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Environmental Impact Characteristics And Risk Evaluation Of The Ariaria-Aba Metropolitan Solid Waste Dumpsite

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***Abstract*—This paper is focused on the determination of risk-factor pollutants in the Ariaria-Aba dumpsite, located in the Aba metropolis. This study was conducted within the period of March and May. Groundwater samples were collected at points: 15m, 25m and 35m away from the edge of the dumpsite, while the collection of soil samples were at measured vertical distances and at designated points around the dumpsite. These samples were analyzed using best practice methods. The results showed that the values of groundwater sample physicochemical parameters analyses were above WHO permissible limits, hence, indicating evidences of pollution, and therefore would require some level of treatment before being used for domestic purposes. Similarly, soil samples collected from around the dumpsite also showed high level concentrations of heavy metals which were also above the WHO limits. Thus, the enrichment of the dumpsite surrounding soil with heavy metals can also be attributed to pollutant migration from the Ariaria-Aba dumpsite which had experienced high level dumping of industrial materials (such as metals, plastics, and other synthetic waste products). An assessment of the impact of these pollutants on the environment (in relation to lead (Pb), chromium (Cr), cadmium (Cd) and mercury (Hg)) using geo-accumulation and pollution load indices showed moderate to high level contamination of the soil environment around the Ariaria-Aba dumpsite. Based on these findings, it can be inferred that the soil environment around the Ariaria-Aba dumpsite is exposed to high risk pollution. Thus, urgent steps need to be taken to put an end to open dumping in the metropolis.**

Keywords—Aba-Ariaria metropolis; dumpsite characteristics; pollution index; risk-factor pollutant, groundwater and soil samples.

1. INTRODUCTION

Aba is a big town in the south-eastern part of Nigeria. It is a metropolis characterized with bevy of industrial and commercial activities as well as large population attributable to the influx of people in search of livelihood, good economy and security. This unprecedented population growth is not only exerting pressure on its existing infrastructures such as water, electricity, road, educational institutions and housing, but also, it heightens waste generation and disposal challenges. The present population level in the city is estimated to be about 2.5 million people[1]. The goods manufactured in this city serves the needs of the residents in the states of the south-east and south-south geopolitical regions of Nigeria, like Enugu, Owerri, Port Harcourt, Bayelsa, Onitsha, Akwa Ibom etc., as well as other parts of Nigeria, including exports to other African countries like Benin, Cameroon, Ghana and Togo.

Therefore, environmental pollution in Aba metropolis could be linked to uncontrolled industrial emissions, and indiscriminate disposal of solid wastes and sewage[2]. This condition arose because of absence of organized waste management system in the metropolis such as modern waste collection and disposal facilities: waste specification system, sorting devices, landfills or central sewage disposal systems. Hence, wastes generated within the area are gathered and disposed off at local pits or at government/community designated dumpsites like the one being considered in this study (i.e. Ariaria-Aba dumpsite). Generally, as the wastes continuously contacts with air, water, sunlight, microbes and other agents in the dumpsites, degradation by solubilization, hydrolysis, corrosion, biodegradation and chemical decomposition will set in[3].

Consequently, these degraded wastes will release pollutants or toxic products with offensive emission and odor. These toxics can contact with

liquid medium, forming highly corrosive and toxic liquids called leachates. These leachates can further migrate into groundwater aquifers and other soil formations via some phenomena that can be enhanced by capillary, eutrophication, permeation and gravity forces[4, 5, 6]. These pollutants has very high tendency of contaminating groundwater aquifer within the vicinity around the dumpsite[7, 8, 9].

Pollutants from the dumpsites can be generally harmful to human and animal, and indeed the environment, especially when inhaled or ingested in high concentrations, or when it heavily interacts with dumpsite host environment. The consequences will be that of human health challenges such as respiratory disorders, organ failure, cancer, and spread of several infectious diseases. Also, the dumpsites can cause release of heavy metals into soils near it, in turn causes reduction in soil fertility, interference with ecosystem food chain, reduction in food and water quality, and food insecurity[10, 11].

