Indexical Evaluation of Heavy Metal Concentrations in Soil around Industrial Area of Ajao-Estate Lagos Nigeria

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Abstract

Heavy metals pollution in soils has become a serious threat to many countries especially developing countries like Nigeria due to increase in urbanization and industrialization. In this study several indexical models (contamination factor (CF), contamination degree (mCd), geo-accumulation index (I_{geo}), pollution load index (PLI), and Nemerow integrated pollution index (NIPI)) were used to assess the pollutions, pollution sources and ecological effect of heavy metals (Fe, Zn, Pb, Cd, Mn, Cu, Cr, and Ni) in industrial soils from Ajao area, Lagos. All the metals are within the standard of Department of Petroleum Resources (DPR) except Cd (1.160, 1.020, and 1.080) mostly around the industrial wastewater dislodging Point. Pb has no significant correlation with other heavy metals in the soil samples whereas other heavy metals, strong to medium positive correlation exist between these heavy metals at 2-tailed significant levels of 0.01 and 0.05 suggests that these metals have the same anthropogenic origin. The 1-geo calculated for heavy metals suggest that all the samples are unpolluted. CF of the heavy metals was in the range of low contamination except Cd that showed moderate contamination. $\sum RI$ of all the heavy metals analysed in this study pose low ecological risks except for Cd which showed moderate potential to considerable potential ecological risk. NIPI result showed some of the samples were slightly polluted while some were heavily polluted. For mCd, all the samples were within very low degree of contamination. The PLI result shows that samples were within unpolluted range in the PLI classification scheme.

Keywords

Geoaccumulation index, Nemerow integrated pollution index, Pollution load index, Contamination factor (CF), Contamination degree, Ecological risk index

Introduction

The evaluation of soil degradation particularly the quality of soil has increased as soil is an important component of the earth, functioning both in the production of food, storage of water, fibres and in the maintenance of environmental quality [1]. Reduction in soil quality has posed serious challenge to increasing agricultural productivity, economic growth, and healthy environment owing to inappropriate land use and soil management and natural causes [2,3]. Soil is defined as being polluted when pollutants/metal concentrations in its bulk horizons exceed baseline values (allowable standard limits) [4,5]. Polluted soil has negative effects on food safety as well as result in increased health risks [6-8]. Soil polluted with heavy metals is of one the most ecological problems because it is related directly to the human health since these metals accumulate in various ecosystems, reflect in both the plant, animal and microbiological processes and finally enter humans through the food chain [9-14]. Most often, these heavy metals are transferred into human tissues through dermal contact absorption, inhalation of soil particles in the form of dust and consumption of contaminated vegetables and foods [15-18]. Although some heavy metals like Zn, Cu, and Cr play essential role in biochemical processes, most

organisms required these metals in a small amount for healthy growth but become toxic at higher concentration [19,20]. But heavy metals like Cd, Pb, Ni etc are not essential and do not cause deficiency disorders if absent, rather, they are toxic even at low concentration [19].

The presence of some heavy metals in the soil are dangerous unlike other pollutants because they are non-degradable and take time to vanish, they geo-accumulate

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and thereby exceed their respective allowable standard limits [21,22]. Their concentration in the soil is a major problem to sustainable water quality, because the soil controls the quality of water especially the underwater which in turn poses a major threat to human health if the water finally gets contaminated [21,23]. Sources of heavy metals can be classified into two; natural and anthropogenic sources. Through natural processes like weathering, parent rocks usually release heavy metals into the soil. Outside the natural sources, anthropogenic activities, such as industrial wastewater, poor solid waste management, automobile workshop, discharge of sewage, mining activities, irrigation with polluted water, and the application of pesticides and fertilizers in farms is another source of heavy metals in the soil [9, 10,24-26]. The most important origin of heavy metals is related to industrial activities from industries like chemistry, mining, iron and steel industry, metallurgy, building and electronics industry, automobile workshops etc and industrial emissions such as fuel combustion, and waste management and transport [27].

Irrespective of various origins or sources of heavy metals, their toxic effects, even at low concentrations, have drawn the attention of many researchers [9]. Because people in urbanised and industrialized areas, with high human populations and anthropogenic activities are more exposed and vulnerable to the negative effects of heavy metal contamination, hence soil quality assessment is becoming a research topic of increasing interest worldwide [11,21,28-30]. Soil quality changes with time and can indicate whether the soil condition is sustainable or not [31,32]. Evaluation of heavy metal concentration in the soil is important so that changes in soil quality can be recognised as they occur with the aid of established baseline. Effective evaluation of soil contamination with heavy metals is the use of suitable indices of pollution/contamination that can be regarded as a

tool and guide for a comprehensive geochemical assessment of the soil environmental status. These indices can also indicate whether the accumulation of heavy metals was due to natural processes or as a result of anthropogenic activities, hence, the indices of pollution can also help in monitoring the amount of environmental risk and the changes in soil due to the accumulation of heavy metals [27]. Furthermore, the indices help to protect and improve long-term agricultural productivity, water quality, and habitats of all organisms including human being [32-35].

