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ASSESSMENT OF HEAVY METAL CONTAMINATION IN WATER AROUND INDUSTRIAL LAYOUT, SAGAMU, OGUN STATE, NIGERIA

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ABSTRACT

Waste from industrial activities has a great impact on water quality thereby limiting water usability for domestic purposes. This study assessed the heavy metal contamination in water around the industrial layout in Sagamu, Ogun State, Nigeria. Seven (7) water samples were collected and analyzed for their physicochemical and geochemical properties using inductively coupled plasma mass spectrometry (ICP-MS). Water facie was determined using a Piper plot. Geo-Accumulation Index (Igeo), Contamination factor (C_f), Contamination degree (C_d), Quantification of Contamination (QoC) and Hazard Index (HI) of the heavy metals in water samples were obtained. Results show the ranges of physicochemical properties as, pH (4.1 - 5.9), total dissolved solid (78 - 292 ppm), electrical conductivity (0.1 - 0.4 µS/cm) and temperature (30.1 - 32.2°C). The concentration of metals in groundwater samples were obtained as Cd (0.001 - 0.004ppm,), As (00007 - 0.0011ppm), Cr (0.005-.01ppm), Pb (0.0003- 0.046ppm), Zn (0.0204-0.26ppm), Fe (0.000005- 0.013ppm), Mn (0.0009-2.5ppm) and Ni (0.001-0.03ppm). Igeo for heavy metals < 5, Fe has C_f of F>6 (strongly polluted) and C_d>32. Fe and Mn have positive QoC values indicating anthropogenic sources. Results show the HI to be greater than 1 indicating children and adults are at low risk of non-carcinogenic health problems. Water in the study area was contaminated with Pb and Mn thereby reducing its quality and exposure through derma and ingestion can cause adverse health effects. Proper sanitation with contamination control and monitoring strategies should be adopted to safeguard the health of water consumers from the study area.

Keywords: Heavy metal, Water facie, Contamination factor, Geo-accumulation Index, Sagamu

INTRODUCTION

Health issues have increased rapidly over the years due to environmental pollution which has decreased the quality of life and diversity of both plants and animals. Sources of pollution have increased tremendously due to anthropogenic activities such as mining, use of pesticides and fertilizers, sewage sludge, effluent discharge from industries and also natural activities such as weathering alteration, volcanic activities and petrogenesis.

The Nigerian construction sector has progressed greatly throughout the past years. Nigeria has enough resources needed for the production of cement. The growing rate of industrialization poses a threat to the environment due to associated air, water, and soil pollution. Production goes through stages such as mining, rock grinding, refining, dispatch and lastly transportation; and pollutants such as arsenic (As), lead (Pb), nickel (Ni), chromium (Cr), copper (Cu), zinc (Zn), cadmium (Cd) are released into the atmosphere (Bluvshtein *et al.*, 2011).

However, the major concern about cement factories is the emission of dust into the atmosphere (Isikilu *et al.*, 2006). It has been observed the dust emitted in cement factories is characterized by high concentrations of dangerous heavy metals (Oluyemi and Oluwole, 1994).

The spread of these toxic heavy metals into the soil changes the physiochemical properties and these metals may be taken up by plants and soil. Heavy metals reduce the quality of soil which makes it lose its fertility (Sharma and Sharma, 1997). This alteration affects the growth of plants because the soil is very essential for the growth of plants. The presence of heavy metals such as Cd is very dangerous to biological systems because the level of its toxicity is very high and this toxic effect can affect the growth of living organisms (Servile and Ainnei, 2005).

Pb toxicity causes hindrance to germination and retardation of plant growth (Igbal and Siddiqui, 1992). These metals get introduced to the body system through ingestion of consumable vegetables from soil substrate, dermis absorption of heavy metals due to direct skin contact, as well as inhaling the contaminated dust (Lai *et al.*, 2010).

One of the main pollutants of groundwater is heavy metals. This is because once the soil gets contaminated with these metals, the water percolating gradually takes a huge number of heavy metals present in the environment then reaches the aquifer system and contaminates the groundwater. Also, Effluent discharge from the industries contains a large amount of dissolved chemicals which percolates into the groundwater. Consumption of this water causes diseases such as cholera, pancreatitis, and constipation and it also weakens the immune system, and many others (Nugendo *et al.*, 2011). The study area covers Lafarge Cement WAPCO Nigeria Plc. and its environs. Sagamu is positioned between latitude 6°49'0" N to 6°50'0" N and longitude 3°36'30"Eto 3°38'0"E (Figure 1).

