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Review Article

A Brief Review on Bioremediation of Oil-Contaminated Soils and It's Engineering Behaviour

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Abstract: In industrial areas leakage of oil and it's penetration into the soil can change the engineering properties of soil as well as cause environmental disaster. Also, recovering the contaminated sites into their natural state and reuse that contaminated material after treatment in the construction field needs remediation techniques which approach environmental friendly as well as geotechically suitable. This review article is an examination of the behaviour of various oil-contaminated soils on the engineering properties as well as physical, chemical and biological properties of soil. It also includes various remediation methods and shows a brief review about bioremediation method and also highlighted a bioremediation method as a sustainable, effective, low cost, and no harmful effect method. The article shows that the, crude oil can change various engineering properties such as optimum moisture content, maximum dry density, shear and compressive strength, settlement and permeability of soil as compared to natural soil. But the bioremediation technique helps in a positive manner to enhancing soil properties and also recover the contaminated soil in to their natural state. The various measurement technique of total petroleum hydrocarbon of crude oil contaminated soil also mentioned in this article. Generally, the application of bio-treated soil as utilized in the construction of liners, road construction, manufacturing portland cement, and erosion control projects.

Keywords: Oil-contamination, Bioremediation, Soil properties, Engineering properties, Total petroleum hydrocarbon (TPH).

Introduction

Oil plays an important role in ensuring national energy security and economic development with the rise of population, growing prosperity and rapid urbanization. The petroleum industry is one of the basic strategic industries of people's livelihood and the driver of the national economy, ensuring national energy security and the smooth operation of the industrial chain [1]. According to the international energy agency (IEA) India's oil consumption is forecast to rise from 4.8 million barrels per day(mbd) in 2019 to 7.2 mbd in 2030 and 9.2 mbd in 2050. Brutal exploitation of natural resources by human as well as industrialization pulverized the environment with contaminating air, water and soil. Considering importance of oil and activities related with oil-industries these are one of the most contaminants [2]. oil spillages are defined as leakage and release of oil from petroleum industries, storage, distribution and refinement sites into the environment, which can intimidate the marine, coastal and land ecosystem and also oil spills have tragic impacts on society, economy and environment [3]. The major oil spillage including Exxon valdez oil spills 1989, spillages due to the destruction of kuwait's oil production facilities through the gulf war in 1991, also the accidents on offshore oil platforms in Australia(Montara, 2009), United States(Deep water Horizon, 2010), China (Penglai, 2011), Brazil(P-34 platform, 2012) and a North Sea gas platform (Elgin/Franklin, 2012) and recent accident of chennai oil spill on January 28th 2017 have raised public awareness and also offshore oil exploitation is increasingly moving into deep water [4,5,6]. Various methods are required for the remediation purpose to removal of crude oil from the contaminated soil, which is quick, nature friendly and cost-effective.

Method includes chemical, physical, thermal, and biological methods and from the paper it concluded that biological method is most sustainable, effective, and eco-friendly method [7]. The application of the contaminated soil after bioremediation is suggested in road construction, erosion control project, construction of light weigh foundation and construction of liners as well as manufacturing portland cement [8,9].

Soil contamination is one of the most crucial cases of contamination it not only changes chemical, physical and biological properties of soil but also affects the geotechnical properties of soil [10]. As per research, there are various effects of crude oil on the physical and chemical characteristics of Wet Tundra Soils [11]. Crude oil exploration and production has been the largest man-made factor contributing to the degradation of momoge wetland, China [12]. some of the physico-chemical changes in the soil by contamination of crude oil in two oil fields of Assam, NE India [13]. Also, includes brief study on the biodegradation of hydrocarbon and its kinetics on kerosene simulated soil [14]. The examination of biological properties was determined by influence of oil contamination on physical and biological properties of forest soil after chainsaw use [15]. Overlook the effect of oil contamination on geotechnical properties of soil will cause complications for the strength and stability of the structures and also might affect to agriculture areas and ground water resources [16], which are now critical environmental problems and their treatment are having very high cost and time taking [17]. Also, with respect to ocean previous research regarding the oil spills shows that toxic and harmful chemicals remain in the ocean for years, often sinking down to the seabed and poisoning the sediment, which can kill surface-dwelling animals and birds by poisoning as well as affecting buoyancy and natural waterproofing.

