

Quantitative Evaluation of Soil Properties Pollution Hazards in Urban Solid Waste Dump Sites in Nigeria

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Abstract: Ado Ekiti was chosen with the purpose of studying the accessibility of heavy metals. These soil samples were analyzed for Fe, Ni, Cr, Pb, Zn, Cu, Co and Mn concentrations in the dump soil. Evaluation of contamination/pollution factor (C/P), enrichment factor (EF), index of geoaccumulation (Igeo) and pollution load index (PLI) were calculated. The observations revealed high C/P values in the dump soil that were polluted by Cd, Cr and Ni. This dump soil acts as a sink for heavy metals. C/P data, EF, PLI and (Igeo) indicated that these heavy metals originated from anthropogenic sources.

Key words: Metal • Dumpsite • Geoaccumulation Index (Igeo) • Contamination/Pollution Factor • Enrichment Factor • Pollution Load Index

INTRODUCTION

Soil is not only a medium for plants growth or waste disposal but also a transmitter of many pollutants to surface water, ground water, atmosphere and food. Soil pollution may threaten human health not only through its effect on the quality of food and drinking water, but also through its effect on air quality. Little attention has been paid to soil pollution when compared to food in the past [1]. Recently, however, the impact of soil pollution on its functions and the biosphere has been increasingly emphasized by the government, environmental protection agencies and the public [2]. Specifically, significant advances have been made in respect of mining related heavy metal pollution of the soil in different parts of the world [3-7].

A survey of heavy metals indicates that they accumulate in soils in some localized areas of human activities when compared with areas that have remained under virgin conditions [8]. In addition to mining activities, concentration of heavy metals in terrestrial environment have increased significantly as a result of human activities such as emissions from thermal power stations, waste disposal and vehicular traffic/road infra-structures [9]. Other non pointed out sources of contamination affecting predominantly agricultural soils include inputs such as, fertilizers, pesticides, sewage sludge, organic manures and composts [10, 11]. Some of

the anomalous accumulation may also be geology-related [12]. The soil is a primary recipient of solid wastes [13]. Millions of tons of these wastes from a variety of sources: industrial, domestic and agricultural, find their way into the soil. These wastes end up interacting with the soil system thereby changing the physical and chemical properties [14]. Soil organic matter influences the degree of aggregation and aggregate stability. It can reduce bulk density and increase total porosity and hydraulic conductivity in heavy clay soils. In fact, municipal wastes increase the nitrogen, pH, cation exchange capacity, percentage base saturation and organic matter [15]. The organic waste can provide nutrients for increased plant growth, with such positive effect increased land application of these wastes. In fact, dumpsites are known to be rich in soil nutrients for plant growth and development, because decayed and composted wastes enhance soil fertility [16]. Dumpsite soils are also used to fill poly-bags and nursery pots to grow seedlings. Dumpsites, especially in most third world countries, comprise of a higher proportion (50–90%) of organic materials [17]; however, a considerable proportions of plastic, paper, metal rubbish and batteries which are known to be sources of metals which may be hazardous to man and his environment are also present [18,19]. Heavy metals may have harmful effects on soils, crop and human health [20]. Many metals act as biological poisons even at parts per billion (ppb) levels. These metals are not

biodegradable and have toxic effects on living organisms at certain level of concentration. Exposure of man to such metals may cause blood and bone disorders, kidney damage and decreased mental capacity and neurological damage [21]. The assessment of dumpsite soils for the concentration levels of hazardous metals is imperative for healthy crop production. The current study was therefore carried out to assess the concentration levels of some hazardous metals in soils in selected urban and rural dumpsites in Nigeria.

MATERIALS AND METHODS

Study Area Description: Ekiti State is located between longitudes $4^{\circ} 15'$ to $5^{\circ} 45'$ East of Greenwich Meridian and latitudes $7^{\circ} 15'$ to $8^{\circ} 5'$ North of Equator. The state is mainly an upland one, about 250 meters above sea level. It lies within the area of undulating land surface with a characteristic landscape that consists of old plane broken by steep-sided outcrops of dome rocks that may occur singularly or in groups or ridges. The state enjoys tropical climate with two distinct seasons. These are the wet season (April-October) and dry season (November-March). The temperature ranges between 20° - 36°C . Tropical forests exists in the south while guinea savannah occupies the northern part of the state.

