

Physicochemical Characterization of Oil Spill Impacted Soils in Emohua LGA of Rivers State

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ABSTRACT

Oil spillage on agricultural soil in the Niger Delta area of Nigeria is a serious threat to agricultural production and food security. This study was carried out to determine the effects of oil spillage on the physicochemical parameters of agricultural soils in Obele community of Emohua LGA. Thirty (30) triplicate soil samples at 3 depth (0-1.0, 1.1-2.0 and 2.1-3.0m) were collected from the study area and analyzed. The Physicochemical parameters were analyzed using standard methods and the results revealed that the total organic content (TOC) of the soils ranged from 0.28 – 1.29%. The lower levels observed may not be unconnected with the severe bush burning induced loss of organic matter at the location and the low level of vegetation cover. The pH values of the surface soils ranged from 4.50 – 5.9 making the soils acidic. The sulphate content (SO_4^{2-}) of the surface and sub-surface soils at the location ranged from 0.013 – 1.25ppm while all the samples recorded low sulphate levels (<10ppm), most of the sample points recorded are considered extremely low sulphate levels (<0.1ppm). The nitrate content (NO_3^-) of the surface and sub-surface soils ranged from 0.14 – 1.47ppm. These values are also very low compared to the levels required for agricultural soils (15 -40ppm). These low levels will impact on the rate of biodegradation driven natural attenuation process. The phosphate (PO_4^{2-}) content ranged between 0.015 – 2.819ppm. The values recorded were low as with the other agriculture/biologically critical anions. The suitable range for best biological function in soil is between 10-20ppm. This low-level like with sulphate and nitrate will negatively affect biodegradation. Sixteen (16) HA points out of 30 (53%) located predominantly at the periphery of the locations had TPH values >50ppm at a depth of 1.1-2m while a total of 14 HA points (46.7%) recorded TPH values >50ppm at depths of 2.1 – 3m. The study recommends cleanup and remediation efforts to mitigate the environmental impact of the oil spillage.

Keywords:

Oil Spill,
Physicochemical,
Agricultural,
Food security,
Characterization,
Soil.

INTRODUCTION

Crude oil spill is the unintentional release of liquid petroleum hydrocarbon into the environment as a result of human activity and equipment failure. The term often refers to marine oil spills where oil is released into the ocean or coastal waters. Most manmade oil pollution comes from land-based activity. Oil spillage occurs due to a number of causes which include corrosion of pipelines, sabotage and oil production operations. Sabotage and oil siphoning has become a major issue in the Niger Delta States as well, contributing to further environmental degradation (Anderson, 2005). Oil spills are one of the most widespread forms of pollution on agricultural lands and water bodies in Nigeria propelled by increasing

demand for energy. Sustainable use of agricultural soil on which plants and animals depend is absolutely necessary for agricultural productivity. Soil is the most valuable component of the farming ecosystem and environmental sustainability largely depends on proper soil management Osuocha et al. (2013). Osuocha et al (2016) also reported that soil represents a dynamic system in which continuous interaction takes place between soil minerals, organic matter and organisms that influence physicochemical and biological properties of terrestrial systems. Crude oil is a complex mixture of various organic compounds including hundreds of aliphatic and aromatic hydrocarbons and trace amounts of heavy metals which are mostly toxic to biota Wilberforce (2016).

In the Niger Delta area of Nigeria, the common sources of soil contamination are crude oil spillage, industrial effluents, agricultural wastes and gas flaring. Soil and water contamination by crude oil is a very sensitive issue since the impact is known to be disastrous Olayinka and Alo (2004). Petroleum hydrocarbons negatively impact the germination and growth of plants in soils by creating conditions which make essential nutrients unavailable for plant growth Hussain et al. (2019), Adam and Duncan (2002). There is a direct need to address soil contamination by oil spillage in order to minimize its harmful effects on the ecosystem, conserve nature and sustain livelihoods. The aim of this study was to determine the effects of oil spillage on physicochemical parameters pH, electrical conductivity, sulphate, chloride, nitrate, total phosphorus, available phosphorus, total nitrogen, nitrate, exchangeable bases (Ca, Mg, K, Na), organic carbon, cation exchange capacity, oil and grease of soil in Emohua LGA

