Tool 4.3: Considerations for Selecting a Method of In Situ Water Treatment

LIMITATION: The following table represents the state of technologies as of January 2022. EPA, DoD, and other agencies are leading ongoing research and technology evaluation, and users of this guidebook should refer to those agencies for the most up-to-date information on technologies and their applicability to the remediation project in question.

In Situ Groundwater Remedial Options
Monitored Natural Attenuation (MNA) *Cost: TBD; Screening Status: Retain*
Description: ✓ MNA for PFAS is an emerging approach to assess and monitor the attenuation of PFAS in vadose-zone soils and in groundwater. MNA would incorporate a multiple LOE approach which evaluates direct and indirect measurements of partitioning- and matrix diffusion-based retention, chemical retention, and plume attenuation, augmented by calculations and models (e.g., groundwater modeling, mass flux calculations) that show no migration or impact to natural resources (Newell et al. 2021a and 2021b). **Implementability:** ✓ Implementable; will require additional study at many sites to build LOE argument for attenuation. **Effectiveness:** ✓ Has not been demonstrated to-date for PFAS; can be effective for other constituents. **Availability / Maturity:** ✓ Emerging

In Situ Groundwater Remedial Options

In Situ Injection of CAC

Cost: High; Screening Status: Retain

Description:

✓ CAC injected into the PFAS-impacted zone; PFAS adsorbed and sequestered in CAC.

✓ CAC may be injected in situ using a grid pattern in source zones, or in a transect pattern perpendicular to the width of a plume to mitigate contaminant flux. The quantity of CAC required and its longevity is based on the mass flux of PFAS and other co-contaminants within the aquifer.

✓ No degradation or destruction of PFAS occurs.

Implementability:

✓ Implementable where injections are feasible. Significant pre-design and pre-injection testing is required to optimize injections. The quantity of CAC is significantly impacted by co-contaminants (e.g., volatile organic compounds [VOCs]).

✓ Regulatory objections to sequestration remedies may present an obstacle to closure.

Effectiveness:

✓ If used as source treatment, will immobilize PFAS in source.

✓ If used as a boundary treatment, will prevent migration of PFAS off-site.

✓ Effectiveness at sequestering various concentrations is addressed via injection and application rates.

Availability / Maturity:

✓ Commercially available.

In Situ Groundwater Remedial Options

Funnel and Gate

Cost: Medium to High; Screening Status: Retain

Description:

✓ Use of traditional engineering techniques to create preferential treatment zones (funnels and gates) where treatment media can be emplaced. Treatment media can then be changed and/or recharged based on monitoring data.

✓ Multiple substrates can be considered for treatment media, including CAC, powdered activated carbon, and modified zeolites. Recent studies indicate that IX and biochar in situ had limited longevity (McGregor, 2020). IX resins are also being evaluated (Coyle et al, 2021). If media must be removed, wastes may need to be disposed of as hazardous waste.

Implementability:

✓ Implementable where construction of barriers (funnels) is viable given future site use (e.g., infrastructure) and aquifer hydraulics allows manipulation of groundwater flow.

✓ Gate media must be optimized for site specific geochemistry. Gate design must be optimized to allow for recharge/replenishment given future site use.

✓ Limitations identified previously for adsorbents will apply; the presence of co-contaminants may significantly impact the quantity of adsorbent required and associated flow-through times within the gate.

Effectiveness:

✓ Treatment effectiveness is dependent on advective movement of groundwater through the gate.

✓ Flow through gate (or sequential gates, depending on design) is required for effective treatment.

Availability / Maturity:

✓ Mature technology; application to PFAS is new.

Slurry Walls/ Hydraulic Barriers

Cost: Medium to High; Screening Status: Do not Retain

Description:

✓ Installation of slurry walls, constructed barriers, or hydraulic barriers to modify groundwater flow direction. May require groundwater extraction (with corresponding treatment) to manage hydraulic gradients.

✓ No degradation or destruction of PFAS occurs.

In Situ Groundwater Remedial Options

Implementability:

✓ Where construction of barriers (funnels) is viable given future site use (e.g., infrastructure) and aquifer hydraulics allows manipulation of groundwater flow.

✓ May need to be combined with groundwater extraction and ex situ treatment options to control groundwater flow.

Effectiveness:

✓ Effective at preventing groundwater flow to sensitive downgradient resources.

✓ Mature.

Redox Manipulation Techniques

Cost: TBD; Screening Status: Do not Retain

Description:

✓ During chemical oxidation, oxidants (ozone, hydrogen peroxide, persulfate) are used to generate free radicals. The different oxidants react with various PFAS precursors and generate PFAS of various chain lengths. Theoretically, longer chain PFAS are sequentially converted to shorter chain compounds. However, the mechanisms of complete destruction are not well understood and there is significant concern regarding formation and migration of shorter chain compounds (ITRC, 2021).

Implementability:

✓ Injection of oxidants into the subsurface is easily implementable and has been demonstrated at many sites for traditional plumes.

Effectiveness:

✓ The technology's use for PFAS is innovative, and effectiveness has not been demonstrated at field scale. The mechanisms of reactions and destruction need to be understood to demonstrate in situ treatment effectiveness (ITRC, 2021).

Availability / Maturity:

✓ At research/ pilot scale.

✓ Limitations/ interferences TBD.

In Situ Groundwater Remedial Options

Phyto-Remediation

Cost: Low to Medium; Screening Status: Retain

Description:

✓ Degradation, sequestration, or evapotranspiration of PFAS by grasses, trees, or constructed wetlands is currently being evaluated in several studies (Huff et al., 2019; Shahsavari et al. 2021; Saenz, 2022). Trees can also be used for hydraulic control (i.e., to manipulate hydraulic gradients) and prevent off-site migration (ITRC 2009).

✓ Extended remedial timeframes are required for a phytoremediation plot to grow to maturity (~10 years) and for trees to achieve full evapotranspiration uptake.

Implementability:

✓ Implementable where high-density planting of trees or other vegetation is viable given future site use (e.g., infrastructure).

✓ May need to be implemented in combination with biological or adsorptive techniques to maximize removal efficiencies (Shahsavari et al. 2021).

Effectiveness:

✓ Phytoremediation effectiveness is still being evaluated for PFAS.

✓ However, it can be successfully used to manipulate hydraulic gradients and reduce/restrict groundwater migration.

Availability / Maturity:

✓ Emerging for PFAS.