Synergistic effect on heavy metals concentration in Soil of waste Disposal sites in Birnin Kudu town in Jigawa State, Nigeria

Ashiru Garba Abdullahi[1], Abba Alhaji Bala[1], AminuAbubakar[2], Auwal Abubakar[2], Muhammad Tajuddeen Garba[3], Abubakar Saidu Shaibu[1]

[1]Advance Center for Nanotechnology and Computational Physics Laboratory Department of Physics, Faculty of Physical Science, Federal University Dutse, P.M.B 7156, Ibrahim Aliyu Bye Pass, Jigawa State, Nigeria.

[2]Alu College of Health Sciences and Technology Birnin Kudu

[3]Department of Physics Yobe State University, Damaturu, Yobe State

[4]Department of Physics Sule Lamido University, Kafin Hausa, Jigawa state

**Corresponding author E-mail*: ashirugarba003@gmail.com

(Received 26 March 2025, Accepted 08 July 2025, Published 16 July 2025)

Abstract

The Widespread practice of open solid waste disposal dump sites in the contemporary era has become a major source of solid waste disposal in urban and semi-urban areas, contributing immensely to severe health risks and other environmental degradation. Due to the rapid growth of settlement and urbanization, the environmental health effects of some solid waste disposal (dumped sites on the soil by heavy metals) are becoming an increasingly urgent calamity to society. This research focuses on geochemical and physiochemical investigation of some heavy metals on soil in solid waste disposal dumpsites in some selected areas of Birnin kudu. The solid waste disposal of the said area were taken of about 10 places as a sample to assess the metal index risk to ascertain the rapid increase in transfer factor by heavy metals on soil to human by inhalation and compared to the other area having no such heavy metals. The sites were mainly contaminated with Cd Cr Fe, Zn Pb as well as partially contaminated by Mg and Mn. Inhalation of such heavy metals results in numerous health risks including stomach pain, liver failure, damage to the kidney, mental illness as well as skin cancer. Moreover, identifying the extent of contamination of heavy metals and coming up with modalities to overcome such health risks, is one of the targets of this research which include the migration of the solid waste disposal dump site too far from the vicinity, advancement of green chemistry practices in local industry, community awareness by enlighten peoples dropping their solid waste disposal dump in the sites, community implementation to take necessary actions. The essential measures that can ensure safeguarding future occurrence and also achieve sustainable development goals 6 (SDG).

Keywords: Heavy metals concentration, soil, waste disposal sites, health risks, Comparison

1. Introduction

Waste disposal sites or dump sites, have become the most vital area where the collections of unused waste products are kept, in many communities the dump sites will be abundant due to negligence and lack of awareness [1][2][3][4]. In many countries unwanted used items in the dump site have been recycled and modified either for industrial applications or commercial purposes, agricultural uses as natural manure [5]. As a result of the rapid increase in population growth, urbanization, industrialization microbial contamination, many dump sites become closer to the houses which leads to an increase in health risks to the people within the vicinity as such heavy metal effluent gives out to solid disposal [6]. Biomedical waste discharge and unsustainable development activities are the main pressures on dump site areas and can easily affect human health [7]. The tremendous increase in waste disposal sites in urban areas aroused the attention of many researchers to investigate the health risks associated with heavy metals in the area. To ascertain elemental composition and toxicity in the waste disposal site [8]. Even though heavy metals are naturally found in the environment, their excessive utilization and release of untreated effluent from various tanning, leather, and chemical industries have significantly disrupted the ecosystem [9]. But the discharged heavy metals infiltrate aquifers, and dissolve in waste sites and water which also simply accumulate in various organs in the human body or some organisms, such as domestic birds, and this is subsequently taken up by the top consumers, Humans [6]. The accumulation of heavy metals in waste disposal and food materials leads to various complications and impairs their physiological functions [10]. The guidelines of the World Health Organization,2021 of some heavy metals like Cd, Cr, Hb, Se, Pb, As, and Co revealed that highly toxic heavy metals are not consumed by organisms rather they are toxic, but some essential elements like Mn, Zn, Cu, and Mn are eco-friendly metals which beneficial to human health at low concentration, in the case may be at high concentration are even more dangerous [11]. As a result of such toxic metals they lead to a carcinogenic, genotoxic, mutagenic, and teratogenic effect in humans [8]. Numerous studies have shown that heavy metal in basins and disposal sites harms humans and causes anthropogenic discharge certainly humans are exposed to heavy metal via inhalation by contamination of air from waste disposal sites or water and soil. In which the health effect depends on the heavy metal exposure [12]. Long-term exposure to heavy metals increases the death rate and illness also consequences of exceeding safe limits can lead to danger to human health [10]. Research has shown that short and long-term exposure to heavy metals can lead to serious health issues that cause liver cirrhosis, renal failure, damage of severe nerve system, cancer, reproductive abnormalities, and heart diseases like cardiovascular diseases [13]. Many studies have been assessing the geochemical and physiological distribution, health risk assessment, and heavy metal pollution indices which are used for managing the environment by planners, managers, and administrators to ascertain the parameters into single factors. Herein heavy metal pollution in waste disposal can draw attention by investigating toxic elements found in dump sites and stating the possible preventive measures against such toxic heavy metals by enlightening people within the vicinity to stay away from the sites. Additionally, its commendable to use a domestic item to reduce the minimum number of concentrations of heavy metals. For example, using neem leaf tree, rice husk or orange feel can testify that it reduces the minimum concentration of lead heavy metal in the environment.

