Remediation of legacy pollutions with focus on developing and operating Industrial sites

Session 1: Networks and funders in remediation

NICOLE Foundation 's Experience in Overcoming Unique Challenges in Assessing Polluted Sites in Conflict-Affected Regions — Lessons from the Kakhovka Reservoir Johan De Fraye, NICOLE Foundation
The investigation following the 2023 breach of the Nova Kakhovka dam illustrates how environmental assessment in conflict-affected regions demands unusually flexible and resilient approaches. Working under severe access restrictions, limited local infrastructure and ongoing security risks, the NICOLE Foundation and its partners developed an adaptive framework combining a conceptual site model, targeted sampling and remote scientific support to evaluate contamination across the exposed reservoir sediments. Despite the constraints, analyses confirmed the presence of metals, hydrocarbons and radionuclides, alongside important data gaps where hotspots remained inaccessible. The project also introduced digital tools and asynchronous training to strengthen local capacity and support future data integration. Overall, the work demonstrates that science-based methodologies, international collaboration and innovative capacity-building are essential to enable credible risk assessment and remediation planning in regions where safety and governance are compromised.

A Collaborative Model for National-Scale Environmental Hotspot Management: Lessons from the POPs Project in Bosnia-Herzegovina Ilona van der Kroef, TAUW bv
The POPs Project in Bosnia and Herzegovina demonstrates how a coordinated funder implementer expert model can drive national scale progress in managing orphan and legacy contaminated sites. Supported by Swedish funding and implemented by UNDP with technical input from specialist networks, the project delivered a comprehensive POPs inventory, identified nearly 20 high-risk hotspots and produced a GIS-based Environmental Hotspots Map to guide risk-based prioritization. The staged investigation of the HAK I site in Tuzla exemplified how international financing and structured cooperation can overcome barriers such as fragmented ownership, severe contamination and limited domestic capacity. Alongside these technical advances, the project embedded long-term capability through targeted training and institutional transfer of best practices. Collectively, the work shows that transparent data integration, aligned funding across investigation and remediation phases, and sustained professional networks are essential to enable durable contaminated-site governance in complex political environments.

Overview Evaluation of Remediation Projects implemented with funding in Hungary Gabriella Gyetvai, TRENECON Ltd
The evaluation of remediation projects funded in Hungary between 2015 and 2023 provides a structured assessment of 15 completed or ongoing initiatives, focusing on their implementation processes, challenges, and overall collective impact. Projects typically spanned two to three years and addressed contamination by heavy metals, organic solvents, and hydrocarbon derivatives, with timelines strongly influenced by site complexity and geological conditions. Rather than comparing technical effectiveness across sites, the study examined common barriers, cost patterns and outcomes to derive system-level insights. Key recommendations include establishing a national remediation strategy to harmonise environmental objectives, strengthening data integration across environmental, urban

planning, water and health databases, and improving prioritization through continuous monitoring and cost-benefit analysis. The study also calls for professional guidelines to enhance consistency and decision-making, support emerging practitioners and increase comparability across projects. Public communication of successful remediation efforts is highlighted as essential for strengthening societal support and reinforcing the value of sustained investment in contaminated-site management.

Session 2: Remediation in Hungary

The key take-aways from session 2 are:

#1 It is realistic that an entire international team of engineers has been working on a remediation project for **10 years**, which is sufficient and just enough for

- site assessment,
- installation of remedial system and
- pilot operation

and there are still opportunities to develop the technology and improve its efficiency before completing the **majority** of the work.

#2 Remediation began in Hungary more than 30 years ago. It is an ongoing action and much has been accomplished, but there is still a lot to do.
Most contaminated sites are owned by the private sector, but the **state also has an important role** to play in cases of contamination that originally fell within its **responsibility, as well** as those with no known owner.

#3 When developing an effective remediation solution, it is very helpful to have a local specialist company with a good knowledge of the area and conditions, and an other company providing the world's most innovative technologies, which, in the best case scenario, will work and **in the very best case scenario**, **the customer will pay its price**.

Session 3: innovation in Sampling, Interpretation, and Analysis

This session examined three key innovations transforming environmental consulting: integrated data management systems that unify diverse information streams, emerging contaminant identification through advanced forensic methodologies and isotopic analysis techniques that provide unprecedented accuracy in source identification and remediation assessment. The presentations highlighted how technological advances are making sophisticated analytical tools increasingly accessible while improving efficiency and decision-making across environmental investigations.