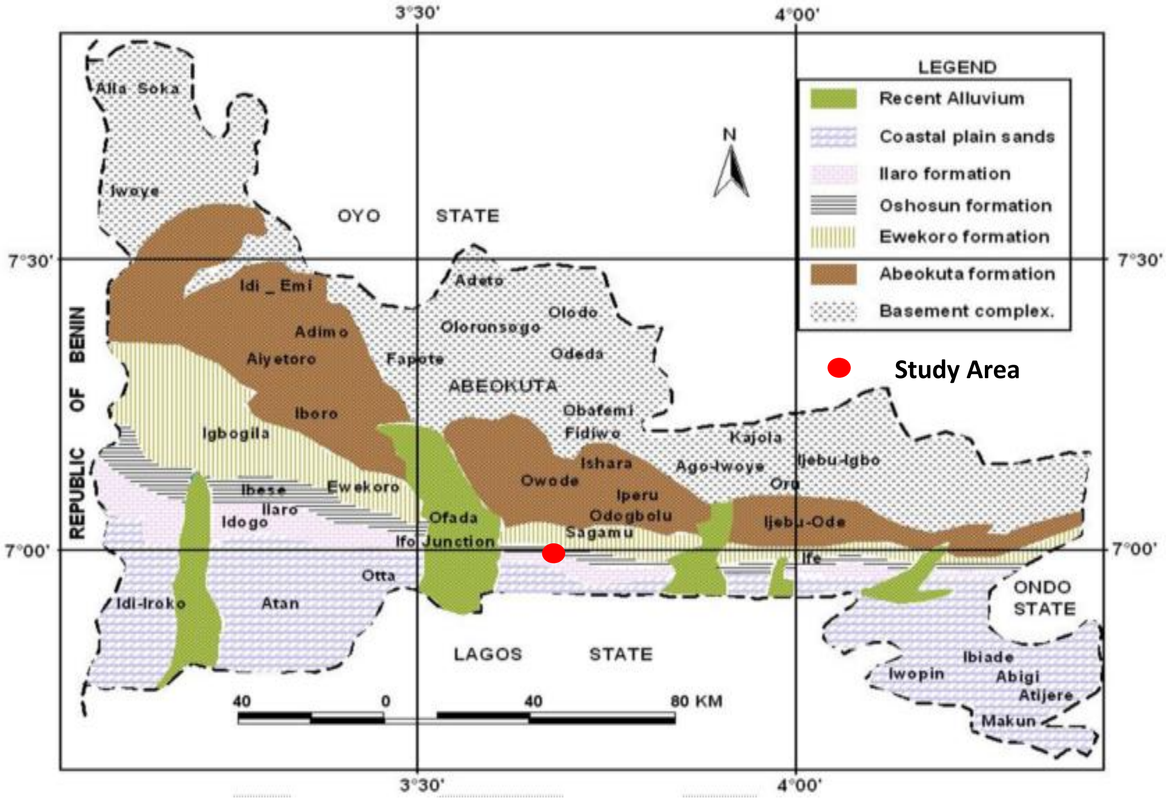

Figure 1: Geological map of the eastern Dahomey basin showing the location of the study area

The geology of the study area

The study area is located within the eastern Dahomey Basin (Figure 1) of Southwestern Nigeria. The rocks are Late Cretaceous to Early Tertiary in age (Adegoke *et.al*., 1969), the sedimentary units within the basin having been divided into the Abeokuta Group, Imo Group, Oshoshun Formation, Ilaro Formation, the Coastal Plain Sands and Tertiary Alluvium (Adegoke & Omatsola, 1981). Limestone for cement production is mined from the Imo Group, which is divided into the limestone-dominated Ewekoro Formation and the shale-dominated Akinbo Formation. The geology of Shagamu is made up of sedimentary rocks which consist of the Abeokuta Formation (Adegoke 1969) which is highly fossiliferous and comprises deposits of limestone, sand with sandstone, siltstone, clay, mudstone, and shale interbed (Agbaje, 2009).

MATERIALS AND METHODS

Seven (7) water samples (Figure 2) were collected from the vicinities of the industrial area for laboratory analysis. The water samples were collected and stored in distilled bottles. Concentrated HNO_3 was added to one of the bottles and the other bottle was not acidified. The water samples were also stored and preserved in a cooler with ice packs. Physicochemical tests such as pH, electrical conductivity (EC), total dissolved solids (TDS) and Temperature were conducted using Hanna instrument HI -9813 multimeter. Geochemical analyses of water samples involving heavy metal concentrations were carried out. These water samples were analyzed with inductively coupled plasma mass spectrometry (ICP-MS). The Piper diagram was constructed to determine the hydrogeochemical facies of the water samples. Geo-accumulation index, developed by Muller (1979), was used to determine heavy metal contamination in water samples. Contamination factor and Contamination degree of heavy metals in water samples using Hakinson's (1980) classification were determined. While the contamination factor is the ratio of heavy metals to background values, the contamination degree is the total addition of all contamination factors of metals examined. The QoC analysis was used to deduce the heavy metals' origin (anthropogenic and geogenic) in the water samples.

Health risk assessments (Wu *et al*., 2009, Odukoya *et al*., 2018) in water samples were carried out to determine the exposure pathways of humans to contaminated water. These pathways can either be by ingestion, dermal or inhalation. Only ingestion and dermal are more applicable in contaminated water (Liyuan et al., 2010).

