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Heavy Metal Pollutants Or Contaminant In Soil Samples Obtained From Wash Boreholes Within Pantisawa, Yorro L.G.A. Of Taraba State

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Abstract

The problem of environmental pollution and its compartments due to an increase in contamination as a result of the accumulation of heavy metals and microorganisms from soil has raised wide-spread of concerns in different parts of the nations and this has compromised the ability of the environments to foster life and render them an intrinsic value. Hence the study aimed to ascertain the level of environmental pollution in soil from wash borehole within Pantisawa Yorro Local Government Area of Taraba State, Nigeria. A total of 45 samples for soil were collected aseptically from the five different zones (Pantisawa Main Market YM, Kapazang YG, Dola YD, Kallau YK and Zabi YZ) of Pantisawa. The levels of trace metals in soil samples were determined using Atomic Absorption Spectroscopy (AAS) PG-990. The results were analyzed using SPSS Version 20. The soil samples result for these metals revealed that iron concentration was between 3000-4010mg/kg most especially for site SD which is higher than all other elements analyzed. Zinc ranges from 2.54-6800mg/kg which is above the standard as prescribed by WHO and FEPA in soil and also exceeded the dutch target values of (Zn**:** 50mg/kg and Cu: 30mg/kg) in some of the sampling sites. Nickel was between 8.47-19.09 mg/kg in soil samples, this is below the toxicity threshold limit of 35mg/kg for safe environment as stated by WHO. Arsenic ranges from 53.06mg/kg–141mg/kg, which is higher than the admissible limit of 50mg/kg in soil recommended by UNEP. The order of all the metal concentration in the areas was Fe>Zn>Mn>As>Pb>Cu>Mn>Co and Cd respectively. Based on this study, the high concentration of the metals such as Zn, As, Cd, Pb, and Co in some of these sites most especially SK, SM and SD within Pantisawa revealed that some of the soil samples collected from these areas were contaminated with heavy metal pollutants which may have serious health risk to the people using it for various activities. The higher concentrations of these toxic metals in soils need to be monitored regularly for heavy metal enrichment.

Keywords: Wash-boreholes; Soil samples; Heavy metals; WHO; Pantisawa LGA.

1. Introduction

Soil heavy metals are an important group of pollutants. They are non-biodegradable, hence are not readily detoxified and removed by metabolic activities once they are available in the environment. This may subsequently lead to their build-up to toxic levels or bioaccumulation in the ecosystem. Bioaccumulation of these heavy metals in man, animals, and plants result in metal poisoning [1]. Environmental heavy metal pollution is mainly of anthropogenic origin and results from activities such as fossil fuels, vehicular emissions, industrial emissions, landfill leachates, fertilizers, sewage, and municipal wastes [2]. They also stated that under certain conditions, these metals may accumulate to a toxic concentration level which can lead to ecological damages [3]. Heavy metal concentrations in soil are associated with biological and geochemical cycles and are influenced by anthropogenic activities such as agricultural practices, industrial activities, and waste disposal methods [4]. Contamination of roadside soils with heavy metals arises from various sources such as vehicles, road wear, and slipperiness control industries. Trace metal concentrations, such as Cd, Cu, Zn, and particularly Pb in surface soils have been the focus of many investigations. Accumulation of these metals in surface soil is greatly influenced by traffic volume and motor vehicles, which introduce several toxic metals into the atmosphere [5].

Heavy metals are introduced to the soil environment through a variety of sources such as combustion, extraction processes, agricultural runoff, transportation of dissolved metals, etc. They are priority toxic pollutants that severely limit the beneficial use of water for domestic and industrial applications. They further stated that frequent use of heavy metal-contaminated water in agricultural field leads to soil pollution and gradually enriching the soil [3].

