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PFAS-Impacted Groundwater an Emerging Issue for Landfills: Solving the Challenge with a New Approach

Given the rapidly changing PFAS regulatory climate, landfill operators are trying to determine how best to handle the incoming PFAS-laden waste streams and manage leachate potentially contaminated with PFAS.

By Ryan Moore

LANDFILLS EVERYWHERE WILL SOON BE DEALING WITH PFAS, commonly known as "forever chemicals." Shown to cause health concerns, these compounds are known to leach from landfills and move offsite with groundwater flow. Advanced technologies are now available to effectively filter out PFAS in the subsurface using colloidal activated carbon, resulting in a less-disruptive, more cost-effective approach to eliminating risk to the public and reducing potential liability for the landfill operator.

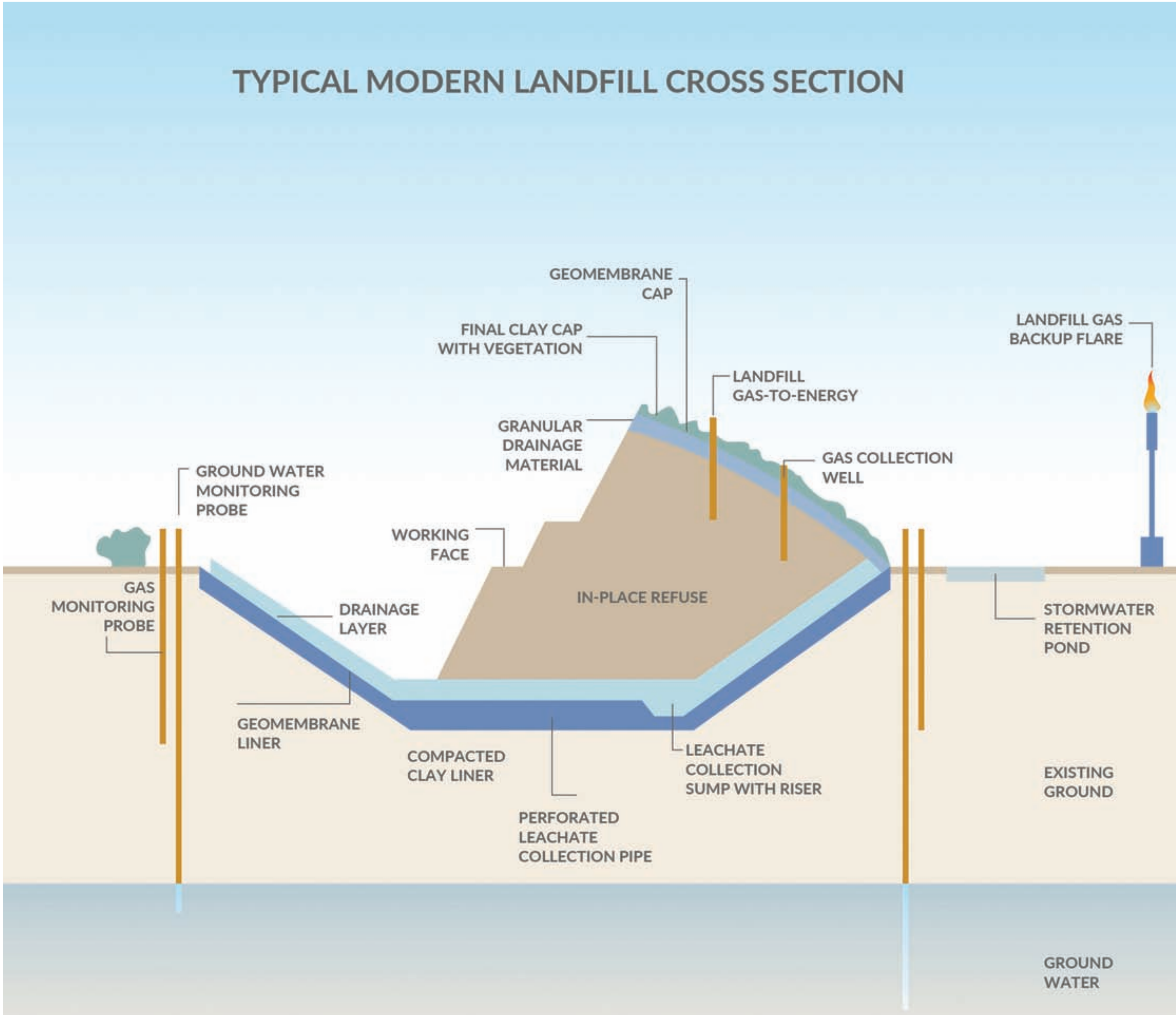
Tracking the PFAS Tsunami: Policy, Politics and Public Outcry

