Received: Jul '24
Revised:
Accepted: Aug '24

ASSESSMENT OF SOIL TEXTURE, MICRONUTRIENTS AND HEAVY METALS IN THE PETROLEUM CONTAMINATES SOIL SAMPLES OF BHATINDA

Shyam Sunder Sharma[1], Gautam Kumar Meghwanshi[2], Prabhu Dan Charan[3] and Abhishek Vashishtha[4*]
[1,2,3]Department of Environmental Science, Maharaja Ganga Singh University, Bikaner
[4]Department of Microbiology, Maharaja Ganga Singh University, Bikaner
E-mail: [4]abhiv24@gmail.com

ABSTRACT

Crude oil spills frequently occur during offshore oil drilling, as well as during the transportation and transfer of oil to onshore facilities. Numerous petroleum refineries are distributed across the nation, processing crude oil—a blend of hydrocarbons and molecules like nitrogen, sulfur, and oxygen—to yield various products. Petroleum waste pollution of soil leads to vegetation loss and reduced aesthetic quality. These contaminants are known to damage the worldwide natural ecosystem. Scientists are trying hard to cope up with the problem. The biological methods of treatment of this sort of pollution have been tried worldwide. Such methods depend on a large number of factors including soil texture and presence of micronutrients and heavy metals. The soil texture directly and indirectly influences the bioremediation process by affecting the Porosity, Bulk density and CO_2 *reflexes. The presence of micronutrients and heavy metals like Phosphate, potassium, zinc, magnesium, iron, and copper affects the health of microbial population and hence the bioremediation process*

Keywords: Heavy Metals, Hydrocarbons, Petroleum, Pollution, Soil Texture

INTRODUCTION

Pollution in soil or water has resulted in a significant threat today. With the raising population and the advancement of urban civilization, pollution resulting from petroleum products and their by-products is escalating exponentially. Oil spills are a major source of heavy metal contamination in both aquatic and terrestrial ecosystems, particularly in regions where oil is produced. Petroleum products serve as fuels, solvents, and feedstocks in various industries such as textiles, pharmaceuticals, and plastics, making them vital energy sources globally. Petroleum and its derivatives have greatly facilitated modern society, providing convenience to humanity. However, utilizing these goods has also led to soil contamination in the neighbouring areas. During the petroleum exploration, exploitation (Zahed *et al.*, 2021), transportation, processing, storage and transportation, transaction, and utilization process, casual accidents of petroleum leakage are almost inevitable, and spilled oils can contaminate the local soil environment (Buragohain *et al.*, 2013, Wang *et al.*, 2019). Oil spillage is one such problem caused by the unintentional release of liquid hydrocarbons (Abatenh *et al.* 2017; Gurav *et al.* 2021). Oil spills can also occur due to natural disasters like earthquakes and hurricanes. The frequent occurrence of oil spills has resulted in a significant issue, namely the pollution of the ocean and coastal areas (Singh *et al.* 2015; Wang *et al.* 2018). Petroleum hydrocarbons present in soil can have an impact on various physical characteristics, such as soil structure, compaction, pH levels, resistance to water infiltration, hydraulic conductivity, and soil chemical properties such as mineral content, concentration of heavy metals, and overall composition (Hreniuc *et al.*, 2015).

Soil, as a crucial component of the ecological system, is significantly contaminated by heavy metals associated with crude oil (Vane et al., 2020). Due to the persistent nature of heavy metals and their tendency to bind to soil particles, soil acts as a primary reservoir for these pollutants (Rashid *et al.*, 2023; Glory and Deka, 2023). Oil contamination can reduce soil productivity and increase the presence of heavy metals, which can build up and intensify in the environment, resulting in health complications (Adams *et al.*, 2014). Heavy metals are credited for their toxic effects, which pose significant risks to human health. Since crude oil contains heavy metals, oil spills can lead to environmental contamination and increase the likelihood of human exposure to these hazardous elements. Heavy metals are metallic elements characterized by a relative density that is at least five times greater than that of water. These elements exhibit various toxic effects in humans, with their toxicity being closely linked to their high density. Once released, heavy metals from crude oil can enter the body through inhalation or ingestion. Since crude oil contains heavy metals, environmental contamination with these elements is strongly linked to oil spills.