Study Area: Ado Ekiti: Ado Ekiti is the capital city of Ekiti State, south western Nigeria. The city is at the centre on latitude $7^{\circ} 45'$ N and longitude $5^{\circ} 15'$ E, situated in a valley 250 m above sea level. As at 2014, Ado Ekiti had an estimated population of 725,482 people with a total land area of about 200 km². The population in the city is unevenly distributed such that commercial, industrial and agricultural, recreational and administrative, auto-mechanic workshops and residential areas are scattered all over the city and these serve as point sources of heavy metals [22]. One sampling station was identified within Ado Ekiti town namely: Atinkankan, an area well known for repairing and maintaining automobiles, centre dumpsite for market traders with a large clientele. It is located at the centre of the city. The grounds of the Afe Babalola University were used as a control site for this station. This site was chosen for investigation, being the major city dumpsite and for its sheer size, daily and frequent usage and because of its long-term waste deposition in the Ado Ekiti Metropolitan Area.

Sample Collection and Sample Treatment: Surface soils are the first locus of input of metals where they tend to accumulate on a relatively long term basis [23]. These

pollutants normally contaminate the upper layer of the soil at a depth (0 - 40) cm [24]. This implies that, high concentration of these pollutants could be present at this depth if assessed. Given the foregoing, 9 surface soil samples were collected randomly from the designated dumpsites at a depth of 0-15 cm. Control samples were collected from Afe Babalola University farm where neither car repairs, industrial nor commercial activities are carried out. The samples were placed in labeled polythene bags and transported to the laboratory. All soil Samples were subsequently air-dried to constant weight to avoid microbial degradation [25]. They were homogenized, made lump free by gently crushing repeatedly using acid pre-washed mortar and pestle and passed through a 3 mm plastic sieve prior to analysis. Thus, a total of 20 surface soil samples were randomly collected from the study areas.

Determination of Physiochemical Properties of the Soils:

The physiochemical properties of the soil samples were determined using routine methods as described by [26] and [27].

Heavy Metal Analysis: One gram of the dried fine soil sample was weighed and transferred into an acid washed, round bottom flask containing 10 cm³ concentrated nitric acid. The mixture was slowly evaporated over a period of 1 hour on a hot plate. Each of the solid residues obtained was digested with a 3:1 concentrated HNO₃ and HClO₄ mixture for 10 minutes at room temperature before heating on a hot plate. The digested mixture was placed on a hot plate and heated intermittently to ensure a steady temperature of 150°C over 5 hours until the fumes of HClO₄ were completely evaporated. The mixture was allowed to cool to room temperature and then filtered using Whatman No.1 filter paper into a 50 mL volumetric flask and made up to the standard mark with deionized water after rinsing the reacting vessels, to recover any residual metal. The filtrate was then stored in pre-cleaned storage bottles ready for analysis.

Blank determinations were carried out simultaneously with the samples concentration of each metal in the sample solution and it was measured against those of serially diluted with standard solutions containing each metal. Cadmium, lead, copper, chromium, zinc, nickel and iron were determined in all standard solutions, samples and blank solutions by Buck scientific model 200A/240 Atomic Absorption spectrophotometer with Air - acetylene flame at Centre Laboratory University of Ibadan.