Big changes are expected for PFAS response. In 2020, Congress introduced House Resolution 535 (H.R. 535), a sweeping bill with the principal thrust to designate PFAS as hazardous substances under the Comprehensive Environmental Response, Compensation and Liability Act of 1980 (CERCLA). Known as the PFAS Action Act, H.R. 535 was introduced and passed in the Democrat-led House and later expired in the Republican-controlled Senate, but it will not remain dead for long. Congresswoman Debbie Dingell, the chief sponsor of the PFAS Action Act, said reintroducing the bill would send a signal to the Biden administration that controlling PFAS is "a top priority in the new Congress."

In the run-up to the election, the Biden-Harris campaign promised to "designate PFAS a hazardous substance, setting enforceable limits for PFAS" as part of their Environmental Justice Plan (EJP). As president, Biden will seek to deliver on this

What Are PFAS?

Per- and polyfluoroalkyl substances (PFAS) are a class of human-made chemical compounds, numbering in the thousands, that have been widely used in commercial products beginning in the 1940s. They have been linked to certain cancers, fetal development problems, thyroid, kidney and liver diseases and immune system malfunctions. PFAS are termed "forever chemicals" due to their ability to persist under the most extreme environmental conditions. Comprised of chains of carbon-fluorine bonds, among the strongest bonds in organic chemistry, PFAS are excellent for many of the functional needs we have come to depend on in our products, principally, repelling water and oils, extinguishing fires and durability. However, these properties also cause them to bioaccumulate in the fat tissue of animals and humans. All of these factors drive their toxicity higher, meaning that exposure to even the smallest concentration (i.e., part-per-trillion levels) detectable in drinking water presents a risk for adverse health effects. Due to their ubiquity, nearly all of us have PFAS in our blood.



Cross-section of a typical modern landfill depicting containment and monitoring systems.
Image courtesy of National Waste & Recycling Association.

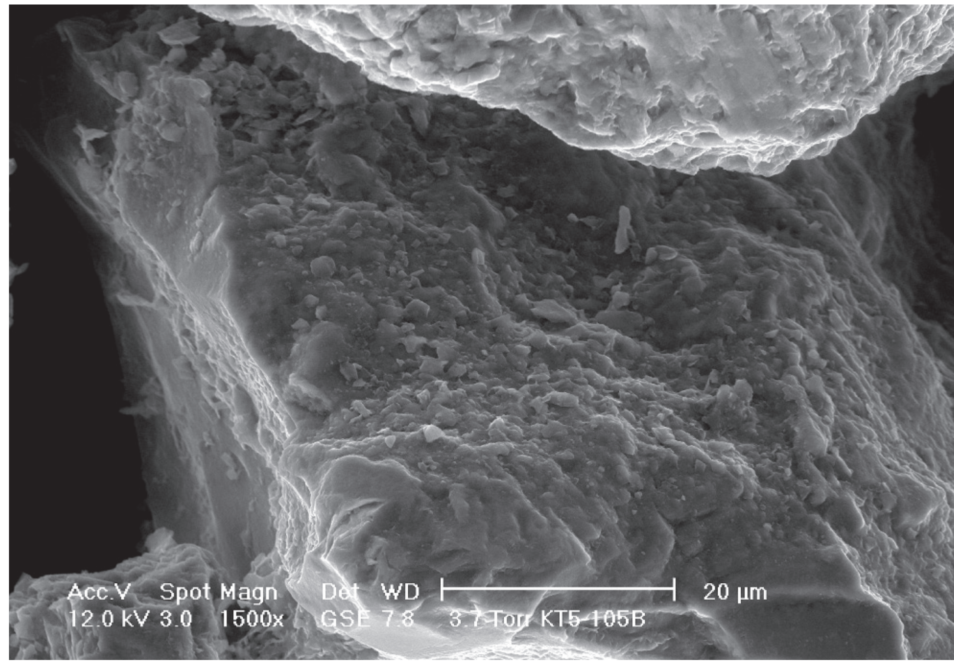
campaign promise through his selection of Michael Regan to lead the Environmental Protection Agency (EPA). Regan serves as Secretary of the North Carolina Department of Environmental Quality (NCDEQ). He has risen to prominence nationally as a PFAS-pollution enforcer, ordering a chemical manufacturer to clean up PFAS that is impacting a river.