The use of boreholes is of great importance to Pantisawa inhabitants, as superficial water sources are lacking in the vicinity. Many boreholes have been drilled with a depth of less than 20m all over Pantisawa Metropolis. Due to the increase in population, public water supply from these boreholes is very unstable and unpredictable as supplies are often irregular. As a result, most of the people drilled their own boreholes at a depth of less than 30m which are often called wash boreholes. These boreholes are widely recognized within the vicinity and it becomes an important source of drinking water in the area. The population congestion and consequent indiscriminate dumping of polluted water may enhance the infiltration of a harmful compound into the ground water. Thus, the possibility of these contaminations may justify the purpose of this research work [6]. It is important to note that soil can be considered as a good indicator of water pollution in terms of heavy metals concentration [7]. In Pantisawa, the environment has undergone damage due to the population growth and its subsequent requirements in terms of housing and traffic density. The increase in diseases caused by soil and water contamination is at an alarming rate. With mercury poisoning causing nervous system disorders; kidney and bone diseases caused by chronic cadmium poisoning and circulatory system diseases from lead and nitrate exposure being more prevalent, there is a need for determination of such pollutants or contaminants in the area. The specific Objectives are to determine the concentrations of heavy metals such as Cu, Ni, Pb, As, Cd, Fe, and Cr in soil samples at Kapazang, Zabi, Dola, Kallau, and Pantisawa Main Market and to compare the result with the standard guidelines set by WHO and other regulatory bodies. Wash boreholes in Pantisawa, Yorro LGA are usually 20-25m deep which is relatively shallow thus the tendency of having contaminations in the form of heavy metals among others. Essentially, soil quality testing is done to ensure that it complies with specifications laid down by regulatory bodies locally and internationally.

2. Materials and Method

2.1. The Study Area

Pantisawa is the capital of Yorro Local Government in Taraba State, located in North Eastern Nigeria. It covers more than 1,275 km^2 of different land units and a Population of 89,410 [8]. It is located between the latitude $8^0$43’0” N and longitude $11^0$37’0” E with an elevation of 802m above the sea level (figure 3.1). Pantisawa and its immediate environments lie within the woodland savannah and mountain grassland vegetation, with a heavy annual rainfall of about 800 to 1000 mm and the average daily temperature ranging from 22 to 35°C, before the onset of the rains in late March to October followed by a dry season from November to early March. It has mainly clay sandy loam soils. The local governments is dominated by Mumuye people who are the major ethnic group in the State. The inhabitants of this area are predominantly hunters, traders, and commercial farmers cultivating crops such as Ground nut, Yam, Maize, Millet, Cassava, and Guinea Corn. It is divided into fifteen (15) different geographical zones. In this study, five geographical zones were randomly selected; these include Kapazang, Zabi, Dola, Kallau, and Pantisawa Main Market.

Figure-3.1. The Map of Taraba State showing Pantisawa, Yorro LGA

3. Method

3.1. Soil Sample Collection and Treatment.

The soil samples were obtained from five different wash borehole locations within Pantisawa from the top surface using (centimetre) to measure the depth. It ranges from (0cm-40cm) at hole one 1, (40-60cm) and (60-100cm) having a different range of (20cm and 40cm). The samples were collected using a hand auger (a stainless steel crew material) and hand spade and were placed in to a clean polythene bags. The samples were labelled appropriately and taken to the analytical laboratory at Nigeria Institute of Geological Mining Jos, Plateau State.

3.2. Sample Treatment

The soil samples were oven dried to remove the moisture contents at 105^{o}C to constant weight for 6 hours. The oven-dried material was crushed and sieved through 2.00mm mesh to obtain a representative sample [8].

