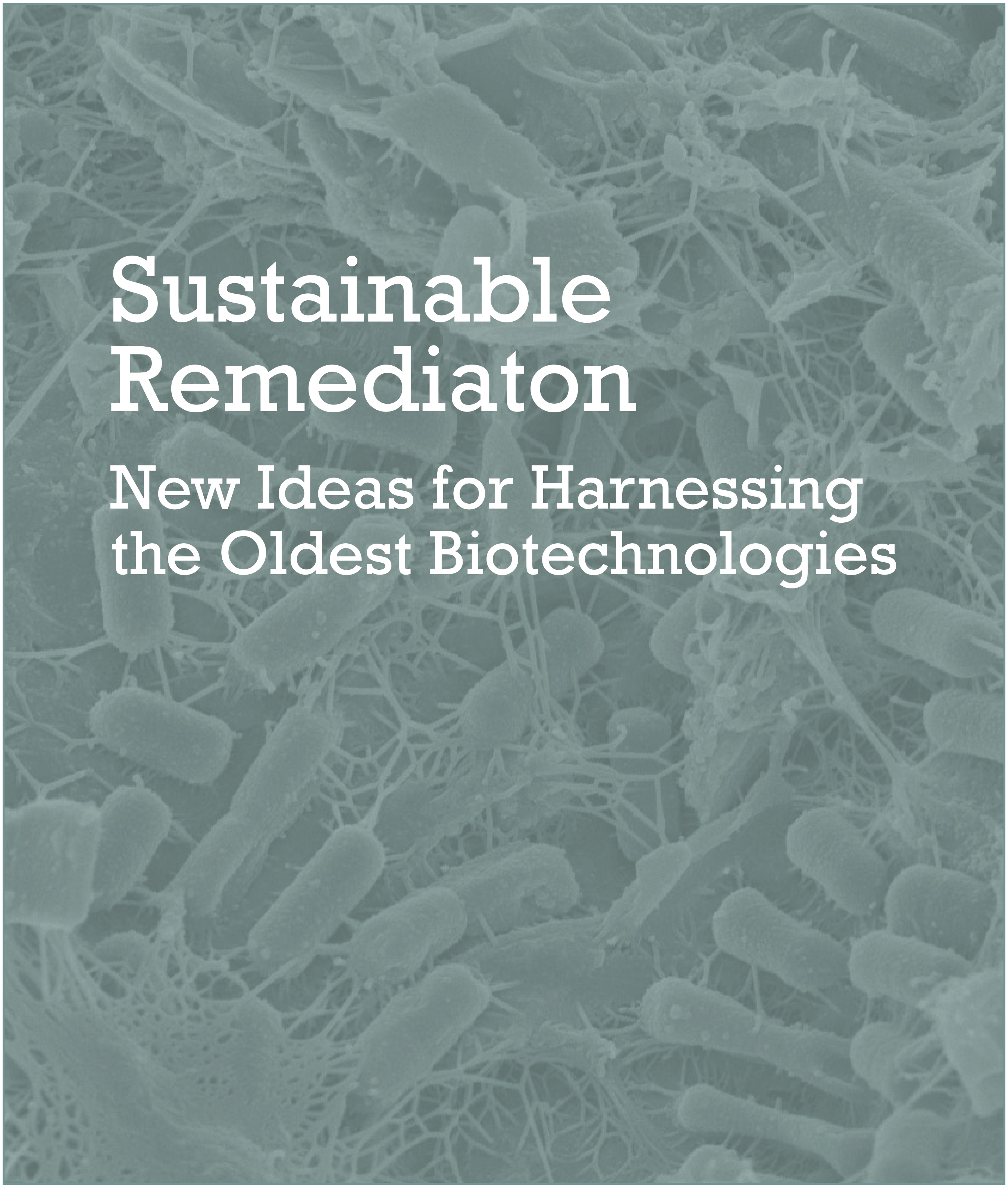

Sustainable Remediaton

New Ideas for Harnessing the Oldest Biotechnologies

Growing Solutions®
INCORPORATED

WHITE PAPER
MAY 2015

Sustainable Remediation:
New Ideas for Harnessing the Oldest Biotechnologies

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EXECUTIVE SUMMARY

Sustainable Remediaton

New Ideas for Harnessing the Oldest Biotechnologies

CHALLENGE

Many of the world's energy and water problems can be solved by capturing the ability of microbial communities to provide sustainable services. The use of microbial agents to achieve remediation is not new. However, the application of a rich and diverse microbial extract, created and applied *in situ*, has not been previously possible on a commercial scale, especially with careful attention to the production of consistent extracts.

For nearly two decades, Growing Solutions, Inc., (GSI) has manufactured its patented technology for the production of a fortified liquid compost extract, a soil amendment with exceptionally high microbial density and species diversity. This extracted solution containing living microorganisms is produced in real time at the site where it is to be used—not desiccated or buffered, stored and shipped.

HISTORY

GSI is building on the history of work done by the environmental remediation community showing that contaminants can be degraded to less or non-toxic compounds by microorganisms, and taking a different, more aggressive approach.

Providing the diversity of organisms to augment and stimulate microbial activity by using on-site resources is at the heart of the service that Growing Solutions now offers. SYNTROPHY™ is at the interface of life science and engineering—an exciting remedial agent not before readily available. A DNA analysis of the SYNTROPHY™ community identified more than 300 distinct types of microorganisms.

LABORATORY RESULTS

This initial phase of testing demonstrates that Growing Solutions SYNTROPHY™ is capable of degrading a wide range of common environmental contaminants.

- Gasoline was reduced by 87% and benzene was reduced by 97% within 17 days. By the end of the 60-day test period, the gasoline concentration was reduced by 94%.
- Motor oil was reduced by 19% within 17 days and 63% at day 60.
- The reduction in soil concentrations for the Benzo-PAHs ranged from 36% to 43% over the 60-day trial.
- The reduction in soil concentrations ranged from 31% for RDX to 93% for 2,4,6-trinitrotoluene over the 60-day trial.
- The reduction in soil concentrations of atrazine and heptachlor was 50% at day 60.

SUSTAINABILITY

Growing Solutions is committed to a sustainable future—our microbiological technology is sustainable, and our regular business practices and techniques are as well.

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ARMENIA FARMS, GUATEMALA

Introduction

Sustainable Remediation, Backed by Nature

In nature, nothing is wasted. As animals sustain themselves by grazing in a field, their resulting waste helps sustain the field for future growth. We now know that it is in great measure the result of microbial activity that has such a significant impact on soil quality. This is what makes the use of compost so prized by organic farmers. Appropriate use of compost and compost derived extracts greatly increases productivity of a large diversity of soil types, leading to increased amounts of organic matter in the soil and enhancing moisture retention qualities, impacts well known to agricultural scientists. The multiplicity and diversity of microorganisms in the biosphere is not without purpose.

Many of the world's energy and water problems can be solved by capturing the ability of microbial communities to provide sustainable services.

For nearly two decades, Growing Solutions, Inc., (GSI) has manufactured its patented technology[1] for the production of a fortified liquid compost extract, a soil amendment with exceptionally high microbial density and species diversity. This extracted solution containing living microorganisms is produced in real time at the site where it is to be used—not desiccated or buffered, stored and shipped.