The study area Ajao-Estate lies latitudes 6° 30' to 6° 33' N and longitudes 3° 18' to 3° 22' E (Figure 1). It is underlain by two distinct Lithologies; the coastal plain sand and the alluvial river sand. Both sands are part of Dahomey Basin [21]. Coastal plain sand is the aquifer in the study area though very shallow in general [21,36]. The dominant activities in Ajao-Estate include commerce, industrial food/wine production processes, automobile workshops and factories with inadequate industrial wastewater disposal [21]. In order to determine changes in the soil quality and the soil environmental status of this industrial area, Ajao-Estate, indexical evaluation of the heavy metals were carried out. To achieve this, various environmental pollution index were modeled in order to ascertain the fragility of the soil and for understanding how improved management might strengthen its resilience [37]. These indices include; geoaccumulation index (Igeo), Nemerow integrated pollution index (NIPI), pollution load index (PLI), enrichment factor (EF), contamination factor (CF), contamination degree (mCd) and ecological risk index (ERI) [11,18,21,23].

Materials and Method

Data sampling and analysis

A total of twenty one (21) soil samples including fifteen (15) soil samples from the study site and six (6) from the
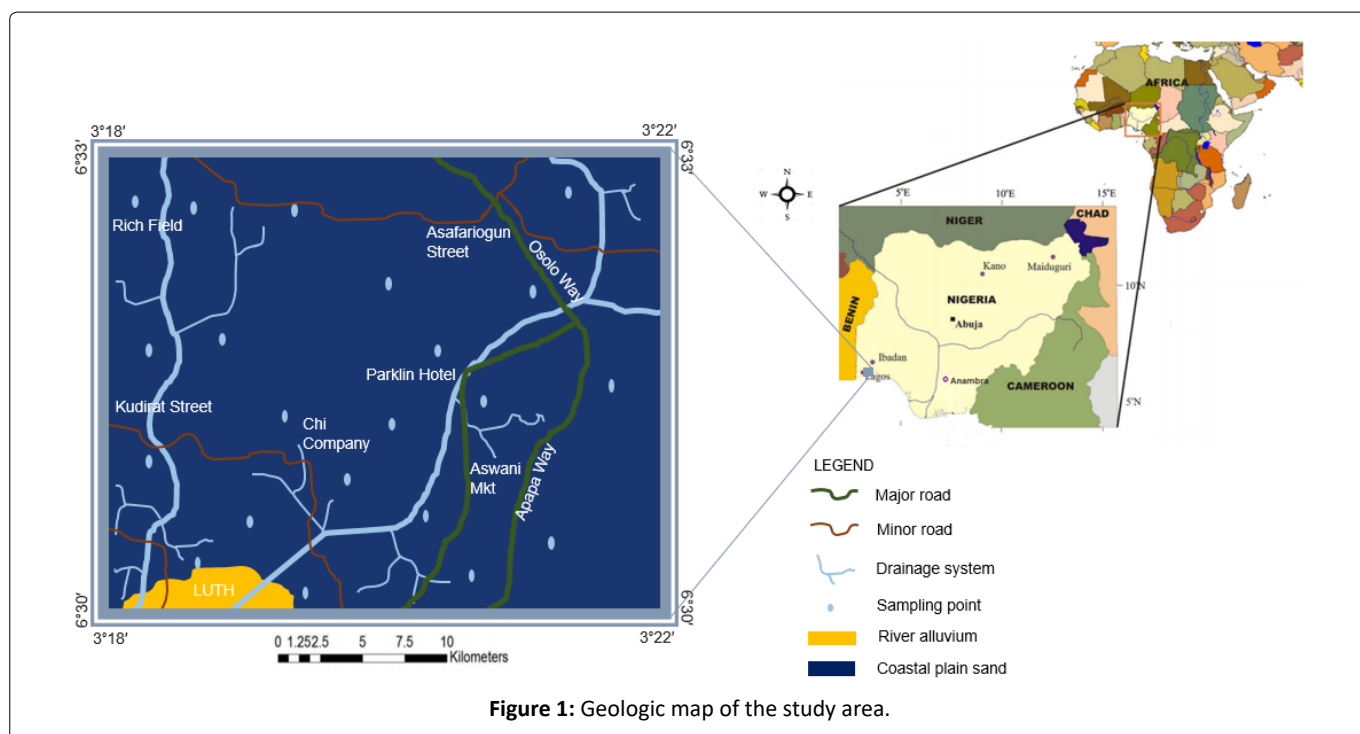