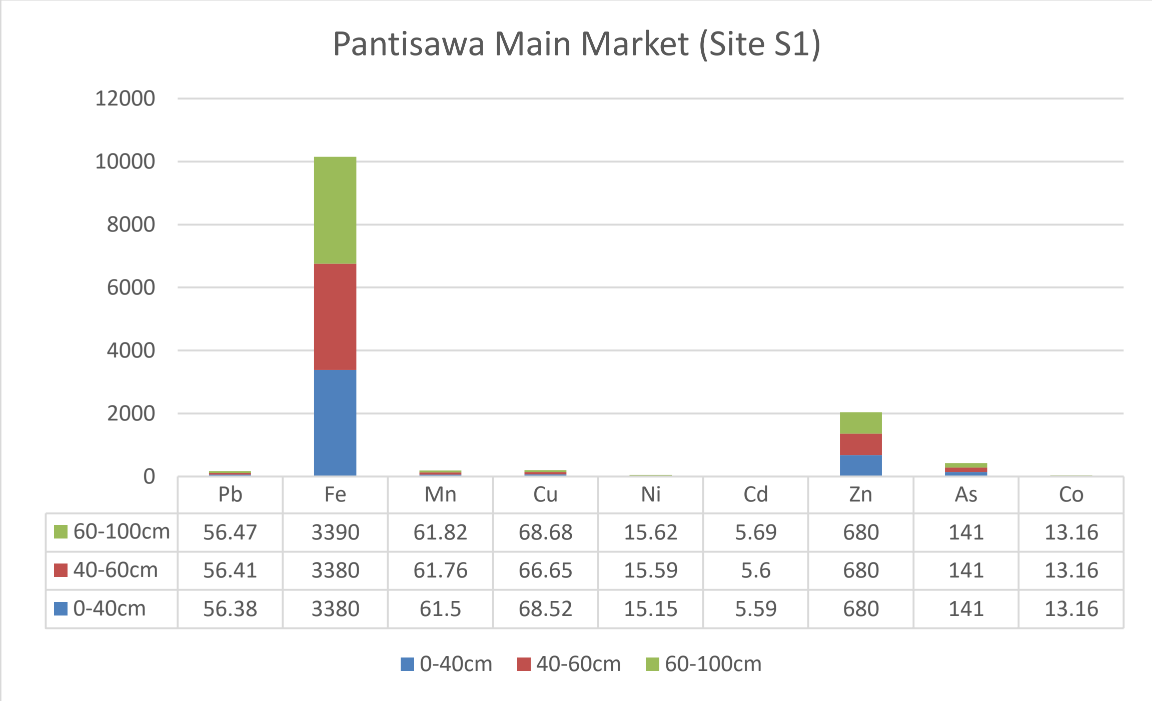
3.2.1. Sample Digestion

The oven-dried sample (1.0 g)was weighed using a top loading balance and placed in a 250ml beaker which has been previously washed with nitric acid and distilled water. The sample was reacted with 5ml of HNO_3, 15ml of concentrated H_2SO_4 and 0.3ml of $HClO_4$ using a dropping pipette. The mixture was digested in a fume cupboard, and heating continued until a dense white fume appeared which was then ingested for 15 minutes, set aside to cool, and diluted with distilled water. The mixture was filtered through acid-washed Whattman No.44 filter paper into a 50ml volumetric flask and diluted to mark volume [8]. The sample solution was then transferred in to the Atomic Absorption Spectroscopic machine at intervals.

4. Results and Discussion

4.1. Concentration of Metals (mg/kg) in Soil Across Different Depths from Pantisawa Main Market Location

The mean concentration from the result obtained in a soil sample from the pantisawa main market (Figure 4.1) shows that iron maintains a constant concentration across the different depths of (0-40, 40-60, and 60- 100) cm^3 exhibiting a value of 3380 mg/kg which is higher than the recommended value for unpolluted soil. The level of lead in soil samples from the sites varied widely from 56.38-56.47 mg/kg. However, there was no variation in the level of Arsenic metal concentration measured across the depth. (Figure 4.1).

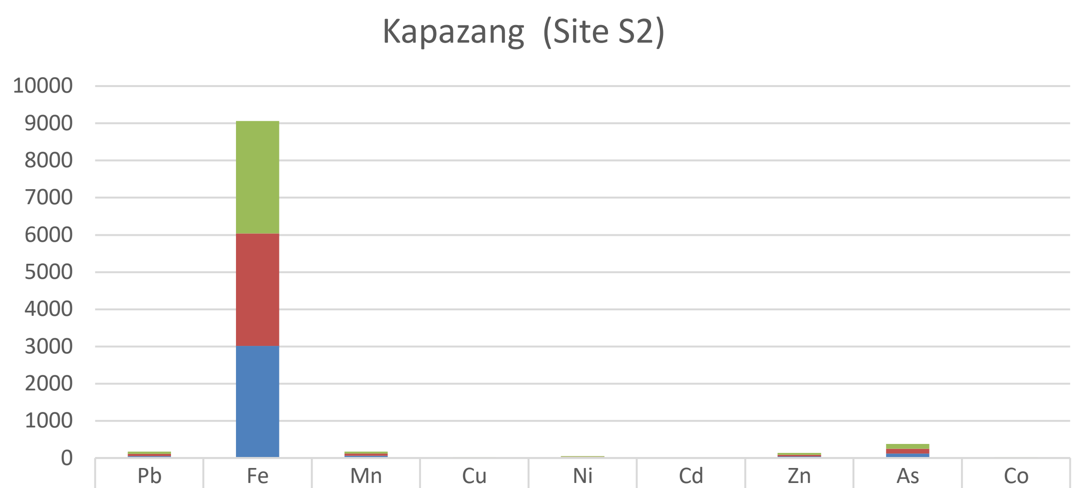


	Pb	Fe	Mn	Cu	Ni	Cd	Zn	As	Co
60-100cm	56.47	3390	61.82	68.68	15.62	5.69	680	141	13.16
40-60cm	56.41	3380	61.76	66.65	15.59	5.6	680	141	13.16
0-40cm	56.38	3380	61.5	68.52	15.15	5.59	680	141	13.16

Fig-4.1. Plot of Concentration (mg/kg) against Heavy metals for Pantisawa Main market sites.