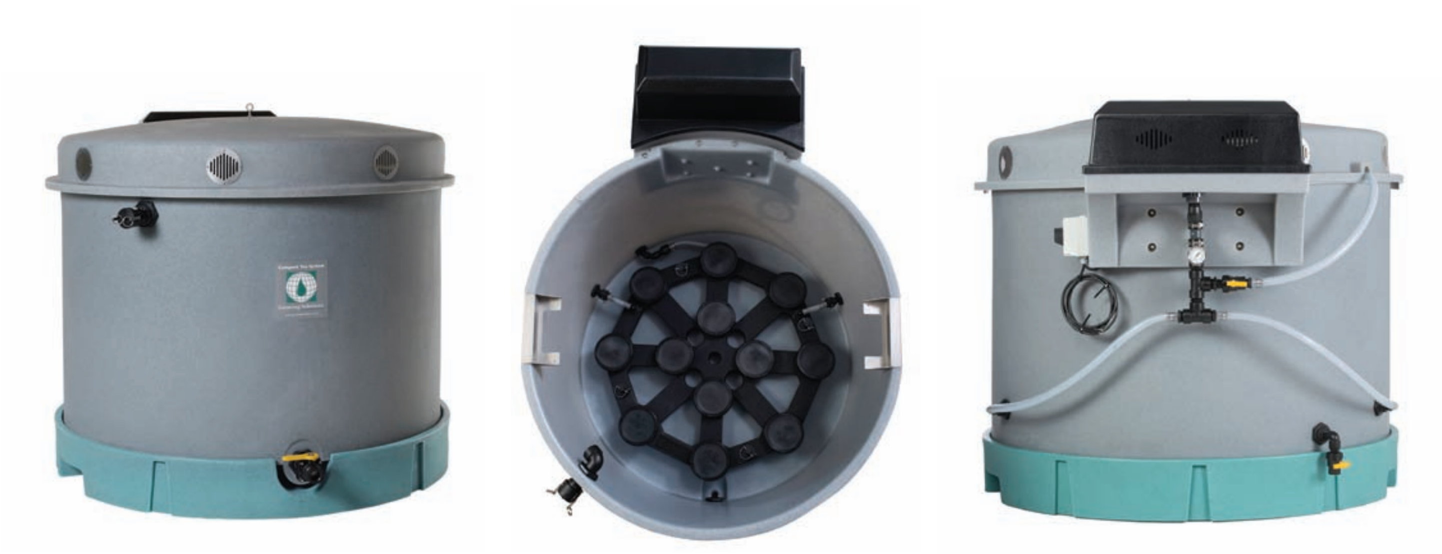
GROWINGSOLUTIONS.COM

Growing Solutions' technology is in use around the world in agriculture, landscape, turf management, horticulture, and vineyard applications. In unsponsored research San Diego State University's Department of Civil and Environmental Engineering undertook a study of the effectiveness of a "compost extract" solution as a remedial agent for BTEX[2], common contaminants at sites that have sustained a petroleum spill or leak, using Growing Solutions' technology. This initial test showed that an extract of organically derived compost is capable of degrading environmental contaminants. GSI has conducted additional independent research demonstrating that our technology is very robust and capable of degrading a wide range of environmental contaminants. Results of the research showing the effectiveness of this fortified microbial extract—Growing Solutions SYNTROPHY™—is presented in this document.

The Search for Solutions

Growing Solutions, Incorporated

The GSI story is about the quest for a sustainable and organic alternative to synthetic agricultural pesticides, herbicides and chemical fertilizers for use by farmers, and vineyard, park, and landscape managers. Michael Alms, CEO and founder, began this journey with a plan to provide equipment for on-site production of compost extracts, then in the early stages of development. GSI's team produced the first commercial Compost Tea System using its patented "fine bubble diffusion" technology to enhance the rapid growth of beneficial microorganisms. GSI currently develops, manufactures and sells these Systems in 37 countries around the world.



GROWING SOLUTIONS SYSTEM500™

Based in Eugene, Oregon, Growing Solutions partners with two production facilities in the Pacific Northwest to manufacture its equipment (made, in large percentage, of recyclable materials). GSI's proprietary microbial nutrient resource—Catalyst—is carefully mixed and packaged by the clients of Pearl Buck Center[3] in Eugene, which offers people with disabilities and their families quality choices and supports to achieve their goals.

Since 1997, GSI has focused on technology solutions for the agriculture, vineyard, horticulture, turf and landscape markets, all linked by two common purposes: **to reduce the use of pesticides, herbicides and chemical fertilizers, and to increase the soil's organic matter to improve moisture retention**. Many high profile clients have benefitted using GSI's technology, including The Presidio Trust, Four Seasons Resort at Hualalai, San Francisco Recreation and Parks, and Martha Stewart.

The use of microbial agents to achieve remediation is not new. However, the application of a rich and diverse microbial extract, created and applied *in situ*, has not been previously possible on a commercial scale, especially with careful attention to the production of consistent extracts. Remediation sites require achievement of specific remedial goals and eventual termination of remedial activities, unlike agricultural farmlands that benefit from continuing seasonal applications. **This fact inspired a new service model approach for GSI, in which a service is provided where and when it is needed for a temporary period, rather than selling equipment and training users.**

SOIL PROFILE/ISTOCK

New Ideas for Harnessing the Oldest Biotechnologies

An Untapped Wealth

The potential of microbial communities to provide essential services to society—such as cleaning up contaminated sites—has been and continues to be discovered and exploited in laboratories and field tests 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.

Many of the world's energy and water problems can be solved by harnessing the abilities of microbial communities to provide sustainable services. In natural geologic environments, microbial communities are an integral part of the production, recovery, distribution, and detoxification of both energy and water.

Why Microorganisms Matter

Why do microorganisms matter? Microorganisms can be thought of as small self-feeding and self-replicating machines that carry out chemical transformations in the process of metabolism[4] (Madigan et al. 1996). Just as humans require water, food and oxygen to sustain life, microorganisms also require food (in the form of organic carbon), energy and a way to respire (breathe). At contaminated sites microorganisms often use contaminants as food and energy sources. Microorganisms have been on the Earth for billions of years, and due to their sheer numbers and diversity, have evolved to be capable of biotransforming a wide range of contaminants.

A single cell microorganism is a complex chemical system. There are five major characteristics that set living cells apart from nonliving chemical systems[5] (Madigan et al. 1996).

1. **Self-feeding or nutrition.** Microorganisms take up chemicals including contaminants from the environment and transform them from one form to another. During these biotransformations there is a release of energy and the elimination of cellular waste products.

2. **Self-replication and growth.** Microorganisms are capable of directing their own existence. As a result of metabolic nutritional processes, microorganisms can grow and replicate.

3. **Differentiation.** Microorganisms can undergo changes in form and function. These changes are usually a direct result of environmental pressures.

4. **Communication.** Microorganisms respond to chemical and physical stimuli in their environment and can interact and communicate with other microorganisms through chemical signaling. Many microorganisms are also capable of movement and respond to various stimuli (e.g. carbon and energy).

5. **Evolution.** Microorganisms are capable of hereditary changes that can influence the overall fitness of the cell.

Elusive Diversity

Each single microbial cell has the aforementioned capabilities. However, in most cases microorganisms do not work to clean up contaminated sites individually, but rather as diverse communities. The diversity of a biological community is a basic concept in ecology, often applied in environmental monitoring[6] (Hosmani, 1987) and conservation management[7] (Bourgeron, 1989). In such systems high diversity usually correlates with ecosystem resistance to ecological stresses such as pollution[8] (Nevo et al. 1986). On the other hand, extreme conditions (temperature, pH, salt concentration) can reduce the diversity of affected communities[9] (Strom, 1985) and a more diverse physical environment often produces a higher community diversity[10] (McArthur et al. 1988). Diversity in microbial communities provides added capabilities for effective microbiotic impacts. Where the historic research was focused on finding the microbial "silver bullet," we now better appreciate that the vast diversity of microorganisms provide for a symbiotic response. **Finding a way to encourage the growth and deliver a virtual galaxy of living organisms on site for remedial purposes has eluded the bioremediation industry.**