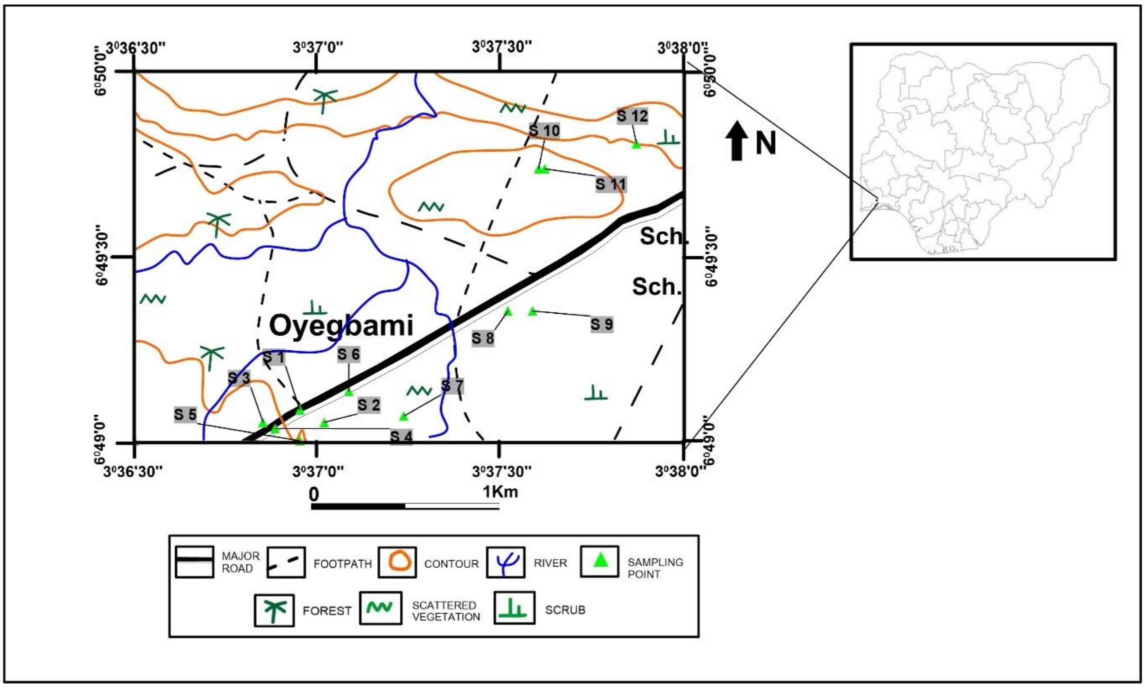

Figure 2: Map showing the sampling points in the study area

RESULTS AND DISCUSSION

Physiochemical parameters

Table 1 shows the physicochemical parameters of water samples from the study area. The pH value of water samples ranged from 4.1 to 5.9 with a mean value of 5.04 which indicates that the water sample is slightly acidic. The mean value for the water sample falls below the WHO (2017) standard. Ingestion of slightly acidic water samples predisposes humans to teeth enamel damage, increased risk of osteoporosis and gastrointestinal irritations. Bad bacteria usually thrive in low-pH environments (Archin *et al*., 2023).

TDS values, which range from 78 - 292 ppm with a mean value of 140 ppm, are considered low when compared with the WHO (2008) standard of 300 ppm. WHO (2008) has recommended that fluid and electrolytes are better replaced in the human body with water containing a minimum of 100 ppm of TDS. Consumption of demineralized water has been attributed to the incidence of cancer, coronary heart disease, arteriosclerotic heart disease and cardiovascular diseases. (Kozisek, 2004).

At the value of 0.1 - 0.4 µS/cm, the EC value is considered very low, so low compared to the WHO Standard which is 500µS/cm. The temperature value range (30.1 to 32.2°C) of water samples from the study area is on the high side when compared with the WHO (2017) standard. Bad bacteria usually bloom in high-temperature environments (Archin *et al*., 2023)

Table 1: Results of Physiochemical parameters of water

Sample	W1	W2	W3	W4	W5	W6	W7	Mean	Max	Min	WHO (2017)
Ph	4.8	4.1	5.9	5.8	5.1	4.6	5	5.04	5.9	4.1	6.5-8.5
TDS (ppm)	193	120	292	78	111	93	94	140.1	292	78	300
EC (µS/cm)	0.26	0.15	0.4	0.1	0.19	0.15	0.12	0.19	0.4	0.1	500
Temp (^{O}C)	31.4	31.5	32.2	30.1	30.4	30.9	31	31.07	32.2	30.1	20 - 25

Geochemical Analysis of Water Samples

Heavy metal

Heavy metal concentrations (Table 2) in the study area are generally below the permissible limit except for Lead, Iron and Manganese. Pb concentrations (Figure 3), which range from 0.0003 - 0.046 ppm, represent concentrations visibly above the WHO permissible limits of 0.01 ppm. A very high concentration of Pb in domestic water signifies a serious hazard to the people within the study area who consume the water. High exposure to Pb can lead to irreversible damage to the body's organs such as kidneys, nervous system and also the reproductive system. It causes cancer and impairment to children's mental development (Piantone, 2007, WHO 1995).

