Physicochemical and Heavy Mineral Characterization of Soil and Groundwater from Ekehuan (Asoro) Dumpsite, Benin City

[1]Salami S. A., [1]Ima-Ibizugbe L.O. & *[2]Itiowe K.
[1]Department of Geology, University of Benin, Benin City
[2]Department of Earth Sciences, Federal University of Petroleum Resources, Effurun
Corresponding author: itiowe.kiamuke@fupre.edu.ng

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Physicochemical and heavy mineral tests were carried out on soil, groundwater, river water, and leachate samples in order determine the negative impact of the dumpsite on soils and groundwater around the Upper Ekehuan (Asoro) dumpsite. A total of forty-two (42) samples consisting of thirty-six (36) soil / sediment, three (3) groundwater, two (2) river water samples (upstream and downstream) and one (1) leachate sample were analysed using Atomic Absorption Spectrophotometer (AAS). The pH analysis revealed values between 6.19-9.21 indicating that the soil tested are slightly acidic to slightly alkaline; while groundwater samples have pH ranges between 5.08-5.58; river water samples have values of pH between 6.52 and 6.55 and leachate has a value of 6.82. The result of soil samples shows that the concentration of Cd (1.83 mg/kg), Cr (6.31 mg/kg), Pb (3.32 mg/kg), Mn (15.04 mg/kg) and Ni (3.39 mg/kg) were much lower than the United States Environmental Protection Agency (USEPA). The soil samples have low to intermediate leaching potentials [(30-49%) - (50-69%) sand fraction]. The average values for Zn, Pb, Cu, Cd, Ni and Cr are lower than the severe effect range of the New York Sediment Criteria and the high effect range of the sediment quality criteria. The World Health Organization (WHO) and Nigeria Standard for Drinking Water Quality (NSDQW) maximum allowed limits were exceeded by the leachate's concentration of heavy metals such Ni, Cd, Cr, Mn, Fe, and Pb as well as turbidity.
Keywords: Dumpsite, Heavy minerals, Leachate, Physicochemical, Hazard assessment

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INTRODUCTION

Waste disposal is a major problem in communities of Nigeria which continues to grow with regard to population increase. Waste disposal are the measures required to manage waste from inception to its final jettison. Improper waste disposal in an area may have adverse effect on the water quality and the compositional value of the soil. For these reasons, more research has been carried out on location of the depth of potable aquifers and geo-environmental evaluation of the impacts of modern dumpsite on soil and groundwater resources (Ikem *et al*., 2002; Ojo *et al*., 2014; Dickenson *et al*., 2023). Inappropriate disposal of waste can result to adverse environmental consequences, because the bio-decomposition of these waste can adulterate both the biological and chemical composition of the water resources and the soil (Dauda & Osita, 2003; Slomczynska & Slomczynski, 2004; Singh *et al*., 2008; Regadio *et al*., 2012; Li *et al*., 2014).

Gully erosion, according to Akujieze 2004, eliminates the top soil and makes it more vulnerable to contamination and pollution, particularly when garbage disposal is done on an open site. In Awka in Anambra State, some communities dispose of their garbage in open water systems which are then carried to the surface water body (Okoye, 2004). The three main causes of the rise of urban garbage in Nigeria are the heavy consumption patterns of people in urban areas, population growth, and poor waste management practices by relevant authorities (Ajadike, 2001).

The use of heavy metal study has been an important tool to check and regulate environmental impact assessment in urban areas (Asuen *et al.*, 2012). Heavy metal presence can cause degradation of soil organic matter and reducing of the fertility potential of the upper soil layer. In general, soil reacts more to air and water than external influence and can cement smaller substances into composite (Ukpebor *et al.*, 2003). Soils that are close to the waste yard have higher tendency to have high number of organic constituents, high concentration of hazardous materials and heavy metals than soils that are far away (Imeokparia *et al*., 2009; Imasuen & Omorogieva, 2013). Low levels of heavy metal contamination are recognized to have possible effects on the environment, human health, and the ground water ecosystem over the long run (Omorogieva *et al.*, 2013). The sources of these heavy metals range from industrial to municipal generation, automobiles, agriculture and poor land practices.

According to Allen *et al*. (1991), the kind of metals and chemical components have a major impact on the transport method of a metal in the groundwater and soil. Chemistry prevents metals from being adsorbed or precipitated, preventing metals from moving through groundwater (Evanko & Dzombak, 1997). Imeokparia *et al.* (2009) carried out a study of heavy metal concentration of some dumpsites in Benin City and found out that the concentration of some heavy metals was very high compare to findings given by Ihenyen (1988). Leachate from the Ikhueniro dumpsite has a considerable impact on subsurface water resources, according to research by Edokpayi (2014).