Figure 1: Geologic map of the study area.

control samples were randomly collected across the Ajao industrial area and its environs. The soil samples were taken between depths of 0-0.5 m with hand shovel and disposable hand gloves, carefully bagged in polyethylene sacks, and legibly labelled. The following heavy metals (Fe, Zn, Pb, Cd, Mn, Cu, Cr, and Ni) in the soil samples were analysed in the laboratory using the specific hollow cathode lamp at a specific wavelength. 5 g of soil samples in a clean porcelain crucible were heated over a hot plate to ignite. In order to completely oxidize the organic matter, the residue was heated in a muffle furnace at 550 °C. The residue left was dissolved in a few drops of aqua regia and then diluted with distilled water [21]. The resulting mixture was then filtered, rinsed, and then aspirated into the flame of the atomic absorption spectrophotometer (AAS) Perkin Elmer Analyst 200, using air acetylene flame for the metal analysis against standard metal solutions. All the analytical procedures described in this study followed the recommendations of American Public Health Association [38].

Heavy metal evaluation of the soil quality

Indexical Tools: Soil contaminant assessment indices are indicators used to assess the presence and intensity of anthropogenic contaminant deposition on soils. In this study, the following pollution assessment indices were employed; contamination Factor (CF), Pollution Load Index (PLI), Modified Contamination Degree (mCD), Geo-accumulation Index (Igeo), ecological risk factor $\left(\sum \mathbf{RI} \right)$ and Nemerow Integrated Pollution Index (NIPI). These indices were used to assess the heavy metals tested in the soil samples collected from the study area (Table 1). Department of Petroleum Resource (DPR) [39], allowable concentration of heavy metals in the soil was used as the background value (Table 1).

Contamination Factor (CF): The contamination factor (CF) was used in the evaluation of the soil samples to indicate the degree of pollution for each heavy metal in a soil samples [21]. The CF value could fall into either of the levels of contamination where CF < 1 refers to low contamination, 1 ≤ CF < 3 indicates moderate contamination, 3 ≤ CF ≤ 6 means considerable high contamination, and CF > 6 refers to very high contamination [21,40]. CF is calculated as follows;

CF = Cmetal/Cbackground

where

Cmetal = The total metal concentration

Cbackground = Average background value of the element in sediment.

Geochemical Accumulation Index (I-geo): The I-geo enables the assessment of contamination by comparing the present heavy metals concentrations and the original pre-industrial concentrations in the soils. Geochemical accumulation index (I-geo) consists of five classes ranging from unpolluted to extremely polluted: I-geo < 1 unpolluted, 1 ≤ I-geo < 2 indicates low pollution, 3 ≤ I-geo < 4 moderately polluted, 4 ≤ Igeo < 5 strongly polluted, and I-geo < 5 is extremely polluted Muller [40] and Martin and Meybeck [41].

I-geo is calculated as;

1-geo = Log_2 (Cn/1.5Bn)

Where Cn is the concentration of the metal pollutant

Bn is the geochemical background concentration of the pollutant in sediment, and

1.5 is the background matrix correction factor due to lithogenic effect.

Pollution Load Index (PLI): The PLI gives a generalized assessment on the level of soil contamination. The PLI is obtained using Thomlinson, et al. [42] with the following classification scheme; PLI = 0 (background concentration), 0 < PLI ≤ 1 (unpolluted), 1 < PLI ≤ 2 (moderately to unpolluted), 2 < PLI ≤ 3 (moderately polluted), 3 < PLI ≤ 4 (moderately to highly polluted and 4 < PLI ≤ 5 (highly polluted) and ≥ 5 (very highly polluted).