2. Literature review

A lot of research has mentioned the significance of health awareness regarding health effects and risk assessments of heavy metal and understanding the possible solutions to the problems associated with such toxic materials, it also highlighted critical levels of heavy metal pollution as well as a way forward to such area which explores the bioaccumulation of heavy metal in waste disposal site and subsequent impact in human health which have insight in health and ecological consequences investigation [14]. These studies, attract the current trends and attention in waste disposal sites monitoring and health risks assessment as a result of dyeing lather spread and agrochemical industries, but the significant risk of heavy metal contamination attributed to industrial zone attributes discharge potential toxicity into to environment. Substantial contamination issues by heavy metals were highlighted the linked to rapid industrialization which led to the accumulation of heavy metals in waste disposal sites such as zinc, lead, cadmium chromium, and iron, in the dump site [15]. A result of thorough investigation revealed that the pose of chronic health risk is due to heavy metal and physicochemical pollutants by the local population. use of different hydrogeochemical and statistical techniques particularly factor analysis combined with GIS is imperative for mapping contamination hotspots, understanding the spatial distribution of pollutants [16]. While these measures have been taken, soil quality and public health need further protection in the area due to the persistent and changing industrial pollution. In this research, there are primary objectives; as

I- the effect of heavy metal contaminations like Cadmium Cd, Nickel Ni, Cobalt Co, Chromium Cr, Zinc Zn, lead Pb, Manganese Mn, Magnesium Mg, iron Fe, and Copper Cu, on soil using waste disposal sites which indicates by assessing the sample with atomic absorption spectrum (AAS) was computed to understand the contamination of heavy metal as well as the implementation of health risk to humans due to utilization of heavy metal in soil.

II- showing the relationship between the physiochemical and geochemical parameters in the soil to waste disposal sites using statistical variates to forecast the origin through the tools.

To highlight the spatial distribution of heavy metal is soil on waste disposal sites in the study area on a map, the objective of this study is to pave the way to the existing knowledge on heavy metals investigations to come up with valuable initiation for academics, stakeholders in the environmental resource management protection

3. Material and Methods

3.1 Study Area

The Birnin Kudu metropolis is located at Birnin Kudu local government area of Jigawa state, Nigeria. As illustrated in **Fig 1**. The study area lies between 11º 26’60.00’’ (N.) and the Longitude’ 9º28’30.00’’ (E) in which the waste disposal sites are within the municipality area [17]. The town has a land mass of 127 (2.451 km^2) and a Density of 289.3/km^2. The nature of the soil in the research area was found to be sandy, clay, and loamy within the sample location [18]. **Table 1** describes the area in which the waste disposal site is located including the coordinates of all the located areas, sample codes, and the distance between the two sites in meters.

Table 1; Description of Soil sample location and its coordinates.

S/No	Description of sites	Sample soil	Latitude (N)	Longitude (E)	Distance in meters
1	Tudun wada	AG1	11º27’28.262N	9º28’14.01E	500m
2	Zarenawa P.S	AG2	11º27’22’500.N	9º28’30.060’’E	350m
3	Mahauta	AG3	11º21’0.372’’	9º28’43.56’’E	430m
4	Bakin Kasuwa	AG4	11º27’33.816N	9º28’61.428E	500m
5	Yadin boni	AG5	11º27’1.446’’N	9º28’30.937’’E	480m
6	Zango Qtrs.	AG6	11º26’51.846’’N	9º28’41.694’’E	550m
7	Makwalla	AG7	11º26’214.051’’N	9º27’847.651’’E	600m
8	Furya	AG8	11º26’45.372’’N	9_o28’35.502’’E	670m
9	Masamawa P.S	AG9	11º27’17.418’’N	9º28’38.076’’E	500m
10	Sabon gari	AG10	11º26’37.086’’N	9º28’28.028’’E	650m