In order to address the issue of water scarcity, Ezomo and Akujieze 2011 employed vertical electrical sounding survey as a technique to search for groundwater in Oluku in Edo State. Their research determined that the aquifer zone that can provide potable water is wet sand/clean sand. The groundwater in Benin West Moat - Ekenwan gully was evaluated for soil degradation and found to contain heavy metals and coliform, which would be harmful to human consumption (Akujieze & Oteze, 2007). In his research, Adesoji 2004 noted that numerous dump sites in the area are poorly managed and that these sites act as a haven for germs that cause a variety of ailments. In order to assess the soil's appropriateness for residential, agricultural, and industrial uses, Ukpebor and Unuigbe (2003) employed atomic absorption spectrophotometry. They discovered that the soils near Benin City's dumpsites are heavily polluted by heavy metals.

Igboama *et al*. (2022) carried out a review on the adverse effect of groundwater contamination in a dumpsite using geophysical and geochemical techniques, the result obtained using soil resistivity methods showed areas of low resistivity as leachate. Soil geophysical and geochemical study was carried out in Ekehuan dumpsite in Benin City to in order to access the adverse effect of the dumpsite on the groundwater quality, the result identified five to eight geo-electric layers and the dipole-dipole profiling low resistivity in some areas which indicate the presence of leachate (Morgan *et al.,* 2023).

In Upper Ekehuan/Asoro Quarters, there is still a limitation in knowledge as regards effects of dumpsites in the environment and to health of residents living close. Therefore, it is important to enlighten the public about the health implication of indiscriminate dumping of refuse. The findings of the study will also serve as environmental data base for further studies. The significance of the study therefore is to identify the various sources of toxic heavy metals in the study area as well as its environmental and health implications and to provide solutions to minimize or eliminate them from further accumulation in the environment. This study's aim is to evaluate the soil and groundwater quality in and around the Asoro dumpsite. The objectives are to determine the physicochemical parameters in the soil, groundwater, river water and leachate, to present and interpret results, to proffer solutions on environmental restoration and sustenance.

The study area is located within Upper Ekehuan Area (Asoro Quarters) in Ovia North Local Government Area, Edo State on latitude 60 19’ 20’’ N – 60 19’ 40’’ N and longitude 50 35’ 0’’E - 50 35’20’’E in the Niger Delta region of Nigeria (Figure 1).The top most Formation, the Benin Formation of the Niger Delta where the study area seats is made up of continental sandstones (Itiowe & Lucas, 2022a; Itiowe & Lucas, 2022b; Itiowe *et al.,* 2020; Itiowe *et al*., 2021; Itiowe *et al*., 2023). The study area comprises a relatively sloppy terrain with a basin-like shape. Refuse and other waste materials are being dumped around. The middle of the dumpsite contains stagnant leachate suspected to have gotten its origin from surface flow and leaching of waste materials. This may be having a direct contact with the ground water body.

