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BIOREMEADIATION OF OILY SLUDGE- A REVIEW

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Abstract: ***Different approaches have been tried since early times to overcome the problem of oily sludge. Some of them are known as, land filling, incineration, natural remediation (like evaporation of volatile organic compounds, auto oxidation, photo oxidation, etc.), land farming, surfactants, and other conventional methods like chemical dissociation, dumping in injection wells, surface impoundment, waste piles, underground injection wells, etc. However the common drawback in all these conventional methods is that they are not the permanent solution and sometimes not cost effective. Therefore, environment friendly technologies are increasingly in demand today for management of oily waste. Natural diversity of soil microorganisms is a useful source for detoxification of hazardous waste contamination sites. The use of bacteria in breakdown and digestion of oily sludge is a biological process known as bioremediation. These beneficial microbes break down a wide variety of toxic substrates present in the oily sludge to the safest form which does not harm the environment. Bioremediation is the most eco-friendly and economically viable among all the available methods of oily sludge management.***

Keywords: Bio augmentation, Bio remediation, Bio stimulation, Bioreactor, Composting, Land farming Landfilling, Oily Sludge

GENERAL INTRODUCTION

Bioremediation is the use of microorganisms for the degradation of hazardous chemicals in soil, sediments, water, or other contaminated materials. Often the microorganisms metabolize the chemicals to produce carbon dioxide or methane, water and biomass. Alternatively, the contaminants may be enzymatically transformed to metabolites that are less toxic or innocuous. It should be noted that in some instances, the metabolites formed are more toxic than the parent compound [3].

Bioremediation is a process that uses naturally occurring microorganisms to transform harmfulsubstances to nontoxic compounds. There are two basic types of bioremediation:"Bio stimulation" provides nutrients to the indigenous microbial populations. This promotes growth and increases metabolic activity that is used to degrade contaminants. "Bio augmentation" introduces specific blends of microorganisms into a contaminated environment or into a bioreactor to initiate the bioremediation process, which increases the population of the fit to handle the bio-degradative process in the contaminated area.

Factors that affect the performance of the bioremediation process are mainly the type of oil contamination, pH and moisture content of the oily sludge, climatic conditions of the location, type of water used for the process etc. [1].

A. ***Potential Advantages and Disadvantages of Bioremediation Technologies***

a. Advantages of bioremediation:

Bioremediation is a natural process and is therefore perceived by the public as an acceptable waste treatment process for contaminated material such as soil. Microbes able to degrade the contaminant increase in numbers when the contaminant is present; when the contaminant is degraded, the biodegradative population declines. The residues for the treatment are usually harmless products and include carbon dioxide, water, and cell biomass. [8]

- Theoretically, bioremediation is useful for the complete destruction of a wide variety of contaminants. Many compounds that are legally considered to be hazardous can be transformed to harmless products. This eliminates the chance of future liability associated with treatment and disposal of contaminated material.
- Instead of transferring contaminants from one environmental medium to another, for example, from land to water or air, the complete destruction of target pollutants is possible.
- Bioremediation can often be carried out on site, often without causing a major disruption of normal activities. This also eliminates the need to transport quantities of waste off site and the potential threats to human health and the environment that can arise during transportation.
- Bioremediation can prove less expensive than other technologies that are used for clean-up of hazardous waste. [8]

b. Disadvantages of bioremediation:

- Bioremediation is limited to those compounds that are biodegradable. Not all compounds are susceptibleto rapid and complete degradation.
- There are some concerns that the products of biodegradation may be more persistent or toxic than the parent compound.
- Biological processes are often highly specific. Important site factors required for success include the presence of metabolically capable microbial populations, suitable environmental growth conditions, and appropriate levels of nutrients and contaminants.
- It is difficult to extrapolate from bench and pilot-scale studies to full-scale field operations.
- Research is needed to develop and engineer bioremediation technologies that are appropriate for sites with complex mixtures of contaminants that are not evenly dispersed in the environment. Contaminants may be present as solids, liquids, and gases.
- Bioremediation often takes longer than other treatment options, such as excavation and removal of soil or incineration.
- Regulatory uncertainty remains regarding acceptable performance criteria for bioremediation. There is no accepted definition of “clean”, evaluating performance of bioremediation is difficult, and there are no acceptable endpoints for bioremediation treatments. [8]

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INTRODUCTION TO BIOREMEDIATION OF OILY SLUDGE

B. ***Source, characteristics, and toxicity of oily sludge:***

a. ***Oily sludge source:*** Both the upstream and downstream operations in petroleum industry can generate a large amount of oily wastes. The upstream operation includes the processes of extracting, transporting, and storing crude oil, while the downstream operation refers to crude oil refining processes. The oily waste generated in petroleum industry can be categorized as either simple oil or sludge depending on the ratio of water and solids within the oily matrix.