PLI is calculated as;

PLI = $(CF_1 \times CF_2 \times CF_3........CF_n)^{1/n}$

Where, CF = Contamination Factor; and n = Number of Metals

Modified Contamination Degree (mC$_d$)

The mC$_d$ is an empirical assessment of the overall degree of contamination by pollutants in an area. The mC$_d$ was calculated as defined by Hakanson [28] as follows:

$$mC_d = \sum_{i=1}^{i=n} CF/n$$

Where Cf = Contamination Factor, n = Number of Analyzed Metals, and i is ith metal.

mC$_d$ classification scheme is as follows; mC$_d$ < 1.5 (very low degree of contamination), ≤ 1.5 mC$_d$ < 2 (low degree of contamination), ≤ 2 mC$_d$ < 4 (moderate degree of contamination), ≤ 4 mC$_d$ < 8 (high degree of contamination), ≤ 8 mC$_d$ < 16 (very high degree of contamination), ≤ 16 mC$_d$ < 32 (extremely high degree of contamination) and ≥ 32 mC$_d$ (ultrahigh degree of contamination).

Ecological Risk Index $\left(\sum \mathbf{RI} \right)$

To evaluate the ecological risk associated with the presence of heavy metals present in the soil, ecological risk index of some heavy metals were calculated. Ecological risk factor (Er^i) for a given contaminant was calculated as suggested by Håkanson [28] and Ukah, et al. [18]

$$\sum \mathbf{RI} = \sum T_i \ x \ CF$$

RI = The potential ecological risk factor of each heavy metal; T$_i$ = The toxic-response factor of heavy metal;

CF = Contamination Factors. The toxic-response factor of heavy metals is given as thus: Cd = 30; As = 10; Co, Cu, Ni and Pb = 5; Cr = 2, and Zn and Mn = 1 [43,44].

The following classification schemes were used to describe the risk factor: Er^i < 40, low potential ecological risk; 40 ≤ Er^i < 80, moderate potential ecological risk; 80 ≤ Er^i < 160, considerable potential ecological risk; 160 ≤ Er^i < 320, high potential ecological risk; and Er^i ≥ 320, very high ecological risk.

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Table 1: Heavy metal results from the soil samples and calculated I-geo, CF and NIPI.

Source	Zn (mg/kg)	Cu (mg/kg)	Cd (mg/kg)	Pb (mg/kg)	Fe (mg/kg)	Ni (mg/kg)	Mn (mg/kg)	Cr (mg/kg)	PI	PIave	NIPI
SS 1	1.890	0.120	0.002	-	0.080	-	0.050	-	2.142	0.26775	1.349776
SS 2	1.980	0.150	0.002	-	0.080	-	0.030	-	2.242	0.28025	1.414026
SS 3	20.410	7.810	1.160	0.005	9.110	0.008	1.280	0.020	39.803	4.975375	14.85467
SS 4	1.290	0.070	1.020	-	0.040	-	0.020	-	2.44	0.305	0.937317
SS 5	1.350	0.080	-	-	0.050	-	0.030	-	1.51	0.18875	0.963879
SS 6	1.063	0.050	-	-	0.020	-	0.020	-	1.153	0.144125	0.758532
SS 7	9.250	2.860	0.003	0.001	0.330	0.002	0.037	0.008	12.491	1.561375	6.633264
SS 8	0.590	0.020	-	-	0.020	-	0.010	-	0.64	0.08	0.421011
SS 9	1.060	0.080	-	-	0.030	-	0.030	-	1.2	0.15	0.757001
SS 10	1.170	0.120	-	-	0.030	-	0.040	-	1.36	0.17	0.836002
SS 11	0.740	0.030	-	-	0.030	-	0.040	-	0.84	0.105	0.5285
SS 12	0.310	0.020	-	-	0.010	-	-	-	0.34	0.0425	0.221254
SS 13	0.490	0.060	-	-	0.010	-	0.002	-	0.562	0.07025	0.350025
SS 14	1.600	0.011	-	-	0.060	-	0.005	-	1.676	0.2095	1.141028
SS 15	0.820	0.040	-	-	0.040	-	0.007	-	0.907	0.113375	0.585343
SS Igeo	-3.74591	-3.69395	-1.83085	-11.0069	-8.10749	-9.75012	-7.57682	-9.79468			
CF	0.301458904	0.32002778	2.73375	7.05882E-05	0.001988	0.0002857	0.0036636	0.00028			
$\sum RI$	0.301459	1.600139	82.0125	0.000353	NOTA	0.001429	0.003664	0.00056			
Range	0.310 - 20.410	0.011 - 7.810	0.000 - 1.160	0.000 - 0.005	0.010 - 9.110	0.000 - 0.008	0.000 - 1.280	0.000 - 0.020			
Mean	2.9342	0.7681	0.1458	0.0004	0.6627	0.0007	0.1067	0.0019			
Std. Dev.	5.2919	2.0770	0.3843	0.0013	2.3382	0.0021	0.3249	0.0054			
CS16	1.840	0.081	0.001	-	0.040	0.003	0.010	-	1.975	0.246875	1.312735
CS17	5.960	2.023	-	0.001	0.040	-	0.008	0.006	8.038	1.00475	4.273823
CS18	8.650	0.040	0.001	0.020	1.720	0.010	1.020	-	11.461	1.432625	6.199795
CS19	2.480	1.440	0.080	0.054	0.020	-	0.310	-	4.384	0.548	1.795927
CS20	11.570	4.710	1.080	0.003	8.540	0.005	0.720	0.250	26.878	3.35975	8.519179
CS21	1.350	0.080	0.000	0.000	0.050	0.000	0.030	0.000	1.51	0.18875	0.963879
CS Igeo	-3.23097	-3.17522	-1.58425	-7.98313	-7.27152	-8.48608	-6.54584	-7.09201			
CF	0.218150685	0.23261111	1.4525	0.000917647	0.002082	0.0005143	0.0048009	0.00256			
$\sum RI$	0.218151	1.163056	43.575	0.004588	NOTA	0.002571	0.004801	0.00512			
Range	1.840 - 11.570	0.040 - 4.710	0.000 - 1.080	000 - 0.054	0.02 - 8.54	000 - .010	0.008 - 1.020	000 - 0.250			
Mean	5.308333	1.395667	0.2324	0.0156	1.735	0.0045	0.349667	0.085333			
Std Dev.	4.159257	1.826334	0.475067	0.022963	3.401022	0.004203	0.429503	0.142637			
DPR	146.000	36.000	0.800	85.000	5000.000	35.000	437.000	100.00			