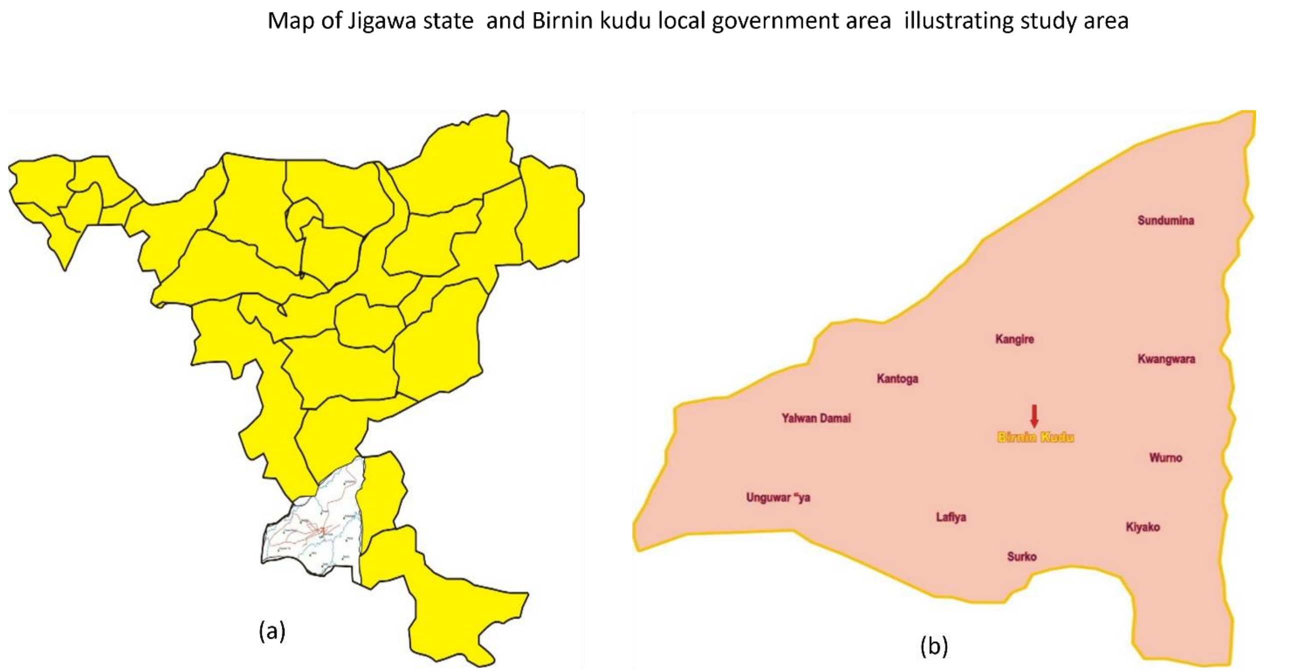

Fig 1: Illustration (a) the map of Jigawa state (b) map of Birnin kudu local government as a study area

3.2. Methodology

It was the random sampling technique used for data collection in which, to quantify soil in waste disposal sites samples throughout the data collection. About 20 samples were used in five different sites whereby 500 miters were covered to take the sample between each waste disposal sites to have a good representation of all potential sources of contaminations within the area of study. The locations of the said sample were chosen based on demographic as well as geographical factors. At the same time, the sites covered were distributed in diverse land. Moreover, the process of selection was coupled with historical data as well as reviews of the related literature to identify the contaminations of the concern area. Atomic Absorption Spectrometer (AAS), Filter paper, Sieve, Plastic plates, volumetric flask, Grinder, Conical flask, Measuring cylinder, Hoe, Analytical balance, Beaker, Funnel, Hot plate, Nitric acid (HNO_3) and Concentrated. Hydrochloric acid (Hcl) [19].

4 Result and Discussion

The results were collected from the study area which was obtained and the sample of the soil using the technique called atomic absorption spectrum (AAS) as shown in the results. The heavy metals investigation of the said study area was detected from the soil sample which was analyzed. The investigations revealed that there are variations in the concentration of the heavy metals in the study area with sample location and points, these heavy metal concentration ranges from 1.388889 to 118.51585. Among all the elements Zinc happens to record the lowest concentration as compared with Cd and Cr but iron has the highest concentration due to its electronic and ionic properties, meanwhile, this shows that all detected heavy metals in the soil possess the potential of groundwater that is contaminated [20].

Table 2: Heavy Metals Concentrations in soil samples obtained from Birnin kudu metropolis dumpsite

S/N	Samples ID	Fe9PPM)	Zn(PPM)	Pb(PPM)	Cd(PPM)	Cr(PPM)
I	AG_1	101.20	2.08	7.40	10.00	4.27
Ii	AG_2	86.67	4.26	3.34	15.00	2.15
Iii	AG_3	79.93	1,89	5.52	17.00	2.70
Iv	AG_4	83.30	4.76	4.52	17.00	10.10
V	AG_5	85.30	2.18	3.35	11.00	5.06
Vi	AG_6	92.21	3.41	8.01	20.00	6.11
Vii	AG_7	90.40	1.62	4.12	15.00	7.24
Viii	AG_8	109.20	2.88	6.26	18.00	3.67
Ix	AG_9	96.75	3.14	5.93	16.00	4.59
X	AG_{10}	78.93	1.58	4.16	10.00	5.52

Table 3: Standard FEPA guidelines for Heavy metals in Soil

SAMPLE ID	*Zn(PPM)*	*Fe(PPM)*	*Pb(PPM)*	*Cd(PPM)*	*Cr(PPM)*
FEPA	B.G	B.G	400	1.6	300-400
E U	3.0	150	B.G	B.G	B.G
WHO	5.0	3.0	0.01	0.003	0.05

