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BIOREMEDIATION A POTENTIAL APPROACH FOR SOIL CONTAMINATED WITH POLYCYCLIC AROMATIC HYDROCARBONS: AN OVERVIEW

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ABSTRACT

Polycyclic aromatic hydrocarbons (PAHs) represent a group of priority pollutants which are present at high concentration in soils of many industrially contaminated sites. Standards and criteria for the remediation of soils contaminated with PAHs vary widely between countries. Bioremediation has gained preference as a technology for remediation contaminated sites as it is less expensive and more environmental friendly. Bioremediation utilizes microorganisms to degrade PAHs to less toxic compounds. This technology degrades contaminants through natural biodegradation mechanisms or enhanced biodegradation mechanism and can be performed in-situ or ex-situ under aerobic or anaerobic conditions. The purpose of this paper is to highlight potential of using isolated strains from municipal sludge on soil remediation. Several indigenous bacteria from municipal sludge namely genus *Micrococus*, *Sphingomonas*, and *Corynebacterium* demonstrated a high removal rate of PAHs with more than 80% of lower molecular weight of PAHs degraded after one week incubation. Laboratory studies had established that these genus able to degrade PAHs on contaminated soil. The successful application of bacteria to the bioremediation of PAHs contaminated sites requires a deeper understanding of how microbial PAH degradation proceeds. An overview of research focusing on biodegradation of PAHs will be presented.

Keywords: *Bioremediation, contaminated sites, polycyclic aromatic hydrocarbons*

1.0 INTRODUCTION

The remediation and reclamation of land contaminated with hazardous material has received increasing attention internationally in recent years, with enhanced awareness of the potential adverse effects on human health and the environment. Contaminants or hazardous material in soil can adversely impact health of animals and human through ingestion, inhalation or come into physical contact with contaminated land. Certain contaminants can be absorbed into the body during contact with the human skin. Plants also can be contaminated when they are grown on contaminated land, as they take up the contaminants through the root systems [1].

Soil contamination can be defined as the presence of man-made chemicals or other alteration in the natural soil environment as a result of natural or man-made activities. Soil contamination has become a pressing concern especially in urban areas where availability of uncontaminated land is becoming scarce.

In Malaysia, soil pollution occurs gradually during the last fifty years as a result of agriculture and industrial activities. The problem became more intense in 1980s, when the Malaysian Industrial Master Plan was implemented. The lack of specific regulation on soil contamination and inefficient enforcement by the authorities has resulted in drastic increase in the number and sizes of potentially contaminated sites in Malaysia.

Contaminated sites containing organic pollutants such as polycyclic aromatic hydrocarbons and inorganic compounds such as heavy metals are considered highly risks areas with potential health hazards as contaminants may be ingested through bioaccumulation process through the food chain [2], [3]. If no attempt is made to address the problem, the number of contaminated sites in Malaysia will continue to grow and add to the growing list of Brownfields.

Over the years, bioremediation is gaining wider approval as a feasible alternative treatment technology for the remediation of soil contaminated with persistent organic pollutants such as PAHs. Indeed, bioremediation is deemed to be safe, efficient, eco-friendly and economical in removing pollutants from contaminated sites. The method applied completely breakdown contaminants to natural elements such as carbon, hydrogen, nitrogen and oxygen then transforming them into other chemical compounds [4], [5], [6].

The purpose of this paper is to highlight the potential of using isolated strains from municipal sludge to remediate PAHs on polluted soil

2.0 CAUSES OF SOIL POLLUTION

The introduction of hazardous substances into the soil matrix will result in soil contamination [7]. Spillages on soil surfaces or leakages from underground storages are the main causes of soil contamination [8]. In most cases, pollutants migrate from the point of spillage or leakage, thus causing a more widespread contamination into the soil matrix and the underlying groundwater. In addition to these accidental occurrences, soil can also be contaminated through agricultural activities excessive application of fertilizers and pesticides [9].

Bad engineering practices in waste management, such as, direct discharge of industrial effluent on soil surface and poor leachate management at landfills also contribute to soil contamination [10], [11].

In the case of PAHs, high concentrations can be found on many industrial sites [4]. As stated in Table 1 sources of PAHs are diverse particularly those associated with oil or petroleum based.

Table 1: Industries and Its Contamination On Soils

Industry	Coal based	Oil/ Petroluem based	Dumping sites
ACTIVITY	Power/Thermal station	Oil/Petroleum Refineries Fuel/Oil/Bulk depot Existing and former petrol station Underground storage tanks Motor workshop	Landfill Other illegal dumping sites
WASTES RELEASED	Fly ash, Bottom ash, dust Hazardous gas Effluent discharge (waste water)	Oil spills fr: Overfilling of tank Leakage of underground tank Wastewater Dust/particle fr: Smelting and burning of gasoline	Leachate Run off water Hazardous gas Waste water

POLLUTANT	Heavy metals (Hg, U, Th, As, Pb, Cu, Zn, Cr, Cd, Al, Sb) Hazardous gas (SO_2, NO_x, CO_2, CH_4) TSP (PM_{10})	Monocyclic aromatic hydrocarbon (benzene, toluene, ethylbenzene, xylenes,) Polycyclic aromatic hydrocarbon (benzo(a)pyrene, naphthalene) Aliphatic hydrocarbon (n-butane, isopentane, 2,4-dimethylhexane) Heavy metals (Pd, Cu, As, Hg etc)	Among: Metal (Al, Fe, Hg etc) Gas (CH_4) persistent organic pollutants (POPs)-including dichloro-diphenyl-tri-chloroethane and its metabolites (DDTs), hexachlorocyclo-hexanes (HCHs), chlordanes, hexachlorobenzene (HCB), and polychlorinated biphenyls (PCBs)

PAHs cause concern because of their carcinogenic and mutagenic charateristics [12]. PAHs are relatively stable and recalcitrant in soils and less easy to degrade compared to other organic compounds.