SS = Soil Sample; CS = Control Sample; STD Dev = Standard Deviation.

Nemerow Integrated Pollution Index (NIPI)

The NIPI was also employed to assess the overall pollution integrity of the area. NIPI was calculated as defined by Nemerow [44] as:

$$NIPI = \sqrt{[(PIave)^2 + (PI\max)^2]/2}$$

Where PIave = Average concentration of all pollution indices considered, and PImax = Maximum pollution index.

Pollution index (PI) is calculated as (PI) = C_s/C_b = The concentration of heavy metals in the sample; C_b = The corresponding background values. The NIPI classification scheme is as NIPI = ≤ 0.7 (safe), > 0.7 NIPI ≤ 1 (precaution), > 1 NIPI ≤ 2 (slightly polluted), > 2 NIPI ≤ 3 (moderately polluted) and > 3 (heavily polluted).

Statistical Analysis

In this research, SPSS (Statistical Package for the Social Sciences) for Windows, version 23.0 (SPSS Inc, USA) was used for descriptive analysis of data.

The descriptive analysis

This describes the basic features of the data in the study. It include mean, standard deviation (SD), minimum and maximum concentration values (Range) of different metal element concentrations were used to indicate indirectly the activeness of the selected element in the sampling Site. A multivariate correlation of heavy metals tested in the soil sample were carried using Pearson correlation coefficients at two-tailed test of 0.02 and 0.05 levels of significance with the

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aid of SPSS. In this study, the higher the value is, the stronger the correlation of the heavy metals to each other [45,46]. Here, correlation coefficients > 0.7 is considered as strong correlation, < 0.7 ≥ 0.5 moderate while < 0.5 is considered as weak correlation. According to Ukah, et al [21], positive correlations always indicate that source of the elements is the same and vice versa.

Result and Discussion

Based on the kind of anthropogenic activities going on in the study eight (8) heavy metals (Fe, Zn, Pb, Cd, Mn, Cu, Cr, and Ni) were tested in the soil samples. The results were summarized in (Table 1). Comparing the results in Table 1 with DPR [39] permissible standard for heavy metal concentration in the soil, all the metals are within the standard except Cd concentration in SS3 (1.160), SS4 (1.020) and CS20 (1.080). SS3 is the wastewater dislodging point for food/wine producing industrial in the study area, followed by SS4 in term of nearness probably; this might be the reason for very high concentration of all the heavy metals in them. Cd being a transitional element has been found to possess biological toxicity if it is absorb by crop and animals [47]. The geology of the area has been described to be dominantly alluvial sands. Such deposits are not naturally rich in heavy metals but are coarse, porous and permeable enough to facilitate the contamination of shallow groundwater [48]. This suggests that there are no geologically rich natural deposits in the heavy metals analysed [21,48]. Considering the role of geology (parent rock) in defining the environmental chemical ions hence; higher concentration of some of the heavy metals in the control than that of the study area. Moreover, the soil in study area is prone to constant hydraulic loading of industrial wastewater unlike the control and this might be the reason for higher concentration of these heavy metals in wastewater dislodging point (SS3) and the nearest sampling point (SS4) than any other sampling points [21]. Thus, the origins of the accumulated heavy metals in the soils are linked to anthropogenic sources.