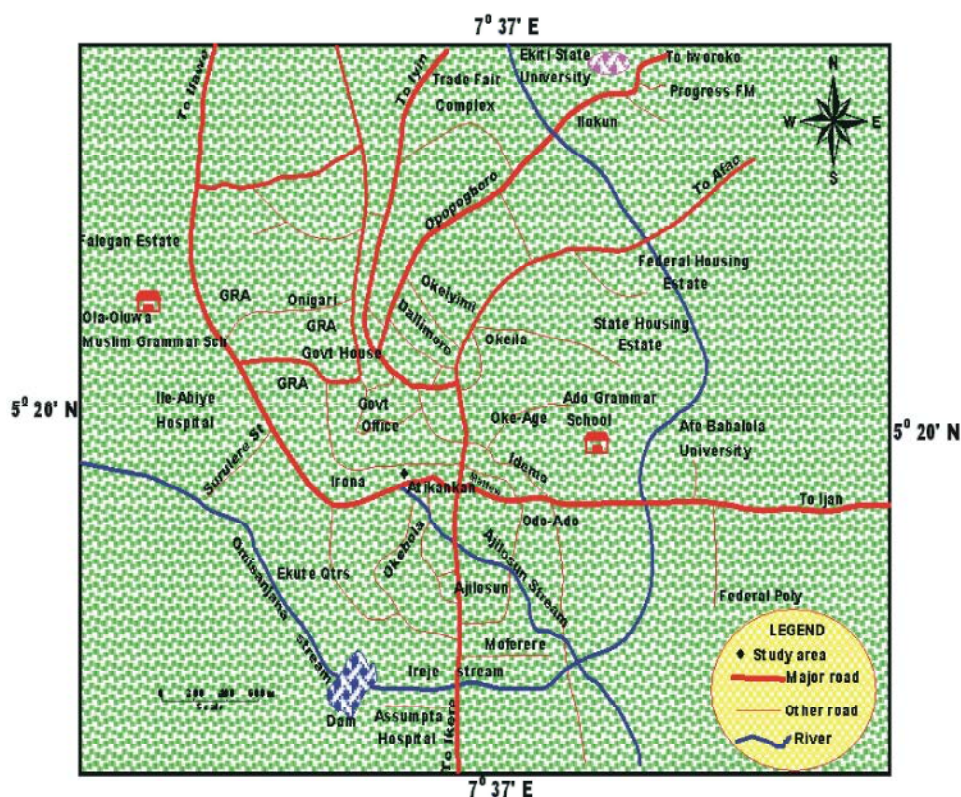


Fig. 1: The study area within Ado Ekiti showing sampling location Atinkankan

Quality Assurance: Quality control test was conducted on soil in order to evaluate the experimental procedures and efficiency of atomic absorption spectrophotometer. This was done by spiking the pre-digested soil with multi-elemental metal standard solution.

Data Evaluation

Geoaccumulation Index (Igeo): Pollution levels of heavy metals in Ado Ekiti could be characterized by the geo-accumulation index (Igeo) [28]. This contamination assessment index has been utilized in environmental studies [29-31] and can be defined as the following equation:

$$I_{\text{geo}} = \ln \{C_n/1.5 B_n\}.$$

where Cn is the measured content of individual heavy metal in Ado Ekiti,

Bn: the background or pristine value of individual heavy metal. The control samples were taken to represent the background and 1.5 is the constant factor introduced to analyze natural fluctuations in the contents of a given substance in the environment and very small anthropogenic influences. There are seven classes of the geoaccumulation index [29] as stated in Table 1.

Table 1: Seven Descriptive classes of Geoaccumulation index.

Class	Range	Description
1	<0	Practically uncontaminated
2	0-1	Uncontaminated to slightly contaminated
3	1-2	Moderately contaminated
4	2-3	Moderately to highly contaminated
5	3-4	Highly contaminated
6	4-5	Highly to very highly contaminated
7	>5	Very highly/strongly contaminated

Contamination/Pollution Index (C/P): This was calculated by employing previously used method [32] with the following modifications/definitions:

C/P = Concentration of the metal in soil/Target value of pollution

The target value was obtained by using the standard formulated by the Department of Petroleum Resources of Nigeria (DPR), for maximum allowed concentration of heavy metals in soils.