Fe concentration (Figure 4) ranges from 0.005-13 ppm and, in some places, exceeds the standard. The Fe that occurs naturally in groundwater is from weathered minerals containing iron and manganese. It may also be from industrial effluent and landfill leachate. Excessive concentration of Fe in groundwater causes health hazards which leads to hemochromatosis, which indicates the sign of tiredness and eventually heart disease, complications in the liver, and diabetes if consumed over time (Rose *et al.,* 2000).

The concentration of Mn (Figure 5), which ranges from 0.009 - 2.5 ppm, is visibly above the WHO permissible limit of 0.04. Excessive Mn in groundwater has a toxic effect on the human body system such as neurological disorders, pancreas disease, liver disease and also kidney disease (Santamaria *et al.*, 2010).

The Piper plot (Figure 6) shows the hydrogeochemical facies of the water samples from Shagamu and its environs to be dominated by CaCl and Cl-type. The concentration of Iron(Fe), Lead (Pb) and Manganese(Mn) exceeded the WHO standard in the study area which corresponds to the study carried out by Mshelia *et al*., (2024).

Table 2: Heavy metal concentration (ppm) in water samples

Sample	W1	W2	W3	W4	W5	W6	W7	Mean	Max	Min	WHO (2017)
As	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
Cd	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.003
Cr	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.05
Pb	0.00	0.05	0.04	0.04	0.00	0.00	0.00	0.02	0.00	0.05	0.01
Zn	0.11	0.26	0.22	0.22	0.04	0.02	0.09	0.14	0.02	0.26	5.00
Fe	0.405	0.053	0.005	0.157	13	7.21	6.32	3.88	0.01	13.00	0.30
Mn	0.18	0.12	0.03	0.03	2.5	0.45	0.46	0.54	0.03	2.50	0.40
Ni	0.01	0.03	0.01	0.01	0.01	0.01	0.00	0.01	0.00	0.03	0.07