Emohua is experiencing a spill on the land and neighbouring water which may also affects the underground water circulation, soil biochemistry leads to low crop output. The impact on the vegetation and mangrove are put to extinction. Some of the aquatic mammals and fishes are reported dead within the locality. Fishermen and women who use the marine water as a means of sustainability to cater for their families also bath with the water observed rashes on their skin (Ordinioha & Brisibe, 2013; Grattan et al., 2011; Shreve, 2011; Ana et al., 2009) and the medical examination entails that the rashes are caused by the spill. Pollution is the evolution of polluting something or the state of being polluted. Therefore, environmental pollution is the proportional mixture of the venomous level of chemicals in the air, water and land. Niger Delta is a region in Nigeria with ecologically and economically significant globally. It is one of the largest wetlands of the world and hosts Nigeria's oil & gas industry. Rivers State, one of the 9 States of the Niger Delta region with a significant amount of crude oil and condensate in Nigeria with some of the pipe lines of international oil companies (IOCs) passing through Emohua LGA.

The National Oil Spill Detection and Response Agency (NOSDRA) which was established in 2006 identified over 2,000 crude oil polluted sites needing remediation in the Niger Delta, with majority of these sites being SPDC sites. Fresh water resources are becoming day by day at the faster rate of deterioration of the water quality is now

a global problem. Water pollution by effluent has become a question of considerable public and scientific concern in the light of the evidence of their extreme to human health and to biological ecosystem. This effluent can alter the physical, chemical and biological nature of receiving water bodies. Water is an essential raw material for human life and a vital factor to the establishment of industries. Without water no life Ibe, (2000).

The availability of water determines the location and activities of humans in an area, and our growing population is placing great demands upon natural freshwater resources. Technological growth has also put the ecosystem we depend on under stress and water resources at risk of being polluted Kulshreshtha (2025); Osibanjo (1996). The accumulation of heavy metals and their effects on aquatic environment have direct consequences on man and the ecosystem in general. Although some metals such as copper (Cu) and Zinc (Zn) are generally regarded as essential trace metals in view of their valuable role for metabolic activities in organisms, other metals like lead (Pb), nickel and mercury exhibit extreme toxicity even at trace levels Merian (1991); DWAF (1996). However, it is of interest to note that most essential metals are toxic when supplied in concentrations in excess of the optimum levels. Heavy metal contamination of aquatic environment is of critical concern due to the toxicity and accumulation in aquatic habitats Tam and Wong (1995). The widespread incidences of oil spills caused by the corrosion of pipes, tanks leakages infrastructures decay and sabotage in Niger delta areas that is Southeast and South South result in many instances of soil and water contamination. The disposal of organic and inorganic wastes on agricultural soils (fig 1), wastewater and wastes from everyday operation at outlet has contributed to the pollution of water and soil. In general, oil spills present problem that affects the economic activities, human health, conservation of natural resources, the ecology, and the aesthetic values of these areas. A polycyclic aromatic hydrocarbon PAH are organic compound composed of multiple aromatic rings. They are often formed during incomplete combustion of organic matter. The simplest representative is naphthalene which are byproduct of hydrocarbon. Some PAH are known to be carcinogenic and pose environmental concern. The aim of this study is to determine the effects of oil spillage on the physicochemical parameters of agricultural soils in Obele community of Emohua LGA.