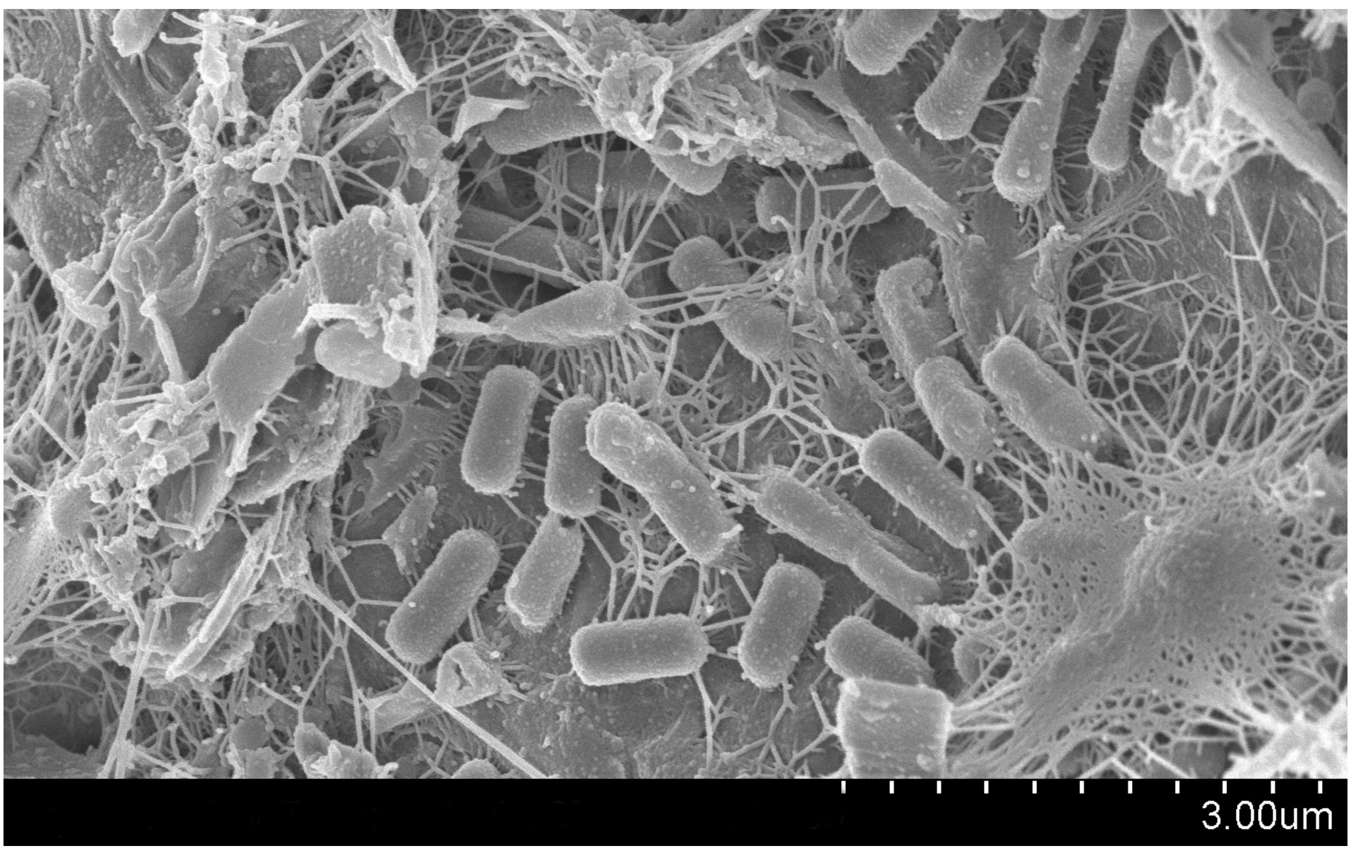


IMAGE COURTESY OF THE LEWIS LAB AT NORTHEASTERN UNIVERSITY.
IMAGECREATED BY ANTHONY D'ONOFRIO, WILLIAM H. FOWLE, ERIC J. STEWART AND KIM LEWIS.

What's On the Menu?

Just like humans, microbial communities need to eat and breathe in order to stay alive. Unlike humans, microbial communities have a much more diverse capacity regarding the types of food (carbon and energy) they can eat and the types of breath (respiration) they can use.

- **Electron Donor (Carbon and Energy).** This is the food "carbon" the microbial community needs for growth and also the energy (via an electron donor) the community needs to survive. Depending on the type of cell, the electron donor can be a range of compounds. In the case of heterotrophic biotransformation, the contaminant molecule may provide the carbon for cell growth and the energy for the cell to survive. In the course of cellular action the contaminant molecule is biotransformed into another daughter compound or completely biodegraded and converted to CO_2.
- **Electron Acceptor.** In order for the microbial community to process the contaminant for carbon and energy and convert it to CO_2, a series of steps are required. Depending upon the particular cellular mechanism that is used, electrons originating from the contaminant are passed via enzymatic pathways through the community and are then discharged to a terminal electron acceptor. The terminal electron receptors that microbial communities can use vary widely and include oxygen, nitrate, manganese (IV), iron (III) and sulfate or may be contaminants like trichloroethylene.
- Besides an electron donor and electron acceptor, the microbial community also needs **nutrients** (trace minerals) to survive and grow.

The sum of the process—carbon plus energy plus nutrients plus an electron acceptor—equals a larger microbial community and the biotransformed products of the original contaminant. **The result of this transformation is the potential microbial mineralization of the contaminants and the production of water and CO2 as by-products.**

Functional Guilds at Work

Bioremediation in the soil or subsurface is catalyzed by different functional guilds of aerobic and anaerobic microorganisms. In aerobic systems (dissolved, vapor phases, and smear zones) contaminant mineralization is coupled via the microbial community to the reduction of oxygen. In the aqueous phase and smear zone, once oxygen is consumed, nitrate reducing guilds capable of contaminant degradation will predominate. As nitrate is depleted, iron and sulfate reducing guilds capable of using contaminants as a carbon and energy source flourish. Finally, fermentative bacteria synthesize hydrolytic enzymes (e.g. amylases, lipases, cellulases, and proteases) that degrade polymers to soluble monomers. The soluble products are then fermented to H_2, CO_2, simple alcohols, and fatty acids. The acetogenic bacterial guild then catalyzes the oxidation of alcohols and fatty acids to H_2, CO_2, and acetate. Lastly, methanogenic Archaea and sulfidogenic bacterial guilds use the H_2, CO_2, and acetate to generate CH_4 and H_2S.

Harnessing Diversity On Site

Biological degradation of contaminants impacting soil and groundwater has been used as a remediation process since the early 1970s. *In situ* biodegradation of contaminants has also been highly documented in peer-reviewed literature and is widely accepted as a remedial option for various contaminated sites. However microbial communities are complex, and harnessing these systems requires both life science and engineering skills. Providing the diversity of organisms to augment and stimulate microbial activity by using on-site resources is at the heart of the service that Growing Solutions now offers. **SYNTROPHY™ is at the interface of life science and engineering— an exciting remedial agent not before readily available.**

Greater Than the Sum

SYNTROPHY™ is produced via a unique technology that amplifies beneficial microorganisms. **A DNA analysis of the SYNTROPHY™ community identified more than 300 distinct types of microorganisms.** Individual microorganisms identified included *Flexibacter spp.*, known to degrade mono and polyaromatic hydrocarbons and also polychlorophenol. Other identified microorganisms included *Pseudomonas spp.*, known hydrocarbon degraders also involved with *in situ* remediation of various metals including chromium and radionuclides. Still other identified microorganisms are associated with PCB contaminated sites and may be involved in PCB dechlorination[11] (Liang et al. 2014).

These are just a sample of the different microorganisms and degradation potential identified within SYNTROPHY™. However the unique application of the product is not necessarily the capacity of the individual microorganisms, but rather the complete microbial community. There are synergies and coordination that arise in biodegradation when there is a diverse and large microbial community present. It is that old adage, the whole is more than the sum of the parts.

Laboratory Data and Analysis

A Different Approach

GSI is building on the history of work done by the environmental remediation community showing that contaminants can be degraded to less or non-toxic compounds by microorganisms, and taking a different, more aggressive approach. Traditionally, either indigenous microorganisms present at a contaminated site are used or a small set of microorganisms are introduced to the subsurface in an effort to treat the unwanted contaminants. Each of these approaches has limitations that GSI is working to improve upon.

Limitations of Traditional Methods of Bioremediation

Indigenous Microorganisms

For small incidental spills of contaminants, indigenous microorganisms are usually sufficient to repair the damage. In these cases the volume of material is not sufficient to migrate and become a health risk or nuisance. If the release is larger, indigenous microorganisms are killed off or weakened by the toxic effects of the contaminant. Over time, the indigenous microorganisms can acclimate, reestablish themselves, and degrade the contaminant. This is a lengthy process that typically ends up degrading contaminants slowly, preventing reuse of properties for years or decades.

Introduced Microorganisms

Microorganisms that are introduced to the subsurface of a site typically arrive in a damaged or weakened state. In addition, only a few species of microorganisms are provided in the mixture. While these microorganisms may be known to degrade certain contaminants, there is generally a limited number of species and population. These introduced microorganisms must compete with the indigenous microorganisms for space and resources, and must increase significantly in population to degrade the contaminants to any meaningful degree. Healthy microbial populations in nature are known to work together cooperatively in order to accomplish the many biochemical processes necessary to survive and sustain themselves. This current approach may be disruptive and in competition with the natural indigenous microorganisms.