4.2. Concentration of Metals (mg/kg) in Soil Across Different Depths from Kapazang Sample Location.

The result from the analysis shows that heavy metals such as Arsenic, Iron, and Zinc concentrations in the soil were very high ranging from 127mg/kg, 3020mg/kg, and 46.34 – 46. 44mg/kg. These values were extremely higher than the recommended limits of 0. Set by WHO (Figure 4.2).

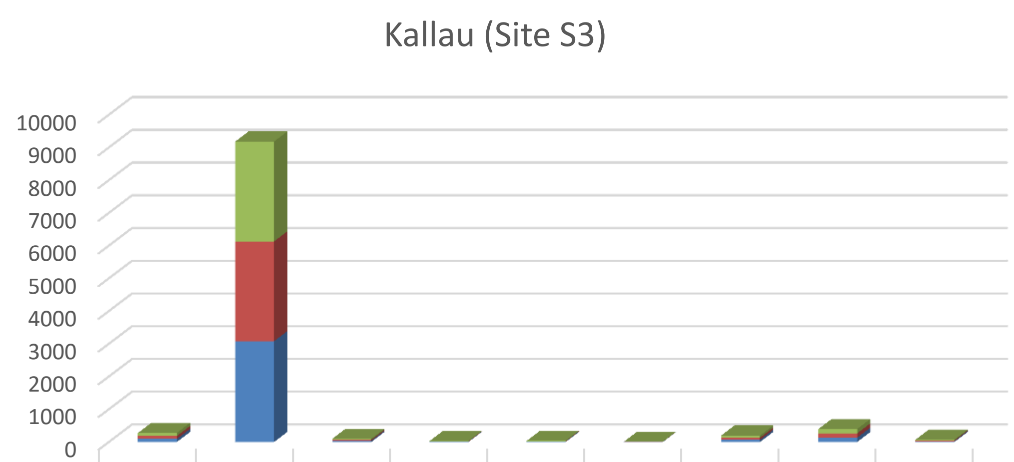


	Pb	Fe	Mn	Cu	Ni	Cd	Zn	As	Co
60-100	58.23	3020	59.24	10.81	18.86	2.5	46.44	127	10.52
40-60	57.96	3020	59.33	10.81	18.94	2.59	46.36	127	10.52
0-40	57.55	3020	59.61	10.8	19.09	2.62	46.34	127	10.52

Fig-4.2. Plot of Concentration (mg/kg) against Heavy metals for Kapazang sample sites

4.3. Concentration of Metals (mg/kg) in Soil Across Different Depths from Kallau Sample Location

The results from this sample site revealed a steady decrease in concentration at different depths for Arsenic ranging from 131.81 – 131.82 mg/kg (Figure 4.3). The highest concentration of iron was observed at 0 – 40cm depth (3080mg/kg) and the lowest concentration at 40-100cm depth (3050mg/kg). However, almost all the concentrations of the metals detected in this area were found to be above the standard limit recommended by WHO of 200mg/kg for lead and 200mg/kg for zinc in soil.



	Pb	Fe	Mn	Cu	Ni	Cd	Zn	As	Co
60-100	92.49	3050	33.37	9.79	12.07	3.63	65.41	131.82	23.69
40-60	92.49	3050	33.34	9.79	12.07	3.63	65.41	131.82	23.69
0-40	92.49	3080	33.33	9.79	12.08	3.63	65.41	131.81	23.69

Fig-4.3. Plot of Concentration (mg/kg) against Heavy metals for Kallau sample sites.

4.4. Concentration of Metals (mg/kg) in Soil Across Different Depths from Dola Sample Location

Figure 4.4 shows the concentration of various heavy metals across the depths profile. All the metals concentration detected in this site maintain the same values for concentration across the different depth which ranges from 130.05 – 130.04 mg/kg for manganese (Mn), 5.58 -5.58 mg/kg for Cadmium (Cd) and 15.16 – 15.16 mg/kg for Nickel (Ni) and highest values were recorded for zinc concentration (6800-6800mg/kg).

