

Characteristic of an Oil Spill Site at Delta State, Nigeria

O. R. Akpomrere¹ and J. Idisi^{2*}

¹*Surveying and Geoinformatics Unit, Delta State Polytechnic, Ozoro, Nigeria.*

²*Department of Civil Engineering Technology, Delta State Polytechnic, Ozoro, Nigeria.*

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information

Editor(s):

(1) Dr. Oscar Jaime Restrepo Baena, Universidad Nacional de Colombia, Colombia.

Reviewers:

(1) D. S. Jaya, University of Kerala, India.

(2) Shweta Umale, Mumbai University, India.

Complete Peer review History: <http://www.sdiarticle4.com/review-history/61301>

Original Research Article

Received 19 July 2020
Accepted 24 September 2020
Published 29 October 2020

ABSTRACT

This study was aimed to evaluate the residual heavy metals concentrations, within the soil of a former petroleum spill site. Soil samples were spatially collected from five locations within a former petroleum spill site, located at Ozoro in Isoko North Local Government Area of Delta State, Nigeria. The concentrations of seven heavy metals (Ni, Cu, Zn, Pb, Cd, Fe and Al) in the soil (0–25 cm) were collected were determined, using the Atomic Absorption Spectrometer. In addition, soil contamination factor and Pollution Load Index were used to assess the heavy metals contamination and distribution within the study area. Results of the soil analysis revealed that the concentrations of the heavy metals were generally higher, when compared with results recorded from the Reference Point. Cadmium (Cd) concentration within the study area exceeded the maximum permissible limit, recommended by World Health Organization (WHO) for soils; while the others heavy metals concentration fall below the maximum permissible limit recommended by WHO for soil. The results revealed that spatial point 3, recorded the highest heavy metals concentrations across the study area. Generally, the contamination factor results showed that there is a considerable degree of residual heavy metals contamination in the cleaned up petroleum spill site. Likewise, the Pollution Load Index results showed that spatial points 2, 3 and 5 zones were highly polluted with heavy metals; while spatial points 1 and 4 zones were moderately

*Corresponding author: Email: erobo2011@gmail.com;

polluted with heavy metals. This study exhibited the importance the oil companies to carry out remediation follow-up in petroleum spill area, to avoid accumulation of residual heavy metals in the environment.

Keywords: Ecological risk; heavy metals; petroleum; pollution load index; spillage.

1. INTRODUCTION

Petroleum is a mixture of hydrocarbons and non-hydrocarbons compounds, which has negative environmental impacts, when spilled into the environment [1]. Globally, Nigeria is leading petroleum producing country, producing about 2.4 million barrels of petroleum per day, and its reserve standing at about 37 billion barrels [2,3]. Petroleum spillage into the environment has been on the increase in Nigeria for the past decade. Shell Petroleum Development Company (SPDC), a leading oil producing company in Nigeria, has attributed about 85% spillage from its facilities to saboteurs and oil thieves [4]. Nigeria Extractive Industries Transparency Initiative (NEITI), reports that Nigeria lost 41.9 billion USD worth of petroleum and its refined products between 2009 and 2018; and between 150,000-250,000 barrels of petroleum were stolen per day. This implies that about 20% of Nigeria daily petroleum production is lost to petroleum criminals [5,6]. Petroleum spillage into the environment constitutes grave risks to both plants and animals inhabiting in the environment. It has being experimentally proven that, petroleum products has the capacity of increasing the toxic heavy metals concentrations in the contaminated soils [7,8].