Types of Microbial Degraders

The two main types of microorganisms found in soil respire by transferring electrons to oxygen (aerobic degraders) or to other water-soluble compounds such as nitrate or sulfate anions (anaerobic degraders). There is a third type—a facultative microorganism—that can survive and function under either aerobic or anaerobic conditions. Due to the greater energy gain when microorganisms transfer electrons to oxygen, aerobic degraders grow/reproduce faster and as a result degrade contaminants more rapidly. GSI utilizes this basic principal in the production of its fortified microbial extract, SYNTROPHY™. Surprisingly, a significant number of anaerobic degraders make it through the 24-hour aerobic enumeration process and add to the robust diverse nature of the extract.

Improving on Traditional Methods

Microorganisms generally work together to accomplish the tasks necessary to feed themselves and sustain their populations. Growing Solutions SYNTROPHY™ contains a highly diverse population of aerobic, facultative, and anaerobic microorganisms that are delivered to the subsurface in very robust concentrations. Applied to the subsurface, this microbial army is bred to work together to thrive, and is capable of degrading contaminants while simultaneously supporting other beneficial biological processes. The microbial army is made on-site and applied to the subsurface at intervals tailored to site conditions. This process ensures that the greatest number of healthy microorganisms is applied to the impacted soil. Nutritional amendments are also added to the subsurface as needed to maximize the rate of biodegradation of the target contaminants.

Preliminary Results

Laboratory testing has been conducted to evaluate the capability of SYNTROPHY™ to biodegrade four different classes of chemical compounds. The testing covered:

- Petroleum Hydrocarbons (TPH)
- Polynuclear Aromatic Hydrocarbons (PAHs)
- Herbicides and Pesticides
- Explosives

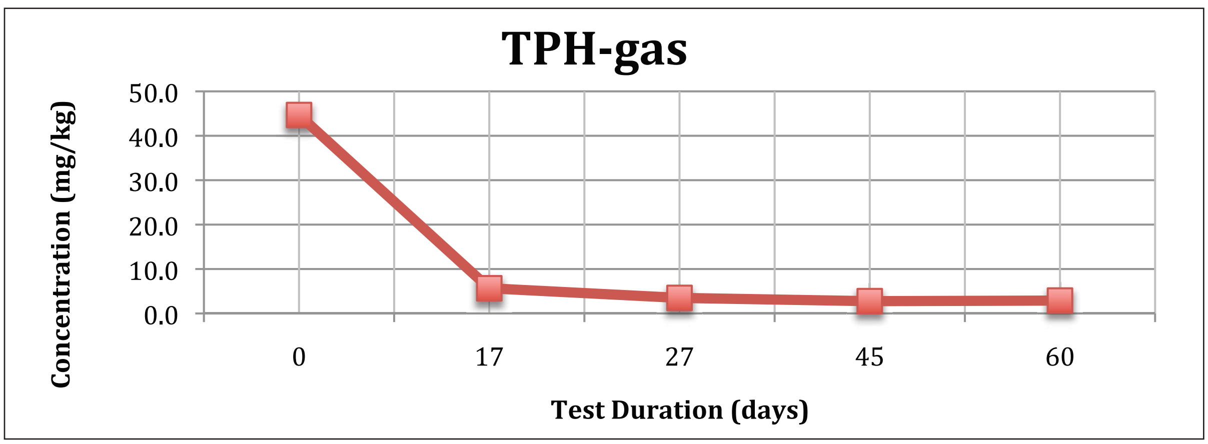
A number of chemicals were tested in each of the four classes of compounds listed above. The testing was conducted in soil microcosms under aerobic conditions using a single application of SYNTROPHY™. No nutritional amendments were added during the testing.

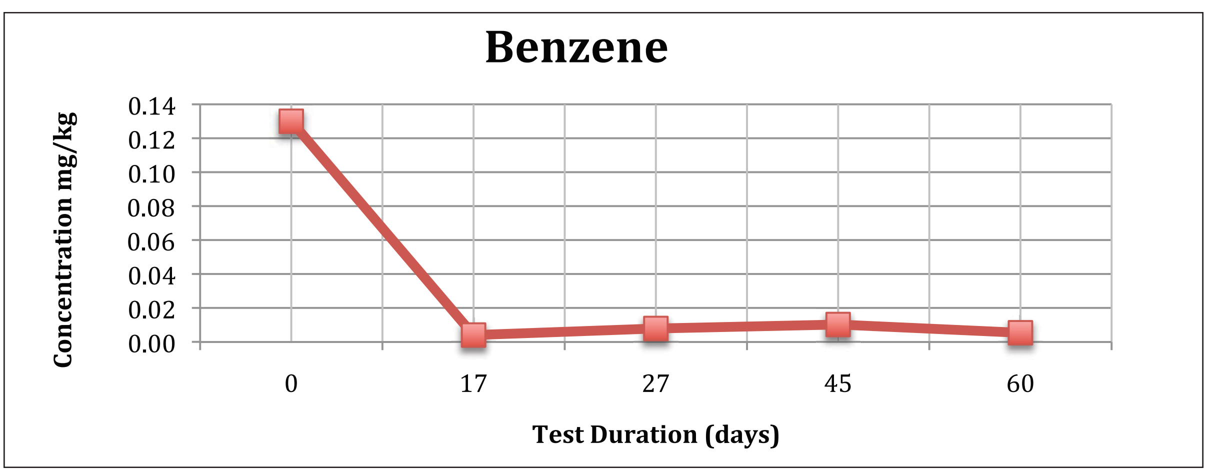
Petroleum Hydrocarbons (TPH)

Degradation effectiveness was tested on gasoline and motor oil. The more toxic components of gasoline were also monitored to determine effectiveness relative to the degradation of benzene, toluene, ethylbenzene, xylenes (BTEX), and MTBE.

Gasoline, BTEX, and MTBE

The graphs below show the reduction in the concentration of gasoline over time. **Gasoline was reduced by 87% and benzene was reduced by 97% within 17 days. By the end of the 60-day test period, the gasoline concentration was reduced by 94%.** Concentrations of the other components were also reduced significantly: toluene 98%, ethylbenzene 98%, xylenes 97%, and MTBE 66%. MTBE's daughter product TBA was not detected at any stage of the testing, indicating that it was degraded to a nontoxic state. These results are significant in that they represent the more toxic and leachable fraction of heavier hydrocarbon mixtures that can threaten groundwater drinking water sources. These compounds would be preferentially degraded at a site impacted with gasoline or mixtures of heavier hydrocarbons significantly reducing the risk posed by contaminant impacts.

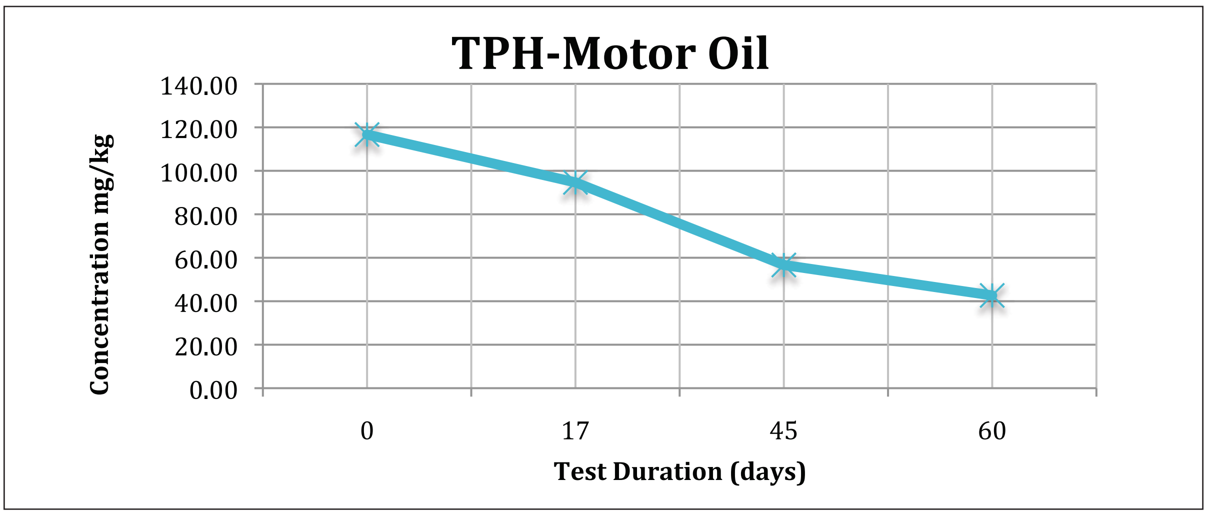




Motor Oil

The graph below shows the concentration reduction for motor oil. **Motor oil was reduced by 19% within 17 days and 63% at day 60.** Motor oil represents a heavier fraction of hydrocarbons impacting environmental sites and is harder to degrade than gasoline due to the predominance of longer chain length hydrocarbons.