Figure 1a: Oil spill on Agricultural land

Source: www.questjournals.org

Figure 1b: Crude oil spill on water

Location and Geomorphology of the Study Area

The study area as shown in figure 2 is located between Longitudes $6^{\circ} 41'$ and $6^{\circ} 41'$ East and Latitudes $5^{\circ} 0' 11$ and $5^{\circ} 0' 15$ North. The study area is underlined by quaternary deposits of the Sombreiro Deltaic Plain directly overlying the prolific aquiferous Benin Formation (Coastal Plain sands) which outcrops on the surface to the east and beyond usually covered by laterite. The typical lithology of this area is sand, silt and gravel of varying thickness, occasionally including clay lenses. A thin veneer of alluvium is found on the course of the Sombreiro River draining north-southward to the west of the study area. The geomorphology of the land is

dominated by an almost flat terrain that is only few meters above mean sea level. Depressions and a few minor undulations that are perennially flooded also occur in the area. The hydrogeology of the area is characterized by relatively low water table. Borehole cuttings are often comprised mostly of well-sorted fine to coarse-grained sand formation. Some part of the aquifer is unconfined at while some portions are confined with significant clay layers outcropping to the surface in some segments of the surface runoff pathways into the Sombreiro River and the aquiferous materials are mainly sands. The aquifer recharge depends on rainfall and on hydraulic exchanges with the Sombreiro River.