However, efforts to establish the pollution status of these dumpsites, as well as proffer solutions to the attendant problems posed by them to the environment have been widely reported. Some of the notable reports are presented: Abdus-Salam[4] assessed the quantities of heavy metals contamination in selected metropolitan dumpsites in Ilorin, Nigeria, using physical, chemical and biological methods. The results showed high magnitudes of heavy metals buildup in the dumpsites soils, especially for iron (Fe), zinc (Zn), cadmium (Cd) and lead (Pb). The researcher suspected the possible spread of the heavy metals and other pollutants from the dumpsites to other places (including groundwater), because of the local practice in the town wherein degraded soils from dumpsites are applied for enriching gardens and farmlands.

Amuno[12] also assessed the heavy metals contamination level for selected dumpsites soil in Ago-Iwoye, Ogun State, Nigeria. Risk-factor parameters such as degree of contamination (CD), contamination factor (CF) and geo-accumulation index (Igeo) were estimated for the dumpsites for selected heavy metals: selenium (Se), lead (Pb) and zinc (Zn). The values of the risk-factors obtained showed high level accumulations of these metals in the dumpsites soil.

In line with the reports of Sunmonu et al.[13] for Aarada-Ogbomosho dumpsite and Abdullahi et al.[14] for Kumbosto-tannery dumpsite, Kano; Achadu et al.[15,16] were also prompted to assess the extent of contamination of selected dumpsites' soil in Port Harcourt and Benin City using geophysical method which is also called 2-D electrical resistivity imaging (or tomography). This technique was a preliminary step approach to the actual measurements of pollutants concentrations in the dumpsites. The results obtained showed the existence of probable contaminations of soils near the dumpsites because of the characteristic low resistivity and high ion concentrations shown in the dumpsites tomogram.

Achadu et al.[2] also studied the possible interaction of leachates from Benin City and Port Harcourt dumpsites with the groundwater in nearby soil environment. To achieve this, hydro-geological parameters of soil samples; physicochemical and biological parameters of borehole water samples were all assessed in order to determine the extent of the interactions. .The results showed high level of interaction between the dumpsite and the groundwater environment as evident in the increased concentrations of the physicochemical and biological parameters of the nearby groundwater environment.

In a like manner, Uyigue and Achadu[17] re-evaluated the radiological level of a previously studied dumpsite (i.e. Eliozu dumpsite) in Port Harcourt using method of gamma-ray spectroscopy. The reasons for this re-evaluation were among other factors based on: (i). Suspected dumping of radiologically contaminated materials in the dumpsite, (ii). Perceived increase in radiological exposure around the dumpsite, (iii). Possible radionuclides migration from the dumpsite to nearby soil and groundwater environments. The results showed the presence of radionuclides (such as Potassium (K-40), Uranium (U-238) and Thorium (Th-232)) both in the soil and groundwater samples, for which the activity concentrations and

equivalent dose rates of the radionuclides identified in the soil and groundwater samples were still within the IAEA and WHO permissible limits.

Also, Uyigue and Achadu[18] treated contaminated soils obtained from near Eliozu and Woji-railway dumpsites, Port Harcourt, using phytoremediation technique. Two edible plants (Fluted-pumpkin and Waterleaf) were used as test plants for the study, while method of pot experiment was used for test plant cultivation, which was monitored within a 50-day study period. The results obtained showed high uptake potentials of the test plants for heavy metals, and a progressive reduction of heavy metals in the treated soils.

This present study will focus on measuring the impact of Ariaria-Aba dumpsite on the characteristics of the surrounding groundwater and soil environments. Consequently, the presence of pollutants in the groundwater and soil samples obtained from around the dumpsite would be identified and quantified using physicochemical techniques, while the impact of the identified risk-factor pollutants in the soil environment around the Ariaria-Aba dumpsite would also be assessed using empirical techniques.