Various studies shows that shear strength effect of motor oil contaminated sand and they concluded that decrease in internal friction angle (Φ) and considerable increase in volumetric strain of loose and dense sand [18]. Oil contaminated kuwait sand suggested a little decrease in strength and permeability and significantly increase in compressibility due to oil contamination. They observed that the effect of crude oil on the strength parameters is greater than the effect of benzene and light crude oil [19]. Geotechnical properties such as Atterberg limit, maximum dry density (MDD), optimum moisture content (OMC), strength and permeability of CL (clay of low plasticity), SM (silty sand), SP (poorly graded sand) soils are decreased due to oil contamination [20]. Effect of oil contamination on clay, silt coastal sediments increase compression coefficient significantly and shear strength parameters are not uniform and shows that decrease in strength with depth due to in-situ penetration in yellow river delta, China [21]. The oil contaminated sample were taken from Tehran oil refinery and it results in increased Atterberg limits, MDD, internal friction angle, compression index and decreased in OMC and cohesion of fine-grained CL soil [2]. By varying gas oil content from 2% to 20% in kaolinite soil, increase in cohesion and compressibility and decrease in internal friction angle and no effect noted in shear strength of soil due to changing gas oil content [22]. To investigate the consolidation behaviour of CL (clay of low plasticity) and CH (clay of high plasticity) soils they were prepare samples by slurry method with water and different concentration of organic fluid (glycerol and ethanol), they concluded that the preconsolidation pressure increased and decrease compression index due to increase of organic fluid [23]. By increasing gas oil content in various soils such as poorly graded sand (SP), low plastic clay and silt (CL and ML) noted reduction in MDD, OMC, and internal friction angle while increase in cohesion. Increase in gas oil content will shows direct effect on liquid and plastic limit and reversely effect on unconfined compressive strength (UCS) of silty soil [24]. In diesel contaminated illite shows that increased OMC values and decreased in MDD, cohesion, internal friction angle, and UCS. It also affect on consolidation settlement and scanning electron microscopy (SEM) images suggested that illite particles are behaves like individually due to contamination [25]. The liquid limit, plastic limit and undrained shear strength were identify for two types of smectites (namely Ca and Na-smectites) with different cations, and pore fluid is varying by dielectric constant and electrolyte concentration, it concluded that decrease in dielectric constant or increase in electrolyte concentration of pore fluid leads to decrease in liquid limit, plasticity and increase in undrained shear strength [26]. The characteristics of the fluid in the pore space can also impact on mechanical properties of clay. The liquid limit act differently to the permittivity or dielectric constant of the fluid. They determined the relation between the index properties and undrained shear strength with different dielectric constant of various clay particles. changing the values of dielectric constant by adding different content of ethanol to distilled water. Test results correlate with undraind shear strength of Na- and Ca- smectites with the actual fluid ration normalized to liquid limit. As kaolinites and illites have less exchangeable cations than smectites, this submit notably smaller ranges for Atterberg limits and decrease the effect of dielectric constant to nearly pure particle-particle interactions [27]. The geotechnical properties of fuel oil contaminated CL soil were improved by using stabilization agents such as cement, lime and fly ash [28].

Rehabilitation of contaminated sites into their natural state and reuse that contaminated material in construction field needs to be remediation technique which is environmentally and geotechnically suitable. Which is based on type, amount of contaminants, soil type, feature of contaminated site, cost, time duration, efficiency and environmental impact [9].

