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Bioremediation; a nature-based approach towards having a healthier environment

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ABSTRACT

Nowadays, biotechnology is considered as an important, new field of science and technology so that it allocates itself a large share of research costs in most large companies. By intensifying hazardous soil and water pollutions in the last two decades, environmental biotechnology has highly been taken into consideration. One of the main achievements of environmental biotechnology is bioremediation highly recommended to control water and soil pollutions. There have been a lot of studies to show the numerous benefits of bioremediation. The present study provides a short introduction to different kinds of bioremediation technique as well as its constraints and benefits in decontamination of soil and water. The result indicated some advantages of bioremediation including being cheap, easiness of use, ensuring permanent removal of pollutants, in-situ cleaning up, etc. However, some drawbacks have been found by the technology included slowness of biological processes and inability of microorganisms to degrade all the pollutants in the environment. To this end, it can be concluded that benefits stemming from bioremediation is much more than its constraints. The different methods of bioremediation techniques provides scientific a variety of choices to clean up contaminated water and soil resources.

Key words: Ex-situ bioremediation, in-situ bioremediation, biostimulation, bioaugmentation

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INTRODUCTION

The entire surface of the earth is estimated to be about 14,477 million hectares of which more than 3000 million hectares have been exposed to chemical contamination. Different kinds of soils greatly differ in terms of geology, hydrology, climate, fertility and other physicochemical and biological characteristics. Physical and chemical characteristics of soils are so important in determining the fate of pollutants. By intensifying hazardous soil and water pollutions in the last two decades, a great deal of attention has lately been paid on environmental biotechnology by enormous scholars around the world and a variety of techniques has been presented by them until now. Environmental biotechnology is a multidisciplinary approach integrating science and engineering to use biochemical potential of microorganisms in order to remove pollutants from contaminated water and soil resources. One of the main achievements of environmental biotechnology is bioremediation highly recommended to control water and soil pollutions. Economic issues have persuaded scientists to apply biological processes in degradation of pollutant materials. Initial attempts to remove contaminants were mainly directed towards physical and chemical methods. However, it was found that the use of these methods alone is very expensive and often does not work. Other than incineration, biological methods including bioremediation would be the only practical solution to complete decomposition of organic materials. Bioremediation is a technique involving the use of microorganism to detoxify and degrade environmental contamination [1]. Nowadays, bioremediation engineering has been emerged by integrating engineering and bioremediation methods. The porous is to use an appropriate set of microbial populations for optimizing the environment for accelerating decomposition reactions of pollutants. In 2000, Sayler and Ripp conducted a review paper to investigate the overall effectiveness and risks associated with introduction of Genetically Engineered Microorganisms (GEMs) to natural ecosystems [2]. Zouboulis and Moussas (2011) concluded that bioremediation is considered as a very promising technology with great potential when dealing with certain types of contaminated sites. However they believe in specific control procedures while applying the method whereas there is the risk of adverse health effects may be present due to the variability of contaminants and their possible biotransformation toward not-controlled metabolites [3]. Dell'Anno et al. (2012) investigated changes of bacterial abundance and biodiversity during bioremediation experiments carried out on oxic and anoxic marine harbor sediments contaminated with hydrocarbons [4]. They concluded that temperature exerted the main effect on bacterial abundance, diversity and assemblage composition. Pelletier et al. (2004) examined the effectiveness of fertilizers for crude oil bioremediation in sub-Antarctic intertidal sediments over a one-year period in a series of ten (10) experimental enclosures [5]. They found that over 90% of *n*-alkanes were degraded in the first six months and most light aromatics (2–3 rings) disappeared during the first year of observation. Lin et al. (2010) presented an innovative bioprocess method, Systematic Environmental Molecular Bioremediation Technology (SEMBT) that combines bioaugmentation and biostimulation with a molecular monitoring microarray biochip to enhance the bioremediation efficiency [6]. After 28 days of the bioremediation process, they were able to achieve degradation efficiencies of diesel oil ($TPH_{C10–C28}$) and fuel oil ($TPH_{C10–C40}$) up to approximately 70% and 63% respectively in the S-series biopiles.

The current research is a descriptive-analytical study focusing on different types of bioremediation to specify some potential advantages and disadvantages of bioremediation process.

The background of bioremediation

The history of using bioremediation by microorganisms to clean and treat pollutants in the environment dates back to 600 BC. At that time, ancient Romans directed wastewater into large pits or tanks outside the city and wastewater treatment was carried out by microbial activities. This was unexpected first start for applying bioremediation in human life. However, after the industrial revolution, water and soil pollution greatly expanded in human environment. Environmental regulations were gradually established whereas such a rapid contamination trend could not continue without interruption. Comparing the performance of various methods applied to clean up the environment from different types of pollutants as well as seeking for cheap and sustainable methods leads to development of bioremediation technology.

