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Research Article

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Assessment of Metal Pollution in Surface Soils in Part of Nnewi Industrial Area, South-eastern Nigeria

Kenechukwu Agbonma Ifeanyichukwu*[1], Elizabeth Okeyeh[1], Onwe Ikechukwu Moses[2], Ogechukwu Ben-Owope[1]

[1]Nnamdi Azikwe University Awka, Nigeria
[2]Alex Ekwueme Federal university Ndufu-Alike, Nigeria
Corresponding author: kene4all@yahoo.com

Abstract Nnewi has been described as the Japan of Africa because of wide range of industries it harbours. These industrial activities are responsible for polluting the surrounding soil in Nnewi. Hence, it becomes paramount to assess the impact of the industrial activities on the quality of the surrounding soil for agricultural purposes. To achieve these, the geology of the study area was determined through surface geological mapping, where as18 soil samples, were collected within the study X-ray fluorescence spectroscopy (XRF) analytical method was used to ascertain the chemical composition of the soil samples. The laboratory results were analysed by employing geochemical indices calculations, and summary statistics. Results from soil pollution indices such as CI, Igeo, EF, NIPI, PLI and mCD when compared with the (DPR 2002) regulatory limits for safe agricultural soils, showed that the soil contamination was from anthropogenic sources, such as industrial effluent and the heavy metal sources is in the order: Pb > As > Ni > Cu > Zn > Cr > Fe > Mn.

Keywords Contamination Index, Enrichment Factor, Geo-accumulation Index, Pollution Load Index

1. Introduction

Heavy metal pollution of soils and the environment is the result from industrialization, urbanization, and intensified irrigation water [1]. Heavy metals pollution led to the poor soil health [2, 3], surface and groundwater [4] and food contamination [5], which is a hazard to human health [6, 7, 8, 9, 10]. Therefore, the information of the heavy metal contamination of soils is needed to decide the combined efforts of governments and scientific communities.

Pollution of the natural environment by heavy metals is a universal problem because these metals are indestructible and most of them have toxic effects on living organisms, when permissible concentration levels are exceeded. Heavy metals frequently reported in literature with regards to potential hazards and occurrences in contaminated soils are Cd, Cr, Pb, Zn, Fe and Cu [11, 12]. Vehicle exhausts, as well as several industrial activities emit these heavy metals so that soils, plants and even residents along roads with heavy traffic loads are subjected to increasing levels of contamination with heavy metals [13].

Road construction has been the main activity for development of industrial units. This has led to the loss of forest cover and subsequent loss of soil fertility. Roadside soils often show a high degree of contamination that can be attributed to motor vehicles. Various researchers have found that the concentrations of the metals Pb, Cu, Zn, Cd and Ni decrease rapidly within 10 to 50 m from the roadsides [14, 15]. According to Panek and Zawodny [16], pollution of roadside soils and plants by combustion of leaded petrol products is localized and usually limited to a belt of several meters wide on either side of the road, and that for similar topography and vegetation, the level of pollution decreases with the distance from the road. Due to their cation exchange capacity, complexing organic substances, oxides and carbonates have high retention capacity for heavy metals. Hence

contamination levels increase continuously as long as the nearby sources remain active. Nevertheless, some heavy metals attached to the soil particles can be removed from the soil surfaces and get translocated elsewhere by the action of water and wind [13, 17, 18].

Plants, especially mosses and lichens are considered to be good bioindicators of metal pollution, [19] but trees are also used to assess the level of heavy metal contamination, especially in cities, where their occurrence is widespread. Tree foliage owing to its large surface area can act as a biological filter and remove considerable numbers of airborne particles, thus improving air quality in polluted environments [20]. Hence, the parts of plants most often used in monitoring are leaves or needles [21, 22, 23], as well as bark [24, 25].Pollution monitoring by trees may provide useful data for the design of deposition monitoring networks and can facilitate analytical determination of trace elements. Tree leaves reflect the cumulative effects of environmental pollution from the soil and the atmosphere, by root transport and through leaves, while metal concentrations in tree bark originate mainly from the atmosphere and can be accumulated for years [25].

The objectives of the present work were to: (1) Determination the concentration of heavy metals in soil, using X-ray fluorescence spectroscopy (XRF) analytical method. (2) Compare the results of the soil analyses with (DPR 2002) regulatory limits for safe agricultural soils. (3) Assessment of Soil Pollution using soil pollution indices such as CI, Igeo, EF, NIPI, PLI and mCD.

2. Geology and hydrogeology of the Study area

The study area is part of Nnewi North LGA of Anambra state, Nigeria, which is located about 22 km from Onitsha town and lies within latitudes 5^0 58^lN and $6^0$$30^l$N and longitudes $6^0$$52^l$E and $6^0$$57^l$E. On the average, altitude is about 202m above sea-level. It is an industrial and a commercial city, the second largest city in Anambra State, Nigeria [26], it is made up of four autonomous communities: Otolo, Uruagu, Umudim, and Nnewichi (Fig. 1). The total coverage of the study area is about 121km^2, with an estimated population of 121,063 according to the Nigerian population commission, 2018.