Heavy metals are those metallic elements in the periodic table, whose relatively density is higher than that of pure water [9,10,11]. Some of the heavy metals are beneficial to both plants and animals even in large concentrations; others are able to induce toxicity even at low concentration. Some of the poisonous heavy metals include; Zinc (Zn), Copper (Cu), Lead (Pb), Mercury (Hg), Nickel (Ni), and Cadmium (Cd). They become extremely harmful to human being if their concentration in the body system is above the maximum permissible limits [12,13,14]. According to Rehman et al. [15] high concentration of Lead the human body can cause anemia, colic, headache, mental disorder, and central nervous system disorder. High concentration of copper can cause cellular disorder which can lead to Wilson disease in human beings [16]. Cadmium compounds have been classified as carcinogens by the

International Agency for Research on Cancer and the U.S. National Toxicology Program [17]. There has been a global increasing trend about the ecological and public health risks associated with heavy metals contaminations in the environment. This accumulation can proceed in the food chain, and will eventually get to the humans who ingest the plants with high heavy metals concentrations [2,18].

Cleaning up and remediation of known petroleum spills sites are currently taking place across Nigeria. But there are not reported literatures on the residual heavy metals on an already cleaned-up petroleum spill area. Therefore, the objective of this study is to evaluate the residual heavy metals concentrations in the soil sampled from an already cleaned up petroleum spill site in Ozoro, Isoko North Local Government Area, Delta State, Nigeria.

2. MATERIALS AND METHODS

2.1 Study Area

The study was conducted at Ozoro, Isoko North Local Government Area of Delta State, Nigeria. Isoko North lies within the Tropical Rain Forest zone, with bimodal rainfall pattern. The study area experienced petroleum spilling during early 2019, and cleanup was done almost immediately by the oil company, to remove the crude oil spilled on the area. The study area is prone to flooding during the wet season.

2.2 Soil Sample Collection

In the study site, five spatial points were selected using the grid system. A total area of 1 km × 1 km was demarcated within the petroleum spill site. Soil samples were collected (depth 0–25 cm) by using the calibrated soil auger. Three (3) soils samples were collected from each sampling point, making it a total of fifteen (15) soil samples from the study area. Another spatial point located at about 20 km from the contaminated site as a Reference point (Control). This is to evaluate the residue heavy metals in the soil after the cleaning up. The Reference point has no petroleum spillage history for the past 15 years,

and similar geographical features as the contaminated site. The collected soil samples poured into plastic bags, coded accordingly, and taken to the laboratory for soil analysis.

2.3 Soil Chemical Analysis

The collected soil samples were air-dried at an ambient laboratory temperature ($27 \pm 4^\circ\text{C}$) for two weeks. The dried soil samples were ground and sieved with a 2 mm gauge stainless steel sieve. 10 g of the soil sample was poured into a round-bottomed conical flask and digested with a mixture of concentrated HCl and HNO_3 (ratio of 3: 1), at a temperature of 80°C . Then the digested product was transferred into a volumetric flask, and diluted with distilled water up to the 100 ml mark. The diluted mixture was filtered with a Whatman filter paper (No. 1), before the heavy metals concentrations of the filtrate was determined [8] using the Atomic Absorption Spectrophotometer (AAS, Perkin Elmer 2380).

All laboratory tests were done at ambient laboratory temperature ($27 \pm 4^\circ\text{C}$), at the Soil and Water Laboratory of Delta State Polytechnic, Ozoro, Nigeria.

2.4 Assessment Heavy Metals Contamination in the Soils

2.4.1 Contamination factor (C_f)

Contamination factor is a ratio of heavy metal concentration in the soil to the heavy metal concentration at the reference point [19]. It is calculated using Equation 1.

$$\text{Contamination factor} = \frac{C_1}{C_2} \quad (1)$$

Where,

C_1 = concentration of heavy metal at a contaminated point;

C_2 = concentration of the same heavy metal at the reference point.

Contamination factor classification:

Low ($C_f < 1$);

Moderate ($1 > C_f < 3$);

Considerable ($3 > C_f < 6$);

Very high ($C_f \geq 6$) [20,21].

2.4.2 Pollution Load Index (PLI)

This is the rate at which the heavy metal in the soil surpasses the Reference Point

concentration. It is calculated as the nth root of the n contamination factors (C_{Fn}) for all the metals multiplied together, as shown in Equation 2 [21].

$$PLI = \sqrt[n]{CF_1 \times CF_2 \times CF_3 \times CF_4 \dots \times CF_n} \quad (2)$$

Where,

CF = contamination factor of each metal;

n = total number of metals.

