ASSESSMENT OF THE LEVEL OF ANTHROPOGENIC CONTRIBUTIONS TO HEAVY METAL POLLUTION ON SOME ABANDONED WASTE-DUMP SITES IN THE YENAGOA METROPOLIS IN BAYELSA STATE

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Abstract: Industrial revolution has caused a great increase in the heavy metal pollution of soils with no exception of soils at waste dump sites. However, anthropogenic sources are not the only sources of heavy metal pollution, hence this research work was aimed at assessing the anthropogenic contributions to metal pollution on some abandoned waste dump sites in the Yenagoa metropolis in Bayelsa State. Soils samples were collected from sites and analyzed using flame atomic absorption spectrometer. Pollution indices were calculated from the analytical results. Concentrations ranged (0.044 mg/kg – 2.048 mg/kg, except Fe), contamination factor (0.274 – 4.604), pollution load index (1.06 – 1.741), ecological risk index (71.61 – 167.67), ecological risk coefficient (0.72 – 138.12), geo-accumulation (- 0.057 – 1.181), Nemerow multi-factor (0.34 – 3.65), pollution contamination indices (0.35 – 3.87), modified degree of contamination indices (1.11 – 2.41), contamination degree indices (7.40 – 14.50), enrichment factor (0.497 – 7.435). Generally, these values indicate that the abandoned waste dump sites are only minimally polluted and may not adversely affect farming activities. The results are also consistent with the low level of industrialization of Bayelsa State.

Keyword: Abandoned, heavy metal, pollution, index, waste

I. INTRODUCTION

Soil is a dynamic resource for the survival of human life and due to its complex matrix; it is the principal receiver of persistent contaminants such as heavy-metals (Luo et al., 2007). Every soil comprises some natural quantities of heavy-metals, at concentrations called backgrounds. The magnitude of a metal's background depends upon the composition of the parent rock material from which the soil was derived (Scazzola et al., 2003). Human activities that add waste material to the soils also influence its metal concentration (Pastor, Hernandez, 2012).

Soil can be contaminated with waste (either solid or liquid), in addition to its land use impact, can cause water and soil pollution as well as soil erosion and other environmental problems. However, heavy-metals are of considerable environmental concern due to their toxicity, wide sources, non-biodegradable properties and accumulative behaviors (Yu *et al*., 2008, Gong *et al.*, 2008, Homa *et al*., 2003).

Soil can be polluted with heavy-metals via industrial, agricultural and domestic activities (Fytianos *et al.* 2001). However, sources related to industrialization are central sources of heavy-metal to soils (Stafilov *et al*., 2010).

However the spread of such pollution is also a major concern; heavy-metals can be transported long distances via atmospheric particulates after liberation into the environment (Wu *et al*., 2010). A portion of metals in the atmosphere may be transferred to soils by atmospheric deposition (Lu *et al.,* 2010). The continual disposal of municipal waste on the soil may lead to increase in heavy metals in the soil surface water that would be inimical to deep feeding plants. Heavy metals such as arsenic, cadmium, lead, chromium, nickel, cobalt and mercury are concerned primarily because of their ability to harm the soil organisms, plants, animals and human beings. More emphatic are untreated dumplings that rapidly increase soil toxicity, making large area dump sites potentially hazardous for agricultural purposes. Dump site fields therefore can be seen to provide farmers with fertile plots for cultivation of vegetables and other surface feeder crops.

Most studies of metals leaching in soil columns or field investigations conclude that trace metals are strongly bound to topsoil (Sukkeriyah *et al.,* 2005). The dump sites also acts as breeding grounds for disease vectors causing serious health problems in the neighborhood.

Some contamination by heavy metals is of most important apprehension throughout the industrialized world (Hinojosa *et al.*, 2004). Heavy metal pollution not only result in adverse effects on various parameters related to plant quality and yield but also cause changes in the size, composition and activity of the microbial community (You H, *et al*., 2003). The adverse effects of heavy metals on soil biological and biochemical properties are well documented. The soil properties, i.e., organic matter, clay contents and pH have major influences on the extent of the effects of metals on biological and biochemical properties.

The effect of different concentrations of heavy metals on soil microbial biomass was studied and conclusions drawn up; if the concentration of heavy metals in the soil was three time above the environment standard, established by the European Union, it could inhibit microbial biomass. The low concentrations of heavy metals could stimulate microbial growth and increase microbial biomass, while high concentration could decrease soil microbial biomass significantly.

Some of these heavy metals i.e. As, Cd, Hg, Pb, and Se are not essential for plant growth, since they do not perform any known physiological function in plants. Others such as Co, Cu, Fe, Mn, Mo, Ni and Zn are essential elements required for normal growth and metabolism of plants, but these elements can easily lead to poisoning when their concentration is greater than optimal values (Rascio

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et al., 2011). The use of compost to improve agricultural yield without caring about the possible negative effects might be a problem since the waste composts are most applied to improve soils used to grow vegetables. Considering the edible part of the plant in most vegetable species, the risk of transference of heavy metals from soil to humans should be a matter of concern (Jordao *et al*., 2007).

Uptake of heavy metals by plants and subsequent accumulation along the food chain is a potential threat to animal and human health. The absorption by plant rots is one of the main routes of entrance of heavy metals in food chain (Jordao *et al.*, 2007).

