Restoring PFAS-contaminated soils to their pristine state: thermal treatment of source zones and pathways to full-scale remediation with Krysalis®

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Innovative aspect : An innovative approach focusing on contaminated soils as primary PFAS sources, combining Thermal Conductive Heating (TCH) with high-temperature destruction (>1400°C) to achieve full mineralization, unlike conventional containment or transfer-based solutions.

Keywords: PFAS, thermal treatment, mineralization, soil restoration, high-temperature destruction

Objectives:
Demonstrate complete PFAS mineralization in contaminated soil
Validate full-scale performance of the thermal treatment

Preferred presentation: oral presentation

Across Europe, the PFAS debate is clearly shifting toward contaminated soils, where these substances have accumulated for decades and continue to act as long-term sources of pollution. This change in perspective is now reflected in policy, through the proposed group-wide PFAS restriction under REACH and the adoption of the EU Soil Monitoring Law (Directive (EU) 2025/2360), which places soil quality and contaminated land at the center of future environmental strategies. Scientific literature increasingly recognizes soils as the main long-term reservoir of PFAS, storing a large share of the total environmental mass and driving ongoing diffuse contamination.

From an economic and practical standpoint, this shift toward soils is unavoidable. Treating PFAS once they have migrated into groundwater or surface water leads to extremely large volumes and prohibitive costs. As an illustration, one cubic meter of soil contaminated at 50 mg/kg total PFAS represents roughly 90 g of PFAS mass. At a regulatory threshold of 100 ng/L in water (current Belgian standard), this amount corresponds to approximately 900,000 m³ of water requiring treatment. This simple order of magnitude demonstrates that managing PFAS primarily through downstream water treatment is neither realistic nor sustainable, as it means chasing massive volumes while the source remains active.

As a result, remediation strategies are increasingly shifting toward highly contaminated source zones, where intervention can effectively limit PFAS diffusion at its origin. These zones include PFAS manufacturing sites, downstream industrial users, and locations with intensive historical use of firefighting foams, such as airports, fire training areas, and military or defense facilities. Acting on these sites provides the greatest environmental benefit for a manageable treatment volume.

One of the key challenges is that very few technologies have demonstrated true PFAS destruction and mineralization at field scale. Many current soil management practices rely on containment, stabilization, or conventional incineration operating at 900–1,100 °C, which often results in partial degradation, pollutant transfer, or long-term storage rather than permanent elimination. In practice, complete mineralization of PFAS requires very high temperatures, typically above 1,400 °C, to reliably break carbon–fluorine bonds and avoid simply moving PFAS from one place to another.

Haemers Technologies has developed one of the first operational thermal solutions to demonstrate effective PFAS destruction and mineralization from contaminated soils, while preserving the soil itself. The technology combines Thermal Conductive Heating (TCH), in which soils are heated to moderate temperatures (typically 350–450 °C) to desorb PFAS without damaging the soil matrix, with direct on-site destruction of the extracted vapors at temperature exceeding 1.400°C. These vapors are captured and reinjected into the heating system, which is specifically designed to achieve complete mineralization. In this configuration, the soil is treated as a material to be restored, not destroyed.

This approach was validated during a full-scale demonstration project in Korsør, Denmark, where approximately 60 tonnes of highly PFAS-contaminated, clay-rich soils were treated. Results showed strong reductions of PFAS concentrations in soils, a significant decrease in leachability, and no detectable PFAS in emissions, confirming effective elimination rather than containment or phase transfer.

Building on these results, a next-generation pilot system focused on energy optimization is under development, alongside a full-scale modular plate-based concept designed to treat much larger soil volumes. Together, these developments support a shift toward complete restoration of PFAS-contaminated source sites, offering a credible and economically viable alternative to chasing PFAS once they have already spread into the environment