Pollution load index classification:

PLI greater than 3 ($PLI > 3$) = polluted area and a deterioration of the environmental quality; PLI less than 1 ($PLI < 1$) = non-polluted area;

PLI greater than 1 but less than 3 ($1 < PLI < 3$) = moderate level of pollution [22].

2.5 Statistical Analysis

The data of this study were statistically analyzed using the Statistical Package for Social Statistics (SPSS version 20.0) software, and the means were separated using The Duncan's New Multiple Range (DNMR) Test ($p \leq 0.05$). The mean results were plotted using Microsoft Excel 2015; while the correlation (r) relationship was determined using the MS Excel 2015.

3. RESULTS AND DISCUSSION

3.1 Heavy Metal Concentration of Soil Samples Collected from the Study Area

The results of the heavy metals concentrations in the soil samples collected from the four spatial points within the study area are presented in Table 1. Comparing the results obtained from the study area with results obtained from the reference point (control); the results revealed that, the heavy metals concentrations in the oil spill site were significantly higher than the control point. This difference in the concentrations portray that external contamination, probably crude oil was responsible for the high heavy metals concentrations in the former oil spill site. Akpokodje *et al.* [23] stated that petroleum has the capability of increasing heavy metals concentrations in the soils, above maximum permissible limits approved by World Health Organization (WHO 1996). In addition, the ANOVA showed a significant ($p < 0.05$)

differences in the concentrations of the seven (7) heavy metals studied across the study area (Table 1), with spatial point 3 generally having the highest heavy metals concentrations. The study revealed that spatial point 4 recorded the least concentrations of most of the heavy metals, except for Ni and Cu, which were higher than in values recorded at spatial point 1. For all cases, cadmium had the lowest concentration, while Iron recorded the highest concentration across the study area. The Iron concentration within the study area ranged between 2366 mg/kg at spatial point 1 to 2413 mg/kg at Spatial Point 3.

The Zinc concentration in the study area ranged from 14.04 mg/kg at spatial point 4 to 20.42 mg/kg at Spatial Point 3 (Table 1). Generally, the study showed that even though the zinc concentration in the oil spill site was considerable high, it was below the WHO maximum permissible limit. Zinc is a trace element required by both plants and animals for growth and performance. Nevertheless, high dosage of it has adverse effects on plants and animals. Wuana and Okieimen [24] stated that zinc being water soluble, its accumulation in the soils can contaminate both the surface and ground waters; thereby, leading to its accumulation in the plants growing in the soils, which human beings may later consumed as food or herbs. In addition, the study revealed that the copper concentration within the study area ranged from 6.89 mg/kg at spatial point 1 to 10.67 mg/kg at Spatial Point 3. These concentrations were significantly lower than the WHO maximum permissible limit.

Nickel concentrations in the study area ranged from 11.45 mg/kg at spatial point 1 to 16.01 mg/kg at Spatial Point 3. Despite the relatively high concentration of Nickel with the former oil spill site, it was still below the WHO maximum permissible limit soils. Nickel is a highly toxic heavy metal that can caused phytotoxicity in plants. With respect to the Cadmium concentration in the soil samples, the results showed that cadmium concentration ranged from 1.12 mg/kg at spatial point 1 to 1.91 mg/kg at Spatial Point 3. These concentrations from all the sampled locations within the study area were above the WHO maximum permissible limit for soils. Cadmium at even low dosage can cause the death of plants, while its consumption by human beings can lead to serious ailments such as; emphysema and bronchiolitis [25]. High

dosage Cadmium ingestion can link to gastrointestinal tract erosion, pulmonary, hepatic or renal injury and coma, depending on the route of poisoning [26,27]. The toxicity of heavy metals to humans and the ecosystems is influenced on their concentrations, dosage consumed, and the target receptors [28].

