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Geoenvironmental Assessment of the Impacts of Ewu-Elepe Dumpsite on Soil and Groundwater Resources at Ikorodu, Lagos State, Nigeria.

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Abstract

The environmental status of the municipal solid waste dumpsite at Ewu-Elepe, Ikorodu Local Government Area of Lagos State was investigated. A total of seventeen (17) samples consisting of twelve (12) soils, three (3) groundwater and two (2) leachate samples were collected and analyzed for different parameters using Atomic Absorption Spectrophotometer (AAS). The results revealed that in the leachate samples, all the heavy metals, Cl^-, COD, salinity, and conductivity contents showed significant increase. The physicochemical results for the groundwater samples agreed with the international standards for drinking water, except for high cadmium content (0.009mg/l) recorded in the groundwater sample W1 which exceeded the NSDWQ and WHO permissible limits of 0.003 and 0.005mg/l respectively for drinking water, and high manganese content (0.09mg/l) recorded also in W1. The results of soil samples from the dumpsite showed that the concentration of all the heavy metals, Zn (23.5mg/kg), Cu (10.8mg/kg), Cr (14.2mg/kg), Ni (3.47mg/kg) and Pb (19.0mg/kg) fall below the Sediment Quality Criteria ISQG-Low level and the Lowest Effect Range of the New York Sediment Criteria except for Cd (16.60mg/kg) which is even higher than the High Effect Range of both the New York sediment Criteria and the Sediment Quality Criteria that the soil within the dumpsite have been moderately impacted is further demonstrated by the application of environmentric parameters treatment such as Contamination Factor (CF), Geo-accumulation Index, Enrichment Factor (EF) and Ecological Risk Factor Analyses. The results of the sediment quality assessment are good evidence to confirm that the soil of the dumpsite is highly polluted with cadmium (Cd), and moderately contaminated with lead (Pb). This study reveals that the solid waste dumpsite is affecting the natural quality of the ambient environment. Therefore, indiscriminate dumping of solid waste at the dumpsite should be prohibited.

Keywords: Enrichment factor; Heavy minerals; Leachate; Physiochemical, Pollution indices

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Introduction

Landfill leachate has long been known to pollute groundwater sources (Hem, 1989; Butow *et al*., 1989; Alloway and Ayres, 1997). Clark (2006) described landfill practices as the disposal of solid waste through land depression filling. Most impoverished countries, including Nigeria, leave many tons of garbage on the streets every day, which serves as a breeding ground for pests that spread disease, clogs sewers, and causes a slew of other health and infrastructure difficulties.

The usage of landfill as a waste disposal technique deviates from typical practices in many developing countries (Mull, 2005; Adewole, 2009; Morgan *et al*., 2023). A standardized landfill system includes carefully chosen locations and is often created and managed using engineering techniques to ensure minimal contamination of air, water, and soil, as well as dangers to humans and animals. Landfilling is the process of 'placing' waste in a lined pit or mound (sanitary landfills) with suitable leachate and landfill gas control techniques (Alloway and Ayres, 1997). In most cases, however, 'landfill' in developing countries refers to an unlined shallow trench (usually little deeper than 50 cm). It is defined by Zurbrugg *et al.* (2003) as "dumps" that receive solid garbage in an unregulated way, making very poor use of limited space, allowing free access to waste pickers, animals, and flies, and frequently emitting unpleasant and toxic smoke from slow-burning fires. In addition, research has shown that even lined (protected) landfills are inefficient at preventing groundwater pollution (Lee and Lee, 2005).

Even in Nigeria's major cities, open dump is almost always an option for solid waste disposal. Sanitary landfill, on the other hand, is unusual and unpopular, except for a few organizations and affluent individuals (Elaigwu *et al*., 2007). Financial and institutional constraints are the immediate recognized reasons of this in Nigeria and several other developing countries, particularly if local administrations are weak or underfunded and rapid population growth persists (Elaigwu *et al*., 2007). The available landfill guidelines are frequently those from high-income countries, and they are based on technological standards and practices suited to the conditions and regulations of the source countries; they frequently do not take into account the various technical, economic, social, and institutional aspects of developing countries. According to Adewole (2009), dumpsites have been adopted for use in Lagos State, Nigeria, because more refined techniques are technically and financially expensive. This also revealed a general lack of understanding of the harmful effects of dumpsites on groundwater sources, on which many city dwellers rely (Foster, 1986; Ako *et al*., 1990). It has also been shown that municipal governments in these countries tend to allocate their limited financial resources to wealthier districts with higher tax yields, where people with more political influence reside (Onakerhoraye and Omuta, 1994).

Additionally, acidification and nitrification of groundwater near their outlets have been linked to dumpsites (Bacud *et al*., 1994), and a number of dumpsites have been implicated in bacterial contamination of drinking water (Torres *et al*., 1991), causing poisoning, cancer, heart disease, and teratogenic abnormalities in some cases (Sia Su, 2008). Inadequate collection and disposal have an impact on city ecosystems, contribute to the degradation of the urban environment, and provide a health risk to urban inhabitants in general. Those who live near dumpsites suffer the most because rubbish has the potential to pollute water, food sources, land, air, and plants (UN-HABITAT, 2008). Lagos is a city that is becoming more urban while suffering less economic, environmental, and health issues (Afullo and Odhiambo, 2009). Among the difficulties are metropolitan authorities' current inability to manage huge amounts of generated solid waste (UNDP, 2006). As a result, uncontrolled and unmonitored garbage

disposal in open dumps has resulted in heavy metal contamination and subsequent ecological damage. Because of its widespread distribution and severe ecological repercussions, this has become a global problem (Nriagu, 1989).