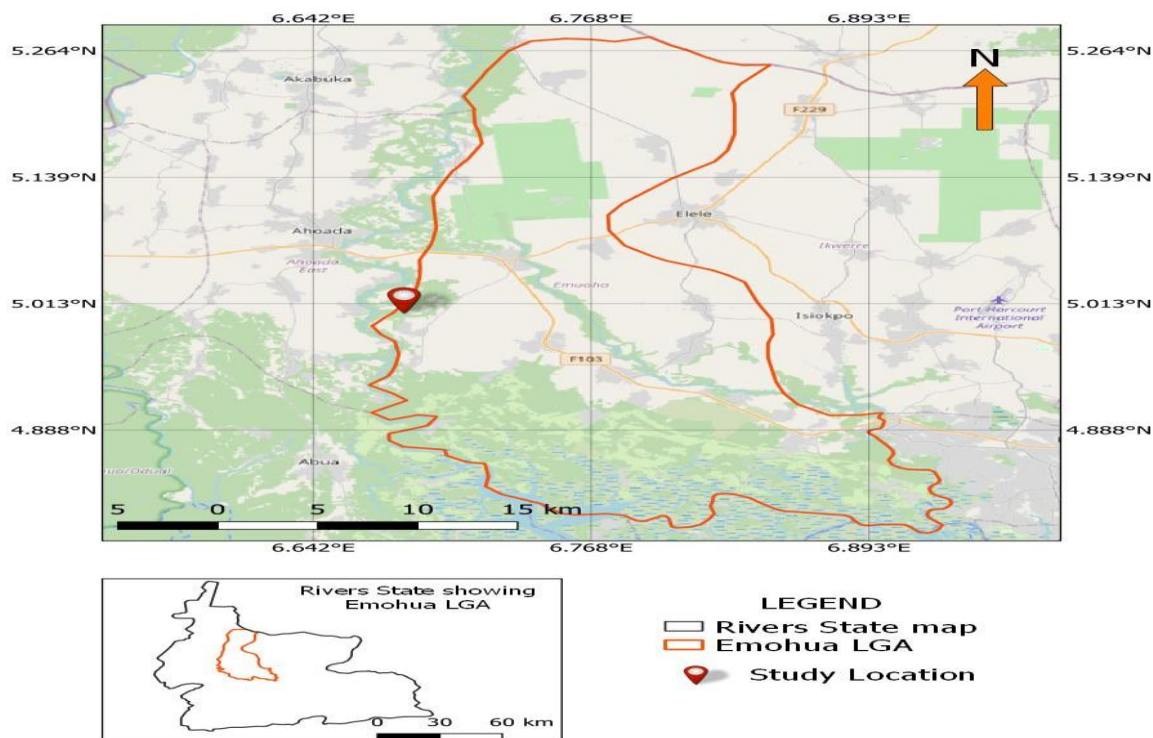


Figure 2: Map of Rivers State showing study area in Emohua LGA

MATERIALS AND METHODS

Trimble GNSS Global satellite Positioning System was used to determine the geodetic system of actual coordinates and approximate altitude above sea level. Other materials used are Atomic Absorption Spectrophotometer, weighing balance, Clamp, separating funnel, Gas chromatography, measuring cylinder, Extractor, computer, Freezer, sample Vials, Sampling Containers, Reagents and Acids, Stainless steel basins and Stainless-steel spoons, Detergent, Methanol and Deionized water, Permanent Markers, Cutlass and Shovels, Vial racks Field logbook/note book and Hand Augers.

Sampling Design/Plan

Standard procedure for sample collection was adopted. This involved collection of samples of right quality and quantity which represents the conditions existing at the point taken and time of sampling. The data gathering exercise for the Soil Characterization (SC) was carried out and the sampling plan involved collection of collection of soil sample at three (3) different depths horizon of 0 - 1.0m, 1- 2.0m and 2 - 3.0m depth below ground level respectively. Adhesive sample labels were affixed to each sample bottle or container and sample identification data written with an indelible marker. This information includes sample number date and time of sampling and sampling point and were analysed in the Laboratory using standard procedures.

Physical observations (table 1) such as colour, odour, soil type, sorting, were made in the field on soil samples collected. The laboratory analysis involved rigorous sample preparation and standardized procedures to ensure accurate and reliable results. Plastic sampling containers were thoroughly washed, dried and treated with acetone and distilled water while all in-situ measuring devices were calibrated using standard solutions. Field parameters such as pH, conductivity, temperature and salinity were measured using digital meters with probes rinsed and readings taken after stabilization. Samples were properly labelled, fixed with recommended reagents, recorded in field logs and transported in ice-chests before refrigeration at 4°C in the lab. For sulphate and nitrate analysis, UV spectrophotometry (DR 5000TM) was used, employing American Public Health Association (APHA) standard methods. Polyaromatic hydrocarbons (PAHs) and total petroleum hydrocarbons (TPHs) in water and sediment were analysed using gas chromatography (Agilent 7890 and 6890GC) following USEPA protocols. Total Organic Carbon (TOC) was assessed via high-temperature combustion and infrared detection. Microbiological tests for total aerobic heterotrophic and hydrocarbon-utilizing bacteria were conducted using APHA 9215C spread plate techniques with serial dilutions, incubations and colony counts reported in cfu/ml or cfu/g, with isolates further cultured for

identification. The concentration of Iron (Fe) was determined using Atomic Absorption Spectrophotometry (ASTM D1068) method. This was carried out using GBC Atomic Absorption Spectrophotometer (AAS) with detection limit of 0.05mg/l. Dissolved Iron (Fe) was determined by aspirating a portion of the filtered sample (without pretreatment) directly in AAS. Concentration of Iron was ascertained from the data generated by the AAS and expressed in mg/l. Quality assurance and quality control measures were adopted and applied consistently throughout the phases of the experiment.

RESULTS AND DISCUSSION

The physicochemical parameter encompasses some key principal components that are crucial in assessing the environmental risk associated with the site following the release of an impact such as crude oil spill. These principal components are namely total petroleum hydrocarbon (TPH), polycyclic aromatic hydrocarbon (PAH), the volatile mono-aromatic hydrocarbons (BTEX), total organic carbon (TOC), SO_4^{2-} , NO_3^{2-} , PO_4^{2-} , Fe^{3+} , heavy metals and soil type. The total petroleum hydrocarbon (TPH) indicates release or presence of petrogenic hydrocarbons such as crude oil. Elevated levels of TPH would indicate a recent release of crude oil from a source. The Environmental Guidelines and Standards for the Petroleum Industry in Nigeria (EGASPIN, 2018) has set risk-based values for TPH; these are the Intervention values and the Target values. These values are meant to be protective of human health, plant and animal life and the environment. These organic compounds are generally hydrophobic in nature due to two or more benzene rings, which make them resistant to structural degradation (Anejionu et al. 2015). This success could be linked to the remediation technique used, probably a combination of soil washing, chemical oxidation, electrokinetic, photo-oxidation, evaporation and microbial oxidation (Polyak et al. 2018; Gitipour et al. 2018).

