Assessment of Physicochemical Parameters of Soils Contaminated with Petroleum from Eleme Port Harcourt, Nigeria

U.P. Ojukwu[1*], A.N. Eboatu[2]

[1]Department of Polymer and Textile Engineering, Nnamdi Azikiwe University Awka
[2]Department of Chemistry, Nnamdi Azikiwe University, Awka
*Corresponding Author

Received: 14 October 2022/ Revised: 25 October 2022/ Accepted: 05 November 2022/ Published: 30-11-2022

Abstract— *The study was conducted to examine the physicochemical parameters of soils contaminated with petroleum using nonpetroleum contaminated soil as control. Six petroleum contaminated soil samples from Eleme, Port Harcourt and one non petroleum contaminated soil sample from Awka were analyzed for pH, texture, moisture content, bulk density, total organic carbon, total organic nitrogen, total organic matter and total petroleum hydrocarbon. Some pH of the soil samples were acidic while others were alkaline and ranged from 5.26-7.84. The textural class of the petroleum contaminated soils (A-F) were silty clay loam while that of the non petroleum contaminated soil (G) was sandy loam implying that samples A-F are somewhat clayey and sample G almost sandy. Total moisture content of petroleum contaminated soils and their water holding capacity were higher than that of the control and fell in the ranges 0.50-40.56% and 13-29% respectively. Total organic carbon (TOC) and Total organic matter (TOM) of petroleum contaminated soils were higher than that of the non petroleum contaminated soil and were within the ranges 7.29-15.09% and 12.57-26.02% respectively. Total organic nitrogen result follow the same pattern with the non petroleum contaminated soil having the least value. The range was 0.365-0.755%. Bulk density results were within the range of 0.80-1.42g/cm^3. The uncontaminated soil (G) had less amount of organic matter in it as a result, the bulk density was the highest (Olaitan and Lombin, 1984). The total petroleum hydrocarbon (TPH) content ranged from 107.5305-626.4060 mg/kg with that of the non petroleum contaminated soil being the least. The results indicated that petroleum contamination affected the physicochemical properties of the soils analyzed. Regular soil assessment is recommended so as to avert any ugly incidence which may occur.*

I. INTRODUCTION

Contamination of the environment by petroleum products from variety of sources represents one of the most frequent contaminations {Mracnova et al.,1999). This is due to the growing demand and supply of fuel oil and new chemicals by the industrialized society of the twenty-first century (Jaffe,1991). High concentration levels of hydrocarbons present in contaminated sites can pose a health risk to humans, plants and animal lives as they are carcinogenic, mutagenic and toxic (Ribes et al., 2003, Freitag et al., 1985 and DEC,1992).

Oil contamination can also affect soil physical and chemical properties (Wang et al., 2013). Soil temperature, total organic carbon, pH, microbial community, available phosphorus and other soil chemical properties are affected (Aislabie et al., 2004, Townsend et al., 2003, Ekundayo and Obuekwe, 2000, Hu et al,. 2006), Oil causes anaerobic environment in the soil by smothering soil particles and blocking air diffusion in the soil pores. In addition, crude oil contaminated soils are hydrophobic compared with pristine sites (Quyum et al., 2002).

An assessment of the physicochemical parameters of petroleum contaminated soils from Eleme, Port Harcourt was embarked upon to monitor the levels of contaminants which can accumulate toxic proportions. The oil finds its way to soil through leakages from pipelines, underground and surface fuel storage tanks, indiscriminate spills, and careless disposal of wastes (Okop, and Ekpo, 2012). Despite improvements to the technical conditions of sites involved in the production, storage and distribution of liquid fuels, the threat to the environment posed by petroleum substance is still very real (PIEP,1995).

II. MATERIALS AND METHOD

2.1 Study Area

Eleme coordinates are 4.7994ºN, 7.1198º E. It is located at east of Port Harcourt and covers an area of 138km^2. At 2006 census, it had a population of 190,884. Precipitation in Port Harcourt averages 2708mm and the average annual temperature is 26.4ºC. The average annual relative humidity is 71.0% (https//weather and climate.com). Awka is found in the south eastern part of Nigeria. It is the capital of Anambra State and is located on Latitude 6º09′N and Longitude 7º12′E. The climate is tropical with an annual rainfall of about 11,450mm, average temperature of 28ºC and relative humidity of 91% at dawn (Nwangwu, 2015).