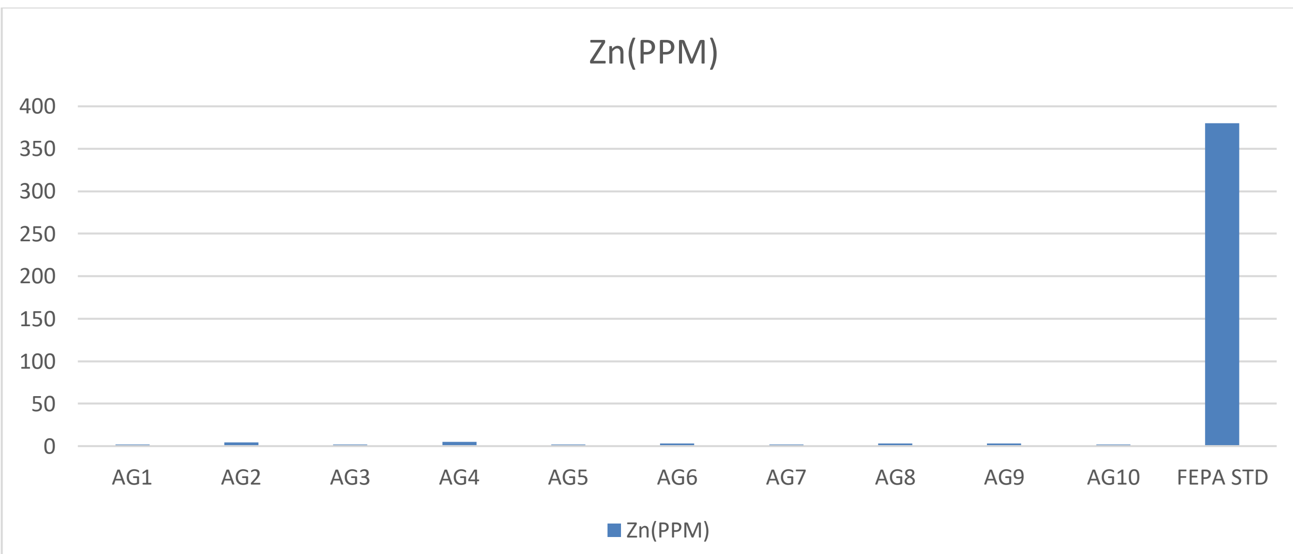

Fig. 2 Zinc concentration in a soil sample with FEPA standard

Fig 2: illustrates the Zn concentration in soil samples in which the concentration of Zn was so negligible as compared with the FERA standard even though the highest and lowest concentrations of zinc PPM were found to be in samples AG_4 and AG_{10} respectively this shows people within the vicinity are at safer side.

