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# BIOREMEDIATION

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Chemicals entering the environment can be classified into three categories with respect to their biotransformation. Those subject to complete biodegradation or mineralization are consumed as organic nutrients and energy sources by the bacteria, yeasts, molds and other microorganisms in the biosphere. The majority of natural and man-made chemicals are in this category. Certain other compounds undergo limited bioconversion without being assimilated for food or energy. Typically this involves co-metabolism reactions in which the compound is modified by enzymes normally active on other substrates. Given the diversity of microorganisms in the environment it is not surprising that some of these altered compounds may then be metabolized further by additional members of the mixed microbial community. In this manner some of the compounds in the co-metabolizable category occasionally may also become mineralized.

A relatively few natural and man-made chemicals are environmentally stable, however, several among these are known to be hazardous to human health. Bioremediation makes use of naturally available assimilatory and co-metabolic processes in the practical, cost-effective treatment of biodegradable wastes. Research and development in bioremediation has the goal of increasing the number of recalcitrent hazardous compounds and mixtures that are returned to the carbon, nitrogen and other cycles of the biosphere.

As with any biological process, this challenge can be expressed in terms of genes and the environment (Fig. 1).

Microorganisms expressing degradative genes + suitable microbial incubation conditions → bioremediation

*Fig. 1. Both appropriate microbes and engineered environmental conditions are required for bioremediation.*

Microbes exist ubiquitously in nature in different forms and life styles and so are available for the degradation of a variety of organic compounds. Traditional microbe-rich systems such as municipal waste treatment facilities, natural wetlands, rhizospheres of green plants, fixed biofilm filters, composting biomass, and land treatment involve diverse microbial communities and incubation conditions characteristic of this relationship. The use of biodegradation for conventional problems such as gasoline or diesel fuel spills is relatively straight forward, indeed indigenous microbes that can degrade these fuels are present in nearly all soils and subsurfaces (1). What is required is an engineering method that provides for essential mineral nutrients, moisture, and an electron acceptor, typically oxygen. Under these conditions the microbes grow on (assimilate) and consume the pollutants. Procedures have been described to degrade gasolin and diesel fuel, in soil or ground water in situ, including bioventing (2), and by air sparging (3).

This fundamental relationship of genes and the environment becomes increasingly complex in the real world of hazardous waste sites and hazardous waste minimalization. Several aspects of this complexity will be cited here, followed by examples of recent research on expanding the applicability of bioremediation to more recalcitrant pollutants.

Logically the process begins with site analysis and risk assessment. Protecting health through hazardous waste remediation can be expensive and this analysis and assessment is necessary for setting priorities among sites that require attention. These initial characterizations are also necessary for determining the end point – a level of clean up that is decided upon for that situation. Then begins the selection and engineering of any bioremediation approach (4). Complexities that make this an imperfect science (5) are signaled in the cartoon shown in Fig. 2. Developing, monitoring, and effecting a biotreatment for such hazardous waste sites requires

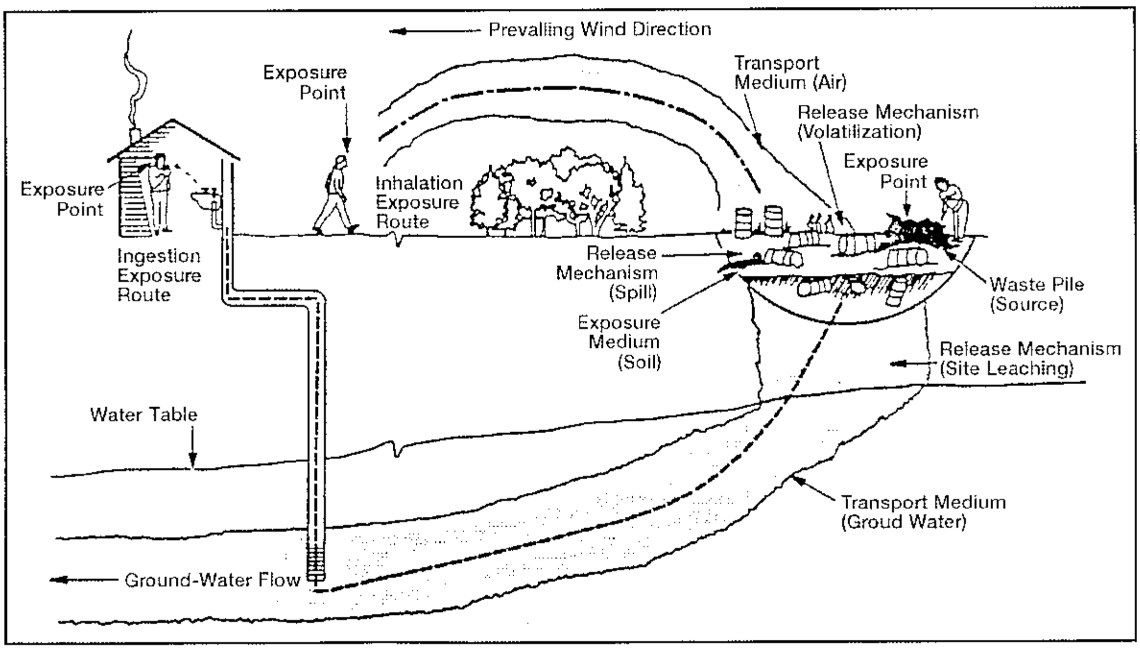


*Fig. 2. Site analysis and risk assessment are necessary for any bioremediation strategy.*