In 2018, Regan created the Environmental Justice and Equity Board at the NCDEQ, which caught the attention of Biden, ultimately leading to his selection as EPA Administrator and the EJP's creation. The EJP promotes establishing an Environmental and Climate Justice Division within the U.S. Department of Justice, pointing the EPA toward a much more aggressive enforcement posture. PFAS in drinking water is identified as a key public health issue in the EJP. As of this writing, Regan's confirmation awaits approval in Congress.

Beyond Washington, PFAS public awareness is growing, and pressure is mounting. With the help of Erin Brockovich and others, citizen action groups (CAGs) have formed across the country, demanding action. The National PFAS Contamination Coalition, an assembly of more than 20 CAGs dedicated to PFAS, are pushing Congress to establish a 1 part per trillion (ppt) maximum contaminant level (MCL) for all PFAS.

Numerous states have already established action levels for PFOA and PFOS, ahead of the EPA. State action levels for these compounds are generally in the range of 10 to 70 ppt, equivalent to a drop or two evenly dispersed in an Olympic swimming pool

An extracted soil core showing CAC coating of soils following PRB application. The target application interval spanned the depths of the soil cores at second and third from left.



Scanning electron microscope image showing sand particles coated with CAC. CAC particle size of 1 to 2 microns shown relative to 20-micron scale.

Images courtesy of REGENESIS

(660,000 gallons). Remediating groundwater to these levels poses a significant challenge for the industry.

Managing the PFAS Waste Streams

Given the rapidly changing PFAS regulatory climate, landfill operators are trying to determine how best to handle the incoming PFAS-laden waste streams and manage leachate potentially contaminated with PFAS.

The PFAS Action Act calls to eliminate the “unsafe” incineration of PFAS waste. However, there are many unknowns, and there is much work to be done to define safe incineration. In the EPA’s Interim Guidance on the Destruction and Disposal of PFAS document (public review period ended in February 2021), some of the concerns and unresolved questions related to the incineration of PFAS waste are presented, including the:

- Incomplete thermal destruction of PFAS due to the high temperatures required
- Recombination of reactive intermediates that can potentially result in the formation of new PFAS compounds
- Differences in operating performance for the various thermal treatment devices in common use
- Lack of established emissions measurement methods

Incineration costs for halogenated hazardous waste (e.g., chlorinated hydrocarbons) are currently more than $1,000 per ton. To investigate and resolve these issues will take time, and PFAS incineration costs are expected to rise dramatically in response.

PFAS in Groundwater: A Growing Challenge for Landfills

Another growing concern for landfill operators is the potential for PFAS-contaminated groundwater. These groundwater impacts can occur via breaching of landfill containment systems over time, improper engineering controls to contain PFAS wastes (e.g., unlined landfills) or from other sources (e.g., neighboring properties).

Few groundwater testing results from landfills are publicly available. Of those that are known, PFAS has been identified above drinking water standards with alarming frequency. For instance, in New Hampshire, all six lined landfills currently operating in the state have identified PFAS that exceed the state health standards in their monitoring network. The New Hampshire Department of Environmental Services says landfill operators with elevated levels will be required to test neighboring private drinking water wells for PFAS and may be held responsible for providing alternate drinking-water sources or installing treatment systems.

Testing is accelerating elsewhere including in New York, where EPA-funded research is currently in progress at more than 200 active and closed facilities to understand the landfill-to-groundwater pathway.

Groundwater Pump and Treat: An Old Method Retrofitted for PFAS

The current most recognized method for treating PFAS in groundwater is by extraction and filtration treatment using granular activated carbon (GAC) and, in some cases, ion-exchange resins. The oldest of groundwater remediation approaches, pump and treat (P&T), is universally accepted and generally reliable for cutting off groundwater contaminant plume migration. However, while these P&T systems could effectively meet remedial objectives for PFAS, there are limited field-proven cases, and their efficiency suffers greatly at low-ppt PFAS concentrations. Further, these systems require substantial upfront capital costs for installation and even more significant operation and maintenance (O&M) costs long-term.

