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REVIEW PAPER ON – PARAMETERS AFFECTING BIOREMEDIATION

MS.MADHAVI GAONKAR NAIK AND MS.MOHINI DILIP DURAPHE

Chemical Engineering Dept, Jawaharlal Nehru Engg College, Aurangabad, Maharashtra.
PG student, Pravara Rural Engg College, Loni, Maharashtra

ABSTRACT

Bioremediation has provided problem solving opportunities in the field of solid waste by detoxifying effluents /wastes. Due to its comparatively low cost and environmental impact it offers attractive and more conventional clean-up technologies. Although the methodologies employed are not technically complex, still considerable experience and expertise knowledge is required to design and implement a successful bioremediation program. In accordance to the need to thoroughly assess a site for suitability and to optimize conditions to achieve a satisfactory result. The goal of bioremediation is to biotransform toxic materials into nontoxic ones so that they enter natural biogeochemical cycles more quickly. This paper gives a brief review of the parameters which affect bioremediation and the possible changes which might affect the process.

Key Words: Bioremediation, parameters, environment, process.

1.1 INTRODUCTION

Contaminated lands generally result from past industrial activities when awareness of the health and environmental effects connected with the production, use, and disposal of hazardous substances were less well recognized than today. The problem is worldwide, and the estimated number of contaminated sites is significant [1]. It is now widely recognized that contaminated land is a potential threat to human health, and its continual discovery over recent years has led to international efforts to remedy many of these sites, either as a response to the risk of adverse health or environmental effects caused by contamination or to enable the site to be redeveloped for use.

A better approach than these traditional methods is to completely destroy the pollutants if possible or at least to transform them to less harmful substances. Some technologies that have been used are high-temperature incineration and various types of chemical decomposition (e.g., base-catalyzed dechlorination, UV oxidation). They can be very effective at reducing levels of a range of contaminants, but have several drawbacks, principally their technological complexity, the cost for small-scale application, and the lack of public acceptance, especially for incineration that may increase the exposure to contaminants for both the workers at the site and nearby residents.

Bioremediation is an option that offers the possibility to destroy or render harmless various contaminants using natural biological activity. As such, it uses relatively low-cost, low-technology techniques, which generally have a high public acceptance and can often be carried out on site.
By definition, bioremediation is the use of living organisms, primarily microorganisms, to degrade the environmental contaminants into less toxic forms. It uses naturally occurring bacteria and fungi or plants to degrade or detoxify substances hazardous to human health and/or the environment.

For bioremediation to be effective, microorganisms must enzymatically attack the pollutants and convert them to harmless products.

1.2 FACTORS AFFECTING BIOREMEDIATION

The control for bioremediation processes is a complex system of many factors. These factors include the existence of a microbial population capable of degrading the pollutants, the availability of contaminants to the microbial population, the environment factors (type of soil, temperature, pH, the presence of oxygen and nutrients).

1.3 MICROBES FOR BIOREMEDIATION PROCESSES

Microorganisms can be isolated from almost any environmental conditions. Microbes will adapt and grow at subzero temperatures, as well as extreme heat, desert conditions, in water, with an excess of oxygen, and in anaerobic conditions, with the presence of hazardous compounds or on any waste stream. The main requirements are an energy source and a carbon source.

Aerobic. In the presence of oxygen. Examples of aerobic bacteria recognized for their degradative abilities are *Pseudomonas*, *Alcaligenes*, *Sphingomonas*, *Rhodococcus*, and *Mycobacterium*. These microbes have often been reported to degrade pesticides and hydrocarbons, both alkanes and polyaromatic compounds. Many of these bacteria use the contaminant as the sole source of carbon and energy.

Anaerobic. In the absence of oxygen. Anaerobic bacteria are not as frequently used as aerobic bacteria. There is an increasing interest in anaerobic bacteria used for bioremediation of polychlorinated biphenyls (PCBs) in river sediments, dechlorination of the solvent trichloroethylene (TCE), and chloroform.

Ligninolytic fungi. Fungi such as the white rot fungus *Phanaerochaete chrysosporium* have the ability to degrade an extremely diverse range of persistent or toxic environmental pollutants. Common substrates used include straw, saw dust, or corn cobs.

Methylotrophs. Aerobic bacteria that grow utilizing methane for carbon and energy. The initial enzyme in the pathway for aerobic degradation, methane monooxygenase, has a broad substrate. For degradation it is necessary that bacteria and the contaminants be in contact. This is not easily achieved, as neither the microbes nor contaminants are uniformly spread in the soil. Some bacteria are mobile and exhibit a chemotactic response, sensing the contaminant and moving toward it . Other microbes such as fungi grow in a filamentous form toward the contaminant. It is possible to enhance the mobilization of the contaminant utilizing some surfactants such as sodium dodecyl sulphate (SDS)[10].

1.4 ENVIRONMENTAL FACTORS

Nutrients

Although the microorganisms are present in contaminated soil, they cannot necessarily be there in the numbers required for bioremediation of the site. Their growth and activity must be stimulated.

Biostimulation usually involves the addition of nutrients and oxygen to help indigenous microorganisms. These nutrients are the basic building blocks of life and allow microbes to create the necessary enzymes to break down the contaminants. All of them will need nitrogen, phosphorous, and carbon.