Enrichment Factor (EF): By following established method [34], EF was employed to assess the degree of contamination and to understand the distribution of the

Table 2: Standard formulated by the Department of Petroleum Resources of Nigeria (DPR), for maximum allowed concentration of heavy metals in soils

	Metal	Maximum allowed concentration (ppm)
1	Pb	85.0
2	Ni	35.0
3	Cr	100.0
4	Cd	0.8
5	Cu	36.0
6	Fe	5000.0
7	Zn	140.0
8	Mn	476.0

The significance of interval of contamination/pollution index [33], are given below.

Table 3: The significance of interval of contamination/pollution index

Class	Range	Significance
1	<.1	Very slight contamination
2	0.10-0.25	Slightly contamination
3	0.26-0.5	Moderate contamination
4	0.51-0.75	Severe contamination
5	0.76-1.00	Very severe contamination
6	1.10-2.0	Slight pollution
7	2.1-4.0	Moderate pollution
8	4.1-9.0	severe pollution
9	9.1-16.0	Very severe pollution
10	>16.0	Excessive pollution

The values less than 1 are defined as contamination range while greater than 1 are defined as pollution range.

Table 4: Descriptive classes of Enrichment factor index

Class	Range	Description
1	<1	Background concentration
2	1-2	Depletion to minimal enrichment
3	2-5	Moderate enrichment
4	5-20	Significant enrichment
5	20-40	Cery high enrichment
6	>40	Extremely high enrichment

elements of anthropogenic origin from sites by individual elements in sediments. Fe was chosen as the normalizing element when determining EF-values, since in wetlands it is mainly supplied from sediments and is one of the widely used reference element [35-38]. Other widely used reference metal elements are Al, Mn [39-41]. The EF is defined as follows:

Enrichment factor = (Cn/Fe) sample/ (Cn/Fe) background,

where, Cn is the concentration of element “n”. The background value is that of control sample. An element qualifies as a reference one if it is of low occurrence

variability and is present in the environment in trace amounts [35]. Elements which are naturally derived have an EF value of nearly unity, while elements of anthropogenic origin have EF values of several orders of magnitude.

Six categories are recognized [42], as stated bellow:

Pollution Load Index (PLI): Pollution load index for each site was evaluated as indicated by [43].

Pollution load index= $(CF1 * CF2 * * CFn)^{1/n}$

where, “n” is the number of metals (six in the present study). The PLI value > 1 is polluted whereas PLI value < 1 indicates no pollution [37, 38].

Quantification of soil contamination (QoC) The third approach using the quantification of anthropogenic concentration of metal employs the concentration in the control samples to represent the lithogenic metal. This is calculated as

Quantification of anthropogenic metal = $(X - X_c)/X \times 100$

where X = average concentration of the metal in the soil under investigation and Xc = average concentration of the metal in the control samples [44]. All the indices were employed to assess the impact of the auto mechanic works on the surrounding soils.

RESULTS AND DISCUSSION

Heavy Metal Concentrations: Concentrations of various heavy metals in soils of the study area are given in Table 6. The analysis was carried out for heavy metals. The geoaccumulation index values (Igeo) are shown in Table 7. The soils were slightly contaminated by iron, zinc and lead but were moderately contaminated by nickel and manganese in all the sites exceeding the normally expected distribution in soil. These results raise concern over suitability of soils in the study area [45]. The C/P index, show the values for lead, chromium, iron and manganese to be in the range of moderate contamination at the site. Nickel and Zinc were in the range of slight contamination. However, cadmium and copper showed very severe pollution in the site.

Nickel: The concentration of Ni in the soil sample at the dumpsite ranged from 89.76 to 118.35mg/kg (Table 6). For the control samples, Ni concentration was 20.84mg/kg.

Table 5: Physicochemical properties of soil close to Atikankan dumpsite.

