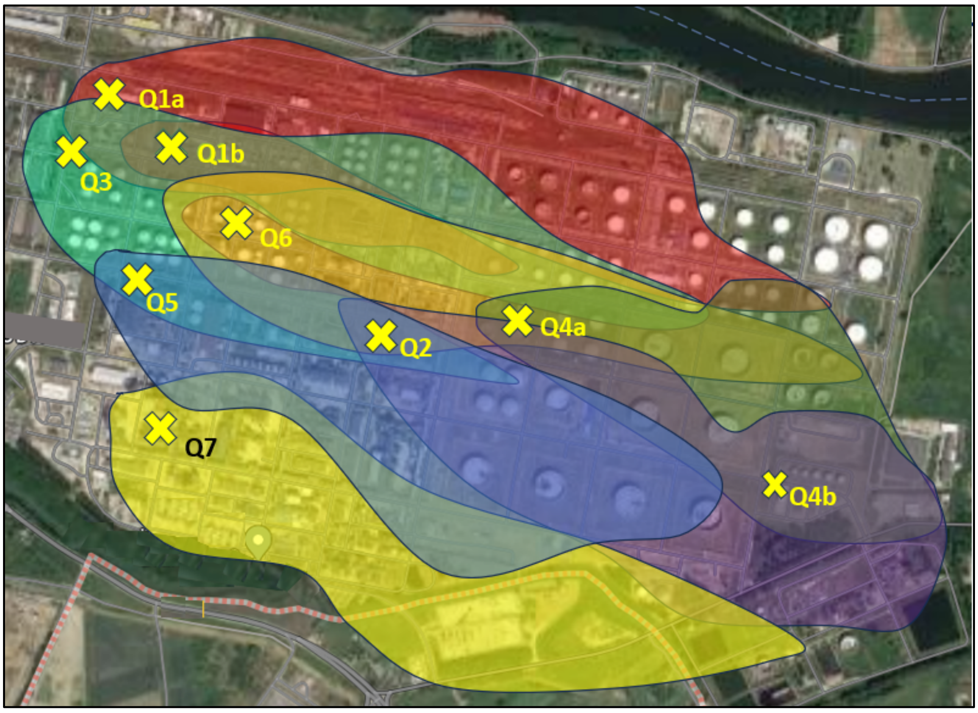


Fig. 5b: PFAS Contamination Source Différenciation in Groundwater.

The AI-MVA (& PVA) PFAS Contamination Source Differentiation shows in the example of Fig. 5a & b) Impacts from different AFFF, former Galvanization Activities, Surfactants from Fluoropolymer production and Landfill Leachates.

AI-MVA (multi-vector analysis based on artificial intelligence) can be used to differentiate and determine individual PFAS source responsibilities in mixed PFAS contamination groundwater plumes much better. This is an innovative method that is constantly being further developed using machine learning and is also supported by the state CNRS as an HPC International research project in cooperation with SORBONNE in France. This R&D project is already being used in some cases for larger mixed PFAS groundwater contaminations in France, Germany, Switzerland and Italy, but is subject to constant R&D development.

## References:


1. Monti C & K. Dasu (2023): Advanced fingerprinting analysis of PFAS in groundwaters: the use of advanced multivariate statistics and Machine learning techniques. Abstract submitted to the Congress "PFAS – Management of Environmental and Health risks". Paris, June 13-14, 2023, 6 pp.

2. Karg, F. (2024): PFAS-Source Identification and Differentiation in Environmental Pollution by use Multi Vector Analysis (MVA) on artificial Intelligence Basis – Application on standard Soil & Water Analysis. Identification et différenciation des sources des PFAS dans les pollutions environnementaux grâce à l'analyse multi-vecteurs (MVA) sur la base de l'intelligence artificielle - Application à l'analyse standard du sol et de l'eau. Congress-Manuscript for the International PFAS-Congress at 04 – 06 June 2024 in Paris.
PFAS24_ABSTRACTS_PG.pdf

3. Karg, F. (2024): **International Experiences and inovative PFAS Management in Germany: Health Risk Assessment & PFAS Pollution Sources identification and Differentiation** / Internationale Erfahrungen und innovatives PFAS-Management in Deutschland: PFAS Source Differenciation and site specific Health Risk Assessments for sustainable site remediation. PFAS-Quellendifferenzierung sowie Einzelbewertung der Vielstoffbelastungen gemäß BBodSchV § 15.4. für verhältnismäßige Sanierungen unter Berücksichtigung der flüchtigen Fluortelomeralkohole (FTOH). Congress-Document for Karlsruher Altlasten-PFAS-Seminar - Perflursan-Workshop / Germany: 18/06/2024. ICP perflusan (icp-ing.de)

4. Karg, F. (2024): Die Bedeutung der Identifizierung und Differenzierung von PFAS-Quellen im Grundwasser mittels Multi-Vektor-Analyse / **Importance of Identification & Differentiation of PFAS Contaminations Source via Multi-Vector Analysis on Artificial Intelligence Basis.** Seminar BEW - Duisburg / Germany. 06/09/2024. https://eur03.safelinks.protection.outlook.com/?url=https%3A%2F%2Fwww.bew.de%2Fveranstaltung%2Faltlasten-bodenschutz%2Fbodenschutz-und-altlastensanierung%2Fbew-forum-bodenschutz-und-altlasten-2021.html&data=05%7C02%7Cfrank.karg%40hpc-international.com%7Cfef5d313ceac431a841808dc8959fd49%7C22a00662dc9e4f69935f9c4326a5d620%7C0%7C0%7C638536266956240209%7CUnknown%7CTWFpbGZsb3d8eyJWIjoiMC4wLjAwMDAiLCJQIjoiV2luMzIiLCJBTiI6Ik1haWwiLCJXVCI6Mn0%3D%7C0%7C%7C%7C&sdata=UGQySGVG5eeQx5GcEKBsDRv%2BuBKl877uFlyv8167Rrc%3D&reserved=0

5. Karg. F. (2024) : PFAS-Quellen Identifizierung & Differenzierung via AI-MVA (Multi-Vektor-Analyse auf Basis von künstlicher Intelligenz). Symposium Script. BAFU Altlasten Symposium (Bundesamt für Umwelt), 31.10.2024. Solothurn – Schweiz / Switzerland. file:///C:/Users/fka/Downloads/Symposium%202024%20Pr%C3%A4sentationen-1.pdf

6. ASSORECA, Angeloni, A, Karg et al. 2024: PFAS Observatory Position Paper. ASSORECA, July 2024.

**Environmental and human health risk assessment for PFAS management**

Beatrice Cantoni, Junior-Assistant Professor
Department of Civil and Environmental Engineering, Environmental Section
Politecnico di Milano (Italy)

**Technical Summary**

**Introduction**

Per- and polyfluoroalkyl substances (PFAS) are a group of synthetic chemicals extensively used for their water- and grease-resistant properties. Their persistence in the environment, bioaccumulation potential, and toxicity have earned them the name "forever chemicals", presenting significant challenges to environmental and public health. This speech addresses the critical aspects of PFAS risk management, emphasizing environmental and human health risk assessment frameworks to guide regulatory and technological interventions.

**Environmental and Health Implications**

PFAS contamination pathways include industrial and municipal wastewater, stormwater runoff, and direct discharge into aquatic ecosystems. These chemicals are ubiquitous in water systems, impacting surface water, groundwater, and potable water. Their adverse effects include ecotoxicity and chronic health risks such as cancer, immune suppression, and developmental issues, with long-chain PFAS being particularly concerning due to their higher toxicity and bioaccumulation properties.

An overview of the regulatory trends will be provided, with updates on evolving global standards for acceptable PFAS levels in different compartments. In fact, regulatory agencies, such as the EU and USEPA, are progressively lowering permissible PFAS levels in drinking water and other environmental compatments to mitigate these risks.

**Risk Assessment Approaches**

Effective PFAS management requires shifting the focus from merely measuring concentrations to comprehensively evaluating the associated risks. Concentrations alone do not provide sufficient insight for optimal decision-making, as they fail to account for the varying toxicity of individual PFAS. While the risk assessment, overcomes this limitation by comparing environmental concentrations to toxicity thresholds.

To address PFAS challenges effectively, a shift from deterministic to probabilistic risk assessment frameworks is necessary. Probabilistic risk assessment approaches are crucial, as they incorporate uncertainties inherent in environmental exposure and toxicological data. Probabilistic models offer a more robust framework for predicting risk, enabling decision-makers to prioritize interventions. Seasonal and geographic factors further influence risk variability, necessitating localized assessments.

A key advancement in this area is the ability to assess PFAS mixtures by weighting the concentrations of individual PFAS according to their relative toxicity. This method, often referred to as the Relative Potency Factor (RPF) approach, ensures that the cumulative risk reflects the combined impact of each PFAS present, rather than treating them as equivalent. For example, while some PFAS may be present at low concentrations, their high toxicity can still pose significant health or environmental risks. Conversely, less toxic PFAS might require less stringent mitigation efforts even at higher concentrations. This risk-based approach supports more effective resource allocation and tailored intervention strategies.

**Management Strategies**

Mitigating PFAS risks requires a dual approach: source control and advanced treatment technologies. Preventive measures include phasing out long-chain PFAS in industrial processes and substituting with less harmful alternatives. However, short-chain PFAS, though less toxic, are more challenging to remove due to their hydrophilicity.

At the treatment level, adsorption using granular activated carbon (GAC) has proven effective, particularly for long-chain PFAS. Pre-treatment with ozonation enhances GAC performance by reducing organic matter that competes for adsorption sites. In wastewater, ozonation followed by adsorption can significantly lower PFAS concentrations, though short-chain PFAS may persist.

Pilot studies and full-scale monitoring have highlighted the importance of tailored solutions based on water matrix characteristics. For example, combining macroporous and microporous carbons in a lead-lag configuration improves the removal efficiency of diverse PFAS compounds.

Moreover, it is important to develop effective monitoring tools, to offer cost-effective proxies for tracking PFAS breakthrough and optimizing treatment processes.

**Future Perspectives**

Effective PFAS management requires an integrated approach encompassing regulatory advancements, technological innovation, and public awareness. Continuous research is vital to develop cost-efficient and scalable solutions, particularly for short-chain PFAS. Cross-sectorial collaboration is essential to implement sustainable practices and minimize PFAS releases across the water cycle.