MATERIALS AND METHODS

2.1 Materials

The main materials employed for this study were soil and groundwater samples collected from near the Ariaria-Aba dumpsite location. Chemical reagents used include; Ammonium acetate (CH_3COONH_4), Nitric acid (HNO_3, 98%w/w, BDH), Hypochlorate ($HClO_4$, 90%w/w, Aldrich), methyl isobutyl ketone ($CH_3C_3H_7CH_2CO$), 99%w/w, Aldrich) and Atomic Absorption Spectrophotometer (AAS) standard solutions for Cd, Cr, Hg, Zn and Pb measurement (100 mg/l each), while the equipment and apparatuses used for this study will consists of oven dryer, weighing balance, digester, mortar and pestle**.** Others are thermometer, glassware's, sieves, filter papers (Whatman-wet-strength type), AAS, pH meter etc. Also, experimental codes and standards relevant to this work would be appropriately referred.

2.2 METHODS

2.2.1 Sample collection

(a). Groundwater Sampling:

Using some 10 liters plastic containers, groundwater samples were collected from different borehole sources located at specified distances away from the edge of the Ariaria-Aba dumpsite: 15m (as BH 1); 25m (as BH 2) and 35m (as BH 3). A control sample (as control BH) was collected from a borehole source that was at a distance 5 km away from dumpsite. All samples were preserved in an ice-chest, and were subsequently transferred to the laboratory for analyses.

(b). Soil sampling:

Soil samples were continuously collected from around the Ariaria-Aba dumpsite for within a period of three months: March to May. This was done by segmenting the dumpsite environment into four quadrants; while three soil samples were each collected per quadrant per month using a hand auger from each quadrant at depths: 0-15 cm, 15-30 cm and 30-45 cm. Soil samples obtained at same depths in the different quadrants were homogenized. The soil samples were stored in well labeled air-tight black polyethylene bags, en-route to the laboratory at the University of Port Harcourt for analyses. Control soil samples were also collected at 5 km distance from the dumpsite epicenter.

2.2.2 Procedure for Sample Analysis

(a). Groundwater Analysis:

The analyses of the groundwater samples were carried out in accordance with the American Public Health Association (APHA) standards for measurement of water and wastewater sample[26]. The procedures for analyses of groundwater samples are presented as follows:

❖ **Determination of pH, Electrical Conductivity, Chloride and Total Dissolved Solids (TDS):**

The pH, electrical conductivity, chloride and TDS were determined by procedures recommended in APHA 4500H^+B, APHA 2510B, APHA 4500-CI and APHA 2510 B respectively.

❖ **Biochemical oxygen demand (BOD_5) and Chemical oxygen demand (COD) Tests:**

BOD_5 and COD of the water samples were tested based on APHA 5210D and APHA 5220D respectively.

❖ **Determination of Heavy Metals Content in Groundwater:**

The levels of heavy metals (such as Pb, Cr, Cd, Hg and Zn) in the groundwater collected at different distances from the Ariaria-Aba dumpsite were analyzed using APHA 3120.

(b). Soil Analysis:

Analyses were performed on a pre-weighed portion of the air-dried soil samples, using portions that were of particle size less than 2mm diameter for heavy metals and other physicochemical parameters measurements. Organic parameters measurement were performed using pre-weighed and well homogenized portion of the wet samples, using method of chemical drying to minimize exposure, and reduce loss of the organic analytes.

Physicochemical parameters measured from the soil samples include pH, moisture content, electrical conductivity and chloride content. Heavy metals content of the soil samples were also measured. Also detected in the soil samples were lead (Pb), mercury (Hg), chromium (Cr), zinc (Zn) and cadmium (Cd). The tests methods for the analysis of the soil samples were in accordance with the American Public Health Association (APHA) and the American standard for Testing and Materials (ASTM).

❖ **Determination of pH, moisture content, electrical conductivity and chloride content:**

The pH, moisture content, electrical conductivity and chloride content were determined by APHA $4500H^{+}B$, ASTM 2216-05, APHA 2510B and APHA 4500-CI-B respectively.

❖ **Determination of heavy metals content in soil:**

Prior to heavy metals measurements in the soil samples, the samples were first prepared by method of soil digestion, while the filtrate was then analyzed using Atomic Absorption Spectrophotometer (AAS) in accordance with ASTM D5198 testing procedure.