These results indicate that hydrocarbon mixtures heavier than motor oil may also be degraded by SYNTROPHY™. The graphs indicate that a single application of SYNTROPHY™ may be sufficient to degrade gasoline and its more toxic components BTEX. Reapplication of SYNTROPHY™ will likely accelerate the degradation rate of motor oil and MTBE. These results also indicate that additional bench testing and/or field trials are necessary to further evaluate the potential use of SYNTROPHY™ in biodegrading hydrocarbon mixtures. GSI will actively pursue potential field trial sites to expand the biodegradation testing of this class of compounds.

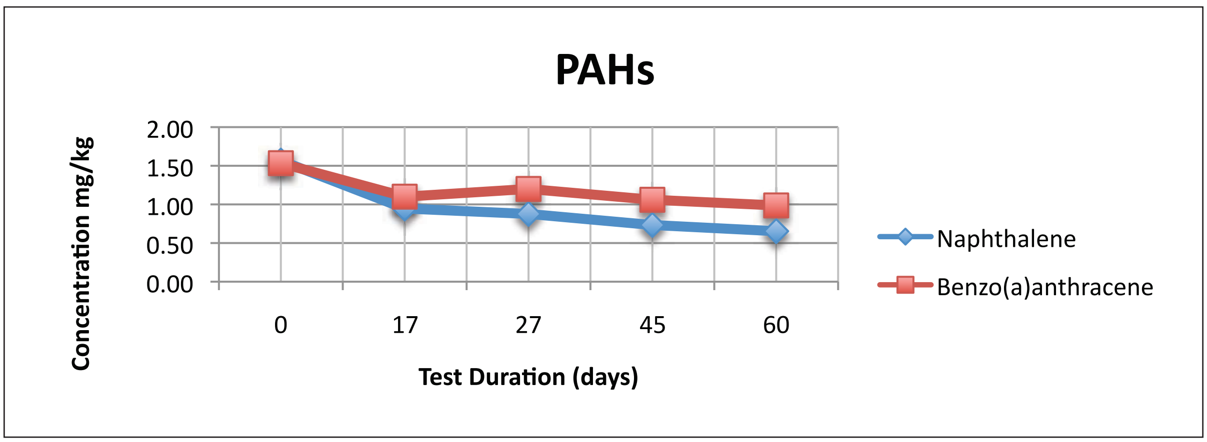


Polynuclear Aromatic Hydrocarbons (PAHs)

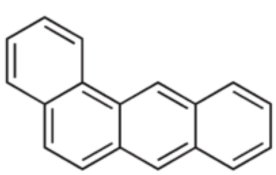
Experience has shown that polynuclear aromatic hydrocarbons (PAHs) are harder to degrade than other hydrocarbons due to their lack of solubility, high molecular stability, and toxicity. Four PAHs were tested:

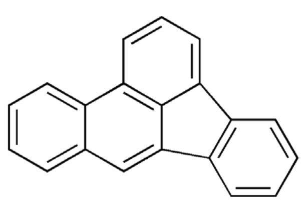
- Benzo(a)anthracene
- Benzo(b)fluoranthene
- Benzo(a)pyrene
- Naphthalene

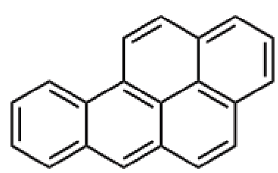
The reduction in soil concentrations for the Benzo-PAHs ranged from 36% to 43% over the 60-day trial. The reduction in soil concentrations for naphthalene was 40% at day 17 and 58% at day 60. The graph below shows the difference in ability of SYNTROPHY™ to reduce soil concentrations of benzo(a)anthracene and naphthalene.

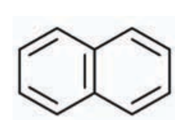


The faster degradation rate for naphthalene can be explained by the fact that naphthalene has a lower molecular weight, is more soluble, and has a relatively lower molecular stability, compared to the Benzo-PAHs. The chemical structures for the PAHs tested are shown below. The structures show the marked difference between naphthalene and the more complex PAHs tested.


Benzo(a)anthracene


Benzo(b)fluoranthene


Benzo(a)pyrene


Naphthalene

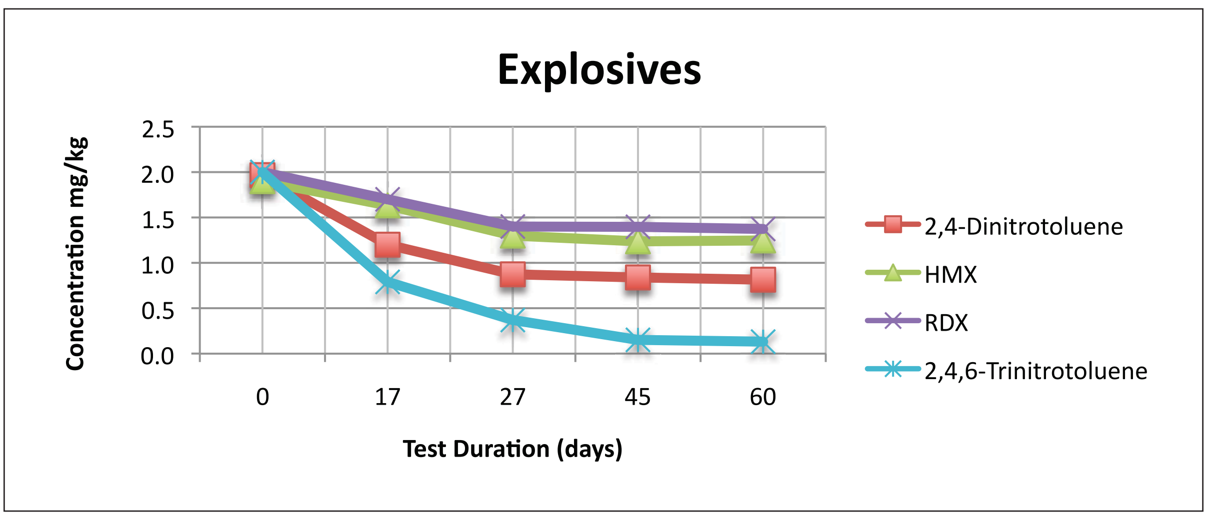
In general these results are significant in that they show SYNTROPHY™ is capable of degrading the more stable and complex compounds present in heavy hydrocarbon mixtures. The results also show that naphthalene would be preferentially degraded. Naphthalene is a risk driver at many environmental release sites. Naphthalene degradation would reduce the effective toxicity for both the leaching to groundwater and indoor vapor intrusion exposure pathways.

Explosives

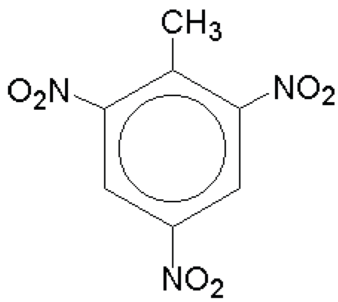
Due to the presence of explosive residues in soil at many military bases and explosives ranges, biodegradation of four common explosives was tested:

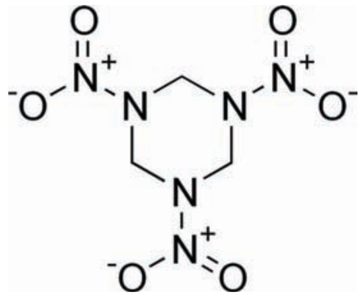
- 2,4-Dinitrotoluene
- 2,4,6-Trinitrotoluene
- RDX
- HMX

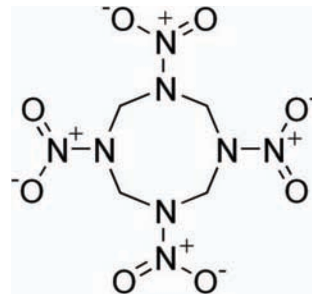
The reduction in soil concentrations ranged from 31% for RDX to 93% for 2,4,6-trinitrotoluene over the 60-day trial. The reductions for 2,4-dinitrotoluene 59% and HMX 34% fell in between those of the other two. The graph below shows the relative reduction rates.