In conclusion, PFAS risk assessment and management are dynamic fields requiring adaptive strategies. By aligning scientific insights with policy and operational practices, we can mitigate environmental and health risks, protecting water resources for future generations.

# Toxicological Health Risk Assessment in Case of oral, dermal and Inhalation Exposure of PFAS (TERQ: Toxicological Exposure Risk Quantification and definition of site use specific Remediation Goals – International State-of-the-Art

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## Abstract:

**PFAS are known for their poly-toxic effects as endocrine disruptors, hepatotoxicity, neurotoxicity, nephrotoxicity, carcinogenicity and their bioaccumulation.** In the case of PFAS contamination in groundwater and soil, a transparent **Health Risk Assessment should be carried out using TERQ** (Toxicological Exposure Risk Quantification) in order to determine **site specific Remediation Goals** in such a way that no unacceptable toxicological risks of multi-substance contamination are permitted. **Around 9 000 – 15 000 PFAS are known…**

This is ensured on the basis of comprehensive toxicological dose-effect relationship values (including RfDs, RPFs, URs, etc.), the risk assessment of all pollutant groups with the same "mode of action" (or the same toxicological target organs and mechanisms of action).

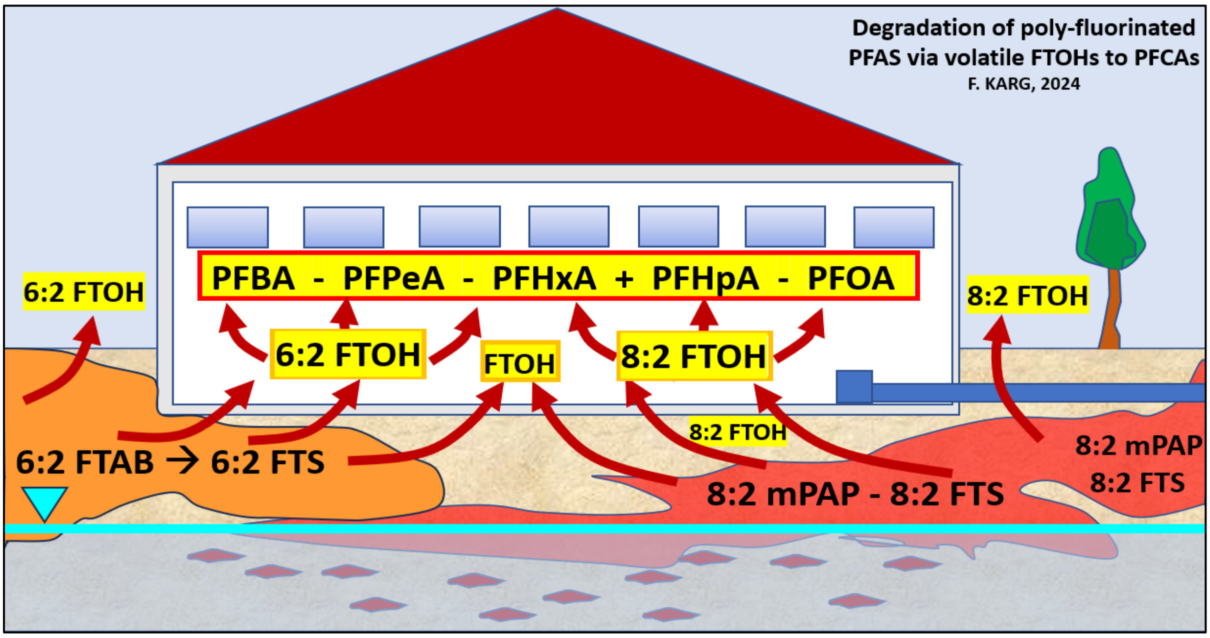


Fig. 1: Bio-transformation of poly-fluorinated PFAS (6:2-FTAB, 6:2-FTS) into volatile FTOHs and stable perfluorinated PFCAs.

In the multi-substance assessment, almost all existing poly-fluorinated PFAS are also integrated using an innovative approach, so that the toxicological effects of (if present) hundreds to thousands of PFAS (but also other pollutants) can be taken into account holistically.

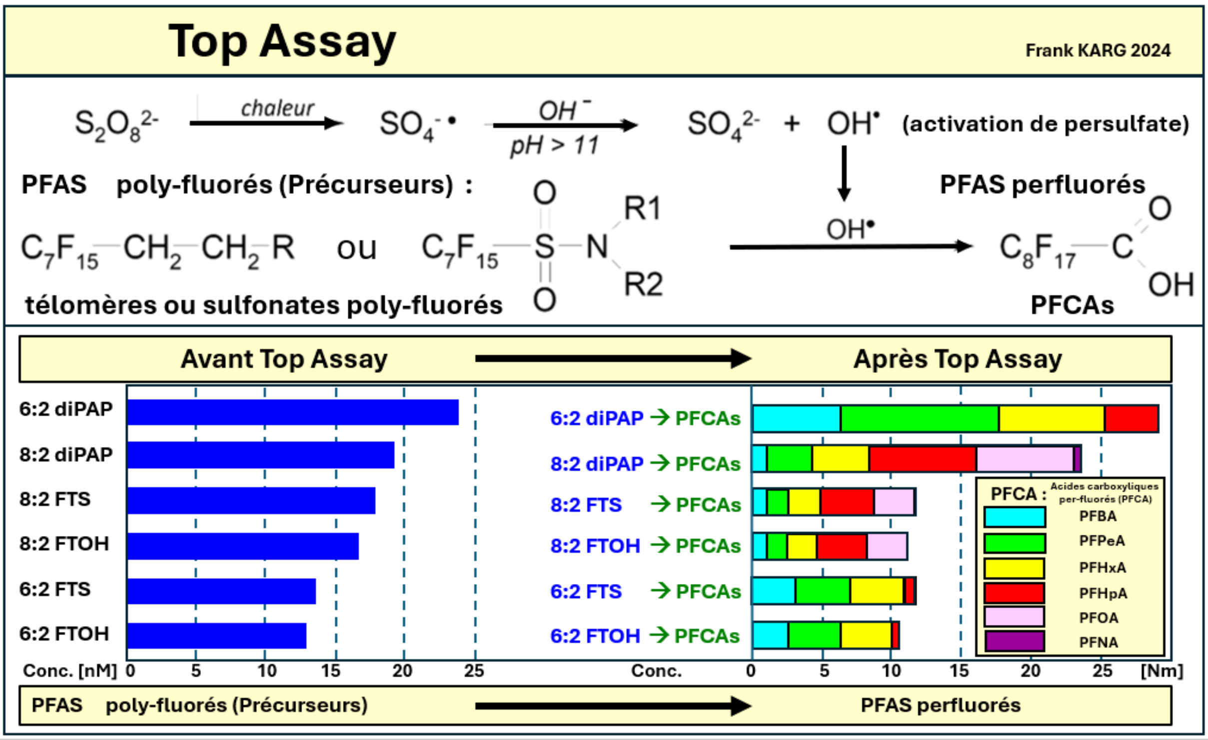


Fig. 2: Transformation of poly-fluorinated PFAS into the final per-fluorinated PFCAs (per-fluoro- carboxylic acids) via the Top Assay. This permits to consider also the totally of poly-fluorinated PFAS in the Health Risk Assessment via the final products of bio-transformation.

Volatile PFAS are also included in soil gas and indoor air, such as FTOH (fluorotelomer alcohols), which can also be bio-transformed into perfluorinated PFAS. Project examples include in Germany and France, as well as schools and kindergartens that are located on soil and/or groundwater PFAS contamination.

Based on the MOA approach to risk assessment of all pollutant groups with the same "mode of action" (or the same toxicological target organs and mechanisms of action), TERQ (Toxicological Exposure Risk Quantification) can ensure a transparent assessment for hazard prevention to determine remediation goals in such a way that no unacceptable toxicological risks of multi-substance contamination are permitted. In the multi-substance assessment, almost all existing per- and poly-fluorinated PFAS are integrated using the Top Assay, so that the toxicological effects of hundreds to thousands of polyfluorinated PFAS can be taken into account holistically in their final per-fluorinated form (PFCAs) and also other pollutants.

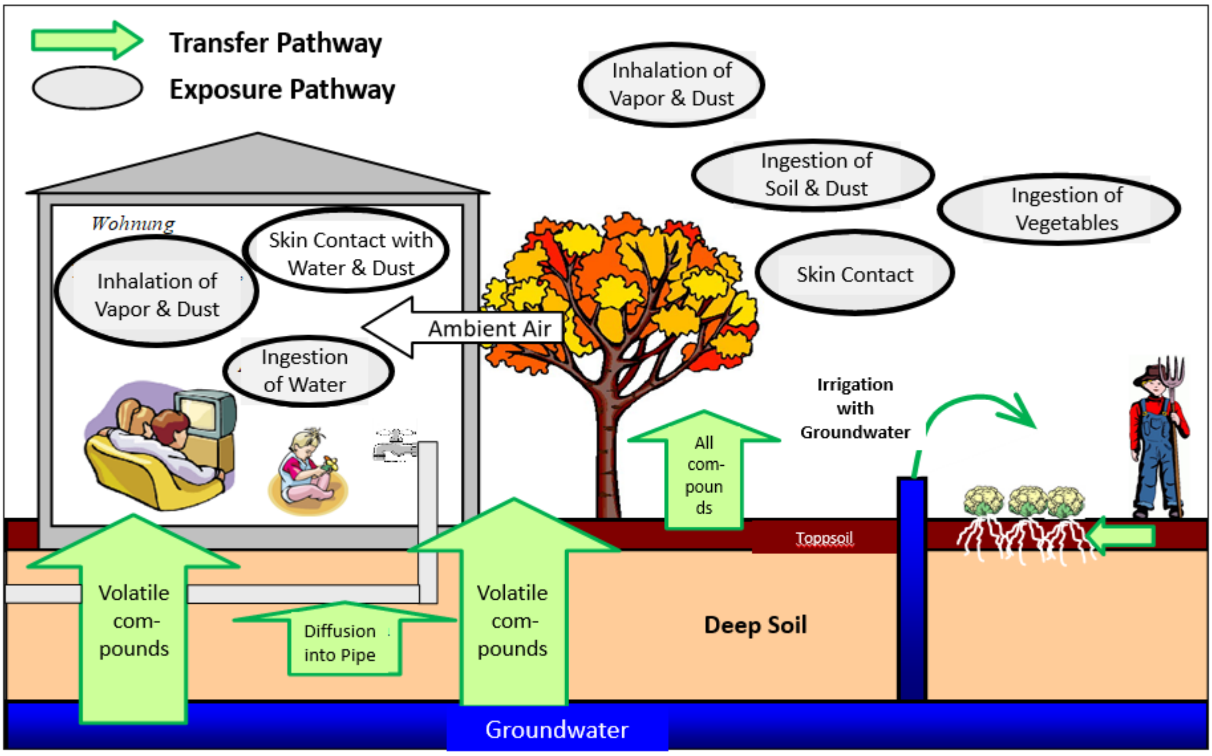


Fig 2: Example of Exposure Pathways for the Exposure Scenario : “Residential Site use”.

