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Recent Development on Biological Treatment of Oil Sludge from Petroleum Industry

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ABSTRACT: *Oil sludge which contains water, sediment, hydrocarbons and other non-hydrocarbons needs to be treated to recover the useful content and appropriately dispose the waste. Out of the various treatment methods, biological treatment had been found to be economical and more environmental friendly. This paper reviewed the recent work done on biological treatment of oil sludge in the oil and gas industry with focus on treatment before its disposal into the environment. Oil sludge can be generally treated biologically by biostimulation, bioaugmentation, bioreactor processes and production/introduction of biosurfactants, bioremediation (which may also involve biostimulation or bioaugmentation), Land filling, land farming, bio pile/composting, bioslury,etc. However, for biological treatment of oil sludge before disposal into the environment biostimulation, bioaugmentation, bioreactors and bio-surfactant treatment should be considered. Apart from removing the hazardous components in the sludge, biological treatment before disposal can also aid recovery of useful oil content in the sludge. Several microorganisms have been investigated on their abilities to effectively treat oil sludge by biodegrading the hydrocarbons in the sludge and possibly recover some of the oil in the sludge. Bacillus sp and Pseudomonas sp of bacteria were found to be very effective in biological treatment of oil sludge.*

Keywords: *Bio-augmentation, bioreactor, bio-stimulation, bio-surfactant, Oil sludge*

I. INTRODUCTION

Oil sludge generation in the oil and gas industry is a great concern majorly because of the hazardous effects of some of its composition. It has been classified by the United States Environmental Protection Agency (US EPA) as a hazardous organic complex (USEPA, 1997; Liu *et al.* 2010). Ordinarily, oil sludge may be regarded as a thick, soft, wet, mud. It is a complex viscous mixture of oil, solids, and water deposited at the storage tank bottom (Greg *et al.*, 2004, Verma *et al.*, 2006). As a result of its hazardous content there is need for adequate treatment of oil sludge before disposing the treated effluent into the environment. Oil sludge is the remains commonly found at the base of tank and other storage facilities in the petroleum industry. It was observed that about 50 tons of oily sludge per year could be generated by a petroleum refinery with a production capability of 105,000 drums per day (Ling and Issa, 2006). This will constitute a huge source of environmental hazard to man and other living organisms at the end of the year if not properly handled. Crude oily sludge is a recurrent problem leading to corrosive effects and a reduction in oil storing capacity. The economic effect includes the cost of sludge removal and disposal, where the greater expense is the disposal fee of the environmentally-unfriendly material (Johnson and Affam, 2019). Furthermore, adverse effects of oil sludge on soil ecology and fertility have been of growing interest among environmental scientist and an important consideration in the development of efficient technologies for remediation of contaminated land, with a view to making such land available for further use (Ubani *et al*, 2013; Johnson and Affam, 2019). The environmental impact of oil sludge contamination includes physical and chemical alteration of natural habitats, lethal and sub-lethal toxic effects on aquatics and terrestrial ecosystem. Some content of oil sludge like semivolatile organic carbons (SVOCs) and volatile organic carbons (VOCs) are genotoxic (Mishra *et al.*, 2001; Bach *et al.*, 2005; Bojes and Pope, 2007; Ubani *et al*, 2013). They have cumulative effect on the central nervous system (CNS) leading to dizziness, tiredness loss of memory and headache, and the effect depends on duration of exposure. Metabolism of some SOVs like polyaromatic

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hydrocarbon (PAH) in the body of human being produces epoxide compounds with mutagenic and carcinogenic properties that affects the blood, immune system, skin, liver, lungs, spleen, kidney and developing foetus (TERA, 2008; API, 2008; Sidney, 2008; Bayoumi, 2009). This can also result in loss of weight among men (Ubani *et al*, 2013).

However, environmental regulations in many parts of the world have stressed on the necessity to decrease emission of volatile organic compounds as well as PAHs, and have placed more restriction on land disposal of oil sludge (Mahmoud, 2004). The various method of treatment of oil sludge include Chemical treatment (solvent extraction, addition of demulsifying agents or tension active chemicals, surfactant recovery) (Taiwo and Otolorin, 2009; Zubaidy and Abouelnasr , 2010; El-Naggaar *et al*., 2011; Al-Doury, 2019), biological treatment (biosurfactant treatment, biofloating, biostimulation, bioaugmentation,) (Rahman *et al.*, 2003; Zhang *et al*., 2007; Cerqueira *et al.*, 2011; Ubani *et al.*, 2013; Lima *et al.*, 2011; Wenyu *et al.*, 2013; Atagana, 2015), thermal treatment (heating or injection of steam, incineration, sludge pyrolysis, temperature gasification), irradiation (microwave irradiation, ultrasonic irradiation), electrical (electrokinetic method), physical method (centrifugation) (Johnson and Affam, 2019).