The study area is underlain by two formation; Eocene Nanka Sands Formations (Ameki group) and Quaternary Ogwashi-Asaba formation [27, 28]. In the study area it is a sequence of poorly consolidated, poorly sorted, friable, medium to coarse sands of Eocene age. The formation contains thin band of clay stone, siltstone and shale. The units have good porosity and permeability. The sandstone unit is aquiferous [29] overlying the Nanka Sands is the Ogwashi-Asaba Formation. This consists of intercalation of lignite and clays.

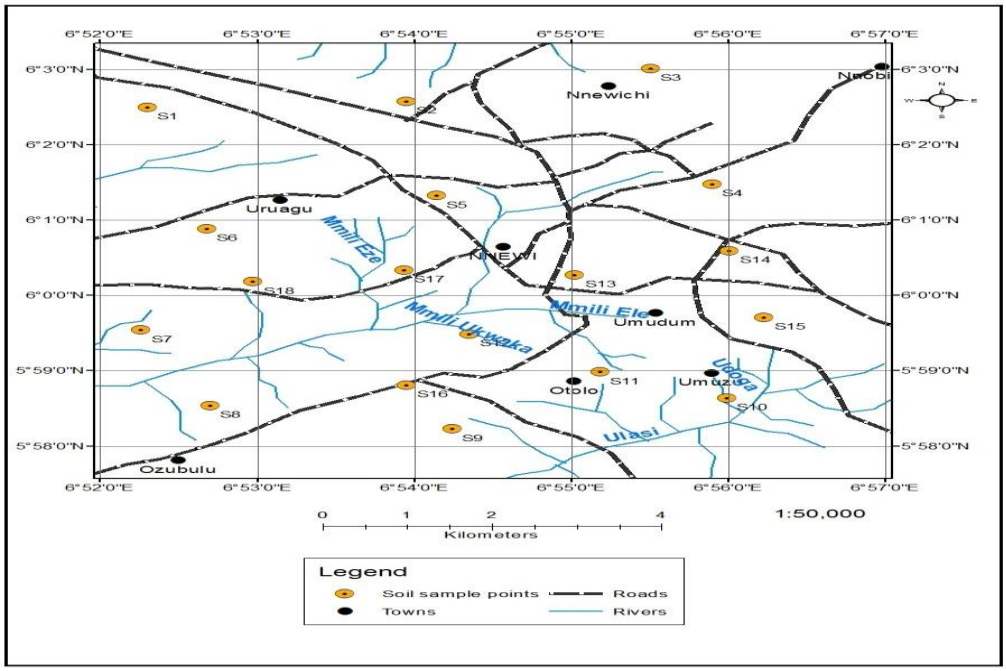

Figure 1: Soil sample location map

3. Methodology

Geological field mapping, by surface traversing, contact identification and detailed outcrop studies, was done to identify the lithologies outcropping in the study area followed by Soil sampling was carried out at the industrial sites and out of the sites as control samples in study area as in Figure 1 and Table 1. A total of eighteen (18) soil samples (SS) was collected from fifteen (15) locations at 0 – 15cm depth with the aid of a hand auger and measuring tape. 10 soil samples were collected directly from the industrial dumps, while 8 samples were taken randomly from normal soil that was not close to industrial sites as control soil samples. Care was taken to wash and clean the auger before sampling each location in order not to contaminate the samples. About one kilogram of soil sample was collected at each sampled depth in pre-labelled polythene bags, after which they were transported to the laboratory for digestion and analysis.

Table 1: Soil Sample Coordinates Points

N/S	Sample Number	Latitude	Longitude
1	S1	6° 24’ 4’’N	6° 52’ 16’’E
2	S2	6° 2’ 38’’N	6° 53’ 56’’E
3	S3	6° 2’ 59’’N	6° 55’ 30’’E
4	S4	6° 1’ 31’’N	6° 55’ 56’’E
5	S5	6° 1’ 19’’N	6° 54’ 12’’E
6	S6	6° 0’ 53’’N	6° 52’ 43’’E
7	S7	5° 59’ 31’’N	6°52’ 24’’E
8	S8	5° 58’ 33’’N	6° 52’ 44’’E
9	S9	5° 58’ 16’’N	6° 54’ 16’’E
10	S10	5° 58’ 38’’N	6° 56’ 0’’E
11	S11	5° 58’ 59’’N	6° 55’ 13’’E
12	S12	5° 59’ 28’’N	6° 54’ 22’’E
13	S13	6° 0’ 16’’N	6° 55’ 4’’E
14	S14	6° 0’ 37’’N	6° 55’ 59’’E
15	S15	5° 59’ 43’’N	6° 56’ 14’’E
16	S16	5°58’50’’N	6° 53’ 56’’E
17	S17	6° 0’ 23’’N	6° 53’ 55’’E
18	S18	6° 0’ 12’’N	6° 53’ 2’’E

3.1. Soil Pollution Indices

Pollution assessment models are indicators used to assess the presence and intensity of anthropogenic contamination index (CI), Pollution Load Index (PLI), modified Contamination Degree (mCD), Geo-accumulation Index (Igeo) and Nemerow Integrated Pollution Index (NIPI).

