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Research Paper

Assessment of physicochemical parameters and heavy metals concentration across artisanal refining sites in the core Niger Delta Region

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ABSTRACT
This study assessed the physicochemical parameters and heavy metals concentration across artisanal refining sites in the core Niger Delta Region. The study used the experimental research design. Therefore, soil samples were collected from both the artisanal refining sites and control sites. These soil samples were sent to the laboratory for analyses. Inferential statistics (one sample t test) was used for data analyses. It was found that soil quality for both the control sites and artisanal refining sites fell below the WHO permissible limits, however, the soil from control sites were less polluted than soils from artisanal refining sites. Also, soil from Delta State was less polluted than Bayelsa and Rivers States. The one sample t test, revealed that, the pollutants detected in soil at artisanal refining sites were statistically different from the WHO permissible limits at p<0.05. Similarly, the pollutants detected at the artisanal refining sites were significantly higher than the one found in the control sites at p<0.05. The detected soil pollutants are detrimental to agriculture, and man. The study thus recommends, environmental remediation and legalization cum improvement in artisanal refining process in the region.
KEYWORDS: Soil-pollution, contaminants, artisanal-refinery, physicochemical.

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I. INTRODUCTION

Artisanal refining is the refining of crude oil with the use of indigenous resources and skills by collecting the crude oil into drums and heating them to boiling afterwards allowing them to cool and condense. Artisanal refineries apply the same principle of distillation used by conventional refineries. It involves the buying of stolen crude oil and refining them using local resources and skills (Addis & Abebaw, 2015; Parajuli, & Duffy, 2013; Steinweg, Dukes, Paul, & Wallenstein, 2013). These local resources/skills are synonymous with those employed in refining local gin in Nigeria (Iheme, Ukairo, Ibegbulem, Okorom, & Chibundu, 2017; Kekane, Chavan, Shinde, Patil, & Sagar, 2015; Kujur, & Patel, 2014; Maharana, & Patel, 2013; Neina, 2019).

In the Niger Delta creeks, artisanal oil refining constitutes part of the economic activities and revenue source for many young persons. This has led to the environmental pollution of the area due to artisanal oil refining. Most Niger Delta indigenes regard the act of illegal refining as reaping from their natural resource. Crude methods are employed in the refining process with thermal cracking used in breaking down the petroleum into its useful components at different temperatures (Deb, Bhadoria, Mandal, Rakshit, & Singh, 2020; Igalavithana, et al, 2017). This gives rise to what is commonly called adulterated product and the entire activity termed illegal.

Presently, Nigeria invests heavily on imported refined petroleum products because the refineries are not working. This has led to the export of crude oil in meager amounts compared to that expended in the import of refined products (Micut, Bădulescu, & Israel-Roming, 2017; Mondal, Pal, Dey, Ghosh, Das, & Datta, 2015). Statistics show that in 2017, Nigeria imported about 22.5b liters of refined petroleum products. However, thirty-five million liters of petrol is consumed daily in Nigeria and data shows that, $2.49 billion (N761b) was spent on importation of refined petroleum products within January to March 2017 (Olaniran, Balgobind, & Pillay, 2013; Bartkowiak, Lemanowicz, & Siwik-Ziomek, 2016; Bło-nska, Lasota, & Zwydak, 2017; Datta, et al., 2017;

Oloyede-Kosoko, Idowu, & Ayoni, 2015). Over the years, attempts geared at making the refineries optimally functional have not yielded desired results rather, these and others have led some youth in the oil producing communities to resort to the use of unconventional technology to make a living and possibly augment the efforts of the Federal Government. This technology has been branded illegal and is hunted for destruction by agents of Government (Li, Meng, Herman, & Lu, 2015; Borowik, & Wyszkowska, 2016; Chen, et al 2019; Chen, Zhang, Liang, Qiu, Liu, Zhou, & Yan, 2016; Chineyre, Obisike, Ugbogu & Osuocha, 2013).