Despite the fact that the majority of the garbage is organic, large amounts of plastic, paper, metal debris, and batteries are present, all of which are known to be significant sources of heavy metals (Lisk, 1988; Zhang *et al*., 2002; Pasquini and Alexander, 2004). Indeed, the nutritive richness of wastes makes them appealing as fertilizers; nevertheless, when untreated wastes are used in crop production, consumers risk contracting diseases like cholera and hepatitis, as well as becoming poisoned with heavy metals (Drechsel *et al*., 1999). Heavy metals are also non-biodegradable and can accumulate to dangerous levels in soils, harming plant and animal life (Karatas *et al*., 2006; Adjia *et al*., 2008).

Drinking contaminated water or eating soil or vegetables grown on contaminated land can introduce trace metals into the body (Dudka and Miller, 1999; Cambra *et al*., 1999). Metals such as lead, mercury, cadmium, and copper are cumulative poisons that are exceedingly deadly and destroy the ecosystem (Yargholi and Azimi, 2008). These metals are a major source of oxidative stress in the cell and have been linked to the development of a number of human diseases, including cancer (Frenkel, 1992; Wang *et al*., 2004; Leonard *et al*., 2004; Hei and Filipic, 2004).

Li *et al.* (2016) carried out a study on twenty trace elements in fine particulate matter in Chengdu, China's southwest megacity, in order to investigate the properties, origins, and potential health risks of particle hazardous heavy metals. According to the results of the health risk assessment, adults and children would be at considerable non-carcinogenic health risk from As, Mn, and Cd. Ecological and human health risk assessment of potentially toxic element contamination in waters of a former asbestos mine. Ecological and human health risk assessment of potentially toxic element contamination in waters of a former asbestos mine in Canari area carried out by Marengo *et al.* (2022), this work offers fresh and practical data to enhance environmental quality monitoring in an area where mining activity has historically occurred and to evaluate the possible health risks associated with fish intake.

In the Ewu-Elepe village, there is still a lack of understanding regarding the dumpsite's influence on the environment and the health of the residents who live nearby. As a result, public education about the health consequences of indiscriminate waste dumping is vital. The outcomes of the study will also be used to create an environmental data base for future research. The purpose of this research is to assess leachate, groundwater, and soil in the vicinity of a municipal dumpsite in Ewu-Elepe to identify the dumpsite's impact on the surrounding ecosystem. The goals are to determine the concentrations of selected heavy metals in soils, groundwater, and leachates, as well as the physicochemical and biological properties of the leachates, groundwater, and soil found at the Ewu-Elepe dumpsite, and to use a multivariate geostatistical tool to aid interpretation.

Materials and methods

Study area

Ewu-Elepe is in Ikorodu Local Government Area of Lagos State, between latitudes 60 35' 47'' N - 60 36' 03'' N and longitudes 30 34' 43'' E - 30 34' 52'' E. The dumpsite occupies a total land area of roughly 9.4ha (Fig. 1). The research area consists of a very muddy terrain with garbage

and other waste products strewn about. This could result in direct contact with a body of groundwater. All storm water that drains down the Ewu-Elepe route ends up in the dumpsite.