In the upstream operation, the related oily sludge sources include slop oil at oil wells, crude oil tank, bottom sediments, and drilling mud residues. A variety of oily sludge sources exist in downstream operation, including (a) slop oil emulsion solids; (b) heat exchange bundle cleaning sludge; (c) residues from oil/water separator, such as the American Petroleum Institute (API) separator, parallel plate interceptor, and corrugated plate interceptor (CPI); (d) sediments at the bottom of rail, truck, or storage tanks; (e) sludge from flocculation–flotation unit (FFU), dissolved air flotation (DAF), or induced air flotation (IAF) units, and (f)excess activated sludge from on-site wastewater biological treatment plant.[4]

b. Characteristics of oily sludge: The pH value of oily sludge is usually in a range between 6.5and 7.5 and its chemical composition varies over a wide range, depending on crude oil source, processing scheme, and equipment and reagents used in refining process.

The PHCs and other organic compounds in oily sludge can be generally classified into four fractions, including aliphatics, aromatics, nitrogen sulphur oxygen (NSO) containing compounds, and asphaltenes. Usually, oily sludge is com-posed of 40–52% alkanes, 28–31% aromatics, 8–10% asphaltenes,and 7–22.4% resins by mass. As a result of diverse chemical compositions in oily sludge, its physical properties such as density, viscosity, and heat value can vary significantly. The property measurements obtained from one oily sludge source cannot be applied to another source or to another sludge sample of the same source but collected on a different day or different location. [4]

c. Toxicity and impact of oily sludge: Theoily sludge contaminated soils may create nutrient deficiency, inhibit seed germination, and cause restricted growth or demisesof plants on contact. Due to its high viscosity, oily sludge components can be fixed in soil pores, adsorbed onto the surface of soil mineral constituents, or form a continuous cover on soil surface. These would lead to reduced hygroscopic moisture, hydraulic conductivity, and water retention capacity of soils.

The PHCs in oily sludge could migrate down through the soil profile and enter groundwater that is linked with other aquatic systems, causing serious adverse consequences such as reduced diversity and abundance of fish in the aquaticsystem.Covalent bonding between organic compounds in sludge residues and humic polymers (e.g., humin, fulvic acid, and humic acid) in soil could form stabledialkylphthalates, long-chain alkanes, and fatty acids that are resistant to microbial degradation. [4]

C. ***Bioremediation process:*** Petroleum industries unavoidably generate enormous quantity of oily sludge /oily soaked soil which constitutes a major challenge for hazardous waste management. Some of the environmental impacts due to oil contamination can include: physical and chemical alteration of natural habitats, lethal or sub-lethal toxic effects on the marine life, changes in the marine ecosystem, aquatic birds die due to hypothermia, drowning loss in flight, poisoning, etc. Crude oil exposure may cause damage to lungs, liver, kidneys, intestines and other internal organs of the birds and animals, reproductive impairment in birds, fish and reptiles. Polycyclic aromatic hydrocarbons (PAH) may lead to skin erythema (reddening), skin cancer, sinonasal cancer, gastrointestinal cancer, and bladder cancer, Inhalation leads to headache, nausea, dizziness, respiratory irritation, BTEX (Benzene, Toluene, Eethyl benzene & Xylene) present in the oil contamination, cause mutations, cancers, birth defects, endocrine disruptions, stillbirths, nervous disorders, liver disease , depression and irregular heartbeats. Plants covered by the oil are unable to photosynthesize. Oil contaminated soil loses its fertility. The mites and other insects cannot survive in oil contaminated land, leading to a major imbalance in the food chain [1].

Bioremediation can occur either in situ (at the site of contamination) or ex situ (contaminant taken out of the site of contamination and treated elsewhere).Bioremediation therefore is a scientifically intensive procedure, which must be tailored to the site-specific conditions. There are different number of *ex-situ* and *in- situ* methods which include biostimulation, bioaugmentation, landfilling, landfarming, bioreactors, and composting. [10]

a. Biostimulation: This involves the management of the natural environment to optimise the growth and activity of the natural microbial population. Biostimulation of indigenous degrading bacteria as a tool in bioremediation process should be encourage, because the process relies on the degrading bacteria that have already adapted to the site's conditions.[10]

b. Bioaugmentation This technique refers to the introduction of specialized or genetically engineered microorganisms that target specific chemical compounds. These organisms have been developed to biodegrade most common organic contaminants ranging from polychlorinated biphenyls (PCBs), organic solvents and petroleum hydrocarbons.[10]

c. Landfilling Landfilling is a deliberate dumping of oil sludge into land (pit) with or without formal treatment. It has been the most common form of sludge disposal. This process has limitations as it requires a large land area and volatile organic compounds are emitted if the oil sludge is not treated before disposal. Most times, the locations of Landfill sites for oil sludge disposal have been selected according to availability of land and convenience rather than consideration of the hydro geological features of the sites. This calls for more strict legislative restrictions on landfilling.[10]