II. COMPOSITION OF OIL SLUDGE

The composition of oil sludge depends on its source. Oil sludge sources from upstream operation include slop oil at oil wells, drilling mud residues, crude oil tank bottom sediments, and crude oil storage tank (Dara and Sarah, 2003). Also, oil sludge sources from downstream operation, include sediments at the bottom of rail, truck, or storage tanks, slop oil emulsion solids, residues from oil/water separator, heat exchange bundle cleaning sludge, excess activated sludge from on-site wastewater biological treatment plant and sludge from flocculation-flotation unit (FFU), dissolved air flotation (DAF), or induced air flotation (IAF) units (Van Oudenhoven *et al.*, 1995). It may be from crude oil storage tanks or refinery-wastewater treatment plants (Shie *et al.*, 2004; Wang *et al*., 2010). Crude oil temporarily housed in storage tanks has a propensity to separate into lighter and heavier petroleum hydrocarbons (PHCs), which often settle along with solid particles and water (Ayotamuno *et al.*, 2007). Oil sludge found in crude oil storage tanks, is mainly made up of saturates, aromatics, resins and asphalthenes (SARA) just as the typical composition of a crude oil is as well as water and solid sediments. The other non-hydrocarbon components of oil sludge are phenols, heavy metals, chlorinated hydrocarbons and inorganic solids such as sand, iron sulfides and iron oxides. In addition to these hydrocarbons and non-hydrocarbons, materials or chemical used in the refinery wastewater treatment plants may add to the list of oil sludge obtained from this source. Verma *et al.* (2006) opined that oil sludge contains complex mixture of petroleum hydrocarbons (such as alkanes, aromatics, resins and asphaltenes), sediments, heavy metals and water. The typical composition of sludge is 10–12% solids, 30–50% water and 30–50% by weight oil (Saikia *et al.*, 2003). Oil sludge with 51.8 to 57.1% of oil, 9.3 to 23.4% solid and water content of between 15 and 21% could be obtained from crude oil storage tank in Niger delta area of Nigeria during tank cleaning process (Taiwo and Otolorin, 2016). Asia *et al.* (2006) observed that elemental composition of petroleum sludge consists of Nitrogen, Phosphorous, Potassium, Iron, Copper, Calcium, Magnesium, Cadmium, Phosphate, Chromium, Zinc, Sodium, and Lead. The saturates PHCs in oil sludge range from C_8 to C_{40} straigth chain alkanes, naphtenes (cycloalakanes), Examples of the saturates that can be found in oil sludge are octane, decane, eicosane, tricosane, hentricontane, and pentatricontane, octadecane, phytane, nonadecane, heneicosane, docosane, tetracosane, pentacosane, hexacosane, heptcosane, octacosane, nanocosane dotricontane and hexatricontane, octadecane, phytane, nonadecane, pristine heneicosane, docosane, tetracosane, pentacosane, hexacosane, heptcosane, octacosane, dotricontane, tricontane, triatricontane, tetratricontane and hexatricontane (Taiwo and Otolorin , 2009; El-Naggar *et al.*, 2011). Li *et al.* (1995) in their study noted that oil sludge from crude oil storage vessels could be typically made up of sulphides, phenols, heavy metals, aliphatic and polycyclic aromatic hydrocarbons (PAHs) of 4, 5, 6 and more rings, in over 10 - 20 fold concentration Li *et al.* (1995). However, United States Environmental Protection Agency observed that high content of aromatic hydrocarbons ranging from C_6 to C_{40} could be found in oil sludge (USEPA, 1997). Examples of important PAHs that are of environmental concern present in oil sludge are 2-methyl naphthalene, acenaphthylene, acenaphthene, fluorene, anthracene, Naphthalene, 1-methyl naphthalene, pyrene, chrysene, benzo[a]anthracene, benzo[b]fluoranthene, benzo[k]fluoranthene, benzo[a]pyrene, indenol(1,2,3-cd) pyrene, phenanthrene and fluoranthene [Ubani *et al.*, 2013; Taiwo and Otolorin, 2009)].