The physico-chemical properties evaluated the retention, volatilization and transport of hydrocarbon in soil. Due to decrease of soil moisture content, vapour phase transfer and increase in soil retention hydrocarbon, also convey nonaqueous phase liquid (NAPL) decreases [29]. Bioremediation is most successful and widely approachable method for the treatment of contaminated soil. It does not cause any negative side effect, having low cost and environment friendly method [30]. Comparison of two types of biostimulation during the application of observed natural attenuation for degrading diesel contaminated clay soil with low carbon content. They are using two types of fertilizer containing nitrogen(N) and phosphorus(P), also stabilized bio-solid containing carbon(C) along with nitrogen(N) and phosphorus(P). After incubation of 8 days, both methods shows 96% of oil degradation in comparison with observed natural attenuation that resulted in 93.8% of degradation. It concluded that using bio-solid as a bio-stimulator is more successful than use of inorganic fertilizer [31]. Indigenous bacteria were used as fixed on peanut hull powder and apply for 12 weeks in crude oil-contaminated soil, which proved more effective method to remove crude oil from contaminated soil compared to the use of free living bacteria due to porous structure and large surface area. By this method total petroleum hydrocarbon remove from 26% to 61% after 12 weeks [32]. In this research they investigated the suitability of reusing remediated soil for new bioremediation project of waste oil sludge. Due to the presence of inherent oil degrading bacterial and fungal communities they noticed a substantial reduction in total petroleum hydrocarbon (TPH) in naturally attenuated technique, reusing remediated soil can be results in low cost and effective method without any special treatment [33]. The efficiency of bacterial bioremediation by accelerate the oil degrading bacteria and mineral nutrients, the oil degradation was achieved approximately 50% to 80%. also results in increase the values of MDD, cohesion and UCS [8]. In recent research of bioremediation, bacteria powder were made by five types of different strains which are mixed with diatomite powder. Almost 50% of crude oil contamination degrades after 30 days. After treatment soil has high shear strength, cohesion and internal friction angle as compared to contaminated soil [9]. Also, various techniques are used for measurement of total petroleum hydrocarbon (TPH) [34].

Remediation Methods

Various methods are required for the remediation purpose to removal of crude oil from the contaminated soil which is quick, nature friendly and cost-effective.

1. Chemical Methods

Chemical oxidation is an effective technique to remove dangerous wastes from the soil at the oil contaminated sites. Efficiency of this method depends on soil matrix. A composition of hydrogen peroxide and ferric ion is used for chemical oxidation, which is also knows as fenton's reagent solution. Hydrogen peroxide produces hydroxyl ions during fenton's reaction while ferric ions acts as catalyst. Hydroxyl ions are very powerful and effective agents that break down the contaminants present in the soil.

Another effective oxidant is ozone which is best way to removal of crude oil from contaminated soil. Polycyclic aromatic hydrocarbons are great reactive with ozone. Ozone also carry microbial community present in the soil as it generates oxygen on its degradation so it can be very helpful in bioremediation method also. This method is quick but chemicals may cause a serious threat to the nearby soil and living beings due to leaching or side reactions.

2. Physical Methods

Excavation of crude oil contaminated soil is quick and cheap but not sophisticated method. First the contaminated soil is removed and transported to suitable landfill site for the disposal. Also check weather the site is clean or not from the excavated area.

Another physical method includes soil washing of contaminated soil. In this method organic solvent such as ethanol-water mixture and ethyl acetate-acetone-water mixture used for the removal of hydrocarbon as well as heavy metals. The efficiency of soil washing can be increased by addition of surfactants. From the previous studies it shows that both natural and artificial surfactants are used in removal of crude oil. Polycyclic aromatic hydrocarbons are removed by natural surfactants saponin and rhamnolipid while aliphatic hydrocarbons are removed by artificial surfactants sodiam dodecyl sulfate (SDS). This method is simple and efficient but time consuming and very costly.

3. Thermal Methods

Thermal stripping and incineration methods are used, in thermal stripping contaminated soil is heated to very low temperature (200-1000°F) to increase the vaporization and separation of low boiling point contaminants from the soil. With the help of this process organic contaminants can be completely or partially decomposed depending upon the temperature of thermal stripping and organic compound present in the soil. Removal of contaminants by this method is approximately 90% but it is very high costly and not eco-friendly.

In incineration method contaminated soil is burned by using fire at high temperature (1600-2500°F). This process is also not environmental friendly as it contains burnable and volatile compounds in crude oil which will cause environment pollution.

Effect of Contaminated Soil on Physico-Chemical and Biological Properties

1. Physico-Chemical

For the study on effect of physical and chemical properties of soil crude oil were added to the surface of wet soil at Barrow, Alaska at volume of 5 and 12 $1/m^2$. from the results it shows that treated with 5 1/m2 has no change in physical and chemical properties of soil but treatment with 12 $1/m^2$ recorded an increase in organic carbon, phosphorus and seasonal thaw, move the PH toward neutrality and decrease in infiltration rate and plant cations (Ca, Mg, and K).

