Table A-18.C. Technical implementation considerations for activated carbon

Data requirements	Site-specific data for technology evaluation	Access	Injection points must be closely spaced. Surface obstructions will reduce effectiveness due to poorer distribution of carbon.
		High-resolution site characterization	Use of MIP/HPT, or continuous soil sampling and frequent laboratory analyses, to target treatment zones and estimate contaminant mass. For colloidal-AC, identify high permeability zones as potential major mass flux.
		Nearby wells, borings, utilities, structures	Unintentional injection of carbon into these features can occur, short-circuiting carbon distribution and wasting material. Inadequate plugging of (historical) borings or wells may become apparent.
		Plume size and soil characteristics	Fractures or soil heterogeneities will control injection orientation and carbon distribution.
		Biological activity (Biotraps, HPC cultures)	Evaluate the occurrence and contribution of continuing biodegradation subsequent to carbon addition where nutrients/bacteria are added.
	Bench-scale testing	Oxidant demand (NOD or SOD) and Fraction of organic carbon (Foc)	If oxidants such as sodium persulfate or calcium peroxide are used, testing similar to ISCO design is recommended to properly dose the oxidant/carbon ratio and maintain a reasonable pH for later biodegradation.
	Pilot-scale testing	Injection pressure/flow	Monitoring of injection pressure and flow rate is important when completing injections, particularly when slurries are injected. Pressure in particular provides insight into geologic conditions and can alert the contractor to poor distribution. Evaluation of various injection tip geometries should be performed during pilot testing to ensure proper tip selection during full scale implementation. Specification of proper equipment and use of an experienced contractor is essential.
		Placement/number of injection points	Injection usually on a triangle grid, points spaced 5-7 ft. (or less) apart.
		Injection interval	Identified by HRSC, confirm zones will accept slurry.
		Minimum injection depth	Near-surface injection (<5 feet) unlikely to be successful due to rapid surfacing.
		Permit consideration	Obtain a UIC permit for pilot testing AND anticipated full-scale design to avoid delay later.
	Full-scale design	Injection pressure/flow	Continuous recording of injection pressure and flow rates is recommended. Pressure plots can distinguish between clay/silt soils versus fine sands and coarser soil types. In addition, pressure can detect injectate channeling into previously injected horizons, defeating the goal of reasonable distribution. Knowledge of the pressure drop across the injection tooling at various flow rates is critical to interpretation of injection pressure data. Flow rate data is a valuable diagnostic tool to assess equipment functionality.
		Placement/number of injection points	Close spacing ensures more uniform distribution but adds to cost. Injection points should be no closer to monitoring wells than half the spacing distance.
		Injection interval	Use short intervals (2 ft.) to best target vertical treatment zones for injection. For colloidal carbon, target high mass flux zones.
		Minimum injection depth	If surfacing or short-circuiting occurs, drill an offset point. Continuing to inject in the same location simply wastes product.
	Performance metrics	Post monitoring	Check monitoring wells for carbon influence. Carbon in a monitoring well may provide negatively biased groundwater samples. Replacement wells may be necessary to maintain a well network and confirm aquifer treatment. Changes in EC, DO, ORP, pH and water level may be useful to monitor during and after injection depending on amendments added.
		Delivered amount	The required dosage must be delivered to the zones specified in the plan. Don't just inject where it can be injected! (Overtreatment of an area is wasteful.)
		Daylighting observed	Account for subsurface conditions to minimize daylighting. Note the distance from point of injection, pressure and flow during injection, and the volume injected prior to surfacing to reduce recurrence.
		Carbon distribution	Small-diameter poly-tubing micro-wells may be installed throughout the treatment area as an aid in documenting distribution and evaluating performance as samples of groundwater can be obtained for analysis. During injection, if injectate reaches a micro-well, slurry will surface which provides insight into distribution. Continuous confirmation soil borings may be advanced post-injection to verify carbon distribution.
		Contaminant reduction/nutrient uptake	Reductions in dissolved hydrocarbon concentrations should be evident immediately or within weeks. Rebound may occur in 6-9 months. Collect samples to monitor NO3, SO4, valence states of Fe and Mn, and/or oxidant activity. Analysis of other biological compounds in addition to QuantArray testing may be useful. Additional amounts of nutrients may be needed to maintain any biodegradation process. Data obtained from monitor wells will be very different from that derived from soil samples.
		Contingency plan	Additional injection events may be necessary to treat recalcitrant areas.
Modeling tools/applicable models		N/A	
Further information		Fan, D., Gilbert, E. and Fox, T., Current State of In situ Subsurface Remediation by Activated Carbon-based Amendments. Journal of Environmental Management 204 (2017) p.793-803. http://dx.doi.org/10.1016/j.jenvman.2017.02.014	
		Winner, E., Experience with Carbon Emplacement for Remediation of Petroleum, 2015 National Tanks Conference (Phoenix) http://www.neiwpcc.org/tanks2015/presentations.asp	
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		Audrain, B. et al, Role of Bacterial Volatile Compounds in Bacterial Biology, FEMS Microbiology Reviews, Volume 39, Issue 2, 1 March 2015, Pages 222–233. https://doi.org/10.1093/femsre/fuu013	