2.2 Sample Collection

Samples from both petroleum contaminated soils Eleme, Port Harcourt (A-F) and non petroleum contaminated soil Awka (G) were collected from a depth of 0-12 cm with soil auger (Okop and Ekpo, 2012). Five samples were randomly collected and mixed to form a representative sample (Edori and Iyama, 2017). The samples which were more than 1kg were transported to the laboratory for immediate analysis.

2.3 Sample Analysis

The pH was determined by the method of APHA (2000). The soil moisture was estimated by the method of Ibitoye (2006).

The textural class was determined by the method of Brady and Weil (2013). The methods proposed by Page (1982), Ibitoye (2006) and Head (1992) were used for the determination of organic matter, organic carbon and organic nitrogen. The total hydrocarbon content was determined by the method described by AOAC, 1990). The bulk density of the soil was determined by the method adopted by Olaitan and Lombin (1984).

III. RESULTS AND DISCUSSION

The pH of the soils samples ranged from 5.26-7.84 as presented in Table1.This is comparable with those obtained by Adoki (2012) for soil samples from borehole drilling at a legacy spill site in Eleme Port Harcourt.

TABLE 1
PHYSICOCHEMICAL PARAMETERS OF SOIL SAMPLES

	Sample A	Sample B	Sample C	Sample D	Sample E	Sample F	Sample G
pH	5.26	5.37	7.69	7.64	7.79	7.84	5.37
Texture	Silty clay loam	Silty clay loam	Silty clay loam	Silty clay loam	Silty clay loam	Silty clay loam	Sandy loam
Moisture content (%)	40.56	16.28	15.61	11.73	19.76	20.48	0.50
Bulk density (g/cm^3)	0.80	0.94	0.90	1.03	1.05	0.95	1.42
Total organic carbon (%)	14.41	15,09	10.68	12.40	10.85	10.68	7.29
Total organic nitrogen (%)	0.721	0.755	0.534	0.620	0.543	0.534	0.365
Total organic matter (%)	24.84	26.02	18.41	21.38	18.71	18.41	12.57
Total petroleum hydrocarbon (mg/kg)	620.9427	319.2833	626.4060	620.9427	163.3685	148.7637	107.5305

The pH of the environment affects the speed and direction of biological processes in the soil and is one of the factors that influence the decomposition of hydrocarbons by microorganisms in the environment (Hawrot-Paw, 2010). According to Arias (2005), soil pH plays the greatest influence on availability of nutrients to plants and the type of organism found in the soil. Although plants have begun to thrive under varying pH conditions, the optimum pH for most agricultural soils is between 5.5-7.5 QDEHP, (2017). As soil becomes increasingly acidic, important nutrients like phosphorus become less available to plants which result in reduced crop yield.

The textural classes of the petroleum contaminated soils are silty clay loam in contrast with the sandy loam of non petroleum contaminated soil (control). The percentage of sand, clay and silt are categorized as textural class. Soil texture is a measure of the physical properties of the soil such as plasticity of the soil, water retention capacity, soil productivity, soil permeability and ease or toughness of tillage of the soil (Brady, 1996). Soills with high percentage of clay have the potential to hold more water within the particles (Osuji, 2007). Sandy soils retain little water and therefore percolation of water through it is high and so promotes ground water contamination while clayey texture prevents water percolation (Schulte, 1999).