Volatile PFAS in soil gas and room air are also included, such as FTOH (fluorotelomer alcohols), which can still be bio-transformed into per-fluorinated PFAS. Project examples include in Germany and France, as well as schools and kindergartens that are located on soil and/or groundwater contamination.

The Fig. 3 shows toxicological Dose-Effect Relationship values for some PFAS Compounds, to be used for the TERQ Health Risk Assessment.

| Subst. | CAS Nr. | Cancero-genic / not cancero-genic | Chronic toxicological value | | | Testing Species / Study Type | Sigle | Security Factor & Origin | Organi-sation |
|---|---|---|---|---|---|---|---|---|---|
| | | | Exposure pathway | Target organ | Value | | | | |
| **PFBA** | **375-22-4** | NC | oral | Hepatic | 1 µg/kg/d | Rate | RfD | $POD_{HED}$ / 900 | TCEQ 2023<br>US-EPA IRIS 2022 |
| | | | inhalation | Hepatic | 3,5 $\mu g/m^3$ | Rate | RfC | from oral value | TCEQ 2023 |
| **PFPeA** | **2706-90-3** | NC | oral | Hepatic | 0,5 µg/kg/d | Rate | RfD | $POD_{HED}$ / 90 | TCEQ 2023 |
| **PFHxA** | **307-24-4** | NC | oral | Hepatic | 0,5 µg/kg/d | Rate | RfD | $POD_{HED}$ / 90 | TCEQ 2023<br>US-EPA IRIS 2023 |
| **PFHpA** | **375-85-9** | NC | oral | Hepatic | 25 ng/kg/d | Rate | DJT | Extrapolation of DJT of Health Canada | ANSES 2017<br>TCEQ 2023 |
| **PFOA** | **335-67-1** | NC | oral | Hematologic | 0,86 ng/kg/d | Rate | TDI | BMDL 5 | UBA 2023<br>BFR & EFSA 2018 |
| | | | | Hepatic, Mammar, Hematologic | 12 ng/kg/d | Mice | RfD | LOAEL / (81 * 300) | TCEQ 2023 |
| | | | | Immune, develop-mental and cardio-vascular | 0,03 ng/kg/d | Epidemi-ologic | RfD | Several studies | US-EPA 2024 [7] |
| | | | inhalation | Hepatic | 4,1 $ng/m^3$ | Rate | RfC | NOAEL / (81 * 3 000) | TCEQ 2023 |
| | | C | oral | Testicular tumors | $2,52 \times 10^{-6}$ $(ng/kg/d)^{-1}$ | Epidemi-ologic | SF | - | New Jersey 2017 |
| | | | | Renal Cell Carcinoma | 0,0293 $(ng/kg/d)^{-1}$ | Epidemi-ologic | SF | - | US-EPA 2024 [7] |

Fig. 3: Examples of some toxicological Dose-Effect Relationship values for some PFAS Compounds, to be used for the TERQ Health Risk Assessment (TRD: Toxic Reference Doses).

Volatile PFAS in soil gas and room air are also included, such as FTOH (fluorotelomer alcohols), which can still be bio-transformed into per-fluorinated PFAS. Project examples include in Germany and France, as well as schools and kindergartens that are located on soil and/or groundwater contamination.

The Fig. 4 shows scientific selection criteria for choosing the most relevant toxicological Dose-Effect Relationship values (or TRD: Toxic Reference Doses).

| No | TRD: Toxicological Reference Dose Choice Criteria | Appreciation | | | |
|---|---|---|---|---|---|
| | | Favorable | Correct | Not favorable | Exclusion |
| 1 | Variability of indicated TRD | (+/- 0 %) | ≤ (+/- 30 %) | > (+/- 30 %) | |
| 2 | Class (potential) Carcinogenic:<br>EC: Class 3/ US-EPA: Class B2, C / IARC: Group 1 | 3 Organisms :<br>CE, US-EPA, IARC, etc. | 2<br>Organism | 1<br>Organism | |
| 3 | Several Organisms shows similar TRD (+/- 50 %) | > 3<br>Organisms | 2<br>Organism | 1<br>Organism | |
| 4 | Age of base Study | ≤ 15 years | 15 – 25 years | < 25 years | |
| 5 | Mechanistic toxicological basement Study (for ex. Genotoxicity): | Epidemiology | Mammal | In-Vitro / In-silico | |
| 6 | Basement Study : Klimisch Quality Criteria | Class 1 | Class 2 | Class 3 | Class 3 |
| 7 | Verified Purity of Compound | Yes | < 95 % | No | |
| 8 | Excipient potentially toxic | No | | Yes | |
| 9 | Presence of population without exposure (test witness) | Yes | | No | |
| 10 | General Quality Criteria (Klimisch) of toxicological effect studies | Standardized Study (OCDE, UE, US EPA, FDA, etc.) | Standardized Study without Details, but correctly documented | Document insufficient for evaluation, systematic deficiencies | |
| 11 | POD : Point of Departure | Quantified Epidemiological Data, BMLD, etc. (PBPK) | NOAEL sensitive NOAEL | LOAEL sensitive, LOAEL, Other | |
| 12 | Uncertainty (or Assessment) Factors | 1 – 100 | > 100 – 1000 | > 1 000 –<br>10 000 | > 10 000 |
| 13a | Transpositions: Between Exposure Pathways | No | | Yes | |
| 13b | Transposition: Animal to Human | No | Yes | | |
| 13c | Transpositions : From in-Vitro | No | | Yes | |
| 13d | Transpositions : From in-Silico | No | | Yes | |
| 14 | Study time-representatively | ≥ chronic (> 180 d) | sub-chronic (90 d)<br>to chronic (180 d) | < sub-chronic<br>(< 90 d) | |
| 15 | Integration of bio-disponibility /<br>Bio-resorption capacity (ex.: DIN 19 738) | Yes | Not known<br>(100 %) | Known, but not considered | |

Fig. 4: Scientific selection criteria for choosing the most relevant toxicological Dose-Effect Relationship values (or TRD: Toxic Reference Doses).

The following Fig. indicates the way of Exposure Dose quantification in case of oral exposure pathways. Other exposure pathways to be evaluated are Inhalation and skin contact.

**Exposure Quantification: Ingestion of soils, water or food:**

$$DED_{ing} = Cm \cdot \frac{Qing}{P} \cdot Fa \cdot \frac{Ex}{Ve} \cdot Fexa \cdot Fexd$$

DEDing = Daily Exposure Dose [mg/kg/d]
Cm = Concentration Pollutants Concentration in the exposure medium : Csoil [mg/kg], Cwater [mg/l], Cfood [mg/kg]
Qi = Ingested Soil quantity and/or food [kg/d] or water [L/d], distinct from the Adults (Qing.A) and the Children (Qing.C)
P(a) = Adult Body Weight [70 kg]
P(e) = Child Body Weight [15 kg]
Fa = Absorption Factor (if failing: 100 % = [1])
Ex = Exposure years in Lifetime (Adult or Child) [y]
Ve = Lifetime: Adult or Child [y]. In case of carcinogenic Pollutants: Ve = Ex [y]
Fexa = Yearly Exposure [d/365 d]
Fexd = Daily Exposure [hrs/24 hrs]

Fig. 5: Exposure Dose quantification in case of oral exposure pathways.

The Calculation types of Health Risk Quantification in Fig. 6 show how to quantify health Risks with Dose Limits (non-cancer systemic Risks) and without Dose Limits (for ex. Cancer Risk).

**Acceptable & Unacceptable Risks:**

- **Individual Cancer Risk : ICR $\leq 10^{-5}$**

**ICR = DED • UR**

**Daily Exposure Dose (mg/kg/d) • Unit Risk or Slope Factor (mg/kg/d)$^{-1}$**

- **Non-Cancer-Risk: Risk Index: RI $\leq$ 1**

**RI = DED / TRD**

**Daily Exposure Dose (mg/kg/d) / Toxic Reference Dose or TDI, ADI, RfD etc. (mg/kg/d) per toxicological target Organ**

Fig. 6: Quantification of Health Risks with Dose Limits (non-cancer systemic Risks) and without Dose Limits (for ex. Cancer Risk).

After the toxicological Heath Risk Quantification via TERQ, transparent results are obtained to identify acceptable (RI $\leq$ 1 and ICR $\leq 10^{-5}$) or non-acceptable Risks (RI > 1 and ICR > $10^{-5}$). In case of non-acceptable Risks, site specific Remediation Goals (Concentration Limits) must be defined for acceptable risks, for example concerning Soil, groundwater, Surface water, Drinking Water and Foodstuff, if needed. The Fig. 7 shows an example of site specific Remediation Goal Exceeding in soil.

This approach is needed for definition of technical & economical Remediation needs and costs to ensure in total transparency the elimination of all non-acceptable health Risks.

