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**CLEANUP TECHNOLOGY**

While excavation and disposal are one way to clean up contaminated properties, there is another: the use of biological microorganisms. There is no one microbe or "bug" that can solve all remediation woes, but cocktails of fortified microbial extracts, or compost teas, have been used effectively to reduce toxicity in soil and improve the vigor of crops. In this article, Richard Opper, of Opper & Varco LLP, provides an overview of the biological processes involved and details case studies in which microorganisms have been used to remediate properties. In addition, microbes can be used to treat stormwater and frack water, he says.

## Forward, Into the Past: The Emerging Use of Microorganisms in Treating Contaminated Soil and Groundwater

BY RICHARD OPPER

Some of the most rewarding technological advances today are built on a better understanding of some very old yet fundamental processes. Understanding the role microorganisms play in our biosphere has moved into new dimensions with modern DNA identification techniques, and new vistas have emerged.

The role of microbial action in a myriad of ecological processes is seen as more germane and powerful than ever before. Microbes are everywhere within the biosphere and critical to biochemical processes in our own bodies. Because they are in every conceivable niche reaching miles into the Earth, in total biomass they dwarf all other living things combined.

### (a) Silver Bullets Miss the Target

In the beginning (relatively speaking), there was an unimaginably vast ocean of microbes, working over billions of years, that helped create the planet's atmosphere. Now we are learning how to harness that power. Many of the chemicals that have to be mitigated as a result of historically poor management practices can be addressed by applying microbiological solutions.

In the urban environment, where redevelopment is a frequent objective, contaminant impacts to soil and groundwater are serious issues that can be addressed by the invisible and diverse army of microorganisms. This isn't new news. Unfortunately, the ''bug salesmen'' of yore, who created as much tumult as the Music Man trying to sell band equipment in the Midwest, knew too little and frequently claimed too much.

In situ (on-site) treatment—as opposed to excavation and disposal elsewhere—gradually has become an accepted science. We call it bioremediation, and although it is widely practiced, there are different degrees of success. When this practice (like medicine, as much art as science) went awry, it sometimes was due to salesmen pitching the ''silver bullet'' approach. However, the belief that one special microbe or ''bug'' would eat all the toxics in the environment like Pac-Man on the video console was folly. With microbes, we now know ''it takes a village.'' Diversity of microbial species is important, because we now better appreciate the syntrophic nature of the entire microbial ecology.

## (b) The Power of Syntrophy

Syntrophy is defined as ''cross-feeding: a phenomenon whereby one species lives off the products of another species.'' Related to the biological phenomenon of symbiosis, syntrophy is a more intimate process. At the microbial level, because single cells are involved, they sometimes literally share membranes to facilitate sharing molecules of all kinds.

To harness this power, we need a way to culture a vast array of microbial species, which is a challenge for the laboratories that have built a market in bug production. Agriculture, however, has pointed the way to a new approach.

Fortified microbial extracts, commonly referred to as ''compost teas,'' have had wide success as an agricultural amendment, significantly reducing the need of high-energy chemical fertilizers, reducing dependence on chemical pesticides and increasing the natural moisture retention capacity of the soil column.

New research is showing that varieties of these microbial extracts can be highly successful in treating contaminated soils and groundwater. Evidence of the success of these strategies has been published in the open literature.

The early research and public presentations by Dr. Fatih Büyüksömnez, Ph.D., PE, Blasker Chair of Environmental Engineering and director of the environmental engineering program at San Diego State University, led to heightened awareness of the environmental properties of these extracts. His research showed these extracts could be used to reduce and destroy chemical residues in the soil and groundwater, providing positive impacts to the soil both by destroying toxic chemicals while reviving conditions that support plant growth and propagation.

## (c) Our Genetic Wealth

Significantly, the approach of this technology isn't to find the ''right'' bug but to deliver a universe of microorganisms, tens of thousands of species, in a dense extract that contains over half a billion microbes per milliliter. This isn't your grandmother's tea.