Contaminated areas had importantly higher ($p< 0.05$) contents of total petroleum hydrocarbon (TPH) and total organic carbon (TOC). But lower ($p< 0.05$) contents of total nitrogen (TN) than uncontaminated areas. Contaminated sites had higher ($p< 0.05$) PH values, C/N and C/P ratios. For total phosphorus (TP) and electric conductivity (EC), there are no significant change were detected.

The effect of crude oil spillage can causes decrease in soil moisture, porosity, soil PH, water holding capacity and extractable phosphorous while increase in total nitrogen, total organic carbon, and exchangeable potassium.

The effect of crude oil for the analysis of physical properties, the values which are obtained from granulometric fractions were not affected by the present of crude oil. But results shows the alternation of chemical properties of soil as increases organic carbon and C/N ratios from unpolluted to polluted soils.

The effective study was conducted on soil with crude oil to examine the effect of hydrocarbons on soil properties such as PH, electrical conductivity, total organic carbon and matter, total nitrogen and phosphorous, and heavy metals (Cd, Pb, Ni, V and Cr). crude oil pollution can cause decrease in PH, electrical conductivity and phosphorous level with notably effect in the growth rate of soil heterotrophic microbes but did not shows any negative effects on the other properties.

2. Biological

Biological properties of soil includes enzymes, earthworms, nematodes, respiration, fungi and bacteria, microorganisms. Major study conducted on the influence of oil contamination on the biological properties of forest soil after chainsaw use. Results shows that oil contamination of soil had importantly effect on soil biological activity. They observed a strong decrease in dehydrogenase activity was noticed at 100 g/m^2 and at 200 g/m^2. Dehydrogenase activity was decreased approximately 50% compared with the activity of controlled soil. A similar pattern was noticed for urease activity. The minimum amount of oil such as 50 g/m^2 resulted in a slight reduction in urease activity, whereas activity was decreased by 40 and 50% at 100 and 200 g/m^2 as we compared with the control. In the experiments the use of chainsaw oil can cause a major influence on the density and biomass of earthworms. Even the lowest amount of oil such as 50 g/m^2 caused a decrease in the population of earthworms from >40 specimens/m^2 in the contro block to approximately 9 specimens/m2. Oil at 100g/m^2 affected the species composition of earthworms, these can be observed by the reduction in biomass, the biomass decreased from greater than 3 to 4 g/m^2.

Effect of Contaminated Soil on Engineering Properties

As per previous researches, effect of crude oil-contaminated soils on engineering properties can be divided in a various principal groups. The main two principal groups are, (a) Dealing with contamination transport processes such as permeability, porosity, density, soil structure, and water saturation. (b) Dealing with the strength and compatibility of soil samples.

Atterberg limit tests were performed on the CL and CH samples. The results indicates as crude oil content increases, liquid limit decreases while plastic limit increases, and plasticity index decreases. This changes in Atterberg limits can be examine by the nature of water in the clay minerals structure. Water molecules are polar and it has a positive charge on one side and negative charge on another side, it is known as dipole. The dipolar water molecules are absorbed by negative charges of clay particles and cations like Ca^{+2}, Mg^{+2}, Na^{+}, K^{+}. The oxygen atoms absorb hydrogen atoms of water molecules in particle surface and some hydrated cation from pore water, which makes the hydrogen bonding. In clay particles the water, which is held by attraction forces is known as double layer water. The innermost layer of double layer water which is more viscous than free water is known as absorbed surface water. Crude oil prevents water molecules to clay particles, it results in water cannot reach the double layer water and more water needed for clay particles to show their plastic properties, which leads to increase in plastic limits. The main reason behind the changes in Atterberg limits, the crude oil molecules are not dipole. They are not capable to make a polar bond with clay particles like water molecules. Also water and crude oil are two different liquid phase, which are known as emulsion. In clay particles, the presence of crude oil results in lowers specific surface area (SSA) of soil, it reduces the water reaction with clay particles. The dielectric constant and viscosity of pore fluids are the factors to changes in soil plasticity.