III. MICROORGANISMS USEFUL FOR TREATING OIL SLUDGE

A substantial numbers of microorganisms have been found by researchers to have the capability of biodegrading some of the components of oil sludge. Microorganisms have different enzymatic abilities and preferences for the degradation of oil compounds depending on their species. For examples, some microorganisms degrade paraffins (linear or branched alkanes, naphthenes) while some degrade aromatics (mono- or polynuclear aromatics and their derivatives). Some microorganisms are capable of degrading both alkanes and aromatics. Various studies of microorganisms in bioremediation systems had made the selection of microorganisms with potential for the degradation and production of compounds with biotechnological applications in the oil and gas industry possible. Some of these investigated microbes are shown in Table 1. Atagana (2015) investigated biological degradation of crude oil refinery sludge with commercial surfactant and sewage sludge by co-composting. In the study, a mixture of oil sludge, surfactant, and sewage sludge was co-composted for 24 weeks in the laboratory while the physical and chemical parameters in the compost were measured every four weeks. The dominant bacterial species observed by the researcher were *Acinectobacter, Rodococcus, mycobacterium, Pseudomonas, Bacillus, Arthrobacter,* and *Staphylococcus* species and fungi were *Pleurotus, Penicillium,* and *Aspergillus sp* (Atagana, 2015). It was further observed that TPH was reduced by 92% in the sewage sludge and surfactant treatment while the PAH concentrations were reduced by between 75 and 100%. Lima *et al.*, (2011) went a step further by using five organisms with two of the five being the ones used in the other articles but of different strands: *Pseudomonas Aeruginosa* LBBMA 88A, *Bacillus sp* LBBMA 111A, *Dietzia maris* LBBMA 191, *Arthrobacter Oxydans* LBBMA 201, *Bacillus subtilis* LBBM 155 the biosurfactants produced by the five bacteria isolates from the LBBMA culture collection proved to be highly efficient for oily sludge treatment, and their use led to a 95% recovery of the oil contained in a fuel oil storage tank oily Sludge (Lima *et al.*, 2011). Cerqueira *et al*. (2011) investigated biodegradation capacity of aliphatic and aromatic hydrocarbons of petrochemical oily sludge in liquid medium by a bacterial consortium. The bacterial consortium was made up of five pure bacteria; three of the bacteria (*Stenotrophomonas acidaminiphila, Bacillus megaterium* and *Bacillus cibi*) were isolated from petrochemical oily sludge and the other two bacteria were (*Pseudomonas aeruginosa* and *Bacillus cereus*) isolated from a soil contaminated by petrochemical waste. When cultivated during 40 days, the bacterial consortium demonstrated an excellent oily sludge degradation capacity, reducing 90.7% of the aliphatic fraction and 51.8% of the aromatic fraction, as well as biosurfactant production capacity, achieving 39.4% reduction of surface tension of the culture medium and an emulsifying activity of 55.1% (Cerqueira *et al.*, 2011). The results indicated that the bacterial consortium has potential to be applied in bioremediation of petrochemical oily sludge contaminated environments, favoring the reduction of environmental passives and increasing industrial productivity (Cerqueira *et al.*, 2011). Yan *et al.* (2012) investigated oil recovery from refinery oily sludge using a rhamnolipid biosurfactant- producing *Pseudomonas aeruginosa* F-2, in laboratory and pilot-scale experiments. They observed that an oil recovery of up to 91.5% was obtained with the equipping of draft tubes during the field pilot-scale studies and that the strain F-2 has the potential for industrial applications and may be used in oil recovery from oily sludge.