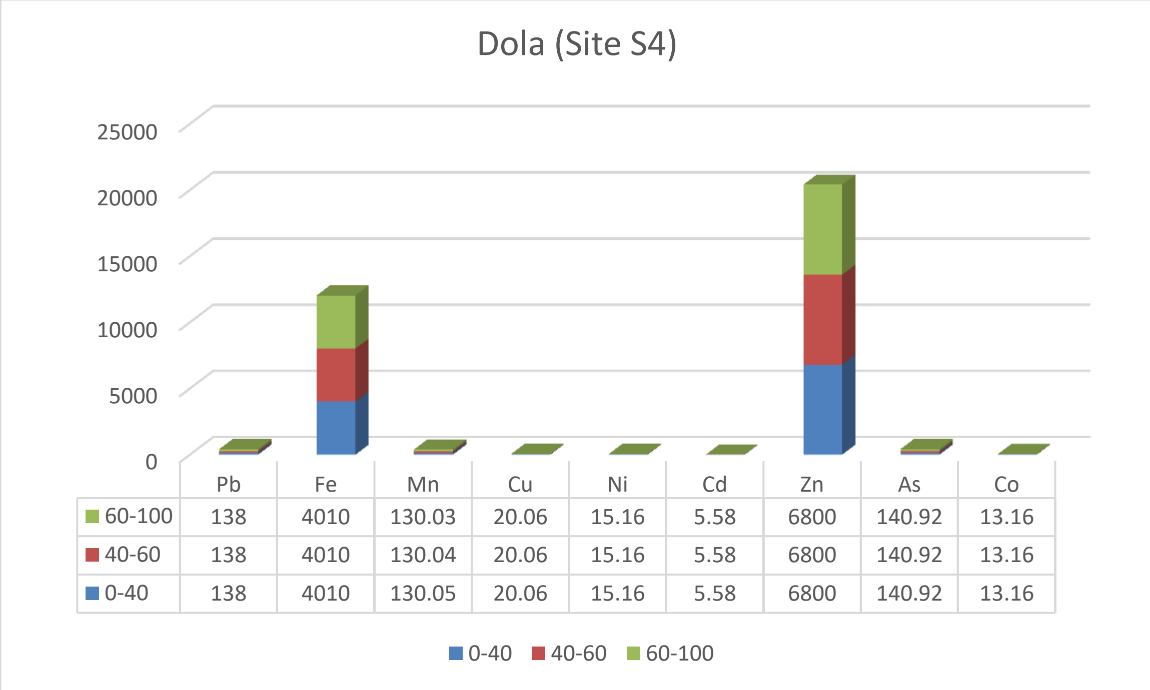


Fig-4.4. Plot of Concentration (mg/kg) against Heavy metals for Dola Sample sites.

4.5. Concentration of metals (mg/kg) in soil across different depths from Zabi Sample Location

The concentration of manganese across the different depth profiles in this site decreases from 40.36 – 37.11mg/kg from the top surface 0- 40 to the bottom 60-100cm. This result also revealed the high concentration of iron (Fe) which ranges from (3130- 3570mg/kg). The Least values detected in this study are the concentration of cadmium Cd, and Zinc Zn, with a record value ranging from 2.78-2.52mg/kg for Cd and 2.54 – 2.76mg/kg for Zinc (Figure 4.5).

