Bioaugmentation: An effective method for reducing contaminant concentrations

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With the growing number of remediation options available, environmental consultants often have a daunting task of determining which approach, or combination of approaches, would be the most appropriate and cost-effective for a given project.

While conventional technique like pump-and-treat, soil vapor extraction and dig-and-haul have clear advantages, the less invasive in-situ treatments have been growing in popularity. According to the U.S. Environmental Protection Agency, 42 percent of all Superfund sites employ in-situ methods for source treatment.

Many sites have been completely remediated by in-situ techniques that inject a variety of materials either as a liquid or slurry to degrade contamination. Under the umbrella of bioremediation, additional microbes can be added to boost the resident populations of nutrients.

In addition, chemicals designed to stimulate the natural degradation processes can be added, such as molasses, permanganate, vegetable oil or oxygen. Each approach has its own unique advantages and limitations.

Introducing specialized microbes at a site to essentially "eat" the contamination is called bioaugmentation. It has proven to be a fast, effective and affordable remediation alternative, and it is finding favor among site managers and remediation experts.

Bioaugmentation is a powerful tool that can be used as a stand-alone remediation alternative, but it works quite well with many other remediation technologies to expedite site clean-ups.

Still, some consultants have yet to fully embrace this technology due to a few common misconceptions.

Is bioaugmentation a viable alternative for your next remediation project? Before using the old standby methods, take a moment to review some of the misconceptions about bioaugmentation. It may actually be the best remedy to solve your next client's contamination problem.

Misconception 1: Bioaugmentation is a slow process

Given favorable conditions, bioaugmentation is anything but slow.

But like any remediation technology, the speed and success of a bioaugmentation product depends almost entirely on a clear understanding of site-specific conditions. Some bioaugmentation products, such as *Pseudomonas* microorganisms, are better suited for aerobic conditions, while others, like *Dehalococcoides* perform best in anaerobic environments.

Both are fast processes, relative to most conventional methods like pump-and-treat, but most experts will agree that aerobic bioaugmentation is faster due to the robust oxidation reaction. The growth rates of aerobic microorganisms are more rapid due to the greater net production of energy.

Regardless of the metabolism type, once the microbes come in contact with the contamination, the concentrations are reduced quickly. With aerobic bioaugmentation, the number of microbes introduced to the treatment area is typically 100 to 1,000 times higher than the indigenous populations, which is why degradation occurs quite rapidly. Greater population increases the opportunity and frequency of cell-to-contaminant contact, which increases the remediation rate.

Bioaugmentation is sometimes confused with biostimulation, which is the addition of chemicals or nutrients into the subsurface to stimulate the indigenous bacteria. The stimulation process often requires some ramp-up time as the bacterial population increases to the numbers necessary to effectively degrade the contaminants.

Biostimulation also presents the risk of stimulating a species or strain of microbes that are unable to metabolize the contaminants of concern or favor other food sources, thus stalling remediation efforts.

For site with conditions that suggest depressed microbial activity, consultants are combining biostimulation with bioaugmentation to get the best of both alternatives.

High numbers of microbes in an ideal environment has proven to be an effective approach.

Misconception 2: Bioaugmentation is only valuable as a final polish

While bioaugmentation is a proven means for providing the final polish to sites where traditional technologies have stalled short of remediation goals, the same microbes can be used to treat large-scale sites with high concentrations of dissolved phase contaminants.

Since microbes can be grown in a fermentation tank to yield as high as 10^{10} colony forming units per milliliter, a small amount of microbial inoculants can be used to treat large volumes of groundwater.

For in-situ applications, a single 55-gallon drum of microbes can treat up to 20,000 gallons of groundwater or 100 tons of soil.

For ex-situ applications, those volumes are considerably higher since the treatment can be manipulated towards ideal conditions.

Aerobic microbes, for example, can even degrade free product (an anaerobic-tending environment) in ex-situ applications because atmospheric oxygen is readily available and can be incorporated into the material to help carry out the oxidation process.

The wastewater industry has been using this ex-situ treatment method for years.

Misconception 3: Bioaugmentation is effective on only a few organic contaminants

It is still thought by some that microbes only react with a small number (of) organic contaminants, but both field and bench-scale tests have proven that microbes can facilitate the degradation of a surprisingly wide range of organic contamination, and this list is still growing.

Aerobic microbes, for example, have already been proven to remediate more than 50 chlorinated solvents and petroleum-based contaminants.

The nutritional diversity of *Pseudomonas* can metabolize more than 100 different carbon sources, which can be degraded by the same strain using more than one pathway.

Laboratory studies have also proven that the chlorinated solvent, tetrachloroethylene, and its degradation products including trichloroethylene, 1,2-dichloroethylene, and vinyl chloride are all completely degradable through aerobic bioaugmentation, which has been long thought possible only through anaerobic methods.

Not limited to laboratory findings, the successful degradation of numerous organics has also been repeatedly demonstrated by field applications.

Misconception 4: Bioaugmentation is pixie dust

Any unconventional product that fails to meet expectations is hard to forget. Wasting time and money with a failed remediation effort will sour both the consultant and the client against the technology.

Vowing to never use the offending technology again, customers quickly return to the tried and true methods.

As with any remedial alternative, bioaugmentation can only be successful if it is compatible with site conditions. An accurate site model that provides a reasonably clear idea of contaminant distribution, site lithology, hydrogeology and groundwater chemistry will result in the selection of the most appropriate remediation plan and also keep expectation realistic.

Impermeable soils, such as clay and silt, may prevent the distribution of microbes throughout the treatment zone. Unfortunately, the inability to make cell-to-contaminant contact is a limitation of all in-situ technologies, and as a result, the bulk of the contamination remains untouched.

Sometimes the geochemistry is unsuitable for bioaugmentation; for example, if the pH is too high or too low to support microbial activity. If unsuitable conditions are unknown or incompletely characterized, any remediation technology is at risk of failure. Bioaugmentation is no different.

It is also important to get quality microbes. Ideally, the microbes should be all natura—not genetically modified. If nutrients are required, care should be taken to ensure the nutrients do not contain excessive inorganic compounds that might create an additional contaminant issue.

You should find a vendor you can trust and who provides clear and useful technical support throughout the life of the bioaugmentation period, not just the sale.

The bottom line is that bioaugmentation is a very effective method for reducing contaminant concentrations at a wide variety of sites by simply introducing a very high population of all naturally-occurring microbes that degrade contaminants through various biological processes.

No single technology is going to be effective at every site, but with a clearer understanding of the available technologies, such as bioaugmentation, environmental consultants can be better equipped to make the best decisions for their clients.

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