The chemical structures for TNT, RDX, and HMX are shown below.







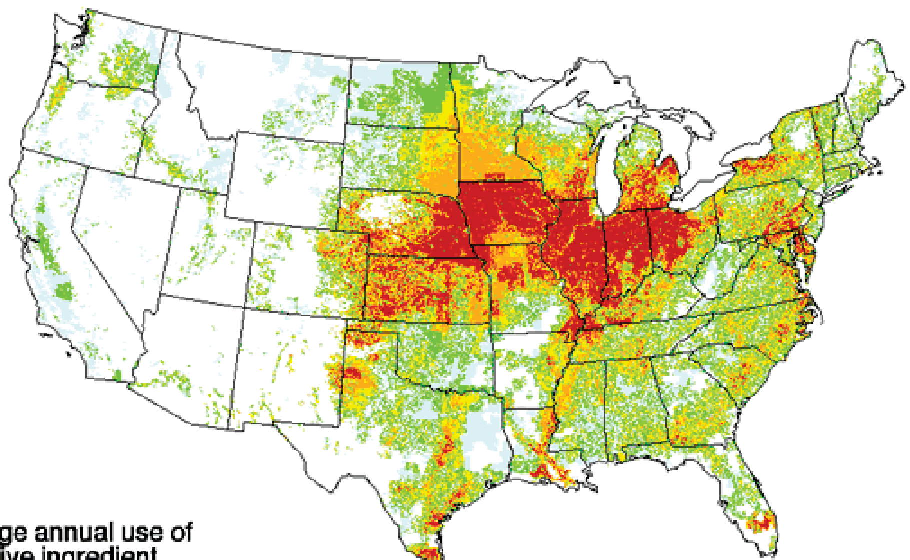
TNT **RDX** **HMX**

The compounds, from left to right, show chemically more complicated structures that are not found in nature. These compounds were developed over time to be safer to handle and store. As a result, the more modern explosives HMX and RDX are more resistant to biodegradation. **The initial results for reduction of these compounds over the 60-day testing period are very encouraging.** The graph indicates that reapplication of SYNTROPHY™ should be done at day 27 where the rate of reduction begins to decrease. GSI will actively pursue possible field trial sites to expand the biodegradation testing of this class of compounds.

It should be noted that the explosives were delivered to the microcosms in a relatively large amount of acetonitrile. This was required to solubilize the explosives so that they could be delivered to the microcosms in a soluble mixture. The biodegradation of acetonitrile was tracked and the concentration was reduced by 70% at day 60. Acetonitrile is a simpler, more easily degradable compound than the explosives. The degradation rate of the explosives may be faster when acetonitrile is not present as would be typical under field conditions.

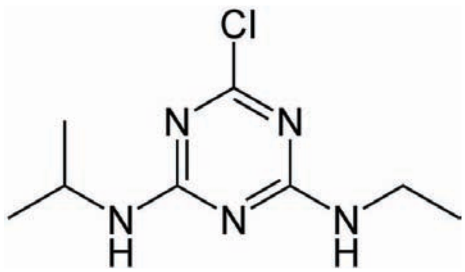
Pesticides and Herbicides

Atrazine and heptachlor have been used extensively as herbicides and pesticides, respectively. The map below shows the widespread use of atrazine in the in the US.

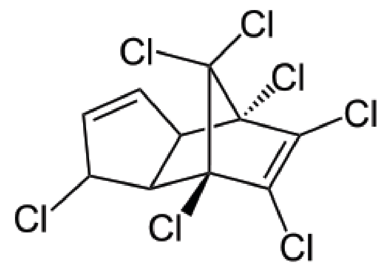


Crops	Total pounds applied	Percent national use
corn	62, 381, 038	84. 00
sorghum	6, 750, 038	9. 09
summer fallow	2, 539, 169	3. 42
sugarcane	2, 203, 421	2. 97
sweet corn	340, 452	0. 46
sod harvested	30, 214	0. 04
other hay	13, 224	0. 02
seed crops	5, 833	0. 01

Due to the widespread nature of the unwanted environmental impacts of these compounds, the effectiveness of SYNTROPHY™ to biodegrade them was tested.

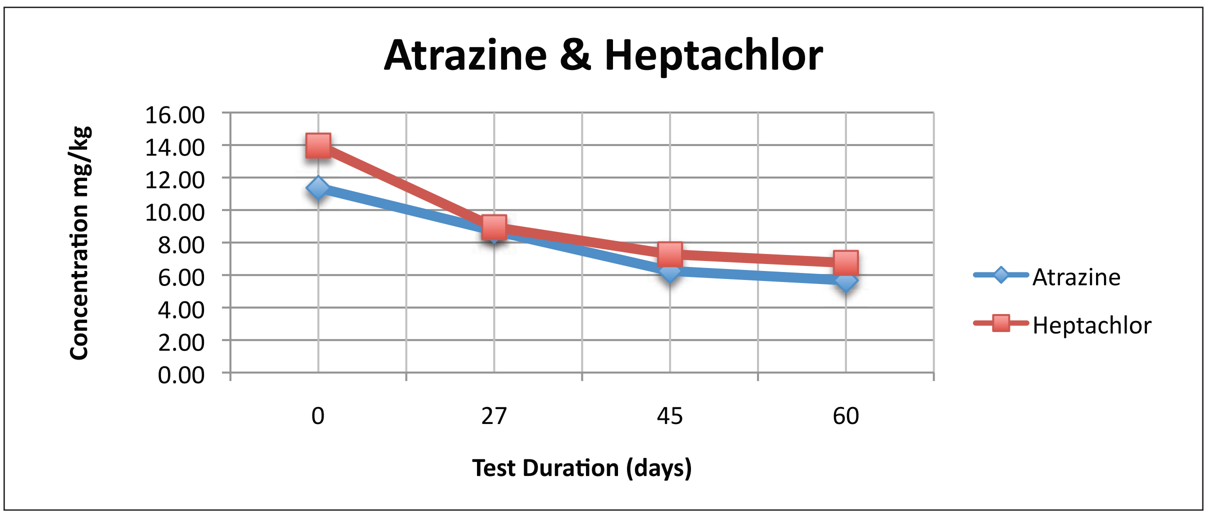


Atrazine



Heptachlor

The reduction in soil concentrations of each compound was 50% at day 60.
The initial results for reduction of these compounds over the 60-day testing period are very encouraging because these compounds are made to kill plants and insects. The graph [below] indicates that reapplication of SYNTROPHY™ should be done at day 45 where the rate of reduction begins to decrease. GSI will actively pursue possible field trial sites to expand the biodegradation testing of this class of compounds.



Conclusion

This initial phase of testing demonstrates that Growing Solutions SYNTROPHY™ is capable of degrading a wide range of common environmental contaminants. The rate and amount of reduction achieved was good, with only a single application of SYNTROPHY™ and no additional nutritional amendments. GSI is actively pursuing possible field trial sites to expand the biodegradation testing of SYNTROPHY™ for the various classes of compounds tested.

Sustainability, Survivability, and Success

There are untold numbers of microbial species that do not survive in the production laboratory environment. Of those that can, many cannot survive the process of desiccation or being freeze-dried for packaging and shipment. SYNTROPHY™ does not suffer from these constraints, resulting in a vastly more robust delivery system of a much broader galaxy of species, ready to apply at the optimum time for the effectiveness of the extract. Because we rely on carefully controlled feedstocks for our production source, we are able to recycle organic matter and harness its power to convert a variety of sometimes harmful or toxic substances into CO_2 and water.

Decades of experience in the world of agricultural soil amendments based on similar microbial extracts illustrates that there is a primary effect with each application (whether for remedial purpose or soil enhancement), and highly valuable secondary effects as well. For example, application of SYNTROPHY™ results in an increase of the organic matter present in the soil column, which in turn, has a significant impact on moisture retention properties in the soil. This has an impact on SYNTROPHY™ users who seek production qualities from the soil, and an impact on the remedial properties as well.