Another prominent researcher, Dr. Aaron Peacock, environmental biotechnology specialist on the management team at Pace Analytical Energy Services™, wrote:

> There is great potential for microbial communities to provide essential services to society—such as cleaning up contaminated sites around the world. It is estimated that there are more than $10^{30}$ individual microorganisms on Earth compared with only $10^{11}$ stars in the Milky Way. The population of terrestrial microorganisms contains a vast untapped wealth of genetic material and potential that can be used to remediate contaminated sites. In many cases microorganisms in the subsurface have a direct impact on the nature, extent, and fate of contaminants. In addition to indirectly creating conditions that hinder contaminant mobility, many microorganisms are known to directly transform contaminants to innocuous or immobile forms.

More experienced environmental engineers now favor treatment that uses a variety of approaches to achieve the desired result. Few now tout their products, be they biological, physical or chemical, as the ''one size fits all'' solution. Often, sequential processes are involved.

The key question is: Which approaches, used together, are most efficient and economical given the constraints and requirements of any given site? What if the timely and appropriate application of a fortified microbial extract was a sufficient adjuvant or accelerant to stimulate response time so remedial goals are attained sooner? On some sites, that could be equated with a significant financial benefit, reducing on-site operation and maintenance costs.

## (d) Microbiology Without the Laboratory

One can't create such a diverse, dense and living cohort of microorganisms for shipment—they have to be created on-site, for use when and where desired. The technology to create this important bioremediation amendment previously hasn't been available on a commercial scale, but a company called Growing Solutions Inc. has been working with agribusiness to develop specialized equipment to that very end.

They have patented equipment that consistently can produce a fortified microbial extract that they have named, appropriately enough, SYNTROPHY™. The process of creating SYNTROPHY™ depends not only on specialized bioreactors and equipment but also on the fortification process as the extract is cultured. Because of the way SYNTROPHY™ is prepared, it is possible to enhance or inhibit particular kinds of microbes leading to an optimized preparation. The company has adapted solar-powered bioreactors mounted on mobile, highway-legal trailers that can be brought to a site and turned into a microbial production facility, sans laboratory.

The substrate used for the organisms is highly processed and regulated compost substrate, and the fortification is made from natural mineral and marine products, added to the process as the natural bioreactor system brews the extract.

Current products we are aware of must use strains of organisms that can both reduce the chemical and survive being cultured in reactors with processed chemical nutrients, then prepared for shipment over a period of days or more to later be ''reconstituted'' in the field for application. This technology has inherent constraints. SYNTROPHY™, however, is prepared on-site from natural ingredients.

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**Case Study #1: Pogo Park, Richmond, Calif.** Obsolete railroad easements provide good opportunities for creative land uses. In Richmond, Calif., an abandoned line is slated to become a new linear park.

Historically, pesticides used by the railroad industry to maintain the rails have collected in the soils, in some cases to a hazardous level. The remedy often requires excavation, transportation and licensed disposal of soils at significant expense.

The city of Richmond has teamed up with Growing Solutions Inc., the producer of SYNTROPHY™, to use the microbial extract to biologically reduce some of the toxic qualities in the soils, rendering them safe for park use without excavation and later disposal. This project currently is under way.

## (e) Stormwater Mitigation, Plant Health

Just as exciting, though, is what the application of extracts like SYNTROPHY™ can mean, not only in the remediation of our chemical legacy regarding affected soils, but in other environmental contexts as well. Our urban environment is under increasing pressure as a result of stormwater runoff from roads and other urban surfaces with a myriad of pollutants with potentially toxic impacts. Increasingly, regulation requires adoption of new methods to treat this stormwater.

Many of those treatments are smaller versions of mitigation practices that have long been required to mitigate soil erosion after the construction of roads or the catastrophe of a forest fire, and are based on the rapid and reliable re-establishment of plant growth. The vigorous and timely re-establishment of the plants and revitalization of the rhizosphere is at the heart of the success of these strategies.