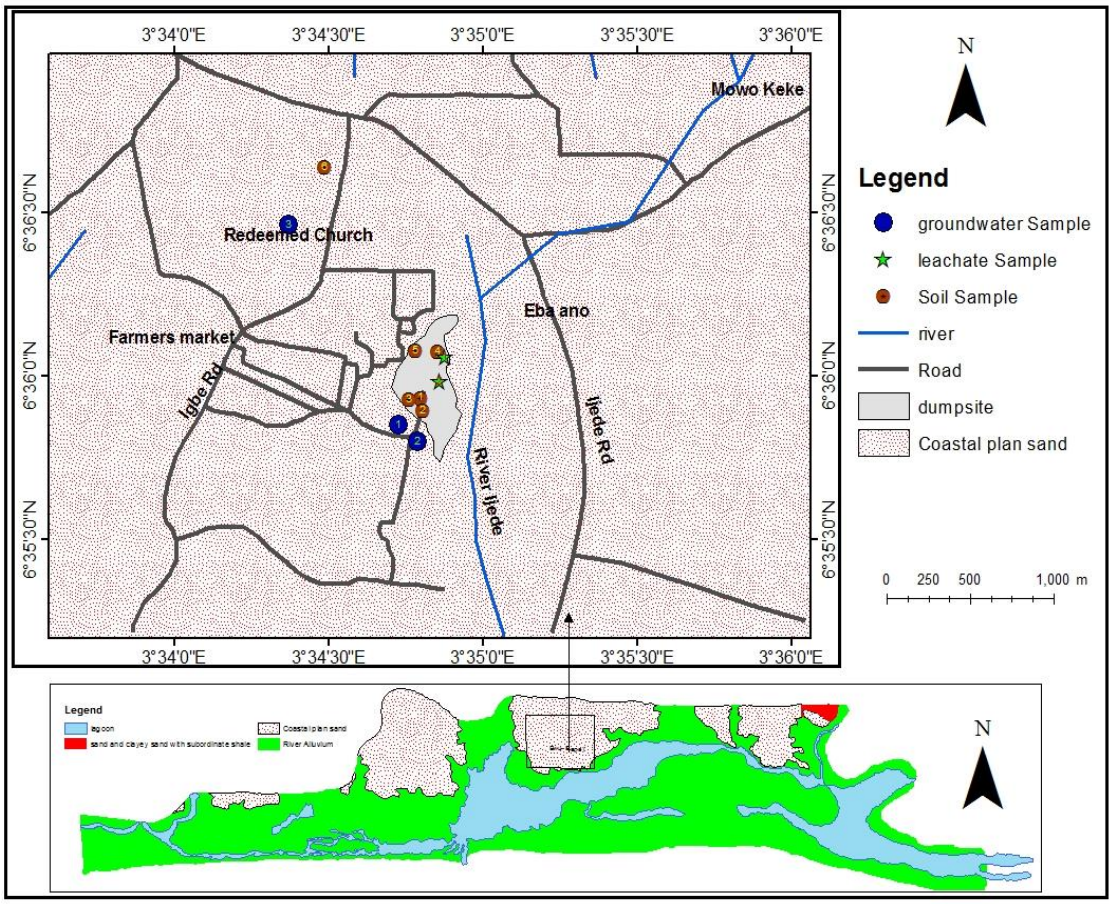

Fig. 1. Map of the study area and sampled locations (Modified after Olorunfemi *et al.,* 2020)

Collection of samples

Prior to sample collection, a reconnaissance survey was carried out in the area of study to ascertain the extent of the open dump, the composition and ways to collect samples. A total of 17 samples were collected. Twelve (12) soil samples were collected with the aid of a soil auger and the various depths were measured and GPS coordinates taken. The depths were 0-15cm and 15-30cm respectively for each sample location.

A control sample was taken about 1450m away from dumpsite at the same depths of samples collected at the dumpsite. Two (2) leachate samples were collected at two different locations within the dumpsite where it was observed to have gathered through seepage from the top of the dumpsite. Three (3) groundwater samples from boreholes and a well were collected at different locations around the dumpsite. Boreholes 1 and 2 were collected from 215m and 1280m from the dumpsite respectively, while the well (hand dug) sample was collected from 160m from the dumpsite.

Analytical techniques

A total of seventeen (17) samples consisting of twelve (12) soil samples, three (3) groundwater and two (2) leachate samples were collected and analyzed using atomic absorption spectrophotometer (AAS). The soil, ground water and leachate samples were analyzed for the following parameters physicochemical parameters: heavy metals (Fe, Cu, Mn, Zn, Cr, Cd, Pb, Ni), anions (PO_4^3, SO_4^{2-}, Cl-, NH_4N), essential metals (Na, K, Ca, Mg), total dissolved solids (TDS), dissolved oxygen (DO), chemical oxygen demand (COD), pH, salinity, turbidity and conductivity.

The statistical analysis for soil samples were carried out using the following pollution indices. The pollution indices are contamination and pollution load indices, ecological risk analysis, geo-accumulation and enrichment factor analyses.

Results and discussion

Physiochemical analysis of groundwater and leachate

The results of water physiochemical analysis (Table 1) revealed that the pH of water samples around the dumpsite ranged from 4.80 – 8.60. The pH of the leachate samples ranged from 7.00 – 8.60 which is slightly basic, while the pH of the groundwater samples ranged from 4.80 – 5.20 which are lower than the minimum permissible limits of NSDWQ and WHO, from the range of values, it can be seen that the water is acidic. Acidity may cause the water to have a sour taste and not desirable for consumption.

The electrical conductivity of the groundwater samples collected fell below the maximum permissible limits of WHO and NSDWQ (490 – 561). The leachate samples however showed higher values of between 2923- 14340 which are greater than the WHO and NSDWQ maximum permissible limits. The high values in the leachate samples could be because of the presence of dissolved salts in them.

The values of chloride ion range from 55.60 – 65.40mg/l for the three groundwater samples collected, this falls below the WHO limit and above the NSDWQ limit. The leachate samples have higher concentration of chloride ion ranging from 177.20 – 254.10mg/l, with the second leachate sample having value greater than the maximum permissible limit of WHO. Chloride is an important parameter in water that affects the taste especially when present in high concentration and watery eyes, chest pain, nose and throat irritation (Igbinosa and Okoh, 2009; Meme *et al*., 2015).

The values of sulphate for both the groundwater samples and the leachate samples are far below the standard limits given by WHO and NSDWQ. The groundwater samples range from 1.68 – 2.56mg/l while the leachate samples range from 3.10 – 9.45mg/l. It is obvious that the leachate samples have higher concentration compare to the groundwater. High level of sulphate ion may give the water a bitter or stringent taste.