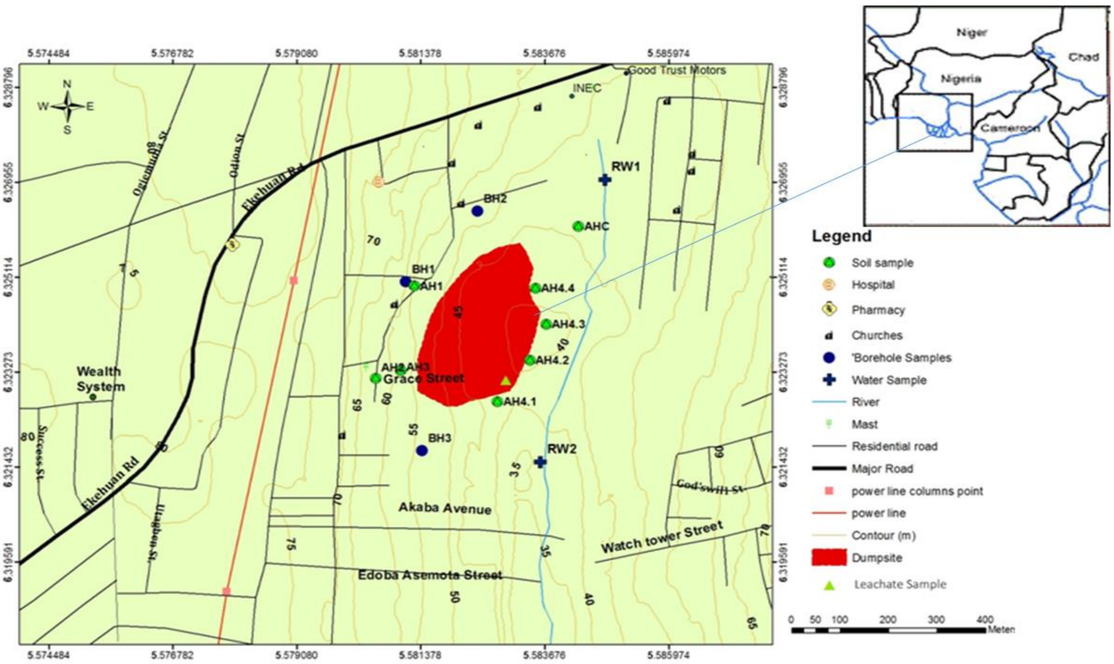

Figure 1: Location of the samples

MATERIALS AND METHODS

All sample locations were taken at different points all around the dumpsite and global positioning system readings were taken at all sample locations. The soil samples collected were kept in a polythene and labelled properly. Four of the auger holes had samples taken at 15cm, 30cm, 2feet, 4feet, 6feet, 8feet and 10feet depths. A total of thirty-six (36) soil samples were collected with the aid of a soil auger at the various depths. For elemental analysis for the soil samples using Atomic Absorption Spectrophotometer (AAS). Three soil samples were collected at depths 0-15cm, 15-30cm and 60.96cm (2ft) for Auger (AU1), Auger (AU2), Auger (AU3), and Auger (AUC) respectively. While two soil samples were taken at 0-15cm and 15-30cm for Auger (AH4.1), Auger (AH4.2), Auger (AH4.3) and Auger (AH4.4) respectively.

For the grain size analysis, a total of twelve samples were collected. At the following sample locations AH1, AH2, AH3 and AHC, four samples each were taken at depths 4ft, 6ft, 8ft and 12ft.

One (1) leachate sample was collected at a location within the dumpsite where it was observed to have gathered through seepage from the top of the dumpsite. Three (3) groundwater samples from boreholes at different locations around the dumpsite and two river water samples were also collected from a flowing river- Ogba (upstream and downstream) at one part of the dumpsite. They were collected with plastic containers. The containers were properly rinsed with distilled water and dried to remove any form of impurity before the samples were taken. They were properly labelled upon collection and transported to the laboratory same day. The water samples were preserved with 1ml nitric acid (HNO_3) and refrigerated.

RESULTS AND DISCUSSION

Physicochemical Analysis of Soil

The results of soil analyses are presented in the Tables 1 and 2. Result of soil physio-chemical analysis shows slightly acidic to slightly alkaline, with pH figures ranging from 6.19-9.21 with an average of 7.77. The various charts on some of the soil physicochemical parameters show that the control samples (AHC) have concentrations higher than some other sample locations at the various depths, while others are observed to have concentration higher than the sample that was used as control. Ordinarily, the control sample is supposed to have concentration lower than the samples from dumpsite locations, but this can be attributed to the fact that the control location might have been part of the dumpsite in the past.

Table 1: Soil analysis (AH1, AH2, AH3, AHC)