Heavy metal accumulation in plants depends upon plant species and the efficiency of different plants in absorbing metals. This is evaluated by either plant uptake or soil to plant transfer factors of the metals (Khan *et al*., 2008). Heavy metals are potentially toxic and phytoxicity for plants may result in chlorosis, weak plant growth, yield depression, and may even be accompanied by reduced nutrient uptake, disorders in plant metabolism and reduced ability to fixate molecular nitrogen in leguminous plants, impairment to enzymes (Xue et al., 2015). In this present study is to assess the heavy metal contamination in top soil of some selected waste dump site in Bayelsa State. Specific objective of this study include the assessment of the level of heavy metal concentration in the top soil from different abandoned waste dump sites in Bayelsa State and to evaluate the pollution levels using different pollution indices which include, contamination factor, pollution load index, heavy metals potential ecological risk coefficient (E_r^i) and potential ecological index, geo-accumulation index, nemerow multi-factors or Nemerow Integrated pollution value, pollution contamination index, modified degree of contamination and contamination degree index, enrichment factor.

The research work was designed to assess the level of contribution of anthropogenic sources to the heavy metal pollution on some abandoned waste dump sites by subjecting concentration data to pollution-indication methods such as contamination factor (CF), degrees of ecological risk, potential Contamination index, Modified degree of contamination, Enrichment factor, geo-accumulation index, Nemerow multi-factor.

II. MATERIALS AND METHODS

Study Area

Yenagoa is geographically located between latitude 4°47[1] and 5°11[1] N and Longitude 6°01 [1] and 6°24[1] and lies within 31 and 32N of World Geodetic System 1984 "WGS84" (Ndiwarri, 2004). The town is located in a humid tropical wetland area with mean annual rainfall of about 2539 mm and an average temperature of 26.2°C.

Sampling, Sample description, and Preparation

Sampling

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Three replicates soil samples (15 cm depth) were collected from three abandoned waste dump sites; one from each community: Azikoro, Etegwe, and Biogbolo, all in Yenagoa (Bayelsa State). For each site, a control sample was also collected, a 100 meters away from each ump site. The soil samples were collected in February 2017 at depths of 0 to 15 cm using soil Auger. Samples were put in polyethylene bags, sealed and labeled properly.

Sample description

In most samples, the soil pH ranged from 6.13 to 7.84 and in one of the samples (collected from the Azikoro village dump site) the mean pH value was 7.05 (Table 1).

The percentage organic matter and percentage organic carbon ranged from 1.89 - 6.28, and 2.18 - 5.41 respectively for the sites under investigation.

Table 1. pH values of the soil samples from waste dump sites

Sites	**1**	**2**	**3**	**Mean**
Etegwe	6.46	7.14	6.14	6.59
Azikoro village	6.13	7.17	7.84	7.05
Biogbolo	7.29	7.52	7.40	7.40

Measurement of Conductivity

The mean conductivity values ranged between 1.14 to 1.22μScm^{-1} in the soil samples of the different abandoned waste dump sites (Table 2). However, the conductivity values of the topsoil of the waste dump sites were all between the normal range 0 – 200μScm^{-1}.

Table 2. Conductivity (μScm^{-1}) values on the soil from the waste dumps sites

Sites	**1**	**2**	**3**	**Mean (μScm^{-1})**
Etegwe	1.14	1.19	1.21	1.18
Azikoro village	1.18	1.15	1.12	1.15
Biogbolo	1.16	1.13	1.13	1.14

Sample preparation and AAS analysis

The samples were spread out and placed in a designed air-dried special room in the laboratory for seventeen days. Then the samples were ground using mortar and pestle and sieved through a 2 mm sieve to get fine powdered samples and stored in plastic cover plate at room temperature.

The soil samples were digested; 2.0 g of sample was mixed with 30 mL of Aqua regia (3:1 of HNO_3: H_2SO_4), heated on a hot plate inside fume cupboard. The digested samples were filtered through Watchman filter paper; the filtrate was diluted with 50 mL of distilled water. The diluted samples were taken for heavy metal determination using Atomic Absorption Spectrophotometer (AAS).

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METHODS FOR ASSESSING THE LEVEL OF ANTHROPOGENIC CONTRIBUTIONS TO METAL POLLUTION IN SOIL (POLLUTION INDICES)

In this present study, contamination factor (CF), heavy metal potential ecological risk coefficient and potential ecological index, pollution contamination index, modified degree of contamination and contamination degree index, and enrichment factor (EF) were used to assess the metal pollution levels in the soil samples. Reference values (Earth crust averages) of the studied metals which were used as background values were taken in different location were no activities are taken placed.

Contamination Factor (CF)

The contamination factor is an expression of the level of metal contamination in the surface sediment. It is the quotient attained by division of the concentration of each metal in the soil by the reference value (Hakanson, 1980; and Maanan *et al.*, 2014). It is given by the formula;

$$\text{CF} = \frac{C_{metal}}{C_{background}}$$

Where C_{metal} is the concentration of a given metal in the sediment and $C_{background}$ is the metal concentration of a control sample.

Table 3. Classification based on contamination factor (CF)

CFs value Scale	Classification
1 and less	No contamination
1-2.0	Suspected
2-3.5	Slight
3.5-8	Moderate
8-27.0	Severe
27 and above	Extremely

Heavy Metal Potential Ecological Risk Coefficient and Potential Ecological Index

Potential ecological risk index method advanced by Swedish Scholar Hakanson, according to the characteristic of heavy metal and its environment behavior, is an approach to evaluate the heavy metal contamination from the perspective of sedimentology.