3.1.1. Contamination Index (CI)

The contamination factors were derived by using the CI equation as defined by Lacutusu [30]:

$$C_i = \frac{C_n}{B_n} \quad (1)$$

Where Cn = measured metal concentration and Bn = background concentration from control site.

3.1.2. Pollution Load Index (PLI)

The PLI gives a generalized assessment on the level of soil contamination. The PLI is obtained using Tomlinson [31] approach as follows:

$$PLI = [CF_1 \times CF_2 \times CF_3 \times \ldots\ldots\ldots CF_n]^{1/n} \quad (2)$$

Where, CF = contamination factor; and n = number of metals.

3.1.3. Geo-accumulation Index (I_{geo})

Geo-accumulation Index, also an indicator used to assess the intensity of anthropogenic contamination, ranges from uncontaminated to strong contaminated soils. The I_{geo} enables the assessment of contamination by comparing the resent heavy metals concentrations and the original pre-industrial concentrations in the soils. It is computed by the following the Muller [32] equation:

$$I_{geo} = \text{Log}_2 \frac{C_n}{1.5B_n} \quad (3)$$

Where Cn = measured metal concentration and Bn = background/control value of that metal obtained from the control site. The constant 1.5 is introduced by Lu et al. [33] to minimize the effect variations in the background concentrations which may be attributed to lithologic difference.

3.1.4. Modified Contamination Degree (mCD)

The mCD is an empirical assessment of the overall degree of contamination by pollutants in an area. The mCD will be calculated as defined by Hakanson[34] as follows

$$mCD = \frac{\sum_{i=1}^{n} Cf_i}{n} \quad (4)$$

Where Cf = contamination factor, n = number of analysed metals, and i is the metal.

3.1.5. Nemerow Integrated Pollution Index (NIPI)

The NIPI will also be employed to assess the overall pollution integrity of the area. NIPI was calculated as defined by Nemerow[35] as:

$$NPI = [0.5 \times (I_{mean}^2 + I_{max}^2)]^{1/2} \quad (5)$$

Where Imean = average concentration of all pollution indices considered, and Imax =maximum pollution index.

3.1.6. The Enrichment Factor (EF)

It can be calculated by dividing its ratio to the normalizing element by the same ratio found in the chosen baseline [36].

EF is calculated by the following equation:

$$EF = (Metal/Fe)_{sample} / (Metal/Fe)_{Background} \quad (6)$$

Background the EF values close to unity indicate crusted origin; those less than 1.0 suggest a possible mobilization or depletion of metals [37]. EFs >1.0 suggest possible anthropogenic origin. EFs >10 is suggested to be a non-crusted source. For geochemical normalization, iron (Fe) was used as the reference element [38]. Summary of all Soil pollution indices classification is in table 2

Table 2: Soil pollution models classification schemes

Contamination Index [30])		Geoaccumulation Index [39]		Modified Contamination Degree [34]		Pollution Load Index [31]		Nemerow integrated pollution index [35]	
Value	**interpretation**	**Value**	**Interpretation**	**Value**	**interpretation**	**Value**	**interpretation**	**Value**	**interpretation**
< 0.1	Very slight contamination	Igeo< 0	practically uncontaminated	<1.5	very low degree of contamination	0	background concentration	≤ .7	safe
0.1 – 0.25	Slight contamination	0<Igeo< 1	uncontaminated to moderately contaminated	≤1.5 mCD< 2	low degree of contamination	>0 ≤1 PLI	unpolluted to moderately polluted	>0.7 NIPI ≤1	precaution
0.26 – 0.5	Moderate contamin	1<Igeo< 2	moderately	≤2 mCD< 4	moderate degree of	>1 ≤2 PLI	moderately	>1 ≤2 NIP	slightly polluted

	ation		contaminated		contamination			polluted			
0.51 – 0.75	Severe contamination	2<Igeo< 3	moderately to strongly contaminated	≤4 mCD< 8	high degree of contamination	>2 ≤3	PLI	moderately to highly polluted	>2 ≤3	NIP	moderately polluted
0.76 – 1.0	Very severe contamination	3<Igeo< 4	strongly contaminated	≤8 mCD< 16	very high degree of contamination	>3 ≤4	PLI	Highly polluted	> 3		heavily polluted
1.1 – 2.0	Slight pollution	4<Igeo<5	strongly to extremely contaminated	≤16 mCD< 32	extremely high degree of contamination	≥5		very highly polluted	-		-
2.1 – 4.0	Moderate pollution	Igeo> 5	extremely contaminated	≥ 32	ultrahigh degree of contamination	-		-	-		-
4.1 – 8.0	Severe pollution	-	-	-	-	-		-	-		-
8.1 – 16	Very severe pollution	-	-	-	-	-		-	-		-
>16	Excessive pollution	-	-	-	-	-		-	-		-

3.1.7. Principal Component Analysis (PCA)

The raw values of the heavy metals were queued into the GenStat analytical program which ran the statistical analysis. The program was set to run the analysis based on the correlation matrix, and to analyse the data in four dimensions, and thereafter display the latent roots, latent vectors (loadings), and principal component scores.