Given PFAS' large and dilute plume-forming behavior and their ubiquitous presence in many landfills, PFAS generally cannot be tied to specific point-sources. Therefore, when estimating lifecycle operation costs, remediation managers must assume that these P&T systems will run for a very long time—multiple decades at a minimum. O&M costs to maintain these systems at the high operational efficiency necessary to treat PFAS effectively will mount over time.

O&M includes routine change-out of the spent carbon and filtration components. PFAS-laden carbon will be subject to material handling, transport, disposal and storage rules for hazardous waste, with their pending designation as hazardous substances. Addressing the issue of spent carbon will lead to further inflation of lifecycle costs to keep these P&T systems running.

A Field-Proven, Effective and Low-Cost Alternative to Pump and Treat: In Situ Colloidal Activated Carbon Barriers

Another method growing in awareness and popularity due to repeated, successful removal of PFAS from groundwater, is the in situ use of colloidal activated carbon (CAC) permeable barriers. As the field-proven successes build, the approach is quickly gaining momentum worldwide as a practical and effective means of addressing migrating PFAS groundwater plumes threatening human and environmental receptors.

The remediation approach involves an in situ injection of CAC in a permeable reactive barrier (PRB). When CAC is applied to an aquifer zone transmitting PFAS contaminants (i.e., PFAS-flux zone), aquifer soils are encapsulated with a thin layer of carbon. Through the use of a proprietary organic polymer dispersion chemistry, CAC achieves high distribution through the subsurface and removes PFAS and other organic contaminants rapidly from groundwater.

CAC particles are minuscule—1 to 2 microns—equal in size to a red blood cell and smaller than most bacteria. Their size allows them to spread across an enormous carbon surface area and results in the subsurface being painted with an activated carbon film.

Unlike GAC used in ex situ systems, the single-micron size of CAC greatly enhances its sorption strength, making it extremely effective at capturing PFAS at the ppt-levels that are most commonly observed. The effect is similar to a Brita® filter; however, it occurs in situ, thereby transforming the aquifer subsurface material into a purifying filter. With the capture of PFAS in place, hazardous waste handling and disposal issues are averted.

Remedial applications for PFAS are designed to last for decades, incorporating flux-based modeling techniques that account for competitive sorption of individual PFAS compounds and other contaminants.

CAC is applied into PRBs by qualified remediation specialists and state-of-the-art injection processes using low-pressure delivery methods through either injection wells, hydraulic-percussion tooling, open boreholes through packers or other means, depending on subsurface geology.

CAC has been used to capture and treat groundwater contaminants since 2014. The longest documented CAC in-field treatment for PFAS is a site in Canada with nearly five years of post-application data. The treatment has maintained a greater than 99.5 percent PFAS-removal rate to below detection levels, safely reducing PFAS below the drinking water criteria. An independent contaminant fate and transport modeling expert studying this site has modeled the treatment's potential longevity at greater than 50 years.