It does not only consider heavy metal level in the soil, but also associates ecological and environmental effects with toxicology, and evaluates pollution using comparable and equivalent property index grading method. The potential ecological risk related to individual pollution coefficient, heavy metal toxicity response coefficient, and its formula is as follows: $RI = \sum E_r^i$ (1)

$$E_r^i = T_r^i \; X \; C_f^i \qquad (2)$$

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$$C_f^i = \frac{C_{surface}^i}{C_n^i} \qquad (3)$$

Where E_r^i is potential ecological risk individual coefficient, T_r^i is toxicity response coefficient of a certain kind of metal toxicity using standard heavy metal toxicity coefficient developed by Hakanson (1980) as reference, in accordance with the normalized toxic response factor of 30, 5, 5, 5, 2 and 1 respectively for Cd, Cu, Pb, Ni, Cr, and Zn.

C_f^i is the accumulating coefficient of element *i* and RI is the potential ecological risk index.

Table 4. Classification based on ecological risk

Ri or E_r^i	**Ecological Pollution degree**
$E_r^i < 40$ or Ri < 150	Low ecological risk for the sediment
$40 \leq E_r^i < 80$ or $150 \leq$ Ri < 300	Moderate ecological risk for the soil
$80 \leq E_r^i < 160$ or $300 \leq$ Ri < 600	Considerable ecological risk for the soil
$160 \leq E_r^i < 320$ or $600 \leq$ Ri	Very high ecological risk for the soil

Potential Contamination Index

The potential contamination index (Cp) can be evaluated by the equation (Dauvalter, Rognerud, 2001; Maanan *et al.*, 2014).

$$Cp = \frac{M_{sample\ max}}{M_{reference}}$$

Where $M_{sample\ max}$ is the maximum concentration of an element in the soil, and $M_{reference}$ is the value of the same element in a reference soil. Cp value were explained as proposed by Dauvalter and Rognerud (2001), where Cp ≤ 1indicates low pollution; 1 < Cp ≤ 3 is moderate pollution; and Cp > 3 is severe or very severe pollution.

Table 5. Concentration of the Elements

Elements:	**Cd**	**Cu**	**Pb**	**Ni**	**Cr**	**Zn**
Max.	0.069	0.139	1.506	0.741	1.420	0.614
reference	0.032	0.092	1.071	0.410	0.907	0.523

Table 6. Classification based on Potential Contamination index

Grade division	**Cp value**	**Pollution level**
1	Cp ≤ 1	Low pollution
2	1 < Cp ≤ 3	Moderate pollution
3	Cp > 3	Severe or very severe pollution

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Contamination Degree (Cd)

In order to simplify contamination control, Hakanson (1980) suggested a method utilizing a diagnostic tool named the contamination degree (Cd). Cd was calculated as the sum of the CF for each sample: $Cd = \sum_{i=1}^{i=n} CF$. In accordance with Hakanson (1980); Cd < 6 indicates a low degree of pollution; 6 < Cd < 12 is a moderate pollution; 12 < Cd < 24 is a considerable degree of pollution; and Cd >24 is high degree of pollution indicating serious anthropogenic pollution.

Modified degree of contamination

The modified degree of contamination (mCd) was presented to approximate the complete degree of pollution (Abrahim, Parker, 2008; Maanan *et al*., 2014):

$$mCd = \frac{\sum_{i=1}^{i=n} CF}{n}$$

Where n is the number of examined elements, i is the ith pollution and CF is the contamination factor.

mCd < 1.5 is nil to a very low degree of pollution;

1.5 ≤ mCd < 2 indicates a low degree of pollution;

2 ≤ mCd < 4 indicates a moderate degree of pollution;

4 ≤ mCd < 8 indicates a high degree of pollution;

8 ≤ mCd < 16 indicates a very high degree of pollution;

16 ≤ mCd < 32 indicates an extremely high degree of pollution;

mCd ≤ 32 indicates an ultra-high degree of pollution.

Enrichment Factor

Enrichment factor is one of the indicators most often used for estimating anthropogenic inputs (Gonzales-Macias *et al*., 2006, Liu Wx *et al*., 2003, and Louri *et al*., 2011). Using this technique, the sediment's EF ratio can be used as a pollution index by comparing the concentrations of selected metals to the background levels of metal in sediments or suspended particulate matter from local or worldwide rivers. The advantage of using measurement concentration of local sediments as background values is that they can be better for comparison. The widely used elements for normalization are Al (Zhang *et al.*, 2009, Kwokal *et al.*, 2002) and Fe (Ghrefat *et al*., 2006, and Cevik *et al*., 2009).

EF is important indicators that quantitatively assess the levels and sources of heavy metal pollution.

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$$EF = \frac{(^{M}/_{Fe})_{samle}}{(^{M}/_{Fe})_{background}}$$

Where $(^{M}/_{Fe})_{samle}$ is the sample value of metal of interest to Fe,

$(^{M}/_{Fe})_{background}$ is the background value of metal to Fe.

Iron was chosen as the element of normalization because natural sources (1.5%) vastly dominate its input.