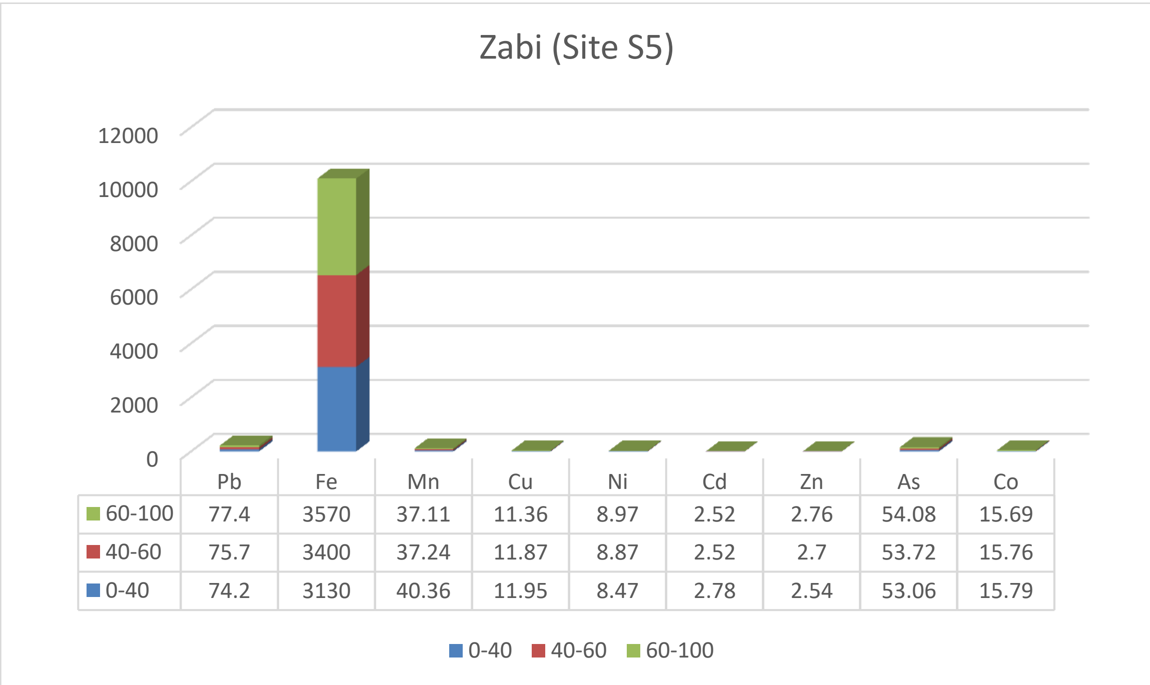


Fig-4.5. Plot of Concentration (mg/kg) against Heavy metals for Zabi sample sites

4.6. The Standard Limit of Selected Heavy Metals (ppm) in Soils as Recommended by International Organizations or Countries

Figure 4.1 is showing the limits of selected heavy metals (ppm) in drinking water and soils as recommended by World Health Organization WHO [9].

Table-4.6. Limits of selected heavy metals in soils as recommended by WHO, China, and USA, EPA

Organization /Country	The Review variable	Recommended limits for the studied heavy metals (ppm)								
	Soil	Pb	Fe	Mn	Cu	Ni	Cd	Zn	As	Co
WHO	Soil	0.1	3000	20	50	0.05	0.003	200	50	20
China	Soil	80-250	NG	NG	50	40–60	0.3–0.6	200	30	NG
USEPA	Soil	200	400	NG	70-80	72	0.48	300-400	50	20

Key: ppm = Part per million; NG stands for Not Given. The source was Geoffrey et al. (10).

The study on a soil sample from all the sample sites within Pantisawa showed that there is an accumulation and variation of metals ions across the different depth profiles of soil samples obtained from different wash boreholes located close to the dumpsite most especially from Pantisawa Main Market site (Figure 4.1) and Dola (Figure 4.4) and hence this can lead to pollution of the Areas. The pollution of soils from dumpsite sources is serious environmental issues. The soils may become contaminated by the accumulation of heavy metals and metalloids through emission from the rapidly expanding industrial areas, mine tailing, disposal of high metal wastes, leaded gasoline, and paints, land application of fertilizers, animal manures, sewage sludge, pesticides waste irrigation, coal combustion residue, spillage of petrochemicals and atmospheric deposition (Ogundele *et al.*,2015). The only imminent danger inherent in the continuous pollution of soil by heavy metal demands that critical efforts be geared toward adequate management of municipal solid waste [10]. This can be reduced if the solid waste is sorted and inorganic parts are recycled. From the result presented in Figure 4.1 it could be observed that there is a steady downward increase in the concentration of some of the heavy metals across the different depths of the soil especially Pb, Fe, Mn, Cu, Ni, and Cd except for Zn, As and Co that showed and maintained same concentration across the depths profile. The analysis of heavy metals in the soil of Pantisawa Main Market shows that iron (Fe) has the highest values which is in line with the previous studies done and reported by Singh and Kalamdhad [11]. Other elements (Cu, Pb, Mn, Zn, As) determined showed higher concentration at Pantisawa Main Market. This could be due to the fact that environmental pollution of heavy metals from soil and road traffics emissions has affirmed much attention in the recent years due to their long-term accumulation [12].

Several studies have proved that wash borehole located around market, road, and dumpsite environments are polluted by heavy metals released during different operations of market and road transport activities especially components wears, corrosion of metals combustion, and fluid leakage. Lead, copper, cadmium, and zinc are released from fuel burning, wear-out tyres, leakage of oil and corrosion of batteries and metallic parts such as radiators [13]. As such this may be a result for the accumulation of heavy metals in the area mentioned above. The result from figure 4.2 (Kapazang) showed a higher accumulation of metals in soil most especially Fe, Ni, and Zn at different depths which are higher than the regulatory limit. This could be due to the fact that the sample site at Kapazang is close to the mechanical workshop, metal and iron bending site, and high way which may contribute to the increase in the level of heavy metals in the soil. Metals added to soils in the application of bio-solids can be leached downward through the soil profile and can have the potential to contaminate groundwater. They leached into the underground waters from the soil, moving along waterways and eventually depositing in the aquifer or are washed away by run-off into surface waters there by resulting in water and subsequently soil pollution [14]. Similar studies were carried out by Raymond and Felix [15] on heavy metal in contaminated soils who reported that soil treated with bio solid has shown increased concentrations of Cd, Ni, and Zn drainage leaches. The analysis from Figure 4.3 (Kallau) revealed a high accumulation of heavy metals in the sample area of Kallau most especially for As, Co, and Mn which exceeded the standard regulatory limit. The accumulation of this metal may be attributed to the presence of a dump site, metal welding and a farm located close to the sample area. The environmental problem with heavy metals is that they are unaffected during the degradation of waste and have a toxic effect on living organisms when exceeding a certain concentration. Exposure to heavy metals may cause blood and bone disorders, kidney damage and decreased mental capacity, and neurological damage [16]. The effect and occurrence of heavy metals (cobalt, manganese, nickel, and cadmium) on soil, plants, human health, and aquatic life was reported by Singh and Kalamdhad [11].