4. Results

4.1. Soil Quality within the Study Area

Table 3 revealed that Cr is above [40] regulatory limit for safe agricultural soils. In all location in the study area except for locations SS7, SS8, SS14 and SS16, where it was not detected. More so, Cu and Pb are above the [40] regulatory limits for safe agricultural soils, in all locations in the study area. Whereas Zn is above the [40] regulatory limits for safe agricultural soils in locations SS1, SS5, SS6, SS7, SS8, SS9, SS12, SS13, SS17 and SS18 in the study area, and was not detected in locations SS10, SS15 and SS16, while it is within the permissible limit in location SS2, SS3, SS11 and SS14. Furthermore, Mn is within the [40] regulatory limits for safe agricultural soils, in all locations except locations SS6 which is above the permissible limit. Fe is within the [40] regulatory limits for safe agricultural soil in all locations except for location SS5, SS6, SS9 and SS10. Locations SS1, SS2, SS3, SS9, SS13, SS15 and SS16 recorded AS in concentration above [40] regulatory limits for safe agricultural soils, but was not detected at locations SS5, SS6, SS7, SS8, SS17 and SS18. More so, for Ni location SS1, SS5, SS7, SS8, SS11, SS12 and SS16 are above [40] regulatory limits for safe agricultural soils and location SS6, SS17 and SS18 are below [40] regulatory limits for safe agricultural soils, while location SS2, SS3, SS4, SS9, SS13 and SS14 are not detected.

Table 3: Result of Heavy metal in soil sample

Sample location	Cr (ppm)	Pb (ppm)	Cu (ppm)	Zn (ppm)	Mn (ppm)	Fe (ppm)	As (ppm)	Ni (ppm)
SS1	1227.7	441.1	183.7	211.6	129	9520	39.61	76.35
SS2	350.8	226.1	200.3	124.5	N/D	11192.4	15.15	N/D
SS3	248.5	226.1	135.8	124.5	N/D	5402.8	66.02	N/D
SS4	628.5	215.8	200.3	373.4	N/D	463.1	30.2	N/D
SS5	423.8	49223.1	1377	2116.1	774.7	497322.9	N/D	827.14
SS6	511.5	133590.9	2002.9	2240.6	981.2	415239.1	N/D	25.45
SS7	N/D	842.7	563.3	1020.7	N/D	39752.5	N/D	50.9
SS8	N/D	1849.7	824.4	2489.5	413.19	83879	N/D	50.9
SS9	701.5	21271.8	751	473	129.1	213171.1	132	N/D
SS10	584.6	1233.1	338	N/D	258.2	55962.2	N/D	38
SS11	160.8	389.2	751	124.5	129.1	10549.2	132	76.35
SS12	175.6	204.3	300	224.1	258.2	9391.4	N/D	50.9
SS13	219.2	214.1	262.9	497.9	129.1	10034.6	13.2	N/D
SS14	N/D	246.6	287.9	124.4	N/D	10549.2	15.15	N/D
SS15	N/D	236.4	479.3	N/D	258.2	7847.6	13.2	50.9
SS16	204.6	205.5	875.3	N/D	387.4	10034.6	39.61	38
SS17	175.4	175.2	375.5	249	129.1	10677.9	N/D	25.45
SS18	175	12331	500.7	298.7	129.1	11707	N/D	12.75
DPR[40] limit	100	85	36	140	850	47000	1	35

4.2. Soil Pollution Indices

4.2.1. Contamination Index (CI)

The results for CI for all metals at various locations are tabulated in tables 4 For Cr the results range from slightly polluted to very severe polluted, 28% of the samples in locations SS11, SS12, SS16, SS17 & SS18 are slightly polluted, 11% of the samples in location SS2 and SS3 are moderately polluted, while 28% of the samples in locations SS4, SS5, SS6 SS9 and SS10 are Severely polluted and only 6% the sample in location SS1is very severely polluted. For Pb the results of CI ranges from moderately polluted to excessively polluted, 50% of the samples in locations SS2, SS3, SS4, SS12, SS13, SS14, SS15, SS16 and SS17 are moderately polluted, then 11% of the sample in location SS1 and SS11 are severely polluted, while17% of the sample in location SS7, SS10 and SS18 are very severely polluted, while 17% of the samples in locations SS7 SS10 and SS18 are excessively polluted.

For the value of Cu, the results of CI ranges from moderately polluted to excessively polluted, only 6% of the sample in location SS3 is moderately polluted, then 28% of the sample in location SS1, SS2, SS4, SS13 and SS14 are severely polluted, while 39% of the sample in location SS7, SS10, SS12, SS14, SS15, SS17 and SS18 are very severely polluted, while 33% of the samples in locations SS5, SS6, SS8, SS9, SS11 and SS16are excessively polluted.