Table 7. Classification based on Enrichment factor (EF)

EF value	Contamination degree
< 1	No enrichment
< 2	Deficiency to minimal enrichment
2-5	Moderate enrichment
5-20	Significant enrichment
20-40	Very high enrichment
>40	Extremely high enrichment

Geo-accumulation index (I_{geo})

The geo-accumulation index (I_{geo}) was utilized to evaluate the degree of element pollution in soils by balancing the present with original concentrations; however it is hard to find original soil.

The I_{geo} values of a sample can be evaluated with the following equation:

$$I_{geo} = \log_2[^{C_i}/_{(1.5Bi)}]$$

Where C_i the current elements concentration in the soil samples and B_i is the geochemical reference value as defined by Taylor and Mclennan (1995). The modified coefficient, constant 1.5 was utilized to characterize the effect of accumulation and geological characteristic and determine the consequence of human activities. I_{geo} can be separated into seven classes (Muller, 1969).

Table 8. Classification based on geo-accumulation index

Igeo value	Class	Sediment Quality
≤ 0	0	Unpolluted
0 - 1	1	From unpolluted to Moderate polluted
1 - 2	2	Moderate polluted
2 - 3	3	From moderate to Strongly polluted
3 - 4	4	Strongly polluted
4 - 5	5	From strongly to extremely polluted
>6	6	Extremely polluted

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The Nemerow multi-factor index

As The sub-index can be used to calculate the single factor in multi-factor comprehensive pollution indices of soil heavy metals (Li *et al*., 2003 and Soldecilla *et al*., 1992). In addition to synthetically and objectively reflecting the degree of contamination of different elements, the comprehensive contamination index is able to highlight the effects of high concentrations of contaminant on environmental soil quality.

To assess the degree of heavy-metal contamination, pollution index (P_i) for each metal and Nemerow multi-factor or integrated pollution index (P_c or $NIPI$) (Yang *et al*., 2011), the single contamination index

$$P_i = {}^{C_i}/_{S_i}$$

Where P_i is the contamination index of soil contaminants i: C_i is the measured value of soil contaminants i in mg/kg, and S_i is the background value of the soil contaminants i in mg/kg.

The soil is not contaminated when $P_i \leq 1$, but is contaminated when $P_i > 1$, and the higher theP_i, the more serious the soil contamination.

The Nemerow multi-factor index, P_c

$$P_c = \{[({}^{C_i}/_{S_i})^2_{ave} + ({}^{C_i}/_{S_i})^2_{max}]/2\}^{1/2},$$

Where P_c is the comprehensive contamination index of the soil contaminants, $({}^{C_i}/_{S_i})_{ave}$ is the average value of the pollution index of soil contaminants, and $({}^{C_i}/_{S_i})_{max}$ is the maximum value of the single contamination index.

Table 9. Classification based on Nemerow multi-factor value

Grade division	Pc	Contamination level	Contamination degree
1	Pc ≤ 0.7	Save	Clean
2	0.7 ≤ Pc ≤ 1	Alert	Still clean
3	1 < Pc ≤ 2	light	Soil slightly contaminated;
4	2 < Pc ≤ 3	moderate	Moderately contaminated
5	Pc > 3	Severely	Severely contaminated

III. RESULTS AND DISCUSSION

Concentration of heavy metals in Etegwe abandoned waste-dump site

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The metal concentrations observed at each sampling site in this study are shown in Table 10. The metal contents ranged over the following concentration: Cd (0.111-0.139 mg/kg), Cu (0.248-0.292 mg/kg), and Pb (0.288-0.389 mg /kg), Ni (0.198-0.691 mg/kg), Cr (1.788-1.874 mg/kg), Zn (1.398-1.742 mg/kg) and Fe (217.348-238.223 mg/kg) respectively. The average concentrations of the metals were 0.125, 0.269, 0.347, 0.487, 1.839 and 1.602 for Cd, Cu, Pb, Ni, Cr and Zn; following the order: Cr > Zn > Ni > Pb > Cu > Cd.

Concentration of Heavy Metals in Azikoro Village abundant Waste Dump Site

The metal concentrations for each sampling site are shown in Table 10. Metal contents ranged over the intervals: Cd (0.109-0.121 mg/kg); Cu (0.278-0.364 mg/kg); Pb (0.249-0.317 mg/kg); Ni (0.619-0.640 mg/kg); Zn (0.237-0.452 mg/kg) and Fe (176.289-226.356 mg/kg) respectively. The mean concentration of the metals were 0.128, 0.316, 0.283, 0.628, 1.693 and 0.373 for Cd, Cu, Pb, Ni, Cr and Zn; defining this order in magnitude: Cr > Ni > Zn > Cu > Pb > Cd.

Concentration of Heavy Metals in Biogbolo abandoned waste Dump Site

The heavy metal concentrations, ranging and averages in the soil samples are shown in Table 10. The metal concentrations were found in the following ranges, Cd: 0.036-0.092 mg/kg; Cu: 0.237-0.272 mg/kg; Pb: 0.765-1.252 mg/kg; Ni: 0.499- 0.663 mg/kg; Cr: 1.516-1.658 mg/kg; Zn: 1.394-1.503 mg/kg; and Fe: 184.216-253.727 mg/kg respectively. While mean concentration were 0.065, 0.254, 0.943, 0.57, 1.573 and 1.441 for Cd, Cu, Pb, Ni, Cr and Zn. The mean concentration values decreases from Cr to Cd as follows: Cr > Zn > Pb > Ni > Cu > Cd.

