IJCRT.ORG ISSN : 2320-2882

INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)
An International Open Access, Peer-reviewed, Refereed Journal

BIOREMEDIATION OF PETROLEUM SLUDGEFROM OIL REFINING OPERATIONS

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Abstract: Various industries release harmful petrochemical contaminants into the environment. To treat these petrochemical contaminants at source, different physical, chemical, and biological methods have been proposed and applied worldwide. However, physical and chemical methods have their own advantages and limitations, in this review we majorly focused on the biodegradation of petrochemical wastes. Firstly, a background study on the literature available in this field is presented. This is followed by a review of the toxic effects of petrochemical waste and various physical and chemical proceses, followed by elaborate biological processes available for petrochemical waste degradation. Further, different aspects of bioremediation, such as modes, factors, limitations, and future perspectives are critically reviewed and presented. It was found that most of the studies performed on bioremediation of petrochemical waste employed bacteria for the degradation purpose. Some studies also made use of algae, fungi, yeast, genetically modified organisms, biosurfactants, or a consortium of these microbes. Moreover, bioremediation is having still limited use at field-scale due to certain limitations which have been elaborated in this article. Overall, we strongly believe that with bioremediation capturing the attention of environmentalists worldwide and need to scale up from lab to land.

***IndexTerms* -** Oily sludge, Bioremediation, Biodegradation, Biosurfactants, Organic pollutants, Petrochemical wastes.

I. INTRODUCTION

Resource-intensive human activities such as mining, crude oil extraction, natural gas production, etc. have modernized our society and made our lives more comfortable, at the cost of increased environmental pollution several folds. Major wastes generated from these activities include BTEX (Benzene, Toluene, Ethylbenzene and Xylene) compounds, phenolic compounds, heavy metals, alkalis, oils, dyes, etc[1]. These compounds are classified as hazardous wastes. They are carcinogenic and have adverse impacts on human helth and environment. They contribute significantly to the pollution of surface and ground water. More than five million sites are identified as contaminated in which about 67% sites are contaminated with petrochemical compounds (some of which are volatile in nature) only [1] . In addition, recent studies have shown that BTEX and other petrochemical compounds are also present in abundance in urban ambient air majorly from gasoline (derived from crude oil) [3]. These compounds adversely impact our planet's health, and therefore, require urgent remediation. The methods available and used for degradation of BTEX and other petrochemical waste products can be categorised into various physical, chemical, and biological categories, depending upon the waste type and composition. Physical methods such as gravity separation, adsorption, membrane separation, reverse osmosis (RO), nano-filtration (NF), ultra-filtration (UF), and micro-filtration (MF) are increasingly being applied for treating oily wastewater. However, these methods have various limitations like production of large volumes of sludge, high cost of equipments, high operating costs etcs [2].
Biological methods used to treat petrochemical waste include activated sludge, trickling filters, sequencing batch reactors, chemo-state reactors, biological aerated filters, bioremediation, bioaugmentation, etc [8]. Bioremediation is a process in which metabolic and enzymatic capabilities of microbes are employed to detoxify or mineralize pollutants, ultimately leading to their degradation [6]. Bioremediation can be done in-situ or ex-situ. When bioremediation occurs on its own, it is termed as 'natural attenuation'; however, when nutrients are added externally so as to stimulate naturally occurring microbes capable of bioremediation, the process is referred to as 'bio stimulation'. When specific microbes are introduced to treat a pollutant, the process is termed as 'bioaugmentation'. Biodegradation of petrochemical waste by indigenous microbial population is one of the most eco-friendly, energy- efficient and cost-effective processes for the remediation of petrochemical pollutants[7]. The most attractive advantage of bioremediation is the generation of basic non-harmful elements like carbon, nitrogen and hydrogen as end-products which easily get assimilated into the environment (El-Naas et al., 2014b). Also, bioremediation efficiency of indigenous microorganisms can be significantly enhanced by optimizing certain factors like adsorption,mass transfer and bioavailability [1].