The nitrate value ranges from 0.46 – 1.32mg/l for the three groundwater samples, these values tend to be below the maximum permissible limit of NSDWQ and WHO. Also, the leachate samples collected have nitrate values lower than the maximum permissible limits given by WHO and NSDWQ, but the concentration of nitrate is higher than those of the groundwater samples. The leachate samples have the values of 8.48mg/l and 17.90mg/l. BH2 has the lowest concentration of nitrate, being the farthest from the dumpsite. The presence of nitrate in water

is caused by the seepage of human sewage from private septic tank systems. Nitrate may cause thyroid disease.

For the groundwater samples collected, the values of sodium ion range from 1.73 – 3.42mg/l, while for the leachate samples, the values range from 17.10 – 28.20mg/l. Sodium is very essential in drinking water but should not be in concentration that exceeds the maximum permissible limit. The WHO permissible limit for sodium is 200mg/l. Excessive sodium in drinking can cause weight gain and bloating.

The concentration of iron in the groundwater samples range from 0.16 – 1.54mg/l. W1 has higher content of iron than the WHO maximum permissible limit and the NSDWQ limit for portable water, while BH1 and BH2 fall within the standard given by both WHO and NSDWQ. However, the leachate samples have iron content within the range 3.62 – 14.30mg/l, which is above the maximum permissible limits of NSDWQ and WHO. The leachate remains the major source by which iron is introduced into the subsurface water system. Dumping of steel and iron scraps in the dumpsite could have been the reason there is high concentration of iron at the site and this could result in the colour of the groundwater (Rowe *et al*. 1995; Bendz *et al*. 1997). Although iron is an essential element in the human body but when the concentration is beyond the tolerable limit, it becomes toxic.

The concentration of zinc in the three groundwater samples range from 0.007 – 0.18mg/l which is below the maximum permissible limits of WHO and NSDWQ. Also, the first leachate sample L1 has the value of 1.33mg/l which is still below the permissible limits given by WHO and NSDWQ, while the second leachate sample has the highest concentration of zinc with the value of 6.11mg/l which exceeds the maximum permissible limits of WHO and NSDWQ. Zinc is essential for the growth of plants and animals but at higher levels it is toxic to living things (WHO, 20I7). High concentration of zinc in the soil can lead to phytotoxicity, which can destroy weed in the soil (Anglin-Brown *et al*., 1995; Abbasi *et al*., 1998), High concentration of zinc in the body can lead to nausea and upset stomach.

The cadmium value of the leachate samples ranges from 0.051 – 0.284mg/l, these leachate samples show higher concentration of cadmium which exceed the WHO maximum permissible limit and the NSDWQ limit, and this can lead to cancer. Also, the groundwater sample W1 has a higher concentration of cadmium (0.009mg/l) which is above the maximum permissible limits of WHO and NSDWQ. The highest levels of Cd obtained in water samples could be as a result of agricultural runoff, where pesticides, fertilizers, and other agro-chemical are used (Mutton *et al*., 1999). However, cadmium could not be detected from the groundwater samples BH1 and BH2.

The lead content in the leachate samples ranges from 0.064 – 0.196mg/l, having a value higher than the maximum permissible limits of WHO and NSDWQ. Also, the groundwater sample W1 has the value of 0.003mg/l which is below the NSDWQ and WHO maximum permissible limit, while lead is not detected in the groundwater sample BH1 and BH2. The high amount of lead could be as a result from dumping of materials with high lead contents such as paints, pipes and batteries (Kale, *et al*., 2009; Smith, 2009). Lead is a cumulative poison, toxic in small concentrations and can cause lethargy, loss of appetite, constipation, anaemia, abdominal pain, gradual paralysis in the muscles and death.

The concentration of chromium in the first leachate sample(L1) is 0.0098mh/l and it is below the maximum permissible limit of WHO while the second leachate(L2) shows a very high

value of 0.157mg/l which is above the maximum permissible limit of WHO. The groundwater sample W1 has the value of 0.005mg/l which is lower than the maximum permissible limit of WHO. Chromium was not detected in groundwater samples BH1 and BH2. Chromium is highly toxic and capable of lowering the energy levels of vital organs of the human system and can cause cancer (O'Flaherty, 1995).

The range of copper content in the groundwater samples is 0.013 – 0.047mg/l while the values of 0.114mg/l and 0.580mg/l were obtained from the leachate samples L1 and L2 respectively. Results of all the samples fall below the maximum permissible limits of both WHO and NSDWQ. High level of copper in water has been traced to gastrointestinal symptoms such as diarrhea, nausea, abdominal pain and vomiting (Turnland, 1988).

The values of the total dissolved solids of both organic and inorganic matter in the leachate samples L1 and L2 are 1482mg/l and 7170mg/l respectively, which are far above the maximum permissible limits of WHO and NSDWQ, while the values for the groundwater samples range from 251 – 283mg/l which is below the maximum permissible limits of WHO and NSDWQ.