Different methods of bioremediation

The common methods of bioremediation can be divided into many different forms based on implementation place (Ex-situ or in- situ), implementation phase (water or soil) and human manipulation in the implementation of this technology (engineering or natural). Figure 1 demonstrates classification of bioremediation methods.

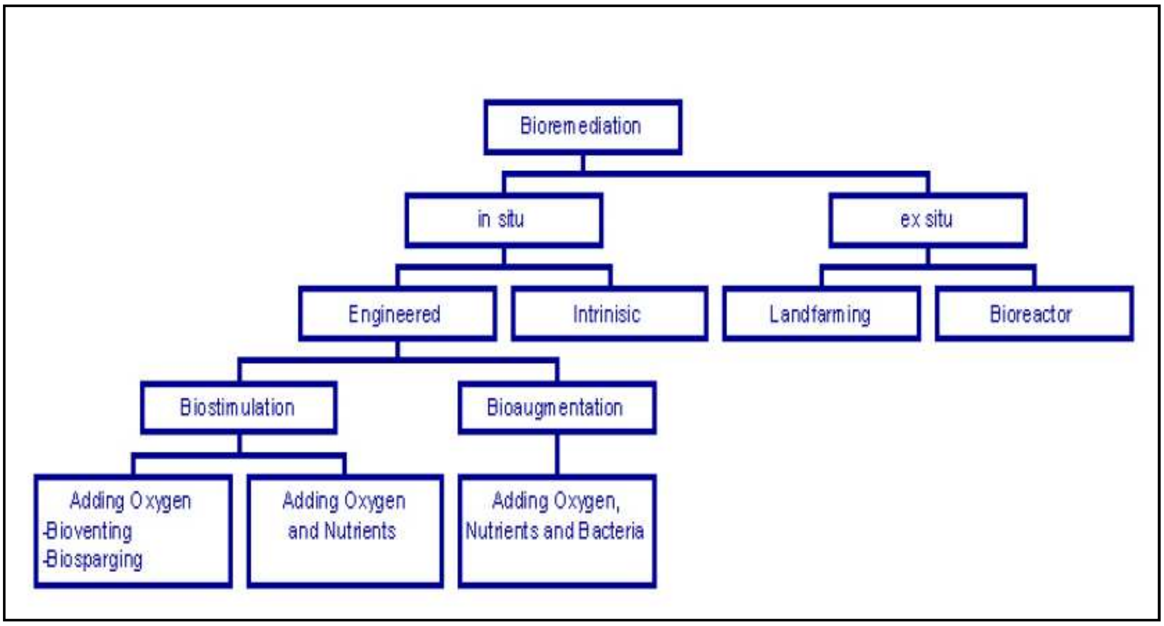


Fig.1: classification of bioremediation methods

The first classification of bioremediation methods is based on implementation place which includes ex-situ and in-situ bioremediations.

a) Ex-situ bioremediation
Ex-situ bioremediation involves the removal of the contaminated materials (soil and/or water) to be treated elsewhere. In this method, drilling and pumping are applied to treat contaminated soils and water, respectively. In-situ bioremediation involves treating the contaminated material at the site, while ex situ involves the removal of the contaminated material to be treated elsewhere. Low operating costs is among the important advantages of the method, however, the process is slow and hard to control. The in-situ bioremediation can be done in two ways, depending on possible human involvement in its implementation.

b) in-situ bioremediation by applying engineering measures
In this method, microbial processes are accelerated by applying specific engineering procedures. Two common forms of this method include biostimulation and bioaugmentation.

Biostimulation: Biostimulation involves microbial population stimulation by adding nutrients and oxygen.

Bioaugmentation: It involves adding microorganisms (inoculation mite) to contaminated place to provide appropriate conditions for their growth. Bioventing is one of the bioremediation applying engineering procedures. As an in-situ remediation technology, it is used to remove pollutants from unsaturated zone which has high permeability to gas. Accordingly, the biodegradation is optimized by passing the air through the zone.

Intrinsic bioremediation: In this method, the activity of microbial populations existed in contaminated places is the only reason for removing contaminants naturally, without human manipulation. Ex-situ bioremediation can be carried out by the following two methods:

1- *farming techniques*
The methods land-farming and biopiles are two common methods of farming techniques

landfarming method: The contaminated soils are spread on an impenetrable surface, after being excavated. Soil moisture and nutrients are controlled to accelerate microbial degradation reactions. It is one of the most common methods of ex-situ bioremediation.

Biopiles method: In this method, the contaminated soil will be collected in the form of large masses and liquid nutrients, moisture and air are passed through them by vacuum pumps.

2- bioreactors
In this method, pollutants are removed by putting the contaminated soil or water into a large tank or bioreactor. By adding nutrients and continued oxygen penetration, optimum conditions would be provided for decomposition reactions.

