

# **Bioremediation & Phytoremediation**

- **Bioremediation** is a means of cleaning up contaminated environments by exploiting the diverse metabolic abilities of microorganisms to convert contaminants to harmless products by mineralization, generation of carbon dioxide and water, or by conversion into microbial biomass. The term bioremediation is made of two words, 'Bios' that refers to living organisms and 'Remediate' refers to rectify or to solve the problem.
- Thus, "Bioremediate" means the use of biological organisms to solve an environmental problem such as contaminated soil or groundwater to degrade environmental pollutants.

- Bioremediation is a natural process that uses microorganisms to transform harmful substances into non toxic carbon dioxide, water and fatty acids.
- **Phytoremediation** ( in soil and groundwater) use of plants to Remediation also occurs when bacteria on the roots of the plant degrade the contamination, The plant tissue, which is rich in accumulated contaminants, can be harvested and safely processed. remove the contaminants degradation of contaminants to a less toxic form.

- **Bioremediation** is a process used to treat contaminated media, including water, soil and subsurface material, by altering environmental conditions to stimulate growth of microorganisms and degrade the target pollutants. In many cases, bioremediation is less expensive and more sustainable than other remediation alternatives.
- Biological treatment is a similar approach used to treat wastes including wastewater, industrial waste and solid waste.

- Most bioremediation processes involve oxidation-reduction reactions where either an electron acceptor (commonly oxygen) is added to stimulate oxidation of a reduced pollutant (e.g. hydrocarbons) or an electron donor (commonly an organic substrate) is added to reduce oxidized pollutants (nitrate, perchlorate, oxidized metals, chlorinated solvents, explosives and propellants).
- In both these approaches, additional nutrients, vitamins, minerals, and pH buffers may be added to optimize conditions for the microorganisms. In some cases, specialized microbial cultures are added (bioaugmentation) to further enhance biodegradation. Some examples of bioremediation related technologies are phytoremediation, mycoremediation, bioventing, bioleaching, landfarming, bioreactor, composting, bioaugmentation, rhizofiltration, and biostimulation.

- Aerobic bioremediation is the most common form of oxidative bioremediation process where oxygen is provided as the electron acceptor for oxidation of petroleum, polyaromatic hydrocarbons (PAHs), phenols, and other reduced pollutants. Oxygen is generally the preferred electron acceptor because of the higher energy yield and because oxygen is required for some enzyme systems to initiate the degradation process.
- Numerous laboratory and field studies have shown that microorganisms can degrade a wide variety of hydrocarbons, including components of gasoline, kerosene, diesel, and jet fuel. Under ideal conditions, the biodegradation rates of the low- to moderate-weight aliphatic, alicyclic, and aromatic compounds can be very high.
- As the molecular weight of the compound increases, so does the resistance to biodegradation

- Anaerobic bioremediation can be employed to treat a broad range of oxidized contaminants including chlorinated ethenes (PCE, TCE, DCE, VC), chlorinated ethanes (TCA, DCA), chloromethanes (CT, CF), chlorinated cyclic hydrocarbons, various energetics (e.g., perchlorate, RDX, TNT), and nitrate. This process involves the addition of an electron donor to: 1) deplete background electron acceptors including oxygen, nitrate, oxidized iron and manganese and sulfate; and 2) stimulate the biological and/or chemical reduction of the oxidized pollutants. Hexavalent chromium (Cr[VI]) and uranium (U[VI]) can be reduced to less mobile and/or less toxic forms (e.g., Cr[III], U[IV]). Similarly, reduction of sulfate to sulfide (sulfidogenesis) can be used to precipitate certain metals (e.g., zinc, cadmium).

# Bioremediation mechanism

Microorganisms destroy organic contaminants in the course of using the chemicals for their own growth and reproduction

Organic chemicals provide:

- carbon, source of cell building material

- electrons, source of energy

Cells catalyze oxidation of organic chemicals (electron donors), causing transfer of electrons from organic chemicals to some electron acceptor

# Electron acceptors

Electron acceptors:

In aerobic oxidation, acceptor is oxygen

In anaerobic, acceptor is (with decreasing efficiency):

nitrate

manganese

iron

sulfate

Microorganisms also need essential nutrients such as nitrogen and phosphorus

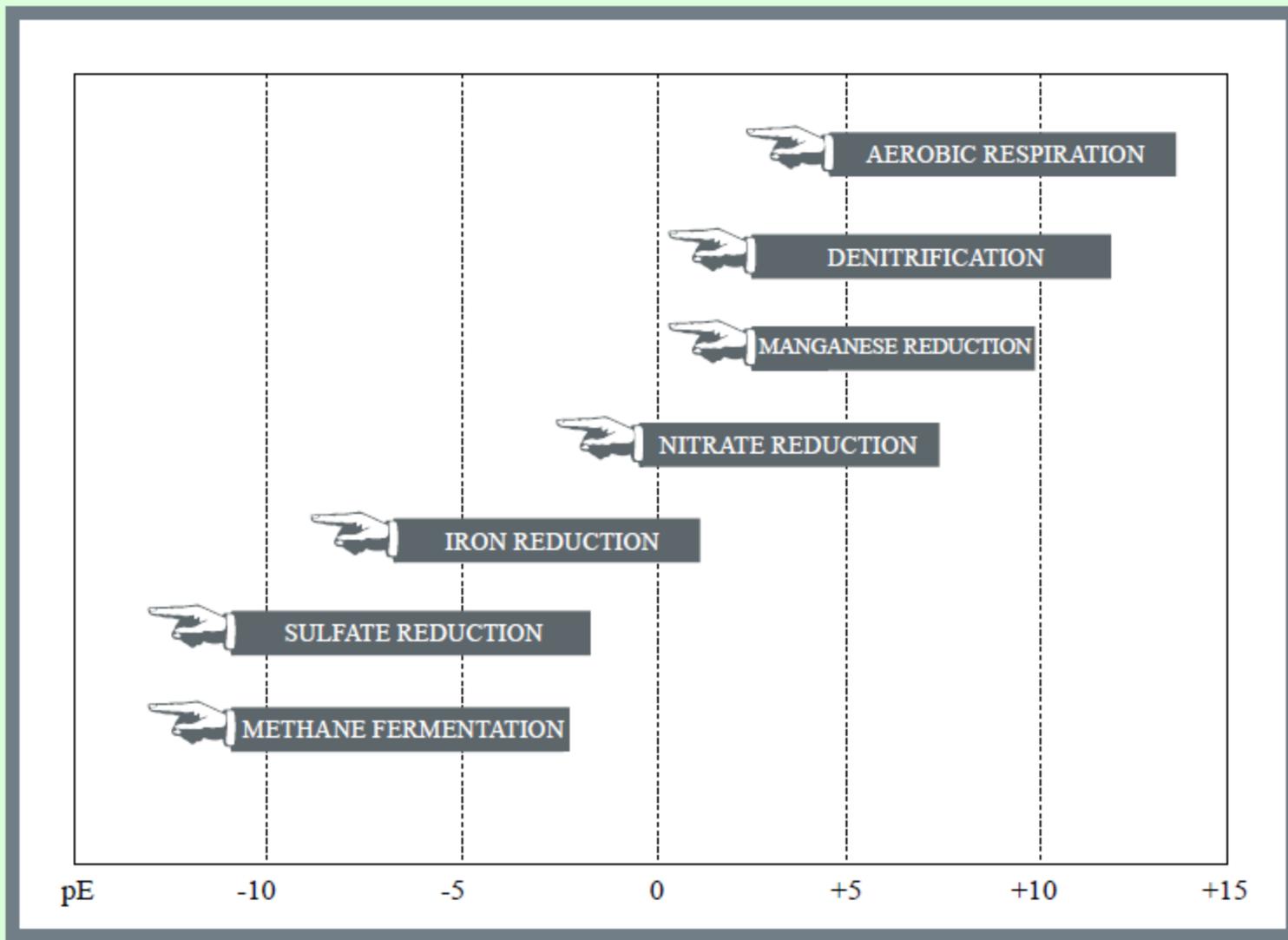


Image adapted from: Wiedemeier, T., J. T. Wilson, D. H. Kampbell, R. N. Miller, and J. E. Hansen, 1995. Technical Protocol for Implementing Intrinsic Remediation with Long-Term Monitoring for Natural Attenuation of Fuel Contamination in Groundwater. Air Force Center for Environmental Excellence, San Antonio, Texas. November 11, 1995. Figure B.5.4, Pg. B5-14.

# Bioremediation technologies for ground water

Bioremediation - addition of one or more of the following to stimulate bacterial growth:

Nutrients

Carbon source (dextrose, molasses)

Oxygen

Circulation

# Limitations to biodegradation

- Adequate bacterial concentrations (although populations generally increase if there is food present)
- Electron acceptors
- Nutrients (e.g., nitrogen and phosphorus)
- Non-toxic conditions (NAPL pools are likely to be toxic)
- Minimum carbon source (which may exceed regulatory limits for toxic chemicals)

Note that rapid growth may be limited by diffusive or advective transport of any of the above