In compaction test, by the increase of crude oil content MDD and OMC values decreases. Because the presence of oil reduces the water absorption and dissipates applied energy which results to low compaction. In the contaminated soils a major part of oil is absorbed by the finer portion of soil and crude oil cannot show any lubricant effect by control water as an interlayer pore fluid when compared with sandy soils. Also oil has higher viscosity compared with water, which causes dissipation of energy of the compaction hammer.

In direct shear test, for the crude oil contaminated samples the stress-displacement graph moves downwards with the increase of crude oil content. For example by the increase of crude oil content up to 12%, at normal stress of 300 kpa the shear strength of sample are decreased from 82.14 kpa to 49.38 kpa (almost 40% deceases). Also effect of crude oil can changed internal friction angle (Φ) and cohesion. By increase of crude oil content the internal friction angle reduces from 12.36° for natural soil to 7.85° for 12% of crude oil contaminated samples (almost 36.5% reduction). similar reduction has been noted fro sandy and clayey soils. The reason behind reduction in internal friction angle was due to lubrication effect of oil on the surface of the particles, which reduces inter particle friction. Also the presence of oil in pores of soil and between the soil particles decreases the cohesion.

In unconfined compressive strength tests, by increasing the oil content upto 12% the UCS values of soil decreases from 321.07 kpa (natural soil) to 203.83 kpa (12% crude oil contaminated sample). further at 8%, the values of UCS increases because the agglomeration of soil particles bonded together by oil film. This bonded soil matrix initially resisted the impact of the loading but thereafter failed by the increment of crude oil content which has weakened the interspatial force of cohesion between soil particles. Some another reason for this behaviour can be the formation of flocculated soil fabric. Flocculated soil has higher strength and permeability and lower compressibility than the same soil in dispersed condition at the same void ratio.

Consolidation is another important engineering property was studied in previous research. The results of most of the samples are immediate settlement, which are small. By the increment of crude oil content the settlement also increases in sandy soils. The consolidation in clayey soil may be larger as compared to immediate settlement. It is the most critical issue in the design of soil structure. In oil contaminated samples, by the increase of oil content for given pressure the settlement also increases due to the lubricant effect of crude oil. Which decreases the friction between soil particles and helps them for placing in tight and compacted packing between each particle. Moreover, crude oil decreases the SSA of soil which results in the decrement of adsorption of water by soil particles. Hence water can be drained more easily. Thus, the consolidation settlement increases.

As per previous researches the permeability test were conducted in poorly graded sand (SP), well graded sand (SW), silty sand (SM) and clayey sand (SC) samples. The results showed that the the permeability coefficient of SP, SW, and SM samples first increases with the increment of crude oil content. The reason is that the crude oil has led to the lubrication of pores and soil particles system. Therefore, the water passes through the porous media of the contaminated samples in faster rate. Hence, the permeability coefficient increases. The permeability coefficient of these samples increases to some extent, but after the increment of crude oil at particular level. The crude oil would block the soil pores media and decreases the permeability of soil samples. The changes of permeability of clay is based on dielectric constant values of motor oil. According to double layer theory, decrease in the value of dielectric constant of pore fluid lead to the reduction in the thickness of the layer. Also, decrease of double layer thickness increases the clay permeability.

Sustainable Method for Remediation Purpose

1. Biological Method (Bioremediation)

Various techniques are applied either in-situ or ex-situ for removal of toxic substances from the soil. The implementation of methods depends on the nature and the intensity of the pollution. Microorganisms can breakdown the chemicals with the help of enzymes. Thus soil and water are clear after treatment.

Bioremediation for oil leakage is a method that eliminates various hydrocarbon from water and soil. Leakage of oil takes place mostly from ships, produce hazards to the aquatic life to a large extent. Also, oceans get polluted with dangerous chemicals due to seepage of oil, petrol, diesel and other types of hydrocarbons due to accidents. Bioremediation is one of the effective methods for removal of oil from the soil and water and making safe for aquatic and terrestrial strains. Bioremediation method can be used by three ways, (1) bacterial species assisted remediation, (2) plant species (Phytoremediation) assisted remediation, (3) fungal species (Mycoremediation) assisted remediation, (4) Plant-microbe (Rhizoremediation) assisted remediation.

1.1. Bacterial Species Remediation

Soil is a diverse ecosystem as it occupies various microbial populations. Hydrocarbon degrading microbes are substantially present naturally in crude oil contaminated soil and by the use of enzymatic system they break down hydrocarbon into the simple form.