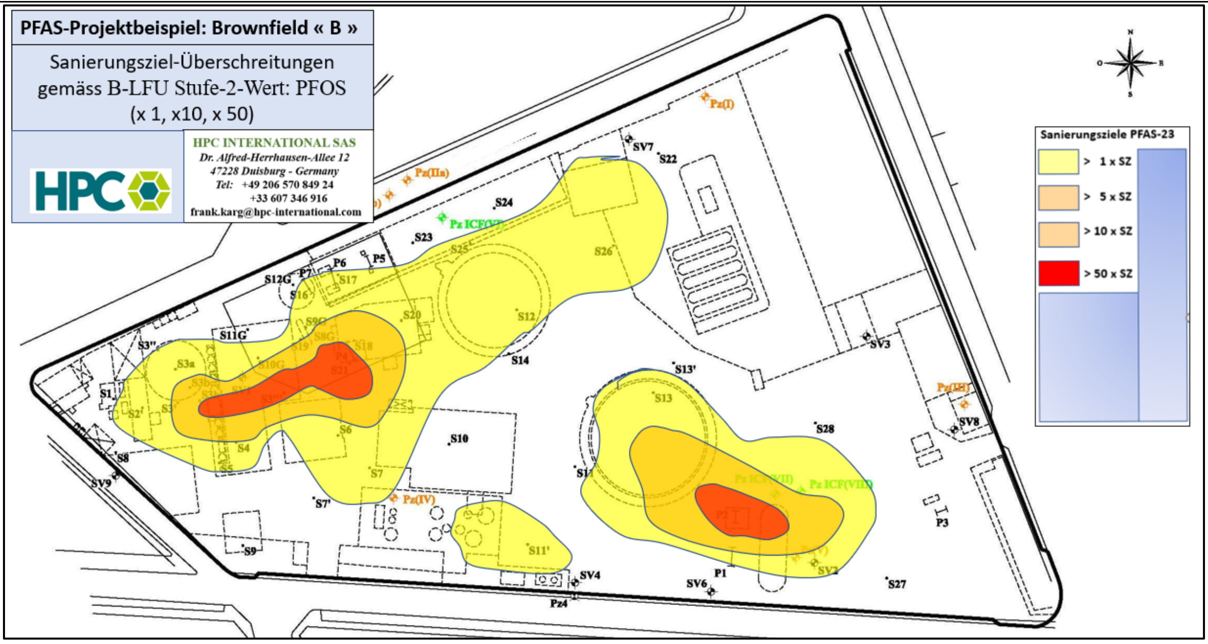


**Fig. 7: Example of site-specific Remediation Goal Exceeding in soil for determination of to be remediated Risk zones.**

## References:


1. **Karg, F. (2022):** ERP sensibles (Ecoles, Crèches) & Habitations et Diagnostics, Evaluation des Risques Toxicologiques et Traitements des PFAS, notamment les FTOH : Fluorotélomère-Alcools volatils / **Public Site Use Scenarios (Schools, Kindergartens & Residences and Site Investigation, Toxicological Health Risk Assessments (TERQ) and Treatments of PFAS, especially volatile FTOH: Fluorotelomere Alcohols.** INTERSOL 2022, Lyon / France: 21-23/06/2022, Congress Minutes. https://www.saturne.net/mud/index.php?d=intersol2022_abstracts_pg

2. **Karg, F. (2022): Management of FTOH: Fluorotelomere Alcohols (volatile PFAS) in ambient air of public site use scenarios (schools, kindergartens) & residences: site investigation, toxicological health risk assessments (TERQ)** / Gestion des FTOH : Fluorotélomère-Alcools (PFAS volatils) dans l'air ambiant des ERP sensibles (écoles, crèches) & habitations : diagnostics et évaluation des risques toxicologiques. AtmosFair, Lyon: 20 & 21/09/2022. Congress Minutes.

   https://www.saturne.net/mud/index.php?d=atmosfair2022_program_abstracts

3. **Karg, F. (2022):** Actualized Legal framework of PFAS management in Soil, Groundwater and soil & discharge effluents and Leachates in Germany and France & EC wide potential evolution of the legislation concerning PFAS management in the next years. RemTech, Ferrara – Italia, 22/09/2022. Minutes of Congress.

4. **Karg, F. (2022):** PFAS: Management of Pollution and Health Risks: Site Investigations, Environmental Chemistry, Risk Assessment (sensitive ERP and others), Regulatory Thresholds and Treatments (including volatile PFAS FTOH in soils, groundwater, soil gas & ambient air). International PFAS-Congress ARET-SFSE-HPC INTERNATIONAL, Paris 20 October 2022. Minutes of Congress. https://www.saturne.net/mud/index.php?d=pfas_congress22_abstracts_pg

5. Karg, F., Hintzen, U., Robin-Vigneron, L. & Mostersteg, (2022): Einzelfallprüfung bei PFAS: Anwendung der neuen Mantelverordnung für verhältnismässige und kostenoptimierte Sanierungen bei Vielstoffbelastung. (**Site specific Risk Assessment and Cost effective Site Remediation of PFAS**). Altlastenspektrum 06/2022, p. 180 – 192, ITVA December 2022. https://altlastendigital.de/ce/einzelfallpruefung-bei-pfas/detail.html

6. Karg, F. & Hintzen, U. (2023): PFAS sicher und preiswert sanieren (**Site specific Risk Assessment and Cost effective Site Remediation of PFAS**): Umweltmagazin 01/2023. VDI: Verein Deutscher Ingenieure. S. 46 – 49.

7. Karg, F. (2023): Traitements in-situ des Polluants émergents dans les Sols et les Eaux souterraines - Exemples des aménagements des sites polluées par des HET-NSO & PFAS. Minutes of Congress INTERSOL Lille / France: 29th to 31st of March 2023.

8. Karg, F., SFSE et. al. (2023): SFSE Guideline on PFAS Pollution Management / Guide et Fiches de gestion des pollutions par des PFAS. Société Francophone de Santé en Environnement. Minutes of International PFAS Congress, Paris 13 & 14 June 2023. https://hpc.ag/wp-content/uploads/PFAS-Congress-Abstract-SFSE-13-06-23-F_ChR.pdf https://hpc.ag/wp-content/uploads/PFAS-Congress-Abstract-SFSE-13-06-23-E_ChR.pdf

9. Karg, F., Hintzen, U., Robin-Vigneron, L. et Girard, P. (2023): PFAS : Environmental Chemistry Investigations, Source Identification, Toxicology and TERQ Risk Assessments, including FTOH. Minutes of International Congress PFAS – Management of Environmental and Health Risks". Paris, June 13-14, 2023. https://hpc.ag/wp-content/uploads/PFAS-Congress-Abstract-KARG-HPC-INTERNATIONAL-2023-F.pdf https://hpc.ag/wp-content/uploads/PFAS-Congress-Abstract-KARG-HPC-INTERNATIONAL-2023-E.pdf

10. Karg, F. & HUETTMANN, S. (2023): Sustainable In-situ Treatments of PFAS in contaminated Soil and Groundwater, Washing with Protein Bio-polymers. Introduction. Minutes of International Congress PFAS – Management of Environmental and Health Risks". Paris, June 13-14, 2023. https://hpc.ag/wp-content/uploads/PFAS-abstract-Sensatec-Huettmann-KARG-E.pdf https://hpc.ag/wp-content/uploads/PFAS-abstract-Sensatec-Huettmann-KARG-F.pdf

11. Lanoy, L. & Karg, F. (2023): Tout savoir sur le nouvel arrêté ministériel du 20/06/2023 sur les PFAS. Environnement Magazine, N° 1805 Septembre 2023. https://www.environnement-magazine.fr/pollutions/article/2023/07/11/145170/tout-savoir-sur-nouvel-arrete-ministeriel-sur-les-pfas

12. Karg. F. (2023): Pollution by volatile PFAS: Health Risks due to vapors and contamination of Ambient Air / Pollution par PFAS volatils : risques pour la santé dus aux émanations et contaminations de l'air ambiant. Minutes of Congress Atmosfair, Paris 27 & 28/06/2023.
https://hpc.ag/wp-content/uploads/PFAS-Atomsfair-Karg-HPC-INTERNATIONAL-E-2023.pdf
https://hpc.ag/wp-content/uploads/PFAS-AtmosFair-KARG-HPC-INTERNATIONAL-27-06-2023-F.pdf

13. Jailler, M., Rousselle, C., **Karg, F**. (2023): Evaluation et Gestion des PFAS: 1. Connaissances générales / **General Knowledge.** Guide de Gestion des PFAS de la SFSE : Société Francophone de Santé et Environnement. Online: 27/11/2023.
https://sfse.wetransfer.com/downloads/e193f037a0dcb952f56e28b7e58a989220231123142128/f19c7b

14. Lanoy, L., Staub, P.-F., Franques, N., Bouhoulle, E., **Karg, F**. (2023): Evaluation et Gestion des PFAS : 2. Cadre règlementaire et juridique / **Legal context**. Guide de Gestion des PFAS de la SFSE : Société Francophone de Santé et Environnement. Online: 27/11/2023.
https://sfse.wetransfer.com/downloads/e193f037a0dcb952f56e28b7e58a989220231123142128/f19c7b

15. **Karg, F.,** Heilier, J.-F., Pradier, F., Triau, O., Rousselle, C., Jailler, M. (2023) : Evaluation et Gestion des PFAS : 3. Hiérarchisation des sources de pollution / **Identification and Prioritization of Contamination Sources**: Exemple de la Ville de Lyon concernant les ERP sensibles. Guide de Gestion des PFAS de la SFSE : Société Francophone de Santé et Environnement. Online: 27/11/2023.
https://sfse.wetransfer.com/downloads/e193f037a0dcb952f56e28b7e58a989220231123142128/f19c7b

16. **Karg, F.,** Rousselle, C. (2023) : Evaluation et Gestion des PFAS: 4. Devenir dans l'Environnement et Biotransformation & Chimie Environnementale / **Environmental Behavior & Environmental Chemistry.** Guide de Gestion des PFAS de la SFSE : Société Francophone de Santé et Environnement. Mise en ligne, le 27/11/2023.
https://sfse.wetransfer.com/downloads/e193f037a0dcb952f56e28b7e58a989220231123142128/f19c7b

17. Peureux, S., Passador, A., **Karg, F.**, Beri, S., Jailler, M. (2023): Evaluation et Gestion des PFAS : 5. Méthodes des prélèvements / **Sampling Methods for Soil, Water & Air**: Sols, Eaux et Air. Guide de Gestion des PFAS de la SFSE : Société Francophone de Santé et Environnement. Online: 27/11/2023.
https://sfse.wetransfer.com/downloads/e193f037a0dcb952f56e28b7e58a989220231123142128/f19c7b

18. Peureux, S., Passador, A., Beri, S., **Karg, F**. (2023): Evaluation et Gestion des PFAS : 6. Méthodes d'analyses : Sols, Eaux, Air / **Analysis Methods for Soil, Water & Air**. Guide de Gestion des PFAS de la SFSE : Société Francophone de Santé et Environnement. Online: 27/11/2023. https://sfse.wetransfer.com/downloads/e193f037a0dcb952f56e28b7e58a989220231123142128/f19c7b

