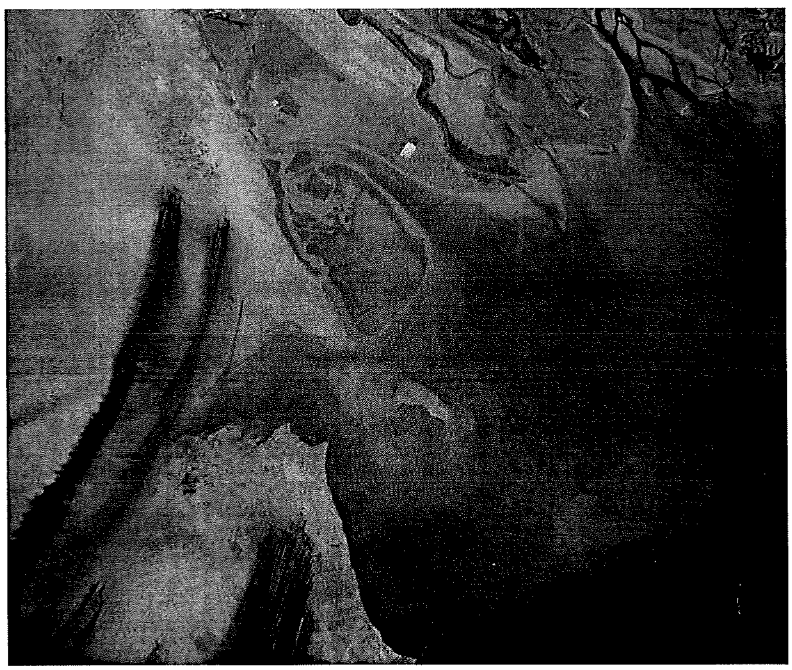
U.S. Ag Industrial

Microbial Remediation

A History & Microbiology Studies

U.S. Ag Industrial's microbial bioremediation compound is a product of current microbiology, specifically designed for use in environmental bioremediation and soil revitalization.

A History - The 1991 Gulf Oil Spill

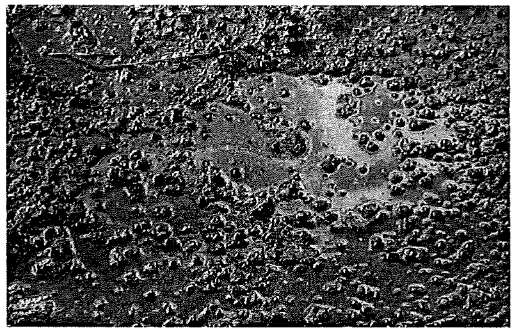


Many petroleum spills occur in open waters and on the surface of the land where there is an abundant supply of oxygen. On January 19, 1990, the world witnessed the single largest, deliberate oil spill ever seen. That day in January, Iraqi troops spilled 500,000 tons of Kuwaiti crude oil into the Persian Gulf. The act of biological warfare led to forecasts of doom for Kuwait's future, and the world watched as oil slicks the size of small nations spread over the waters of the Gulf, contaminating coastlines along the Saudi Arabian shore.

However, instead of annihilation of all life in the polluted area as predicted, scientists discovered millions of organisms thriving - microorganisms growing in blue-green mats within the seas of crude oil. This consortium of microorganisms was made up of naturally occurring blue-green bacteria, which associated with millions of other marine microbes to begin the first critical steps of recovery from the environmental war crime in the Persian Gulf.

It was this mixture of several types of microbes (a consortium) that enabled others of the group to initiate the first steps of the clean-up process. At the outset, the blue-green bacteria (cyanobacteria) provided needed nutrients and a safe haven within their microbial mat for the other microbes to live and work in breaking down the crude oil. In return, the cyanobacteria benefited by having hydrocarbons broken down into a ready supply of nutrients for their own use. With many microbial types working together, the task of finding another meal was done more quickly and efficiently.