Different bacterial strain is choosing different hydrocarbon as per their degrading capability.

They can work in two conditions such as aerobic and anaerobic. In aerobic condition, bacterial dioxygenase enzymes absorb oxygen into carbon molecule through a series of enzyme catalyzed reaction to generate hydrocarbon with alcohol group. Alcohol groups are oxidized to aldehyde and then converted into carboxylic group by the action of other enzymes which in turn is degraded to acetyl co-A by beta oxidation while in anaerobic condition, bacteria use nitrates, sulfates and iron as electron acceptor to degrade the hydrocarbons.

Some of the major bacterial species that showed crude oil degrading capability such as Acinetobacter, Aeromonas, Alcaligenes, Athrobacter, Bacillus, Flavobacterium, Micrococcus, Moraxella, Mycobacterium, Nocardia, Pseudomonas, Rhodococcus, Sphingomonas, Xanthomonas, Zospirillum.

1.2. Phytoremediation

Phytoremediation is an effective, economical and solar driven method that uses plant for the removal of contaminants from the soil.plants have the capability to grow in polluted area by accumulating the harmful compounds in their roots. Different types of mechanism are obtained by plants for the removal of contaminants i.e., phytoaccumulation, phytodegradation, phytovolatization and phytostabilization.

1.3. Mycoremediation

In mycoremediation technique fungi were used for remediatio process. Fungi are main decomposers in the natural environment. They create enzymes to degrade the plant polymers cellulose and lignin and also they can breakdown some toxic substances from the contaminated soil. Mycoremediation can be used in contaminated soil and water, oil leakage, industrial chemicals. There are some examples of mycoremediation includes Lentinus edodes, Pleurotus pulmonaris, Phanerochaete chrysosporium.

1.4. Rhizoremediation

In this method plants are required that can grow in contaminated soil. Also, plant-microbe strategy not only increase the metabolic activities of rhizosphere microbes, but also improves chemical and physical properties of soil. Bioremediation of crude oil contamination by using yellow alfalfa in combination with acinetobacter sp. strain improves the remediation efficiency.

Enhancing Soil Properties by Bioremediation Technique

As per previous research, the results shows that the used of oil degrading bacteria have better efficiency in sandy soils. Because highly plastic clay (CH) are finer than sandy soils. They have larger specific surface area and lower permeability. Due to the oil contamination, the yellow color of soil change to the brown and the texture of soil is smooth. In bio-treated samples, the brown color of samples returns to yellow again. Which is indicating the efficiency of bioremediation process. The bioremediation has changed the soil structure to an agglomerated and porous one, and lumps and clods of soil are visible. Also white spots on the samples are bacterial biomass and by products of bioremediation of crude oil.

The shear strength of soils has successfully influence on stability, deformation, and stress distribution of foundations, tunnels and slopes. Due to the oil contamination the shear strength of soil decreases. Hence, the bioremediation method was help to increases shear strength for contaminated soils. From the previous researches in the bio-treated samples, the stress-displacement curve for the sample containing 4% crude oil is greater than others. However, the crude oil content increases upto 8% and 12% the shear strength decreased. For example, at normal stress of 300 kpa the shear strength of soil increased from 82.14 kpa to 95.7 kpa for bio-treated samples at 4% of crude oil. By increase of 4% to 12% the shear strength of soil decreased from 95.7 kpa to 69.01 kpa. There is no change in internal friction angle for bio-treated sample at 8% and 12% of crude oil in comparison with natural soil while the internal friction angle risen to 14.27° for bio-treated at 4% crude oil. Due to the presence of residual oil and biomass, a reduction can expected to occur in internal friction angles for bio-treated samples. The internal friction angle of bio-treated sample is higher than the corresponding values of oil contaminated samples due to the degradation of oil and agglomeration of soil structure. Oil contamination as well as bioremediation resulted in decreased in soil cohesion except bio-treated sample at 4% of crude oil. Adding the oil to the soil reduces the double layer, which leads to reduction in cohesion of soil. In addition, unconfined compressive strength and failure strain both are increasing for bio-treated samples. For consolidation process, the settlement of bio-treated samples increased due to the increase of oil content up to 8%, and it starts decreases for further increment of crude oil. Bioremediation increases the soil porosity and void ratio by reducing the oil and producing biomass and other by-product in the soil.