3.0 PRINCIPLES OF BIOREMEDIATION

The use of bioremediation as a remediation technology has expanded enormously in recent years to encompass a wide variety of chemicals and broad array of sites. Moreover, new technologies have emerged which had markedly enhanced biodegradation.

Bioremediation involves the use of microorganisms to break down hazardous organic material into harmless compounds. It involves biologically catalyzed reduction in complex chemicals or mediates the transformation of hazardous chemicals to less toxic and environmental acceptable compounds. In the case of organic pollutants, biodegradation occur as microorganisms metabolize and mineralize into inorganic products such as carbon, nitrogen, phosphorus, sulphur and other metabolic waste product [13], [14], [15]. Different compounds of parent molecule will convert into different elements of inorganic product. In the case of organic pollutants such as PAHs, extensive degradation occurred by cleavage of one or the entire ring. Many organic pollutants are commonly oxidized by a series of reaction that yield the corresponding alcohol, aldehydes and carboxylic acids [14], [16].

Natural communities of microorganisms in various habitats have an amazing physiological versatility. They are able to metabolize and often mineralize an enormous number of complex organic molecules into less hazardous compounds to human health and that which are less detrimental to the environment. The presence of indigenous microorganism in contaminated system can result in contaminants being altered through reactions that take place as a part of their metabolic processes.

The bioremediation technology had been well developed in industrialized countries but has yet to gain acceptance in developing countries including Malaysia. Application of bioremediation technology in Malaysia is still limited on few cases like composting process using natural bamboo bin as bioreactor and on site biodegradation process at a sanitary landfill located at Air Hitam Forest Reserve managed by Worldwide Environmental Management [17]. Currently, there is limited published literature, in application of bioremediation technology to treat micropollutants in municipal sludge.

Like other technologies, the application of bioremediation has its limitations. Several conditions must be satisfied for biodegradation to occur. These include the presence of organism that has the necessary enzymes to degrade the target pollutants. These organisms must exist with sufficient quantity and have ability to transform the polluted compound and bring the concentration to levels that meet regulatory standard. Beside that, the target pollutants must be accessible to the organisms. In some cases, the additions of nutrient or substrate are needed for accelerating and stimulating the microbial activity. Successful implementation of bioremediation technology also relies on optimum environmental condition that is conducive for microbial growth. Integrated knowledge on pollutants, microbes and environmental factors will result in better application of bioremediation technology

4.0 METHODS OF BIOREMEDIATION

In general, bioremediation are classified based on the location where treatment is done as either in-situ or ex-situ. In addition it can also be classified based on nature of the bio-chemical processes as either aerobic or anaerobic. In-situ systems involved the remediation of contaminated material within the boundaries of the area in which it was originally polluted. While ex-situ system, require contaminated material to be removed from location and transport to treatment facilities [18], [19].

In term of cost, in situ method is cheaper as it does not involve excavating contaminated soil the affected area. A part from that, this technique generates less dust and cause less release of contaminants to environment. As opposed to the advantages some drawback of this technique included being less subject to rigorous control, time consuming, difficult task to manage and not very effective in impermeable soil. Previous studies reported on various practices on in-situ bioremediation such as the use of biorestoration, bioattenuation and bioaugmentation [14].

Ex-situ systems can be faster, easy to control and able to treat a broad range of contaminants compared to in-situ systems. However, these techniques require excavation of contaminated soil. Even though ex situ is normally more costly but it is a choice of practice if the in-situ method is not feasible. The higher costs of an ex-situ treatment come from expenses of moving the contaminated material, the capital required for constructing the needed equipment for the particular cleanup, additional labour, and the need for power or a combination of these factors. Ex-situ systems include slurry phase bioremediation and solid phase bioremediation.

5.0 POTENTIAL STRAINS IN PAHs DEGRADATION

The scientific literature had documented a considerable number of bioremediation studies on PAHs contaminated soil employing various bacterial strains. *Pseudomonas paucimobilis* had demonstrated the ability of in utilizing fluoranthene as the sole carbon and energy source [20]. Other researcher reported on the degradation pathway for fluoranthene and cometabolism pathway for pyrene by *Sphinogomonas* sp [21]. This strain also has the ability to metabolize the methylated forms in the PAHs and it is versatile in its specificity for PAHs [22]. These findings indicate that fluoranthene is able to induce enzymes that can catalyze the degradation of a variety of PAHs [20]. Three bacterial strains, namely, *Pseudomonas aeruginosa*, *Bacillus* and *Micrococcus* isolated from hydrocarbon contaminated soil successfully treat hydrocarbons [23].

Extensive research activities on PAHs remediation had been conducted in Malaysia. Strains were isolated from petroleum and municipal sludges. Tests were performed under indigenous conditions. Several indigenous bacteria from municipal sludge namely genus *Micrococcus, Rhodococus*, *Corynebacterium, Pediococcus, Sphingobacterium* and *Tsukamurella* demonstrated 80% of the lower molecular weight PAHs are degraded after one week incubation. In addition to the application of bioremediation strategies for enhancing bioremediation rates, studies also focused on favourable environmental condition for bacterial growth

6.0 CONCLUDING REMARKS

Taking into account that bioremediation technology has proven to be effective, economic and environmental friendly for the treatment of contaminated soil, focused research in some specific areas is desired for more effective treatment design and performance. Some areas where further research may be directed include strategies to enhance bioavailability and mass transfer of contaminants, optimization of process factors, system configurations and multiple process integration.

This review has highlighted that bioremediation is a potential method in treating PAHs contaminated soil.

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