Table 10. The concentration of heavy metals in abandoned waste-dump sites

Sampling	**Elements**						
Point	**Cd**	**Cu**	**Pb**	**Ni**	**Cr**	**Zn**	**Fe***
Etegwe							
Mean	0.125	0.269	0.347	0.487	1.839	1.602	226.676
Max	0.139	0.292	0.389	0.691	1.874	1.742	238.223
Min	0.111	0.248	0.288	0.198	1.788	1.398	217.348
Azikoro village							
Mean	0.128	0.316	0.283	0.628	1.693	0.373	201.82
Max	0.121	0.364	0.317	0.64	1.745	0.452	226.356
Min	0.109	0.278	0.249	0.619	1.711	0.237	176.289
Biogbolo							
Mean	0.065	0.254	0.943	0.570	1.573	1.441	222.475
Max	0.092	0.272	1.252	0.663	1.658	1.503	253.727
Min	0.036	0.237	0.765	0.499	1.516	1.394	184.216

The Concentration of Heavy Metal in Background Study

The heavy metal concentrations for the background study are shown in Table 11. The metal content was found in the following intervals: Cd (0.027-0.04 mg/kg); Cu (0.061-0.109 mg/kg); Pb (0.938-1.239 mg/kg); Ni (0.327-0.459 mg/kg); Cr (0.79-0.99 mg/kg);

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Zn (0.358-0.68 mg/kg); and Fe (504.448-521.626 mg/kg). The mean background value concentrations were 0.032, 0.092, 1.071, 0.41, 0.907, 0.523 and 514.287 for Cd, Cu, Pb, Ni, Cr, Zn and Fe respectively. The background concentration decreases as follows: Pb > Cr > Zn > Ni > Cu > Cd.

Table 11. The Background concentration of abandoned waste dump sites

Sampling Point	**Elements**						
	Cd	**Cu**	**Pb**	**Ni**	**Cr**	**Zn**	**Fe***
UPL 1	0.03	0.109	0.938	0.327	0.99	0.532	521.626
UPL 2	0.027	0.108	1.036	0.459	0.973	0.68	516.789
UPL 3	0.04	0.061	1.239	0.444	0.76	0.358	504.448
Mean	0.032	0.092	1.071	0.41	0.907	0.523	514.287

Replicates sampling sites: UPL 1, UPL 2, and UPL 3

Contamination Factor (CF) In Etegwe Waste Dump Sites

The highest average contamination factor was found in Cd of 3.926, which indicates moderate contamination (Table 12). Zn, Cu and Cr have average values of 3.062, 2.923 and 2.027 respectively, which indicate slight contamination in the soil. Ni has value of 1.187, which indicates suspected contamination, but Pb has no contamination in the soil.

Contamination factor (CF) in Azikoro village waste dump site

Table 12 shows the contamination factors for metals in Azikoro site. The highest average contamination factor of 4.01 in Cd, indicates moderate contamination in the soil. Cu has the value of 3.437, which indicates slight contamination, Cr and Ni have average values of 1.866 and 1.531, which indicate suspected contamination in the soil. But Pb and Zn have values of 0.264 and 0.713 respectively, which indicates no contamination. The order of contamination factors is; Cd > Cu > Cr > Ni > Zn > Pb.

Contamination Factor (CF) In Biogbolo Waste Dump Site

The contamination factors of metals in Biogbolo waste dump site are shown in Table 12. The contamination factors of Zn and Cu were 2.755 and 2.764, indicating slight contamination; Cd (2.083), Ni (2.085) and Cr (1.734) indicate suspected contamination, Pb shows no contamination.

Table12. The contamination factor (CF) of the abandoned waste dump sites

Sampling Point	**Elements**					
	Cd	**Cu**	**Pb**	**Ni**	**Cr**	**Zn**
Etegwe Mean	3.926	2.923	0.323	1.187	2.027	3.062
Azikoro Mean	4.01	3.437	0.264	1.531	1.866	0.713
Biogbolo Mean	2.083	2.764	0.881	2.085	1.734	2.755

Pollution Load index in Etegwe abandoned waste dump sites

The soil from the Etegwe dump site is polluted because it gave PLI value range of 1.783 to 1.808 (Table 13), which is higher than 1.

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Pollution Load Index in Azikoro Village Abandoned Waste Dump Site

The calculated PLI values of Azikoro village dump site have the range of 1.368 to 1.439 (Table 13), which signifies pollution occurrence in the soil.

Pollution Load index in Biogbolo abandoned waste dump site

Based on the data provided in Table 13, the PLI value is higher than 1 which indicates pollution.