The results presented in Figure 4.2 indicated a higher concentration of Pb, As, Fe, Mn, and Zn without variation across the depth profile in the soil sample area of Dola. The high accumulation of heavy metals in this area could be associated with the presence of an electric power station, animal farmhouse, metal waste disposal, pesticides, and phosphate fertilizer deposit located within the sample site. The soil may become contaminated by excess accumulation of heavy metals from such activities taking place around the area. The exposure and accumulation of lead and arsenic in the body through direct ingestion (eating) of contaminated soil or dust. The risk of lead poisoning through the food chain increases as the soil lead level rises above 300ppm [15]. Lead and arsenic can cause serious injury to the brain, nervous system, red blood cells, kidney and and gastrointestinal symptoms such as severe vomiting, nausea, and headaches [14]. Zinc, Manganese, and iron are considered to be relatively non-toxic especially if taken orally. However excess amount can cause system dysfunction that results in poor growth and reproduction. The clinical sign of toxicities has been reported as vomiting, diarrhea, bloody urine, icterus (yellow mucus membrane), liver failure, kidney failure, and anaemia [15, 17]. Values of heavy metals in Zabi sample site (Figure 4.5) showed that zabi is much contaminated by As and Fe. An above limit value of As and Fe was measured. It is probably caused by the presence of broken bottles contained in a waste material coming from the bar located close to the sample area and also the poultry house sited near the sampling point. Metal added to the soil profile in the application of bio-solid can be leached downward through the soil profile and can have the potential to contaminate groundwater. Arsenic contained in poultry health products may also have the potential to cause metal contamination of soil [15]. The high values of these metals in the soil above the permissible limit are evidence of insufficient protection of the environment against the penetration of toxic substances. This study is in line with the previous studies reported by Yusuf, *et al.* [8], Ogundele, *et al.* [12], Oladeji and Saeed [18], Sanusi, *et al.* [19], Angelovičová and Fazekašová [20], and Geoffrey, *et al.* [21] on contamination of soil and water environment by heavy metals.

5. Conclusion

In conclusion from the soil samples, the heavy metals are analyzed in terms of depth profile (0-40, 40-60, and 60-100cm). The results are reflective of the depth profile given values from lower to higher ranges. Seven out of the nine metals analyzed exceeded the permissible level, sample sites SM (Ni, As Co, and Cd), SD (As, Cd, Zn and Fe) and SZ (As, Fe, and Mn) among others. Similarly, the high concentrations of these metals might be due to erosion, fecal dumps, chemicals, and refuse dumps implying that the inhabitant around the sampling site is liable to heavy metal pollution.

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Author Declaration

The authors hereby declare that the work presented in this article is original and has not been previously submitted to any journal.

References

[1] Bulinski, R., Bloniarz, J., and Libelt, J., 2009. "Presence of some trace elements in polish food products. Xv. Contents of lead, copper, cadmium, nickel, chromium, zinc, cobalt, manganese, copper and iron in some milk products." *Bromatologiai. Chemiatoks,* vol. 26, pp. 23-27.

[2] Xianfeng, C., Jarmila, D., Tomas, D., Qianrui, H., Wufu, Qi, Shuran, Y., Liling, Z., Yungang, X., *et al.*, 2018. "Pollution assessment of trace elements in agricultural soils around copper mining area." vol. 10, pp. 1-18. Available: www.mdpi.com/journal/sustainability

[3] Musa, J. J., Mustapha, H. I., Bala, J. D., Ibrahim, Y. Y., Akos, M. P., Daniel, E. S., Oguche, F. M., and Kuti, I. A., 2017. "Heavy metals in agricultural soils in nigeria: A review." *Arid Zone Journal of Engineering, Technology and Environment,* vol. 13, pp. 593-603.