Parameters	Units	AH1	AH1	AH1	AH2	AH2	AH2	AH3	AH3	AH3	AHC	AHC	AHC
		0-15cm	**15-30cm**	**60.96 cm (2ft)**	**0-15cm**	**15-30cm**	**60.96 cm (2ft)**	**0-15cm**	**15-30cm**	**60.96 cm (2ft)**	**0-15cm**	**15-30cm**	**60.96cm (2ft)**
pH		6.55	6.35	6.40	7.66	7.76	6.19	6.96	6.43	6.39	8.19	8.24	8.55
EC	uS	597	367	325	566	451	387	617	564	408	544	517	19
Porosity		50	37.5	37.5	37.5	44.5	44.5	31.32	46.85	50	37.5	46.85	38.86
OC	%	0.83	0.77	0.19	0.06	1.69	0.32	0.74	0.51	0.16	0.26	0.1	0.06
OM	%	1.43	1.33	0.33	0.1	2.91	0.55	1.28	0.88	0.25	0.45	0.17	0.1
Na	mg/kg	0.79	0.64	0.32	1.35	1.03	1.26	1.35	1.11	0.79	0.47	0.24	0.40
K	mg/kg	0.36	0.36	0.22	3.12	2.16	3.06	1.86	0.66	0.22	0.57	0.68	0.46
Ca	mg/kg	24.0	16.8	16.0	40.8	18.4	28.0	27.2	12.0	10.4	23.2	22.44	20.0
Mg	mg/kg	6.67	8.00	5.33	24.00	9.34	13.34	10.67	16.34	9.34	26.67	13.34	4.00
Mn	mg/kg	18.1	20.85	19.40	19.35	19.70	10.85	20.35	13.6	20.65	15.65	14.65	9.65
Zn	mg/kg	19.85	22.6	21.85	20.65	18.65	17.8	25.6	19.6	13.35	20.55	22.3	15.85
Cd	mg/kg	2.05	2.6	2.4	1.75	1.95	1.8	2.65	2.3	2.15	1.6	1.35	1.0
Cr	mg/kg	10.65	5.1	7.35	7.85	9.7	9.1	7.0	5.9	4.1	6.6	6.2	4.0
Cu	mg/kg	46	37.8	31.15	44.25	38.15	18.15	37.4	37.15	26.5	25.65	23.7	21.8
Pb	mg/kg	5.6	4.8	4.1	5.3	2.7	2.2	4.85	4.05	3.15	3.15	2.45	2.1
Fe	mg/kg	238.65	198.1	208.65	191.25	181.1	144.4	231.45	201.15	170.65	143.75	144.7	133.15
T.N	%	0.369	0.285	0.303	0.317	0.322	0.278	0.300	0.322	0.253	0.374	0.246	0.285
P	mg/kg	11.69	8.98	10.13	7.25	2.33	1.46	2.46	1.82	1.64	2.35	1.61	1.30
Ni	mg/kg	1.65	2.75	1.70	2.65	3.60	4.75	6.00	3.85	4.30	3.70	2.95	4.10

Table 2: Soil analysis (AH4.1- 4.4, AHC)

Para.	Units	AH4.1 0-15cm	AH 4.1 15-30cm	AH4.2 0-15cm	AH4.2 15-30cm	AH4.3 0-15cm	AH 4.3 15-30cm	AH4.4 0-15cm	AH 4.4 15-30cm	AHC 0-15cm	AHC 15-30cm	AHC 60.96cm (2ft)
pH		8.33	7.42	8.99	8.91	9.21	9.05	8.93	8.94	8.19	8.24	8.55
EC	uS	247	134	110	162	106	101	88	656	544	517	19
Porosity		52.8	46.81	43.69	33.52	41.89	39.5	43.69	51.6	37.5	46.85	38.86
OC	%	0.38	0.35	0.54	0.32	0.16	0.64	0.51	0.22	0.26	0.1	0.06
OM	%	0.66	0.60	0.93	0.55	0.28	1.10	0.88	0.38	0.45	0.17	0.1
Na	mg/kg	1.11	0.40	1.25	0.79	0.47	0.55	0.32	0.79	0.47	0.24	0.40
K	mg/kg	0.41	0.41	3.65	0.30	0.57	0.66	0.30	4.37	0.57	0.68	0.46
Ca	mg/kg	30.4	17.6	78.4	46.4	44.8	28.0	24.0	20.0	23.2	22.4	20.0
Mg	mg/kg	6.67	10.67	10.67	9.34	8.00	5.33	5.33	13.34	26.67	13.34	4.00
Mn	mg/kg	14.25	7.75	18.7	17.45	12.85	13.15	12.7	11.15	15.65	14.65	9.65
Zn	mg/kg	21.85	11.4	18.05	19.5	18.3	18.7	18.6	14.3	20.55	22.3	15.85
Cd	mg/kg	1.15	BDL	2.15	2.5	1.1	1.3	1.5	1.55	1.6	1.35	1.0
Cr	mg/kg	5.75	3.4	4.35	4.8	8.85	6.5	5.8	3.25	6.6	6.2	4.0
Cu	mg/kg	24.6	29.15	41.35	34.20	31.35	19.15	24.30	17.0	25.65	23.7	21.8
Pb	mg/kg	2.7	2.95	4.25	3.75	2.2	2.0	1.7	2.3	3.15	2.45	2.1
Fe	mg/kg	138.65	136.4	158.8	204.1	144.95	139.6	153.6	106.65	143.75	144.7	133.15
T.N	%	0.327	0.207	0.244	0.025	0.278	0.306	0.246	0.301	0.374	0.246	0.285
P	mg/kg	6.95	7.37	27.23	14.29	20.79	6.21	7.83	4.41	2.35	1.61	1.30
Ni	mg/kg	3.20	3.10	1.75	2.30	2.70	3.95	5.20	3.60	3.70	2.95	4.10

