Assessment of Impact and Safety Status of Remediation of Lead Contaminated Soil using Excavation Method: A Case Study of Olodo, Ibadan, Southwestern Nigeria

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Abstract

This study aimed to assess the impact and safety status of the excavated waste site of a lead-acid accumulator factory. Soil samples (3 each) were collected from the five pits of depth 1 m each at four angles and one at the centre of the site at interval of 0.5 m. Five soil samples were also collected from five different locations outside the site as a control. All the samples were analysed after pulverisation and digestion using AAS analytical instrument for major, trace and heavy metals such as, Ca, Mg, K, Na, Mn, Cu, Fe, Zn, Co, Cr, Cd, Pb and Ni. Ten water samples were collected, four from shallow hand dug well and six from surface water around the site, and analysed for major ions and trace metals. Using Hakanson (1980) approach, contamination factor of Mn, Zn, Cr and Ni showed low to considerable contamination in A and C-horizon but low contamination factor in B-horizon. This is probably due to the fact that B-horizon could be more porous which served as medium for leaching into C-horizon. Fe, Cu, Cd, Co and Pb revealed considerable contamination factor to very high contamination factor which increase from A-horizon (surface soil) through B to C-horizon (subsurface soil). Degree of contamination show the soil is highly contaminated from top soil through B to C-horizon. Surface water revealed higher concentration of Pb, Cd and Fe in samples from the downstream of the dumpsite which could be due to wash-off by erosion into the rivers.

Keywords: Urbanization, Environment, Sustainability, Contamination Factor and Safety status

Introduction

Environment has been an endowment and gift of nature to man. However, due to man's careless and indiscriminate activities, this gift has become a threat to his existence. The most important environmental components are soil and water, which are poise to alteration by direct or indirect human activities. In the urban centres of most of developing countries, industrial and municipal wastes were usually dumped in an open space in locations believed to be the outskirt of the town. In no time, due to rapid development and expansion of the urban centres across the world, these areas, which were in the past waste sites suddenly turns to site for housing development, especially for immigrants from the rural areas who are desperate to have at least a building in the relatively developed city centres which they believed can earn them opportunity to enjoy the social amenities and infrastructures.

A waste site in Olodo, which is one of the villages around Ibadan in southwestern Nigeria in late 1980s to late 2000, used to be a waste site for moribund lead acid manufacturing company known as EXIDE BATTERY. Ibadan, being a one of the fastest growing cities in the world and the largest city in West Africa, has in recent time expanded and encapsulated most of the villages around it. Olodo village is not an exemption. This led to the allocation of the site, which used to be a waste dump in the past, to people, for housing development. In 2006, there was outbreak of diseases which was traced to Lead poisoning among the inhabitants of the Olodo village by the medical experts and some researchers. These forced both the Federal and Oyo State Ministry of Environment to intervene and compelled the company to carry out excavations on the site for proper remediation of the contaminated soil. This type of soil has deviated from the natural function of soils, which include sustaining biological productivity of soil, maintaining the quality of surrounding air and water environments, as well as promoting plant, animal, and human health (Doran et al., 1996).

Several workers have carried out environmental assessment on soil and water in different locations around the world using different approaches such as geophysical, geochemical and hydrogeochemical methods (Sing and Sing, 2010; Adepelumi et al., 2008; Boreysza et al., 2006; Shakar et al., 2000). Odewande and Abimbola (2008) assessed the contamination and migration level of hydrocarbon contents in both water and soil. Arsenic pollution was also assessed using the geochemical method and saltwater intrusions into freshwater aquifer were delineated using the VES method. In this work, geochemical method was used in the assessment of the waste site soil. In recent times, however, in developing countries of Africa, little or no attention has been laid on the assessment of decontaminated and remediated soil and water. This is due to nonchalant attitude of the government towards environmental status in these parts of the world.

Study Area

The study area is a waste site, which is located in east central part of Olodo village, located north-east of Ibadan, southwestern Nigeria between Longitude $7^0$13'39''N - $7^0$33'39''N and Latitude $3^0$49'56''E - 407'58''E (Figures 1 and 2). Geology of Ibadan and environs falls wholly within the Pre-Cambrian rocks of Southwestern Nigeria which is part of the Nigerian Basement Complex. The rock types have undergone various episodes of tectonism depicted by foliation of the rock (Rahaman, 1976). Major rock types underlying the area include mica schist, quartzite and quartz schist, biotite and biotite-hornblende-gneiss, granite-gneiss and migmatite. Minor rock types are Augen-gneiss, pegmatite and amphibolites (Jones and Hockey, 1964). The study area is underlain by a thick overburden, which comprises mainly lateritic soil, with the impression of the parent rocks still showing in some areas.

