Table A-14.C. Technical implementation considerations for bioventing/biosparging

Data requirements	Site-specific data for technology evaluation	Soil permeability (to air in unsaturated zone)	Permeability to air directly affects the radius of treatment that can be developed around each bioventing point; lower-permeability soils may require more biovent or biosparge points per unit area or a higher injection pressure to achieve desired air flow. Usually, but not always, the radius of influence is greater in vadose zone than groundwater.
		Groundwater conductivity	Conductivity directly affects the volume of air that can be injected and may impact the radius of treatment that can be developed around each biosparging point; for a given soil structure higher permeability soils may require more biosparge points per unit area than moderately permeable soils. Low permeability soils require more air pressure to overcome flow resistance.
		Soil heterogeneity	Soil heterogeneity impacts both bioventing and biosparging, however the impacts can be significantly different. For bioventing soil heterogeneity will impact uniformity of treatment; low permeability layers can be more difficult to treat, but also can increase radius of influence. For biosparging vertical anisotropy can have a significant impact on air distribution, in general the higher the ratio of horizontal to vertical permeability the greater the radius of influence. Heterogeneity controls where injected air travels, and the uniformity, or lack of uniformity of treatment.
		LNAPL characteristics	Can be applicable to any biodegradable LNAPL, and most all hydrocarbons are biodegradable. However lighter hydrocarbons tend to biodegrade more rapidly than heavier so treatment time can be impacted.
		Groundwater temperature	Bioventing has been successfully applied to sites with a very wide range of temperature, to sites with near 0 C soils (i.e., in Alaskan permafrost) to very hot desert environments (i.e., Phoenix, AZ and Palm Springs, Ca). If soils are artificially heated to above 45 C, microbial activity may decrease.
		pH of the aquifer	Bioventing has been applied in a very wide range of pH environments and pH limitations have only been observed under very acidic conditions (i.e., pH < 3).
		Microbial Population Density	Historically, total heterotrophic bacteria analysis was conducted on many bioventing sites, however no clear correlation between measured microbial density and biodegradation rates were observed. In situ respiration testing was found to be a more direct and accurate measure of biodegradation rates.
		Nutrients	Nutrient addition is not typically required for bioventing or biosparging. Nutrients are necessary for biological biomass, however the relatively low rates of biodegradation observed in bioventing and biosparging require very little nutrients and can typically be supported by naturally occurring nutrients. EPA (1995) examined over 100 bioventing sites where no nutrients were added. Biodegradation occurred at all of the sites, however there was little or no evidence that any of the sites were nutrient limited. The common rule of thumb ratios for nutrient requirements do not appear to apply at low biodegradation rate sites such as bioventing or biosparging.
		Aquifer thickness and depth to groundwater	Depth to desired air injection must be sufficient to allow installation of an adequate well seal. Shallow water tables can increase the risk of vapor intrusion and/or surface emissions.
	Bench-scale testing	N/A	None required

	Pilot-scale testing	Required for larger or more complex sites	Smaller sites can at times be implemented based on professional experience, the need for pilot testing should be cost/benefit driven. Biosparging does not typically result in sufficiently uniform air distribution for estimation of a uniform ROI, and pilot testing can be more challenging.
		ROI	Radius of influence (more so for bioventing) observations indicate injection point spacing and optimal flow rates/pressures.
		Equipment sizing	Flow rates and pressures determined from pilot testing determine equipment specifications. On smaller, simpler sites this may be based on professional judgment.
	Full-scale design	Number of points	Depends on site conditions and ROI. For biosparging, a rule of thumb of 20 to 30 ft. spacing is often used.
		Piping flow/pressure losses	Depends on site conditions and ROI.
	Performance metrics	Air flow and pressure	Appropriate air flow into injection points, based on oxygen demand and ROI. For biosparging pulsed operation can often increase treatment efficiency.
		Soil vapor	For optimal biodegradation, O_2 in excess of 5% should be maintained in the vadose zone, and for biosparging DO should be maintained above 2 mg/l in groundwater. For bioventing rates can be measured using in situ respiration testing (see EPA 1995), or by monitoring O_2 and CO_2 in soil gas.
Modeling tools/ applicable models		SOILVENT, HypeVent	
Further information (note many of the sources of information for SVE and air sparging are also useful for bioventing and biosparging)		EPA 1995. Bioventing Principles and Practice, Volumes 1 and 2, EPA/540/R-95/534a. https://cfpub.epa.gov/si/si_public_record_report.cfm?dirEntryId=124631	
		EPA. 1995. How to Evaluate Alternative Cleanup Technologies for Underground Storage Tank Sites: A Guide for Corrective Action Plan Reviewers, Chapters 3 and 8. https://www.epa.gov/ust/how-evaluate-alternative-cleanup-technologies-underground-storage-tank-	
		AFCEE, 1995, Bioventing Performance and Cost Results from Multiple Air Force Test Sites, Air Force Center for Environmental Excellence. https://frtr.gov/matrix2/section4/4_1.html	
		Battelle, 1996, Bioventing Design Tool User's Guide. http://www.dtic.mil/dtic/tr/fulltext/u2/a286983.pdf	
		Battelle. 1996. Principles and practices of bioventing, Volume II: Bioventing design. http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.556.1901&rep=rep1&type=pdf	
		NAVFAC Bioventing webpage https://www.navfac.navy.mil/navfac_worldwide/specialty_centers/exwc/products_and_services/ev/erb/tech/rem/biovent.html	
		NAVFAC, 2000, Passive Bioventing in Stratified Soils and Shallow Groundwater Conditions. NFESC TDS-2083-ENV. https://clu-in.org/products/tins/tinsone.cfm?id=15243454	
		AFCEE, 2004, Procedures for Conducting Bioventing Pilot Tests and Long-Term Monitoring of Bioventing Systems, Air Force Center for Environmental Excellence. http://www.dtic.mil/dtic/tr/fulltext/u2/a423587.pdf	
		Florida Department of Environmental Protection Biosparging Pilot Test Guidance. https://floridadep.gov/sites/default/files/BPSS12C_BioSpargeGuidance.pdf	
		Government of Canada, Environmental and Natural Resources Biosparging fact sheet http://gost.tpsgc-pwgsc.gc.ca/tfs.aspx?ID=4&lang=eng	