Soil Heavy Metals analyses

Hazard assessment of heavy metals

Table 3 displays the results of the soil samples' heavy metal concentrations that were acquired from the Ekehuan /Asoro dumpsite. The concentration of heavy metal occurrence takes the following order of Fe > Cu > Zn > Cr > Pb > Ni >Cd. Because they can contaminate plants, pose a threat to animals, and ultimately harm human health through the food cycle chain, heavy metals like Cd and Pb have their implications (Imeokparia *et al*., 2009). Table 4 compares the average concentration of heavy metals in the dumpsite with the New York Sediment Criteria, the criteria is divided into low effect range effect and severe effect range effect; and the Sediment Quality Criteria, the criteria which is divided into low effect range effect (ISQG Low) and high effect range effect (ISQ High). The low range effect denotes that the sediment contaminants do not have adverse effect on living organisms in the sediment. While the high range effect denotes that, the contaminants certainly have adverse effect on the organisms that live in the sediment. According to this comparison, the level of all the heavy metals falls below the low-level effect range (ISQG-Low level) of the Sediment Quality Criteria and the lowest effect range of the New York Sediment Criteria. This indicates that the sediment contaminated do not have adverse effect on the living organism.

Result of soil analysis was compared to regulatory standard on dumpsite by Imeokparia *et al.* (2009) for cadmium, chromium, copper, lead, manganese and nickel (Table 5). Cadmium was observed to have an average of 1.74mg/kg as against 10.00 ± 1.14, 6.90 ± 0.82 and 5.0 ± 0.78 implying a low concentration. Chromium was observed to have an average concentration of 6.31mg/kg as against 11.15 ± 1.30, 9.20 ± 0.94, 6.15 ± 0.80; which is observed to be low. Lead and manganese are also seen from the table 4.6 to be having lower concentration. Nickel was observed to have an average concentration of 3.39mg/kg against 11.40 ± 0.70, 62.10 ± 2.00 and 15.00 ± 1.18, also implying a low concentration. Copper was observed to have an average concentration of 30.44mg/kg as against 13.25 ± 1.02, 11.05 ± 1.22 and 5.90 ± 0.64, implying a higher concentration for the three different dumpsites according to Imoekparia *et al.* (2009).

Table 3: Heavy metal concentration of the soil at Ekehuan / Asoro dumpsite

LOCATION	SAMPLE	Zn (mg/kg)	Cu (mg/kg)	Cr (mg/kg)	Cd (mg/kg)	Ni (mg/kg)	Pb (mg/kg)	Fe (mg/kg)
1	AH1; 0-15cm	19.85	46.00	10.65	2.05	1.65	5.60	238.65
1	AH1; 15-30cm	22.60	37.80	5.10	2.60	2.75	4.80	198.10
1	AH1;60.96cm(2ft)	21.85	31.15	7.35	2.40	1.70	4.10	208.65
2	AH2; 0-15cm	20.65	44.25	7.85	1.75	2.65	5.30	191.25
2	AH2; 15-30cm	18.65	38.15	9.70	1.95	3.60	2.70	181.10
2	AH2; 60.96cm (2ft)	17.80	18.15	9.10	1.80	4.75	2.20	144.40
3	AH3; 0-15cm	25.60	37.40	7.00	2.65	6.00	4.85	231.45
3	AH3; 15-30cm	19.60	37.15	5.90	2.30	3.85	4.05	201.15
3	AH3; 60.96cm (2ft)	13.35	26.50	4.10	2.15	4.30	3.15	170.65
4	AH4.1; 0-15cm	21.85	24.60	5.75	1.15	3.20	2.70	138.65
4	AH4.1; 15-30cm	11.40	29.15	3.40	BDL	3.10	2.95	136.40
4	AH4.2; 0-15cm	18.05	41.35	4.35	2.15	1.75	4.25	158.80
4	AH4.2; 15-30cm	19.50	34.20	4.80	2.50	2.30	3.75	204.10
4	AH4.3; 0-15cm	18.30	31.35	8.85	1.10	2.70	2.20	144.95
4	AH4.3; 15-30cm	18.70	19.15	6.50	1.30	3.95	2.00	139.60
4	AH4.4; 0-15cm	18.60	24.30	5.80	1.50	5.20	1.70	153.60
4	AH4.4; 15-30cm	14.30	17.00	3.25	1.55	3.60	2.30	106.65
5 (Control)	AHC; 0-15cm	20.55	25.65	6.60	1.60	3.70	3.15	143.75
5 (Control)	AHC; 15-30cm	22.30	23.70	6.20	1.35	2.95	2.45	144.70
5(Control)	AHC;60.96cm (2ft)	15.85	21.80	4.00	1.00	4.10	2.10	133.15
Min		11.40	17.00	3.25	1.00	1.65	1.70	133.15
Max		25.60	46.00	10.65	2.65	6.00	5.60	238.65
Average		18.97	30.44	6.31	1.74	3.39	3.32	168.49
EPA		364	310	---------	1.0	----------	183	Nil