The concentrations of manganese in the two leachate samples are above the maximum permissible limits of WHO and NSDWQ having the values of 0.99mg/l and 2.34mg/l. Also the groundwater sample W1 has the value of 0.09mg/l which exceeds the maximum permissible limits of WHO but below that of NSDWQ, while the groundwater samples BH1 and BH2 have values of 0.02mg/l and 0.05mg/l respectively, which fall within the maximum permissible limits of WHO and NSDWQ. The high concentration of manganese could be connected to the disposal of old batteries at the dumpsite.

Table 1: Physicochemical parameters of groundwater and leachate from Ikorodu

Parameters (Units)	W1 160m from dumpsite	BH1 215m from dumpsite	BH2 (BHC) 1280m from dumpsite	L1	L2	NSDWQ	WHO
pH	4.8	4.9	5.2	7.0	8.6	6.5 – 8.5	6.90 – 9.50
EC (µS/cm)	490	561	522	2923	14340	1000	1200
Sal. (g/l)	0.22	0.25	0.24	1.32	6.49	-	-
Col. (Pt.Co)	ND	ND	ND	194	257	-	-
Turb. (NTU)	ND	ND	ND	180	244	5.0NTU	5.0NTU
TSS (mg/l)	ND	ND	4.3	35.2	77.1	-	-
TDS (mg/l)	251	283	260	1482	7170	500	1500
DO (mg/l)	6.1	6.8	5.7	5.2	4.9	-	4.0
BOD_5 mg/l	2.3	1.1	1.9	21.2	39.7	-	0.5
COD (mg/l)	25.2	9.4	12.7	124	168	-	-
HCO_3 (mg/l)	36.6	57.4	48.8	84.7	211.1	150	-
Na (mg/l)	1.73	3.42	2.91	17.1	28.2	200	200
K (mg/l)	0.64	0.51	0.38	9.10	12.5	-	200
Ca (mg/l)	7.23	11.1	9.14	58.2	95.6	-	100
Mg (mg/l)	2.95	8.02	3.16	34.3	71.8	-	20
Cl (mg/l)	57.8	65.4	55.6	177.2	254.1	0.01	250
P (mg/l)	1.10	0.36	0.74	7.45	23.6	-	0.1
NH_4N (mg/l)	0.038	0.011	0.018	5.14	9.25	-	0.5
NO_2 (mg/l)	0.016	ND	0.010	0.94	2.71	0.2	3.0
NO_3 (mg/l)	1.32	0.50	0.46	8.48	17.9	50	50
SO_4 (mg/l)	1.68	2.56	2.13	3.10	9.45	100	500
Fe (mg/l)	1.54	0.16	0.34	3.62	14.3	0.3	1.0
Mn (mg/l)	0.09	0.02	0.05	0.99	2.34	0.2	0.05
Zn (mg/l)	0.18	0.07	0.11	1.33	6.11	3.0	5.0
Cu (mg/l)	0.047	0.013	0.016	0.114	0.580	1.0	2.0
Cr (mg/l)	0.005	ND	ND	0.098	0.157	0.05	0.05
Cd (mg/l)	0.009	ND	ND	0.051	0.284	0.003	0.005
Ni (mg/l)	ND	ND	ND	0.024	0.045	0.02	0.02
Pb (mg/l)	0.003	ND	ND	0.064	0.196	0.01	0.05
V (mg/l)	ND	ND	ND	0.015	0.09	-	-
THC (mg/l)	ND	ND	ND	0.09	0.17	-	-

ND = not detected, mg/l = milligrams per liter

Hazard assessment of heavy metals

The results of heavy metal measurement and statistical analysis of heavy metal concentrations in soil samples taken from the Ewu-Elepe dumpsite are presented in Tables 2 and 3. The occurrence of heavy metals in the dumpsite was measured in the following order: Fe > Zn, Pb > Cd, Cr > Cu, and Ni > Ni. High levels of Cd, Ni, and Pb pollution represent a significant risk due to their accumulation and negative effects on marine life and the human population. Numerous studies have shown heavy metals such as Cd and Pb as a concern to vegetation and animals, ultimately influencing human health via the food chain. ISQG-Low implies that the pollutants in the sediment would be harmful to aquatic species in the sediment. ISQG-Low suggests that the contaminants in the sediment would be hazardous to aquatic organisms. ISQG-High indicates that the pollutants are virtually certainly harmful to the organisms that live in the sediment. According to this comparison, all heavy metal levels are below the ISQG-Low threshold and the lowest effect range of the New York Sediment Criteria. The sediment quality evaluation results show that the soil at the dumpsite is highly polluted with cadmium (Cd) and moderately polluted with lead (Pb).

