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SPECIAL SECTIONS

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Life cycle analysis proves in situ approach is more sustainable and cost-effective for PFAS remediation

By **Gareth Leonard**

Remediating PFAS will require a tremendous response to address thousands of contaminant plumes in groundwater in Canada alone. Since PFAS do not biodegrade, they migrate farther than most common groundwater contaminants, such as benzene, trichloroethylene (TCE), with plumes often extending well beyond their sources, affecting large aquifer volumes.

When these PFAS plumes threaten wellfields, surface water bodies, or other receptors, they must be contained to eliminate exposure risks and environmental impacts. The widespread occurrence, persistence, and voluminous size of PFAS plumes are factors that combine to threaten many of these potential receptors, presenting a daunting challenge to environmental remediation practitioners.

METHODS TO CONTAIN A PFAS PLUME

Hydraulic containment is an ex situ method where groundwater is pumped above ground to create a hydraulic barrier (capture zone) in the aquifer that the plume cannot move beyond. The pumped groundwater is treated to remove PFAS, typically by filtering with carbon or other sorbent materials.

Pumping must be continuously maintained until the plume stops advancing, which in the case of PFAS, may take centuries. Additionally, these pump-and-treat processes accumulate PFAS-saturated wastes that must be managed and disposed of. A newer foam-fractionation process that concentrates the PFAS has been shown to reduce the waste stream, but at the significant expense of more energy applied, resulting in a higher carbon footprint.

Alternatively, passive filtration is an in situ approach that involves injecting the patented colloidal activated carbon, or

CAC technology, into the groundwater to form a subsurface PFAS filter. Contaminants are quickly removed as the groundwater containing PFAS contaminants passes through the filtration zone. Once a PFAS subterranean filter is in place, no energy is required to operate it and since the treatment occurs below ground, no waste is generated.

On a per plume basis, whether the ex situ or in situ approach is employed, billions of litres of groundwater may require treatment over decades-long time frames. Government agencies worldwide seek effective and economical methods to address environmental pollution while minimizing raw material/energy usage, greenhouse gases, and waste during the remediation process. As such, sustainability will ultimately drive the remediation decision-making to contain these plumes.

An evaluation of remediation sustainability was recently completed at a commercial airport in the UK to determine the most sustainable remediation solution to stop a PFAS plume from migrating toward a sensitive receptor.

In recent years, numerous methods and tools have been developed to assess and quantify the relative sustainability of remediation approaches and are gaining widespread adoption. At the UK commercial airport site, several assessment methods were employed to provide a comprehensive sustainability evaluation of ex situ and in situ remedies to contain the PFAS plume.

Specifically, these methods included a life cycle assessment (LCA), a life cycle cost analysis (LCCA), and a sustainability assessment. Ramboll, a global engineering, architectural, and consulting firm, conducted the extensive evaluation, which is considered the most comprehensive assessment to date for remediating a PFAS contaminant plume in groundwater.

LIFE CYCLE ASSESSMENT (LCA)

The LCA was completed according to ISO 14044/ISO 14025 for a real-world application of a CAC permeable sorptive barrier, commercially available as PlumeStop, located downgradient of the PFAS source at the airport site. Two alternative pump-and-treat approaches, where groundwater is pumped to the surface and treated either by filtering with granular activated carbon (GAC) or concentrating the PFAS waste stream using foam fractionation (FF), were evaluated for comparison.

These remedial methods were designed to achieve the same containment goal: preventing a PFAS plume's off-site migration in groundwater toward sensitive receptors over a project life cycle of 15 years.

Ramboll completed the LCA using the GaBi Professional LCA software tool, meeting the EN 15804 international standard for an Environmental Product Declaration (EPD). EPDs are standardized and verified reports that provide transparent and comparable information about the environmental performance of a product over its entire life cycle.

For the CAC material, the life cycle boundaries extend from "cradle to grave"

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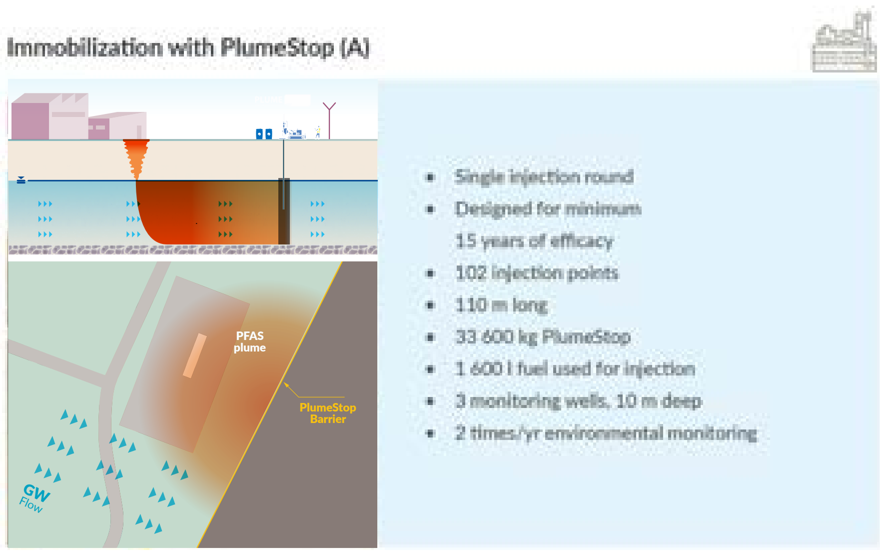
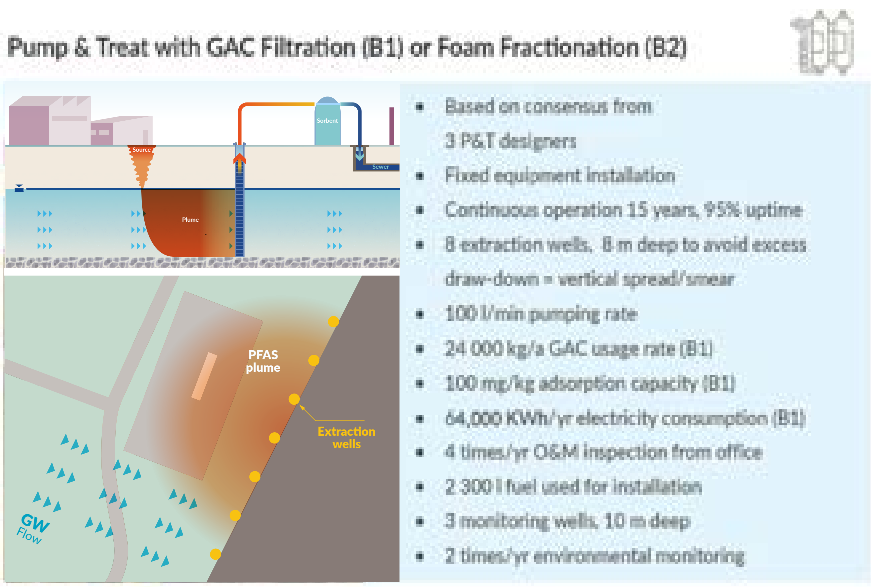


