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Biodegradation of Petroleum Hydrocarbon Contaminated Wastes: A Review

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ABSTRACT

In industrialized countries petroleum effluents, oily sludge and oil spills are the biggest threat to the environment as they produce toxic, mutagenic and carcinogenic substances and contaminating soil and groundwater affecting flora and fauna adversely. Management of this waste material is the biggest challenge to the petroleum industry through conventional methods (pit formation). Petroleum is a complex mixture of hydrocarbons and related compounds generally classified into four fractions: aliphatic, aromatic, polars or resins and asphaltenes. Aromatics and polars are considered as less degradable than aliphatics while asphaltene is classified as non biodegradable. Biodegradation is complete mineralization of organic constituents of wastes into harmless CO_2, water and inorganic components through enzymatic action of microbial populations in environment friendly manner. Moving forward in this direction TERI (Tata Energy and Resources Institute) and IOCL (Indian Oil Corporation Ltd.) successfully invented a group of microbial consortia named "Oilzapper" and OiliVorous" respectively, which can degrade oily wastes completely. This paper will provide an overview of biodegradation of petroleum wastes by microbial consortia which can be proved beneficial for the students, researchers and industries for their respective innovations.

Highlights

- Microbial consortia 'Oilzapper' contain five kind of microbial strains while 'OiliVorous' contains six microbial strains.
- Both of microbial consortia degrade oily wastes in environment friendly manner.
- 'OiliVorous' is more efficient than 'oilzapper' to degrade oily wastes.

Keywords: Biodegradation, petroleum waste, Oilzapper, OiliVorous

One of the biggest and most frequent problems for any petroleum refinery is oil sludge. There are 22 refineries in India and all create toxic waste. It was estimated that more than 20.000 tonnes of petroleum sludge is generated every year indigenously. In past, refineries had to construct polymer-lined pits with a special leachate collection system to prevent the dumped sludge from leaking into the earth and groundwater. A pit requires broad space and each refinery needs several such pits which costs 10 million/pit. Since oil is lighter than water it floats above water and catches fire swiftly, endangering the ecosystem of rivers and waters. Oil spills on land (due to leakage from pipelines, pilferage, etc.) too cause fire hazards and pollute soil, groundwater and air. The contamination of soils and groundwater with petroleum compounds is among the most prevalent problems in environments worldwide (Alquati *et al.* 2005). Oil contamination has also severe impacts in the plant and animal ecosystem including human health (Mandal *et al.* 2007). Crude oil exposure may cause damage to lungs, liver, kidneys, intestines and other internal organs as they are carcinogenic. Polycyclic aromatic hydrocarbons (PAH), a component of petroleum may lead to cancer, Inhalation leads to headache, nausea, dizziness, respiratory irritation while other constituents i.e. BTEX (Benzene, Toluene, Eethyl benzene & Xylene)

cause mutations, cancers, birth defects, nervous disorders, liver disease, irregular heartbeats etc. (Mandal *et al.* 2012). Oil contaminated soil lose its fertility and have impact on seed germination and plant growth and development (Yoshida *et al.* 2006). Hence disposal of the oily waste in an improper manner may cause a serious environmental problem,Various conventional methods like land filling, incineration, air spurging, etc. have been applied since early times for remediation of oily waste (Vidali 2011). It was observed that none of the conventional methods is environment friendly solution (Sood *et al.* 2009). The most common drawback is that they are not the permanent and effective solution for the environmental pollution (Mandal *et al.* 2007). Now-a-days, In situ biodegradation is a major practice in oil refineries by which petroleum and other hydrocarbons are eliminated from the environment. Bacteria which can metabolise and degrade hydrocarbon based waste constituents, are widely distributed in marine, freshwater, soil habitats and their use in bioremediation of hydrocarbon-contaminated soils has been established as an efficient, environment friendly and economical treatment of oily wastes (Margesin and Schinner 1997).

Petroleum compounds consist of four fractions: saturated hydrocarbons, aromatic hydrocarbons, nitrogen-sulphur-oxygen (NSO) containing compounds and asphaltenes. Normally, of the saturated hydrocarbons, the straight-chain *n*-alkanes are most susceptible to biodegradation, whereas branched alkanes are less vulnerable to microbial attack. The aromatic fraction is more difficult to biodegrade and the susceptibility of its components decreases as the number of aromatic or alicyclic rings in the molecule increases (Barthakur 1997). Polycyclic (polynuclear) aromatic hydrocarbons occur extensively as pollutants in soil and water and are important environmental contaminants because of their recalcitrance. The nitrogen-sulfur-oxygen containing and aspholtene fractions will not be addressed here. Microorganisms that biodegrade the components of petroleum hydrocarbons are isolated from various environments, particularly from petroleum-contaminated sites (Whyte et al., 1997).