19. Bouhoulle, E., Jacquemin, P., Jailler, M ., Jailler, M., **Karg, F.** (2023): Evaluation et Gestion des PFAS : 7. Bruit de fond / **Environmental chemical Background**. Guide de Gestion des PFAS de la SFSE : Société Francophone de Santé et Environnement. Online : 27/11/2023. https://sfse.wetransfer.com/downloads/e193f037a0dcb952f56e28b7e58a989220231123142128/f19c7b

20. SFSE, Jailler, M., **Karg, F.,** Bouhoulle, E., Le Bonniec, S., Robin-Vigneron, L. (2023): Evaluation et Gestion des PFAS : 8. Comportement dans l'Environnement : Paramètres physico-chimiques des PFAS / **Physical and Chemical Parameters**. Guide de Gestion des PFAS de la SFSE : Société Francophone de Santé et Environnement. Online : 27/11/2023. https://sfse.wetransfer.com/downloads/e193f037a0dcb952f56e28b7e58a989220231123142128/f19c7b

21. Heilier, J.F., Rousselle, C., **Karg, F.,** Ronga, S., Charlate, P., Pouzaud, F., Robin-Vigneron, L. (2023 + 2024) : Evaluation et Gestion des PFAS : 9. Toxicité et Valeurs Toxicologiques de Référence. Guide de Gestion des PFAS de la SFSE : Société Francophone de Santé et Environnement. Mise en ligne, le 27/11/2023. https://sfse.wetransfer.com/downloads/e193f037a0dcb952f56e28b7e58a989220231123142128/f19c7b

22. **Karg, F.,** Heilier, J.-F., Ronga-Pezeret, S., Rousselle, C., Bouhoulle, E., Robin-Vigneron, L. (2023 + 2024) : Evaluation et Gestion des PFAS : 10. Evaluation Quantitative des Risques Sanitaires et mélanges. Guide de Gestion des PFAS de la SFSE : Société Francophone de Santé et Environnement. Mise en ligne, le 27/11/2023. https://sfse.wetransfer.com/downloads/e193f037a0dcb952f56e28b7e58a989220231123142128/f19c7b

23. Rousselle, C., Ruthy, I., Jacques, A., Bouhoulle, E., **Karg, F.** (2023): Evaluation et Gestion des PFAS : 11. Données de Biomonitoring Humain / **Human Bio-monitoring**. Guide de Gestion des PFAS de la SFSE : Société Francophone de Santé et Environnement. Online: 27/11/2023. https://sfse.wetransfer.com/downloads/e193f037a0dcb952f56e28b7e58a989220231123142128/f19c7b

24. **Karg, F.,** Rousselle, C. (2023): Evaluation et Gestion des PFAS : 12. Méthodes de dépollution des sols / **Soil Remediation Methodologies**. Guide de Gestion des PFAS de la SFSE : Société Francophone de Santé et Environnement. Online: 27/11/2023. https://sfse.wetransfer.com/downloads/e193f037a0dcb952f56e28b7e58a989220231123142128/f19c7b

25. **Karg, F**., Rousselle, C. (2023): Evaluation et Gestion des PFAS: 13. Méthodes de dépollution des eaux souterraines et traitement des eaux usées et de l'eau potable / **Water Treatment Methodologies.** Guide de Gestion des PFAS de la SFSE : Société Francophone de Santé et Environnement. Online: 27/11/2023. https://sfse.wetransfer.com/downloads/e193f037a0dcb952f56e28b7e58a989220231123142128/f19c7b

26. **Karg, F.,** Rousselle, C. (2023): Evaluation et Gestion des PFAS : 14. Méthodes d'assainissement des gaz du sol et de l'air ambiant / **Soil Vapor and Ambiant Air Treatment.** Guide de Gestion des PFAS de la SFSE : Société Francophone de Santé et Environnement. Online: 27/11/2023. https://sfse.wetransfer.com/downloads/e193f037a0dcb952f56e28b7e58a989220231123142128/f19c7b

27. Karg, F. (2024): Evaluation des risques sanitaires d'une multitude des PFAS par application des Top Assays sur les substances polyfluorés (Précurseurs). **Health Risk Assessments for large PFAS Cocktails by Application of the Top Assays concerning the poly-fluoro Substances (Precursors).** Congress-Manuscript for the INTERSOL Congress at 26-28 March 2024 in Paris. https://www.saturne.net/mud/index.php?d=intersol2024_pg_abstracts

28. Karg, F. (2024): PFAS-Source Identification and Differentiation in Environmental Pollution by use Multi Vector Analysis (MVA) on artificial Intelligence Basis – Application on standard Soil & Water Analysis. Identification et différenciation des sources des PFAS dans les pollutions environnementaux grâce à l'analyse multi-vecteurs (MVA) sur la base de l'intelligence artificielle - Application à l'analyse standard du sol et de l'eau. Congress-Manuscript for the International PFAS-Congress at 04 – 06 June 2024 in Paris.
PFAS24_ABSTRACTS_PG.pdf

29. Karg, F. (2024): Integrated PFAS Quantitative Health Risk Assessments via TERQ (Toxicological Exposure Risk Quantification) by use of Top Assay Analysis for integration of the large Mass of poly-flourinated Alkyl Substances. Évaluations quantitatives des risques pour la santé des PFAS via des EQRS, en application des Analyses du Top Assay pour l'intégration de la grande masse de substances alkyles polyfluorées. Congress-Manuscript for the International PFAS-Congress at 04 – 06 June 2024 in Paris.
PFAS24_ABSTRACTS_PG.pdf

30. Karg, F. (2024): Advanced in-situ Remediation of PFAS by application of in-situ Washing with Proteinic Bio-Polymers. Dépollution in situ avancée des PFAS par application d'un lavage in situ via des Bio-polymères protéiques. Congress-Manuscript for the International PFAS-Congress at 04 – 06 June 2024 in Paris. PFAS24_ABSTRACTS_PG.pdf

31. Karg, F. (2024): **International Experiences and inovative PFAS Management in Germany: Health Risk Assessment &PFAS Pollution Sources identification and Differentiation** / Internationale Erfahrungen und innovatives PFAS-Management in Deutschland: PFAS Source Differenciation and site specific Health Risk Assessments for sustainable site remediation. PFAS-Quellendifferenzierung sowie Einzelbewertung der Vielstoffbelastungen gemäß BBodSchV § 15.4. für verhältnismäßige Sanierungen unter Berücksichtigung der flüchtigen Fluortelomeralkohole (FTOH). Congress-Document for Karlsruher Altlasten-PFAS-Seminar - Perflursan-Workshop / Germany: 18/06/2024. ICP perflusan (icp-ing.de)

32. Karg, F. (2024): Die Bedeutung der Identifizierung und Differenzierung von PFAS-Quellen im Grundwasser mittels Multi-Vektor-Analyse / **Importance of Identification & Differentiation of PFAS Contaminations Source via Multi-Vector Analysis on Artificial Intelligence Basis.** Seminar BEW - Duisburg / Germany. 06/09/2024. https://eur03.safelinks.protection.outlook.com/?url=https%3A%2F%2Fwww.bew.de%2Fveranstaltung%2Faltlasten-bodenschutz%2Fbodenschutz-und-altlastensanierung%2Fbew-forum-bodenschutz-und-altlasten-2021.html&data=05%7C02%7Cfrank.karg%40hpc-international.com%7Cfef5d313ceac431a841808dc8959fd49%7C22a00662dc9e4f69935f9c4326a5d620%7C0%7C0%7C638536266956240209%7CUnknown%7CTWFpbGZsb3d8eyJWIjoiMC4wLjAwMDAiLCJQIjoiV2luMzIiLCJBTiI6Ik1haWwiLCJXVCI6Mn0%3D%7C0%7C%7C%7C&sdata=UGQySGVG5eeQx5GcEKBsDRv%2BuBKl877uFlyv8167Rrc%3D&reserved=0

33. Karg, F. (2024): Measurements and Health Risk assessments of volatile PFAS in indoor Ambient Air (FTOH: Fluortelomere alcohols, etc.). Progress concerning work relating to Nurseries and Schools in Rhône-Alpes / France: Choice and application of TRV*, Space-Time Budgets, Respiration Rates, etc. for volatile PFAS & COHV, etc.) (* Toxicological Reference Values). Congress-Manuscript ATMOSFAIR Lyons, 22-23/10/2024. https://www.saturne.net/mud/index.php?d=atmosfair2024_october_9

34. Karg. F. (2024) : PFAS-Quellen Identifizierung & Differenzierung via AI-MVA (Multi-Vektor-Analyse auf Basis von künstlicher Intelligenz). Symposium Script. BAFU Altlasten Symposium (Bundesamt für Umwelt), 31.10.2024. Solothurn – Schweiz / Switzerland. file:///C:/Users/fka/Downloads/Symposium%202024%20Pr%C3%A4sentationen-1.pdf

35. Karg. F. (2024): Evaluation des risques toxicologiques dans le cas des multi-expositions aux PFAS poly- & perfluorés, via l'application des Top Assays sur les substances polyfluorés (Précurseurs). Document du Congrès de Toxicologie de la SFT : Société Française de Toxicologie, Lyon 14 – 15/11/2024. https://www.sftox.com/index.php/actualites/congres

36. Karg. F. (2024) : PFAS : Évaluation des Risques toxicologiques (EQRS) avec la prise en compte des précurseurs & métabolites stables et expériences et applications conforme au Guide de Gestion des PFAS de la SFSE / Toxicological Exposure Risk Assessment (TERQ) considering stable Precursors & Metabolites and expériences & applications in compliance to the SFSE's PFAS Management Guideline. Congrès de la SFSE : Société Francophone de Santé et Environnement. Paris 21/11/2024. Seminar Script. https://www.sfse.org/congres/presentations/21

37. ITVA-H1, U. Hintzen, F. Karg, et al. (2024): In-situ-Quellensanierung (In-situ Decontamination & Remediation of Pollution Sources). ITVA-Arbeitshilfe: Quellenbehandlung: Handbook / Deutschland (Germany). ITVA-Website: 08-2024. https://www.itv-altlasten.de/wp-content/uploads/2024/12/ITVA-H1-17-In-situ-Quellensanierung-Stand-5.11.2024.pdf

38. ASSORECA, Angeloni, A, Karg et al. 2024: PFAS Observatory Position Paper. ASSORECA, July 2024.

39. Karg, F., Heilier, J.-F., Ronga-Pezeret, S., Robin-Vigneron, L. (2025): Evaluation des risques toxicologiques dans le cas des multi-expositions aux PFAS poly- & per-fluorés, via l'application des Top Assays sur les substances polyfluorés (Précurseurs). In: Traité en Toxicologie et d'évaluation des risques. SFT : Société Française de Toxicologie et d'évaluation des risques. TDM Editions.