Calvo *et al* (2004) studied the growth, biosurfactant activities and petroleum hydrocarbon compounds utilisation of strain 28-11 of *Bacillus pumilus* isolated from a solid waste oil. They observed that the strain grew well in the presence of 0.1% (w/v) of crude oil and naphthalene under aerobic conditions and utilised these substances as carbon and energy source. Furthermore *Bacillus pumilus* strain 28-11 looks promising application in environmental technologies due to its capacity to emulsify crude oil and ability to remove hydrocarbons (Calvo *et al.*, 2004). Dhote *et al.*, (2009) carried out studies to test the ability of the bacterial strains *Bacillus sp.* (Chry 2) and Pseudomonas sp. (Chry 3), isolated from the oily sludge obtained from Gujarat refinery, India, for biodegradtion of chrysene in the liquid medium. It was observed that the percent degradation of the compound was 15.0% by Chry 2 and 17% by Chry 3. The researchers noted that both strains possess catechol 1, 2-dioxygenase and catechol 2, 3-dioxygenase enzyme activities which indicated their potential for degradation of PAHs through meta cleavage degradation pathway. The strains thrived the presence of chrysene as the sole carbon source (Dhote *et al.*, 2009). Verma *et al.*, (2006) investigated bacterial strains, *Bacillus sp.* SV9, *Acinetobacter sp.* SV4 and *Pseudomonas sp.*, SV17 isolated from contaminated soil in Ankleshwar, India for their ability to degrade oily sludge. It was observed from gravimetric analysis that Bacillus sp. SV9 degraded approx. 59% of the oily sludge in 5 days at 30 °C whereas *Acinetobacter sp.* SV4 and *Pseudomonas sp.*

SV17 degraded 37% and 35%. It was further observed from their study that after 5 days the *Bacillus* strain was able to degrade oily sludge components of chain length C_{12}–C_{30} and aromatics more effectively than the other two strains and after 72 hours, maximum biosurfactant production (6.7 g l−1) in *Bacillus sp.* SV9 accompanied maximum drop in surface tension (from 70 to 28.4 mN/m). Thus, bacterial strain *Bacillus sp.* SV9 has considerable potential for bioremediation of oily sludge (Verma *et al.*, 2006).

Table 1 Microorganisms used in biological treatment of oil sludge

Type of Microbes	Microorganism	Researchers	Mode of treatment	Findings
Bacteria	*Arthrobacter sp* *Rodococcus sp.* *Pseudomonas sp.* *Bacillus sp.* *Mycobacterium sp.* *Acinectobacter sp.* *Staphylococcus sp.*	Atagana, 2015	Sewage sludge and surfactant treatment	TPH was reduced by 92% and PAH conc reduced by between 75 and 100%
	Bacillus sp. SV9, *Acinetobacter sp.* SV4 and *Pseudomonas sp.*, SV17	Verma et al., (2006)	Biodegradation in bacteria culture & Bioaugmentation	SV9 - 59%, SV4 - 37% and SV17 - 35% degrading capacity approx.
	Stenotrophomonas acidaminiphila, Bacillus megaterium, Bacillus cibi, Pseudomonas aeruginosa Bacillus cereus	Cerqueira et al, 2011	Biodegradation in bacteria culture & Bioaugmentation	Excellent oily sludge degradation capacity, reducing 90.7% of aliphatic and 51.8% of aromatic fractions; biosurfactant production capacity, 39.4%; surface tension reduction and emulsifying activity of 55.1%
	Pseudomonas aeruginosa *Bacillus subtilis* *Dietzia maris* *Arthrobacter Oxydans* *Bacillus sp.*	Lima *et al.*, 2011	Biosurfactant culture	95% recovery of the oil contained in a fuel oil storage tank oily Sludge
	Pseudomonas sp.	Yan et al., 2012.	Biosurfactant production and growth	Oil recovery of up to 91.5% was obtained
	Bacillus pumilus	Calvo et al., 2004	Bioaugmentation and bio surfactant activities	strain grew well in the presence of 0.1% (w/v) of crude oil and naphthalene
	Bacillus sp. (Chry 2) *Pseudomonas sp.* (Chry 3)	Dhote et al., 2009.	Bioaugmentation	Degradation of the compound was 15.0% by Chry 2 and 17% by Chry 3
Fungi	*Penicillium sp.* *Pleurotus, sp.* *Aspergillus sp.*	Atagana, 2015	Sewage sludge and surfactant treatment	TPH was reduced by 92% and PAH conc reduced by between 75 and 100%

IV. MECHANISMS OF THE BIOLOGICAL TREATMENT

To successfully exploit the microbial degradation of oil sludge, it is imperative to understand and master the mechanism needed in order to manipulate the microbial activities (Ubani *et al.*, 2013). Four biological methods namely biostimulation, bioaugmentation, bioreactors and production/introduction of biosurfactants are considered in this review for the treatment of oil sludge before disposal into the environment (either soil or water bodies). The two major methods employed biologically in treatment of oil sludge are biostimulation and bioaugmentation. The other two could be also very effective treatment methods, especially when useful oil from the sludge is to be considered.