Oilzapper: One of the biggest and most frequent threats for any oil refinery is oil sludge. There are 16 refineries in India and all create toxic waste. Estimates suggest that about 20 000 tonnes of petroleum sludge is generated every year. At present, refineries have to construct polymer-lined pits with a special leachate collection system to prevent the dumped sludge from leaking into the earth and groundwater. A pit costs about 10 million rupees and each refinery needs several such pits. With more refineries being set up, space is always a constraint. What's more, a pit gets filled up in three to four years whereas with Oilzapper, one just needs 200 tonnes of environment-friendly bacteria to clean up 20 000 tonnes of oily waste. When an oil spill occurs at sea, oil floats above water since it is lighter.

Table 1: Details of amount oily sludge treated in India (according to TERI)

Refinery/ Oil installation site	Quantity of sludge treated (tonnes)
Indian Oil Corporation Ltd.	
- Mathura	3750
- Barauni	11400
- Digboi	1000
- Guwahati	80
- Gujarat	1650
- Haldia	3500
- Kanpur	50
Bharat Petroleum Corporation Ltd., Mumba, Hindustan Petroleum Corporation Ltd.	300
Visakhapatnam	2350
Oil India Ltd., Duliajan	700
Reliance Refinery, Jamnagar	20
Indian Petrochemicals Ltd., Nagothane	50
Hindustan Petroleum Corporation Ltd., Panipat	10
Hindustan Petroleum Corporation Ltd., Kandla	100
Indian Oil Corporation Ltd., Rajkot	350
Oil and Natural Gas Corporation Ltd.	
- Jorhat	200
- Mehsana	370
- Nazira	250
- Sanatnagar	20
Total	**26150**

It therefore catches fire swiftly, endangering the ecosystem for all times. Oil spills on land (due to leakage from pipelines, pilferage, etc.) too cause

fire hazards and pollute groundwater and air. With Oilzapper, a contamination of 20% (say, 200 grams per kilogram of oil) can be taken care of in two months. A blessing for the oil exploration and production sites and oil refineries, the Oilzapper has proven particularly relevant in the wake of the everincreasing movement of oil across land and water, the many oil-transport related accidents in the past and oilwaste management issues at the refineries.

"OiliVorous S": This is a blend of microbes adsorbed on a naturally occurring biodegradable carrier matrix has been named 'OiliVorous' and is currently under trademark protection. Depending upon the compositional characteristics and source/ type of sludges to be treated, the variants of microbial mix are designated as 'OiliVorous-S'for tank bottom sludge and 'OiliVorous-A'for acidic sludge. The major attributes of the product are: It contains "Natural Isolates, "Not Genetically Modified" Safer to handle, no disease causing organisms, excellent capability to degrade wide range of hydrocarbon contaminants including organosulur compounds. The technology has been widely used for treatment of oily sludge at various refinery locations and the application rate of OiliVorous-S/ Acidic consortium, the biodegradation profile, the requirement of tilling, irrigation and nutrient application, cost of treatment of sludge and ecological safety of the process has been well established. Further, OiliVorous-S can be effectively employed for disposal of oily sludge generated at Oil refineries for crude oil tank, bottom sludge, Marketing installations for product storage tank sludge, Pipeline installations, Drill cuttings, and oil spills at oil exploration sites. In addition, a large volume of valuable data was generated for future applications.

The 'Oilzapper' (blend of five different microbial strains) and 'OiliVorous' (blend of six different microbial strains) have not just snapped up wasted oil but also several eminent scientific awards in India and outside like the All India Biotech Association Award 2001, given by the All India Biotech Association, New Delhi; the Biotech Product & Process Development for Commercialization Award 2002 by the DBT, Government of India; the Jawaharlal Nehru Memorial National Gold Medal Award 2002 for excellence in Environmental Biotechnology Research by the International Greenland Society, Hyderabad; and the Best Paper Oral Presentation award in the 5th International Petroleum Conference and Exhibition (PETRO-TECH 2003) organized by the Oil and Natural Gas Corporation Ltd, India; the National Petroleum Management Programme Award 2002/03 for Creativity and Innovation in the R&D category by the Ministry of Petroleum and Natural Gas, Government of India; and the Burhani Foundation-NEERI Award 2002 by the National Environmental Engineering Research Institute, Nagpur. A cheap-and-quick solution to one of the most menacing environmental issues sure deserves these accolades.

CONCLUSION

This technology not only offers a solution to the problem of oily sludge generation, it is also being taken up now in a big way to bioremediate contaminated soil, tackle oil spills on land and also to dispose off large inventory of historically accumulated sludge in both upstream and downstream sectors of oil industry. The cost effectiveness of this technology provides much sought after solution to the problem of historically accumulated sludge not only in India but also overseas. Bioremediation, offers immense potential for hazardous waste disposal and for remediation of contaminated land not only in the hydrocarbon industry, other chemical industries can also benefit from it. Nowadays, acceleration of petroleum hydrocarbon biodegradation through biotechnological processes with the use of effective bacteria cultures (isolated from severely contaminated areas) has been among the most common research. Due to relatively low costs and high effectiveness, biological methods have been applied in a technical scale. This technology can therefore be extended to find solutions to other industries also.

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