A similar consortium such as this is what makes up the microbial package found in U.S. Ag Industrial's **TerraMax.**

Toxic Compounds Degraded – A General & Scientific Overview

Upon the reintroduction of these hand-picked microbes into natural environments like water or soil, they are able to use any contaminants as a food source: even contaminants such as diesel fuel and other petroleum products. Man has been adding foreign chemicals to the soil for many years, substances such as solvents, pesticides, herbicides, and other compounds. In the early 1960s, it was discovered that members of the Pseudomonas group of microbes were primary degraders of chemicals in the soil and water. There are many such species in U.S. Ag Industrial's microbial blend, which can degrade troublesome chemical mixtures. Some of the toxic compounds degraded by our product are as follows:

A. BTX is an aromatic compound consisting of benzene, toluene,and xylene. BTX aromatics are found in diesel fuel, gasoline, and jet fuel, and they are used by certain microbes as sources of food and energy. **TerraMax** contains these microbes. As the fuel is broken down into smaller, simpler byproducts by one set of microbes, other microbes in **TerraMax** are then able to complete the work of breaking it down completely to carbon dioxide and water in a process known as mineralization.

B. Heterocyclic organic compounds (oil, diesel, pesticides, herbicides) are broken down by microorganisms at the surface level where there is an ample supply of oxygen. The microbes degrade petroleum products particularly well where there is a ready supply of oxygen, which is required for the breakdown process. However, microorganisms in deep soil do not work as quickly as their aerobic counterparts. The degradation process by microbes in petroleum-contaminated soils deep beneath the surface becomes more difficult, but it is still possible. To speed up such degradation, the addition of microorganisms and certain fertilizers is needed. The rate of degradation depends upon soil type, pH, temperature, and by the type of contaminant being degraded. Anaerobic microbes also degrade heterocyclic compounds, but the time scale must be extended.

C. Recalcitrant chemical compounds such as polychlorinated biphenyls (PCBs), poly [ADP-riboses] (PARs), and other halogenated compounds have been shown to be biodegradable as well, but the beginning of the breakdown process is accomplished without air. It is under anaerobic conditions that these microorganisms begin dechlorinating the PCBs. Under aerobic conditions, they degrade other parts of the PCB molecule using a different process. Some pesticides and herbicides are also oxidized in microbial biochemical processes.

Required Factors for Bioremediation

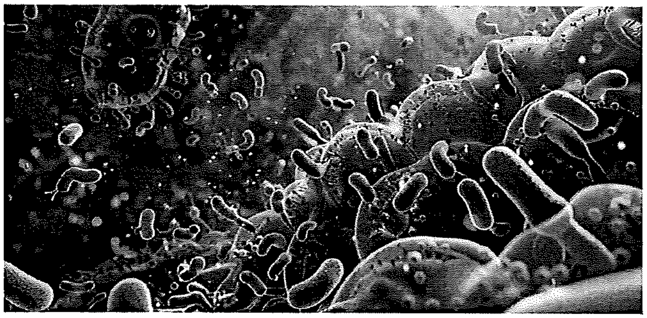
Two components are needed for the successful biodegradation of contaminants in water or soil, namely the right microbes and a favorable environment. The bacteria requirements for the breakdown of toxins on-site are as follows:

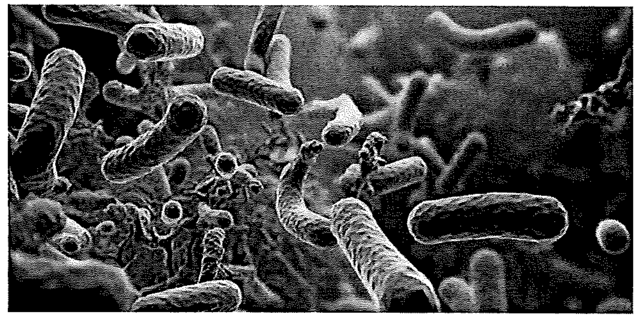
1. Some microorganisms in the mixture must have the ability to degrade contaminants that are present.
2. Microbial blend must have the ability to be grown and stored prior to use with a long shelf life.
3. Microorganisms must be able to survive and function in the environment in which they will be introduced.