II. Various Method Used

2.1. BIOPILE/COMPOSTING:

The treatment method whereby petroleum wastes are turned into piles meant for degradation through indigenous or extraneous micro-organisms is known as Bio pile. This treatment technology can replace land treatment which requires large areas of land. This technology is called composting when organic materials are added to improve its efficiency S[7] . Wang et al. reported that addition of bulking agent cotton stalk can significantly improve the metabolic microbial activity when composting is employed in the treatment of oily sludge. Bio-augmentation using crude manure and straw was found to reduce the TPH content by 46-53% during the composting of oily sludge within

56 d in the piles whilst 31% reduction rate was recorded for control piles. Biopile/composting treatment is environmentally friendly and requires less land space compared to landing farming; however, large area of land is still needed and is also consume more time [11].

2.2. LAND FARMING:

Land farming treatment is a biological, chemical, and physical degradation of oily sludge contaminants by mixing it with soil. Land treatment is more preferable to other disposal methods because of its low cost, low energy consumption, has potential to accommodate large volumes of sludge, and require simple operating procedure . However, it is time consuming and requires a very large area of land; it may not be effective in cold regions. Marin et al. reported that land farming treatment of oily sludge can remove 80% of PHCs within 11 mon of treatment in a semi-arid climate, the removal of half of the oily sludge occurred within the first three months [9].

2.3. BIOSLURRY TREATMENT:

This method of treatment involves the mixture of sludge-associated solids and water (5-50% w/v), the contaminants is dissolved into the aqueous phase where solubilized pollutants will be obtained in large quantity. Microbial degradation of the pollutants will reduce the toxicity or turn the end product into carbon dioxide and water. Ayotamuwo et al. reported that a TPH reduction of 40.7-53.2% can achieved within two weeks and 63.7-85.5% can be achieved within six weeks in the application of bio-slurry treatment for oily sludge [13].

III. SELECTING CRITERIA AND COMPARISON

Bioremediation demonstration project focused on the clean-up technique known as“biopiles”. The biopile process is very similar to active bioventing, where air, as an oxygen source, and other amendments are forced through the vadose zone sediments either by vacuum extraction or by injection to stimulate the microbial oxidation of the hydrocarbons(for a complete set of definitions see Hazen. As the name implies, biopiling is an exsitu process [3]. The contaminated material is excavated and recombined or amended with other materials e.g., nutrients, sand, sawdust, wood chips, compost or other similar bulking agents, as needed, to improve permeability and moisture retention, and then placed in an engineered structure (configuration), to support and stimulate the biological reactions necessary to oxidize the hydrocarbons [11]. Typically, this is a composting process which utilizes forced air via injection or vacuum extraction, moisture control, nutrient addition and environmental monitoring. Using commercially available vacuum pumps, or blowers, leachate pumps, moisture probes, thermocouple temperature probes, and real time soil gas monitoring equipment provides a mature and effective technology base for the operation and monitoring of the biopile [16].

THP Biodegradation Rate by Operating Campaign and Treatment [5]:

Campaign	Average	Passive	Active
OC-1	80	44	119
OC-2	88	82	94
OC-3	<33	33	0
OC-4	<37	0	37
OC-5	91	60	121

THP Inventory by Operating Campaign [5]:

	Baseline	OC1	OC2	OC3	OC4	OC5
MetricsTons	148	100	68.6	66.8	66.8	28.1

% Remaining	100	68	46	46	45	19

IV. COST ESTIMATION

	Polish Z	US $
Total Costs	$594,882	$401,405
Cost /cy remediated M.T	$142.76	$96.33
Cost/cy less special equipment	$105.35	$86.98

Cost Analysis of the biopile project[12]:

Bioremediation Treatment Costs	Cost/CY	Reference
Biopile costs at LSL	$30.75	Kastner et al [10]
Prepared Bed bioreactor	$46.07	Kastner et al [10]
Land Treatment	$10-$100	EPRI [1988]
Bio Treatment	$40-$100	Levin and Gealt [1993]
Bioremediation	$39-$111	Molnaa and Grubbs [13]

V. RESULTS AND CONCLUSION

This study presents a comparative study of a critical assumption for the successful demonstration of the technology is that the system, as designed, will function with little or no down time and provide operating conditions that minimize fugitive air emissions and maximize biodegradation rates[16]. The equipment and operation went through a number of delays during the initial 3 months of operation, due to differences in voltage, planning, weather and manpower delays from a variety of sectors in this multi-institutional and multi-national demonstration.The simplistic design served theproject well and helped make the project the success it was[17].

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