The study showed that the Lead concentration in the study area ranged from 20.96 mg/kg at spatial point 4 to 25.34 mg/kg at Spatial Point 3 (Table 1). The results revealed that concentration of Lead across the study area was below the WHO permissible maximum limit for soils. High accumulation of Lead in the body system can lead to nervous system disorder. The Agency for Toxic Substances and Disease Registry (ATSDR), stated that one of the major mechanisms by which Lead can exercises its toxicity is through biochemical processes that include its ability to inhibit or mimic the actions of calcium and to interact with the proteins [27,29]. According to Devkota and Schmidt [30], heavy metals tend to bio-accumulate in soils and plants with time; thereby, negatively influencing plants' physiological activities, causing reductions in their growth performance and yield in the process [6].

3.2 Contamination Factor (C_f) and Pollution Load Index (PLI)

The results of the contamination factor of the heavy metals are presented in Table 2. The contamination factor showed that the contamination of the heavy metals was generally at considerable level across the study area; apart from spatial point 3, where the contamination degree was relatively higher. The study revealed that spatial point 3 displayed very high contamination of Ni and Cd; considerable contamination of Cu, Pb and Zn; and moderate contamination of Fe and Al. Cadmium contamination was very high at spatial point 2, spatial point 3 and spatial point 5, making it the predominant heavy metal across the study area. Considerable level of contamination of Pb and Zn were observed at all the locations from where soils were sampled across the study area. Similarly, Fe exhibited moderate degree of contamination across spatial points 1, 2, 3, and 4; apart from spatial point 2, where low degree of contamination was recorded. This showed that some degree of residual heavy metals in the already cleaned up oil spill site.

Table 1. Residual heavy metals in soil samples

Heavy metal	Point 1	Point 2	Point 3	Point 4	Point 5	Control	WHO*
Ni	11.45	15.32	16.01	13.23	14.48	2.64	35
Al	2.21	2.77	2.85	2.34	2.81	1.09	NA
Fe	1366	1412	1413	1107	1401	1297	NA
Cu	6.89	7.24	10.67	8.12	9.85	3.53	100
Zn	15.17	17.51	20.42	14.04	16.22	4.18	300
Cd	1.12	1.56	1.91	1.32	1.73	0.31	0.80
Pb	21.23	23.42	25.34	20.96	24.89	5.50	50

* WHO [31]

Table 2. Contamination factors of heavy metals in the cleaned up oil spill site

Spatial point	Heavy metals						
	Ni	Al	Fe	Cu	Zn	Cd	Pb
Point 1	4.34	2.03	1.05	1.95	3.63	4.31	3.86
Point 2	5.8	2.54	1.09	2.05	4.19	6.00	4.26
Point 3	6.06	2.61	1.09	3.02	4.89	7.35	4.61
Point 4	5.01	2.15	0.85	2.30	3.36	5.08	3.81
Point 5	5.48	2.58	1.08	2.79	3.88	6.65	4.53

Table 3. Pollution load index of heavy metals in the cleaned up oil spill site

Sampling Point	PLI	Level	Remark
Point 1	2.716	1 <PLI <3	Location moderately polluted
Point 2	3.212	PLI ≥3	Location highly polluted
Point 3	3.65	PLI ≥3	Location highly polluted
Point 4	2.806	1 <PLI <3	Location moderately polluted
Point 5	3.374	PLI ≥3	Location highly polluted

3.3 Pollution Load Index (PLI)

Results of the Pollution Load Index of the heavy metals are presented in Table 3. The results showed that area where spatial points 2, 3 and 5 covered was highly polluted with heavy metals. Spatial point 3 had the highest PLI (3.65), compared with other spatial points from where soil were sampled for this study. Furthermore, as seen in Table 3, the area where spatial points 1 and 4 covered was moderately polluted with heavy metals. Pollution Load Index helps to provide information about the total level of heavy metal toxicity in the soil [32].