The life cycle analysis was completed for a real-world application of PlumeStop, a CAC permeable sorptive barrier.



Two alternative pump-and-treat approaches, were evaluated for comparison during the life cycle analysis.

including upstream material sourcing, core manufacturing processes, and the downstream processes of transport and injection. The pump-and-treat boundaries encompass the equipment manufacturing and civil works for system construction, system operation & maintenance (O&M), and waste management. Remediation performance monitoring is considered for all cases.

LCA RESULTS

Compared to using pump-and-treat to achieve the same PFAS-exposure-risk-elimination goal, the in situ CAC filtration approach has a 40 to 70 times lower carbon footprint, negating thousands of tons of carbon dioxide (CO_2) emissions. Additionally, the in situ approach has a 95+% smaller raw material, energy and waste footprint.

LIFE CYCLE COST ANALYSIS

An LCCA is an economic method for assessing the total life cycle cost of ownership, accounting for all costs of acquiring, building, owning, and disposing of an object, process, or project. The LCCA for the commercial airport site compared the three remediation alternatives based on the total cost of ownership in net present value (NPV).

As with the LCA, a 15-year time frame was used for the evaluation. The results of the LCCA showed the in situ method to be 2.5 to 2.8 times less expensive (61% to 65% cost reduction), saving the project between $2.4 to $2.9 million ($USD equivalent) over 15 years.

SUSTAINABILITY ASSESSMENT

Finally, a Tier 2 sustainability assessment was completed by Ramboll using its SURE model, a free, publicly accessible model, complying with ISO 18504:2017 and ASTM E2893-16. It evaluates 15 sustainability indicators pertaining to the environment, society, and the economy.

Each indicator was numerically scored for each option on a scale of one to five, with one reflecting the worst option and five the best with respect to sustainability. The results of the sustainability assessment using SURE showed that the in situ approach had a 100% overall higher sustainability score.

Informed by the first-of-its-kind multi-faceted remediation sustainability evaluation for PFAS, the in situ CAC remedy was selected to mitigate the PFAS plume at the study site. The remedy was also applied at another private airport site in the UK during the same time frame.

IN SITU CAC FILTRATION OF PFAS

Working with the airport managers, environmental consultants, and regulatory authorities, CAC subsurface PFAS filtration zones were installed at the two UK airport sites to clean up groundwater and eliminate PFAS risk. Initial partial-scale applications were designed at both sites to assess the approach's effectiveness and allow for fine-tuning the remedial designs before full-scale implementation.

After installation, PFOS and PFOA, the targeted PFAS compounds for treatment, were reduced below detection limits. Additionally, the total PFAS concentrations were also reduced significantly. These reductions were maintained throughout the assessment period for the initial phase applications.

The results of the initial phase applications were presented to the project stakeholders, including the local and national regulatory authorities, who authorized implementing the full-scale applications at both sites.

CONCLUSIONS

As environmental regulations for PFAS are beginning to be promulgated, groundwater remediation professionals will soon be challenged with addressing PFAS pollution economically while avoiding further environmental impacts caused by the cleanup activities.

Now more than ever, simply containing a plume before it impacts drinking water wells, surface waters, or other receptors is not enough. Sustainable remediation approaches must be employed to promote greater community and ecological sustainability, towards a future that is more viable, pleasant, and secure.

The in situ CAC remedy applied at the UK commercial airport site reduces the carbon footprint by 98% and saves the project millions of dollars in unnecessary costs, while reducing waste, energy, and raw material usage by 95%.

> **Sustainable remediation is defined by the International Organization for Standardization (ISO 18504:2017) as "the elimination and/or control of unacceptable risks in a safe and timely manner whilst optimizing the environmental, social, and economic value of the work."**

This approach will stop PFAS plume migration by filtering more than a quarter billion litres of groundwater in place over 15 years, effectively eliminating the exposure risk with no pumping involved. These CAC barriers can be flexibly designed to accommodate site-specific remediation time frames, typically spanning decades.

Widescale adoption of PlumeStop CAC to mitigate PFAS exposure risk promises to save billions of dollars and eliminate millions of tons of CO_2 emissions, while protecting drinking water resources and public health. ■

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