Table 13. Pollution Load indices of the abandoned waste dump sites

Sampling Point	**Element**						**PLI**	**Pollution evaluation**
	Cd	**Cu**	**Pb**	**Ni**	**Cr**	**Zn**		
Etegwe abandoned waste dump site								
EP 1	3.468	3.173	0.268	1.685	1.971	3.33	1.783	Polluted
EP 2	4.343	2.695	0.363	0.482	2.066	2.673	1.495	Polluted
EP 3	3.968	2.902	0.339	1.395	2.046	3.183	1.808	Polluted
Azikoro abandoned waste dump site								
AC1	4.843	3.956	0.265	1.524	1.886	0.453	1.368	Polluted
AC2	3.406	3.021	0.232	1.509	1.923	0.824	1.335	Polluted
AC3	3.781	3.336	0.295	1.56	1.789	0.864	1.439	Polluted
Biogbolo abandoned waste dump site								
BW 1	2.156	2.576	0.714	1.336	1.671	2.665	1.689	Polluted
BW 2	1.218	2.956	1.169	1.617	1.704	2.728	1.774	Polluted
BW 3	2.875	2.76	0.76	1.217	1.828	2.873	1.833	Polluted

Replicates sampling sites of Etegwe: EP 1, EP 2, and EP 3; replicates sampling sites of Azikoro: AC 1, AC 2, and AC 3; Replicates sampling sites of Biogbolo: BW 1, BW 2, and BW 3

POTENTIAL ECOLOGICAL RISK COEFFICIENT AND POTENTIAL ECOLOGICAL INDEX

The potential ecological risk (R_i) posed by heavy metals in soil was estimated by using the method developed by (Hakanson 1980). The criteria for assessment is tabulated in Table 4. The calculated average ecological risk coefficient (E_r^i) for Cd was 51.21 (Table 14), which is higher than 40, indicating moderate ecological risk level. The E_r^i of Cu, Pb, Ni, Cr and Zn are 15.67, 1.36,

Heavy Metal Potential Ecological Risk Coefficient (E_r^i) and Potential Ecological Index in Etegwe Waste Dump Site

The E_r^i, for Cd was 117.79 (Table 14), indicating considerable ecological risk level in the soil, but Cu, Pb, Ni, Cr and Zn have average values that ranged from 1.61 to 14.61, indicating no ecological or low ecological risk level. Potential ecological index of the surface soil for Etegwe was 147.06, indicating that the soil poses low ecological risk level according to the data in Table 4. The ecological risk level in single metals are; Cd > Cu > Ni > Cr > Zn > Pb.

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Heavy Metal Potential Ecological Risk Coefficient (E_r^i) and Potential Ecological Index in Azikoro Village Abandoned Waste Dump Site

The potential ecological risk coefficient were found in the following order: Cd > Cu > Ni > Cr > Pb > Zn (Table 14). The E_r^i values of all sample points were less than 40 in Cu, Ni, Cr, Pb and Zn (low risk), except Cd that was higher than 80 and average of 120.27, which is placed in considerable ecological risk level. The values of R_i in the soil of AC 2 and AC 3 of the sampling points were 130.50 and 143.73 respectively, representing low ecological risk, but R_i in AC 1 in the sampling point have 178.15, indicating moderate ecological risk. The average value of R_i in the dump site is 150.80 (moderate).

Heavy Metal Potential Ecological Risk Coefficient (E_r^i) and Potential Ecological Index in Biogbolo Waste Dump

The average potential ecological risk coefficients (E_r^i) for Cu, Ni, Pb, Cr and Zn were less than 40 (Table 14), indicating low ecological risk, but the value for Cd was 62.49 in average indicating moderate ecological risk in the soil. The R_i have an average value of 93.84, indicating considerable ecological risk in the soil. The order of E_r^i were found as Cd > Cu > Ni > Pb > Cr > Zn.

Table 14. Heavy metal Potential Ecological Risk Coefficient (E_r^i) and Potential Ecological Index of abandoned waste dump sites

Sampling Point	E_r^i						**Ri**
	Cd	**Cu**	**Pb**	**Ni**	**Cr**	**Zn**	
Etegwe Mean	117.79	14.61	1.61	5.93	4.05	3.06	147.06
Azikoro Mean	120.27	17.13	1.31	7.65	3.72	0.71	150.80
Biogbolo Mean	62.49	13.79	4.40	6.94	3.46	2.75	93.84

Geo-accumulation index in Etegwe abandoned waste dump site

The surface soil of Etegwe waste dump can be classified unpolluted to moderate polluted because the geo-accumulation index value of Cd, Cu, Zn and Cr ranged from 0.356 - 1.533 with an average value ranging from 0.421 - 1.382. The geo-accumulation index value for Pb and Ni were negative indicating un-pollution (Table 15).

Geo-Accumulation Index in Azikoro Village Abandoned Waste Dump Site

The soil from Azikoro village abandoned waste dump was unpolluted with Cd, Cu, Ni and Cr because the average geo-accumulation index values ranged from 1.259 and 1.187 (Table 15). Ni and Cr have average values of 0.032 and 0.315, which indicates unpolluted state of the soil. Pb and Zn have negative geo-accumulation values (-2.509 and - 1.187), indicating unpolluted soil.

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Geo-Accumulation Index in Biogbolo Waste Dump Site

The soil from the Biogbolo waste dump was not polluted with Cd, Cu, Cr, Zn Pb and Ni because they respectively have average geo-accumulation index values of 0.476, 0.879, - 0.803, - 0.120, 0.208 and 0.877; values less than 1 (Table 15) The Geo-Accumulation Index values show no pollution to slight pollution of the soils.