4.1 Biostimulation

Biostimulation is the addition of limiting nutrients to support microbial growth (Adams *et al.* 2015). It involves stimulating existing bacteria that are capable of bioremediation within an environment (like petroleum sludge) by the modification of that environment. The modification of the environment can be done by addition of various forms of limiting nutrients and electron acceptors, such as nitrogen, phosphorus, oxygen and carbon, which may be present in the environment in little quantities low enough to constrain microbial activity (Adams *et al.*, 2015). Perfumo *et al.* (2006) described biostimulation as the addition of nutrients, oxygen or other electron donors and acceptors to the coordinated site (e.g. petroleum sludge) in order to increase the population or activity of naturally occurring microorganisms available for bioremediation. Furthermore, biostimulation may be regarded as a type of natural remediation that can improve pollutant degradation by optimizing conditions such as aeration, addition of nutrients, pH and temperature control (Margesin and Schinner, 2001). They opined that biostimulation can be considered as an appropriate remediation technique for petroleum pollutants removal in soil and requires the evaluation of both the intrinsic degradation capacities of the autochthonous microflora and the environmental parameters involved in the kinetics of the in situ process. Major advantage of biostimulation is that bioremediation will be undertaken by already present native microorganisms that are well-suited and well distributed spatially within the oil sludge. The basic disadvantages of biostimulation are that the delivery of additives in a manner that allows the additives to be readily available to subsurface microorganisms is based on the local geology of the subsurface. Also, the addition of nutrients might promote the growth of heterotrophic microorganisms which are not innate degraders of Total Petroleum Hydrocarbon thereby creating a competition between the resident microorgansms. Utilization of biostimulation on freshly generated oil sludge in the oil and gas industry can also yield can also better results than some of the physical and chemical methods. The existing microorganisms in the oil sludge can be stimulated to effectively biodegrade the sludge. An alternative to biostimulation is bioaugmentation.

4.2 Bioaugmentation

Bioaugmentation is the addition of living cells capable of degradation (Adams *et al*., 2015).It is the addition of oil-degrading microorganisms to supplement the indigenous populations. This approach is based on the fact that indigenous microbial populations may not be capable of degrading the wide range of potential substrates present in complex mixtures such as petroleum (Leahy and Colwell, 1990) or that they may be in a stressed state as a result of the recent exposure to the components of the petroleum sludge. Also, bioaugmentation may be considered when the indigenous hydrocarbon-degrading population is low, the speed of decontamination is the primary factor, and when seeding may reduce the lag period to start the bioremediation process (Forsyth *et al.*, 1999). Bioaugmentation may also be considered as a method of adding efficient microbial inoculants into oily sludge, so as to accelerate the biodegradation of petroleum hydrocarbons (Wneyu *et al.*, 2013). The microorganisms to be used for the bioaugmentation in petroleum sludge must be able to degrade most petroleum components, maintain genetic stability and viability during storage, survive in foreign and hostile environments, effectively compete with indigenous microorganisms, and move through the pores of the sediment to the contaminants (Goldstein *et al.*, 1985). For many years, bioaugmentation has been proposed as an alternate strategy for the bioremediation of oil contaminated environments. Bioaugmentation can be divided into single bacteria strengthening and bacterial consortium strengthening. Single bacteria strengthening involve the introduction of microorganisms isolated from the petroleum sludge or carefully selected and genetically modified to support the biological treatment of the petroleum sludge. The carefully selected and genetically modified method is found necessary when it is observed that the indigenous organisms within the oil sludge cannot biodegrade petroleum hydrocarbon. Bacterial consortium strengthening involves introduction of consortium of microorganisms isolated from the petroleum sludge or carefully selected and genetically modified to support the biological treatment of the petroleum sludge. Bioaugmentation treatments of petroleum sludge profitability depend on the use of inocula consisting of microbial strains or microbial consortia that have been well adapted to the oil sludge to be treated. Factors affecting proliferation of microorganisms used for bioaugmentation including the chemical structure and concentration of pollutants, the availability of the contaminant to the microorganisms, the size and nature of the microbial population and the physical environment should be taken into consideration when screening for microorganisms to be applied.

Various researchers have utilized biostimulation only for biodegradation while some others employed bioaugmentation only. However, some researchers have attempted the combination of the two methods in treatment of petroleum sludge. Ouyang *et al.* (2005) investigated the effect of bio augmentation on the composting of oily sludge and the TPH content decreased by 46-53 in the piles after 56 days of treatment but only decreased by 31 in composting piles. Admon *et al.* (2001) also observed similar degradation pattern through experiments on the land-farming of refinery oily sludge and 70–90% of PHCs degradation occurred within 2 months while a relatively high biodegradation activity was observed in the first 3 weeks of treatment. Mishra *et al.* (2001) combined bio-augmentation (introducing extraneous bacterial consortium) and biostimulation (addition of nutrients and water) for oily sludge decontamination and discovered oily sludge recovery to be 65 of the initial sludge mass.