The total moisture content of the soils varied from 0.50 to 40.56% with those of the petroleum contaminated soils being higher than the non petroleum contaminated soil. The results are similar to those of Azlan et al., (2012) and are in agreement with the findings of Wang et al., (2013) which stated that hydrocarbon contamination can increase soil total organic carbon. Oil clogs the pores of soil particles and thus hinders evaporation of water (Olaitan and Lombin, 1984). Aggregation due to force of adhesion existing in oil particles is responsible for the high moisture content of petroleum contaminated soils (Atkins and Jones, 1999). Also sandy soil retains very little water while clay will hold the maximum amount. Any soil with high concentration of organic components has the capacity to retain water for a long time and the drying takes longer time than usual. High moisture content is due to de-aeration which displaced air in the soil and also oxygen content of the soil and decreased microbial activity (Brady and Weil, 2008).

The water holding capacity of soils fell in the range 13-29%. These are comparable with those of the petroleum contaminated soils which are silty clay loam in texture and have higher water holding capacity than the non petroleum contaminated soil which is sandy loam. Oil blocks air diffusion in the soil pores and affects soil microbial communities (Townsend et al., 2003). The blockage of air diffusion also reduces pore spaces which results in an increase of water holding capacity and of the humidity needed for bacterial growth which eventually increases the total organic carbon and soil organic matter content. The presence of large pores results in an decrease of water holding capacity and of the humidity needed for bacterial growth (Azlan et al., 2012). Also, the presence of a relatively high percentage of clay in samples A-F accounts for the ability of the soils to hold more water within the particles.

The bulk density of samples were within the range 0.80-1.42 g/cm^3. Clay soils have bulk density values ranging from 1.10to1.40g/cm^3. Loams, sandy loams and sand have bulk densities ranging from 1.20-1.80g/cm^3 (Olaitan and Lombin, 1984).

The total petroleum hydrocarbon content of the samples compares favourably with those of Okop and Ekpo, (2012) and Adoki, (2012). The results fell within the range 107.5305- 626.4060 mg/kg and increased in the following order C>A, D >B>E>F>G. The petroleum contaminated samples show elevated concentrations of TPHs when compared with the control (non-petroleum contaminated sample) and could be attributed to oil spilling effect at the sampled areas (Asaolu, 2000). Hydrocarbon contamination can increase soil total organic carbon (Ekundayo and Obuekwe, 2000) and change soil pH values (Hu et al., 2006). The total organic carbon (TOC) content varied from 7.29 to 15.09% and the total organic matter (TOM) content varied from 12.57 to 26.02%. The total organic nitrogen (TON) range is 0.365-0.755%. The results of the TOC and TOM agree favourably with those Edori and Iyama (2017). The TOC, TOM and TON of petroleum contaminated soils are higher than that of the control and this is in agreement with the work of Nwankwoala and Ememu (2018). Soil organic matter (SOM) is the soil nutrient pool and the changes will affect the quality and quantity of soil fertility. SOM stabilizes soil pH which plays an important role in controlling the supply of nutrients and their availability for plant intake (Azlan et al., 2012). Concentration and turnover of SOM is affected by the formation of a large number of factors such as climate (Ganuza and Almendros, 2003), topography (Burke, 1999), vegetation (Finzi et al., 1998), the parent material (Spain, 1990) and management (Yang and Wander, 1999). The soil organic carbon is obtained by decomposition of the plants, animals and anthropogenic sources such as chemical contaminants, fertilizers or organic rich waste (Kong et al., 2009).

Higher levels of organic nitrogen are observed in samples A-F (petroleum contaminated soils) than in sample G (control). This again is due to increased level of decayed organic matter and contamination by petroleum in samples A-F. Nitrogen compounds detected in petroleum include polycyclic aromatic amines, carbazole, benzocarbazole, heterocyclic aromatics, triaromatic azaarenes, nitrogen heterocycles as well as diaromatic nitrogen bases (Thomas and Ringen, 1985).

REFERENCES

[1] Mracnova, R, Sojak, L, kubinec, R and Kraus, A (1999). Analysis of Petroleum Hydrocarbons in Soil from View of Bioremediation Process Comenius University Bratislava (Research Grant No., UK/ 3673/99) and Grant Agency VEGA (Grant No 1/6108/99, Slovakia, p436.

[2] Jaffe,R. (1991.Fate of Hydrophobic Organic Pollutants in the Aquatic Environment, A Review, Environ.Pollut. 69:237-257.