Statistical description of the heavy metals in the soil samples

The descriptive analysis: Statistically (Table 1), Zn averaged 2.9342 mg/kg with a range of 0.310 - 20.410 mg/kg. While in control, the average is 6.1000 mg/kg and it ranged from 1.84 to 11.57 mg/kg. The standard deviation for the sample

is 5.2919 and 4.11385 for the control. The concentrations of both samples are within the DPR standard. Foe Cu; the mean value here is 0.7681 mg/kg, range of 0.011 - 7.810 mg/kg and the standard deviation of 2.0772, while in control, the mean is 1.65880, varied from 0.04 - 4.71 mg/kg with standard deviation of 1.910517. The mean value of Cd is 0.1458 mg/kg, and varied from 0.000 - 1.160 mg/kg. In control, the mean value of 0.212456 mg/kg with the range of 0.00 - 1.080 mg/kg were obtained. However, the standard deviation of sample is 0.3843 and in control, 0.475067. Cd being a transitional element has been found to possess biological toxicity if it is absorb by crop and animals [47]. Here, the mean value of Fe is 0.6627 mg/kg with the range of 0.010 - 9.110 mg/kg while in control the mean value is 2.0720 mg/kg and the range is 0.02 - 8.54 mg/kg. 2.3382 for the standard deviation of the samples and 3.68876 for the control. Mn had an average value of 0.1067 mg/kg, varied from 0.000 - 1.280 mg/kg and standard deviation of 0.3249. While in control, it averaged 0.41360/kg and varied from 0.008 - 1.020 mg/Kg. with standard deviation of 0.447141. Pb averaged 0.0004 and ranged 0.000 - 0.005 with standard deviation of 0.0013 but in averaged 0.01560, ranged from 000 - 0.054 and standard deviation of 0.022963 for the control. Ni averaged 0.0007 and ranged from 0.000 - 0.008, varied in control from 0.000 to 0.01 with mean value of 0.00360 mg/kg. The standard deviation is 0.0021 for the samples and 0.004159 for the control respectively. The mean value of Cr is 0.0019 with the range of 0.000 - 0.020 and standard deviation of 0.0054 while in the control, the mean is .05120 mg/kg, range of 0.000 to 0.25 mg/Kg and standard deviation of 0.111163. The heavy metal concentrations in the soil samples (Table 1) where compared with the allowable concentration stipulated by department of petroleum resources [39], it was discovered that the concentration of all the elements in both soils meet up the standard except Cd.

Correlation analysis of the heavy metals in the soil: From the correlation analysis result in Table 2, Pb has no significant correlation with other heavy metals in the soil samples. This suggest that Pb although found in few soil samples has a different anthropogenic sources from others. Sources Pb in the soil samples may be attributed to automobile mechanic workshops, industrial plants, Pb-acid batteries, effluents from textile tanning industries and air conditioning coolants [51]. Zn correlates positively and strongly with Cu (0.934), Fe (0.870), Ni (0.801) and Mn (0.863) and also moderately with Cd (0.657), at a 2-tailed significant of 0.01 but weakly with Cr

Table 2: Statistical correlation of the heavy metals.

Correlations								
	Zn	Cu	Cd	Pb	Fe	Ni	Mn	Cr
Zn	1							
Cu	0.934**	1						
Cd	0.657**	0.724**	1					
Pb	0.126	0.117	0.000	1				
Fe	0.870**	0.890**	0.808**	0.040	1			
Ni	0.801**	0.578**	0.459*	0.206	0.703**	1		
Mn	0.863**	0.728**	0.607**	0.346	0.833**	0.919**	1	
Cr	0.437*	0.509*	0.586**	-0.020	0.712**	0.336	0.394	1

** Correlation is significant at the 0.01 level (2-tailed); * Correlation is significant at the 0.05 level (2-tailed).

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(0.437) at a 0.05 significant level. Cu correlate strongly and positively at 2-tailed significant level of 0.01 with Cd (0.724), Fe (0.890), Mn (0.728) and moderately with Ni (0.578) and moderately with Cr (0.509) at 0.05 level of significant. Cd correlates positively and strongly at 2-tailed level of 0.01 levels with Fe (0.808), moderately with Mn (0.607). Cr (0.586) and weakly with Ni (0.459) at 2-tailed significant level of 0.05. At a 2-tailed significant level 0.01, Fe correlates positively strongly with Zn (0.870), Cu (0.890), Cd (0.808), Ni (0.703), Mn (0.833) and Cr (0.712). Ni correlates strongly with Mn (0.919) at 2-tailed significant level of 0.01. Significant strong to medium positive correlation existing between these heavy metal presented in Table 3 suggests that these metals have the same anthropogenic origin such as industrial wastewater, e-waste, Ni/Cd batteries, paints etc [45,52].