Field Sampling and Analytical Method

Fifteen (15) soil samples were collected from five (5) pits (each of 1 m deep), which were dug on the edges and centre of rectangular shaped dump site from which tree soil samples were collected from top, depth 0.5 m and 1 m respectively. Four (4) top soil samples were also collected from the area outside the site which was use as a control for those ones stated earlier. Six surface water were collected, 2 from upstream, midstream and downstream along the river flowing eastward along the down-slope of the site. Four shallow hand-dug well were sampled within the vicinity of the site. Physico-chemical parameters of the water samples such as pH, EC, TDS and temperature were measured on the field using multiparameter portable meter (model Testr-35). Analysis of cations and trace metals in soil and water samples were carried out using AAS, while the anions in the water samples were analysed using Ion Chromatography methods. The analytical results were subjected to statistical analysis such as descriptive statistics, factor analysis and evaluation in respect of background value of relevant trace metals from existing literature. Furthermore, following the approach of Hakanson (1980), contamination factor (CF) and degree of contamination (C_{deg}) were calculated with the formula writhen below. Groundwater and surface water characterisation was carried out using Piper and Schoeller diagrams, while quality assessment was done by comparing the analytical values with their respective WHO standard values.

$$CF = \frac{Cm}{Bm}$$

$$C_{\deg} = \sum \left[\frac{C_m}{B_m} \right] i$$

were Cm= Concentration of metals in Sediment

Bm= Background concentration of metal in sediment.

i = Number of Metals considered in the study

CF = Contamination Factor.

C_{deg}= Degree of Contamination

Results and Discussion

Statistical summary of the results of chemical analysis of major cations and trace metals in the soil are shown in the Table 1. Results of major cations, such as Ca, Mg, K and Na revealed average values of 291.55, 163.05, 605.89 and 3915.37; 3682.11, 2092, 3237 and 2139; 2536.24, 1407.33, 1724.45 and 1454.05; 7454., 8506.22, 4658.48 and 322.9124 mg/g for topsoil, subsoil at depth 0.5 m and 1.0 m and controlled soil respectively. Trace metals Mn, Fe, Cu, Zn, Co, Cr, Cd, Pb, and Ni have values of 357.07, 232.98, 833.71 and 732.61; 49010.47, 33710.23, 74330.3 and 20783.0; 80.66, 67.50, 100.23 and 24.27; 73.30, 85.12, 242.36 and 60.41; 37.21, 22.09, 44.32, and 16.52; 29.86, 26.28, 41.92, and 35.98; (9.26, 6.28, 11.15 and 1.48; 2881.65, 1804.52, 2827.43 and 1258.51; 35.74, 36.37, 38.55, and 18.75mg/g respectively. All the major ions, except Calcium, have concentrations greater than their background values across the depth of topsoil (0.0 m), B-horizon (0.5 m) and C-Horizon which is the evidence of contamination within the excavated waste site. Trace metals in the soil indicated higher concentration far above their background values (Table 1). Correlations in Table 2 reveal high values among Ca, Fe, Mg, Na, Zn, Co, Mn, and Ni at 0.01 significant level. This is an indication of impact of the waste on the soil which could be due to leaching from the excavated waste as a result of residence time and dissolution of these metals in the rain water that infiltrated the soil.