Plate 1. Artisanal refining sites Source (2020)

The major problem with artisanal refinery is that it pollutes the environment. According to Ukpong, Antigha, & Moses, (2013), most people are exposed to hydrocarbons at elevated concentrations because of artisanal refining pollution, sometimes through air and others through drinking water (Kumari, Rao, Padmaja, & Madhavi, 2017; Kwiatkowski, Harasim, Feledyn-Szewczyk, & Antonkiewicz, 2020; Lemanowicz, & Siwik-Ziomek, 2019). Acute exposures to aromatic hydrocarbons especially through crude oil pollution results in respiratory symptoms. Utobo, & Tewari, (2015) reported that the activities of artisanal oil refineries lead to the contamination of soil and ground water making them unsafe for either drinking or use in other domestic works by the inhabitants of the rural communities where these activities are carried out.

The operations of artisanal refineries have placed heavier pollution load on the Niger Delta Environment for instance, Diesels make up 41 percent of illegally refined products; Petrol, kerosene and bitumen make up just 4 percent while the remaining 55 percent is deposited as waste in the Niger Delta Environment (Ogala, 2013). The present efficiency of the artisanal refining system is so low that a very large chunk of the product cannot be refined and ends up being deposited on the Niger Delta Environment (Attah, 2012) these are buttressed in plates 1 and 2.

Plate 2: Pollution from an Illegal refinery. Source IIPELP, (2011).

Today, the farmers and fishermen can no more practice the traditional economic activity in the area, due to pollution from artisanal refineries. This study therefore assessed the physicochemical parameters and heavy metals concentration across artisanal refining sites in the Niger Delta region.

II. MATERIALS AND METHODS

The Niger Delta Region sits directly on the Gulf of Guinea in the Atlantic Ocean. It comprises of nine states which include all six states of the South-South region of Nigeria (Rivers, Bayelsa, Delta, Edo, Akwa-Ibom and Cross-Rivers) and others, such as, Ondo, Abia and Imo all of which are oil producing states. The present-day Niger Delta covers a mass of 70,000 km^2 (27,000 sq mi) and make up 7.5% of Nigeria's land mass (figure 3.1). The region is in the Southern part of Nigeria and stretches within Latitude 4^0 12’ 30.892”N through Latitude 4^0 50’ 10.7”N and Longitude 4^0 56’ 15”E through longitude 9^0 40’ 2.654”E (see figure 1).