**PFAS: A constantly evolving analytical challenge**

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'Perfluoroalkyl and polyfluoroalkyl substances', abbreviated as PFAS, are a large group of substances containing one or more fully fluorinated carbons and include thousands of chemical compounds with widely varying physical and chemical properties, health and environmental profiles, uses and benefits. These substances are used in the manufacture of products and additives in innumerable sectors.

PFAS are receiving increased attention from regulatory authorities due to their persistence and (eco)toxicological profile, as well as their widespread use and consequent ubiquitous presence. It has been said that there are more than 15,000 PFASs, but also people familiar with the subject can only name a few dozen.

The environmental persistence of PFASs is linked not only to the strength of the carbon-fluorine bond, one of the most energetic single bonds in organic chemistry, but above all to the reduced ability of microorganisms to degrade, and in particular to defluorinate, the fluorinated chains. This results in a very high environmental persistence of that molecules, originally introduced into the environment, which contains the carbon-fluorine bond. Moreover, unlike most POP's, their high solubility in water increases their mobility in the environment and their amphiphilic properties at high concentrations increase their ability to aggregate into micelles.

The analytical complexity, therefore, lies not only in the high number of per- and polyfluorinated compounds (around 15,000) but especially in the extreme variability of chemical forms they can take in the environment.

The most widely used analytical techniques for the determination of the most commonly used compounds (the perfluoroalkylcarboxylic and perfluoroalkylsulphonic acids from C4 to C13) are now well established and formalised in official ASTM, EPA, ISO etc. methods. These methods, however, are or can be extended to the determination of sulphonated fluorotelomers, amides and acetic acids with some specific instrumental optimisations. To date, there are about fifty poly or perfluorinated compounds that can be analysed. The number of compounds that can be analysed in accordance with ISO 17025 is constrained by the availability of certified reference standards and surrogates/labelled compounds on the market.

The largest difficulty in the determination of target compounds is the regulatory framework, which is aimed at reducing the legal limits more and more. This trend leads to the need to apply increasingly refined instrumental techniques combined with essential concentration techniques in order to achieve the necessary sensitivity results. One of the fundamental problems is that, at concentrations around ppb and below, some of the analytes become ubiquitous and, in addition, determinations must take into account possible losses of analytes during sampling, enrichment and instrumental analysis.

The most challenging matrices are groundwater, drinking water and wastewater due to the remarkably low regulatory limits (often below ppt) and landfill leachate, liquid and solid wastes due to the considerable amount of interferents contained in these complex matrices. These characteristics do not allow their concentration with the same methods used for 'lighter' matrices and adversely affect the performance of

The tendency of PFASs to degrade into shorter PFASs has led laboratories to search for specific methods for Ultrashort PFAS, which have a number of carbons of three or less. They must be determined by means of chromatographic columns that differ from those used up till now for 'classical' PFAS. There are currently no official methods for these compounds, but it is possible to determine them with sufficient accuracy.

A French regulation provides for the determination of absorbable organic fluorine (AOF) in addition to certain target PFASs, in wastewater that become from companies with a high environmental impact. In these cases the technique is chromatographic analysis preceded by combustion of the sample (combustion ion chromatography CIC) and it is under constant development. This technique may prove useful in the evaluation of those samples in which the determination of target compounds could result in an underestimation of the content of per- and polyfluorinated substances.

Another EC Communication presents the dosage of EXTRACTABLE organic fluorine (EOF), together with target measurements of PFAS and trifluoroacetic acid (TFA), for the measurement of PFAS compounds that are present but cannot be dosed directly.

These two techniques, together with the TOP Assay, are part of the un-target analysis techniques and are useful for investigating the possible presence of compounds that can be traced back to PFAS, by analogy of structure even after degradation. The biggest challenge is that of the limits of quantification, which are not low enough to measure appreciable values in some applications and are often subject to high environmental background values.

An increasingly pressing need is the dosing of PFASs in the air matrix. Indeed, it has been observed that some molecules of this class can be carried by the wind and deposited in locations other than the production site. To date, there are a number of air sampling devices suitable for the adsorption of certain classes of PFAS, which can speed up and improve (thermal) desorption and instrumental analysis.

Another requirement is to determine PFASs in the emissions of sewage sludge incineration facilities, in order to assess their abatement capacity.

The methods currently in use focus on the ability to capture pollutants using techniques that vary according to the polarity and chemical-physical characteristics of the pollutants. The different extraction and determination procedures come from the existing methods described above. In fact, to date, the analytical techniques used for PFAS analysis range from liquid chromatography to GC-MS, used for example for the analysis of volatile and/or apolar compounds.

**Never Say Forever:**
**Unlocking the Potential of Activated Carbon for PFAS Removal and Destruction**

Speaker: Dr. Annemie Houben, R&D Manager, Desotec

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**Abstract:**

Per- and polyfluoroalkyl substances (PFAS) are a pressing global challenge due to their persistence in the environment and adverse health effects. DESOTEC, an international environmental services company, provides sustainable mobile filtration solutions based on activated carbon, a proven and effective method for PFAS removal from liquid and gaseous streams. Recognized as a Best Available Technology (BAT) under the Stockholm Convention (March 2021), activated carbon offers a versatile and robust approach to addressing PFAS contamination.

Activated carbon's effectiveness stems from its highly porous structure and extensive surface area, enabling strong adsorption of PFAS molecules. However, the performance of any activated carbon-based filtration system depends on several critical parameters:

- **Activated carbon characteristics**: The source material, activation process, and resulting pore structure, surface chemistry, and specific surface area of activated carbon influence adsorption capacity and selectivity for PFAS. These characteristics allow selection of the appropriate carbon type for specific applications while maintaining cost-effectiveness.
- **PFAS concentration and chemical properties**: The chemical structure, size, charge, and hydrophobicity of PFAS molecules can influence their adsorption onto activated carbon. Longer chain PFAS compounds, such as perfluorooctanoic acid (PFOA) and perfluorooctanesulfonic acid (PFOS), are generally more easily adsorbed than shorter chain PFAS compounds such as perfluorobutanoic acid (PFBA).
- **Contact time and filter design**: Effective PFAS removal requires extended contact times compared to other contaminants. By selecting the appropriate filter, or combining two or more filters in series, adequate interaction between the carbon and PFAS-laden water is ensured.
- **Water Matrix Composition**: Parameters such as pH, ionic strength, and the presence of competing organic or inorganic compounds significantly impact adsorption efficiency. For example, elevated pH levels or competing ions can reduce PFAS removal unless carefully managed.
- **Filter Configuration and Monitoring**: To mitigate challenges like delayed analysis results (often requiring 5–10 days), DESOTEC recommends a dual-filter system in series. This configuration ensures any breakthrough at the first filter is captured by the second, guaranteeing complete PFAS retention.

Beyond filtration, DESOTEC provides a comprehensive service encompassing filter takeback and rigorous adherence to regulatory standards. Saturated activated carbon undergoes detailed analysis to quantify PFAS content, ensuring compliance with the Persistent Organic Pollutants (POP) directive. This directive specifies strict limits for PFOS, PFOA, and Perfluorohexanesulfonic acid (PFHxS) concentrations on spent carbon eligible for thermal reactivation, guaranteeing both regulatory alignment and operational integrity. To address the limitations of traditional measurement methods, DESOTEC collaborated with VITO, a leading independent research institute, to develop an advanced extraction and analysis methodology for accurate PFAS quantification on spent activated carbon. This

methodology enhances reliability and regulatory compliance, giving operators confidence in their waste management practices.

Once spent carbon is assessed, and meets all acceptance criteria, it is processed through thermal reactivation, an environmentally sustainable solution. During reactivation, under the right conditions, PFAS molecules are destroyed through pyrolysis, converting them into inert compounds while regenerating the carbon for reuse. DESOTEC's research, using extensive analytics, demonstrates PFAS below detection limit on the reactivated carbon, and in the stack gasses further supporting this circular economy approach. In parallel, the flue gas treatment systems integrated into our reactivation facilities neutralize mineralization byproducts such as hydrogen fluoride, and sulfur dioxide ensuring safe and compliant operation throughout the process. This is further evidenced by continuous monitoring of stack emissions.

This presentation will explore the interplay of these factors in optimizing PFAS removal and destruction using activated carbon. We will discuss the parameters influencing adsorption performance, the dual-filter approach, and the advanced PFAS measurement technique developed with VITO. Additionally, we will share detailed findings from our reactivation research, demonstrating the efficacy of PFAS destruction and the environmental advantages of carbon reuse. Through these insights, DESOTEC underscores its commitment to delivering sustainable, effective solutions to one of the most critical environmental challenges of our time.

**Advanced oxidation and biological processes for PFAS removal in landfill leachate**

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In the last decades, the solid waste generation is continuously rising due to socioeconomic and demographic factors. Despite efforts to increase the recycling of urban waste, landfilling is still a widely used disposal technique in many countries. Within landfills, waste undergoes a number of physical, chemical and biological processes and releases a variety of pollutants within the landfill leachate, making this matrix one of the most difficult to treat. In landfill leachate perfluoralalkyl substances (PFAS) have also been found. These micropollutants have great relevance in the context of the urban integrated water cycle since they are present in many daily uses in the civil and industrial fields. PFAS exposure is linked to a range of health effects, including developmental disorders, liver damage, immune system disruption, and an increased risk of certain cancers. The persistence of PFAS in the environment exacerbates the hazard, as their bioaccumulation in the food chain can lead to prolonged human exposure.

The treatment of medium-age landfill leachates containing different PFAS levels was investigated at laboratory scale by employing several set-ups including an innovative biological step, performed by a SBBGR (Sequencing Batch Biofilter Granular Reactor), with or without ozone enhancement, followed or not by a polishing stage with Advanced Oxidation Processes (AOPs) based on photo-electro-catalysis, electrochemical oxidation or photolysis with excimer lamps. Objectives of the investigation were to compare different treatment strategies in order to evaluate the effectiveness of the treatment schemes in terms of gross parameters and PFAS removals.