The pH values of the surface soils ranged from 4.50 – 5.9 for top 0 – 0.15m and bottom 0.16 – 0.3m depths making the surface soils acidic. This is not unexpected as the soils in the Niger Delta environment are generally acidic. The total organic content (TOC) of the surface soils ranged from 0.28 – 1.29%. Th the lower levels observed may not be unconnected with the severe bush burning induced loss of organic matter at the location and the low level of vegetation cover. The sulphate content (SO_4^{2-}) of the surface and sub-surface soils at the location ranged from 0.013 – 1.25mg/kg. while all the samples recorded low sulphate levels (<10ppm), most of the sample points recorded are considered extremely low sulphate levels (<0.1ppm). The nitrate content (NO_3^-) of the surface and sub-surface soils ranged from 0.14 – 1.47ppm. These values are also very low compared to the levels required for agricultural soils (15 -40ppm). These low levels will

impact on the rate of biodegradation driven natural attenuation process. The phosphate (PO_4^{2-}) content of the surface and subsurface soils ranged between 0.015 – 2.819ppm. The values recorded were low as with the other agriculture/biologically critical anions. The suitable range for best biological function in soil is between 10-20ppm. This low-level like with sulphate and nitrate will negatively affect biodegradation. Geographic Information System (GIS) was applied along the Chennai Coast in India to assess the environmental sensitivity and oil spill (Kankara et al. 2016). Similar to these studies, our study used Trimble GNSS Global satellite Positioning System to map hydrocarbon pollution in the Emohua area of the Niger Delta region.

Hand Augers (HA) Samples

Sixteen (16) HA points out of 30 (53%) located predominantly at the periphery of the locations had TPH values >50ppm at a depth of 1.1-2m while a total of 14 HA points (46.7%) recorded TPH values >50ppm at depths of 2.1 – 3m. The highest TPH value was 6,667ppm at 3m depth was recorded in HA08, while Hand Auger samples HA06, HA12, HA9, HA19, HA26 HA24 and HA21 recorded TPH values >100ppm at 3m depths with

values of 1481ppm, 573ppm, 562ppm, 396ppm, 342ppm and 161ppm respectively. 16 out of 30 HA points recorded TPH values greater than the EGASPIN target level of 50ppm at depths of 1.1 – 2m bgl with HA19 recording the highest value of 4147ppm. The other values recorded were 4106ppm, 682ppm, 622ppm, 542ppm, 505ppm, 404ppm for HA02, HA09, HA12, HA28, HA22 and HA 26 respectively. Other values were 379ppm, 343ppm, 260ppm, 191ppm, 145ppm, 127ppm, 90.47ppm, 79.94ppm and 73.36ppm for HA23, HA20, HA14, HA16, HA10, HA27, HA21 HA24 and HA03 respectively. The maximum depth of soil core samples with the Hand augers was 3m.

The BTEX content in table 2 and figure 3 of the soil ranged between 0.03 – 1.73 mg/kg with a mean of 0.48 ± 0.4 mg/kg across the study area. The three depth intervals of 1m, 2m, and 3m had BTEX values of 0.03 – 1.73 mg/kg, 0.15 – 0.68 mg/kg and 0.03 – 1.05 mg/kg respectively with mean values of 0.52 ± 0.57 mg/kg, 0.40 ± 0.18 mg/kg and 0.52 ± 0.36 mg/kg in that order. The BTEX trend (figure 3) shows that the middle soil profile (2.0m depth) recorded the lowest BTEX mean in the study area. These values are similar to the results obtained by Hafiz et. al (2022).