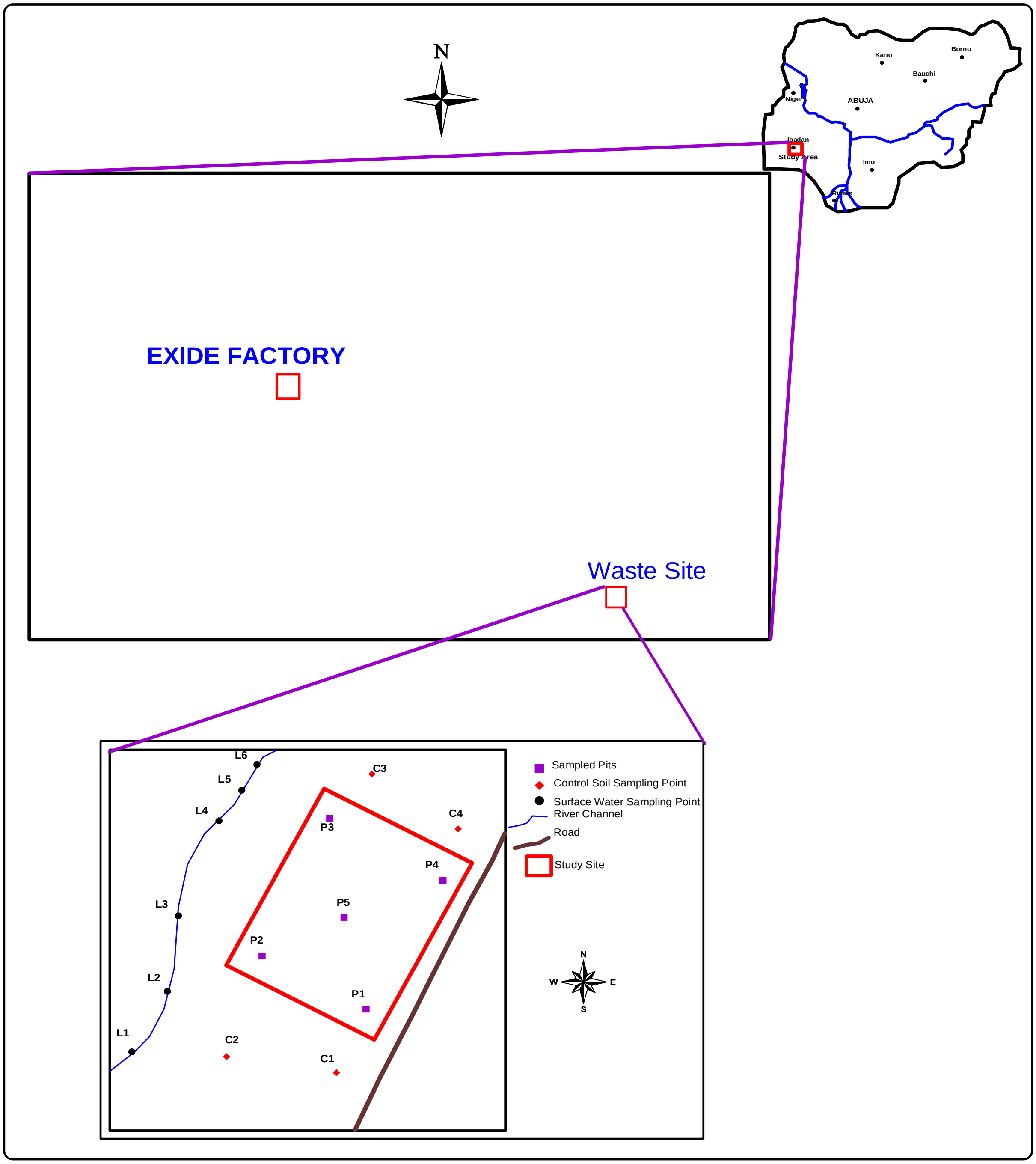

Figure: 1. Aerial Photo Image of the Study area, (Adapted from Google-earth Image, 2011)