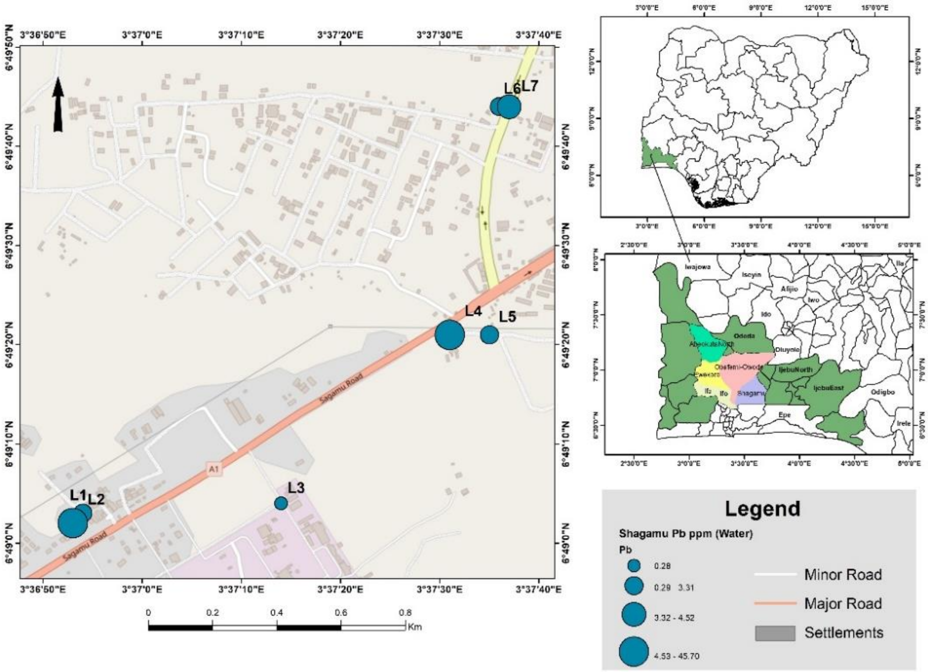

Figure 3: Geochemical map showing the distribution of Pb in water at Shagamu

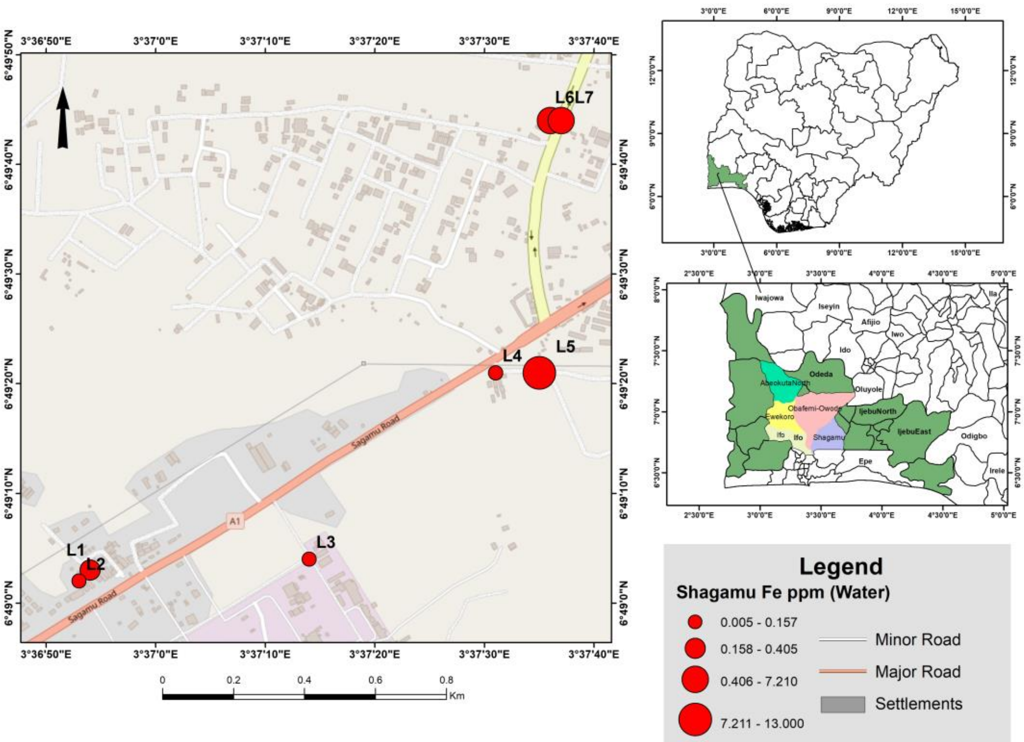

Figure 4: Geochemical map showing the distribution of Fe in water at Shagamu

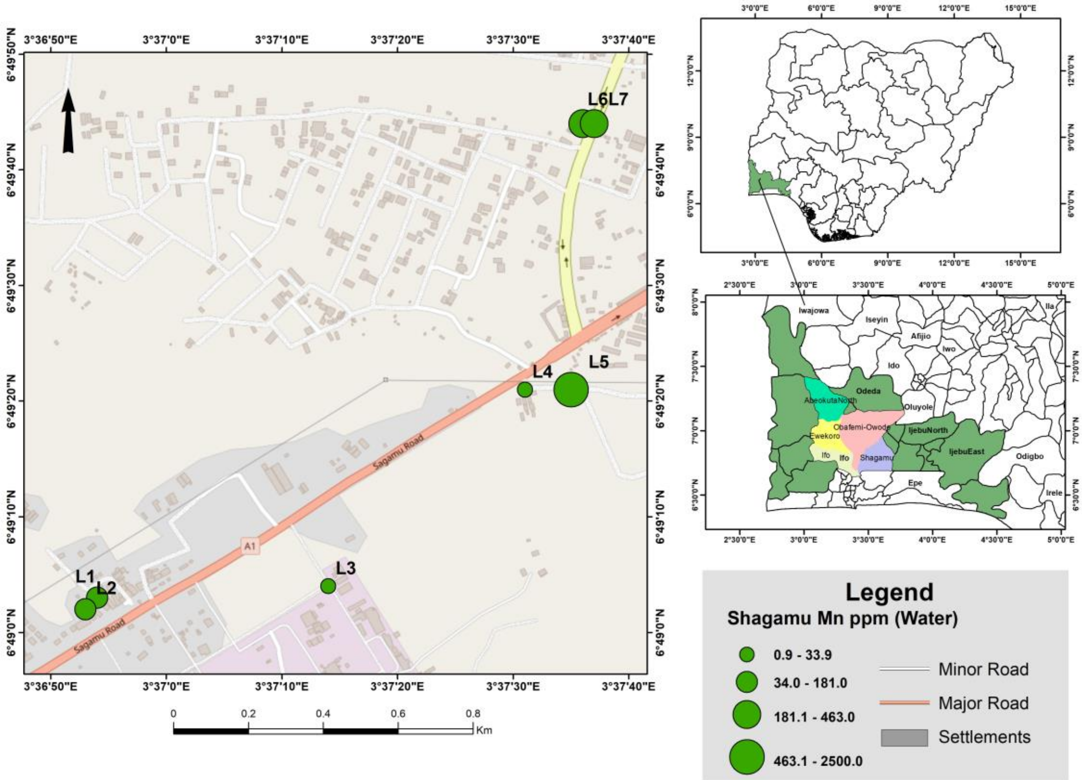

Figure 5: Geochemical map showing the distribution of Mn in water at Shagamu

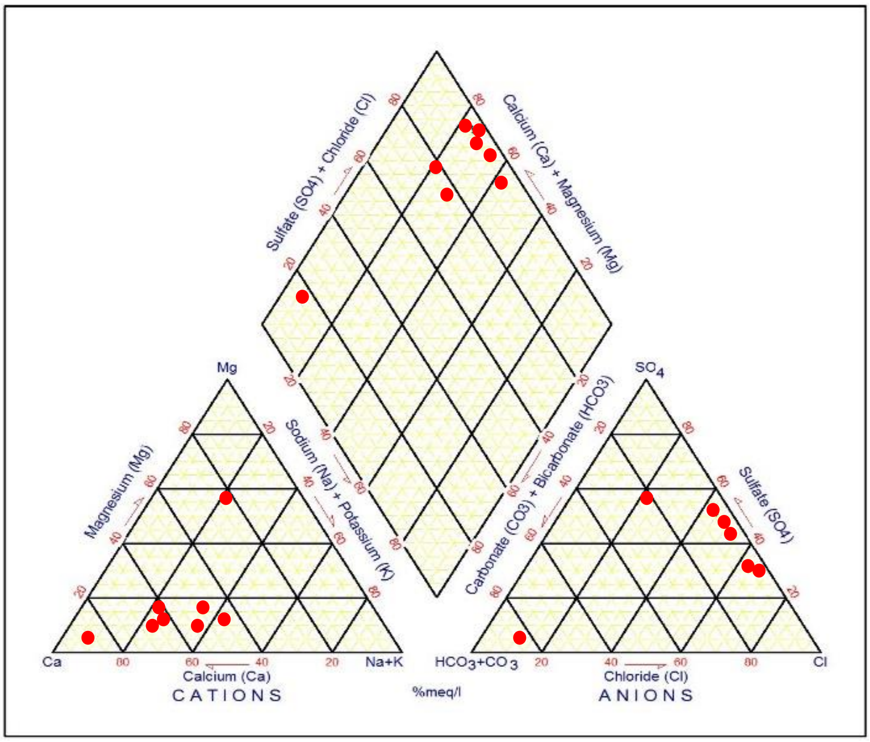

Figure 6: Piper plot showing major hydrochemical facies of water samples from Shagamu

Geo-accumulation index, Contamination factor and Contamination degree of groundwater

The Geo-accumulation index for Heavy Metals in groundwater (Table 3) revealed that the water samples are practically unpolluted by As, Cd, Cr, Zn, and Ni. On the other hand, the water samples are moderately polluted by Pb and Mn while it is strongly polluted by Fe (CF>6). The contamination factors (Table 4) of all the metals are generally less than 6 except for Fe and Mn where the CF is greater than 6 indicating a very high contamination factor for the two metals. Using Hakinson's (1980) classification table of contamination factors, the results revealed a low contamination degree of As, Cd, Cr, Pb, Zn, Mn, and Ni while only Fe showed a very high degree of contamination (Cdeg>32) as shown in Table 4