[4] Ndiokwere, C. C. and Ezehe, C. A., 1990. "The occurrence of heavy metals in the vicinity of industrial complexes in Nigeria." *Environmental International,* vol. 16, pp. 291-295.

[5] Usman, S. O. A. and Ayodele, J. T., 2002. "Bioaccumulation of four heavy metals in leaves of calotropis procera." *Journal of chemical society of Nigeria,* vol. 27, pp. 26-27.

[6] Isa, A. M., Ibrahim, A. A., Haruna, Y. I., and Abubakar, S., 2013. "Physicochemical and bacteriological analyses of drinking water from wash boreholes in Maiduguri Metropolis, Borno State, Nigeria." *African Journal of Food Science,* vol. 7, pp. 9-13.

[7] Danesino, C., 2009. *Environmental indicators for heavy metal pollution": Soils and higher plants dipartmento di scienzedella*. Pavio Italy: Universita di Pavia, via Ferraata 1,271000.

[8] Yusuf, M., El-fighi, F. M., Zaidi, S. A., Abdullah, E. C., and Khan, M. A., 2015. "Applications of graphene and its derivatives as an adsorbent for heavy metal and dye removal: A systematic and comprehensive overview." *RSC Advances,* vol. 5, pp. 50392-50420.

[9] World Health Organization WHO, 2017. *Chemical Contaminants in drinking water. Guidelines for Drinking-Water Quality incorporating the first addendum*. 4th ed. Geneva, Switzerland: WHO Press. p. 398.

[10] David, S. K. and Minati, S., 2018. "Levels and health risk assessment of heavy metals in soil, water, and vegetables of dares salaam, Tanzania." *Hindawi Journal of Chemistry,* vol. 18, pp. 1- 9.

[11] Singh, J. and Kalamdhad, A. S., 2011. "Effects of heavy metals on soil, plants, human health and aquatic life." *International Journal of Research in Chemistry and Environment,* vol. 1, pp. 15- 21.

[12] Ogundele, D. T., Adio, A. A., and Oludele, O. E., 2015. "Heavy metal concentrations in plants and soil along heavy traffic roads in north central Nigeria." *Journal of Environmental and Analytical Toxicology,* vol. 5, pp. 2-5.

[13] Isa, B. K., Amina, S. B., Aminu, U., and Sabo, Y., 2015. "Health risk assessment of heavy metals in water, air, soil and fish." *African Journal of Pure and Applied Chemistry,* vol. 9, pp. 204-210.

[14] Manju, M., 2015. "Effects of heavy metals on human health." *International Journal of Research Granthaalayah,* pp. 1-7.

[15] Raymond, A. W. and Felix, E. O., 2011. "Heavy metals in contaminated soils: A review of sources, chemistry, risks and best available strategies for remediation." *International Scholarly Research Network Ecology,* vol. 201, pp. 1-20.

[16] Engwa, A. G., Udoka, P. F., Nweke, N. F., and Unachukwu, M. N., 2019. *Mechanism and health effects of heavy metal toxicity in humans*. Creative Commons Attribution, pp. 1-23.

[17] Mmolawa, K. B., Likuku, A. S., and Gaboutloeloe, G. K., 2011. "Assessment of heavy metal pollution in soils along major roadside areas in Botswana." *African Journal of Environmental Science and Technology,* vol. 5, pp. 186-196.

[18] Oladeji, S. O. and Saeed, M. D., 2015. "Assessment of cobalt levels in wastewater, soil and vegetable samples grown along Kubanni stream channels in Zaria, Kaduna State, Nigeria." *African Journal of Environmental Science and Technology,* vol. 9, pp. 765-772.

[19] Sanusi, K. A., Mohammed, S. H., Muazu, A. A., and Aishatu, M. K., 2017. "Assessment of heavy metals contamination of soil and water around abandoned pb-zn mines in yelu, alkaleri local government area of bauchi state, Nigeria." *International Research Journal of Public and Enviromental Health,* vol. 4, pp. 72-77.

[20] Angelovičová, L. and Fazekašová, D., 2014. "Contamination of the soil and water environment by heavy metals in the former mining area of rudňany (slovakia)." *Soil and Water Resources Journal,* vol. 9, pp. 18–24.

[21] Geoffrey, K. K., Ngure, V., Dunstone, B., Reuben, L., Wangila, A., and Kamau, L., 2020. "Levels of heavy metals in wastewater and soil samples from open drainage channels in nairobi, Kenya: community health implication." *Scientific Reports,* vol. 10, pp. 1-13.