Growing Solutions is committed to a sustainable future—our microbiological technology is sustainable, and our regular business practices and techniques are as well. Components in our SYNTROPHY™ Systems are selected for sustainability, whether in recyclable content or performance longevity:

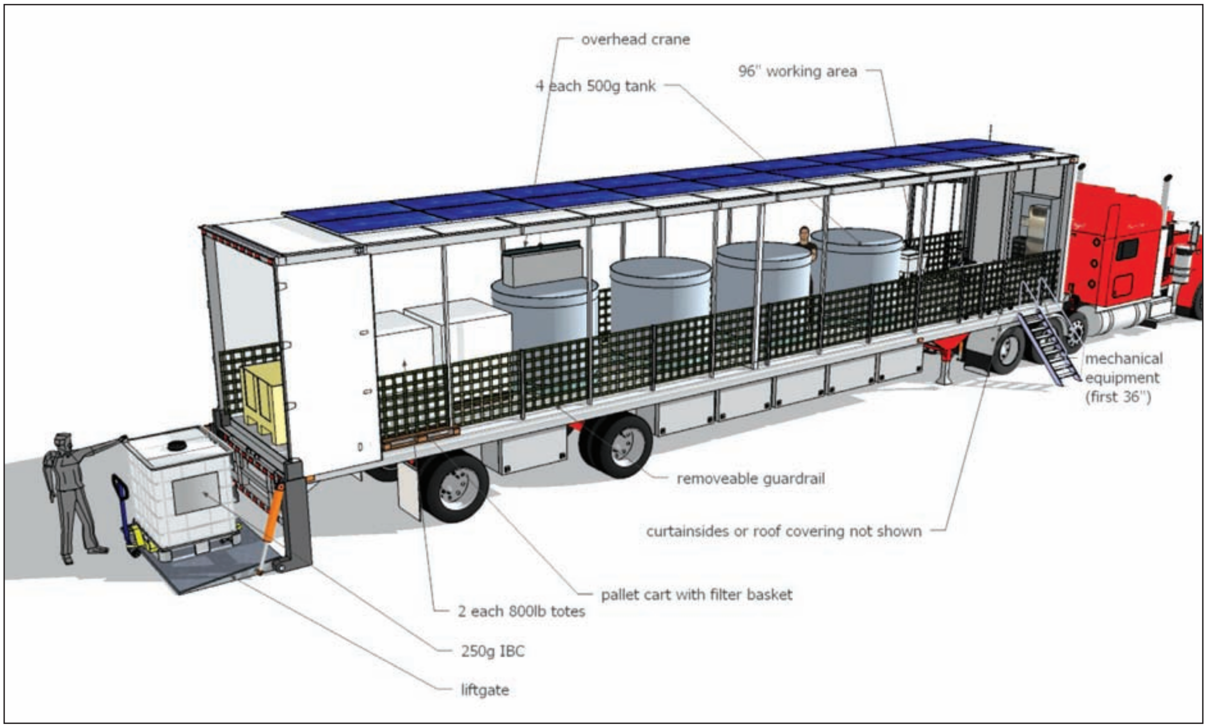
- Engineered HDPE (high density polyethylene) rotational molded tanks, bases and shelving are UV stabilized and 100% recyclable.
- Engineered ABS (acrylonitrile butadiene styrene) vacuum molded components are manufactured of 50% recycled material, and are 100% recyclable.
- Stainless steel and brass fasteners ensure performance longevity, resulting in a greater lifespan and preventing unnecessary accelerated waste.

GSI technology efficiently converts compost into SYNTROPHY™, a liquid high value added product. The compost is sourced from a former waste stream product in the form of manure, and converted into compost.

- Three cubic feet of compost covers an area of 12.0’ x 12.0’ x 0.25’ thick.
- Three cubic feet of compost converted into SYNTROPHY™ via GSI technology covers 20 acres.

Our SYNTROPHY™ Systems are very energy efficient. The System500 uses the equivalent of seven lightbulbs (1 lightbulb = 65 watts) of energy in a 24 hour cycle.

We continue to incorporate these decades-proven practices and strive to achieve greater sustainability as we bring the SYNTROPHY™ on-site delivery system online.



Growing Solutions SYNTROPHY™ Mobile Production Facility is built onto a 45' long trailer, containing four 500-gallon Growing Solutions SYNTROPHY™ Systems capable of producing 2,000 gallon per day.

The trailer utilizes three options for energy: grid tie in, back up generator, and state-of-the-art flexible PV solar array attached to the roof of the trailer, upholding our values for energy efficiency while remaining versatile to all location parameters.

Equipped with lift gate for easy loading and unloading of product, OSHA-approved guardrails for maximum safety and visibility the SYNTROPHY™ Mobile Production Facility is a combination of safety, efficiency, and capacity to meet all site conditions.

Growing Solutions' commitment to sustainable practices includes policies to ensure that our use of leased truck tractors is consistent with the best available technology. We require trucks to comply with US EPA's 2007+ On-Road Heavy Duty Vehicle emission standards of 0.01 g/bhp-hr of PM. This HDV standard is a requirement that cannot be waived but for emergency circumstances. We require our equipment to be run on Ultra-Low Sulfur Diesel (ULSD) and we will phase in a requirement for HDVs with On-Board Diagnostics that monitor almost every emission related component as that regulation is fully implemented by state and federal air control agencies.

References

[1] Growing Solutions was issued U.S. Patent No. 6,649,405 on November 18, 2003, for its Compost Tea Systems. The patent covers Growing Solutions' innovative System design that features Fine Bubble Diffusion technology. Below is the official abstract: "A compost tea system uses a water-holding tank for containing process water. Compost is immersed into the water in the tank in baskets defining a filter media. Air is pumped into membrane disk diffuser modules in the tank and the liquid is sparged with fine bubbles to thoroughly agitate the liquid, extract nutrients and microorganisms from the compost, and to ensure a high concentration of dissolved oxygen in the liquid. The high level of oxygen selects for desired aerobic organisms to produce a rich compost tea. The finished tea is drained out of the tank and the tank and its components are easily cleaned and sanitized." http://www.google.com/patents/US6649405

[2] Büyüksömnez, Fatih, Ph.D, P.E. (2012) Use of Compost Tea for Biodegradation and Bioremediation

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[8] Strom, P.F. (1985) Effect of temperature on bacterial species diversity in thermophilic solid-waste composting. Appl. Environ. Microbiol. 50, 899-905.

[9] McArthur, J.V., Kovacic, D.A. and Smith, M.H. (1988) Genetic diversity in natural populations of a soil bacterium across a landscape gradient. Proc. Natl. Acad. Sci. 85, 9621-9624.

[10] Madigan, M.T., J.M. Martinko and J. Parker. 1997. Brock Biology of Microorganisms. *Simon and Schuster*, New Jersey.

[11] Liang Y, Martinez A, Hornbuckle KC, Mattes TE. Potential for Polychlorinated Biphenyl Biodegradation in Sediments from Indiana Harbor and Ship Canal. Int Biodeterior Biodegradation. 2014 Apr 1;89:50-57.

Michael Alms
Founder and CEO

Growing Solutions Incorporated founder and CEO Michael Alms came to Oregon in 1996, selling greenhouse systems for Teufel Nursery. One of his accounts, Karl Rubenerger of Umpqua Organic Farm in Roseburg, had created a prototype system that produced an aerated microbial solution from compost to use as an organic foliar spray on his Asian Pear trees. Alms negotiated an arrangement with Rubenberger, honed the design, and developed a manufacturing process and distribution network that formed the basis of Growing Solutions as a business. Production of the 50-gallon MicrobBrewer™, the first commercial Compost Tea system, began in 1999.

In 2000, Alms made substantial design modifications in order to streamline production and enhance performance of the systems. The first of the newly designed systems was the 25-gallon Compost Tea System25™, followed by the 100-gallon Compost Tea System100™, and the 500-gallon Compost Tea System500™. United States Patent No. 6,649,405 Compost Tea System was issued in 2003.

The Compost Tea System10™, a 10-gallon unit intended primarily for homeowners, was introduced in 2005. Alms lead the team developing the first commercial microbial food source to ensure that the extracted microorganisms would flourish—Growing Solutions' Compost Tea Catalyst™. It is OMRI-listed and suitable for use in certified organic operations.

In 2003, he co-developed the compost tea program for the San Francisco Recreation and Parks District. More recently, he co-authored "Compost Tea Use in Tropical Environments" manual, a publication of the University of Hawaii. He has served on the Hawaii Organic Farmers Association board of directors, founded the Compost Tea Industry Association and is a current member of the US Composting Council.