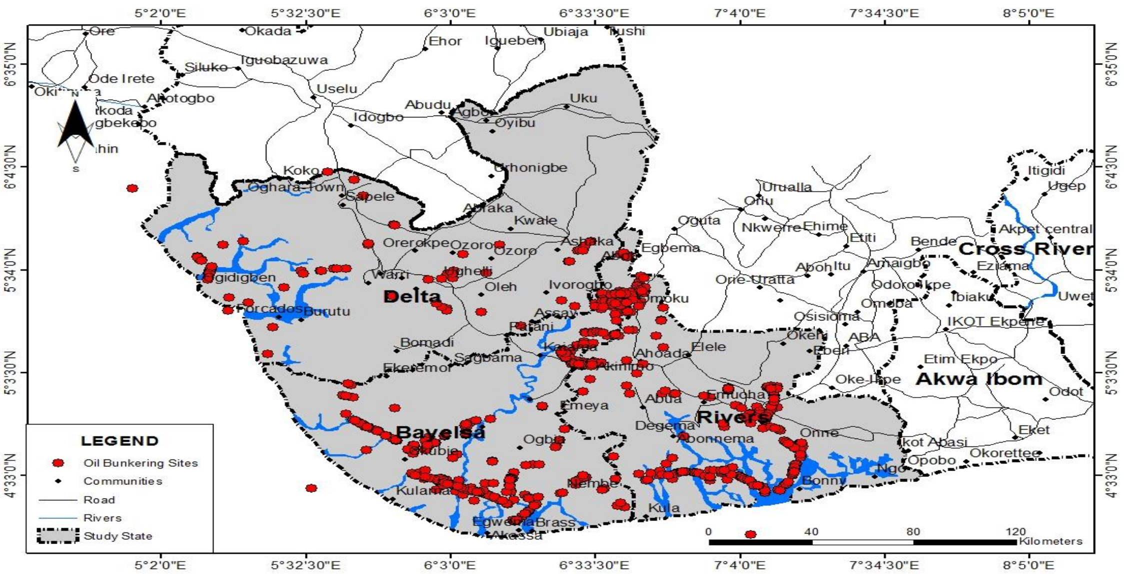

Figure 1: South-South Artisanal Oil Refining Sites

The Niger Delta is bounded by the Atlantic Ocean separated by the barrier island ridges bordering the Atlantic Ocean falling within the classification of a generally low-lying terrain consisting of unconsolidated mud and sandy particles resulting in little or no resistance to tidal and wave impact on its shoreline (Oyegun, 1993). The Niger Delta is one of the world’s largest Tertiary Delta System and an extremely prolific hydrocarbon province. The climate falls with the tropical type and temperature ranges from 30^{0}C to 31^{0}c in the dry season and 25^{0}c to 27^{0}c. Rain falls through two maxima in one year. The first peak is reached in July, while the second peak happens in September. The annual rainfall ranges from 1890 mm in Edo state to 2350 mm in Calabar.

The study used the experimental research design. Soil samples were collected and sent to the lab for analyses. This was done for both the artisanal refining sites and control sites. The researchers used control sites because it was expedient to show how much artisanal refineries have affected the soil in the study area. The data for the study were obtained from primary and secondary sources. The primary source of data was the soil samples (90 samples) collected and sent to laboratories for analysis, while the secondary data was data (on permissible limits) generated from World Health Organization (WHO). The data for the study were analyzed using one sample t test.

III. RESULTS

Table 1 shows the physicochemical parameters of the soils in the study area in comparison with the WHO standard. All the parameters were higher than the WHO minimum permissible limits. Also, emphasis in table 1 is on the fact that the pollution rates in Rivers and Bayelsa States are higher than it is in Delta State. This partly explains the higher values of the physicochemical parameters detected in the former than the later.

Table 1: Soil Physicochemical parameters and WHO standards

Parameters	Rivers	Bayelsa	Delta	WHO Standard
Conductivity (ds/m)	11.77	11.51	10.65	3
pH	4.89	5.12	5.36	6.5-7

Moisture (%)	82.43	82.54	82.39	<80
TOC (mg/kg)	421.90	393.83	391.28	0.5
Total Organic Matter (mg/Kg)	28.13	27.13	25.33	10
Nitrate (NO_3^-) (%)	0.69	0.54	0.49	0.03
Temperature (°C)	35.45	34.29	34.82	24
Total Organic Carbon (%)	14.91	16.90	17.01	0.015
TOC (mg/Kg)	11.76	20.84	28.41	2
THC	22.55	20.78	19.30	0.03
Total Nitrogen (%)	2.82	2.92	2.31	0.05
Mg (%)	4.21	4.06	3.70	0.03

Table 2: heavy metals (mg/kg) with WHO standard

States	Pb	Ni	V	Cd	Co	Zn	Mo	Cu
Rivers	18.63	161.30	590.50	0.60	66.90	215.63	5.77	604.07
Bayelsa	19.33	145.05	489.90	0.60	66.00	210.48	4.62	502.01
Delta	16.03	133.20	345.30	0.60	62.10	205.33	4.17	453.18
WHO standard	2	10	1.1	0.02	0.05	0.6	0.07	10

Table 2 presented the concentration of heavy metals in soil in the component states of the study area, compared to WHO standard. The heavy metals compared to WHO standard as follows; Lead (pb), Delta 16.03 mg/kg, Rivers State 18.63 mg/kg and Bayelsa 19.33 mg/kg and all > WHO standard of 2 mg/kg; Nickel (Ni) which ranged from 133.2 mg/kg in Delta State to 442.8 mg/kg in Rivers State were also higher than WHO standard of 10 mg/kg; Vanadium (V) ranged from 345.3 mg/kg in Delta State to 509.5 mg/kg in Rivers State and > WHO standard of 1.1 mg/kg; cadmium (Cd) and carbon (Co) were relatively same across the study sites in the study area but were far higher than the WHO standard of 0.02 and 0.05 mg/kg respectively. Same can be said of Zinc (Zn) and Mo. However, Copper (Cu) ranged from 453.18 mg/kg in Delta State to 604.07 mg/kg in Rivers State and higher than WHO standard of 10 mg/kg.