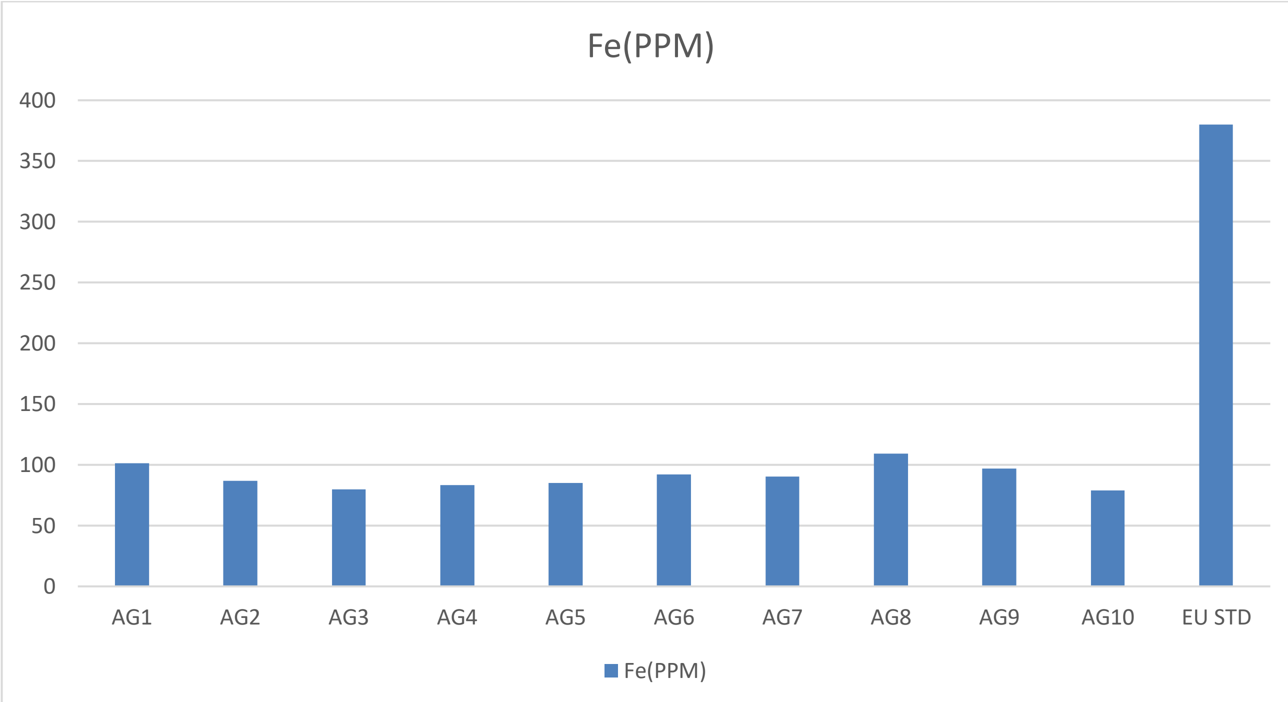

Fig 3: Iron concentration in a soil sample with EU standard

In the above fig. 3 it was revealed that the concentration of iron varies in some points with the concentration of the samples this indicates sample AG_4 became the highest point with high concentration and sample AG_9 has the lowest concentration of iron, but the interesting all the points sample are with the permissible limit meaning it is below the standard by the federal environmental protection agency FEPA.

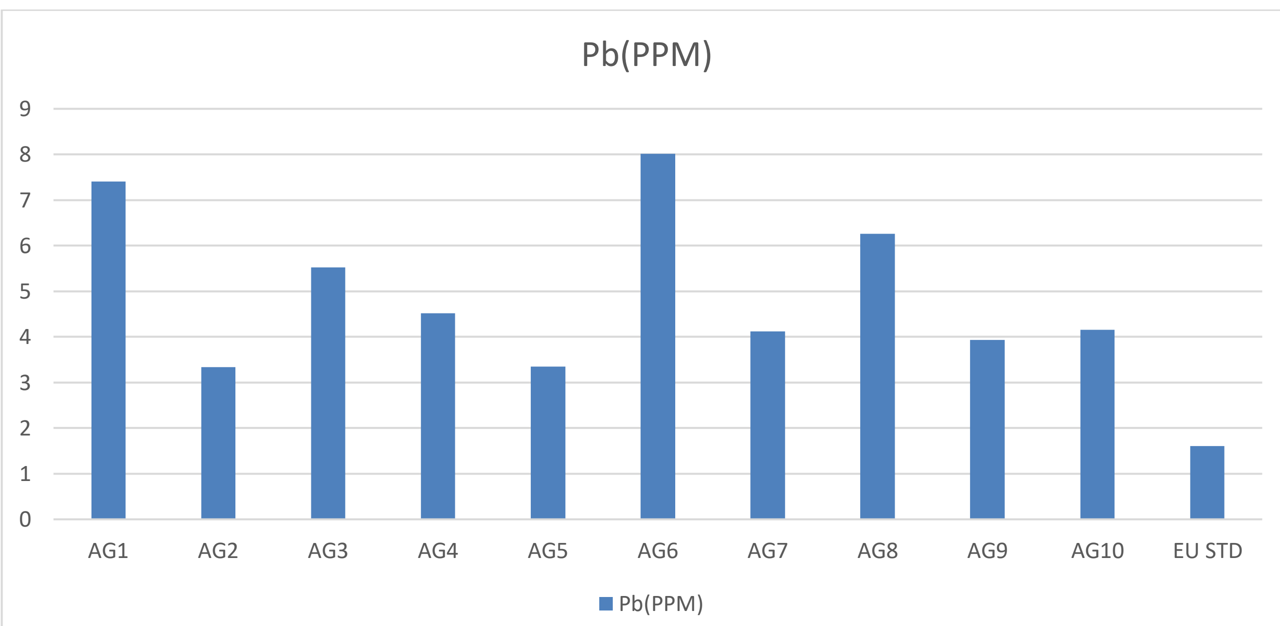

Fig 4: Lead concentration in soil with EU standard

From the above Fig. 4, there is the presence of lead concentration within the study area certainly the sample AG_6 has the highest lead concentration. Considering the whole sample the concentration of lead is above the permissible limit of heavy metal standard in soil stated by FEPA which is 1.6. In this regard, the potential of lead in the study area may cause adverse effects when exposed, because it is one of the common contaminants having toxicity in the environment, as such presence may be attributed to natural and anthropogenic sources like the use of some pesticides in agricultural farms, another adverse effect includes poisoning of lead in humans and chronic neurological disorder especially in children and fetuses [21].