Parameter	Distance 0 Depth 0 - 15cm	Distance 10m Depth 0 - 15cm	Distance 20m Depth 0 - 15cm	Control 0 - 15cm
pH	7.26 ± 0.03	7.26 ± 0.04	7.03 ± 0.01	6.60 ± 0.04
Sand %	46.32 ± 0.11	43.13 ± 0.06	41.62 ± 0.04	52.01 ± 0.01
Silt %	15.10 ± 0.04	15.13 ± 0.03	14.96 ± 0.03	14.43 ± 0.01
Clay %	44.07 ± 0.09	43.52 ± 0.13	43.61 ± 0.04	30.11 ± 0.03
OC %	2.80 ± 0.03	2.55 ± 0.04	2.28 ± 0.02	0.39 ± 0.03
Om %	4.83 ± 0.02	4.40 ± 0.02	3.91 ± 0.01	0.67 ± 0.01
EB (cmol/kg)	6.02 ± 0.01	5.73 ± 0.03	5.78 ± 0.02	1.43 ± 0.01
EA (cmol/kg)	0.68 ± 0.02	0.62 ± 0.02	0.59 ± 0.03	0.47 ± 0.01
ECEC	6.70 ± 0.03	6.35 ± 0.02	6.37 ± 0.02	1.90 ± 0.02

Table 6: Metal concentration in soil close to Atikankan dumpsite.

Parameters	Distance 0 Depth 0 - 15cm	Distance 10m Depth 0 - 15cm	Distance 20m Depth 0 - 15cm	Control 0 - 15cm
Pb (mg/kg)	182.05 ± 1.25	144.85 ± 2.20	136.91 ± 1.13	23.68 ± 0.04
Ni (mg/kg)	118.35 ± 0.23	101.22 ± 0.12	89.76 ± 0.06	20.84 ± 0.02
Cr (mg/kg)	115.86 ± 0.08	115.22 ± 0.14	98.11 ± 0.03	12.10 ± 0.02
Cd (mg/kg)	11.62 ± 0.02	11.02 ± 0.02	10.13 ± 0.01	0.16 ± 0.01
Cu (mg/kg)	550.92 ± 1.12	521.30 ± 1.00	426.25 ± 0.32	315.02 ± 0.02
Fe (mg/kg)	4387.52 ± 3.12	4263.23 ± 2.51	3981.51 ± 2.23	1892.43 ± 1.33
Zn (mg/kg)	311.06 ± 0.12	280.32 ± 0.10	251.76 ± 0.16	99.12 ± 0.08
Mn (mg/kg)	221.36 ± 0.04	202.41 ± 0.11	181.14 ± 0.02	87.42 ± 0.04

Table 7: Geoaccumulation index of soil close to Atikankan dumpsite.

Parameter	Distance 0 Depth 0 - 30cm	Distance 10m Depth 0 - 30cm	Distance 20m Depth 0 - 30cm	Mean Igeo
Pb	1.63	1.41	1.35	1.46
Ni	1.33	1.18	1.06	1.37
Cr	1.85	1.85	1.69	1.80
Cd	3.88	3.83	3.74	3.81
Cu	0.15	0.10	-0.10	0.05
Fe	0.44	0.41	0.34	0.40
Zn	0.74	0.63	0.53	0.63
Mn	0.52	0.43	0.32	0.42

Table 8: Contamination /pollution index of soil close to Atikankan dumpsite.

Parameter	Distance 0 Depth 0 - 15cm	Distance 10m Depth 0 - 15cm	Distance 20m Depth 0 - 15cm	Mean C/P
Pb	2.14	1.70	1.61	1.82
Ni	3.38	2.89	2.57	2.95
Cr	1.16	1.15	0.98	1.10
Cd	14.53	13.78	12.66	13.66
Cu	15.30	14.48	11.84	13.87
Fe	0.88	0.85	0.80	0.84
Zn	2.22	2.20	1.80	2.07
Mn	0.47	0.43	0.38	0.43

Table 9: Enrichment factor index of soil close to Atikankan dumpsite

Parameter	Distance 0 Depth 0 - 15cm	Distance 10m Depth 0 - 15cm	Distance 20m Depth 0 - 15cm	Mean EF
Pb	3.23	2.62	2.62	2.82
Ni	2.46	2.18	2.09	2.24
Cr	3.71	3.86	3.57	3.71
Cd	3.00	3.00	3.00	3.00
Cu	0.76	0.73	0.64	0.71
Fe	1.00	1.00	1.00	1.00
Zn	1.37	1.27	1.21	1.28
Mn	1.11	1.04	1.00	1.05