The present study was conducted to assess the presence of micronutrients and heavy metals in the hydrocarbon contaminates sites near in and around the GSS refinery, Bhatinda. This area is heavily populated and harbours a number of hydrocarbon-contaminated sites.

MATERIALS AND METHODS

Sample Collection

Three soil samples were gathered from the Guru Gobind Singh Refinery area in Phulokhari, Bhatinda, Punjab, from both surface and subsurface layers (5-30 cm depth). Post-collection, the samples were subjected to drying, sieving, and removal of superficial debris to ensure purity before further analysis. The samples were placed in sterilized bags for subsequent evaluations.

The samples were brought to the laboratory in sterilized poly bags and kept to air dry for 5 days at room temperature. Any stone material, plant litter, etc., that was superficially present was removed by hand. The samples were then passed through a 2 mm sieve to eliminate any useless items.

Study of Soil Texture

Different types of soil are composed of unconsolidated granular particles such as rock segments, mineral particles, or remnants from the ocean. According to the International Society of Soil Science, weathered minerals can be categorized into different groups.

Based on the relative proportion of mineral particles of different sizes, soil can have four different textures:

Type of soil	Particle size
Gravel	> 2.0 mm diameter
Fine sand	0.2 - 0.02 mm diameter
Coarse sand	2.0 - 0.2 mm diameter
Silt	0.02 - 0.002 mm diameter
Clay	0 < 0. 002 mm diameter

The soil samples were carefully pulverized and passed through sieves with varying mesh sizes. The particles of various sizes were weighed and soil texture was evaluated based on the relative percentage of each component. This analysis, often called particle size distribution classifies the soil texture into classes like sand, silt, and clay. This categorization is based on the proportions of different particle sizes that affected soil properties, including water retention, drainage and availability of nutrients. Soil texture was characterized using the soil texture triangle which is a key tool in soil sciences for understanding the soil behavior in different environmental conditions and management practices.

Micronutrients

The concentration of micronutrients in the soil substantially affects its microbial status. The concentration of Phosphorus, Potassium, Zinc, Magnesium, Iron and Copper was estimated in all the three soil samples. The process for quantifying the phosphate content involved a complexation reaction that yields a coloured molybdate-phosphorus complex. This complex result when a soil sample containing phosphates is heated with Ammonium Molybdate in the presence of acid and excess Ascorbate ions. This prevents colour degradation by retarding molybdate oxidation. The intensity of so produced blue complex depends upon the initial concentration of phosphate in the sample. Phosphate levels are determined by comparing the blue colour with phosphate standards of known concentration. The standards were treated similarly with molybdate. Using this comparison, the phosphate concentration in the soil was calculated using a standard curve.

The Potassium content was measured using a standard stock solution of 1000 ppm potassium chloride is prepared by dissolving 1.909 g of potassium chloride-AR in one liter of double-distilled water. This stock solution is then diluted to obtain concentrations of 10 ppm, 20 ppm, 40 ppm, 60 ppm, 80 ppm, and 100 ppm. The flame photometer is calibrated using the 20 ppm, 40 ppm, 80 ppm, and 100 ppm potassium chloride solutions. The sample extract is fed into the photometer, and if the unit displays “out of range,” a known volume of the extract is diluted in a 25 ml or 50 ml volumetric flask with double-distilled water. The diluted solution so obtained was then fed into the atomizer of the flame photometer for analysis.

Zinc was extracted from the soil by utilizing 0.1 N HCl as an extractant. The zinc concentration in the extract was assessed using atomic absorption (AA) spectrophotometry. Zinc standard containing 1.6 ppm Zn was used. The diluted standards were used to calibrate the AA spectrophotometer.

For analysis of the Magnesium content, 2 ml of the soil extract was mixed with 20 ml of distilled water followed by the addition of 10-12 drops of NH_4Cl+ NH_4OH buffer. This was followed by titration against 0.01 N EDTA using EBT till the colour changed from pinkish red to Sky blue. The reading so obtained was used to calculate the Magnesium content. Iron and copper content were measured in agriculture station in Bikaner.

Result and Discussion

Bhatinda is the fifth largest district of Punjab and is located in Indo-Gangetic alluvial plains at 30.20°N 74.95°E coordinates. Three samples (SA1, SA2 and SA-3) of hydrocarbon-polluted soil and one control soil were collected from the area in the vicinity of the Bhatinda refinery.