Quantification Of Contamination (QoC)

Table 5 shows that all the metals, except for Fe and Mn at some locations, returned negative values of QoC. This signifies the geological source for these metals. The positive QoC values observed for Fe and Mn in some locations indicate mostly anthropogenic sources, possibly from the iron smelting companies in the vicinity of the study area.

Table 3: Geo-accumulation index for Heavy Metals in Ground Water

Heavy metals	W1	W2	W3	W4	W5	W6	W7
As	-6.85	-7.74	-4.28	-4.3	-3.73	-3.97	-4.12
Cd	-3.19	-1.74	-5.02	-3.62	-2.78	-3.2	-2.54
Cr	-4.38	-2.91	-7.23	-5.64	-7.23	-6.38	-6.09
Pb	-2.18	1.61	-5.74	1.33	-2.97	-2.33	-1.73
Zn	-6.1	-4.85	-7.75	-5.1	-7.68	-8.52	-6.32
Fe	-0.15	-3.09	-6.49	-1.52	4.85	4.00	3.85
Mn	-1.73	-2.36	-9.4	-4.15	2.06	-0.41	-0.37
Ni	-3.87	-2	-6.45	-3.09	-3.83	-3.39	-5.58

Table 4: Contamination Factor and Contamination Degree for water in the study area

Heavy metals	W1	W2	W3	W4	W5	W6	W7	Cdeg
As	0.01	0.01	0.08	0.08	0.11	0.1	0.09	0.468
Cd	0.16	0.45	0.05	0.12	0.22	0.16	0.26	1.42
Cr	0.07	0.2	0.01	0.03	0.01	0.02	0.02	0.362
Pb	0.33	4.57	0.03	3.77	0.19	0.3	0.45	9.64
Zn	0.02	0.05	0.01	0.04	0.01	0.004	0.02	0.15
Fe	1.35	0.18	0.02	0.52	43.33	24.03	21.07	90.5
Mn	0.45	0.29	0	0.08	6.25	1.13	1.16	9.37
Ni	0.1	0.37	0.02	0.18	0.11	0.14	0.03	0.95