Note: EPA- US Environmental Protection Agency for metal (2007)

Table 4: Concentration of heavy metals in this study in accordance with standards for sediment quality in mg/kg (modified after Seyedeh *et al*., 2012)

Subject	Cu	Pb	As	Cd	Ni	Zn	Cr	Hg
New York Sediment Criteria								
Lowest effects range	16	32	6	0.6	16	120	26	0.15
Severe effects range	110	110	33	9.0	50	270	110	1.30
Sediment Quality Criteria								
lowest effects range (ISQG-low)	16	31	6	0.6	16	120	26	0.2
High effects range (ISQG-high)	110	250	33	10	75	270	110	2
Present study (Average values)	3.32	3.32	-	1.74	3.39	-	6.31	-

Table 5: Heavy metal concentration in top soil samples, mg/kg (Adapted from Imeokparia & Onyeobi, 2009)

Dumpsite	Distance from dumpsite	Metal concentration in mg/kg							
		Zn	Ni	Cu	Pb	Cr	Cd	Mn	Fe
Iyaro	0.00	-	130±3.3	30±1.0	159.541± 4.22	120±3.30	10.20±1.20	294.5	-
	50.0	-	11.4±7.0	13.25±1.02	26.41±1.98	11.15±1.3	10.0±1.4	40±1.58	-
Siluko	0.00	-	708.0±17	16.70±0.64	63.90±2	24.0±2.3	29±0.98	344±15	-
	50.0	-	62.0±2.0	11.051±1.22	4.8±0.09	9.2±0.94	6.9±0.82	211±11.46	-
West	0.00	-	54.0±1.74	30.02±2.36	80±3.22	35.0±3.0	7.30±0.99	228±4.4	-
Circular	50.0	-	15.1±11.0	5.90. ± 0.64	18.0±1.30	6.15±0.8	5.00±0.78	54.0±2.27	-
This study		-	3.39±0.54	30.44±4.11	3.32±0.56	6.31±0.99	1.74±0.03	15.54±1.89	-

Soil Particle Size Fraction and Leaching Potential

The subsurface depths of the dumpsite were investigated in order to assess their ion mobility and propensity for leaching. Brown *et al.*, 1997 summarised the percentage sand fraction and the leaching potential that characterizes the fraction (Table 6). The soil leaching potential ranges from low to moderate depending on how much soil fractionation is present. (Table 7).

Table 6: Scale of soil leaching potential (According to Brown *et al.*, 1997)

Texture	Leaching Potential
(90-100) % Sand fraction	V.H. (Very high potential)
(70-89) % Sand fraction	H. (High potential)
(50-69) % Sand fraction	I. (Intermediate potential)
(30-49) % Sand fraction	L. (Low potential)
(>30) % Sand fraction	V.L (Very low potential)

Table 7: Grain size percentages of soil samples / soil leaching potentials.

		Particle Size Distribution				
Sample location	Depth (ft)	% Clay	% Silt	% Sand	% Gravel	Soil leaching potential [30].
AH1	4	37	3	59	1	I. (Intermediate)
AH1	6	31	11	57	1	I. (Intermediate)
AH1	8	46	12	41	1	L. (Low)
AH1	10	34	13	62	1	I. (Intermediate)
AH2	4	18	25	56	1	I. (Intermediate)
AH2	6	34	13	62	1	I. (Intermediate)
AH2	8	46	1	52	1	I. (Intermediate)
AH2	10	34	17	47	2	L. (Low)
AH3	4	21	20	58	1	I. (Intermediate)
AH3	6	15	29	55	1	I. (Intermediate)
AH3	8	37	12	50	1	I. (Intermediate)
AH3	10	34	13	52	1	I. (Intermediate)
AHC	4	18	17	64	1	I. (Intermediate)
AHC	6	12	21	65	2	I. (Intermediate)
AHC	8	15	17	64	4	I. (Intermediate)
AHC	10	14	14	62	9	I. (Intermediate)

Physicochemical Analysis of Groundwater and Leachate

Result of water physicochemical analysis reveals that the pH of water samples around the dumpsite ranges from 5.08-6.82 (Table 8). This simply shows that they are below the maximum permissible limits of NSDWQ (2007) and WHO (2017). From the range of values, it can be seen that the water is slightly acidic. Leachate and river water samples are also observed to be acidic and this could be an influencing factor. Acidity can cause water to have a sour taste and not desirable for consumption.

