Table A-3.A. Vacuum-enhanced skimming

Technology	Vacuum-enhanced skimming	LNAPL & vapor are the fluids removed. LNAPL drawdown and vacuum induce an LNAPL gradient toward the recovery point. Also referred to as bioslurping or vacuum enhanced fluid recovery (VEFR). ***(See illustrations for potential configurations.)***	
Remediation process	Physical mass recovery	Yes (primary)	1.Skimming removes liquid LNAPL from saturated zone and perched LNAPL zones. 2. Induced vacuum extracts LNAPL vapors from unsaturated zone and capillary fringe.
	Phase change	Yes (secondary)	The induced vacuum volatilizes and evaporates the LNAPL.
	In situ destruction	Yes (secondary)	Infiltration of oxygenated air from the surface enhances in situ aerobic biodegradation of the LNAPL.
	Stabilization/ binding	No	
Objective applicability	LNAPL saturation	Yes	Vacuum-enhanced skimming reduces LNAPL saturations.
		Example performance metrics	Direct analysis of soil to measure changes in LNAPL saturation; direct measurement of LNAPL thickness reduction in wells, reduced LNAPL transmissivity/LNAPL conductivity, LNAPL-to-water ratio for a given vacuum induced, asymptotic recovery of LNAPL from a well, dissolved-phase stability, and LNAPL plume monitoring.
	LNAPL composition	Yes	Vacuum-enhanced skimming reduces the volatile constituent fraction of the LNAPL and likely also the soluble fraction of the LNAPL. Aerobic degradation reduces LNAPL concentrations of degradable compounds in dissolved phase and drives preferential dissolution of those compounds from LNAPL. More volatilization occurs closer to the well(s) than at greater distance.
		Example performance metrics	Removal of VOC concentrations in extracted vapor to a concentration end point, reduced dissolved-phase concentrations to regulatory standard at compliance point.
Applicable LNAPL type	All LNAPL types, although better suited to less viscous LNAPLs (e.g., gasoline, kerosene).		
Geologic factors	Unsaturated zone	Permeability	More effective in higher-permeability materials where vapor flow is easier but can also be applied in lower-permeability materials through the use of stronger vacuum.
		Grain size	More applicable to sands and gravels but can also be applied in silts and clays.
		Heterogeneity	In heterogeneous soils, vacuum extracts LNAPL from preferential pathways, possibly short-circuiting remediation coverage, but LNAPL is often also in preferential pathways.
		Consolidation	Not typically a factor.
	Saturated zone	Permeability	Can achieve faster LNAPL removal and lower LNAPL saturations in higher-permeability materials.
		Grain size	More applicable to sands and gravels but can also be applied in silts and clays.
		Heterogeneity	Fractured bedrock and heterogeneous soils will induce preferential flow. More applicable to perched LNAPL and unconfined LNAPL. Less applicable to confined conditions because the benefits of the applied vacuum are limited, although vapor treatment may still be necessary. The ratio of vacuum induced drawdown to water production-induced drawdown can be optimized for the given hydrogeologic scenario (e.g., perched LNAPL would require little to no water production, focusing the vacuum enhancement on the LNAPL recovery).
		Consolidation	Not typically a factor.