A Soil Texture

The soil texture was studied using sieves with varying mesh sizes and using a soil texture triangle. The results are as under:

Sample	Gravel %	Slit%	Clay%
Sample I (SA-1)	36.2±1.1	39.2±1.8	24.6±2.0
Sample II (SA-II)	31.6±1.6	34.5±1.3	33.9±1.2
Sample III (SA-III)	36.3±1.2	38.6±1.9	25.1±1.6
Control soil	46.3±2.0	34.2±1.0	19.5±1.1

Table 1: Texture of the soil samples

Contaminated soil samples (SA-I and SA-II) had the highest silt content but SA-III had more gravel content. The texture and structure of the soil significantly affect the penetration and permeability of soil fluids and air. It also affects the soil ability to hold and retain water. The soil texture is known to affect various other soil properties, including bulk density, water holding capacity, permeability and porosity. Sandy soils exhibit high permeability and low water-holding capacity, while soils with higher silt and clay content are known to hold more water and have lower permeability. This property of soil also affects the plant root system and CO_2 efflux. The soil texture thus directly or indirectly affects the biological properties of the soil and thus the fate of hydrocarbons in the soil.

In a study Haghollahi *et al*., (2016) reported that the highest removal percentage of total petroleum hydrocarbons (TPH) was observed in sandy soil, reaching 70% with an initial TPH content of 69.62 g/kg. In contrast, clay soil exhibited the lowest removal percentage at 23.5%, despite having a similar initial TPH content of 69.70 g/kg. However, in a separate experiment where the clay soil was mixed more frequently, the removal percentage improved to 57% within a month. This suggests that the low degradation of hydrocarbons in clay soil may be attributed to limited oxygen availability.

Heavy Metals and Micronutrients

The presence and concentration of micronutrients in soil significantly influence its microbial status. The phosphorus, potassium, zinc, magnesium, iron and copper content were estimated in all the three soil samples. Varied concentrations of phosphate, potassium and copper were found in each soil sample (Table 2). The Zinc, Magnesium and Iron were recorded in very high concentrations (2-5 times higher) in all contaminated samples. The highest zinc and magnesium content were found in sample III with the values of 10.33 PPM and 14.25 PPM. Sample III had the highest iron content of 29.5 PPM. The control sample had zinc, magnesium, iron, and copper levels of 3.49 PPM, 3.13 PPM, 5.23 PPM, and 0.33 PPM, respectively.

S. No.	Soil Sample	Phosphate (Kg/hectare)	Potassium (Kg/hectare)	Zinc (PPM)	Magnesium (PPM)	Iron (PPM)	Copper (PPM)
1	Control	40 ± 0.86	285 ± 5.71	3.56 ± 0.16	3.63 ± 0.074	5.43 ± 0.059	0.54 ± 0.16
2	Sample I	32 ± 0.98	210 ± 7.25	9.80 ± 0.08	11.24 ± 0.074	33.4 ± 0.064	2.74 ± 0.056
3	Sample II	35 ± 0.71	300 ± 8.28	8.46 ± 0.14	13.20 ± 0.035	25.63 ± 0.45	2.34 ± 0.057
4	Sample III	38 ± 0.66	270 ± 4.89	11.33 ± 0.16	15.24 ± 0.075	30.50 ± 0.31	1.62 ± 0.020

Table 2: Micronutrients in the soil samples

In a study Chinedu and Chukwuemeka (2018) identified the following heavy metals in oil - manganese (Mn), iron (Fe), copper (Cu), zinc (Zn), lead (Pb), nickel (Ni), cobalt (Co), cadmium (Cd), and chromium (Cr). It has been found that although the concentrations of heavy metals may vary slightly among different oil contaminant sites, manganese (Mn) consistently appears in higher average quantities than the other heavy metals found in crude oil from this region. Glory and Deka, (2023) found that heavy metals have a considerable negative impact on the biological activities of the soil. However, the presence of micronutrients in one way or another has positive impact on the process of bioremediation. Therefore, scientists are now working on bioaugmentation and similar strategies.