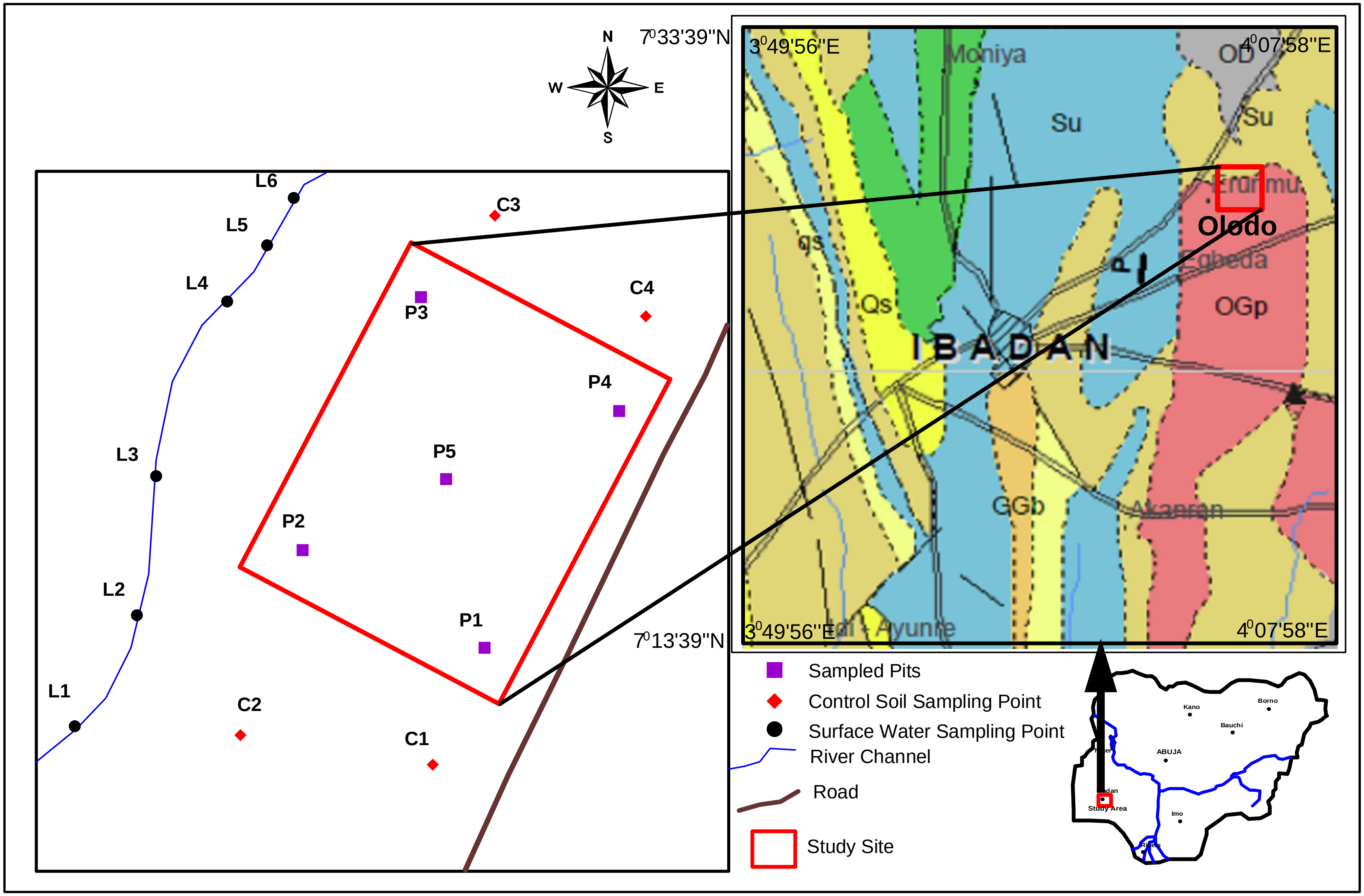

Figure: 2. Map of the study with Sketch of the dump site. (Modified from NGSA, 2006)

Table 1: Statistical Summary of the Chemical analysis of the Soil sampled from the Pits and the controlled soil sample.