4. CONCLUSION

This study was carried out to evaluate the residual heavy metals in an already cleaned up petroleum spill site. Soil samples were spatially collected from five locations, within a former petroleum spill site in Delta State. The results if the soil analysis showed that there is considerable concentration of residual heavy metals within the spill site. Cadmium concentration within area exceeded the

maximum permissible limit, recommended by WHO for soils; while the others heavy metals concentration fall below the maximum permissible limit recommended by WHO for soil. Generally, the contamination factor results showed a considerable degree of residual heavy metals contamination in the study area. Likewise, the Pollution Load Index results showed that spatial points 2, 3 and 5 zones were highly polluted with heavy metals; while spatial points 1 and 4 zones were moderately polluted with heavy metals. This study exhibited the importance the oil companies to carry out remediation follow-up in petroleum spill area, to avoid accumulation of residual heavy metals in the environment.

DISCLAIMER

The products used for this research are commonly and predominantly use products in our area of research and country. There is absolutely no conflict of interest between the authors and producers of the products because we do not intend to use these products as an avenue for any litigation but for the advancement of

knowledge. Also, the research was not funded by the producing company rather it was funded by personal efforts of the authors.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Anderson CM, LaBelle RP. Update of comparative occurrence rates for offshore oil spills. *Spill Science Technology Bulletin*. 2000;6(5/6):303-321.
2. Obah GE, Akpokodje OI, Uguru H. Influence of Organic Wastes on Ecotoxicity of Petroleum Hydrocarbons in Contaminated Soil. *Journal of Environment and Waste Management*. 2020;7(1):318-326.
3. OPEC. Nigeria facts and figures; 2020. Available: https://www.opec.org/opec_web/en/about_us/167.htm. Retrieved on February 21, 2020
4. SPDC. "Oil Spill Data"; 2020. Available: <https://www.shell.com.ng/sustainability/environment/oil-spills.html>.
5. Nigeria Extractive Industries Transparency Initiative –NEITI. NEITI: \$42B Lost To Crude Oil And Products Theft In Ten Years; 2019. Available: <https://neiti.gov.ng/index.php/me-diacycenter/news/487-neiti-42b-lost-to-crude-oil-and-products-theft-in-ten-years>.
6. Akpomrere OR, Uguru H. Spatial distribution of residual petroleum hydrocarbons in an oil spill site located at Isoko South LGA, Delta State, Nigeria. *Journal of Environment and Waste Management*. 2020;7(1):312-317.
7. Abioye OP, Agamuthu P, AbdulAziz AR. Biodegradation of used motor oil in soil using organic waste amendments. *Biotechnology Research International*. 2012;1-8.
8. Akpokodje OI, Uguru H. Phytoremediation of petroleum products. *Archives of Current Research International*. 2019;18(1):1-8.
9. Fergusson JE. *The Heavy Elements: Chemistry, Environmental Impact and Health Effects*. Oxford: Pergamon Press; 1990.
10. Bradl H. *Heavy Metals in the Environment: Origin, Interaction and Remediation*, London: Academic Press. 2002;6.
11. Akpomrere OR, Uguru H. Ecotoxicity effect of illegal refineries on the environment: A case study of Delta State, Nigeria. *International Journal of Innovative Agriculture & Biology Research*. 2020;8(2):40-49.
12. Duffus JH. Heavy metals-a meaningless term? *Pure and Applied Chemistry Journal*. 2002; 74(5):793–807.
13. Khan I, Ali J, Tullah H. Heavy metals determination in medicinal plant *Withania somnifera* growing in various areas of peshawar, NWFP, Pakistan. *Journal of the Chemical Society of Pakistan*. 2008;30(1):69–74.
14. Akpokodje OI, Uguru H. Impact of farming methods on some anti-nutrients, nutrients and toxic substances of cassava roots. *International Journal of Engineering, Science and Technology*. 2019;6(4):275-284.
15. Rehman A, Ullah H, Khan RU, Ahmad I. Population based study of heavy metals in medicinal plant *Capparis decidua*. *International Journal of Pharmacy and Pharmaceutical Sciences*. 2013;5(1):108–113.
16. Tchounwou P, Newsome C, Williams J, Glass K. Copper-induced cytotoxicity and transcriptional activation of stress genes in human liver carcinoma cells. *Metal Ions in Biology and Medicine*. 2008;10:285–290.
17. International Agency for Research on Cancer (IARC). *Monographs – Cadmium*. Lyon, France; 1993.
18. Gibson DT, Perales R. Aromatic hydrocarbon dioxygenases in environmental biotechnology. *Current Opinion in Biotechnology*. 2000;11:236 – 243.
19. Brady JP, Ayoko GA, Martens WN, Goonetilleke A. Development of a hybrid pollution index for heavy metals in marine and estuarine sediments. *Environmental Monitoring and Assessment*. 2018;187(5):306.
20. Abdullah MZ, Saat A, Hamzah, Z. Optimization of energy dispersive x-ray fluorescence spectrometer to analyze heavy metals in moss samples. *American Journal of Engineering and Applied Sciences*. 2011;4:355-362.
21. Bashir IM, Zakari, YI, Ibeanu IGE, Sadiq U. Assessment of heavy metal pollution in flooded soil of Kudenda, Kaduna State, Nigeria. *American Journal of Engineering Research*. 2014;3:197-204.