In a previous study [22], Ni ranged between 18-335mg/kg at the surface layer of soil for all the dumpsites. In another study, Nickel content in soil has been found to be as low as 0.2mg/kg and as high as 450mg/kg while the average was about 20mg/kg [46]. Global input of nickel to the human environment is approximately 150,000 and 180,000 metric tons per year from natural and anthropogenic sources, respectively, including emissions from fossil fuel consumption and the industrial production, use and disposal of nickel compounds and alloys [47]. The Igeo range for Nickel (1.06-1.33) obtained revealed that the samples examined fell into class 3 indicating moderately contaminated with Nickel as per Muller's six classes of geoaccumulation index. The contamination/pollution index (C/P) was high and ranged from 2.57 to 3.38, showing slight pollution with Nickel (Table 8). The EF was low and ranged from 2.09 to 2.46, indicating moderate enrichment with nickel (Table 9). In soil of temperate humid climatic zones, Ni is likely to be fixed by Fe-oxides and becomes immobile. Nickel in soil may be easily mobilized under different physico-chemical conditions.

Chromium: Chromium is a low mobility element, especially under moderately oxidizing and reducing conditions and near-neutral pH values. Cr^{6+} adsorption decreases with increasing pH and Cr^{3+} adsorption increases with increasing pH. However, Cr^{6+} is toxic for biological systems [48]. Chromium levels in the study area ranged from 98.11 to 115.86 mg/kg (Table 6). The Igeo showing moderately contaminated, revealed that nearly all the samples examined fell into class 3, ranging from 1.69 to 1.85. The C/P obtained for Cr ranged from 0.98 to 1.16, which falls under the class 5-6 of very severe contamination to slight pollution and the EF obtained for Cr ranged from 3.57 to 3.86, which falls under the class 3 of moderate enrichment. Therefore, the source of Cr appears to be anthropogenic from the existing mechanic workshop, where they dump chromium compounds. The normal range of chromium in soil is 100 mg/kg [49] and all the samples examined exceeded the normal value. In a previous study [50], chromium is one of the heavy metals whose concentration in the environment steadily increasing due to industrial growth, especially the development of metal, chemical and tanning industries. Other sources of chromium pollution are water erosion of rocks, liquid fuels, industrial and municipal waste. Although Cr toxicity in the environment is relatively rare, it still presents some risks to human health since chromium can be accumulated in skin, lungs, muscles, fat, in liver, dorsal spine, hair, nails and placenta where it is traceable to various health conditions [51].

Copper: Copper values were found to be high in the study area. The copper levels in soil samples ranged from 426.25 to 550.92 mg/kg (Table 6). The Igeo obtained for copper was pointing to uncontaminated to slightly contaminated and the values ranged from minimum of -0.10 to maximum of 0.15. The C/P for Cu ranged from 11.84 to 15.30 and the EF for Cu ranged from 0.64 to 0.76. The normal threshold recommended for Cu in soil is 30 mg/kg; its accumulation in the surface horizons, is due to the ease of bioaccumulation and recent anthropogenic sources [52]. In this study area copper accumulation in the soil was found to be as a result of nearby industries like steel manufacture, blast furnace and those of agrochemicals in the agro-based industry. Furthermore, copper is characterized by the so called point sources of contamination like uncontrolled, active or untended waste dumps which are present in large numbers in this study area.