PARAMETERS	TOP SOIL AT 0.0M N=5			SOIL AT DEPTH 0.5M N=5			SOIL AT DEPTH 1.0M N=5			CONTROL SOIL SAMPLE N=4			BC-SW	
PAR(mg/g)	**AVE**	**MIN**	**MAX**	**AVE**	**MIN**	**MAX**	**AVE**	**MIN**	**MAX**	**AVE**	**MIN**	**MAX**	**MEDIAN**	
Ca	291.55	120.13	885.04	163.05	121.53	280.06	605.892	49.54	2000.06	3915.37	66.04	13300.1	4800	5571
Mg	3682.11	2260.14	5750.12	2092.30	1445.63	2590.34	3237.36	2705.68	3700.17	2139.14	1370.33	3735.42	1300	511
K	2536.24	1325.68	4430.17	1407.33	870.11	1805.36	1724.45	1115.6	2415.67	1454.05	1030.42	2060.17	9400	31328
Na	7454.24	1860.17	12750.82	8506.22	1110.06	19100.23	4658.48	780.84	10300.2	322.908	243.51	428.75	560	21685
Mn	757.07	248.17	1320.34	232.98	149.57	306.08	833.706	487.51	1150.38	732.613	373.84	1430.34	395	228.6
Fe	49010.47	32900.08	71250.17	33710.23	28250.16	43300.19	74330.3	36750.1	105750	20763	8750.58	29950.6	27400	15555
Cu	80.66	48.75	108.55	67.50	42.55	90.15	100.228	70.25	170.04	24.275	19.75	30.55	21.5	12.4
Zn	73.30	63.55	87.55	85.12	59.95	137.52	242.358	148.06	328.55	60.4075	56.61	65.55	108	70.7
Co	37.21	14.45	61.95	22.09	9.92	34.80	44.342	19.46	81.56	16.515	8.86	24.93	18.4	4.1
Cr	29.86	25.28	37.23	26.28	21.83	36.08	41.918	24.73	63.95	35.9775	21.73	64.45	58	83.4
Cd	9.26	1.95	32.83	6.28	2.05	12.35	11.15	2.95	22.9	1.4825	1.15	1.78	0.1	0.19
Pb	2881.65	419.54	10630.04	1804.52	600.53	5465.43	2827.43	1131.04	5515.46	1258.51	176.54	2450.81	46.4	67.9
Ni	35.74	19.64	42.83	36.35	17.45	55.35	38.546	20.53	61.13	18.75	13.65	23.36	24.1	11.4

BC-SW Background Concentration in Southwest Soil.

Table.2. Correlation between Major Cations and Trace Metals in Soil

Parameters	**Ca**	**Mg**	**K**	**Na**	**Mn**	**Fe**	**Cu**	**Zn**	**Co**	**Cr**	**Cd**	**Pb**	**Ni**
Ca	1												
Mg	.166	1											
K	.022	**.886****	1										
Na	-.296	.303	.351	1									
Mn	**.499***	**.455***	.321	-.185	1								
Fe	-.190	**.550****	**.431***	.337	.145	1							
Cu	-.327	.239	-.008	.204	-.185	**.496***	1						
Zn	.106	.175	-.023	-.046	.300	**.653****	.391*	1					
Co	-.133	**.571****	**.558****	.397*	**.540****	**.730****	.096	**.444***	1				
Cr	-.152	-.012	-.060	-.147	.179	-.040	.147	**.434***	-.047	1			
Cd	.175	.044	.044	-.021	.259	**.458***	.051	.373	**.503***	-.169	1		
Pb	.144	-.279	-.397*	-.372	-.199	-.100	.386	.219	-.358	.153	-.003	1	
Ni	-.232	.381	**.451***	.703**	.143	**.631****	-.026	.281	**.764****	-.212	**.496***	-.405*	1

*Correlation is Significant at the 0.05 Level (1-Tailed)

**Correlation is Significant at the 0.01 Level (1-Tail)

FACTOR AND COMPONENT ANALYSIS

Table: 3 Factor and Component Analysis of the soil Major ions and Trace Metals.

	Component		
Parameters	**1**	**2**	**3**
Co	0.919	-0.015	0.099
Fe	0.836	0.373	0.008
Ni	0.830	-0.055	-0.336
Mg	0.741	-0.246	0.198
K	0.702	-0.395	0.006
Cd	0.480	0.257	0.100
Cu	0.227	0.704	-0.088
Pb	-0.388	0.652	0.188
Zn	0.462	0.641	0.442
Mn	0.419	-0.302	0.766
Na	0.537	-0.077	-0.656
Ca	-0.126	-0.556	0.579
Cr	-0.057	0.384	0.424
%Variance	33.397	17.446	15.755
Cumulative	33.397	50.844	66.599

Several authors such Tijani et al (2005) and Abimbola et al (2008) have employed the Principal Component statistical method. This analysis was performed on the soil analytical data in order to better understand their interrelationships, source and to explore the reduction of the experimental variables. Components, eigenvalues and associated variance are explained in the chemical data and communities. All the three components had eigenvalues higher than one (the most significant one) (Miller and Miller 2000). Component 1 assigned factor values ranging from 0.537 in Na to 0.919 in Co which include Ca, Mg, K, Fe and Ni. Component 2 has factor range from 0.641 to 0.704 with metals member of Cu, Pb and Zn while Component 3 comprises of Mn with factor value 0.766. Percentage variance values of Component 1, 2 and 3 are 33.79, 17.446 and 15.755% respectively. Component 1 revealed a typical lateritic soil chemically enriched by chemical leaching from the waste while Components 2 and 3 typified soils containing disseminated metals from the degraded solid metals from electrode materials of the battery waste.