For the value of Mn, the results range from slightly polluted to very severe polluted, 33% of the samples in locations SS1, SS9, SS11, SS13, SS17 and SS18 are slightly polluted, 28% of the samples in location SS8, SS10, SS12, SS15 & SS16 are moderately polluted, and only 6% the sample in location SS6 is very severely polluted.

For the value of Zn, the results range from slightly contaminated to very moderately polluted, 22% of the samples in locations SS2, SS3, SS11 & SS14SS18 are slightly contaminated, 22% of the samples in location SS1, SS12, SS17 & SS18 are moderately contaminated, while 14% of the samples in locations SS4, SS9 & SS13 are severely contaminated and only 6% the sample are very severely contaminated and slightly polluted in

locations SS13 and SS7 respectively, while 14% of the samples in locations SS5, SS6 and SS8 are moderately polluted.

For the value of Fe, the results of CI ranges from slightly contaminated to very severe polluted, only 67% of the samples in locations SS1, SS 2, SS3, SS4,SS10, SS11,SS12, SS13,SS14, SS15, SS16, SS17 and SS18 are slightly contaminated, only 6% of the sample in location SS7 are very severely contaminated, while 11% of the sample in location SS8 and SS10 are very slightly polluted, more so, 6% of the sample in location SS9 is severely polluted and11% of the sample in location SS5 and SS6 are very severely polluted.

For the value of As, the results of CI ranges from very severe polluted to excessive polluted, 22% of the samples in locations SS2, SS13, SS14 & SS15 are very severe polluted, while 33% of the samples in locations SS1, SS3, SS4, SS9, SS11 and SS16 are excessive polluted.

For the value of Ni, the results range from very slightly contaminated to severely polluted, only 6% of the sample in location SS18 are very slightly contaminated, 17% of the samples in location SS6, SS10 and SS16 are slightly contaminated, while 28% of the samples in locations SS1, SS7, SS8, SS12 & SS15 are moderately contaminated more so 6% the sample in location SS5 is severely polluted.

4.2.2. Geo-accumulation Index (Igeo)

The Igeo is used as a reference of calculating the level of metal pollution. The result of Igeo, for metals and locations are tabulated in tables 4. For Cr the result ranges from uncontaminated to moderately contaminated and moderately to strongly contaminated, 50% of the soil are uncontaminated to moderately contaminated, 22% of the soil samples are moderately contaminated, only 6% of the soil samples is moderately to strongly contaminated.

For Pb, the results of Igeo ranges from uncontaminated to moderately contaminated and moderately to strongly contaminated, 56% of the soil samples are uncontaminated to moderately contaminated, 11% of the soil samples are moderately contaminated, only 6% of the soil samples are moderately to strongly contaminated.

For Cu, the results of Igeo ranges from uncontaminated to moderately contaminated and extremely contaminated, only 6% of the soil sample are uncontaminated to moderately contaminated, 17% of the soil samples are moderately to strongly contaminated, more so, 6% of the soil samples are strongly contaminated, while 22% of the soil samples are strongly to extremely contaminated and 6% of the soil sample is extremely contaminated.

For Mn, the results ofIgeoare moderately contaminated for all 72% of the soil samples. For Zn, the results of Igeo ranges from uncontaminated to moderately contaminated and strongly contaminated, 61% of the soil samples are uncontaminated to moderately contaminated, only 6% of the soil sample are moderately contaminated, while 14% of the soil samples are strongly contaminated. For Fe, the results of Igeo ranges from uncontaminated to moderately contaminated and moderately to strongly contaminated 89% of the soil are uncontaminated to moderately contaminated, only 6% of the soil sample in location are moderately contaminated. More so, 6% of the soil sample moderately to strongly contaminated.For As, the results of Igeo ranges from moderately to strongly contaminated and extremely contaminated, 11% of the soil samples in locations are moderately to strongly contaminated. More so 11% of the soil samples are strongly contaminated, while 22% of the soil samples are extremely contaminated.For Ni, the results of Igeo ranges from uncontaminated to moderately contaminated and strongly to extremely contaminated, 61% of the soil samples are uncontaminated to moderately contaminated. While only 6% of the soil sample are strongly to extremely contaminated.

4.2.3. The Enrichment Factor (EF)

The result for EF for all metals and locations are tabulated in tables 4. For Cr, Pb, Cu, Mn, Fe the result show that all soil samples are contaminated from anthropogenic activities. Expect for Zn and Ni that about 6% and 11% are from depletion of metal respectively while the remaining percentages are anthropogenically contaminated.