2.2.3 Evaluation of risk-factor pollutants in the soil environment

Pollution load indicators were used to assess the level of contamination posed by the Ariaria-Aba dumpsite on the surrounding soil and water environments. These indicators includes contamination factor (CF), geo-accumulation index (Igeo), modified contamination degree (MCD) and pollution load index (PLI), which are shown respectively in (1) to (4),

$$CF = \frac{C_e}{C_b} \quad (1)$$

$$Igeo = \log_2\left[\frac{C_e}{1.5C_b}\right] = 1.44\ln\left[\frac{CF}{1.5}\right] \quad (2)$$

$$MCD = \frac{1}{n}\sum_{i=1}^{n} CF_i \quad (3)$$

$$PLI = \left[\prod_{i=1}^{n} CF_i\right]^{1/n} = (CF_1.CF_2.....CF_n)^{1/n} \quad (4)$$

Where, CF_i = contamination factor for individual heavy metal; C_e = Heavy metal concentration in dumpsite soil sample; C_b = Background concentration of heavy metal in soil sample (or heavy metal concentration in soil sample at control point); n = number of heavy metal elements tested.

3. RESULTS AND DISCUSSION

The results obtained from this study are presented in Tables 1 to 4, while the discussions of the results are presented under the following subheadings: Dumpsite impact on the Ariaria groundwater and soil environments, and assessment of the risk factor pollutants in the environment around Ariaria-Aba dumpsite.

3.1 Dumpsite impact on the Ariaria groundwater and soil environments:

(A). Ariaria groundwater environment:

The results of the physicochemical property analyses of groundwater samples obtained at different distances (or borehole sampling points, BH) around the Ariaria-Aba dumpsite location are presented in Table 1. These measurements were carried out in a 3-month study plan which cut across the months of March to May. The pH values of the water samples were generally ranged from 5.49 to 5.66 (for the test samples), and 5.9 to 6.10 (for the control samples).

Although, the pH values were generally less than the world health organization (WHO) standard for borehole water quality, yet it is a strong indication of a slightly acidic status for the

Ariaria groundwater, for which the acidity was observed to be increasing as the borehole sampling point distance from the dumpsite decreases. Also, the observed reduction in the pH value of the groundwater samples across all sampling points between the months of March and May (see Table 1) could be adduced to dilution effect caused by increased water volume due to rain-water contact with groundwater aquifer. These trends are however, indications of dumpsite impact on groundwater quality in the Ariaria environment.

The other measured properties of the Ariaria groundwater samples: electrical conductivity (EC), total dissolved solids (TDS), chlorides (Cl), biochemical and chemical oxygen demands (BOD and COD) also showed similar trends like that of its pH, wherein a progressive increase in the values of properties as the water sampling point distance from dumpsite reduces were evident. This was also a confirmation that the Ariaria-Aba dumpsite had impacted on the surrounding groundwater environment. However, the presumed effect of dilution due to seasonal rainfall occurrence within the period of the study was not highly evident in the case of EC, TDS, Cl, BOD and COD. The reason for this trend could have been due to several factors for which the level of residual pollutants in the aquifer is one of it.

The BOD and COD values of the test samples collected across the sampling points within the study period were ranged between 20.5 to 28 mg/l (for BOD), and 532 to 602 mg/l (for COD). These values were above the WHO permissible standards. Thus, indicating that the Ariaria groundwater environment contains high level organic pollutants, in which BOD and COD treatments will be required for groundwater in the Ariaria environment. These findings are corroborated by Sokpuwu[19] and Onwughara et al.[20] in Eleme and Umuahia towns respectively, wherein groundwater quality assessments in these locations showed similar pollution status like the one in this present study even though the sources of the pollution were not identified.

The heavy metals detected in the Ariaria groundwater samples are lead (Pb), mercury (Hg), chromium (Cr), zinc (Zn) and cadmium (Cd). These metals concentration values were higher than the WHO permissible standard for heavy metals in groundwater (Table 1). In the same vein, the heavy metals content in groundwater test samples collected near the dumpsite were higher than those collected farther away from the dumpsite. This is another confirmation of dumpsite impact on the heavy metals content of the Ariaria groundwater. In assessing the heavy metals content distribution trend in the test samples obtained within the study period, it was observed (with Cr exclusive) that the heavy metals: Pb, Hg, Zn and Cd showed increased concentrations across the study period (March to May). Generally, the profile of the heavy metals concentration characteristics in the Ariaria groundwater test samples followed the trend as shown: Hg > Pb > Cr > Zn > Cd.