Soil indexical evaluation models: Soil contaminant assessment indices are indicators used to assess the presence and intensity of anthropogenic contaminant deposition on soils. In this study, the following pollution assessment indices were employed; contamination Factor (CF), Pollution Load Index (PLI), Modified Contamination Degree (mCD), Geo-accumulation Index (Igeo) and Nemerow Integrated Pollution Index (NIPI). These indices were used to assess the heavy metals tested in the soil samples collected from the study area (Table 1). Department of Petroleum Resource (DPR) [39] standard for allowable heavy metals concentration in the soil in Nigeria was used as the background value for this study.

Igeo gives insight to the extent of heavy metal enrichment in the soil samples studied, According to Muller [40] and Martin and Meybeck [42] I-geo classification scheme for soil pollution, the 1-geo calculated for heavy metal concentration in the soil sample, suggest that all the samples are unpolluted since the soil samples are within I-geo classification scheme of less than 1 (< 1) (Table 1).

The contamination factor indicates the degree of pollution for each heavy metal in all the soil samples. The CF of the heavy metals ranged from 7.05882E-05 (Pb) to 2.73375 (Cd) in the soil samples while in control samples, CF ranged from 0.0005143 (Ni) to 1.4525 (Cd) (Table 1). Cd falls in the range of moderate contamination (1 ≤ CF < 3). Higher CF value resulting from Cd in both samples proved that Cd has the highest impact in the soil especially the industrial soil. Heavy metal concentrations in both soil samples fall within low to moderate contamination based Cf classification scheme [21,43]. This observation indicates that the inhabitants of this industrial area are more likely to be exposed to environmental risks due to Cd enrichment in the soil.

Following the $\sum RI$ classification scheme by Hakason [28], all the heavy metals analysed in this study pose low ecological risks except for Cd (82.0125) which showed considerable potential ecological risk since it falls within $80 \leq Er^i < 160$, considerable potential ecological risk while Cd (43.575) in the control falls within moderate potential ecological risk, $40 \leq Er^i < 80$ (Table 1). This suggests among all the heavy metals analysed, Cd pose highest danger to the ecosystem, and threats to both plants and animals [49] around the study area

NIPI gives a better and overall understanding of the heavy metals pollution in an individual sample, rather than revealing a general pollution degree of each heavy metal like in the case of geo accumulation index (I-geo). In this study, NIPI model further assess the cumulative index values and overall impact of the heavy metal pollutants in each of the soil samples (Table 1). Based on NIPI classification scheme by Nemerow [29], samples SS8, SS9, SS11-SS13 and SS14 were safe, SS4,-SS6 and SS10 requires precaution while dealing on the soil samples. Samples SS1, SS2 and SS14 were slightly polluted however samples SS3 and SS7 were heavily polluted. In the control, one sample (CS21) requires precaution, three of the six were slightly polluted while two where heavily polluted but not as heavy as that observed in the wastewater dislodging point (Table 1). This suggests that the inhabitant of this study especially those around SS3 and SS7 are under severe pollution threat.

In this study, mCd provides the sum of the contamination factor of all the elements analysed in each of the soil samples collected (Table 2). Irrespective of the variation in the empirical result from mCd in the soil samples, all the samples within the range (0.000335-0.226492) 0f very low degree of contamination [28].

Pollution severity and its variation along the sample locations were determined with the use of pollution load index (PLI). This index is a quick tool in order to compare the pollution status of different places. It also provides the degree of heavy metal pollution with respect to all the heavy metals present in the soil sample [50] The PLI result shows that sample SS3 (0.005309), SS7 (0.000524) and CS20 (0.005152) show little value whereas the rest of the samples remain insignificant (Table 3), indicating that the samples within unpolluted range in the PLI classification scheme.