Table 15. Geo-accumulation index of abandoned waste dump sites

Sampling Point	**Igeo**					
	Cd	**Cu**	**Pb**	**Ni**	**Cr**	**Zn**
Etegwe						
Mean	1.382	0.958	- 2.224	- 0.525	0.421	1.024
Azikoro						
Mean	1.259	1.187	- 2.509	0.032	0.315	- 1.187
Biogbolo						
Mean	0.476	0.879	- 0.803	- 0.120	0.208	0.877

Nemerow Multi-Factor Values For Etegwe abandoned Waste Dump Site

The Etegwe waste dump is moderately polluted in the overall categorization of pollution, 2.37 being the average Nemerow multifactor (Table 16). The values in table show that the soil is severely polluted with Cd (4.13), Zn (3.19), and Cu (3.05); moderately polluted with Cr (2.04); slightly polluted with Ni (1.45). The soil is contaminated with Pb at save level.

Nemerow Multi-Factor Value for Azikoro Village abandoned Waste Dump Site

Nemerow Multi-factors, P_C of metals show the soil from Azikoro village waste dump site is seriously contaminated with Cd (P_C ,4.44), Cu (P_C ,3.70); slightly contaminated with Cr (P_C ,1.89) and Ni (P_C ,1.54). The site only contaminated at save level with Pb and Zn (Table 16).

Nemerow Multi-Factor Values For Biogbolo Waste Dump Site

The average Nemerow multifactor (P_C) is 2.14 for the Biogbolo waste dump site, which indicate moderate contamination in the soil. At individual metal level, the soil is moderately contaminated with Cu (P_C, 2.86), Zn (P_C, 2.81) and Cd (P_C, 2.51); slightly contaminated with Ni (P_C, 1.86), Cr (P_C, 1.78) and Pb (P_C, 1.03) (Table 16).

Table 16.Nemerow Multi-factor values of abandoned waste dump sites

Elements	Pc	Contamination level	Contamination degree
Etegwe waste dump site			
Cd	4.13	Severely Contaminated	Severely contaminated
Cu	3.05	Severely	Severely contaminated
Pb	0.34	Save	Clean
Ni	1.45	Light Contaminated	Soil slightly contaminated
Cr	2.04	Moderate	Moderately contaminated
Zn	3.19	Severely	Severely contaminated
Average	2.37	Moderate	Moderately contaminated

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Azikoro waste dump site			
Cd	4.44	Severe	Seriously contaminated
Cu	3.70	Severe	Seriously contaminated
Pb	0.27	Save	Clean
Ni	1.54	Light	Slightly contaminated
Cr	1.89	Light	Slightly contaminated
Zn	0.79	Save	Clean
Average	2.10	Light	Slightly contaminated
Biogbolo waste dump site			
Cd	2.51	Moderate	Soil moderately contaminated
Cu	2.86	Moderate	Soil moderately contaminated
Pb	1.03	light	Soil slightly contaminated
Ni	1.86	Light	Soil slightly contaminated
Cr	1.78	Light contamination	Soil slightly contaminated
Zn	2.81	moderate	Soil moderately contaminated
Average	2.14	moderate	Soil moderately contaminated

Pollution Contamination Index in Etegwe Waste Dump Site

The results of the pollution contamination index study for the Etegwe waste dump site are shown in Table 17. The soil can be classified as moderately polluted because it has an average Cp of 2.49. Based on the Cp values, the soil is not polluted with Pb (Cp, 0.36); moderately polluted with Zn (Cp, 3.33) and Cu (Cp, 3.17); severely polluted with Cd (Cp, 4.34). The order of pollution contamination indices is: Cd > Zn > Cu > Cr > Ni > Pb.

Pollution Contamination Index in Azikoro Village Abandoned Waste Dump Site

The comprehensive pollution contamination index of metals from Azikoro village abandoned waste dump site was 2.06 (Table 17), indicating moderate level of pollution of the site. However, the site is severely polluted with Cu (Cp, 3.95), Cd (Cp, 3.78) and Cr (Cp, 1.92); moderately polluted with Ni (Cp, 1.56) but the soil is not polluted with Zn (Cp, 0.86) and Pb (Cp, 0.29). The order of pollution is: Cd > Cu > Cr > Ni > Zn > Pb.

Pollution Contamination Index in Biogbolo Waste Dump Site

The overall assessment result for the pollution contamination index in Biogbolo waste dump site showed an average value of 2.21 (Table 17), indicating moderate pollution. The pollution contamination index for Cd, Cu, Ni, Cr and Zn were 2.87, 2.95, 1.61, 1.82 and 2.86 respectively, indicating moderate pollution. The order of pollution contamination index is: Cu > Cd > Zn > Cr > Ni > Pb.

Table 17.Pollution Contamination indices of abandoned waste dump sites

Elements	Cp value	Pollution level
Etegwe abandoned waste dump site		
Cd	4.34	Very Severe pollution
Cu	3.17	Severe pollution
Pb	0.36	Not pollution
Ni	1.68	Moderate pollution
Cr	2.06	Moderate pollution
Zn	3.33	Severe pollution

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Average	2.49	Moderate pollution
Azikoro abandoned waste dump site		
Cd	3.78	Severe pollution
Cu	3.95	Severe pollution
Pb	0.29	Not polluted
Ni	1.56	Moderate pollution
Cr	1.92	Moderate pollution
Zn	0.86	Not polluted
Average	2.06	Moderate pollution
Biogbolo abandoned waste dump site		
Cd	2.87	Moderate pollution
Cu	2.95	Moderate pollution
Pb	1.16	Low pollution
Ni	1.61	Moderate pollution
Cr	1.82	Moderate pollution
Zn	2.86	Moderate pollution
Average	2.21	Moderate pollution