[3] Ribes,A, Grimalt, J.O., Torres, C.J and Cuevas, E.(2003). Polycyclic Aromatic Hydrocarbons in Mountain Soils of the Subtropical Atlantic, Journal of Environ. Qual., 32:977-987.

[4] Freitag, D, Ballhorn, L., Geyer,H., and Korte, F., (1985). Environmental Hazard Profile of Organic Chemicals, Chemosphere, 14:1589-1616.

[5] Department of Environmental Conservation-DEC (1992). Petroleum Contaminated Soil Guidance Policy, Spills Technology and Related Series (STARS), Revised, New York State.

[6] Wang, Y., Feng, J., Lin, Q., Lyu, X, Wang, X. and Wang, G. (2013). Effects of Crude Oil Contamination on Soil Physical and Chemical Properties in Momoge Wetland of China, Chin. Geogra. Sci. 23(6):708-715.

[7] Aislabie, J.M., Balks,M.R., Foght, J.M. et al., (2004). Hydrocarbon Spills on Antarctic Soils: Effects and Management, Environmental Science and Technology, 38(5):1265-1274.

[8] Townsend, G.T., Prince, R.C and Suflita, J.M. (2003). Anaerobic Oxidation of Crude Oil Hydrocarbons by the Resident Microorganisms of a Contaminated Anoxic Aquifer, Environmental Science and Technology, 37 (22):5213-5218.

[9] Ekundayo, E., Obuekwe, O. (2000). Effects of an Oil Spill on Soil Physicochemical Properties of a Spill Site in a Typic Udipsamment of the Niger Delta Basin of Nigeria, Environmental Monitoring and Assessment, 60(2):235-249.

[10] Hu, Y., Wang, S and Yan, S. (2006). Research Advances on the Factors Influencing the Activity and Community Structure of Soil Microoganism, Chinese Journal of Soil Science, 37 (1):170-176.

[11] Quyum, A., Achari, G., Goodman, R. (2002). Effect of Wetting and Drying and Dilution on Moisture Migration through Oil Contaminated Hydrophobic Soils, Science of The Total Environment, 296 (1):77-87.

[12] Okop, I.J. and Ekpo, S.C. (2012). Determination of Total Hydrocarbon Content in Soil after Petroleum Spillage, Proceedings of the World Congress on Engineering, vol. 111, July 4-6, London, Uk.

[13] Polish Institute of Environmental Protection –PIEP, (1995). Methodological Guidelines Concerning the Degree of Contamination of Soil and Groundwater with Petroleum Products and Other Chemical Substances in Remediation Processes, Warazawa.

[14] Edori, O.S. and Iyama, W.A. (2017). Assessment of Physicochemical Parameters of Soils from Selected Abbatoirs in PortHarcourt, Rivers State, Nigeria, J.Environ. Anal, Chem. 4:194.

[15] APHA, (2000). Standard Methods of Examination of Water and Wastewater, American Public Health Association, Washington DC.

[16] Olaitan, S.O. and Lombin, G. (1984). Introduction to Tropical Soil Science, Macmillan Education Ltd, London, pp1-43.

[17] Brady,N.C. and Weil, R.R.(2013). The Nature and Properties of Soils, Pearson Education Inc., India, p130.

[18] Page, A.L. (1982). Methods of Soil Analysis Part 2, Chemical and Microbiological Properties, 2nd edition, Madison Wisconsin, U.S.A., pp202, 561-570.

[19] Ibitoye, A.A. (2006). Laboratory Manual on Basic Soil Analysis, 2ndedn., Foladave Nig Ltd, Akure, Ondo State, Nigeria, pp6-35, 76.

[20] Head, K.H. (1992). Manual of Soil Laboratory Testing (Soil Classification and Compaction Tests) 3rd edition, Whittles Publishing, Scotland, UK, 1:282-283.

[21] Association of Official Analytical Chemists (1990). Official Methods of Analysis, 15th edition, Washington DC, USA,

[22] Adoki, A. (2012). Soil and Groundwater Characteristics of a Legacy Spill Site, J. Appl. Sci. Environ. Manage,16(1):113-123.