Table 2: Physiochemical analysis showing heavy metals

Parameters (Units)	S_1 0-15cm	S_2 15-30cm	S_3 0-15cm	S_4 15-30cm	S_5 0-15cm	S_6 15-30cm	S_7 0-15cm	S_8 15-30cm	S_9 0 – 15cm	S_{10} 15 – 30cm	S_{11} 0 - 15cm	S_{12} 15 – 30cm
pH	6.4	5.7	7.2	6.8	5.8	4.6	6.9	5.7	5.3	5.0	5.4	5.8
EC (µS/cm)	1687	1326	694	512	460	222	541	243	642	517	195	164
Org. C (%)	0.83	0.69	1.65	0.74	2.25	1.76	0.80	0.42	0.31	0.27	2.68	1.61
T.N (%)	0.09	0.07	0.16	0.08	0.20	0.16	0.07	0.04	0.03	0.02	0.22	0.15
Org.M (%)	1.46	1.19	2.85	1.29	3.86	3.03	1.38	0.74	0.54	0.47	4.59	2.77
EA (Meq/100g)	0.3	0.8	0.2	0.3	0.7	1.1	0.3	0.6	1.1	1.3	1.2	0.9
Na^+ (Meq/100g)	0.79	0.51	0.48	0.31	0.65	0.53	0.74	0.66	0.81	0.55	0.39	0.25
K^+(Meq/100g)	0.04	0.01	0.10	0.08	0.19	0.13	0.09	0.07	0.04	0.01	0.11	0.09
Ca^{2+} (Meq/100g)	5.29	4.77	3.21	2.73	4.38	2.56	3.99	2.47	4.08	1.95	2.40	1.65
Mg^{2+} (Meq/100g)	1.22	1.10	0.74	0.63	1.01	0.82	1.15	1.03	0.94	0.62	0.57	0.38
Cl (mg/kg)	181.2	121.0	92.7	85.3	76.7	37.5	90.2	48.5	97.0	86.2	32.5	27.3
Av.P (mg/kg)	4.76	4.04	7.12	5.75	9.12	6.32	3.45	2.57	3.48	2.56	7.41	5.08
NH_4N (mg/kg)	2.21	1.88	3.31	2.67	4.24	2.94	1.60	1.19	1.62	1.19	3.44	2.36
NO_3^- (mg/kg)	6.97	5.53	12.5	9.80	15.7	13.9	5.11	3.28	4.43	3.48	9.38	6.43
SO_4^{2-} (mg/kg)	1.61	1.58	1.02	0.78	0.93	0.49	1.35	0.79	1.13	1.02	0.47	0.36
Fe (mg/kg)	665.3	534.2	490.6	310.1	511.9	212.7	671.2	589.3	336.8	263.0	121.8	95.3
Mn (mg/kg)	44.4	29.6	35.5	19.8	32.0	21.2	41.7	39.3	22.5	17.5	5.11	3.45
Zn (mg/kg)	59.1	37.7	41.8	26.7	45.1	28.3	61.4	52.6	30.1	23.5	10.9	7.51
Cu (mg/kg)	18.9	15.6	12.7	10.1	17.4	11.1	21.9	16.5	12.1	10.8	1.91	1.37
Cr (mg/kg)	23.0	19.2	27.5	23.2	18.7	11.4	20.6	12.7	19.5	14.2	0.39	0.21
Cd (mg/kg)	26.8	22.4	32.1	27.0	21.8	13.3	24.0	14.8	22.7	16.6	0.78	0.44
Ni (mg/kg)	3.83	2.38	2.85	1.29	3.86	3.03	1.35	0.74	4.54	3.47	0.11	0.09
Pb (mg/kg)	30.8	25.7	36.9	31.1	25.5	15.3	27.6	17.0	26.1	19.0	0.61	0.17
V (mg/kg)	2.49	1.22	1.65	0.74	2.90	2.76	0.83	0.42	3.31	2.27	0.08	0.03
THC (mg/kg)	11.4	8.5	15.2	10.7	7.8	5.6	14.6	10.2	12.5	8.1	0.5	0.2
Clay (%)	7.9	7.1	5.8	6.8	5.9	5.5	9.7	8.1	7.1	6.1	5.2	5.5
Silt (%)	3.9	3.2	2.1	2.7	3.0	2.1	2.6	2.3	1.8	1.4	3.0	2.8
Sand (%)	88.2	89.7	92.1	90.5	91.1	92.4	87.7	89.6	91.1	92.5	91.8	91.7

Table 3: Heavy metal concentration of the soil at Ewu-Elepe dumpsite (mg/kg)

Site	Sample	Zn	Cu	Cr	Cd	Ni	Pb	Fe
A	S_1	59.1	18.9	23.0	26.8	3.83	30.8	665.3
A	S_2	37.7	15.6	19.2	22.4	2.38	25.7	534.2
B	S_3	41.8	12.7	27.5	32.1	2.85	36.9	490.6
B	S_4	26.7	10.1	23.2	27.0	1.29	31.1	310.1
C	S_5	45.1	17.4	18.7	21.8	3.86	25.5	511.8
C	S_6	28.3	11.1	11.4	13.3	3.03	15.3	212.7
D	S_7	61.4	21.9	20.6	24.0	1.35	27.6	671.2
D	S_8	52.6	16.5	12.7	14.8	0.74	17.0	589.3
E	S_9	30.1	12.1	19.5	22.7	4.54	26.1	336.8
E	S_{10}	23.5	10.8	14.2	16.6	3.47	19.0	263.0
Min		23.5	10.1	11.4	13.3	0.74	15.3	212.7
Max		61.4	21.9	27.5	32.1	4.54	36.9	671.2
Ave		40.63	14.71	19.00	22.15	2.74	25.49	458.51
EPA		364	310	---------	1.0	---------	183	Nil