Table 3 presented the one sample t test results for the comparison of heavy metals detected with WHO standard. Lead (pb) detected in the study area was significantly different from WHO standard at $p<0.05$(t 39.17, n=90). This means we have reached significance, this implies that there is a significant difference in the lead detected in the study area and WHO standard. Nickel (Ni) detected in the study area was significantly different from WHO standard at $p<0.05$(t 471.9, n=90). This means we have reached significance, this implies that there is a significant difference in Nickel detected in the study area and WHO standard. Vanadium (V) detected in the study area was significantly different from WHO standard at $p<0.05$(t 471.9, n=90). This means we have reached significance, implying that there is a significant difference in Vanadium detected in the study area when compared with WHO standard. Cadmium (Cd) detected in the study area was significantly different from WHO standard at $p<0.05$(t 0.40, n=90). This means we have reached significance, implying that there is a statistical significant difference in cadmium detected in the study area as compared with WHO standard. Carbon (Co) detected in the study area was significantly different from WHO standard at $p<0.05$(t 113.8, n=90). This means we have reached significance, implying that there is a statistical significant difference in carbon detected in the study area compared to WHO standard. Zinc (Zn) detected in the study area was significantly different from WHO standard at $p<0.05$(t 77.9, n=90). This means we have reached significance, implying that there is a statistical significant difference in zinc detected in the study area compared to WHO standard. Copper (Cu) detected in the study area was significantly different from WHO standard at $p<0.05$(t 35.2, n=90). This means we have reached significance, implying that there is a statistical significant difference in copper detected in the study area compared to WHO standard.

Table 3: Comparison of heavy metals (mg/kg) with WHO standard

One-Sample Test

	T	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference		WHO standard
					Lower	Upper	
Pb	39.177	89	.000	19.28466	18.3063	20.2631	Test Value = 2
Ni	471.968	89	.000	135.75934	135.1879	136.3308	Test Value = 10
V	47.189	89	.000	357.98017	342.9089	373.0514	Test Value = 1.1
Cd	0.40	89	.000	.4000	.3140	.5000	Test Value = 0.2
Co	113.889	89	.000	68.85233	67.6511	70.0536	Test Value = 0.5
Zn	77.990	89	.000	206.80432	201.5355	212.0732	Test Value = 0.6
Cu	35.801	89	.000	363.84322	343.6499	384.0366	Test Value = 10

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Table 4: Comparison of heavy metals (mg/kg) with control sites in the study area

One-Sample Test

	T	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference Lower	Upper	Control site
Pb	32.121	89	.000	19.3212	17.3063	21.2231	Test Value = 08
Ni	142.241	89	.000	125.75934	134.1879	136.3308	Test Value = 19
V	42.159	89	.000	331.4017	352.4389	374.2314	Test Value = 48
Cd	0.401	89	.000	.4000	.2340	.4000	Test Value = 0.38
Co	101.239	89	.000	67.1233	67.1141	71.0212	Test Value = 14.6
Zn	48.310	89	.000	210.1041	201.1435	221.2312	Test Value = 25.5
Cu	61.923	89	.000	313.1322	331.6499	352.1134	Test Value = 12.5

Table 4 presented the one sample t test results for the comparison of heavy metals detected with Control site. Lead (pb) detected in the study area was significantly different from Control site at p<0.05(t 32.1, n=90). This means we have reached significance, this implies that there is a significant difference in the lead detected in the study area and Control site. Nickel (Ni) detected in the study area was significantly different from Control site at p<0.05(t 142.2, n=90). This means we have reached significance, this implies that there is a significant difference in Nickel detected in the study area and Control site. Vanadium (V) detected in the study area was significantly different from Control site at p<0.05(t 42.2, n=90). This means we have reached significance, implying that there is a significant difference in Vanadium detected in the study area when compared with Control site. Cadmium (Cd) detected in the study area was significantly different from Control site at p<0.05(t 0.401, n=90). This means we have reached significance, implying that there is a statistical significant difference in cadmium detected in the study area as compared with Control site. Carbon (Co) detected in the study area was significantly different from Control site at p<0.05(t 101.23, n=90). This means we have reached significance, implying that there is a statistical significant difference in carbon detected in the study area compared to Control site. Zinc (Zn) detected in the study area was significantly different from Control site at p<0.05(t 48.6, n=90). This means we have reached significance, implying that there is a statistical significant difference in zinc detected in the study area compared to Control site. Copper (Cu) detected in the study area was significantly different from Control site at p<0.05(t 61.9, n=90). This means we have reached significance, implying that there is a statistical significant difference in copper detected in the study area compared to Control site.