4. Microorganisms must have the ability to grow from small inoculum levels.
5. The microorganisms themselves should produce no toxic effects on the environment.
   a. Some microbes may have the ability to fix nitrogen levels, which is an additional benefit.

Conditions of the environment, which must also be met, include:

1. A food source (preferably the contaminant of choice) and/or other supplemental nutrients (nitrogen, phosphorus, potassium, iron, and vitamins) must be available in the same physical location as the microbes.
2. Chemicals and compounds that are toxic to the microorganisms must be absent from the site or readily degradable by some microbes in the mix (i.e. heavy metals inhibit growth of many, but not all, microbes).
3. Appropriate levels of oxygen must be maintained, whether oxygen is required for the degradative process to occur (as in petroleum breakdown), or if the requirement is no oxygen as in the first steps of PCB degradation.





Soil Profile for Microbial Growth & Fertilizer Benefits for Remediation

The differences in soil types are varied and many. Thus, it is impossible to characterize levels at which microbes and other microorganisms flourish or flounder. Since there are major chemical and physical differences between soils in different climatic areas, the microbial populations also vary accordingly. However, in a "healthy" soil, there may be from 106 to 109 microbes per gram in each soil sample: higher populations than microbial numbers found in fresh water or the ocean. A lot also depends on plant growth, as there are much higher numbers of microbes found in association with plant roots and the organically rich surface layer of soil than in the underlying mineral layers of soil and above the bedrock. Relative percentages of aerobic and facultative bacteria commonly found in soil are as follows:

***Asterisks denote the organisms found in TerraMax**

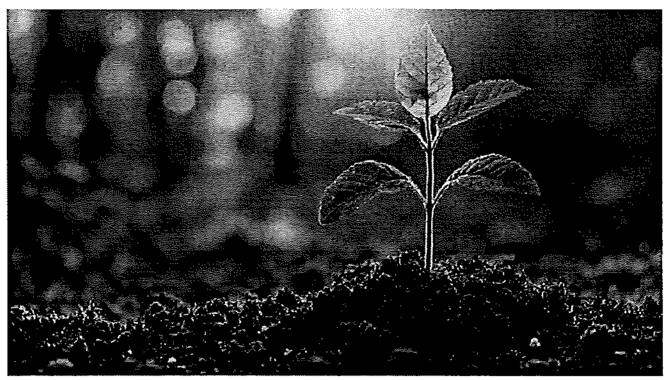
Genus	Percentage
Arthrobacter*	5-60
Bacillus*	7-67
Actinomycetes*	10-33
Pseudomonas*	3-15
Agrobacterium	1-20
Alcaligenes*	2-12
Flavobacterium*	2-10
Corynebacterium*	<5
Micrococcus*	<5
Xanthomonas	<5
Mycobacterium	<5

Earth texture is another crucial factor in the colonization of microbes in the soil. Whether sand, silt, clay, or any combination, the ability of the microorganisms to adhere to the surface of those soil particles is an important consideration in the upkeep of the microbial population. Soils have within them many microhabitats with differing physical and chemical properties, which enable growth of different microbial populations.

In a typical healthy soil environment, many different microorganisms may be found. However, in abused soils which have been tilled (tillage increases the loss of humus, soil compaction, and topsoil erosion) and with chemicals applied as fungicides, herbicides, insecticides, and high-salt fertilizers, the resident microbial populations can be negatively affected. Augmenting the soil's depleted microbial population with additional microorganisms has been practiced in agriculture for several decades. The addition of nutrients and soil amending conditioners, along with microbes, may be desirable, even necessary. Reasons to use microbes plus nutrients (i.e. humic acid or trace minerals) are as follows:

1. To supply nutrients to crops.
2. To stimulate plant growth due to production of plant growth hormones by microbes.
3. To work as an antagonist to inhibit growth of plant pathogens.
4. To improve soil structure.
5. To promote mineralization of organic pollutants.
6. To promote microbial breakdown of inorganic substances.