Table 4: Igeo and Ef of heavy metals for surface soil

	Soil pollution assessment	**Soil value**	**Interpretation**	**No of locations**	**% of samples**	**Samples**
Cr	CI	1.1 – 2.0	Slight polluted	5	28	SS11, SS12, SS16, SS17 & SS18
		2.1 – 4.0	Moderate polluted	2	11	SS2, SS3,
		4.1 – 8.0	Severe polluted	5	28	SS4, SS5, SS6 SS9 & SS10
		8.1 – 16	Very severe polluted	1	6	SS1
	Igeo	0< Igeo< 1	uncontaminated to moderately contaminated	9	50	SS2, SS3, SS11, SS12, SS13, SS16, SS17 & SS18
		1< Igeo< 2	moderately contaminated	4	22	SS4, SS6, SS9 & SS10
		2< Igeo< 3	moderately to strongly contaminated	1	6	SS1
	Ef	>1	anthropogenic origin	9	50	SS4, SS6, SS9, SS11, SS12, SS13, SS16, SS17 & SS18
		>10	non crust source	4	22.2	SS1, SS2, SS3, & SS10
Pb	CI	2.1 – 4.0	Moderate pollution	9	50	SS2, SS3, SS4, SS12, SS13, SS14, SS15, SS16 & SS17
		4.1 – 8.0	Severe pollution	2	11	SS1, & SS11
		8.1 – 16	Very severe pollution	3	17	SS7, SS10 & SS18
		>16	Excessive pollution	4	22	SS5, SS6, SS8 & SS9
	Igeo	0< Igeo< 1	uncontaminated to moderately contaminated	10	56	SS2, SS3, SS4, SS11, SS12, SS13, SS14, SS15, SS16 & SS17
		1< Igeo< 2	moderately contaminated	2	11	SS1 & SS11
		2< Igeo< 3	moderately to strongly contaminated	1	6	SS10
		Igeo > 5	extremely contaminated	3	17	SS5, SS6 & SS9
	Ef	>10	non crust source	6	100	SS1, SS2, SS3, SS4, SS5, SS6, SS7, SS8, SS9, SS10, SS11, SS12, SS13, SS14, SS15, SS16, SS17, & SS18
Cu	CI	2.1 – 4.0	Moderate pollution	1	6	SS3
		4.1 – 8.0	Severe pollution	5	28	SS1, SS2, SS4, SS13 & SS14
		8.1 – 16	Very severe pollution	7	39	SS7, SS10, SS12, SS14, SS15, SS17 & SS18
		>16	Excessive pollution	6	33	SS5, SS6, SS8, SS9, SS11 & SS16
	Igeo	1< Igeo< 2	moderately contaminated	7	39	SS1, SS2, SS4, SS10, SS12, SS13 & SS14,
		2< Igeo< 3	moderately to strongly	3	17	SS15, SS17 & SS18

			contaminated			
		3< Igeo< 4	strongly contaminated	1	6	SS7
		4<Igeo<5	strongly to extremely contaminated	4	22	SS8, SS9 SS11 & SS16
		Igeo > 5	extremely contaminated	2	11	SS7 & SS11
	Ef	>1	anthropogenic origin	3	17	SS5, SS9 & SS10
		>10	non crust source	15	83	SS1, SS2, SS3, SS4, SS5, SS7, SS8, SS11, SS12, SS13, SS14, SS15, SS16, SS17 & SS18
Mn		0.1 – 0.25	Slight contamination	6	33	SS1, SS9, SS11, SS13, SS17 & SS18
		0.26 – 0.5	Moderate contamination	5	28	SS8, SS10, SS12, SS15 & SS16
		0.76 – 1.0	Very severe contamination	1	6	SS6
	Igeo	1< Igeo< 2	moderately contaminated	13	72	SS1, SS5, SS6, SS8, SS9, SS10, SS11, SS12, SS13, SS15, SS16, SS17 & SS18
	Ef	>1	anthropogenic origin	11	61	SS1, SS5, SS6, SS8, SS9, SS10, SS11, SS12, SS13, SS17 & SS18
		>10	non crust source	2	11	SS15 & SS16
Zn	CI	0.1 – 0.25	Slight contamination	4	22	SS2, SS3, SS11 & SS14
		0.26 – 0.5	Moderate contamination	4	22	SS1, SS12, SS17 & SS18
		0.51 – 0.75	Severe contamination	3	14	SS4, SS9 & SS13
		0.76 – 1.0	Very severe contamination	1	6	SS13
		1.1 – 2.0	Slight pollution	1	6	SS7
		2.1 – 4.0	Moderate pollution	3	14	SS5, SS6 & SS8
	Igeo	0< Igeo< 1	uncontaminated to moderately contaminated	11	61	SS1, SS2, SS3, SS4, SS9, SS11, SS12, SS13, SS14, SS17 & SS18
		1< Igeo< 2	moderately contaminated	1	6	SS7
		3< Igeo< 4	strongly contaminated	3	14	SS5, SS6 & SS8
	Ef	<1	depletion of metal	1	6	SS9
		>1	anthropogenic origin	12	61	SS1, SS2, SS3, SS5, SS6, SS7, SS8, SS11, SS12, SS14, SS17 & SS18
		>10	non crust source	2	11	SS4 & SS13
Fe	CI	0.1 – 0.25	Slight contamination	12	67	SS1, SS 2, SS3, SS4, SS10, SS11, SS12, SS13, SS14, SS15, SS16, SS17 & SS18
		0.76 – 1.0	Very severe contamination	1	6	SS7
		1.1 – 2.0	Slight pollution	2	11	SS8 & SS10