CONCLUSION

The buildup of heavy metals (HMs) associated with crude oil in contaminated areas continues to be a major global issue. Research has indicated that crude oil contains numerous inorganic and carcinogenic pollutants, including heavy metals, which can significantly endanger the surrounding environment. There fore there is an immediate need to design strategies for the remediation of petroleum-contaminated sites have high build-up of heavy metals.

REFERENCES

Abating E., Gizaw B., Tsegaye Z., and Wassie M. 2017. The role of microorganisms in bioremediation—a review. Open J Environ Biol., 2 (1): 038-046.

Adams G.O., Tawari – Fufeyin P., Igelenyah E., Odukoya E. 2014. Assessment of Heavy Metals Bioremediation Potential of Microbial Consortia from Poultry Litter and Spent Oil Contaminated Site. Int J Environ Bioremediat Biodegrad., 2(2), 84-92.

Buragohain S., Deka D.C., and Devi A. 2013. Fenton oxidation and combined Fenton-microbial treatment for remediation of crude oil contaminated soil in Assam – India Environ. Sci.: Process. Impacts, 15, 1913-1920.

Chinedu E., and Chukwuemeka CK. 2018. Oil Spillage and Heavy Metals Toxicity Risk in the Niger Delta, Nigeria. J Health Pollut. 8(19):180905. doi: 10.5696/2156-9614-8.19.180905. PMID: 30524864; PMCID: PMC6257162.

Glory G., and Deka H. 2023. Crude oil associated heavy metals (HMs) contamination in agricultural land: Understanding risk factors and changes in soil biological properties, Chemosphere, 310,136890,https://doi.org/10.1016/j.chemosphere.2022.136890.

Gurav R., Bhatia S.K., Choi T.R., Choi Y.K., Kim H.J., Song H.S., Park S.L., Lee H.S., Lee S.M., Choi K.Y., and Yang Y.H. 2021. Adsorptive removal of crude petroleum oil from water using floating pinewood biochar decorated with coconut oil-derived fatty acids. Sci Total Environ.;10 (781): 146636.

Haghollahi A., Hassan M., and Schaf M. 2016. The effect of soil type on the bioremediation of petroleum contaminated soils. Journal Environ. Manag. 180, 197–201. doi:10.1016/j.jenvman.2016.05.038

Hreniuc M., Coman M., and Cioruţa B. 2015. Consideration regarding the soil pollution with oil products in Sacel-Maramures. International Conference of scientific paper AFASES. Brasov. 28-30.

Menage P.M.A., and Pridmore B. 1973. Automated determination of phosphate using Bray No 1 Extractant. CSIRO Division of Soils. Notes on Soil Techniques, pp80-82.

Rashid A., Schutte B.J., Ulery A., Deyholos M.K., Sanogo S., Lehnhoff E.A., and Beck L. 2023. Heavy Metal Contamination in Agricultural Soil: Environmental Pollutants Affecting Crop Health. *Agronomy*, *13*, 1521. https://doi.org/10.3390/agronomy13061521

Singh A., Asmath H., Chee CL., and Darsan J. 2015. Potential oil spill risk from shipping and the implications for management in the Caribbean Sea. Mar Pollut Bull.;93 (1): 217–227.

Vane C.H., Kim A.W., Moss Hayes V., Turner G., Mills K., Chenery S.R., Barlow T.S., Kemp A.C., Engelhart S.E., Hill T.D., Horton B.P. 2020. Organic pollutants, heavy metals and toxicity in oil spill impacted salt marsh sediment cores, Staten Island, New York City, USA. Mar. Pollut. Bull., 151. Article 110721

Wang Y., Liang J., Wang J., and Gao S. 2018. Combining stable carbon isotope analysis and petroleum-fingerprinting to evaluate petroleum contamination in the Yanchang oilfield located on loess plateau in China. Environ Sci Pollut Res.; 25:2830–2841.

Wang M., Zhang B., Li G., Wu T., and Sun D. 2019. Efficient remediation of crude oil-contaminated soil using a solvent/surfactant system RSC Adv., 9, 2402-2411.

Zahed M.A., Salehi S., Madadi R., and Hejabi F. 2021. Biochar as a sustainable product for remediation of petroleum-contaminated soil Curr. Res. Green Sustain. Chem., 4, Article 100055.