Also noticed was that the Zn concentration in the control samples were generally higher than that in the test samples. This could be adduced to possible contacts of control samples with residual Zn in the existing formations. The Cd concentration values in this present study corroborated with Akachukwu[21] wherein Umuakam-Umuahia groundwater environment in Abia state, Nigeria showed similar values of Cd concentrations in test water samples. Thus, the Ariaria groundwater needs to be subjected to appropriate treatments for heavy metals removal prior to domestic use. This is because, the consumption of groundwater's with high concentrations of Cr, Cd and Pb can cause cancers in humans, while excess Cd and Hg can also affect the human kidney and central nervous system[18].

Table 1: Physicochemical properties of groundwater samples from around Ariaria-Aba dumpsite

Parameter	Borehole sample	March	April	May	WHO [27]
pH	BH 1	5.49±0.01	5.50±0.01	5.51±0.01	6.5-8
	BH 2	5.51±0.01	5.52±0.01	5.53±0.01	
	BH 3	5.62±0.01	5.64±0.01	5.66±0.01	
	Control BH	5.90±0.01	6.00±0.01	6.10±0.00	
EC(μScm^{-1})	BH 1	71.65±0.01	73.20±0.01	75.40±0.02	250
	BH 2	71.51±0.02	72.00±0.02	72.99±0.01	
	BH 3	68.71±0.01	69.82±0.02	69.91±0.01	
	Control BH	11.45±0.01	11.70±0.02	12.80±0.02	
Chloride (mg/l)	BH 1	16.50±0.03	16.00±0.01	15.00±0.02	250
	BH 2	14.91±0.01	14.20±0.02	14.18±0.01	
	BH 3	13.83±0.02	13.80±0.02	13.57±0.01	
	Control BH	6.80±0.01	6.50±0.01	6.00±0.02	
TDS(mg/l)	BH 1	5.83±0.02	5.99±0.02	5.20±0.03	NA
	BH 2	4.57±0.01	4.92±0.01	5.01±0.01	
	BH 3	4.31±0.01	4.40±0.01	4.48±0.01	
	Control BH	3.21±0.01	3.32±0.02	3.41±0.02	
BOD (mg/l)	BH 1	26.15±0.03	27.10±0.03	28.02±0.03	6-9
	BH 2	24.14±0.02	25.82±0.02	25.90±0.03	
	BH 3	20.51±0.01	20.91±0.01	21.82±0.02	
	Control BH	15.30±0.02	15.91±0.03	16.00±0.03	
COD (mg/l)	BH 1	601.60±0.03	602.30±0.02	605.15±0.03	NA
	BH 2	582.12±0.03	591.34±0.03	593.83±0.03	
	BH 3	531.99±0.02	538.21±0.02	554.83±0.02	
	Control BH	349.35±0.01	350.10±0.01	352.15±0.02	
Cr (mg/l)	BH 1	0.21±0.01	0.20±0.03	0.20±0.02	0.05
	BH 2	0.18±0.03	0.17±0.01	0.17±0.01	
	BH 3	0.12±0.02	0.12±0.01	0.11±0.01	
	Control BH	0.10±0.01	0.10±0.02	0.09±0.01	
Cd (mg/l)	BH 1	0.13±0.01	0.13±0.01	0.14±0.01	0.005
	BH 2	0.11±0.01	0.11±0.01	0.12±0.01	
	BH 3	0.10±0.02	0.11±0.02	0.11±0.01	
	Control BH	0.08±0.02	0.08±0.01	0.09±0.01	
Pb (mg/l)	BH 1	0.35±0.01	0.36±0.01	0.37±0.02	0.01
	BH 2	0.29±0.01	0.30±0.01	0.31±0.02	
	BH 3	0.27±0.01	0.26±0.01	0.24±0.01	
	Control BH	0.21±0.01	0.20±0.01	0.20±0.01	
Hg (mg/l)	BH 1	0.78±0.01	0.79±0.01	0.79±0.01	0.006
	BH 2	0.71±0.02	0.70±0.01	0.70±0.01	
	BH 3	0.68±0.01	0.67±0.01	0.65±0.01	
	Control BH	0.21±0.01	0.20±0.01	0.20±0.01	
Zn (mg/l)	BH 1	0.18±0.01	0.19±0.01	0.19±0.02	NA
	BH 2	0.15±0.01	0.16±0.01	0.16±0.02	
	BH 3	0.12±0.01	0.13±0.01	0.14±0.01	
	Control BH	0.86±0.03	0.85±0.01	0.86±0.01	