[23] Hawrot-Paw, M. (2010). Biodegradation of Selected Petroleum Products in Variable Temperature Conditions and pH of the Environment, Acta Sci. Pol., Formatio Circumiectus 9(4):17.

[24] Arias, M.E., Gonzalez-Perez, J. A., Gonzalez-Villa, F.J., Ball, A.S.(2005). Soil Health: A New Challenge for Microbiologist and Chemists, Int. Microbiol 8:13-21.

[25] Queensland Department of Environment and Heritage Protection-QDEHP (2017).

[26] Brady, N.C. (1996). The Nature and Properties of Soils (eds. 11th), Macmillan, New York, pp621.

[27] Osuji, L .C. and Nwoye, I.(2007). An Appraisal of the Impact of Petroleum Hydrocarbons on Soil Fertility: The owaza Experience, Afrj. Agri Res 2:318-324.

[28] Schulte, E.E. (1999). Soil and Applied Chlorine, College of Agriculture and Life Sciences, University of Wisconsin-Madison and University of Wisconsin Extension, Cooperative Extension, Wisconsin, USA.

[29] Azlan, A., Aweng, E.R., Ibrahim, C.O., NoorHaidah, A. (2012). Correlation between Soil Organic Matter, Total Organic Matter and Water Content with Climate and Depths of Soil at Different Land Use in Kelantan, Malaysia, J.Appl. Sci. Environ. Manage., 16(4)353-358.

[30] Atkins,P and Jones, L, (1999).Chemical Principles , W.H. Freeman and Company New York, p201.

[31] Brady, N.C and Weil,R.R. (2008).Soil Colloids : Seat of Soil Chemical and Physical Acidity, The Nature and P roperties of Soils, Pearson Education Inc., Upper Saddle River, NJ, USA, pp311-358.

[32] Asaolu, S.S. (2000). Total Hydrocarbon Content in water and Sediment Samples from Ondo State Coastal Area, The Journal of Technoscience, 4:20.

[33] Edori, O.S and Iyama, W.A. (2017). Assessment of Physicochemical Parameters of Soils from Selected Abattoirs in Port Harcourt, Rivers State, Nigeria J.Environ. Anal. Chem. 4:194.

[34] Ganuza, A.G and Almendros, (2003). Organic Carbon Storage in Soils of the Basque Country (Spain): The Effect of Climate, Vegetation Type and Edaphic Variables, Biology and Fertility of Soils, 37: 154-162

[35] Burke, I.C.(1999). Spatial Variability of Soil Properties in the Short Grass Steppe: The Relative Importance of Topography, Grazing, Microsite and Plant Species in Controlling Spatial Patterns, Ecosystems, 2: 422-438

[36] Finzi, A .C. Breemen, N.V.and Canham, C.D.(1998).Canopy Tree Soil Interactions Within Temperate Forests:Tree Species Effects on Carbon and Nitrogen, Ecological Applications,8:440-446.

[37] Spain, A.V. (1990). Influence of Environmental Conditions and Some Soil Chemical Properties on the Carbon and Nitrogen Contents of Soil Tropical Australian Rainforest Soils, Australian Journal of Soil Research, 28:825-839

[38] Yang, X.M and Wander, M.M. (1999). Tillage Effects on Soil Organic Carbon Distribution and Storage in a Silt Loam Soil in Illinois, Soil and Tillage Research,52:1-9

[39] Kong, X.B, Dao,T.H., Qin, J, Qin, H, Zhang, F. et al.,(2009). Effects of Soil Texture and Land Use Interactions on Organic Carbon in Soils in North China Cities' Urban Fringe, Geoderma, 154:86-92.

[40] Thomas, J and Ringen, S. (1985). Non Metal Elements and Compounds, Analytical Chemistry 15(5): 210R-212R.

[41] Nwangwu, C.E. (2015). Effect of Rainfall Variation on Cassava Yield in Awka, Anambra State, Unpublished Thesis, Nnamdi Azikiwe University, Awka

https//weather-and-climate.com/-month