Can all plants easily survive in the typical bio-swales we routinely place around commercial and industrial facilities as a stormwater mitigation measure? Let's just say they need all the help they can get. These are organisms under more than the usual environmental stress. Applications of products such as SYNTROPHY™ show great promise in addressing the health and success of these mitigation measures.

Dr. Stephen Koenigsberg, a consultant with a background in plant science and microbiology, believes hydro-seeding supported by a fortified microbial extract could be demonstrably more effective than the current techniques that rely on chemicals, or frequently nothing at all. This, of course, is based on the proven track record SYNTROPHY™ has had in agriculture.

Dr. Koenigsberg thinks of the use of a bio-swale as a form of phytoremediation, in which plants are active agents of bioremediation. He recently wrote:

> Just looking at phytoremediation there are two aspects. On the one hand, the plants themselves can absorb and transform contaminants, but they also stimulate conditions in the root zone, or rhizosphere, that favor microbial activity, which in turn plays its own important role in the bioremediation process. Microbes do at least three important things for plants: they can make nutrients more available, they can produce molecules that serve as plant growth factors directly and they can even play a role with molecules that can interact directly with the DNA or genes in plants to activate them. This is the very definition of SYNTROPHY™.

Plants and microbes, working together, can ensure the efficacy of mitigation measures such as bio-swales and the propagation success of a hydro-seeded hill. Are there more applications for such an extract?

**Case Study #2: Coffee Rust Blight in Guatemala.** The importance of the coffee crop to the economy of Guatemala and the lives of its citizens is significant. Recent appearance of the blight called ''coffee rust'' has caused extreme concern among many sectors of the country. Finding a cost-effective, sustainable and organic remedy that can be produced on-site has been elusive.

Growing Solutions teamed with local dairy farmers to create a high quality compost substrate being used to make SYNTROPHY™ locally that targets factors that inhibit coffee rust and assists in the health and productivity of the coffee trees. This project is under way and may result in fundamental changes to the Guatemalan coffee industry.

**Case Study #3: Erosion Control Project, Medina, Wash.** Pictured is an erosion control project in Medina, Wash., where compost tea was used to accelerate vegetation of a steep hillside that needed to take root quickly in light of an anticipated storm event the following winter.

Planting occurred in the spring, and the ''after'' photograph was taken the following fall, just a few months later. Note the accelerated flush of foliage growth on the conifer in the background—normally a much slower response post construction time to growth of this degree.

## (f) Fracking and Beyond

Another frontier in the use of fortified microbial extracts is to address the large-scale issues we face on the road to energy independence. The management of ''frack water,'' for example, a byproduct of the hydraulic fracturing process, poses challenges.

In many areas where fracking is practiced, such as the Western Basin, water is scarce. When it comes to the surface after doing its job, it is laden with chemicals that inhibit its re-use. Microbial extracts can be a significant tool for the bioremediation of these waters in retention ponds so there can be re-use. This application isn't limited just to the frack water itself but to the soils where waste oil or petrochemical products have to be mitigated—all provide opportunities to harness microbiology.

Lastly, there are many to whom a new technology is always examined under the lens of sustainability. This is a lens under which microbial extracts shine. Made 100 percent from recycled materials, naturally produced with no manufactured chemicals added to the organic substrate, cultivated in a bioreactor that can be solar-powered and using water from local supplies, this is an approach that fits within any definition of sustainability.

## (g) Conclusion

This new technology augments soil with microorganisms that reduce toxics, enhance plant growth and ultimately produce simple water and carbon dioxide. Perhaps the answer to restoring the planet lies not so much in applying our engineering knowledge as in learning how to harness the power of the incredibly diverse biology with which we already are blessed.

It very well may be the dawning of a new age. Forward, into the past!

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*The opinions expressed here do not represent those of Bloomberg BNA, which welcomes other points of view.*

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