Table 5: Quantification of contamination of groundwater from sample areas

Heavy metal	W1	W2	W3	W4	W5	W6	W7
As	-7692	-14286	-1299	-1316	-885	-1042	-1163
Cd	-6098	-2230	-21583	-8219	-4580	-6110	-3881
Cr	-1389	-499	-10000	-3333	-10000	-5555	-4545
Pb	-302	-17	-3571	-23	-521	-335	-221
Zn	-4555	-1897	-14323	-2261	-13658	-24508	-5315
Fe	-34	-501	-6000	-175	12985	717	627
Mn	-203	-332	-44944	-1177	234	-44	-40
Ni	-972	-265	-5833	-568	-945	-699	-3182

Health Risk Assessments for Groundwater

Human health risk assessment was used in this study to determine the severe possible health effects associated with exposure to environmental hazards by humans. When Hazard Quotient (HQ) < 1, the water is safe for consumption while HQ >1 is deemed unsafe. The values of the hazard quotient (HQ) for all samples taken for adults and children were found to be less than 1 (HQ < 1) which indicates no non-carcinogenic effect. The total Hazard Index (HI) of analyzed groundwater at the sample area taken for both adults and children indicates that the HI is less than 1 (HI < 1). This signifies a low risk for both adult and child consumption (Table 6). The result of this study shows that the risk level in the study area is lower compared to the findings of Odukoya and Ifarajimi (2021)

Table 6: Result of hazard quotient and hazard index of the water samples

Sample	W1	W2	W3	W4	W5	W6	W7	HI
As(A)	6.19E-07	3.33E-07	3.67E-06	3.62E-06	5.38E-06	4.57E-06	4.10E-06	2.23E-05
As(c)	5.78E-06	3.11E-06	3.42E-05	3.38E-05	5.02E-05	4.27E-05	3.82E-05	0.00021
Cd(A)	1.41E-06	3.84E-06	3.97E-07	1.04E-06	1.87E-06	1.40E-06	2.21E-06	1.22E-05
Cd(C)	1.31E-05	3.59E-05	3.71E-06	9.73E-06	1.75E-05	1.31E-05	2.06E-05	0.00011
Cr(A)	4.69E-03	1.28E-02	1.32E-03	3.48E-03	6.24E-03	4.68E-03	7.36E-03	4.06E-02
Cr(C)	4.37E-02	1.20E-01	1.24E-02	3.24E-02	5.82E-02	4.36E-02	6.87E-02	3.79E-01
Pb(A)	1.00E-06	2.00E-05	1.00E-07	2.00E-05	8.00E-07	1.00E-06	2.00E-06	3.90E-05
Pb(C)	1.30E-05	1.74E-04	1.07E-06	1.44E-04	7.31E-06	1.14E-05	1.72E-05	3.67E-04
Zn(A)	5.21E-07	1.24E-06	1.66E-07	1.04E-06	1.74E-07	9.71E-08	4.47E-07	3.69E-06
Zn(C)	4.87E-06	1.16E-05	1.55E-06	9.73E-06	1.63E-06	9.07E-07	4.17E-06	3.44E-05
Fe(A)	8.27E-08	1.08E-08	1.02E-09	3.20E-08	2.65E-06	1.47E-06	1.29E-06	5.54E-06
Fe(C)	7.71E-06	1.01E-06	9.52E-08	2.99E-06	2.48E-04	1.37E-04	1.20E-04	5.17E-04

Mn(A)	1.80E-05	1.20E-05	9.10E-08	3.50E-06	2.60E-04	4.60E-05	4.70E-05	3.80E-04
Mn(C)	1.70E-04	1.10E-04	8.50E-07	3.20E-05	2.40E-03	4.30E-04	4.40E-04	3.60E-03
Ni(A)	5.10E-07	1.90E-06	8.60E-08	8.80E-07	5.30E-07	7.10E-07	1.60E-07	4.80E-06
Ni(C)	4.80E-06	1.70E-05	8.00E-07	8.20E-06	4.90E-06	6.70E-06	1.50E-06	4.40E-05

A-Adult
C-Children

CONCLUSION

This study has shown that the pH of the water is slightly acidic which makes the water suitable to dissolve the heavy metals. The result of the study showed that some heavy metals assessed such as As, Cr, Cd, and Zn would not pose health risks because their mean concentration fell within the permissible limit of WHO standards for drinking water except for Pb, Mn and Fe with high mean concentration making it unsafe for consumption. The contamination indices result indicates that the groundwater is moderately contaminated, this could be due to the improper disposal of hazardous waste thereby causing it to leach into the groundwater. The hazard index of the heavy metal is very low and therefore shows low non-carcinogenic impacts on both adults and children.
Geochemical studies showed moderate to high contamination values.

REFERENCES

Adegoke, O. S. (1969): Eocene stratigraphy of southwestern Nigeria. Mineral Memoir, 69, 23–46.

Adegoke, O. S., and Omatsola, M. E. (1981): Tectonic evolution and Cretaceous stratigraphy of the Dahomey Basin. *Journal Mining and Geology,* Vol. 8(1), 130–136.