Dan Alexander, COO of EarthSoft, opened the session by examining the challenges organizations face in data management and flow. He provided an overview of how data moves through systems and the common bottlenecks that impede efficiency and decision-making.
The discussion then turned to a critical distinction in the field: the differences between structured and unstructured data. Dan explained how structured data differs fundamentally from unstructured data like field notes, photographs, PDF reports, and email correspondence. Each type presents unique storage, retrieval and analysis challenges that environmental and industrial organizations must address.

Mr. Alexander presented the value that emerges when organizations can effectively integrate both formats. He made a case for unified database approaches that handle structured and unstructured data within the same AI-curated system rather than maintaining separate silos. According to Dan, this integrated approach delivers significant benefits: reduced infrastructure costs, improved data accessibility across teams, enhanced search and retrieval capabilities, and greater operational efficiency. By eliminating the need to switch between multiple systems or manually correlate information across platforms, organizations can streamline workflows and make more informed decisions based on their complete data landscape.

Dr. Ken Scally of Normec DETS delivered an important presentation on 6PPD-quinone, a contaminant only recently gaining recognition despite its widespread presence and significant ecological impact.
The presentation focused on the compound's catastrophic effects on salmon populations throughout the Pacific Northwest. Increasing concentrations in salmon habitats, delivered primarily through stormwater runoff, have been linked to significant mortality events. Dr. Scally acknowledged the research of Dr. Zhenyu Tian, whose work was instrumental in identifying this specific compound as the culprit behind unexplained salmon deaths.
One compelling aspect was Dr. Scally's description of the forensic methodology used to isolate 6PPD-quinone from among more than 2,000 potential pollutants in tire leachate. Researchers systematically narrowed down candidates until they conclusively identified this single compound. He also highlighted the dramatic differences in sensitivity across salmon species, with some proving far more vulnerable than others.
Dr. Scally addressed an unexpected connection to electric vehicles. Despite their air quality benefits, EVs exacerbate tire wear particle problems due to increased battery weight and higher torque delivery, potentially releasing more 6PPD-quinone into the environment.
Perhaps most concerning, he referenced Chinese studies showing tire wear particles in nearly 100% of human subjects tested, raising questions about bioaccumulation and potential human health effects beyond aquatic toxicology.
The presentation concluded with a regulatory assessment: among regulatory bodies worldwide, only the United States has officially taken concrete action to address it.

Dr. Kevin Kuntze, CEO of IsoDetect, concluded the session with an exploration of remediation assessment methods, emphasizing compound specific isotope analysis (CSIA).
Dr. Kuntze surveyed the current analytical toolbox available to environmental consultants, walking through various techniques while candidly discussing each method's pros and limitations.
The presentation then examined how isotope analysis overcomes many conventional method limitations. Kevin explained how CSIA delivers significantly higher accuracy in characterizing contaminants and their environmental behavior, offering insights traditional analytical chemistry cannot provide.
A particularly valuable aspect was the discussion of forensic applications. He demonstrated how isotope analysis identifies specific pollution sources through unique isotopic signatures, essentially creating a "fingerprint" for each contamination source. This proves invaluable in complex sites with multiple potential contributors or when determining liability requires source apportionment.
Dr. Kuntze also explained how CSIA definitively proves whether biodegradation is occurring and assesses the current state and progress of degradation processes. This allows consultants to verify natural attenuation, evaluate remediation effectiveness, and make informed site management decisions.

He concluded by noting that as analytical technologies advance and methodologies standardize, isotope analysis costs continue to decrease, making these powerful forensic capabilities available to a broader range of environmental investigations.

Session 4: Innovation and decision-making challenges

Three speakers present innovative techniques or experiments aiming to remediate emerged contaminants and/or to understand the processes during remediation of emerged contaminants. These insights can contribute to better decision-making when choices have to be made between different remediation techniques.

Glauco Giordano from Jacobs addressed the dynamic challenges and opportunities to remediate primary and emerged contaminants. He emphasized that we need hybrid strategies to tackle different types of contaminants at the same time. Therefore, we need flexible designs, close collaboration between different stakeholders, and smart monitoring systems. Visualization tools can help improving decision-making.