IV. DISCUSSION

An investigation of the soil physicochemical parameters showed that all the parameters were higher than the WHO minimum permissible limits. Also, established is that pollution rates in Rivers and Bayelsa States were higher than it is in Delta State. This partly explains the higher values of the physicochemical parameters detected in the former than the later. The concentration of heavy metals in soil in the component states of the study area, compared to WHO standard were as follows; Lead (pb), Delta 16.03 mg/kg, Rivers State 18.63 mg/kg and Bayelsa 19.33 mg/kg and all > WHO standard of 2 mg/kg; Nickel (Ni) which ranged from 133.2 mg/kg in Delta State to 442.8 mg/kg in Rivers State were also higher than WHO standard of 10 mg/kg; Vanadium (V) ranged from 345.3 mg/kg in Delta State to 509.5 mg/kg in Rivers State and > WHO standard of 1.1 mg/kg; cadmium (Cd) and carbon (Co) were relatively same across the study sites in the study area but were far higher than the WHO standard of 0.02 and 0.05 mg/kg respectively. Same can be said of Zinc (Zn) and Mo. However, Copper (Cu) ranged from 453.18 mg/kg in Delta State to 604.07 mg/kg in Rivers State and higher than WHO standard of 10 mg/kg. The one sample t test results for the comparison of heavy metals detected with WHO standard showed that Lead (pb) detected in the study area was significantly different from WHO standard at p<0.05(t 39.17, n=90). Nickel (Ni) detected in the study area was significantly different from WHO standard at p<0.05(t 471.9, n=90). Vanadium (V) detected in the study area was significantly different from WHO standard at p<0.05(t 471.9, n=90). Cadmium (Cd) detected in the study area was significantly different from WHO standard at p<0.05(t 0.40, n=90). Carbon (Co) detected in the study area was significantly different from WHO standard at p<0.05(t 113.8, n=90). Zinc (Zn) detected in the study area was significantly different from WHO standard at p<0.05(t 77.9, n=90). Copper (Cu) detected in the study area was significantly different from WHO standard at p<0.05(t 35.2, n=90). The problem with the presence of these heavy metals in the environment is that they stick around for a very long time, making its penetration of plants, fishes and animal very propense. The connection of these metals with diseases such as cancer, kidney disorder, renal failure, headaches, nausea etc has been established in previous studies (Iheme, et al, 2017; Kekane, et al, 2015; Kujur, & Patel, 2014; Maharana & Patel, 2013; Neina, 2019). The one sample t test results for the comparison of heavy metals detected with control site showed they were all statistically significantly different from Control site at p<0.05 and as follows; lead (t 32.1, n=90); Nickel (Ni) p<0.05(t 142.2, n=90); Vanadium p<0.05(t 42.2, n=90);

cadmium p<0.05(t 0.401, n=90); carbon (Co); p<0.05(t 101.23, n=90); Zinc (Zn); p<0.05(t 48.6, n=90); Copper (Cu) p<0.05(t 61.9, n=90).

V. CONCLUSION AND RECOMMENDATIONS

Rivers state had the most polluted soil followed by Bayelsa and Delta States. The concentration of heavy metals in mg/kg, with distance from the production sites decreased with distance from the site of production. This study concludes that, while improving the production process of artisanal refining in the study area, it is also important to remediate the already destroyed environments. Soil physicochemical parameters showed that all the parameters were higher than the WHO minimum permissible limits. This partly explains the higher values of the physicochemical parameters detected in the former than the later. As a result, this study concludes that more attention on environmental rehabilitation be paid to Rivers and Bayelsa States since they are the most affected of the three states.

As a result this study recommends as follows:
a) A legal framework should be developed on how to make artisanal refining in the Niger Delta region legal. This would be achieved through licensing of citizens of the region and others to operate modular refineries. Investors should be encouraged with soft loans to achieve this process.
b) As a matter of urgency, the Government should embark on a study of the process of artisanal refining and improve where need be in the process to braze-up the tide and stimulate local capacity in refining.
c) Oil companies operating in the region in collaboration with government should increase their corporate social responsibility through the encouragement and support the development and expansion of the local economy for rural inhabitants in the state, such as provision of social and welfare amenities, companies (to engage youths).
d) there is need for the government and the NGOs to partner in the remediation of the already destroyed environment.

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