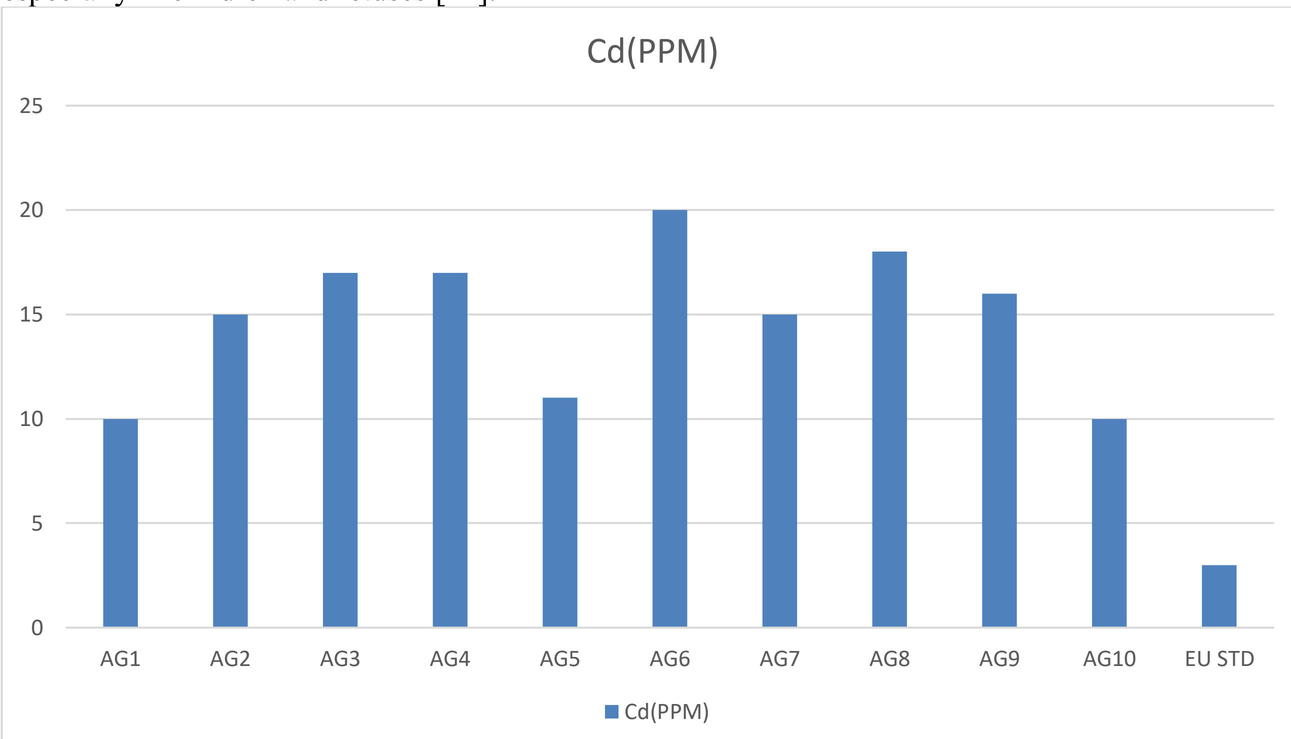

Fig 5: Cadmium concentration in a soil sample with EU standard

Fig 4: illustrates the presence of cadmium concentration in soil samples in this regard the samples AG_1 and AG_{10} have the lowest concentrations while sample AG_6 has the highest concentration, this indicates that all the above samples are higher than the permissible limit which is 3.0ppm by EU standard. The result reveals the high level of cadmium concentration in the study area due to the dumping of substances like batteries in high quality, which leads to leaching into the ground. Cadmium has become one of the toxics and carcinomic elements in the environment, it causes cancer and other health defects. The main routes of exposure to cadmium are via inhalation or cigarette smoke, and ingestion of foods, this can be possible through several ways like eating contaminated food and smoking cigarettes, as it can cause serious adverse effects like pulmonary and gastrointestinal irritation as a result of acute ingestion symptoms such vomiting, nausea, abdominal pain, burning sensation, salivation, shock loss of consciousness and convulsion [21].