Lead: The species of Pb vary considerably with soil type; it is mainly associated with clay minerals, Mn oxides, Fe and Al hydroxides and organic matter. In some soil types, Pb may be highly concentrated in Ca carbonate particles or in phosphate concentrations. A baseline Pb value for surface soil on the global scale has been estimated to be 25 mg/kg levels; otherwise concentrations above this value suggest anthropogenic influences [53]. However, in the study area Pb content in the soil was falling into moderately contaminated with Igeo ranging from 1.35 to 1.63. Additionally the C/P ranging from 1.61 to 2.14 indicated slight pollution in most of the samples. The EF values ranging from 2.62 to 3.23 (mean value = 2.82) showed moderate enrichment in most of the samples. The concentration of lead in soil samples of the study area ranges from 136.91 to 182.05 mg/kg as shown in Table 6. This finding of elevated Pb concentrations at these refused dumps is consistent with previous work [49], which investigated the occurrence of heavy metals at automobile mechanic villages in Ibadan and reported concentrations ranging between 18.25-151.00mg/kg in the soil. Furthermore, Lead is released from smelting, motor-vehicle exhaust fumes and from corrosion of lead pipe work. Lead solubility is controlled principally by PbCO_3 and low-alkalinity and low-pH waters can have higher Pb concentrations [54].

Cadmium: Cd values at the dumpsites ranged from 10.13 to a high of 11.62mg/kg at the study area, while the control samples had < 0.16mg/kg. A previous study [22] reported cadmium levels of 219 - 330 mg/kg at the surface layer of dumpsites and none at 200m away.

These results are similar to the work carried out on soils of Obafemi Awolowo University central refuse dumpsite [55]. However, their results were higher compared to the dumpsites in this study. The deposition of industrial waste, mining activities, incidental accumulations, atmospheric deposition and agricultural chemicals are some sources for the pollution of soils with heavy metals [56]. The mobile forms of those heavy metals constitute a risk as they may leach into groundwater that is used for human or animal consumption [57]. Human diseases have resulted from consumption of cadmium contaminated foods [58]. However, in this study area, Cd content in soil was falling in class 5 and classified as highly contaminated with Igeo ranging from 3.74 to 3.88. In the current work, the source appears to be due anthropogenic contribution of Cd in soil.

Manganese: Manganese levels ranged from 181.14 to 221.36mg/kg in the study area (Table 6). A previous study reported concentration in the range of 263.95 - 406.00 mg/kg at dumpsite and a range of 19.21 - 485.00 mg/kg at 100 m away from the dumpsite located within Akwa Ibom state [59]. There was no significant variation in the concentration of manganese in virtually all the dumpsites ($p \leq 0.05$). This shows that the observed concentration of manganese might have been due to background concentration. Manganese may be found in most soils since it is one of the elements in the Earth crust [60]. The Igeo indicated that the soils in the area fell under the class 2 ranging from 0.32 to 0.52 showing uncontaminated to slightly contaminated. The C/P indicated moderate contamination (class 3) with content ranging from 0.38 to 0.47. The EF indicated depletion to minimal enrichment (class 2) with a mean content of 1.05 ranging from 1.00 to 1.11. Normal threshold value for Manganese in soils is 100 mg/kg [61].

Zinc: Zinc belongs to a group of trace metals, which are essential for the growth of humans, animals and plants and are potentially dangerous for the biosphere when present in high concentrations. The main sources of pollution are industries and the use of liquid manure, composted materials and agrochemicals such as fertilizers and pesticides in agriculture [62]. The zinc concentration in the study area ranged from 251.76 to 311.06 mg/kg and is considered high (Table 6). The Igeo indicated that the soils in the study area fell under the class 1 ranging from minimum of 0.53, practically uncontaminated and maximum of 0.74, showing slightly contaminated. The C/P indicated slightly polluted, ranging from 1.80 to 2.22 and the EF

indicated depletion to minimal enrichment with a mean content of 1.28 and ranging from 1.21 to 1.37. In Nigeria 47% of soils are depleted in zinc, however high concentrations of Zn were found in this dumpsite area, which clearly suggest that the source is anthropogenic instead of natural [63].