Soil Contamination Assessment

Analytical results from the surface and sub-surface soil samples from the excavated waste site was subjected to evaluation using Hakanson (1980) for their Contamination Factor (CF) and assessment of Degree of Contamination (C_{deg}). The values revealed low to very high level of contamination from the top soil to sub-surface soil at depth 0.5 m and 1 m respectively. The results also revealed considerable to very high degree of contamination from the topsoil to the sub-surface soil with highest degree of contamination observed in the sub-surface soil named Horizon-C which is probably due to gravitational effect on leached metals. See Tables 4, 5, 6 and 7.

Table.4. Degree of Contamination Classification

Index Range	**Description**
Cdeg<8	Low degree of contamination
8<Cdeg<16	Moderate degree of contamination
16<Cdeg<32	Considerable degree of contamination
32<Cdeg	Very high degree of contamination

Table.5. Contamination Factor Classification

Index Range	Description
C'f>1	Low contamination factor
1<C'f<3	Moderate contamination factor
3<C'f<6	Considerable contamination factor
6<C'f	Very high contamination factor

Table.6. Summary of Contamination Factors of Trace metals in the Soil

	Top Soil		B-Horizon		C-Horizon		Control Samples	
Trace Metals	**Min**	**Max**	**Min**	**Max**	**Min**	**Max**	**Min**	**Max**
Mn	0.67	3.54	0.40	0.82	1.31	3.08	0.1	3.83
Fe	3.76	8.14	3.23	4.95	4.20	12.08	0.1	3.42
Cu	2.53	5.62	2.20	4.67	3.64	8.81	0.1	1.58
Zn	1.12	1.55	1.06	2.43	2.62	5.80	0.1	1.16
Co	1.63	6.99	1.12	3.93	2.20	9.21	0.1	2.81
Cr	1.16	1.71	1.00	1.66	1.14	2.94	0.1	2.97
Cd	1.70	28.55	1.78	10.74	2.57	19.91	0.1	1.55
Pb	2.38	60.21	3.40	30.96	6.41	31.24	0.1	13.88
Ni	1.44	3.14	1.28	4.05	1.50	4.48	0.1	1.71

Table.7. Classification of degree of contamination base on number of samples from each depth

	Soil Degree of Contamination			
Soil Type	**Cdeg<8**	**8<Cdeg<16**	**16<Cdeg<32**	**32<Cdeg**
Top Soil	0%	0%	40%	60%
B-Horizon	0%	0%	80%	20%
C-Horizon	0%	0%	0%	100%
Control Samples	0%	25%	75%	0%

Environmental Status and Implications

The trilinear diagrams of Piper (1953) are very useful in determining chemical relationships in groundwater in more definite terms than is possible with other plotting methods (Schoeller, 1965). Piper's trilinear diagram method is used to classify the groundwater, based on basic geochemical characters of the constituent ionic concentrations. This can be a very useful tool in detection of contamination as the expected water characterization in the basement rock groundwater is HCO_3^- water type. Any other types found here is an indication of anomalies, which could be due to mineral dissolution or point source pollution. Chemical data of the groundwater samples collected from the study area are plotted in the Piper's diagram (Figure 3). The diagram revealed two water type in the study area with 20% of SO_4-Cl and 80% of Na(K)-HCO_3. The SO_4-Cl water type indicates pollution and contamination from the waste site as a result of possible run-off that discharged directly into the adjacent river. 80% of the sample revealed low contamination and pollution which could be as a result of dilution in one hand on surface water and soil attenuation on the other hand in the shallow hand dug well samples. The sampled water also revealed higher values of some trace metals (Figure 5) such as Mn, Fe and Pb. Analytical hydrochemical data when compared with their respective WHO (1993) standard (Table 8) revealed that cation such as Na and Cl show values higher than the standard while trace metals such as Mn, Ni, Pb, Cd and Fe also recorded higher values, all of which agree with the result in the bar chart and schoeller diagram and form an indication of pollution and contamination from the excavated site. Water physicochemical parameters such as pH, EC and TDS show range of values from 7.20-7.60, 250-2660us/cm and 187.5-1995mg/l with mean values of 7.54, 913.10 us/cm and 684.83 mg/l respectively. The high value of EC is an indication of high dissolved ions in the water which is responsible for degradation of cement block in the foundation of the buildings under construction within the excavated site. In addition, inhalation of dust from this area by inhabitant can lead to serious lung ailment.