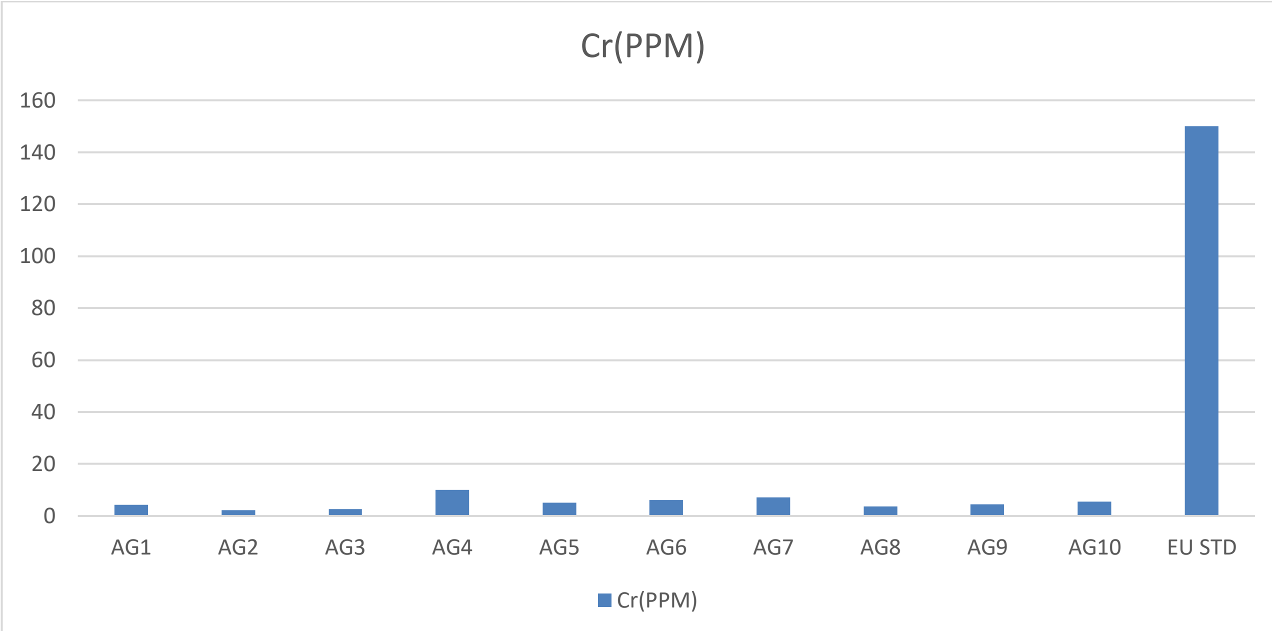

Fig 6: Concentration of chromium in soil samples with EU standard

In Fig. 6, the concentration of chromium in soil was found to be lower than the permissible limit by the European Union which is 150ppm stated in 2002. The chromium concentration in the study area is considerably less contaminated as affects the biological activity of the soil. The amount of small chromium stimulates the rapid growth of crops but access to it can lead to numerous health risks, but the chromium toxicity depends on its oxidation status. Meanwhile, chromium occurs in two states in soil (1) chromium oxidation CrO_2 is highly mobile, and toxic in soil and grown water. Also reduced ions chromium Cr (III) from weal soluble hydroxide or stable complexes with soil minerals [22].

5. Conclusion

The research reveals that the concentrations of heavy metals in soil in the study area are in two categories, the first category is the heavy metals with high concentration in the area study area and the attention can be drawn to the people within the vicinity and concern authority in taking precautionary measures in curtailing such problems, these high concentrated heavy metals are cadmium Cd and lead Pb. The other categories of heavy metals with low concentrations in the study area are Zinc Zn, Chromium Cr, and iron Fe. In this category, the heavy metals proved to be in safer sites for people living in the study area, as such low access to the heavy metals can be an advantage to the community in terms of agricultural achievements and otherwise. These results underscore the urgent need for action to mitigate the contamination of heavy metals and their environmental growing impact. The research reveals to provide regulatory agencies with data to establish safe buffers in soil around the study area, and to minimize human exposure as well as protect people in the area. Moreover, the framework for risk assessment supports the advancement of soil monitoring programs which are very vital in detecting early contamination trends and providing timely interventions.

Acknowledgment

The Tertiary Education Trust Fund (TET Fund), Nigeria, under the program of the National Research Funds (NRF)-2020 intervention [TET Fund/ES/DR&D-CE/NRF2020/SETI/77/VOL.1] provided funding for this research.

Reference

[1] S. Islam *et al.*, “Toxicity assessment of heavy metals translocation in maize grown in the Ganges delta floodplain soils around the Payra power plant in Bangladesh,” *Food Chem. Toxicol.*, vol. 193, no. August, p. 115005, 2024, doi: 10.1016/j.fct.2024.115005.

[2] T. Li *et al.*, “Integrated physiological and transcriptome analyses of the effects of water-soluble amino acid fertilizer on plant growth,” *J. King Saud Univ. - Sci.*, p. 103504, 2024, doi: 10.1016/j.jksus.2024.103504.

[3] S. Dange, K. Arumugam, and S. Saraswathi, “Geochemical Insights into Heavy Metal Contamination and Health Hazards in Palar River Basin : A Pathway to Sustainable Solutions,” *Ecol. Indic.*, vol. 166, no. August, p. 112568, 2024, doi: 10.1016/j.ecolind.2024.112568.

[4] M. A. Salem, D. K. Bedade, L. Al-ethawi, and S. M. Al-waleed, “Heliyon Assessment of physiochemical properties and concentration of heavy metals in agricultural soils fertilized with chemical fertilizers,” *Heliyon*, vol. 6, no. October, p. e05224, 2020, doi: 10.1016/j.heliyon.2020.e05224.

[5] K. Sharafi, A. Khalid, B. Mansouri, and T. Massahi, “Heliyon Transfer of heavy metals from soil to vegetables : A comparative assessment of different irrigation water sources,” *Heliyon*, vol. 10, no. 11, p. e32575, 2024, doi: 10.1016/j.heliyon.2024.e32575.

[6] M. Anis *et al.*, “Colloids and Surfaces C : Environmental Aspects Comprehensive assessment of heavy metal contamination in soil-plant systems and health risks from wastewater-irrigated vegetables,” *Colloids Surfaces C Environ. Asp.*, vol. 2, no. August, p. 100044, 2024, doi: 10.1016/j.colsuc.2024.100044.