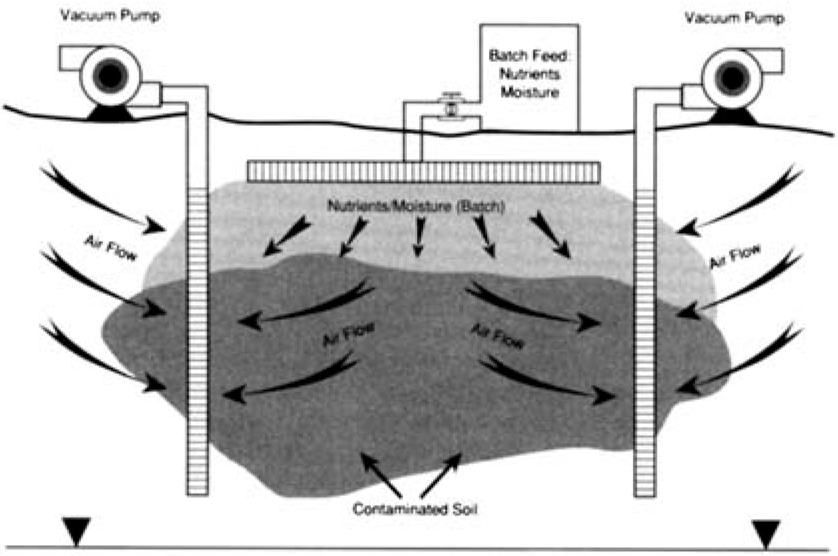
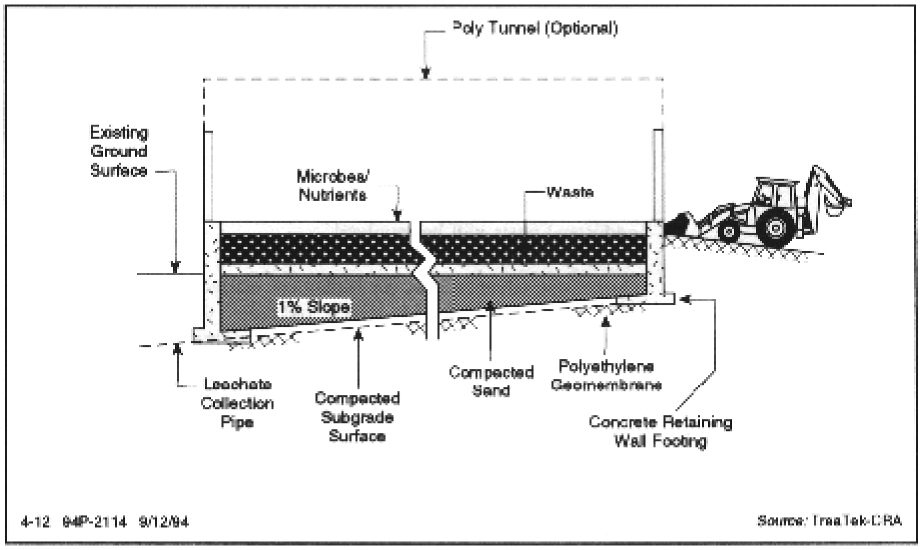


Fig.2: In-situ bioremediation by applying engineering measures [1]



4-12 TYPICAL LANDFARMING TREATMENT UNIT

Fig.3: land-farming ex-situ bioremediation [8]

CONCLUSION

Like any other methods, bioremediation technique has also its own advantages and disadvantages which are briefly discussed here. Application of bioremediation methods will be followed by numerous benefits. The technique provides possibility of in-situ cleaning of contaminated environments, therefore, there will be no need to displace or transport toxic wastes and minimal disturbance will be imposed to the site. Accordingly, transportation costs of contaminated water and soil will be saved and workers' direct contact with toxic wastes will be decreased, as well. The technique ensures permanent removal of pollutants so that there will be no need for resuming the operation after using once only. Bioremediation technique is so easy to use due to the reasons such as low operating costs, proper performance at room temperature, and simultaneous removal of soil and groundwater contaminations. Bioremediation method degradates pollutants to harmless materials. It provides removal possibility of toxic waste pollution in places such as under buildings and highways. The performance of the method is in accordance with the standards presented by Department of environment (DoE). In spite of enormous advantages of bioremediation method, there are some drawbacks that must be taken into the account while choosing the technique [9]. Microorganisms commonly found in contaminated sites won't be able to degrade all the pollutants in the environment. There are some microorganisms in nature that are resistant to microbial degradation. Bioremediation process is so difficult to control. Moreover, slowness of biological processes will lead to the prolongation of the time to achieve results, especially when the time needed to complete clearing operations is important [10]. in general conclusion can be said that bioremediation is a site-specific process required feasibility studies before full-scale remediation can be successfully applied [11].

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