Note: BH 1, BH 2, BH 3 and control BH are borehole sampling points that are respectively 15 m, 25 m, 35 m and 5 km away from the dumpsite epicenter;
NA = Not applicable.

(B). Ariaria-Aba dumpsite soil environment:
From the results obtained in Table 2, the pH of the soil samples collected from around the dumpsite environment showed a near-neutral status within the period of the study (for both test and control samples). The pH values ranged between 6.22 and 7.24, in which slight increases in pH of soil were observed for increasing soil depth within the period of study. This observation could be due to dilution, presumably caused by increased rainfall during the period (March to May). In other word, the impact of the Ariaria-Aba dumpsite on its soil environment may have been affected by dilution.

Similarly, the soil moisture content (for both test and control samples) showed increased values within the period of the study (Table 2), while on the other hand, electrical conductivity (EC) for the test-soil samples showed reduction in values as soil depth increases. Thus, dilution effect created by excess rainfall during this period is attributable to this trend. However, in the case of chloride content, test-soil samples showed varying trends from that of electrical conductivity (EC), wherein chloride content of test-soil samples increased along with increasing soil depth irrespective of the rainfall occurrence. This observation may have been presumably caused by the presence of residual chloride in the Ariaria soil formation, as well as chloride migration from the Ariaria-Aba dumpsite.

Test-soil samples from around the Ariaria-Aba dumpsite showed presence of heavy metals whose mean concentrations within the period of study were ranged as follows: Lead (0.96 – 1.98 mg/kg);. Chromium (0.22 – 0.29 mg/kg); Cadmium (0.12 – 0.29 mg/kg); Mercury (0.15 – 0.48 mg/kg) and Zinc (20.95 – 23.79 mg/kg) (Table 2). The metals concentrations were all above the WHO standard and that of the controls. This is indeed an indication of soil pollution in which the dumpsite surrounding soil was impacted (or enriched) with heavy metals from the Ariaria-Aba dumpsite. Previous investigations which support these findings include Olayiwola et al.[22] for the Awotan dumpsite in Ibadan, western Nigeria; Imaseun and Omorogieva[7] in Oluku dumpsite near Benin City, and Atedhor and Orobator [23] in other selected dumpsites in Benin City.

