Bioresource Technology 223 (2017) 277–286

Contents lists available at ScienceDirect

Bioresource Technology

journal homepage: www.elsevier.com/locate/biortech

Review

Microbial degradation of petroleum hydrocarbons

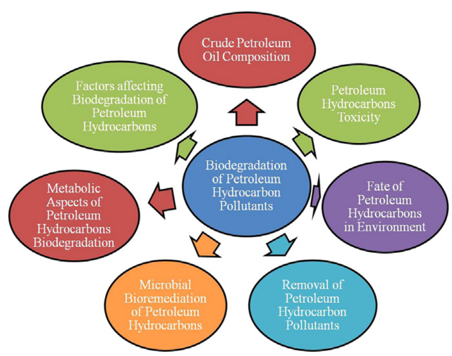
Sunita J. Varjani

School of Biological Sciences and Biotechnology, Indian Institute of Advanced Research, Gandhinagar 382007, Gujarat, India

HIGHLIGHTS

- Petroleum hydrocarbon pollutants are classified as persistent organic pollutants.
- These pollutants pose adverse effects on human and environmental health.
- Combat environmental pollution due to hydrocarbon pollutants is big issue for scientists.
- Biodegradation is an eco-friendly and economic method to control hydrocarbon pollution.
- Oleophilic microorganisms can be used for oil spill bioremediation.

GRAPHICAL ABSTRACT



ARTICLE INFO

Article history:
Received 18 September 2016
Received in revised form 12 October 2016
Accepted 13 October 2016
Available online 15 October 2016

Keywords:
Biodegradation
Enzymes
Crude oil
Petroleum hydrocarbons
Oil spill
Oleophilic

ABSTRACT

Petroleum hydrocarbon pollutants are recalcitrant compounds and are classified as priority pollutants. Cleaning up of these pollutants from environment is a real world problem. Bioremediation has become a major method employed in restoration of petroleum hydrocarbon polluted environments that makes use of natural microbial biodegradation activity. Petroleum hydrocarbons utilizing microorganisms are ubiquitously distributed in environment. They naturally biodegrade pollutants and thereby remove them from the environment. Removal of petroleum hydrocarbon pollutants from environment by applying oleophilic microorganisms (individual isolate/consortium of microorganisms) is ecofriendly and economic. Microbial biodegradation of petroleum hydrocarbon pollutants employs the enzyme catalytic activities of microorganisms to enhance the rate of pollutants degradation. This article provides an overview about bioremediation for petroleum hydrocarbon pollutants. It also includes explanation about hydrocarbon metabolism in microorganisms with a special focus on new insights obtained during past couple of years.

Contents

E-mail address: drsvs18@gmail.com

http://dx.doi.org/10.1016/j.biortech.2016.10.037
0960-8524/

1. Introduction

Petroleum hydrocarbons are important energy resource and a raw material for various industries. Increasing demand for petroleum products in day to day life may cause their scarcity and increase their cost as suitable alternatives are still not found (Varjani et al., 2015; Varjani and Upasani, 2016b). Petroleum hydrocarbon pollutants are recalcitrant compounds and are classified as priority pollutants (ATSDR, 2011; Costa et al., 2012). Anthropogenic activities such as industrial and municipal runoffs; effluent release; offshore and onshore petroleum industry activities as well as accidental spills cause petroleum hydrocarbon pollution. This pollution affects the environment and pose direct or indirect health risk to all life forms on planet earth (Margesin and Schinner, 2001; Deppe et al., 2005; Souza et al., 2014; Sajna et al., 2015). Marine environment is considered as the ultimate and largest sink for petroleum hydrocarbon pollutants, therefore it is necessary to combat pollution problem (Ron and Rosenberg, 2014; Varjani and Srivastava, 2015). Remediation of hydrocarbon pollutants and enhanced oil recovery are two main burning issues of petroleum industry (Sajna et al., 2015; Varjani et al., 2015; Varjani and Upasani, 2016a,c). To understand the scope and strategies of pollutant bioremediation it is essential to first understand properties of crude oil, environment of concern, fate of oil in that environment, mechanisms of crude petroleum biodegradation and factors that control its rate (Atlas, 1981; Boopathy, 2000; Varjani, 2014).