22. Chen TB, Zheng YM, Lei M, Huang ZC, Wu HT, Chen H, Tian QZ. Assessment of heavy metal pollution in surface soils of urban parks in Beijing, China. *Chemosphere*. 2005;60(4):542–551. DOI:10.1016/j.chemosphere.2004.12.07.
23. Akpokodje OI, Uguru H, Esegbuyota D. Evaluation of phytoremediation potentials of different plants' varieties in petroleum products polluted soil. *Global Journal of Earth and Environmental Science*. 2019;4(3):41-46.
24. Wuana RA, Okieimen FE. Heavy Metals in Contaminated Soils: A Review of Sources, Chemistry, Risks and Best Available Strategies for Remediation. *International Scholarly Research Notices*; 2011.
25. Tasrina RC, Rowshon A, Mustafizur ARM, Rafiqul I, Ali MP. Heavy metals contamination in vegetables and its growing soil. *Journal of Environmental Analytical Chemistry*. 2015;2(3):1-6.
26. Baselt RC. *Disposition of Toxic Drugs and Chemicals in Man*. 5th Ed.. Foster City, CA: Chemical Toxicology Institute; 2000.
27. Tchounwou PB, Yedjou CG, Patlolla AK, Sutton DJ. Heavy metals toxicity and the environment. *NIH Public Access*. 2014;101:133–164. DOI:10.1007/978-3-7643-8340-4_6.
28. Itai T, Otsuka M, Asante KA, Muto M, Opoku-Ankomah Y, Ansa-Asare OD, Tanabe S. Variation and distribution of metals and metalloids in soil/ash mixtures from Agbogboshie e-waste recycling site in Accra, Ghana. *Science of the Total Environment*. 2014;470:707–716.
29. Agency for Toxic Substances and Disease Registry (ATSDR). *Toxicological Profile for Lead*. Public Health Service. Atlanta: U.S. Department of Health and Human Services; 1999.
30. Devkota B, Schmidt GH. Accumulation of heavy metals in food plants and grasshoppers from the Taigetos mountains, Greece. *Agriculture, Ecosystems and Environment*. 2000;78(1):85-91.
31. WHO. *Permissible limits of heavy metals in soil and plants* (Geneva: World Health Organization), Switzerland; 1996.
32. Muzerengi C. Enrichment and Geoaccumulation of Pb, Zn, As, Cd and Cr in Soils near New Union Gold Mine, Limpopo Province of South Africa. In C. Wolkersdorfer, L. Sartz, M. Sillanpää, & A. Häkkinen (Eds.), *Mine Water and Circular Economy*. Finland: Lappeenranta; 2017.

© 2020 Akpomrere and Idisi; This is an Open Access article distributed under the terms of the Creative Commons Attribution License (<http://creativecommons.org/licenses/by/4.0>), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

Peer-review history:

*The peer review history for this paper can be accessed here:
<http://www.sdiarticle4.com/review-history/61301>*