Table 2: Physicochemical properties of Ariaria-Aba dumpsite soil samples

Parameter	Month	Soil sample			Control sample			WHO [27]
		(0-15) cm	(15-30) cm	(30-45) cm	(0-15) cm	(15-30) cm	(30-45) cm	
pH	March	6.22±0.02	6.86±0.01	7.15±0.02	7.10±0.01	6.79±0.01	6.75±0.01	NA
	April	6.64±0.02	6.92±0.01	7.21±0.02	7.05±0.02	6.81±0.02	6.65±0.02	
	May	6.87±0.03	6.94±0.02	7.25±0.02	7.24±0.01	6.93±0.01	6.79±0.02	
Moisture (%)	March	19.81±0.01	19.42±0.03	17.38±0.02	15.35±0.02	15.33±0.02	15.05±0.03	NA
	April	22.20±0.01	21.68±0.01	20.00±0.03	17.05±0.01	16.56±0.01	16.10±0.01	
	May	25.09±0.01	24.04±0.02	20.25±0.01	19.94±0.01	19.02±0.01	18.19±0.01	
EC (μScm^{-1})	March	135.85±0.01	131.70±0.02	128.05±0.02	105.00±0.02	104.30±0.02	102.45±0.01	NA
	April	131.70±0.02	129.55±0.02	128.70±0.01	104.05±0.02	105.35±0.02	106.25±0.02	
	May	127.35±0.02	121.40±0.02	120.30±0.03	106.05±0.03	106.70±0.01	103.55±0.02	
Chloride (mg/kg)	March	10.19±0.02	12.35±0.02	9.75±0.02	10.78±0.02	11.29±0.02	11.29±0.03	NA
	April	9.69±0.01	12.34±0.01	19.43±0.02	10.03±0.02	11.27±0.03	12.03±0.03	
	May	10.00±0.02	13.00±0.02	20.00±0.02	11.00±0.02	12.00±0.03	12.50±0.02	
Pb (mg/kg)	March	1.41±0.01	0.98±0.01	1.97±0.01	0.56±0.01	0.17±0.01	0.23±0.02	0.4
	April	1.39±0.02	0.96±0.01	1.87±0.01	0.47±0.02	0.15±0.01	0.18±0.01	
	May	1.41±0.03	0.97±0.01	1.98±0.01	0.69±0.01	0.18±0.01	0.36±0.02	
Cr (mg/kg)	March	0.25±0.01	0.26±0.01	0.29±0.01	0.12±0.01	0.14±0.01	0.13±0.01	0.05
	April	0.22±0.01	0.24±0.02	0.28±0.01	0.14±0.02	0.13±0.01	0.15±0.02	
	May	0.25±0.01	0.26±0.02	0.27±0.01	0.13±0.02	0.14±0.01	0.14±0.01	
Cd (mg/kg)	March	0.21±0.01	0.12±0.02	0.24±0.02	0.02±0.00	0.02±0.01	0.06±0.01	0.07
	April	0.29±0.01	0.15±0.01	0.23±0.01	0.03±0.01	0.02±0.01	0.04±0.01	
	May	0.23±0.01	0.19±0.01	0.25±0.02	0.04±0.01	0.03±0.01	0.05±0.01	

Hg (mg/kg)	March	0.48±0.01	0.32±0.02	0.16±0.02	0.06±0.01	0.06±0.01	0.05±0.01	
	April	0.41±0.01	0.23±0.01	0.15±0.01	0.06±0.01	0.05±0.01	0.06±0.01	
	May	0.47±0.01	0.22±0.01	0.16±0.01	0.07±0.01	0.06±0.02	0.05±0.01	NA
Zn (mg/kg)	March	20.95±0.02	21.65±0.02	21.24±0.02	16.72±0.02	16.64±0.01	16.14±0.02	
	April	23.79±0.01	22.78±0.01	21.75±0.02	16.98±0.01	17.63±0.02	17.35±0.02	
	May	21.84±0.01	21.25±0.02	21.25±0.02	17.66±0.02	17.8s2±0.01	17.25±0.02	NA

NA = Not available

3.2 Assessment of risk-factor pollutants in the environment around Ariaria-Aba dumpsite

The pollution assessment indices used for this study include contamination factor (CF), geo-accumulation index (Igeo), modified contamination degree (MCD) and pollution load index (PLI). These values were obtained from widely tested empirical relations as presented in (1) to (4), while the estimated values of these indices for all measured heavy metals in the test-soil samples collected around Ariaria-Aba dumpsite within the study period are presented in Table 3.

The Igeo values for Pb, Cr, Cd and Hg were generally ranged from 0.07 to 2.81 for across the soil depth during the period (Table 3). This is an indication of moderate to high level soil contamination with respect to the heavy metals referred, in which Cr contamination was of lowest magnitude. In the same vein, the geo-accumulation index for Zn was generally less than zero (Igeo < 0: -0.1 to -0.36) for across the same soil depth like the other metals (Table 3). This is also an indication that the test-soil samples were uncontaminated with Zn.

The other pollution assessment indices tested for this study are the pollution load index (PLI) and modified contamination degree (MCD). The PLI for test-soil samples (around Ariaria-Aba dumpsite) from across the different soil depth showed values greater than unity (PLI > 1), and were specifically ranged between 2.47 and 3.53 (Table 4). This is an indication of high level soil contamination with heavy metals. Also, the characteristic drop in the PLI values of test-soil samples across different soil depth in the month of May could be adduced to pollutants migration into water aquifer due to excessive rainfall.