With an international presence in more than 30 countries, Alms leads the Growing Solutions sales force and research and development team as the company's technology continues to benefit new market sectors worldwide.

Douglas Oram, PhD
Senior Scientist

Dr. Douglas Oram joined Growing Solutions as Senior Scientist in July 2014. With his extensive work in soil remediation, Dr. Oram is developing integrated biological management systems for agriculture and bioremediation. Dr. Oram concurrently is a consultant for ETIC Engineering. He has more than 20 years of experience in the design, implementation, and evaluation of remedial engineering projects and subsurface investigations, two years of experience in analytical chemistry, and six years of experience in synthetic chemistry and process development. He is the author of more than 30 technical publications and co-author of Selection of Representative TPH Fractions Based on Fate and Transport Considerations.

He is co-author of an MTBE and TBA Natural Attenuation Demonstration Guidance Manual developed from a basin-wide evaluation of MTBE and TBA impacted sites in Orange County, California. Dr. Oram is also co-author of the Total Petroleum Hydrocarbon Criteria Working Group Series, Volume 3 article titled "Selection of Representative TPH Fractions Based on Fate and Transport Considerations."

Dr. Oram has prepared or directed the design and implementation of soil, sediment, and groundwater remedial actions at more than 100 sites located in Alaska, California, North Carolina, and New York. Remedial designs have covered all common technologies and a number of newer or innovative *in situ* oxidation and reduction technologies. He received his doctorate in Organometallic Chemistry in 1989 and his Bachelor of Science in Chemistry in 1983, both from the University of California, Davis.

Aaron Peacock
PhD, Consultant

Dr. Aaron Peacock is an environmental scientist with Pace Analytical Energy Services. With 19 years of experience in academia, government and industry, he is an expert in bioremediation and Environmental Molecular Diagnostics (EMDs). Similar to how new personalized medicine techniques are being applied to managing health, Dr. Peacock leverages genetic and isotopic tests to help clean up environmentally contaminated sites.

Working with Fortune 1000 organizations and government entities, Dr. Peacock develops, evaluates, and implements new technologies for environmental surveillance, monitored natural attenuation (MNA), and enhanced bioremediation of soils, sediments, water and air. He also develops and uses sensors and EMDs to evaluate sites for *in situ* bioremediation/ MNA potential and remediation program performance. Additionally, Dr. Peacock is brought in to conduct forensic tests to help determine the source of contaminants.

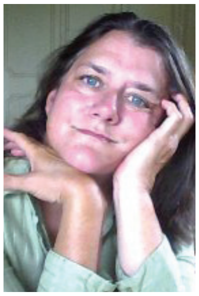
Dr. Peacock is a frequent publisher and speaker on topics related to bioremediation and EMDs. He has conducted research for the Department of Energy's (DOE) Subsurface Biogeochemical Research (SBR) Program, the U.S. Department of Agriculture and the Strategic Environmental Research and Development Program (DOD, EPA and DOE).

Richard G. Opper
Chief Counsel

Richard G. Opper has been a lawyer since 1976, and for the past 25 years has focused his work in the area of brownfield redevelopment. Getting contaminated properties cleaned and reused has been the subject of much of his writing and scholarship. He is a founding partner of the law firm of Opper & Varco LLP, in San Diego, California. Prior to starting this firm he was a partner in some nationally prominent firms, where he headed those firm's environmental practice groups on the west coast. Before entering private practice, Opper served as the Attorney General for the Territory of Guam (1983–1986), where he represented Guam EPA, among other agencies, in civil and criminal environmental enforcement matters.

Opper served as the strategic planner for environmental issues at Petco Park, a major league baseball park in San Diego which ultimately became a billion dollar project, and later served as trial counsel and appellate counsel defending novel applications of California law to assist in the cleanup and reuse process used for the project. Opper received his undergraduate degree from the University of California, Santa Cruz, his law degree from the University of California, Los Angeles (in 1976), and a Master's in Public Administration from the Kennedy School at Harvard University.

Cindy Salter
Associate Scientist
Regulatory Compliance Specialist



Cindy Salter has been professionally involved in the environmental, solid waste, composting, compost tea, and sustainable agriculture industries since 1982. She has worked for public, private and nonprofit entities. Salter is an Associate Scientist and Regulatory Compliance Specialist with Growing Solutions Incorporated. She holds a Bachelor of Science in Agronomy from Texas A&M University and has lived in Texas, North Carolina, and Oregon. She was one of the founders of the state composting association in North Carolina and has held board seats with Carolina Farm Stewardship Association, Composting Council of Oregon, Oregon Tilth, Compost Tea Industry Association, and the School Garden Project of Lane County, Oregon.

August York
Technical Support
Field Services

August York comes with a background in sustainable agriculture and a BA degree in Ecological Design and Ecology from Prescott College. The only son of the late Alan York, world-renowned Biodynamic farm consultant, August grew up surrounded by innovative thinking and creative problem solving.

During his time at Prescott, August attended Ecosa Regenerative Design program, immersing himself in ecological design foundations, urban renewal theory, and architectural practicum. At Prescott College he studied ecology and systems thinking, and helped found the Butte Creek Restoration Council, part of a community stewardship and riparian restoration project. In 2012 he served as the student representative on the Prescott College Master Planning Committee, and was a leading Ecosa design student on the town of Sedona's 2020 Master Planning Committee.

In the spring of 2013 August went to work for 22 months as the lead Compost Coordinator and Orchard Assistant at Apricot Lane Farms, a leading Biodynamic farm in sustainable agricultural practices and holistic grazing. There August was in charge of producing 1,800 liters of compost tea per day, six days per week using two of Growing Solutions 500 gallon Compost Tea Systems and Compost Tea Catalyst. He gained extensive hands-on experience with Growing Solutions equipment, as well as practical application and efficacy of compost tea use. August also managed the farm's commercial size vermicomposting reactor, and large scale windrow compost production.

August joined Growing Solutions in January of 2015 and is currently serving as Project Lead and co-designer of Growing Solutions Mobile Production Facility. August assists Michael Alms in design and technical support and provides field services for procedure, application, and testing for agricultural clients.

Growing Solutions INCORPORATED

MATERIAL SAFETY DATA SHEET

SECTION 1	**Identification**
Manufacturer's name	Growing Solutions, Incorporated
Emergency telephone number	541-343-8727
Address	1702 W. 2nd Avenue, Suite B, Eugene, OR 97402
Chemical name	Microbial inoculant for bioremediation
Trade name	SYNTROPHY™
Microbial formulation	Naturally occurring microorganisms derived from compost

SECTION 2	**Hazardous ingredients**
Principal hazardous components	Contains no hazardous substances

SECTION 3	**Physical data**
Boiling point (°F)	212°F
Specific gravity	1
Vapor density (Air = 1.0)	N/A
Percent volatile by volume (%)	N/A
Evaporation rate	N/A
Solubility in water	N/A
Appearance and odor	Dark brown liquid/pleasant earthy odor

SECTION 4	**Fire and explosion hazard data**
Flash point (method used)	N/A
Flammable limits	N/A
Extinguishing media	N/A
Special fire fighting procedures	N/A
Unusual fire and explosion hazard	None

SECTION 5	**Health hazard data**
Toxicology	Chronic fathead minnow test: survival LC50>100 mg/L; growth IC50>100 mg/L
Special notes	Not for human and animal consumption
Emergency first aid procedures	Eye contact: Rinse in eye wash for 15 minutes Skin contact: Rinse with soap and water Inhalation: N/A Ingestion: Seek medical attention

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MATERIAL SAFETY DATA SHEET

SECTION 6	Reactivity data
Stability	Stable
Incompatibility (material to avoid)	None
Hazardous decomposition products	None
Hazardous polymerization	None

SECTION 7	Spill or leak procedures
Steps to be taken in case material is released or spilled	No hazard. Wash away with plenty of water.
Waste disposal method	Apply to any outside soil area

SECTION 8	Special handling and protection information
General precautions	Try to avoid splashing of product in eyes or on skin
Respiratory protection	Not necessary
Ventilation	Not necessary
Eye protection	Wear eye protection to avoid splash in eyes
Special precautions	Not necessary

SECTION 9	Additional information
Version	March 2015

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