Mainly petroleum is constituted by saturates/paraffins, aromatics, resins and asphaltenes (Varjani, 2014). Crude oil is a mixture of variety of simple and complex hydrocarbons which are degraded by several indigenous microorganisms, each capable of breaking down a specific group of molecules (Zanaroli et al., 2010). Sugiura et al. (1997), and Ghazali et al. (2004), have reported that same compound in different crude oil samples was degraded to different extents by same organisms/consortium, the reason could be bioavailability of a particular compound in a crude oil sample and not it's chemical structure.

Bioremediation of crude oil polluted sites is often limited due to poor biodiversity of indigenous microflora and/or scarcity of native specialized microbes with complementary substrate specificity required for degrading different hydrocarbons occurring at polluted site (Ron and Rosenberg, 2014). There are various reports available on metabolic versatility of mixed cultures that have demonstrated superiority of mixed cultures to pure cultures to utilize hydrocarbon pollutants in petroleum crude as sole carbon source (Cerqueira et al., 2011; Das and Chandran, 2011; Varjani et al., 2013). Bacterial and fungal co-culture(s) have shown improved degradation rates of diesel oil and many polyaromatic hydrocarbons (PAHs) when checked in laboratory conditions (Li et al., 2008; Wang et al., 2012; Varjani and Upasani, 2013). Hence catabolic cooperation between different microbial groups during biodegradation is very important (Atlas, 1981; Varjani et al., 2015).

The intent of present review is to expand bioremediation scope of petroleum hydrocarbon pollutants. It includes consideration of toxicity and fate of petroleum hydrocarbons in environment. It also discusses factors affecting biodegradation rate, microbial metabolism of petroleum hydrocarbon pollutants, pathways for hydrocarbon pollutants degradation and types of bioremediation technologies as well as processes.

2. Composition of crude petroleum oil

Petroleum is produced by thermal decay of buried organic material over millions of years. Crude oil (naturally occurring raw oil) once extracted from subsurface is transported to refineries where it undergoes distillation to produce various products (Speight, 2007; Varjani, 2014). *Petroleum*, in Latin means "*rock oil*", which occurs as a dark, sticky, viscous liquid (Vieira et al., 2007). Petroleum hydrocarbons mainly consists of varying proportions carbon and hydrogen. However they also contain nitrogen, sulfur and oxygen in some amount (Chandra et al., 2013; Varjani et al., 2015). Crude oil can be classified as light, medium or heavy oil based on relative proportions of heavy molecular weight constituents present in it (Varjani, 2014). Crude oil composition may vary with location and age of an oil field as well as depth of oil well. About 85% components of all types of crude oil can be classified as (a) asphalt base, (b) paraffin base and/or (c) mixed base (Atlas, 1981; Varjani, 2014).

Crude oil is categorized in four broad fractions (a) Saturates (aliphatics), (b) Aromatics (ringed hydrocarbons), (c) Resins and (d) Asphaltenes (Balba et al., 1998; Widdel and Rabus, 2001; Speight, 2007; Chandra et al., 2013). Saturates are defined as hydrocarbons without double bonds and represent the highest percentage of crude oil constituents. They are categorized according to their chemical structures into alkanes (paraffins) and cycloalkanes (Abbasian et al., 2015). Aromatic hydrocarbons have one or several aromatic rings usually substituted with different alkyl groups (Meckenstock et al., 2016). In comparison to saturated and aromatic fractions, resin and asphaltenes contain non-hydrocarbon polar compounds. Resins and asphaltenes have very complex and mostly unknown carbon structures with addition of many nitrogen, sulfur and oxygen atoms (Harayama et al., 2004; Chandra et al., 2013). Each component has a unique chemical behavior that affects their biodegradability (Costa et al., 2012). In structural arrangement of four main hydrocarbon components of crude oil, saturates make up the outermost layer, whereas asphalthenes being greater molar mass component constitute the innermost portion of oil (Speight, 2007; Varjani, 2014).