Potential Longevity

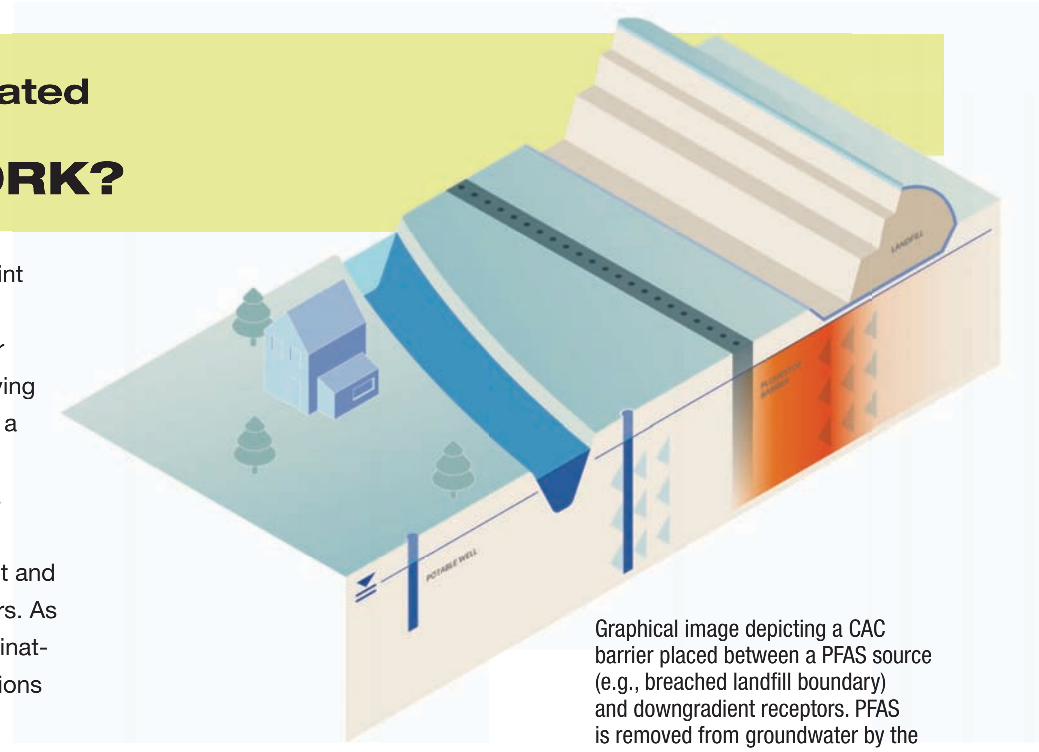
Through flux-modeling analysis, many CAC PRB designs indicate potential longevity for more than a century. However, when, or if, a breakthrough does eventually occur, a second PRB can be installed downstream of the first to continue PFAS removal from the aquifer. Additionally, there is robust research evaluating methods for the safe, biological destruction of PFAS, including a new startup funded by Bill Gates and other investors. If successful, these efforts could allow for the efficient treatment of PFAS sequestered in CAC PRBs.

Substantial cost savings may be realized when using CAC to eliminate PFAS in groundwater at landfills. A lifecycle cost analysis was completed comparing the CAC treatment at the Canadian PFAS site to the installation and 20 years of O&M of a P&T system. The cost savings realized in this case approaches 20X.

Abinash Agrawal, a leading soil and groundwater remediation expert at Wright State University, is studying ex situ and in situ treatment methods for PFAS in groundwater. He prefers in situ CAC

What is a Colloidal Activated Carbon (CAC) PRB and HOW DOES IT WORK?

A CAC PRB is constructed of an injection point array with its orientation perpendicular to the principal groundwater flow direction. Soon after injection, the CAC binds to the aquifer soil, leaving the soil grains coated with carbon and creating a reactive sorption zone. As groundwater passes through the treatment zone, the flow of PFAS is slowed (i.e., retarded) by orders of magnitude, effectively binding them, halting their movement and eliminating exposure to down-gradient receptors. As the exposure to downgradient receptors is eliminated, so is the risk. In essence, a CAC PRB functions as an in situ purifying filter for groundwater.



Graphical image depicting a CAC barrier placed between a PFAS source (e.g., breached landfill boundary) and downgradient receptors. PFAS is removed from groundwater by the barrier (red-shaded area).
Image courtesy of REGENESIS.

treatment, stating: "It is a superior approach for PFAS remediation in aquifers because it's cost-effective, less disruptive, fast-acting and has proven to be effective."

In total, there are 116 projects at various stages of planning and implementation. All field installations applied thus far are meeting performance expectations. In a commitment to ensure the remedial approach meets objectives, warranties on the performance of CAC PRBs may be considered. | WA

__Ryan Moore__, CHMM, is a REGENESIS (San Clemente, CA) PFAS Program Manager. In this capacity, he is focused on collaborating with environmental professionals and the industry at large in communicating effective, proven approaches to manage sites where PFAS contaminants exceed regulatory standards. Ryan has managed the use of PlumeStop®, Colloidal Activated Carbon™, available exclusively through REGENESIS, to treat PFAS and other organic pollutants since its inception in 2014. Ryan's background is in situ groundwater and soil treatment, site investigations, corrective action evaluations, operation and maintenance of remediation systems, large soil removal remedial projects, vapor intrusion assessments, and environmental laboratory operations such as QA/QC evaluations, data interpretations, and business development provide a strong foundation for his effective approach to PFAS remediation. He has more than 20 years of experience as an environmental project manager and laboratory account executive relating to multimedia contamination sites throughout the U.S. and has presented at multiple conferences on PFAS in situ remediation. Ryan can be reached at (219) 286-4838 or e-mail rmoore@regenesis.com.

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