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Principles of microbial degradation of petroleum hydrocarbons in the environment

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ABSTRACT

Petroleum hydrocarbons (PHs) are a big group of chemicals that have caused a major concern because of their widespread distribution into the environment, bioaccumulation potential, harmful effects and biodegradation resistance. Soil and water pollution is mainly attributed to hydrocarbons from oil refineries, petrochemical industries, human activities and other sources. The mechanisms and factors that affect biodegradation should be further understood because the choice of bioremediation technique depends on them. This review described fungal PHs degradation, emphasized the relevant physicochemical and biological factors, and discussed the enzymatic systems influencing PHs biodegradation.

Contents

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Introduction

Petroleum hydrocarbons (PHs) are considered the main energy source and materials for different industries (Varjani and Upasani, 2016a). Many threats exist in the environment when PHs are used as energy sources. PHs are major environmental pollutants generated by wide-scale production, transport, coastal oil refining, shipping activities, offshore oil production and accidental spilling (Arulazhagan et al., 2010). Human activities, such as municipal run-offs and liquid release and industrial, cause PH pollution which impacts the environment and poses a direct or indirect health hazard to forms of life (Sajna et al., 2015). In an accidental leak, on-site removal, treatment or recovery of contaminants is facilitated but contaminants in petrol stations and spills may persist because the amount of leakage is small. PH leakage due to frequent accidental and illegal disposal of oil waste at sea severely harms various ecosystems. PHs are toxic compounds classified as priority pollutants (Costa et al., 2012). Aliphatic and aromatic hydrocarbons are two major PH components that have been reported because they are recalcitrant and harmful to health. Aliphatic hydrocarbons are easily degraded by microorganisms, but large branched aliphatic chains are not easily degraded; therefore, they persist in the environment (Hasanuzzaman et al., 2007). Likewise, aromatic hydrocarbons are difficult to degrade because of their complex structures. In vitro and in vivo experiments have showed that polycyclic aromatic hydrocarbons (PAHs) are carcinogenic, cytotoxic, genotoxic and environmentally toxic. PAHs are fused aromatic ring compounds found in the atmosphere and relatively resistant to the biodegradation; as such, they accumulate to significant levels into the environment (Freeman and Cattell, 1990). A biological treatment is an alternative pollutant removal method because this technique does not elicit deleterious effects on the environment. This treatment may also be less expensive than other techniques. The success of bioremediation depends integrally on pollutant biodegradation, pollutant-degrading organism accessibility and biological activity optimization. Biodegradation by indigenous microorganisms is a major mechanism and a reliable method that operates by biologically removing foreign contaminants, such as crude oil (Ghanavati et al., 2008). Bacteria, yeast and fungi can utilize PHs (Haritash and Kaushik, 2009). Fungi such as *Aspergillus, Penicillium, Fusarium, Amorphotheca, Neosartorya, Paecilomyces, Talaromyces, Graphium Cunninghamella* are microorganisms which can degrade persistent pollutants, see Table 1. This review provides current information on PH degradation by fungi to enhance our understanding of bioremediation challenges.

Degradation of PHs by microbial activity

PHs degradation is a very hard method that influenced mainly in the amount and nature of the PHs present. PHs divided in four categories which are as follows: aliphatics, aromatics, resins (carbazoles, sulfoxides, pyridines, quinolines and amides) and asphaltenes (phenols, ketones, esters, porphyrins and fatty acids,) (Steliga, 2012). Numerous studies have reported that different environmental factors influence the biodegradation of PHs (Cooney et al., 1985). The limited availability of microorganisms in the environment is one of the most significant factors that restrict biodegradability of oil contaminants. Bioremediation of sites polluted with crude oil are oftentimes limited because of the poor biodiversity of local microbes or the scarcity of local specialized microbes with supplementary substrate properties required for the degradation of various hydrocarbons present in contaminated sites (Ron and Rosenberg, 2014) Some of the PAHs with a high molecular weight are probably not degraded at all. Degradation of Microbial is a major and a final natural mechanism which can help to clean-up PH contaminants in the environment (Juhasz and Naidu, 2000). Bacteria and filamentous fungi participate in the PH biodegradation (Rahman et al., 2003). In the past few years the biodegradation of ligninolytic fungi has been studied. Major enzymes in the lignin system including lignin peroxidases, manganese-dependent peroxidases, phenol oxidases (laccases and tyrosinases) and H2O2-producing enzymes, have been proven to degrade PAHs (Lee et al., 2015). Many species of fungi have been proven to have a high potential for PH degradation. Furthermore, numerous fungi are naturally living on soil waste and can be grown in soil and propagated during a solid matrix to remove PHs. Those criteria indicate to the environmental fungi role in bioremediation (Lee et al., 2015).

Table 1
PHs degradation by different species of fungi.

Fungi	Compound	References
Trichoderma harzianum	Naphthalene	Mollea et al. (2005)
Aspergillus fumigatus		Ye et al. (2011)
Aspergillus spp	Crude oil	Zhang et al. (2016)
Cunninghamella elegans	Phenanthrene	Romero et al. (1998)
Aspergillus niger	n-hexadecane	Volke-Sepúlveda et al. (2003)
Penicillium sp		Pointing (2001)
Cunninghamella elegans	Pyrene	Cerniglia and Yang (1984)
Aspergillus ochraceus	Benzo[a]pyrene	Passarini et al. (2011)
Trametes versicolor		Collins et al. (1996)
Penicillium sp. RMA1 and RMA2	Crude oil	Al-Hawash et al. (2018a)
Aspergillus sp. RFC-1	Different PHs	Al-Hawash et al. (2018b)

Factors influencing the degradation of PHs

Many studies and successful applications have been done in the treatment of contaminated soil and water. A comprehensive study on pollution caused by PHs and bioremediation methods has also been performed. The activity of microbial can be affected by the following factors: temperature, oxygen, pH and nutrients, see Fig. 1. For successful biodegradation, microorganisms should develop a catabolic activity by the following processes: new metabolic capabilities development by changes of genetic, induction of specific enzymes and eclectic enrichment of microorganisms that are capable to convert the pollutants. When conditions are favorable to the microorganisms, biodegradation of PHs will reach a maximum level. The chemical composition of the PHs is the fundamental and influential factor in biodegradation. Fedorak and Westlake (1981) reported that the aromatic hydrocarbons were attacked more quickly during the crude oil degradation by marine microbial populations. Rambeloarisoa et al. (1984) used a continuous culture fermenter and a mixed culture of marine bacteria, and showed that the degradation of all fragments of crude oil was at

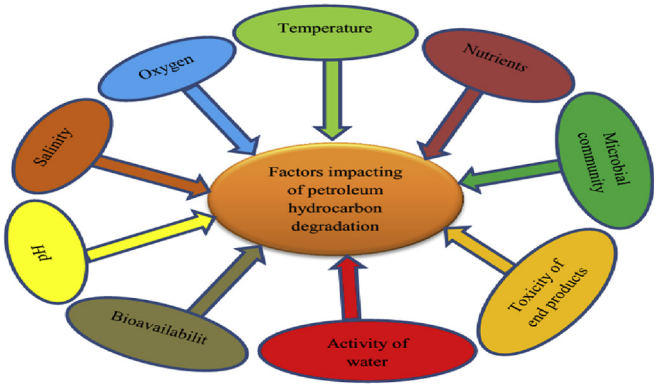

Fig. 1. Factors affecting in biodegradation of petroleum hydrocarbons.