Table 8 Statistical Summary of the chemical analysis of Major ions and Trace Metals in Water

Water Samples N=10

Parameters	Min	Max	Mean	Std. Dev	WHO STD
Ca^{2+}(mg/l)	13.57	61.86	30.44	17.11	75
Mg^{2+}(mg/l)	5.15	19.96	11.58	5.79	20
Na^+(mg/l)	21.22	642.58	158.08	236.00	200
K^+(mg/l)	1.39	9.92	6.05	3.58	200
HCO^-_3(mg/l)	36.60	250.10	81.13	63.27	100
Cl^-(mg/l)	25.20	237.60	82.08	82.25	200
SO_4^{2-}(mg/l)	0.05	0.22	0.11	0.05	250
NO_3(mg/l)	0.50	4.27	1.50	1.26	10
Mn^{2-}(mg/l)	0.02	1.03	0.29	0.31	0.1
Fe^{2+}(mg/l)	0.30	2.84	1.03	0.77	1.00
Cu^{2+}(mg/l)	0.01	0.05	0.03	0.01	0.5
Zi (mg/l)	0.05	0.22	0.11	0.05	0.01
Co (mg/l)	0.00	0.02	0.00	0.01	0.01
Cr (mg/l)	0.00	0.00	0.00	0.00	0.05
Cd (mg/l)	0.00	0.06	0.01	0.02	0.003
Pb(mg/l)	0.02	1.17	0.32	0.36	0.01
Ni (mg/l)	0.00	0.09	0.02	0.03	0.02
pH (mg/l)	7.20	7.60	7.34	0.12	6.2-7.8
EC(us/cm)	250.00	2660.00	913.10	927.18	500
TDS(mg/l)	187.50	1995.00	684.83	695.38	300