		4.1 – 8.0	Severe pollution	1	6	SS9
		8.1 – 16	Very severe pollution	2	11	SS5 & SS6
	Igeo	0< Igeo< 1	uncontaminated to moderately contaminated	16	89	SS1, SS2, SS3, SS4, SS7, SS8, SS9, SS10, SS11, SS12, SS13, SS14, SS15, SS16, SS17 & SS18
		1< Igeo< 2	moderately contaminated	1	6	SS6
		2< Igeo< 3	moderately to strongly contaminated	1	6	SS5
	Ef	>1	anthropogenic origin	18	100	SS1, SS2, SS3, SS4, SS5, SS6, SS7, SS8, SS9, SS10, SS11, SS12, SS13, SS14, SS15, SS16, SS17 & SS18
As	CI	8.1 – 16	Very severe pollution	4	22	SS2, SS13, SS14 & SS15
		>16	Excessive pollution	6	33	SS1, SS3, SS4, SS9, SS11 & SS16
	Igeo	2< Igeo< 3	moderately to strongly contaminated	2	11	SS13 & SS15
		3< Igeo< 4	strongly contaminated	2	11	SS2 & SS14
		Igeo > 5	extremely contaminated	6	22	SS1, SS3, SS4, SS9, SS11 & SS16
	Ef	>1	anthropogenic origin	5	28	SS1, SS2, SS9, S14 & SS15
		>10	non crust source	6	33	SS3, SS4, SS11, SS13 & SS16
Ni	CI	< 0.1	Very slight contamination	1	6	SS18
		0.1 – 0.25	Slight contamination	3	17	SS6, SS10 &SS16
		0.26 – 0.5	Moderate contamination	5	28	SS1, SS7, SS8, SS12 & SS15,
		4.1 – 8.0	Severe pollution	1	6	SS5
	Igeo	0< Igeo< 1	uncontaminated to moderately contaminated	11	61	SS1, SS6, SS7, SS8, SS10, SS11, SS12, SS15, SS16, SS17 & SS18
		4<Igeo<5	strongly to extremely contaminated	1	6	SS5
	Ef	<1	depletion of metal	2	11	SS6 & SS10
		>1	anthropogenic origin	9	50	SS1, SS5, SS7, SS8, SS11, SS12, SS15, SS16 & SS17
		>10	non crust source	1	6	SS18

4.2.4. Nemerow Integrated Pollution Index (NIPI)

The results of NIPI in figure 2 showed that the soils are heavily polluted of Pb, Cu, Zn, As and Ni moderately polluted of Cr, slightly polluted of Fe, and precaution of Mn. In order of decreasing magnitude, the heavy metals responsible for the high NIPI in the soil are Pb> As > Ni > Cu > Zn > Cr > Fe > Mn with values of 1115.6, 99.7, 75.1, 40, 12.6, 9.18, 7.5, and 0.8 respectively.

4.2.5. Pollution Load Index (PLI)

The results of PLI in figure 3 showed that the soil is very highly polluted of Pb, Cu, As and Ni, highly polluted of Zn, moderately polluted of Cu, unpolluted to moderately polluted for Mn and Fe. In order of decreasing magnitude, the heavy metals responsible for the high PLI in the soil are As> Pb> Cu > Zn > Ni > Cr > Fe > Mn, with values of 34, 10, 9.6, 2.6, 1.49, 1.46, 0.48, and 0.28 respectively.

4.2.6. Modified Contamination Index (mCD)

The results of mCD in figure 4 showed that the soil is in excessive pollution of Pb, high degree of contamination of Cu and Zn, ultrahigh degree of contamination of As and Ni, low degree of contamination of Fe then very low degree of contamination of Mn. In order of decreasing magnitude, the heavy metals responsible for the high PLI in the soil are Pb> As > Cu > Zn > Ni > Fe > Cr> Mn, with values of 178, 49.6, 14.36, 5.49, 3.03, 1.67, 1.46, and 0.40 respectively.