Upon the application of **TerraMax,** our microorganisms will go to work with nitrogen-rich fertilizers, promoting the proper breakdown of ammonium salt while freeing ammonia or urea found in the fertilizer, helping avoid the loss of nitrates through leaching and denitrification and thus preventing the waste of expensive fertilizer and the risk of groundwater contamination. Hardier plants are one result of proper nitrate breakdown by **TerraMax** microbes, which in turn helps increase crop yield and prevents damaging run-off to nearby streams and ponds.



Compaction & Hardpan Ripping vs. Microbial Soil Amending

In independent studies, after the application of **TerraMax** into highly compacted soil, the soil hardpan layer caused by compaction and repeated application of nitrogenous fertilizers was significantly reduced.

Compaction is caused by the destruction of soil structure, which causes the soil aggregates to bind to each other and form a hard layer of soil and chemicals (hardpan). This binding of soil particles seals the pores, causing them to shed water; they are deficient in oxygen and have reduced water-holding capacity. The water and plant nutrients in compacted soil are tightly bound to the soil particles and are not available to the plants as a food source. Compaction also has a detrimental effect on the plant by restricting root development, thus limiting the plant's ability to reach the subsoil moisture and nutrients. The toxic conditions caused by the binding of fertilizer salts and chemical residues reduce the humus fraction of the soil, which in turn limits the soil's ability to hold water, nutrients, and oxygen. Other causes of soil compaction include the use of heavy equipment, tilling the land, and even the application of irrigation water.

- Heavy equipment contributes to compaction by further compressing the soil particles that are already bound together by chemical fixation. This compression of the soil particles further limits the soil's ability to hold water, oxygen, and nutrients. Tilling practices can further the compaction damage by puddling the soil, thus increasing pore compression even more. Irrigation water adds to compaction damage by concentrating minerals in the hardpan layer.

Typical soil remediation practices include hardpan ripping, which is a short-term solution to the compaction problem. Ripping does nothing to improve the soil structure long-term: it is merely a mechanical means of cutting through the hardpan compaction. Ripping requires high horsepower equipment to shatter the hardpan layer. The estimated cost of ripping 18" to 24" deep is about $25.00-$50.00 per acre.

Biological improvement practices offer both short- and long-term benefits in the reduction of hardpan in soils. The diverse families of U.S. Ag Industrial's microbes begin improving the soil profile with just a single application. They accomplish this by aerating the soil and increasing its water-holding capacity. Their ability to digest chemical components of hardpan releases the bound soil particles, moisture, and nutrients, making them available to plants.

1. Short-term benefits of using **TerraMax** are the immediate increase in root mass and the ability for roots to penetrate the hardpan layer. This allows the plant to use subsoil moisture and nutrients in or below the hardpan.
2. Long-term benefits of using **TerraMax** are the increase of the humus fraction of the soil, higher moisture-holding capacity, and improved aeration of the soil. The increased biological activity in the soil by beneficial microbes causes an increase in the humus fraction of the soil that contains microbially-produced enzymes, hormones, and antibiotics, thus leading to a more productive soil and healthier, hardier plants.

The Conclusion & Solution

The use of **TerraMax** in bioremediation shows prolific benefits in overall environmental restoration and health, as well as the diminishing of exorbitant overhead costs, while assuring of the safety of residents, wildlife, and hired personnel. Monitored success of bioremediation strategies for the reduction of toxic contaminants in soil and water, the removing of hardpan in farmland, and the overall optimization in the growth and augmented health of plant life are but a few of the positive results in the use of **TerraMax.** By applying **TerraMax** for bioremedation, with its combination of soil amendments, fertilizers, and microbial families, normal ecological balance can be restored and maintained.