



Butane Biostimulation Technology™ Applications

Petroleum Hydrocarbons

With millions of gallons of gasoline, oil, and other petroleum products stored in underground tanks throughout the world, leaking tanks and petroleum spills continue to be a major source of soil and groundwater contamination. **Butane Biostimulation Technologies™ (BBT) provide a rapid and cost effective means for enhanced *in situ* natural attenuation of a wide range of petroleum compounds.** Where natural attenuation alone may not be sufficient, BBT can be used to rapidly and strategically achieve plume control to meet remediation goals.

Gasoline and other fuel hydrocarbons are a complex mixture of refined petroleum components. Crude oil and weathered fuel products are likewise complex hydrocarbon mixtures. Biodegradation of hydrocarbons by indigenous microorganisms in soils and groundwater is well documented (15, 20, 24, 25). Many of these studies also document the evolution of microbial communities in response to biogeochemical changes to hydrocarbons in the environment following a leak or spill (4, 7, 11). Although degrading bacteria often grow on only a few specific hydrocarbons, alkane monooxygenases often cometabolize a wider range of alkanes than those which support growth (8). Strains that can use both gaseous and liquid alkanes or other, more complex hydrocarbons, as growth substrates have been characterized as well (4, 25).

Butane Biostimulation Technology™ Description and Benefits

For the treatment of petroleum hydrocarbons using BBT, a mixture of butane and air (or an alternative source of oxygen) is injected into the soil or groundwater to stimulate the indigenous microbial community and enhance natural degradation of contaminants through direct metabolism and cometabolism. Because butane is the heaviest (having 4 carbon atoms) and most soluble of the alkane gases, the simplest of the hydrocarbon species, it provides a preferential substrate for naturally-occurring bacteria that degrade butane and other hydrocarbons (6). Butane injection provides an easily metabolized carbon source which leads to the rapid development of a robust and diverse biomass and consequently, a healthy microbial ecosystem capable of providing the enzymes and cofactors necessary for complete and rapid degradation of fuel hydrocarbons.

Butane and air injection rates are carefully managed using GBI's patented control panel. The process is optimized by injecting butane cyclically to sustain a healthy microbial ecosystem without creating competitive inhibition (repression of target contaminant degradation due to the supply of an alternate substrate). When treating hydrocarbons, Butane Biosparging™ is typically combined with Butane Bioventing™ to oxygenate the soils resulting in the enhanced microbial degradation of petroleum compounds in the capillary fringe and vadose zone. Since the offgas from the bioventing system is piped back into the treatment zone, O&M costs are reduced by eliminating the need for carbon treatment or air stripping. The bioventing system



also maximizes the radius of influence and controls the potential migration of hydrocarbon vapors from the treatment area into adjacent buildings.

The gaseous nature of butane makes BBT uniquely suited to remediation in low-permeability soils, beneath structures, and even in fractured rock, reducing costs and improving the effectiveness of treatment. As a gas, butane is dispersed rapidly and broadly in the subsurface through advective and diffusive transport mechanisms. An added benefit is that contaminated soil in the unsaturated zone and capillary fringe is also treated by the advective and diffusive migration of butane above the water table. Diffusion is the mechanism by which soil gas moves from high concentration to low concentration due to a concentration gradient. Advection is the transport mechanism by which soil gas moves due to differences in pressure. As a result of the high diffusivity of butane gas, BBT overcomes the limitations of groundwater mixing seen with liquid chemical injection and solid phase release compound systems.

It is also noteworthy that butane-utilizing bacteria have been shown to fix nitrogen. Consequently they are able to produce their own nutrients. This capacity was not observed in comparative studies using propane (18). In nutrient-limited environments the ability to fix nitrogen can substantially improve the sustainability of the remedial process.

Injected butane gas provides a sustainable carbon source to stimulate the growth of indigenous microbial communities. This is essential for complete mineralization of target contaminants. When fuel hydrocarbons are not present in sufficient concentrations to act as the primary metabolic substrate they cannot support microbial growth as the only electron donors (24). If contaminants are actively transformed to innocuous by-products by biochemical processes that are present in natural systems and if energy is available to drive these processes to completion, then degradation is inherently sustainable (2). Butane provides an ideal carbon source to accelerate and ensure the sustainability of these processes.

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