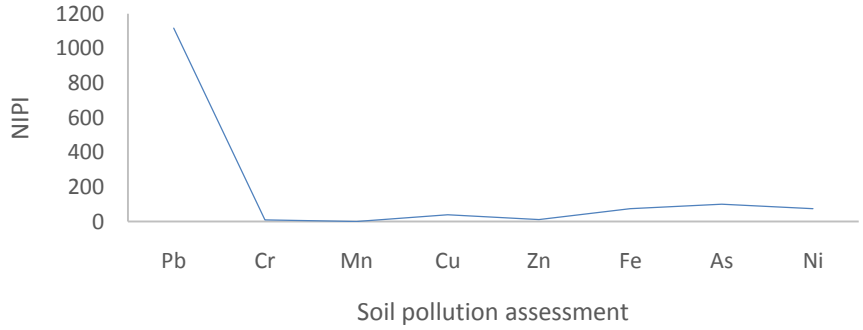

Figure 2: Nemerow Integrated Pollution Index for soil in study the area

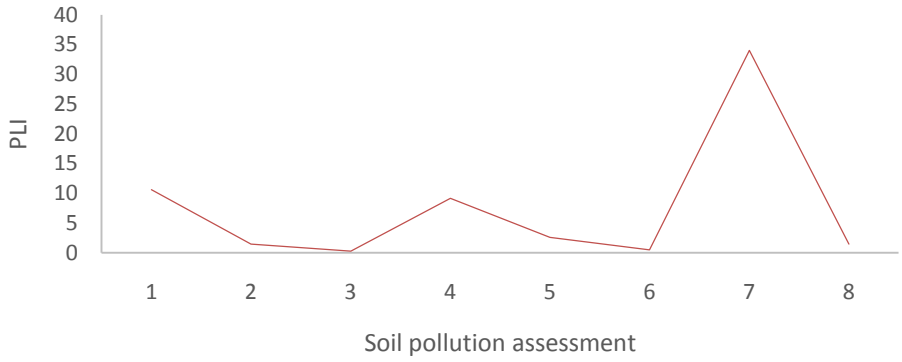

Figure 3: Pollution Load Index classification for soil in study the area

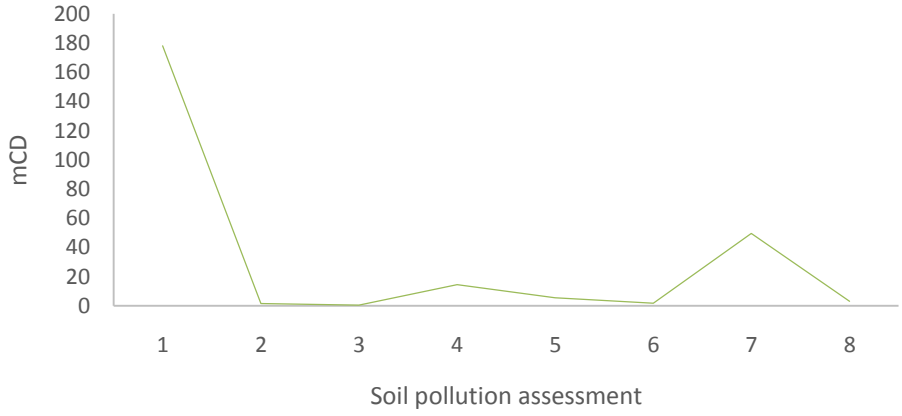

Figure 4: Modified Contamination Degree classification for soil in study the area

4.2.7. Principal Component Analysis for Soil Sample

The principal component analysis in Table 5, in PC1, Fe, Mn, Cu, Pb, and Zn is contributing 57% to the total heavy metal quality of the soil samples, whereas in PC2 (Cr), PC3 (Ni), and PC4 (As) are contributing 17%, 10%, and 9%, respectively.

In table 6, it can be observed that at location SS1, PC2, PC3 and PC4 are contributing to the soil quality, whereas at location SS2, SS3, SS4 and SS14 only the heavy metals in PC1 are contributing to the groundwater quality. At location SS5 and SS6, the heavy metals in PC1, PC3 and PC4 are contributing to the soil quality whereas at location SS7 and SS9, only the heavy metal in PC2 is contributing to the soil quality, in location SS11, the heavy metals in PC2 and PC4 are contributing to the soil quality. In location SS10, SS12, SS13, SS15, SS16, SS17, and SS18 there is no principal component which predominates in these locations. It could be deduced that other heavy metals which were not in PC1-PC4 may be responsible for the soil quality in these locations. They are basically control soil samples that were not collected from the industries which show that the control soils are not polluted.

Table 5: PCA results showing heavy metal that affects soil quality and their dimension of influence

Dimension	First	Second	Third	Fourth
Principal Component (PC)	PC1	PC2	PC3	PC4
Heavy metals that are contributing to the groundwater quality index	Fe, Mn, Cu, Pb, & Zn	Cr	Ni	As
Latent roots	5	1	1	1
Percentage variation	57	17	10	9

Table 6: PCA results showing heavy metal that affects soil quality and locations of their influence

Location	PC1	PC2	PC3	PC4
SS1		X	X	X
SS2	X			
SS3	X			
SS4	X			
SS5	X		X	X
SS6	X		X	X
SS7		X		
SS8	X	X		
SS9		X		
SS10				
SS11		X		X
SS12				
SS13				
SS14	X			
SS15				
SS16				
SS17				
SS18				

5. Conclusion

Upon completion of the assessment of soil quality in parts of industrial areas in Nnewi North Local Government Area, South East Nigeria, it was discovered that the study area is underlain by Nanka Sand and Ogwashi-Asaba. The levels of metals found in the present study were generally above the Department of Petroleum of Petroleum Resources target values for metals in save agricultural Soils and Soil Pollution assessment using CI, Igeo, EF, NIPI, PLI and mCD indicates that the soil contamination is anthropogenic and percentage contributions of each heavy metal in the soils are in the order: Pb > As > Ni > Cu > Zn > Cr > Fe > Mn in the study area.

The Principal Component Analysis for heavy metals from the soil indicat**es** that in PC1, Fe, Mn, Cu, Pb, and Zn are contributing 57%, whereas in PC2 (Cr), PC3 (Ni), and PC4 (As) are contributing 17%, 10%, and 9%, respectively.

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