Table 4: Concentrations of heavy metals in this study with sediment quality guidelines in µg/g (Modified after Kwon and Lee (1998)

Subject	Zn	Pb	Cu	Cd	Ni	As	Ag	Cr
New York sediment criteria								
lowest effects range	120	32	16	0.6	16	6	0.15	26
severe effects range	270	110	110	9.0	50	33	1.30	110
Sediment quality criteria								
lowest effects range (ISQG-low)	120	31	16	0.6	16	6	0.2	26
high effects range (ISQG-high)	220	250	110	10	75	33	2	110
Present study (Average values)	40.63	25.49	14.71	22.15	2.74	-	-	19.00

Pollution indices

Contamination and pollution load indices

The calculated values of contamination factor (CF) are shown in Table 5. From the results, the values varied from 0.21 to 22.15. Several studies described cadmium (Cd) and lead (Pb) to originate mainly from industrial processes including mining, burning of fossil fuels, waste recycling, cement manufacturing, as well as paper and glass production. Metals like zinc (Zn), copper (Cu) and lead (Pb) have lower (< 1) values which according to Muller (1969) indicated low contamination factor, while cadmium (Cd) which showed higher values (> 6) indicate very high contamination factor. According to Muller (1969), contamination factor (CF) values between 0.5 and 1.5 indicate that, the metal is entirely from the crust or natural processes, whereas, CF values greater than 1.5 suggest that, the sources are more likely to be anthropogenic (Table 6). Also, the degree of contamination values ranging from 18.51 to 30.75 obtained from the metals in Ewu-Elepe dumpsite indicate extremely high degree of contamination.

The results of the computed PLI values for the soil samples are also presented in Table 5. From the results, the PLI values range from 1.02 to 2.35, which indicate that, the soils are contaminated. The pollution Load Index provides a simple comparative means for assessing a site. A value of zero (0.0) indicates perfection, value of one (1.0) indicates only baseline level of pollutants present, and values above one (>1) indicate progressive deterioration of the site (Table 7). Indication from both data sets is that, sediments from the soils are polluted.

Table 5: Contamination factor and pollution load index for the soil samples

Site	**Contamination factor of single metal**					**Degree of contamination**	**Pollution Load Index (PLI)**
	Zn	Cu	Cr	Cd	Pb		
A (n=2)	0.28	0.35	0.23	24.60	0.40	25.86	2.35
B (n=2)	0.20	0.23	0.28	29.55	0.49	30.75	2.16
C (n=2)	0.21	0.29	0.17	17.55	0.29	18.51	1.15
D (n=2)	0.33	0.38	0.19	19.40	0.32	20.62	1.92
E (n=2)	0.15	0.23	0.19	19.65	0.32	20.54	1.02
Average	0.23	0.30	0.21	22.15	0.36	23.26	

Table 6: Terminology used for the contamination factor Pekey *et al*. (2004)

Terminology	Contamination factor interpretation
$C^i_f < 1$	Low contamination
$1 \leq C^i_f < 3$	Moderate contamination
$3 \leq C^i_f < 6$	Considerable contamination
$C^i_f \geq 6$	Very High Contamination

Table 7: Terminology used for the pollution load index Hakanson (1980)

Terminology	Pollution load index Interpretation
PLI < 1	No pollution
PLI = 1	Heavy metal loads close to the background level
PLI > 1	Polluted

Ecological risk analysis

The potential ecological risk indices of zinc Zn), copper (Cu), chromium (Cr), cadmium (Cd) and lead (Pb) in the samples collected from Ewu-Elepe dumpsite are shown in Tables 8 and 9 with detailed grade as recommended by Muller (1969). For the single-factor pollution, cadmium (Cd) has the highest average value of 66.5 which indicates moderate potential ecological risk, while zinc (Zn) has the lowest average value of 0.23 which indicates low potential ecological risk. copper (Cu), chromium (Cr) and lead (Pb) have values not up to 2. The comprehensive potential ecological risk has the highest value of 890.86 at sampling site B, followed by 742.49 at sampling site A, these values indicate very high potential ecological risk for both sites A and B. Sampling site C has the lowest value of 529.95 followed by 586.21 at sampling site D and 592.78 at sampling site E, indicating considerable potential ecological risk. The main contributors to the potential ecological risk are cadmium (Cd), lead (Pb) and copper (Cu), especially cadmium (Cd).