MODIFIED DEGREES OF CONTAMINATION (mCdi) AND CONTAMINATION DEGREE INDEX (Cdi)

The modified degrees of contamination and contamination degree index values for heavy metals in the sites under investigation are given in Table 18. Modified Degree of Contamination and Contamination Degree Index in Etegwe Dump Site

Results of the Cdi and mCdi assessments are given in Table 18. The modified degree of contamination varied from 1.30 to 2.31 with an average value of 1.90, indicating a low degree of pollution. The contamination degree index varied from 12.62 to 13.89, with an average value of 13.44, representing a considerable degree of pollution.

Modified Degree of Contamination and Contamination Degree Index in Azikoro Village Abandoned Waste Dump Site

The Azikoro village abandoned waste dump sites can be assessed to be moderately polluted with the metals of interest because the Cdi values varied from 10.91 to 12.92 with an average value of 11.81 (Table 18) but the site can be categorized low degree of pollution mCdi values of the metals ranged from 1.93 to 2.15 with an average of 1.96.

Modified Degree of Contamination and Contamination Degree Index in Biogbolo Waste Dump Site

The Biogbolo waste dump site is moderately polluted as evident in the Cdi values that ranged from 11.11 to 12.31 with an average value of 11.60 (Table 18), the mCdi values, ranging from 1.85 to 2.05 with an average value of 1.93, indicating a low degree of pollution.

Table 18. Modified degree of contamination and contamination degree index of abandoned waste dump sites

Sampling Point	Element						Cdi	mCdi
	Cd	**Cu**	**Pb**	**Ni**	**Cr**	**Zn**		
Etegwe abandoned waste dump site								
EP 1	3.46	3.17	0.26	1.68	1.97	3.33	13.89	2.31
EP 2	4.34	2.69	0.36	0.48	2.06	2.67	12.62	2.10

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EP 3	3.96	2.90	0.33	1.39	2.04	3.18	13.83	1.30
Azikoro abandoned waste dump site								
AC1	4.84	3.95	0.26	1.52	1.88	0.45	12.92	2.15
AC2	3.40	3.02	0.23	1.50	1.92	0.82	10.91	1.81
AC3	3.78	3.33	0.29	1.56	1.78	0.86	11.62	1.93
Biogbolo abandoned waste dump site								
BW 1	2.15	2.57	0.71	1.33	1.67	2.66	11.11	1.85
BW 2	1.21	2.95	1.16	1.61	1.70	2.72	11.39	1.89
BW 3	2.87	2.76	0.76	1.21	1.82	2.87	12.31	2.05

Replicates sampling sites of Etegwe: EP 1, EP 2, and EP 3; replicates sampling sites of Azikoro: AC 1, AC 2, and AC 3; Replicates sampling sites of Biogbolo: BW 1, BW 2, and BW 3

Enrichment Factor in Etegwe Waste Dump Site

The enrichment factors of metals for the Etegwe site are shown in Table 19. The EF values show that the soil is significantly enriched (EF greater than 5) with Cd, Cu, and Zn; moderately enriched with Cr and Ni but not enriched (EF, 0.732) with Pb. The order of enrichment factors is: Cd > Zn > Cu > Cr > Ni > Pb.

Enrichment Factor in Azikoro Village Abandoned Waste Dump Site

The average enrichment factors for metals in Azikoro waste dump site ranged from 0.681 to 9.572 (Table 19). The EF values indicate that the soil is significantly enriched with Cd (EF, 9.281), Cu (EF, 9.572), and Cr (EF, 5.232); moderately enriched with Ni (EF, 4.000) and Zn (EF, 2.089); not enriched with Pb (EF, 0.681).

Enrichment Factor in Biogbolo Waste Dump Site

The average EF values of Cd, Cu, Pb, Ni, Cr and Zn were 4.789, 6.470, 2.051, 3.273, 4.063 and 6.460 respectively (Table 19); ordered as follows: Cu > Zn > Cd > Cr > Ni > Pb. From the assessment of the enrichment factors, the soil is significantly enriched with Cu and Zn; moderately polluted with Pb and Ni.

Table 19. Enrichment factor of abandoned waste dump sites

Sample point	EF					
	Cd	**Cu**	**Pb**	**Ni**	**Cr**	**Zn**
Etegwe						
Mean	8.907	6.649	0.732	2.700	4.604	6.958
Azikoro						
Mean	9.281	9.572	0.681	4.000	5.232	2.089
Biogbolo						
Mean	4.789	6.470	2.051	3.273	4.063	6.460

IV. Conclusion

Having a good knowledge of the quality of soil prior to the commencement of farming cannot be over-emphasized. Potential farmlands (abandoned waste dumpsites in Yenagoa metropolis) were assessed for quality for potential farming activities and the pollution indices (contamination factor (CF), degrees of ecological risk, Potential Contamination index, Modified degree of

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contamination, Enrichment factor, geo-accumulation index, Nemerow multi-factor) show that the abandoned dumpsites are only slightly polluted with (Cd) and may not pose health threats to man when used for farming. The low level of pollutions is also consistent with the low level of industrialization of the state.

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