4.3 Biosurfactants Treatment

Furthermore, microorganism like bacteria produce biosurfactants which are used to form emulsions of oil substrates (Liu *et al.*, 2010; Lima *et al.*, 2011; Calvo *et al*, 2004; Dhote *et al.*, 2009) the biosurfactants can emulsify petroleum hydrocarbon in oil sludge and make them bioavailable to bacteria for biodegradation in the system. Thus, they can act as important agents that will enhance the effective uptake of petroleum hydrocarbons by bacteria and fungi (Cort and Bielefeldt, 2000; Ubani *et al.*, 2013). The biosurfactant increase the surface area of the substrates and as a result increased their solubility (Dhote *et al.*, 2009; Ahimou *et al.*, 2000; Mukherjee and Das, 2005). The advantages of biosurfactants from microorganisms over chemical surfactants are higher effectiveness, natural status, non-toxic, biodegradable and a cost effective approach that can help in solubilisation of oil sludge hydrocarbons during biodegradation (Liu *et al.*, 2010; Lima *et al.*, 2011; Calvo *et al.*, 2004). Cerqueira *et al.*, (2011) observed that the microbial consortium composed of five (*Stenotrophomonas acidaminiphila, Bacillus megaterium, Bacillus cibi, Pseudomonas aeruginosa* and *Bacillus cereus*) bacteria used in their study degraded high concentration of saturated and aromatic compounds in the oil sludge producing biosurfactant efficiently (Cerqueira *et al*., 2011).

4.4 Bioreactor Process

Also, bioreactor process is used as a fermentation technology to degrade oil sludge into non-hazardous effluents with very low level of hydrocarbon (Singh *et al.*, 2001; Soriano and Pereira, 2002). 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 are used in this method of biological treatment of oil sludge. Singh *et al.* (2001) reported that the known oil-degrading bacteria such as *Pseudomonas, Acinetobacter, Rhodococcus* and *Alcaligenes* are involved in the process. It was observed that more than 90% of the TPHs contained in the oil sludge were degraded and after a successful treatment, 80% of the processed materials were disposed of and the reactor were reloaded with another batch of oil sludge using the remaining 20% left in the reactor to serve as inoculums for the next run (Singh *et al.*, 2001). The bioreactor technique can be used in the recovery of recyclable oil, biodegradation of oil sludge and disposal of treated oil sludge (Ubani *et al.*, 2013).

V. CONCLUSIONS

The use of biological methods for treatment of oil sludge are attracting the attention of researchers worldwide recent years over the last decade, and are viewed as ready-made approaches for bioremediation of petroleum contaminated sites. Operations in the oil and gas industry lead to generation of oil sludge, which treatment is a great concern in the industry. The oil sludge which contains water, sediment, hydrocarbons and other non-hydrocarbons needs to be treated to recover the useful content and appropriately dispose the waste. Out of the various treatment methods, biological treatment had been found to be economical and more environmental friendly. This paper reviewed the recent work done on biological treatment of oil sludge in the oil and gas industry with focus on treatment before its disposal into the environment. Oil sludge can be generally treated biologically by various methods which includes biostimulation, bioaugmentation, bioreactor processes and production/introduction of biosurfactants, bioremediation (which may also involve biostimulation or bioaugmentation), Land filling, land farming, bio pile/composting, bioslury, etc. However, for biological treatment of oil sludge before disposal into the environment biostimulation, bioaugmentation, bioreactors and production/introduction of biosurfactants should be considered. The biological treatment before disposal can apart from removing the hazardous components in the sludge also aid recovery of useful oil content in the sludge. Several microorganisms have been investigated on their abilities to effectively treat oil sludge by biodegrading the hydrocarbons in the sludge and possibly recover some of the oil in the sludge. *Bacillus sp* and *Pseudomonas sp* of bacteria were found to be very effective in biological treatment of oil sludge. Some other species of *Bacillus sp* and *Pseudomonas sp* that have not been specifically investigated for treatment of oil sludge should be other fruitful areas of research to embark upon.

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