Table 8: Results of ecological risk analysis

Site	Contamination factor of single metal					Comprehensive ecological risk	Ecological pollution degree (Grade)
	Zn	Cu	Cr	Cd	Pb	(Ri)	
A (n=2) Risk	0.28	1.75	0.46	738.00	2.00	724.49	Very high ecological risk
B (n=2) Risk	0.20	1.15	0.56	886.50	2.45	890.86	Very high ecological risk
C (n=2) Risk	0.21	1.45	0.34	526.50	1.45	529.95	Considerable ecological risk
D risk (n=2)	0.33	1.90	0.38	582.00	1.60	586.21	Considerable ecological risk
E (n=2) Risk	0.15	1.15	0.38	589.50	1.60	592.78	Considerable ecological risk
Average	0.23	1.48	0.42	664.5	1.82	668.46	Very high ecological risk

Table 9: Terminology used for the potential ecological risk index given by Hakanson (1980)

Terminology	Ecology risk interpretation
RI < 150	Low ecological risk
150 RI < 300	Moderate ecological risk
300 RI < 600	Considerable ecological risk
RI > 600	Very high ecological risk

Geo-accumulation and enrichment factor analyses

The results of the I-geo of the metals investigated at Ewu-Elepe dumpsite are presented in Table 10. The I-geo scale consists of seven grades or five grades, ranging from uncontaminated to extremely contaminated (Table 11). The six metals fall within three I-geo class, based on Muller's interpretation; moderately to strongly contaminated (Zn and Cu), strongly contaminated (Ni and Cd) and extremely contaminated (Cr and Pb). This contamination can only result from anthropogenic activities. The results of the enrichment factor analysis of the heavy metals at Ewu-Elepe dumpsite are presented in Table 12. The enrichment factor consists of five grades as shown in Table 13. The six metals fall within three enrichment class, based on Sutherland's interpretation: depletion to mineral enrichment (Zn), moderate enrichment (Cu) and significant enrichment (Ni, Cd, Cr and Pb).

Table 10: Results of Geo-accumulation index

Site	Zn	Cu	Cr	Cd	Pb	Ni
A	1.82	2.81	5.55	4.74	5.58	4.37
B	1.31	2.21	5.82	4.74	5.85	3.79
C	1.41	2.53	5.06	4.25	5.11	4.52
D	2.04	2.96	5.21	4.40	5.24	2.81
E	0.96	2.22	5.23	4.42	5.26	4.74
Average	1.51	2.55	5.37	4.56	5.41	4.05

Based on the references of heavy-metal background values in soil of Ginti Estate.

Table 11: The classes of the value of geo-accumulation index (Igeo) given by Muller (1969)

Seven grades			**Five grades**		
Igeo	**Class**	**Soil quality**	Igeo	**Class**	**Soil quality**
Igeo 0	1	Practically polluted	Igeo 0	1	Uncontaminated/ slightly contaminated
0<Igeo<1	2	Unpolluted to moderately polluted	0<Igeo<1	2	Moderately contaminated
0<Igeo<2	3	Moderately Polluted	1<Igeo<3	3	Moderately/strongly contaminated
2<Igeo<3	4	Moderately to strongly	3<Igeo<5	4	Strongly contaminated
3<Igeo<4	5	Strongly polluted	5<Igeo	5	Extremely contaminated
4<Igeo<5	6	Strongly to very strong			
5<Igeo	7	Very strong pollution			

Table 12: Enrichment factor analysis outcomes

Site	Ni	Zn	Cu	Cr	Cd	Pb
A	5.63	0.95	1.90	12.73	7.30	13.11
B	5.61	1.01	1.88	22.91	13.13	23.63
C	10.34	1.19	2.60	15.03	8.62	1.67
D	1.81	1.07	2.02	9.56	5.48	9.85
E	14.51	1.05	2.53	20.33	11.66	20.93
F	7.58	1.05	2.19	16.11	9.24	16.64

Based on the references of heavy-metal background values in soil of Ginti Estate.

Table 13: Terminology used for the enrichment factor given by Sutherland (2000)

Terminology	**Enrichment factor interpretation**
EF < 2	Depletion to mineral enrichment
2 ≤ EF < 5	Moderate enrichment
5 ≤ EF < 20	Significant enrichment
20 ≤ EF < 40	Very High enrichment
EF > 40	Extremely high enrichment

Conclusion

The study has critically investigated the impact of Ewu-Elepe dumpsite on soils and groundwater around the dumpsite. The present study showed that cadmium is the main contributor to the pollution of soils in Ewu-Elepe dumpsite, which the population around Ewu-Elepe community can be exposed to through drinking of the water. The harmful effects of excessive metal concentrations on plants and the possibility of some metals migrating into vegetable products and then being consumed by people or grazing animals have made heavy metals a significant worry in this area. All of the heavy metals, Zn (23.5 mg/kg), Cu (10.8 mg/kg), Cr (14.2 mg/kg), Ni (3.47 mg/kg), and Pb (19.0 mg/kg), have concentrations below both the Lowest Effect Range of the New York Sediment Criteria and the ISQG-Low level, according to the results of soil samples taken from the dumpsite. The exception is Cd (16.60 mg/kg), which is even higher than the High Effect Range of both the New York sediment Criteria and the Sediment Quality Criteria. The use of geoenvironmental parameters treatment, such as Contamination Factor (CF), Geo-accumulation Index, Enrichment Factor (EF), and Ecological Risk Factor Analyses, further demonstrates that the soils within the dumpsite have been moderately contaminated. The sediment quality assessment's findings provide strong proof that the dumpsite's soil is significantly contaminated with lead (Pb) and cadmium (Cd). This study shows that the ambient environment's natural quality is being impacted by the solid waste dumpsite. As a result, it ought to be illegal to dump solid waste at the dumpsite carelessly.

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