Conclusions

The industrial soils from Ajao urban area, Lagos, Nigeria were investigated with the aim of unravelling the indexical characteristics of heavy metals pollution status, possible pollution sources and impact on ecological. The following conclusions were drawn from the findings of this research:

All the metals are within the standard except Cd concentration in SS3, SS4 and CS20. Pb has no significant correlation with other heavy metals in the soil samples. This suggest that Pb although found in few soil samples has a different anthropogenic sources from others. While for other heavy metals strong to medium positive correlation exist between these heavy metals at 2-tailed significant levels of 0.01 and 0.05 suggests that these metals have the same anthropogenic origin.

The 1-geo calculated for heavy metal concentration in the soil sample, suggest that all the samples are unpolluted since the soil samples are within I-geo classification scheme of less than 1 (< 1). CF of the heavy metals was in the range of low contamination except Cd that showed moderate contamination The $\sum RI$ of all the heavy metals analysed in this study pose low ecological risks except for Cd (82.0125) which showed considerable potential ecological risk since it falls within $80 \leq Er^i < 160$, considerable potential

Table 3: Calculated mCd and PLI of the heavy metals in the samples.

Source	CF Zn	CF Cu	CF Cd	CF Pb	CF Fe	CF Ni	CF Mn	CF Cr	MCd	PLI
SS1	0.012945	0.003333	0.0025	0	0.000016	0	0.000114	0	0.002364	0
SS 2	0.013562	0.004167	0.0025	0	0.000016	0	6.86E-05	0	0.002539	0
SS 3	0.139795	0.216944	1.45	5.88E-05	0.001822	0.000229	0.002929	0.0002	0.226497	0.005309
SS 4	0.008836	0.001944	1.275	0	0.000008	0	4.58E-05	0	0.160729	0
SS 5	0.009247	0.002222	0	0	0.00001	0	6.86E-05	0	0.001443	0
SS 6	0.007281	0.001389	0	0	0.000004	0	4.58E-05	0	0.00109	0
SS 7	0.063356	0.079444	0.00375	1.18E-05	0.000066	5.71E-05	8.47E-05	0.00008	0.018356	0.000524
SS 8	0.004041	0.000556	0	0	0.000004	0	2.29E-05	0	0.000578	0
SS 9	0.00726	0.002222	0	0	0.000006	0	6.86E-05	0	0.001195	0
SS 10	0.008014	0.003333	0	0	0.000006	0	9.15E-05	0	0.001431	0
SS 11	0.005068	0.000833	0	0	0.000006	0	9.15E-05	0	0.00075	0
SS 12	0.002123	0.000556	0	0	0.000002	0	0	0	0.000335	0
SS 13	0.003356	0.001667	0	0	0.000002	0	4.58E-06	0	0.000629	0
SS 14	0.010959	0.000306	0	0	0.000012	0	1.14E-05	0	0.001411	0
SS 15	0.005616	0.001111	0	0	0.000008	0	1.6E-05	0	0.000844	0
CS16	0.012603	0.00225	0.00125	0	0.000008	8.57E-05	2.29E-05	0	0.002027	0
CS17	0.040822	0.056194	0	1.18E-05	0.000008	0	1.83E-05	0.00006	0.012139	0
CS18	0.059247	0.001111	0.00125	0.000235	0.000344	0.000286	0.002334	0	0.008101	0
CS19	0.016986	0.04	0.1	0.000635	0.000004	0	0.000709	0	0.019792	0
CS20	0.079247	0.130833	1.35	3.53E-05	0.001708	0.000143	0.001648	0.0025	0.195764	0.005152
CS21	0.009247	0.002222	0	0	0.00001	0	6.86E-05	0	0.001443	0
DPR	146.000	36.000	0.800	85.000	5000.000	35.000	437.000	100.00		

ecological risk while Cd (43.575) in the control falls within moderate potential ecological risk, $40 \leq E_r^i < 80$. Based on NIPI classification scheme, samples SS8, SS9, SS11-SS13 and SS14 were safe, SS4,-SS6 and SS10 requires precaution while dealing on the soil samples. Samples SS1, SS2 and SS14 were slightly polluted however samples SS3 and SS7 were heavily polluted. In the control, one sample (CS21) requires precaution, three of the six were slightly polluted while two where heavily polluted but not as heavy that observed in the wastewater dislodging point (SS3). For mCd, all the samples within the range (0.000335-0.226492) of very low degree of contamination. The PLI result shows that sample SS3 (0.005309), SS7 (0.000524) and CS20 (0.005152) show little value whereas the rest of the samples remain insignificant, indicating that the samples were within unpolluted range in the PLI classification scheme.

Conflict of Interest Statement

The authors hereby declare that there is no competing interest regarding this paper.

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