Carbon is the most basic element of living forms and is needed in greater quantities than other elements.

Microbial growth and activity are readily affected by pH, temperature, and moisture. Although microorganisms have been also isolated in extreme conditions, most of them grow optimally over a narrow range, so that it is important to achieve optimal conditions.

If the soil has too much acid it is possible to rinse the pH by adding lime. Temperature affects biochemical reactions rates, and the rates of many of them double for each 10 °C rise in temperature.

Above a certain temperature, however, the cells die. Plastic covering can be used to enhance solar warming in late spring, summer, and autumn. Available water is essential for all the living

organisms, and irrigation is needed to achieve the optimal moisture level.
The amount of available oxygen will determine whether the system is aerobic or anaerobic.
Hydrocarbons are readily degraded under aerobic conditions, whereas chlorinate compounds are degraded only in anaerobic ones. To increase the oxygen amount in the soil it is possible to till or sparge air. In some cases, hydrogen peroxide or magnesium peroxide can be introduced in the environment. Soil structure controls the effective delivery of air, water, and nutrients. To improve soil structure, materials such as gypsum or organic matter can be applied. Low soil permeability can impede movement of water, nutrients, and oxygen; hence, soils with low permeability may not be appropriate for *in situ* clean-up techniques.

1.5 BIOREMEDIATION STRATEGIES

Different techniques are employed depending on the degree of saturation and aeration of an area. *In situ* techniques are defined as those that are applied to soil and groundwater at the site with minimal disturbance.
Ex situ techniques are those that are applied to soil and groundwater at the site which has been removed from the site via excavation (soil) or pumping (water).

Major factors affecting bioremediation

Microbial
Growth until critical biomass is reached
Enrichment of the capable microbial populations
Production of toxic metabolites
Lack of nutrients
Too low concentration of contaminants
Chemical structure of contaminants
Toxicity of contaminants
Solubility of contaminants
Biological aerobic vs anaerobic process
Oxidation/reduction potential
Growth substrate vs co-metabolism
Type of contaminants
Concentration
Alternate carbon source present
Microbial interaction (competition, succession, and predation)
Physico-chemical bioavailability of pollutants
Incorporation into humic matters
Mass transfer limitations
Oxygen diffusion and solubility
Diffusion of nutrients
Solubility/miscibility in/with water

Non-scientific factors affecting bioremediation several non-scientific factors hinder the development of bioremediation technologies.

Regulatory factors

Regulations both drive and constrain the use of bioremediation. Regulation creates the bioremediation market by dictating what must be cleaned up, how clean it must be and which clean-up methods may be used (Caplan, 1993). The use of genetically engineered microorganisms (GEMs) presents additional regulatory hurdles. There is much debate over whether to use natural or GEMs in bioremediation. The advantages of naturally-occurring microbes currently outweigh those of GEMs.

1.6 Research and technical factors

Although there are a number of contaminants that are biodegradable, including petroleum hydrocarbons, alcohols and solvents, many widely used industrial chemicals such as PCBs, pesticides, coal tars, chlorinated solvents, and polynuclear aromatic hydrocarbons are not degraded so readily. So more intensive research is needed, but funding for this kind of basic research is diminishing.
Unlike the conventional treatment technologies, bioremediation technique must be tailored specifically to each polluted site. Each waste site has unique characteristics, and thus requires individual attention. As yet no criteria for evaluating the success or failure of a particular strategy have not been established.

Human resource factor

Because bioremediation is a new technology, there is a lack of trained human resources in this field. A successful bioremediation program requires a multidisciplinary approach, integrating fields such as microbiology, engineering, geology, hydrogeology, soil science and project management

Economic and liability factor

Unlike other industries, bioremediation does not result in the production of high value-added products. Thus, venture capital has been slow to invest in the technology and, as a consequence, commercial activity in R and D has lagged far behind other industrial sectors. As bioremediation is considered innovative technology, clients and regulatory agencies often scrutinize bioremediation more closely than conventional technologies. Consequently, tighter restrictions and performance standards are frequently imposed on bioremediation than on other remediation technologies.

1.8 CONCLUSION

Each of the factors discussed above may limit the use of bioremediation in specific circumstances. All the factors are positive in some cases where bioremediation technology has been successfully completed. Knowledge of the susceptibility to biodegradation of some contaminants is still lacking and toxicity testing is becoming more important. Many reports indicate that bioremediation of petroleum hydrocarbons can lead to reduced toxicity and have been taken as evidence of favorable biochemistry in these cases.

There are many factors that limit bioavailability and have the impact of slowing the transport of specific compounds into aqueous phase where biological uptake occurs readily. The importance of bioavailability is strongly dependent on the nature of the contaminant, the soil chemistry, and the matrix. In some cases, bioavailability is relatively unimportant, while in others it may be critical. The influence of site-specific bioavailability on bioremediation must be considered.

Bioactivity includes consideration of those parameters that have long been recognized as influencing the rate of bioremediation.

This suggests that certain sites may be particularly favorable for in situ strategies, because the bioactivity may be easily maintained. The trend is slowly changing and for bioremediation using both indigenous and non-indigenous, naturally occurring microorganisms, the regulatory hurdles are decreasing.

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