d. Land farming Land farming involves the controlled application of the oil sludge on the land surface. This method requires tilling of the topsoil (for easy mixture with oil sludge), addition of water and addition of desired nutrient such as organic fertilizers and manures. Tilling in this process is important as it aids aeration, proper mixture of sludge and nutrient, thereby making the sludge bio-available for microbial degradation. Proper Land farming practice has minimal impact on the environment (good site appearance, absence of odour, relatively low-cost compliance with sound industrial practices and government regulation, minimal residue disposal problems and compatibility of the method with the climate, location and type of sludge treated). Land farming gained popularity over incineration and Landfilling following its advantages such as low energyconsumption, low risk of pollution of the surface and groundwater due to the immobility of hydrocarbons and metals through the soil.[10]

e. Bioreactor This uses petrozyme in a bioreactor process as a fermentation technology to degrade oil sludge into non-hazardous effluents with very low level of hydrocarbon. This method uses a naturally selected and acclimated indigenous bacterial culture supplemented with a carefully designed blend of nutrients such as nitrogen, phosphate, essential minerals and a surfactant for degradation. The design and process operating conditions of the technique promoted the growth of highly active microbial population, which rapidly converted the oil sludge components to carbon dioxide and water. It was further reported that the bacteria involved are known oil-degrading bacteria such as Pseudomonas, Acinetobacter, Rhodococcus and Alcaligenes.[10]

f. Composting Composting process which involves the careful control and addition of nutrients, watering, tilling, addition of suitable microbial flora and bulking agents (wood-chips or hay) were considered an alternative option to improve the bioremediation of oil sludgeThe process leads to the production of carbon dioxide, water, minerals and stabilized organic matter.Compost systems can be on three general bases: oxygen usage, technological approach and temperature. Oxygen usage is divided into aerobic and anaerobic. Aerobic composting involves the activity of aerobic microbes, and hence the provision of oxygen during the composting process.Anaerobic composting is characterized by low temperatures, the production of odorous intermediate products, and generally proceeds at a slower rate than aerobic composting.[10]

LITERATURE REVIEW

Ajoy Kumar Mandal et al "Developed, An indigenous microbial consortium by assemble of four species of bacteria, isolated from various oil contaminated sites of India, which could biodegrade different fractions of total petroleum hydrocarbon (TPH) of the oily waste to environment friendly end products. The said consortium was applied on field scale and successfully bioremediated>200,000 tonnes of different types of oily waste in India. In >200 field case studies of different batch size on in situ and ex situ bioremediation process, the initial TPH content varying from 5% to 52% has been biodegraded to <1% in major cases in 2 – 12 months. The bioremediated soil was non-toxic and natural vegetation was grown on the same. Successful fish culturing was done in one oil contaminated lake after bioremediation." [3]

I.G. Petrisor et alstudied on "The degradation of sludge hydrocarbons by selected bacterial consortia. The bioremediation studies were conducted at Potlogi Oil Field, Dambovita County (Southern Romania). The experiments were carried out in field plots with and without addition of special selected bacterial inoculums. The results from the periodic analyses of sludge samples from Potlogi field experiment indicate an over 90 % reduction of residual hydrocarbons in all the parcels, after 2 years. The degradation percentages increased gradually over the 2 year-period, with slightly higher rates in the first and the last 6 months. After the end of this experiment, bean and corn were cultivated on the parcels. The crop development was optimal, demonstrating the success of our field experiment." [6]

M. J. Ayotamunoa et al studied on "Bio-remediation of a sludge containing hydrocarbons. The use of bio-augmentation in the bioremediation of the BTIP oily sludge reduced the THC of the sludge from an initial 69,372mg/kg of sludge to 10,734mg/kg of sludge (representing an 84.5% reduction) after six weeks of treatment. But in the control reactor, only a 12.8% THC reduction was achieved during the same period. This shows that the addition of microbes enhanced the degradation of the oily sludge, which implies that bioaugmentation is an effective bioremediation technology for dealing with an oily sludge." [5]

TanviH. Makadia et al studied on "Re-use of remediated soils for the bioremediation of waste oil sludge. The possibility of re-using remediated soils for new bioremediation projects was investigated by spiking these soils with waste oil sludge in laboratory based microcosms. This study has shown that soils previously used for successful bioremediation possess sufficient microbial hydrocarbon degrading potential which can be re-harnessed for new bioremediation projects.It can also extend a landfill's lifespan as soils can be re used again before landfill disposal." [9]

Kiran H. Udiwal et al studied on "Restoration of Oil Contaminated Soil by Bioremediation for Ground Water Management and Environment Protection. Reduction in TPH has taken place within a period of 135 days from 7.87% to 0.7% and biodegradation reached to 90.98% at site -I indicate successful in-situ bioremediation of the oil contaminated soil. The land has become cultivated."[7]

CONCLUSION

- Based on this review, biodegradation could be considered as a key component in the cleanup strategy development in the future for treatment of oil sludge contamination keeping in mind consortia type and concentration.
- Unlike the conventional treatment technologies, bioremediation technique must be tailored specially to each polluted site. Each waste site has unique characteristics, and thus requires individual attention, so an official criterion for evaluation the success or failure of the particular strategy is needed.

In addition, a successful biodegradation program require a multidisciplinary approach, integrating fields such as microbiology, engineering, geology, soil science, and project management.

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