SBBGR is an innovative biological technique which allows to transform the existing activated sludge in a particular kind of sludge made up of biofilm and granules bounded in a plastic porous material. This configuration allows reaching very long sludge retention times (SRTs), longer than 300 days, thus reducing sludge production (up to 8 times). The high SRTs enable enrichment of slow growing microorganisms and forces biomass to use unusual substrates (e.g., PFAS). Furthermore, the particular structure of the biomass (i.e., a mixture of biofilm and granules) favours PFAS absorption on biomass.

Depending on the treatment scheme and based on target analysis, the total PFAS removal ranged between 19% and 71%, with complete removal of some of the target compounds such as PFOA, PFHpA, PFHXs and 6,2-FTS. However, given the complex chemical composition of the leachates, the authors suggest further evaluation of the effectiveness of the tested treatment schemes based on Top Assays, AOF and EOF analysis.

Keywords: Landfill leachate, PFAS removal, SBBGR, PEC, sludge reduction, ozone, electrochemical oxidation, photolysis

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## Accelerating transformation for a sustainable future
## How TDK leverages technology expertise to tackle the global PFAS pollution challenge

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Founded in 1935, TDK Corporation pioneered the commercialization of ferrite, a critical material for electronic and magnetic products. This innovation laid the foundation for TDK's enduring commitment to material science and technological advancement. Over the years, TDK has strategically expanded its technological capabilities and market reach through targeted acquisitions, always with the goal of eventually capturing the complete value chain.

The aim of this presentation is to guide the audience through the innovation journey of TDK, from the early days of commercialization of ferrite to where the company stands today. The talk will briefly guide the audience through the decision-making process behind this growth path, as well as how these decisions ultimately led to the creation of SUIKI, a PFAS remediation start-up in the making.

To best present this journey, the talk is divided into three sections:

1. TDK's Legacy of Innovation and Strategic Acquisitions
2. Commitment to Sustainability and Emergence of SUIKI
3. SUIKI Development journey and Technological Innovations

Tapping into the social responsibility and environmental stewardship of TDK, SUIKI came out as a top supported idea of the internal start-up incubator ideation, and since late 2023 SUIKI has been an internal project at TDK, focusing on technology development for PFAS remediation (starting from PFAS destruction using electrochemical oxidation). Leveraging the material expertise and large-scale production capabilities of TDK, as well as the robust supply and customer chains, SUIKI aims to disrupt the PFAS market through fast and focus technology development, and to ultimately provide engineered solutions for different PFAS contamination scenarios.

To present the journey of building a PFAS remediation company, we will delve into key learnings and pains identified from the market through reach-out activities conducted with the purpose of conducting a comprehensive analysis of the market. As part of that process, a deep dive into the regulatory landscape was performed, and major fragmentation observed. Therefore, we will touch on how different regulations may affect PFAS technology development speed and investment potential, and why it is important to approach every stream or project independently, and why one single technology will never be enough to address PFAS pollution. With that, we will present example streams from the environment, comparing the PFAS profiles of the different streams (several landfill leachate streams, industrial wastewater, firefighting foam), highlighting the importance of utilizing synergies between different treatment processes to be able to address the wide spectrum of different PFAS commonly found in environmental streams, as well as the highly varying flowrate treatment needs of the different stakeholders. Additionally, common practical challenges with the different water matrices and co-contaminants (to PFAS) will be presented from the perspective of an electrochemical oxidation solution.

Finally, we will discuss the technology development efforts at SUIKI, presenting selected preliminary results from conducted feasibility studies and what we have learned from them. We will further discuss the expected byproducts considering the literature suggested degradation mechanisms and delve into the mass balancing needs of the market and problems encountered when attempting to close the mass balance (e.g. presence of complexing agents for released fluoride).

## Photoelectrocatalytic advanced oxidation of PFAS in contaminated groundwater of Veneto Region, Italy

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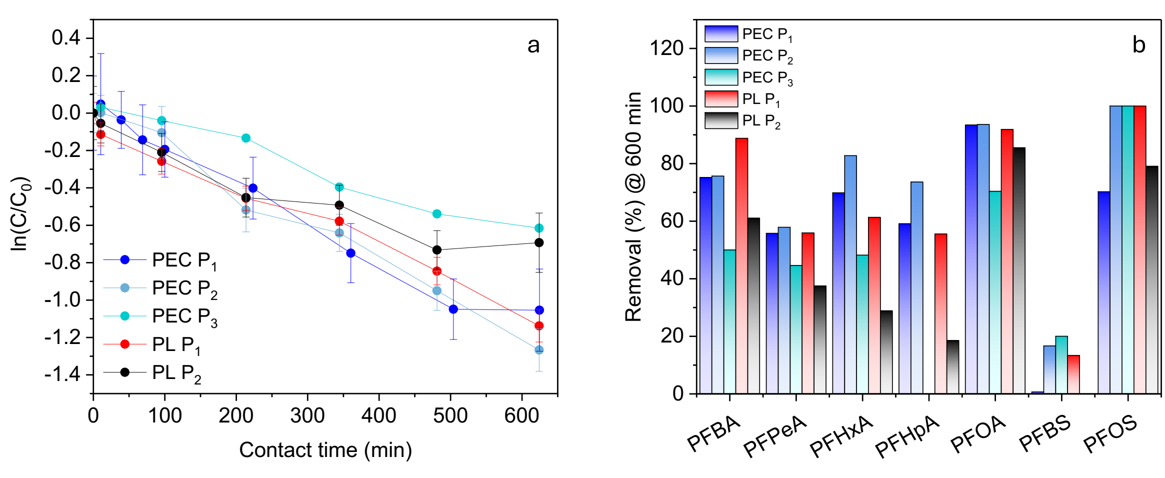
Per- and polyfluoroalkyl substances (PFAS) are a group of organofluoride compounds (> 10000) of antropic origin finding a large number of industrial and commercial applications [1]. Most of PFASs present in the environmental matrices are not biodegradable, show high mobility and bio-accumulate in animals, plants and humans causing several acute and chronic diseases [2]. Conventional treatment schemes (biological, chemical and physico-chemical processes) are ineffective toward PFASs. Photoelectrocatalysis (PEC) is a powerful advanced oxidation process [3], which is here applied to achieve PFAS remediation in groundwater of the Veneto region, where a well-known PFAS contamination is present. Groundwater was collected from a well located in the Vicenza province, Veneto Region (Italy), where a dramatic PFAS contamination of the aquifer was detected. The total initial concentration of the monitored PFASs was about 870 ng/L. PEC tests were performed in a laboratory-scale reactor fully described elsewhere [4]. As a benchmark, photolysis (PL) tests were also performed using the same reactor.

PEC tests were carried out at using different lamps (P1, P2 and P3). In **Figure *1*.** Sum of PFAS as a function of the contact time at different lamp power (P1, P2, P3) during PEC and PL tests (a) and removal percentage of the individual species after 600 min of contact time (b). a, the sum of PFAS as a function of contact time is shown. After 600 min, PEC allowed the reduction of the total PFAS concentration by 65% (P1), 72% (P2) and 46% (P3). As shown **Figure 1**b, the removal percentage for the individual PFAS species was in the range 0-20% (PFBS), 70%-100% (PFOS), 50%-76% (PFBA), 45%-58% (PFPeA), 48%-82-% (PFHxA), 0%-76% (PFHpA) and 70%-94% (PFOA), depending on the operation conditions. Among the analyzed compounds, only PFBS was not (P1) or scarcely (P2 and P3) affected by PEC treatment.




**Erreur ! Source du renvoi introuvable.**

**Figure 1.** Sum of PFAS as a function of the contact time at different lamp power (P1, P2, P3) during PEC and PL tests (a) and removal percentage of the individual species after 600 min of contact time (b).

A preliminary evaluation of the PEC operation expenses was done on the basis of the Electrical energy for order ($E_{EO}$). Based on the $E_{EO}$ values on PFOA degradatio, the operation costs of PEC was in the range 86 to 25 $kWh.m^{-3}$ depending on the lamp power. Based on literature data, in selected experimental conditions PEC is competitive with the less energy-consuming techniques, i.e. plasma treatment (28 $kWh.m^{-3}$) and advanced reduction processes (24 $kWh.m^{-3}$) [5].

**Keywords**

PFAS; groundwater; photoelectrocatalysis; titanium dioxide; immobilized catalyst.

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**References**

[1] J. Glüge, M. Scheringer, I.T. Cousins, J.C. Dewitt, G. Goldenman, D. Herzke, R. Lohmann, C.A. Ng, X. Trier, Z. Wang, Environ Sci Process Impacts 22 (2020) 2345–2373.

[2] E.M. Sunderland, X.C. Hu, C. Dassuncao, A.K. Tokranov, C.C. Wagner, J.G. Allen, Journal of Exposure Science & Environmental Epidemiology 2018 29:2 29 (2018) 131–147.

[3] S. Murgolo, S. Franz, H. Arab, M. Bestetti, E. Falletta, G. Mascolo, Water Res 164 (2019).

[4] S. Franz, D. Perego, O. Marchese, M. Bestetti, Journal of Water Chemistry and Technology 37 (2015) 108–115.

[5] B.N. Nzeribe, M. Crimi, S. Mededovic Thagard, T.M. Holsen, Crit Rev Environ Sci Technol 49 (2019) 866–915.

## The LIFE CASCADE project: treatment technologies for the removal of PFAS and Microplastics from wastewater in textile companies and in centralized wastewater treatment plants

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The EU LIFE CASCADE project (Closed-loop wAter Systems in textile industrial distriCts: orchestrAteD rEmoval of emerging pollutants from textile wastewater) (EU Call LIFE-2022-SAP-ENV) aims to develop analytical procedures and wastewater treatment technologies to detect and remove the two most critical categories of emerging micropollutants for the textile sector: Microplastics (MPs) and poly- and per-fluorinated substances (PFAS).

The project, coordinated by Centro Tessile Serico Sostenibile (CTSS), involves research laboratories of different universities and organizations (Politecnico di Milano, Università degli Studi dell'Insubria, Università degli Studi di Brescia, AquaSoil, Acquedotto Industriale, Biochemie, CITEVE, COMO ACQUA, De Nora, Lariana Depur, ZDHC) with world-class expertise in the management of pollutants in wastewater (WW).