For the electrical conductivity, all water samples (including leachate and river water samples) collected fall between 21-783µS/cm. The electrical conductivity for all ground water samples is seen to be lower than the WHO (2017) and NSDWQ (2007) maximum permissible limits. The ability of water to conduct electric current is determined by its electrical conductivity. This is in most cases influenced by dissolved salts such as sodium chloride and potassium chloride.

The values of chloride ion ranges from 106.5-177.5mg/l for the three water samples. The leachate sample was observed to be 124.3mg/l and river water samples were observed to be 35.5mg/l and 35.5mg/l respectively. Water samples have chloride content higher than the WHO and NSDWQ limits. Chloride is a very important parameter in water that affects taste especially when present in high concentration.

Values of sulphate for the three water samples here are seen to be far lower than that of the NSDWQ and WHO limits. The leachate is observed to have higher concentration of sulphate. Although the sulphate concentration in this area is much lower than the guidelines, the high levels of sulphate give the water a laxative impact when drunk and a bitter or astringent flavour.

The nitrogen cycle and nitrate pollution are significantly influenced by nitrates, a salt that is water soluble. Their presence in water is usually caused by seepage of human sewage from private septic tank systems. Nitrate ranges from 0.01-0.76mg/l for the water samples collected with a mean value of 0.38mg/l. The leachate value is 0.07mg/l, while the river water samples have values of 0.23mg/l and 0.26mg/l respectively. All are far below the WHO and NSDWQ standards as seen in the chart.

For groundwater samples collected, the sodium ion values range from 0.44-1.11mg/l. It is very essential in drinking water but should not be in concentration that exceeds the maximum permissible limit. Here the permissible limit for Na^+ was not specified.

The figures of iron range from 0.40-0.41mg/l for water samples with a mean value of 0.41mg/l. All water samples collected have higher content of iron than the WHO (2017) maximum permissible limit and the NSDWQ limit for water. Iron content in the leachate sample is 2.27mg/l. Leachate remains the major source by which iron is introduced into the subsurface water system. River water samples have values of 0.27mg/l and 0.24mg/l respectively. The result shows a very high level of iron as compared to WHO standard and NSDWQ (except for the river water). Iron is an essential element in the human body but when the concentration is beyond the tolerable limit, it becomes toxic and contributes to the hardness of water.

The range of zinc for groundwater samples falls between 0.11-0.18mg/l having a mean value of 0.15mg/l. Leachate sample value is 0.34mg/l, while the river water samples have values of 0.13 and 0.15mg/l respectively. It is observed the samples all fall below the WHO limit and NSDWQ limit for drinking purpose. The average of all the water samples is below the NSDWQ limit and WHO standards. Zinc is hazardous metal and a week killer (Anglin-Brown, 1995). Excessive amount of zinc in the soil will result to phytotoxicity (Abbasi *et al.*, 1998)

The range of copper content in the water samples varies from 0.11-0.32mg/l, the mean value for this is 0.24mg/l. Value of 0.45mg/l was obtained for leachate sample. Values of 0.13mg/l and 0.17mg/l were obtained for river water samples 1 and 2 respectively. Result from all water samples fall below the WHO Limit and also the NSDWQ limit. High level of Cu in water has been traced to gastrointestinal symptoms such as nausea, abdominal pain, diarrhoea and vomiting (Turnland, 1998).

Nickel ranges from 0.01-0.03mg/l for all groundwater samples collected at various locations around the dumpsite with a mean value of 0.02mg/l. This result is far above the WHO and NSDWQ standards for potable water. Leachate sample have value of 0.28mg/l. The concentration of leachate could also be an influencing factor in the presence of high amount of nickel in the water. River water samples have values of 0.07mg/l and 0.03mg/l respectively.

Cadmium values for the three borehole samples and the two river water samples are below detection level (BDL). Leachate sample have value of values of 0.01mg/l. Groundwater samples were observed to have concentration of cadmium far lower than the WHO maximum permissible limit and the NSDWQ limits respectively. Here, results show low concentration of cadmium in the groundwater and river water samples while the leachate sample has a higher concentration than the WHO and NSDWQ limits. Cadmium is a highly toxic metallic pollutant which does not have any metabolic benefit. Excess consumption from drinking water may lead to renal tubular disease (Green *at al*., 1996).