Arhin, Emmanuel & Osei, Jeff Dacosta & Anima, Prisca & Damoah-Afari, Peter & Yevugah, Lily. (2023): The pH of Drinking Water and Its Human Health Implications: A Case of Surrounding Communities in the Dormaa Central Municipality of Ghana. Journal Healthcare Treatment Development. 15-26. 10.55529/jhtd.41.15.26.

Bluvshtein, N., Mahrer, Y., Sandler, A., and Rytwo, G. 2011: Evaluating the impact of a limestone quarry on suspended and accumulated dust. Atmospheric environment, 45(9), 1732-1739.

Hakanson, L. (1980): An ecological risk index for aquatic pollution control. A sedimentological approach Water Res., 14(1980), pp. 975-1001

Igbal, M.Z., and Siddiqui, D.A. (1992): Effects of lead toxicity on seed germination and seedling growth of some tree species. Pakistan Journal of Scientific and Industrial Research, 35: 139-144.

Işıklı, B., Demir, T. A., Akar, T., Berber, A., Urer, S. M., Kalyoncu, C., and Canbek, M. (2006): Cadmium exposure from the cement dust emissions: a field study in a rural residence. Chemosphere, 63(9), 1546-1552.

Kozisek, F. (2004): Health Risk from Drinking Demineralised Water. Rolling Revision of the WHO Guidelines for Drinking Water Quality. 8-9.

Lai, H.Y., Hseu, Z.Y., Chen, T.C., Chen, B.C., Guo, H.Y., and Chen, Z.S., (2010). Health risk-based assessment and management of heavy metals-contaminated soil sites in Taiwan. Int. J. Environ Res Public Health, 7(10): 3595-3614.

Liyuan C, Zhenxing W, Yunyan W, Xie W (2010): Ingestion risks of metals in groundwater based on TIN model and dose-response assessment - A case study in the Xiangjiang watershed, centralsouth China. Sci Total Environ 408(16):3118–2

Muller, G. (1979): Heavy metals in the sediment of the Rhine Changes seity.1971. UmschWiss Tech 79: 778-783.

Odukoya AM, Olobaniyi SB, Oluseyi TO (2018): Assessment of potentially toxic elements pollution and human health risk in the soil of Ilesha Gold Mining Site, Southwest Nigeria. Indian J Geochem 91(6):645–764

Odukoya, M.A. and Ifarajimi, T. W. (2021): Assessment of selected major and trace elements in groundwater of Lagos based on land use and implication on human health. Applied Water Science (2021) 11:54. https://doi.org/10.1007/s13201-021-01383-

Oluyemi, E.A., Asubiojo, O.I., Oluwole, A.F. (1994): Elemental concentrations and source identification of air particulate matter at a Nigerian site: a preliminary study. Journal of Radioanal and Nuclear Chemistry 179(2), 187-194.

Omatsola, M.E and Adegoke, O.S (1981): Tectonic Evolution and Cretaceous stratigraphy of Dahomey Basin Jour. Of mining geology Oshosun formation in Southwestern, Nigeria Journal of mining Geology. Vol 17 (1). Pp 97-103.

Piantone, P. (2007): Mercure natural et Sante. Geoscience et Sante No. 5 BRGN's Journal for Sustainable Earth, Pp46-51.

Rose B, Narins R (2000): Clinical physiology of acid-base and electrolyte disorders. McGraw-Hill Companies, New York

Servilia, O. F., N. and Ainnei, A. (2005): Effects of heavy metal on plant growth and photosynthetic activity. Unpublished M.sc thesis. University of Agriculture sciences and veterinary medicine. Pp. 107-110.

Sharma, R. K., and Sharma, U. (1997): Physiological perspectives of Copper. Report of Department of Zoology, India. Kurukshetra University, 698–713.

USEPA. (1989). Risk assessment guidance for superfund. human health evaluation manual. EPA/540/1-89/002, vol. I. Office of solid waste and emergency response. US Environmental Protection Agency. Washington, DC.. http://www.epa.gov/superfund/programs/risk/ragsa/index.htm>.

World Health Organization (1995): Inorganic lead Environmental Health Criteria no. 165 IPCS (international program on Chemical Safety).

World Health Organisation (WHO) (2008): Guidelines for Drinking-Water Quality 3rd edition, Vol.1, Recommendations. World Health Organisation, Geneva.

World Health Organization (2017): Guidelines for Drinking-Water Quality, 4th ed.; Incorporating first addendum; World Health Organization: Geneva, Switzerland, Available online: https://www.who.int/publications/i/item/

Wu B, Zhao DY, Jia HY, Zhang Y, Zhang XX and Cheng SP (2009): Preliminary risk assessment of trace metal pollution in surface water from Yangtze River in Nanjing section, China. Bull Environ Contam Toxicol 82(4):405

Yusuf Madu Mshelia, Mbursa Arhyel and Abah Boniface (2024): assessment of Heavy Metal Contamination and Health risk associated with selected borehole water Proximal to a dumpsite in Giwo, Bauchi state. FUDMA Journal of Science Vol. 8(3), pp 66-70. DOI: https:///doi.org/10.33003/fjs-2024-0803-2318