In addition, the MCD for the heavy metals contents of test-soil samples also showed values greater than unity (MCD > 1) in which actual MCD values ranged from 3.01 to 4.87 (Table 4). This is another strong indication of high level heavy metals pollution in the soil around Ariaria-Aba dumpsite. It also confirms the negative impact of the dumpsite on the environment. These findings was corroborated by the report of Likuku et al.[24], wherein a copper-nickel mine site located in the Selebi-Phikwe region of eastern Botswana was found to have impacted negatively on its surrounding environment by enriching and contaminating the soils with heavy metals. And also by Demie and Degefa [25], wherein the Shashemane open dumpsite in Ethiopia was observed to have highly contaminated nearby local community soils with heavy metals.

Table 3: Geo-accumulation index for test-soil samples collected around Ariaria-Aba dumpsite

Heavy metal	Study period	Geo-accumulation Index, Igeo (at different soil depth)		
		0-15cm	15-30cm	30-45cm
Pb	March	0.75	1.94	2.51
	April	0.98	2.09	2.79
	May	0.45	1.84	1.87
Cr	March	0.48	0.32	0.58
	April	0.07	0.30	0.32
	May	0.36	0.32	0.36
Cd	March	2.81	2.00	1.41
	April	2.68	2.32	1.93
	May	1.93	2.07	1.73
Hg	March	2.40	1.83	1.09
	April	2.19	1.61	0.73
	May	2.16	1.28	-0.10
Zn	March	-0.26	-0.20	-0.19
	April	-0.10	-0.22	-0.26
	May	-0.36	-0.33	-0.29

Table 4: PLI and MCD for test-soil samples collected around Ariaria-Aba dumpsite

Pollution Index	Study Period	Test-soil sample depth (cm)		
		0-15cm	15-30cm	30-45cm
Pollution Load Index (PLI)	March	3.53	3.39	3.18
	April	3.36	3.50	3.23
	May	2.82	3.08	2.47
Modified Contamination Degree (MCD)	March	4.87	4.49	3.52
	April	4.05	4.33	3.69
	May	3.86	4.35	3.01

4. CONCLUSION

The dumping of solid wastes at the Ariaria-Aba dumpsite has been poorly handled because the engineering and sanitary practices are operated below recommended standard. Hence, pollutants in the dumped wastes are released uncontrollably into the air, soil and water environments around the dumpsite. These assertions are drawn from the results obtained in this study. The Arairia soil environment is hydrogeologically permissive to pollutants migration which was much intense within the period of this study because of rainfall occurrence. Consequently, the characteristics of the surrounding groundwater environment were impacted negatively beyond the WHO limit by the Ariaria-Aba dumpsite, causing increased acidity, electrical conductivity, chloride and organic impurities. Similarly, the heavy metals content in the groundwater was progressively enriched within the period of study, and in the order of magnitude: Hg > Pb > Cr > Zn > Cd. The extent of impact was known to be higher at 15 m distance (or at closer distance) of groundwater source to dumpsite.

In the same vein, the characteristics of the dumpsite nearby soil environment (such as moisture, chloride and heavy metals contents) were practically above that of the WHO standard. This also indicates heavy metals enrichment above that of the control samples, which is implied a negative impact on the surrounding soil environment by the Ariaria-Aba dumpsite. Although, the electrical conductivity of the soil samples is somehow affected by dilution (or reduction in value) across soil depths within the period of study. This was presumably caused by increased rainfall. The empirical

measurement of the impact of the Ariaria-Aba dumpsite on the characteristics of the surrounding soil environments using pollution assessment indices (such as Igeo, PLI and MCD) showed moderate to high degrees of contamination of the soil environment, for which lead (Pb), chromium (Cr), cadmium (Cd) and mercury (Hg) were identified as high risk-factor pollutants. Therefore, an urgent step by concerned agencies to put an end to open dumping in the Aba metropolis is recommended.

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