Quantification of Soil Contamination (QoC): On the basis of the quantification of anthropogenic input of the heavy metals in the soils presented in Table 10, the order of contamination with individual metals is as follows: Atinkankan dumpsite: Cr > Cd > Pb > Ni > Zn > Mn > Fe > Cu. I-geo factor is not readily comparable with C/P and EF due to the nature of *I-geo* calculation which involves a logarithm function and a background multiplication factor 1.5. However, results from the different impact-assessing indices are consistent with each other as shown in Fig. 2. This could simply be an indication that the anthropogenic sources of the metals in the soils surrounding these waste dumpsites are of similar origin, with anthropogenic inputs in soils of the metals, generally, in a decreasing order of Cd (98.53%) > Cr (88.97%) > Pb (84.68%) > Ni (79.79%) > Zn (64.73%) > Mn (56.66%) > Fe (55.06%) > Cu (36.93%) as shown in Table 10.

Pollution Load Index: The PLI values calculated for the site was found to be polluted (PLI > 1), suggesting inputs from anthropogenic sources.

Conclusion and Recommendations: The results of this study demonstrate the impact of anthropogenic agents on the abundances of heavy metals in soils of the study area. The dumpsite is extremely contaminated due to many years of random dumping of hazardous and metal workshop wastes. The high content of toxic metals in the soil can lead to an increase in their contents in ground waters due to leaching. The detected levels of total metal contamination in many of the samples were found to exceed international threshold values. High concentration of Cr, Cd, Pb, Ni, Zn, Mn, Fe and Cu obtained in the soil of the study area suggest that the pollution of the heavy metals originated mainly from dumping of industrial waste or from the release of uncontrolled effluents in to the ground and these may eventually contaminate the water bodies and streams in the study area. A considerable amount of surface soil/waste from this dumping site and other heavily contaminated areas should be excavated and transported to landfill site dedicated for hazardous waste. This study clearly highlights the necessity of immediate control measures for the exceptionally severe

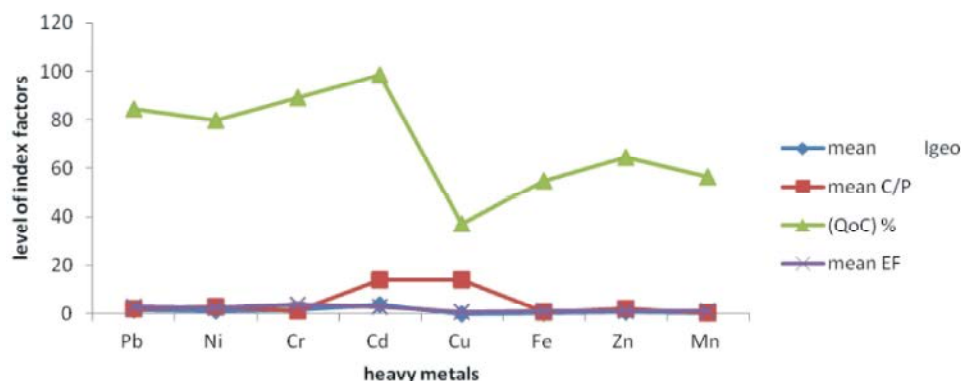


Fig. 2: Pattern of metal fluctuations in the dumpsite as shown by index factors

Table 10: Average geo-accumulation index (I-geo), contamination factors (CF), quantification of contamination (QoC), enrichment factor (EF) of heavy metals in soils of Atikankan dumpsite

Parameter	Mean Igeo	Mean C/P	(QoC) %	Mean EF
Pb	1.46	1.82	84.68	2.82
Ni	1.37	2.95	79.79	2.24
Cr	1.80	1.10	88.97	3.71
Cd	3.81	13.66	98.53	3.00
Cu	0.05	13.87	36.93	0.71
Fe	0.40	0.84	55.06	1.00
Zn	0.63	2.07	64.73	1.28
Mn	0.42	0.43	56.66	1.05

heavy metal pollution in the study area and the soils in the area, it is recommended urgently for bioremediation and/or other remediation technologies such as phytoremediation involving growing certain plants in the area to minimize the rate of contamination and extent of future pollution problems.

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