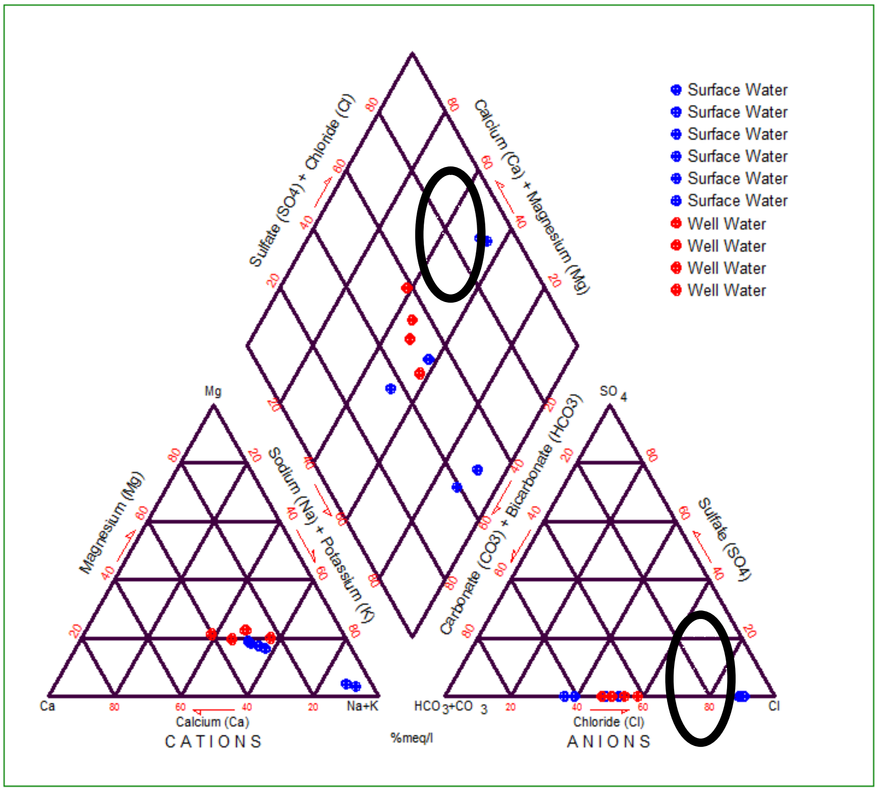

Figure: 3. Piper trilinear plot of the hydrochemical data

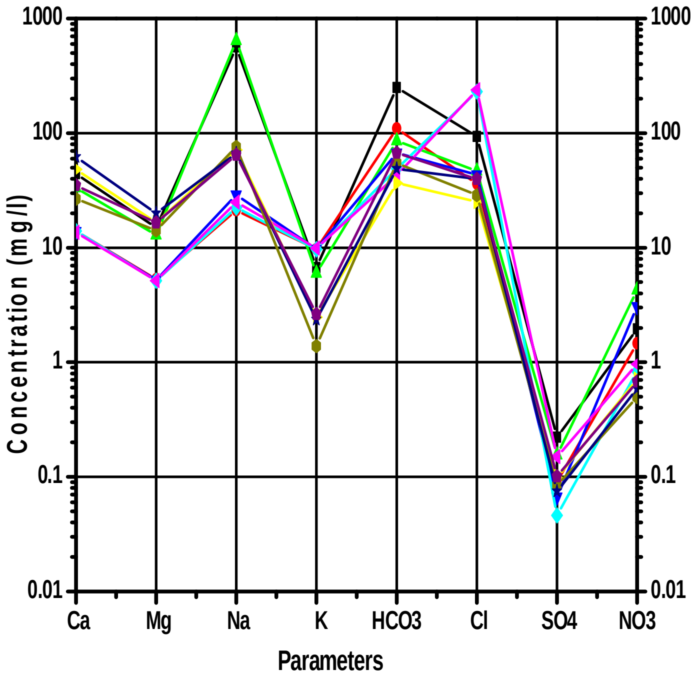

Figure: 4 Schoeller Diagram for major ions in water

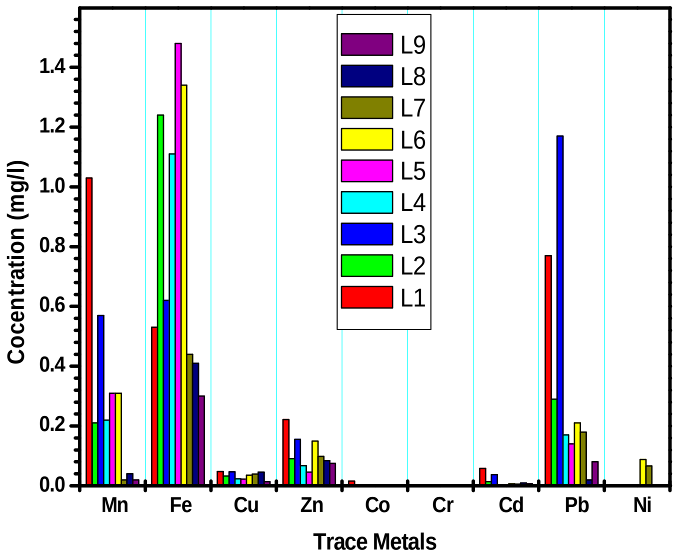

Figure: 5. Bar Chart showing the Trace Metals Distribution in water

Conclusion

This study has assessed the impacts and safety status of excavation carried out on the waste site of moribound EXIDE battery factory located in Olodo village, Ibadan, southwestern Nigeria. Results revealed considerable to very high degree of contamination of soil samples from surface and subsurface soil of the site. Contamination was also observed on the soil samples outside the site which could be as a result of contamination through wash-off by surface erosion, as the site is located on sloppy terrain which encourages down-slope movement of sediments. Piper and Schoeller diagram also revealed the impact of the waste on groundwater quality of the area as most of the samples have higher values of some trace metals. This revealed the need for pre and post excavation geochemical assessment of any waste site for better understanding of the type, scope and method to be employed for effective and efficient remediation of contaminated soil. Further detail remediation and decontamination measure should be carried out to avoid any outbreak of diseases in the near future as the area is occupied by inhabitant who believed the waste has being completely removed. Finally, geochemical mapping should be encouraged as such will help in environmental auditing, urban planning and development and proper land use.

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