Tom Bosma (Deltares) presented the results of experiments applying different nature remediation technologies to treat PFAS contaminated soils. With bioreactors, the full removal of PFOS and PFOA can be obtained. In a phytoremediation system operated outside, only little PFAS is being removed, while in greenhouse experiments PFAS uptake by sunflowers was much higher then in comparable experiments outside. There is a high need for data/results to prove which of the nature-based solutions are most efficient and can be applied in real cases.

Finally, **Tamás Madarász** from the University of Miskolc showed an improved DKS (diffusion, convection, sorption) permeameter, which is useful to understand back diffusion. This is not only important for pump and treat, but also for other in situ remediation technologies. Additional parameters, such as temperature, are being investigated to further improve the application of the DKS permeameter.

Session 5: Innovation for remediation of recalcitrant contaminants

There were presented innovative remediation techniques for cleanup of organic and recalcitrant contaminants, with particular emphasis on thermal remediation of PFAS, biogeochemical degradation of chlorinated compounds and enhanced microbiological solutions for reduction of hydrocarbon contaminants, in various media conditions. These results support evidence-based decision-making in the comparative assessment of remediation techniques for soils contaminated with recalcitrant compounds.

Maël Makoudi (Haemers Technologies) presented an innovative thermal treatment technology for PFAS destruction able to achieve complete degradation at elevated temperatures, around 1,400 degrees Celsius: *Krysalis – Field-deployable Thermal Reburn System* for PFAS Soil Remediation is the winner of NICOLE Innovation Award 2025. Pilot-scale testing demonstrated effective vapor capture and high-temperature combustion, resulting in non-detectable PFAS concentrations with practical energy demand. The process generates clean, reusable soils without harmful by-products and is adaptable to various soil types, indicating strong potential for full-scale deployment.

Josephine Molin from Evonik presented the biogeochemical remediation (BGCR) process integrating biological enhanced reductive dechlorination (ERD) and abiotic in situ chemical reduction (ISCR) to degrade chlorinated volatile organic compounds (CVOCs) *in situ*. Highly reducing conditions are generated which are favourable to the production of BGCR-enhancing iron sulphide minerals such as mackinawite (FeS), and pyrite (FeS_2). These minerals have been demonstrated to abiotically degrade CVOCs. Field applications in Brazil and California confirmed effective treatment of chromium, CVOCs, and heavy metals under high-sulphate concentration and low-biological-activity conditions. Technology sustained strong abiotic reactivity, improved reductive kinetics, and achieved durable in situ metal stabilization, even in soils inherently unfavourable to natural degradation. Overall, it provided an efficient, safer and cleaner remediation solution.

Zsuzsanna Nagymate (Fermentia Ltd.) presented an eco-friendly remediation approach using organohalide-respiring bacteria to enhance PCE dechlorination under site-specific conditions. By combining microbial inoculation, targeted biostimulation, and bioaugmentation, the method improves reductive conditions and enables more complete transformation of chlorinated hydrocarbons toward non-hazardous final products: dechlorination may stall at toxic intermediates (e.g. vinyl chloride). Bioaugmentation (microbial inoculants) has demonstrated field-scale success when combined with a biostimulation strategy (electron donors, redox control) and molecular monitoring (dehalogenase genes). Groundwater flow governed amendment distribution, highlighting the effectiveness of microorganism-based strategies for sustainable hydrocarbon contaminant treatment.

These three approaches exemplify the ongoing shift toward innovative, integrated and sustainable remediation technologies. Biogeochemical treatments couple abiotic and microbial mechanisms to accelerate the transformation of chlorinated compounds and promote metal immobilization. Concurrently, the use of organohalide-respiring microorganisms and specialized microbial inoculants provides a selective, biologically driven, and eco-efficient pathway for degrading short-chain halogenated hydrocarbons. In parallel, deployable thermal systems engineered for PFAS destruction constitute a major advancement in on-site treatment of highly persistent contaminants.

The conclusions of Session 5:

- Remediation innovation lies in the convergence of biological, chemical, and thermal processes.
- In situ strategies are becoming increasingly efficient, traceable, and environmentally sustainable.
- Advanced tools enable the remediation of historically recalcitrant contaminants with higher efficacy and reduced environmental footprint.