[7] K. Cai *et al.*, “Heavy metal pollution from standardized e-waste dismantling activities : Pollution index , risk assessment and intervening measures,” vol. 484, no. August 2024, 2025, doi: 10.1016/j.jhazmat.2024.136614.

[8] A. Shahzad *et al.*, “Ecotoxicology and Environmental Safety Modern perspectives of heavy metals alleviation from oil contaminated soil : A review,” *Ecotoxicol. Environ. Saf.*, vol. 282, no. July, p. 116698, 2024, doi: 10.1016/j.ecoenv.2024.116698.

[9] A. Haghighizadeh *et al.*, “Comprehensive analysis of heavy metal soil contamination in mining Environments : Impacts , monitoring Techniques , and remediation strategies,” *Arab. J. Chem.*, vol. 17, no. 6, p. 105777, 2024, doi: 10.1016/j.arabjc.2024.105777.

[10] B. Li, S. Jian, X. Gao, J. Huang, and L. Huang, “Target immobilized phases of heavy metals in hazardous waste based lightweight aggregate,” *J. Hazard. Mater.*, vol. 481, no. August 2024, p. 136522, 2025, doi: 10.1016/j.jhazmat.2024.136522.

[11] D. Gyabaah, E. Awuah, P. Antwi-agyei, and R. Amankwah, “Physicochemical properties and heavy metals distribution of waste fine particles and soil around urban and peri-urban dumpsites,” *Environ. Challenges*, vol. 13, no. October, p. 100785, 2023, doi: 10.1016/j.envc.2023.100785.

[12] P. Pibul, S. Jawjit, and S. Yimthiang, “Heliyon Soil heavy metal pollution from waste electrical and electronic equipment of repair and junk shops in southern Thailand and their ecological risk,” *Heliyon*, vol. 9, no. 10, p. e20438, 2023, doi: 10.1016/j.heliyon.2023.e20438.

[13] E. Kravchenko *et al.*, “Ecological and health risk assessments of heavy metal contamination in soils surrounding a coal power plant,” *J. Hazard. Mater.*, vol. 484, no. December 2024, p. 136751, 2025, doi: 10.1016/j.jhazmat.2024.136751.

[14] L. Liu, J. Wang, J. Zhai, D. Yan, and Z. Lin, “Chemosphere Regional disparities and technological approaches in heavy metal remediation : A comprehensive analysis of soil contamination in Asia,” *Chemosphere*, vol. 366, no. September, p. 143485, 2024, doi: 10.1016/j.chemosphere.2024.143485.

[15] A. Isah, E. Nsukhoridem, O. Adedeji, R. Adebayo, A. Sunday, and T. El-badawy, “Journal of

African Earth Sciences Characterizing groundwater contamination flow-paths and heavy metal mobilization near a waste site in Southwestern Nigeria," *J. African Earth Sci.*, vol. 221, no. July 2024, p. 105460, 2025, doi: 10.1016/j.jafrearsci.2024.105460.

[16]W. Mathew and C. Gideon, "Heavy metal contamination of the Nigerian environment from e-waste management : A systematic review of exposure pathway and attendant pathophysiological implications," *Toxicology*, vol. 509, no. September, p. 153966, 2024, doi: 10.1016/j.tox.2024.153966.

[17]A. Abdullahi, S. N. Muhammad, Z. I. Takai, A. G. Abdullahi, and S. G. Abdullahi, "Assessment of heavy metals concentration in soil of waste disposal sites in Dutse metropolis," 6, no. 2, pp. 135–145, 2019.

[18]A. G. Abdullahi, I. Jibril, and S. G. Abdullahi, "Assessment of radiation dose on occupational health workers of some selected hospitals in Jigawa state , Nigeria," vol. 10, no. 2, 2024.

[19]J. Kumar, R. Rautela, R. Jambhulkar, A. Kumar, and S. Kumar, "Effect of heavy metals contamination due to leachate migration from uncontrolled dumpsites : A comprehensive analysis on soil and groundwater," *J. Environ. Manage.*, vol. 373, no. December 2024, p. 123473, 2025, doi: 10.1016/j.jenvman.2024.123473.

[20]H. Dai *et al.*, "Effects of lysine on the physiochemical properties of plant-protein high-moisture extrudates," *LWT*, vol. 173, no. 100, p. 114410, 2023, doi: 10.1016/j.lwt.2022.114410.

[21]S. Andleeb *et al.*, "Journal of King Saud University – Science Human health risk hazards by heavy metals through consumption of vegetables cultivated by wastewater," *J. King Saud Univ. - Sci.*, vol. 35, no. 2, p. 102467, 2023, doi: 10.1016/j.jksus.2022.102467.

[22] Afifa Tariqa, Noorfatimah Yahayab, Muhammad Sajidc- " Low cost adsorbents derived from vegetables and fruits: Synthesis, properties, and applications in removal of heavy metals from water" Desalination and Water Treatment 320 (2024) 100626, https://doi.org/10.1016/j.dwt.2024.100626