Measurement of Total Petroleum Hydrocarbon(Tph) by Various Technique

The hydrocarbons extracted from soil and water are measured in various different techniques. One of the simplest methods is complete evaporation of solvent and weighting the residue. This is called traditional "oil and grease" method. Alternatively, spectrophotometric and gas chromatography/mass spectrometry (GC/MS) techniques are also used for measurement of TPH.

1. Gravimetric Analysis

Complete evaporation of the extraction solvent and weighting the residue is the simplest method of TPH measurement. Some limitation includes such as interferences from suspended solids and coextracted lipids, and complete loss of volatile fraction.

2. Spectrophotometric Analysis

Spectrophotometric includes Infra-red (IR) and Fluorescence analysis.

2.1. Infra-Red (IR)

IR measures the maximum absorbance of the stretching of carbon-hydrogen bonds in methylene groups at 2930 cm^{-1}, in this level of frequency the compounds always have methylene groups. In this types of petroleum hydrocarbon predominant are the saturates, aromatics without alkyl substitution. This is indicated by IR spectra of naphthalene and n-hexadecane solution in the range of 3200 to 2700 cm^{-1}. which is 300 times greater for hexadecane.

The accuracy problem with the saturates and aromatics contributes is one of the limitation of this method, because the aromatics and saturates content of crude oil and its residues varies while the ratio of saturates to aromatic in standard oils used for calibration is fixed. Errors greater than 50% are observed depending on oil source and the extent of weathering. Another limitation of this method is that use of fully halogenated solvent is required.

2.2. Fluorescence

This spectrometry has been widely used to monitor aromatic hydrocarbons in environmental samples. This analysis has been proposed in screening methods for total PAH concentration. Procedures are all similar in that excitation is at fixed wavelength 254 nm, and emission is monitored. A standard solution of single or mixed PAH are used for calibration.

Fluorescence spectrometry measurement suffer same accuracy problem as the IR-measurement.

3. Chromatographic Analysis:

Chromatography is a process of mixture separation. This process is based on differences in the rate or the extent to which different compounds move through a solid or liquid absorbing matrix. Gas chromatographic (GC) used as a best technique which detected and quantified specific petroleum hydrocarbon constituents.

Gas Chromatography with Flame Ionization Detector (GC-FID)

The aliphatic hydrocarbons were determined from GC-FID instrument with the help of Hewlett-Packard Model 5890. GC-FID includes following conditions.

Table 1: GC-FID conditions

Carrier gas	Hydrogen, 11 psi
Column	Fused Silica capillary column, 0.31 mm I.d. 25m length
Injection temperature	250°C
Detector temperature	300°C
Initial oven temperature	60°C
Initial time	2 min
Program rate	5°C/min to 200°C
Final time	12 min
Injection Volume	1 μl

Conclusion

The main goal of this review article is to analyse the effect of crude oil contamination and bioremediation on geotechnical, physical, chemical, and microstructural properties in different types of soils. From the all previous researches it seems that, a broad range of laboratory tests including atterberg limits, compaction parameters, unconfined compressive strength, direct shear, and consolidation tests were conducted on natural soil, oil-contaminated samples, and bio-treated samples. Also, it includes some observation about total petroleum hydrocarbon, organic carbon, nitrogen, phosphorous tests. There are many other methods are also mentioned in this article such as chemical, physical, thermal, and biological methods. Among all these methods biological (bioremediation) method is more effective. Bioremediation method degrades crude oil contamination about 50% after 30 days, and this process helps to produce biomass and bio-product material within the soil. In clay particles, oil contamination reduces SSA of soil and water reaction which led to the rising of soil plasticity, similar behaviour was noted for bioremediation.

By the increase of crude oil contamination, OMC, MDD, cohesion, and internal friction were decreased. However, for bio-treated samples values of cohesion are slightly more as compared to contaminated samples. In general, oil contamination reduces unconfined compressive strength for contaminated samples. However, by increase an bio-treatment time, unconfined compressive strength increases and give better performance. The usage of bio-treated soil is suggested in road construction and erosion control projects. Also, it helps in the construction of light weight foundations on top of these soils does not pose any significant problem.

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