Table 1: Physical Observations on soil sample collected

Sample ID	Observations	0.0 – 1.0m	1.1 – 2.0m	2.1 – 3.0m
HA1	Smell	Yes	Yes	Nil
	Sheen	Yes	Yes (Free phase)	
	Color	Dark brown	Dark brown	
	Soil Type	Sandy	Sand	
HA2	Smell	Yes	Yes	Yes
	Sheen	Nil	Yes	Yes
	Color	Dark brown	Dark sand	Dark sand
	Soil Type	Sandy	Sandy	Sandy
HA3	Smell	Nil	Nil	Yes
	Sheen	Nil	Nil	Nil
	Color	Dry brown	Wet brown	Wet dark brown
	Soil Type	Sand	Sand	Sand
HA4	Smell	Nil	Nil	Nil
	Sheen	Nil	Nil	Nil
	Color	Brown	Damp Brown	Damp Brown
	Soil Type	Fine sand	Sandy	Sandy
HA5	Smell	Nil	Nil	Yes
	Sheen	Nil	Nil	Yes
	Color	Brown	Light Brown	Wet light brown
	Soil Type	Sandy	Sandy	Sandy
HA6	Smell	Yes	Yes	Yes
	Sheen	Yes	Nil	Yes
	Color	Dark sand	Light wet sand	Light wet sand
	Soil Type	Sand	Sand	Sand
HA7	Smell	Yes	Yes	Yes
	Sheen	Nil	Yes	Yes
	Color	Light Brown	Light wet sand	Light wet sand
	Soil Type	Sand	Sand	Sand

Table 2: BTEX content of deeper soil profiles

	Study area	BTEX (mg/kg)		
		1.0m	2.0m	3.0m
Min	0.03	0.03	0.15	0.03
Max	1.73	1.73	0.68	1.05
Mean	0.48	0.52	0.40	0.52
SDEV	0.41	0.57	0.18	0.36