The chromium values range from 0.010-0.011mg/l for groundwater samples collected with a mean value of 0.030mg/l. The river water samples have values of 0.013 and 0.017mg/l respectively. These are lower than the WHO and NSDWQ limits. Leachate sample was observed to have value of 0.076mg/l which is higher than the WHO and NSDWQ limits. Chromium is not known to have any biological function. It is very toxic and capable of lowering energy levels of vital organs of the human system (Flaherty, 1995).

The ground water samples' lead concentration was below the detection level (BDL). This is lower than the WHO maximum permissible limit for lead in potable water. Lead is known to be very toxic and can be very harmful. River water sample 1 is below detection level (BDL) while the 2 has a value of 0.01mg/l. Leachate sample have a value of 0.06mg/l which is above the WHO and NSDWQ limits for lead in water.

Values of total dissolved solids of both organic and inorganic matter were found to be far lower than the NSDWQ (500) and WHO (1500) maximum permissible limits for all water samples.

Table 8: Comparison of the analysed water parameters with NSDWQ and WHO standards

Parameters	Units	BH1	BH2	BH3	RW1	RW2	SW1	NSDWQ (2007)	WHO (2017)
pH		5.08	5.32	5.78	6.52	6.55	6.82	6.5-8.5	6.90-9.50
EC	uS/cm	23	46	21	75	89	783	1000	1200
Cl^-	mg/l	106.5	177.5	124.3	35.5	35.5	124.3	0.01	250
SO^{2+}_4	mg/l	2.50	0.90	0.49	0.56	30.8	0.14	100	500
NO^3	mg/l	0.76	0.01	0.28	0.23	0.26	0.07	50	50
PO^{3+}_4	mg/l	0.039	10.24	0.029	0.039	0.048	0.039	-	-
Na^+	mg/l	0.83	1.11	0.44	0.22	4.49	1.51	-	-
K^+	mg/l	1.01	2.02	0.08	0.78	23.9	2.50	-	-
Mg^{2+}	mg/l	0.49	0.49	1.46	2.43	1.46	7.78	-	-
Ca^{2+}	mg/l	0.8	0.8	0.8	6.4	8.0	47.3	-	-
Fe^{3+}	mg/l	0.40	0.41	0.41	0.27	0.24	2.27	0.3	1.0
Zn^{2+}	mg/l	0.16	0.11	0.18	0.13	0.15	0.34	3.0	5.0
Cu^{2+}	mg/l	0.11	0.32	0.28	0.13	0.17	0.45	1.0	2.0
Ni^{2-}	mg/l	0.01	0.03	0.02	0.07	0.03	0.28	0.02	0.02
Cd^{2+}	mg/l	BDL	BDL	BDL	BDL	BDL	0.01	0.003	0.005
V^{2+}	mg/l	BDL	BDL	BDL	BDL	BDL	0.19	-	-
Cr^{6+}	mg/l	0.010	0.011	0.010	0.013	0.017	0.076	0.05	0.05
Pb^2+	mg/l	BDL	BDL	BDL	BDL	0.01	0.06	0.01	0.05
Color		0.005	0.009	0.568	0.001	0.006	0.038	15	15
Turbidity	mg/l	0.0	4.0	0.0	2.0	4.0	211.0	5.0	5.0
Hardness	mg/l	0.24	0.04	0.16	0.32	0.56	1.8	-	500
TDS	mg/l	0.2	0.003	0.047	0.02	0.06	0.002	500	1500

BH = Borehole, RW = River water, SW = Surface water (leachate), BDL = Below detection level.

CONCLUSION

The study has critically investigated the impact of Upper Ekehuan/Asoro dumpsite on soils and groundwater around the vicinity. It was observed from physicochemical analysis that groundwater around the dumpsite is not just slightly acidic, but the leachate contains heavy metals like Iron in higher concentrations higher than the WHO, 2017 and NSDWQ, 2006. This may have been influenced by the leachate that is being washed down slope from waste materials arising from anthropogenic activities which include dumping of refuse, waste water and faeces.

Also, the leachate sample has higher concentrations of chromium, lead, Nickel, cadmium than the WHO and NSDWQ standards. There is a high-risk potential in the environment as a result of the continuous leaching of waste materials from the top of the heap of waste materials to the bottom through the rugged terrain and could have been the main source of the contamination of groundwater through seepage. Heavy metals and other forms of contaminants may find their way into groundwater body. Result of soil physicochemical analysis revealed that the soil is slightly alkaline and slightly acidic in places. It was observed that the soils around the dumpsite have low contamination when compared with regulatory standards. The soil presently poses a threat to food crops around the dumpsite especially those that are edible to residents living within the vicinity. The continuous dumping of waste will soon render the land completely useless and may cost a lot of money to remediate if not attended to immediately.

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