The implementation of the treatments will reduce the discharge into the environment of these micropollutants both from the treated wastewater and from the sewage sludge and will allow the reuse of the treated wastewater.

The output of the project includes three layers: standardized and multi-lab validated analytical protocols to detect and quantify PFAS and Microplastics contaminants in heterogeneous textile wastewaters (WW); a modular set of WW treatment units to be installed at factory- and central treatment plant levels; a risk-based methodology to support the design and implementation of the best combination of treatment modules according to the textile district configuration and WW characteristics.

The project also foresees deepening an evaluation of the ecotoxicity of treated WWTP effluents and the response of the macrobenthos community to PFAS and MP presence.

## Risk assessment of PFAS findings in groundwater: An approach based on data trends from 1500 small industrial sites

by Katerina Tsitonaki | Thomas H. Larsen | Bolette Badsberg Jensen | Nina Tuxen | Kim Sørensen

WSP Danmark | Capital Region of Denmark | Capital Region of Denmark

**Background**

An assessment from the Danish Regions estimates that there are over 15.000 sites potentially contaminated with PFAS in Denmark.

Contaminated sites are investigated at different levels of detail. Additionally, there is uncertainty about the role of diffuse PFAS content in industrial areas that originate from numerous smaller sources.

**Aim**

There is an immediate need for a systematic and scientifically grounded methodology that enables risk assessment at PFAS sites. Even though the available knowledge on PFAS fate and transport may be incomplete.

The purpose of this project is to introduce a set of guidelines for the risk assessment of PFAS findings in groundwater at sites where a thorough PFAS focused investigation is not possible. The guidelines aim at pointing out "insignificant" PFAS sites, hence focusing future investigation and efforts at sites that pose a greater risk.

**Conclusion**

Data analysis from 1500 sites has examined trends in PFAS findings for different industries. Data is used to forecast the expected source strength and vertical PFAS distribution for a site belonging to a specific industry. Furthermore, it showed that several smaller industrial sites, such as dry-cleaners, have levels of PFAS contamination that typically pose no significant risk to groundwater resources. Three approaches to risk assessment are then presented depending on how well PFAS contamination at a site is characterized.

**Strategy and environmental solution for the effective and sustainable PFAS removal from wastewater**

**The case of the GEA S.r.l. landfill leachate treatment plant in Sant'Urbano**

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Perfluoroalkyl substances (PFAS) constitute a large family of synthetic chemical compounds. These are substances containing carbon-fluorine bonds, among the strongest chemical bonds in organic chemistry. PFAS consist of a fully (per) or partially (poly) fluorinated carbon chain linked to several functional groups.
Their peculiar chemical structure makes PFAS particularly resistant to chemical reactions, heat and abrasion or friction, and gives the materials that contain them non-stick properties, thermal resistance and impermeability to both water and oils.

The high industrial use of these compounds, the presence of the C-F bond which makes their natural degradation by biological agents, oxidizing agents or photolysis difficult, combined with their solubility in water, have led to water contamination at global.
The primary way PFAS enter the environment is through manufacturing processes, industrial discharges, and the use and disposal of products containing them.

Landfill leachates are a potential source of PFAS contamination because of waste placed over the years especially sewage sludge highly contaminated by these compounds.

ARPA Veneto carried out specific monitoring of landfill leachates from 2014 to 2016 to evaluate the type and concentration of PFAS present.
Based on the results of the monitoring carried out, the Veneto Region has established provisional limits for PFAS for clean water before discharge into surface waters, for wastewater purification plants and for liquid waste treatment plants.

GEA S.r.l. ladfill has undertaken a series of collaborations with leading companies dealing with water purification aimed at identifying the best technology (BAT) or a combination of the best technologies suitable for treating dirty and complex matrices such as leachates until the provisional limits set for discharge into surface waters from the Veneto Region.

The market technologies evaluated for the removal of PFAS were the following:

a) chemical oxidation processes,

b) chemical-physical adsorption processes (mainly on CA),

c) physical separation processes on membrane under pressure or evaporation.

Not all of these processes are really applicable to landfill leachate and with requested removal yields. In general, the choice of the most suitable removal technology took into consideration aspects such as:

• the high stability of C-F type bonds (high energy bonds) which determine high chemical and thermal inertia,

• the concentration of other polluting ''substances'' present in the liquid matrix whose presence contributes to influencing or interfering with the treatment process,

• the variability of molecular weights (so that we refer to long-chain or short-chain PFAS),

• the high solubility values for some PFAS (particularty PFOA and PFOS) which determine a greater affinity of PFAS for the aqueous phase than for the air matrix.

Due to these considerations, GEA Srl has identified the reverse osmosis (RO) process as BAT for the treatment of landfill leachate.
The reverse osmosis (RO) process through the implementation of a triple-stage plant, in addition to the removal of PFAS, determines the removal of other pollutants present in the leachate with the production of a permeate consisting of completely purified water and a concentrate to be sent for thermal destruction.
The plant engineering solution choice by GEA Srl, in addition to achieving the purification performances required for PFAS by the Veneto Region, also consider environmental sustainability aspects such as:

• maximize the recovery of fundamental resources such as water,
• reduce the quantities of waste produced (sludge, concentrates) to be sent for final disposal (thermal destruction),
• promote the use of renewable energy: residual heat, electricity from biogas, etc.

For this purpose, an evaporation system was inserted downstream of the reverse osmosis (RO) to reduce the quantity of concentrate to be sent to final disposal.

The GEA Srl leachate treatment plant was authorized with Veneto Region Decree no. 75 of 9 November 2018 and became operational in april 2021.

In the plant, the leachate after a preliminary mechanical filtration phase (sand filter and cartridge filter) is treated in a triple-stage RO section.
The permeate of the third stage of osmosis has analytical and microbiological characteristics suitable for discharge into surface water or for its reuse in other landfill management operations.
The concentrate exiting from reverse osmosis is sent to the triple-effect vacuum evaporator.

The evaporator is made up of 3 effects (boilers). The latent heat of condensation of the first effect is transferred to the second which feeds the third and final effect.
The reverse osmosis (RO) concentrate enters the boiler of the third effect to end up in the first (counter-corrent flow).
The distillate is sent back to the second stage of reverse osmosis (RO) while the super-concentrate is sent to the storage tank and sent to thermal destruction according with UE directive.

**The super-concentrate represents 8% of the initial leachate**, while **the permeate equal to 92% of the initial leachate is made up of water which is re-introduced into the environment**.

**The whole plant is powered by electricity and heat obtained from landfill biogas (renewable source).**

The combination of these factors leads to the GEA Srl leachate treatment plant being identified as a concrete example of **eco-sustainable technology.**

## Environmental solution for PFAS Remover: Effective and sustainable direct removal from wastewater and landfill leachates

Julik Zanellato, Depura - Tea Group (Italy)

Per- and polyfluoroalkyl substances (PFAS, acronym for PerFluorinated Alkylated Substances) are synthetic chemical substances, a cause of great concern due to their environmental persistence, bioaccumulation potential and harmful impact on human health. These compounds (around 5,000 molecules) have been included in the category of "*Emerging Contaminants*", as although present in the environment in very low concentrations, they also cause great concern due to the difficulties encountered in attempting to remove them. Due to their intensive use and their ability to pass from one matrix to another, they can be present in various types of aqueous solutions, and in particular the highest concentrations of PFAS are found in landfill leachates, as over time, various materials contaminated and/or composed of these substances have accumulated in landfills. The removal of PFAS from leachates is therefore a significant problem for environmental contamination and human health. Since 2017, monitoring campaigns aimed at detecting the presence of PFAS in leachates have been carried out by various subjects and in over 50% of cases the concentration of PFAS exceeded 50,000 ng/l.

In this case study we want to bring the experience of what has been achieved by Depura srl, TEA Group, in Castiglione d/Stiviere, as an example of an industrial solution to directly remove PFAS from leachates in an environmentally sustainable way, through the creation of a treatment plant consisting of 2 pairs of 2 granular activated carbon filters in series, 2 mineral activated carbon filters (section 1A and 1B) and 2 vegetable activated carbon filters (section 2A and 2B) complete with internal distribution network and diffusion nozzles. The combination of the two types of coal, in fact, represents the best solution for the treatment of landfill leachate for the removal of PFAS with long chain and short chain carbon atoms. This system has been specifically designed for the abatement of PFAS which, being a particularly varied family of compounds, requires treatment on different carbons. Furthermore, this solution allows the efficiency of the system to be optimized, because it makes it possible to completely exhaust the carbon used and allows the by-pass of one of the filters in the section when maintenance is required.

The solution created, i.e. adsorption on granular activated carbon (GAC), is today the most used process on a global scale for the removal of PFAS from contaminated water.

The system solution, which came into operation in January 2024, made it possible to obtain these results:

1. treatment always effective in reducing PFAS compounds (removal > 80%_ C8 and C6/C4);

2. thanks to the filters in series, the maximum possible reduction is guaranteed in all conditions;

3. it is possible to reverse the logic of the filters (the first filter in the series can also function secondly, this arrangement allows the carbon to always be completely exhausted without compromising the quality of the wastewater at the outlet;

4. Coal replacement operations use pneumatic loading to be quick and easy.

The long-term performance depends on the degree of saturation of the GAC filters, which is why Depura srl and the TEA Group are now committed to managing this new technology by collecting, day after day, with the utmost commitment, the results of the treatments carried out on liquid waste special non-hazardous products which, as well as being positive, are environmentally sustainable.

The redevelopment of the Castiglione d/Stiviere plant with the integration of a section for the removal of PFAS into the existing treatment platform was possible thanks to a long process of collaboration, dialogue and sharing with the territory and Mantua institutions. The plant now boasts the most innovative technology that respects the most recent industry standards and includes solid operating processes that make its activity safe for humans and the environment. Our Group's almost thirty years of experience in the management of environmental systems constitutes a further guarantee for the territory.

This technology was born after a long journey of studies and insights with our partners Erica srl and STA srl, experiments with a pilot plant in the field, data analysis and continuous discussion with institutions, universities and research bodies. The objective has always been to identify the best technology that would allow the reduction of PFAS in landfill leachates thanks to an economically and environmentally sustainable solution."

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