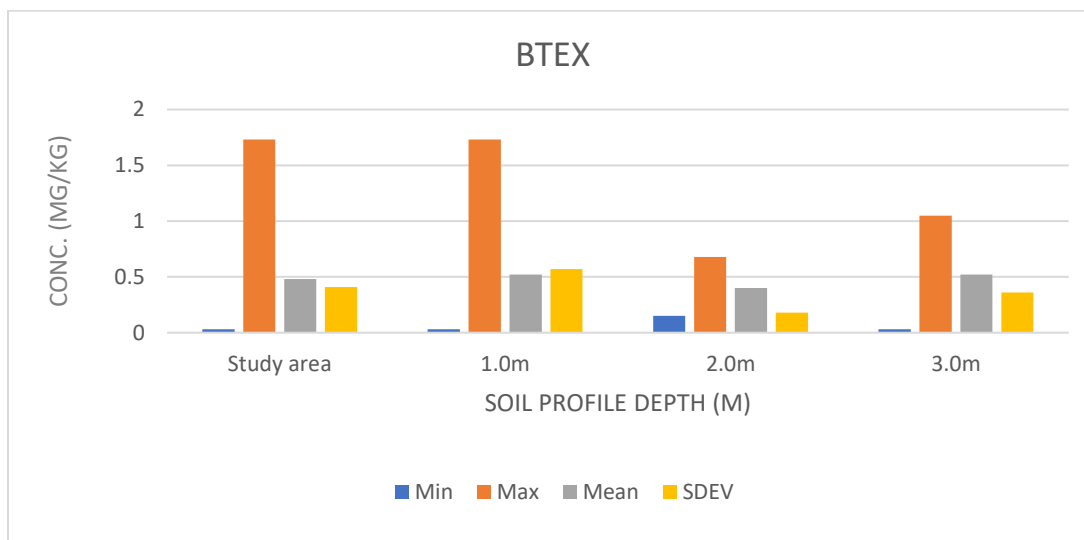


Figure 3: BTEX Distribution of the soil profiles

Table 3: Physicochemical result of hand auger soil cores

	Ph			TOC (%)			Sulphate (mg/kg)			Nitrate (mg/kg)			Phosphate (mg/kg)			TPH (mg/kg)		
depth (m)	-0.1-1.0	1.1-2.0	2.1-3.0	-0.1-1.0	1.1-2.0	2.1-3.0	-0.1-1.0	1.1-2.0	2.1-3.0	-0.1-1.0	1.1-2.0	2.1-3.0	-0.1-1.0	1.1-2.0	2.1-3.0	-0.1-1.0	1.1-2.0	2.1-3.0
HA01	5.2	5.4	4.3	1.1	0.88	0.88	0.312	0.664	0.419	0.014	0.026	0.055	0.365	0.298	0.142	14.23	12.18	8.35
HA02	4.2	4.6	4.6	1	0.79	0.69	0.426	0.123	0.131	0.056	0.092	0.101	0.132	0.12	0.135	2059	4106	6141
HA03	5.4	5.2	5.3	1.06	1	0.70	0.459	0.423	0.421	0.053	0.48	0.522	0.836	0.643	0.741	141	73.36	
HA04	5.55	5.3	5.3	0.85	0.65	0.77	0.518	0.536	0.534	0.163	0.148	0.152	0.583	0.544	0.554	112	36.68	
HA05	4.6	5	5.2	1	0.77	0.78	0.122	0.194	0.199	0.037	0.026	0.040	0.392	0.27	0.29	28.44	23.51	
HA06	4.6	4.5	4.8	0.5	0.66	0.79	0.056	0.047	0.088	0.184	0.172	0.183	0.195	0.143	0.185	1150	40.14	1481
HA07	5.2	5.4	5.3	0.45	0.86	0.77	0.125	0.143	0.181	0.094	0.123	0.107	0.435	0.555	0.468	48.15	39.17	33.1
HA08	4.9	4.9	4.3	0.88	0.74	0.91	0.06	0.058	0.044	0.548	0.492	0.613	0.013	0.018	0.062	15.31	28.6	15.47
HA09	4.6	5	5.1	0.65	0.77	0.56	0.162	0.144	0.129	0.123	0.159	0.136	0.112	0.134	0.105	43.4	682	562
HA10	4.5	4.8	5.1	0.91	0.8	0.86	0.652	0.518	0.631	0.362	0.348	0.350	0.628	0.554	0.601	26.48	145	
HA11	4.5	4.5	4.8	0.88	1.03	1.00	0.062	0.055	0.054	0.388	0.177	0.255	0.473	0.498	0.501	31.29	33.11	
HA12	5.4	5.3	5.4	0.76	0.77	0.69	0.167	0.128	0.097	0.051	0.066	0.074	0.154	0.133	0.185	1890	622	573
HA13	5.1	5.1	5.0	1.07	0.99	1.00	0.352	0.214	0.344	0.86	0.047	0.098	0.248	0.287	0.289	45.37	40.93	
HA14	5.4	5.5	5.3	1.01	0.89	0.98	0.291	0.197	0.188	0.066	0.024	0.068	0.162	0.174	0.184	4524	260	
HA15	5.3	5.2	5.3	1.02	1.00	0.99	0.085	0.100	0.099	0.026	0.027	0.033	0.336	0.345	0.355	72.32	225	
HA16	5.4	5.5	5.4	0.94	0.99	1.00	0.241	0.173	0.188	0.012	0.024	0.021	0.071	0.082	0.075	603	191	
HA17	5.3	5.3	5.2	0.88	1.02	0.89	0.413	0.201	0.389	0.248	0.229	0.033	0.014	0.016	0.020	260	31.15	
HA18	4.9	4.8	4.9	0.77	0.8	1	0.228	0.318	0.39	0.342	0.389	0.221	0.022	0.028	0.044	75.22	22.83	42.55
HA19	4.7	4.8	4.5	1.06	0.97	1.2	0.521	0.578	0.463	0.016	0.014	0.11	0.395	0.328	0.312	288	4147	396
HA20	5.3	5.4	5.3	0.86	0.9	1.12	0.082	0.064	0.099	0.236	0.444	0.51	0.441	0.412	0.433	198	343	38.37
HA21	5.3	5.1	5.3	1	0.92	0.9	0.028	0.023	0.044	0.346	0.255	0.391	0.094	0.028	0.055	343	90.47	73.47
HA22	5.6	5.2	5.4	1.06	0.66	0.78	0.128	0.136	0.195	0.19	0.137	0.122	0.013	0.017	0.014	62.56	505	17.32
HA23	5.4	5.2	5.2	0.89	0.82	1.02	0.056	0.024	0.033	0.248	0.261	0.21	0.182	0.186	0.117	782	379	8.51
HA24	5.1	4.8	4.9	1.33	1.21	0.86	0.071	0.016	0.022	0.512	0.439	0.476	0.297	0.283	0.198	191	79.94	161
HA25	5.3	5.1	4.7	0.82	0.93	0.77	0.562	0.514	0.287	0.028	0.024	0.081	0.582	0.529	0.511	24.23	22.13	1.68
HA26	5.4	5.2	5.5	0.89	1.02	0.87	0.551	0.596	0.444	0.049	0.047	0.035	0.269	0.24	0.28	84.5	404	342
HA27	5	5.2	5.2	0.77	1.03	1.1	0.052	0.057	0.044	0.586	0.521	0.549	0.054	0.016	0.098	37.03	127	23.47
HA28	4.7	4.5	4.7	0.88	0.93	0.76	0.258	0.249	0.231	0.201	0.298	0.203	0.071	0.098	0.052	29.85	542	33.24
HA29	5.1	4.8	5	1.03	0.88	0.92	0.081	0.072	0.022	0.517	0.442	0.236	0.152	0.179	0.111	70.58	14.54	8.14
HA30	5.1	4.8	5	0.81	0.83	1.01	0.081	0.072	0.022	0.517	0.442	0.236	0.152	0.179	0.111	9.29	9.16	65.31
MIN	4.2	4.5	4.3	0.45	0.65	0.56	0.028	0.016	0.022	0.012	0.014	0.035	0.013	0.016	0.014	9.29	9.16	1.68
MAX	5.6	5.5	5.5	1.33	1.21	1.2	0.652	0.664	0.463	0.86	0.521	0.613	0.836	0.643	0.511	4524	4147	6141
MEAN	5.07	5.04	4.97	0.90	0.88	0.88	0.24	0.23	0.17	0.24	0.22	0.23	0.26	0.24	0.18	441.98	450.03	501.25
STDEV	0.36	0.30	0.36	0.17	0.13	0.16	0.19	0.20	0.15	0.22	0.17	0.17	0.21	0.19	0.14	915.26 (± 5sd)	1020.16 (± 4sd)	1338.67 (± 5sd)

CONCLUSION

The study revealed that while soil anions, PAHs, BTEX and heavy metal concentrations were within regulatory limits, hydrocarbon levels in the soil, particularly in the vadose zone, capillary fringe and saturated zones exceeded the NUPRC/NOSDRA intervention thresholds. The apparent absence of PAHs in surface soils was attributed to extensive cleanup operations such as thermal desorption and ongoing bush burning. However, the presence of hydrocarbon-degrading microorganisms (bacteria and fungi) in the soil indicates ongoing biodegradation activity. Hydrocarbon concentrations were found to increase with depth, reaching up to 3 meters below ground level where free-phase oil was detected suggesting vertical migration and contamination of shallow subsurface layers. Seasonal fluctuations also influence the presence of crude oil due to rising and falling groundwater levels. From the findings, the study recommends targeted follow-up investigations in areas where free-phase oil was observed around the 3m depth to better understand the extent, thickness and spread of the contamination plume. Additionally, it advocates for the development and implementation of a structured remediation action plan to address zones with hydrocarbon concentrations above regulatory limits ensuring long-term environmental recovery and compliance.

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