Resources and Environment 2020, 10(1): 4-9
DOI: 10.5923/j.re.20201001.02

Assessment of Heavy Metals in Soils Samples from Lambun Sarki Irrigation Sites of Katsina Metropolis

Usman Armaya'u[1], Zakariyya Uba Zango[1,*], Haliru Aivada Kadir[2], Suleiman Rabiu Musawa[1]

[1]Department of Chemistry, Al-Qalam University Katsina, Katsina, Nigeria
[2]School of Chemical Sciences, Universiti Sains Malaysia, Pulau Penang, Malaysia

Abstract Increase in environmental pollution caused by heavy metals released from anthropogenic activities due to ongoing rapid economic boost of industrialization and urbanization is becoming a global environmental problem due to their toxic and non-biodegradable nature. In this study, determination of heavy metals was conducted in soil sample obtained from Lambun Sarki irrigation site in Katsina metropolis, Nigeria. The sample was prepared in the laboratory using aqua regia acid digestion. Afterward, heavy metals (Cr, Cd, Cu, Pb, and Zn) were determined using Atomic Absorption Spectrophotometer (AAS) and the results obtained revealed that the soil from the area was heavily contaminated with Cadmium and Lead in comparison to the World Health Organization (WHO) and Nigerian Federal Environmental Protection Agency (FEPA) permissible limits. Further, observation shows that there exists a gradual red-shift in the level of these heavy metals as evident from the results obtained. The contamination of the soil by Pb and Cd could be associated with the anthropogenic activities being carried out around the farmland and the sewage water used in irrigation.

Keywords Environment, Irrigation, Heavy Metals, Pollution, Soil

1. Introduction

Soil as a basic human environment is currently facing with threats from various forms of pollutions. These pollutions are mostly caused by anthropogenic activities due to the ongoing rapid economic boost, even though some occur as a result of natural causes (Sule et al., 2016). Pollution by heavy metals is a vital issue due to the toxic effects it poses on humans, flora and fauna plants coupled with their non-biodegradable nature, hence it becomes a key area in need of continuous attention of researchers (Garba et al., 2016). In addition, considering the fact that the soil forms the major sink of heavy metals in the environment, therefore, it plays a vital role in the overall metal cycle in the environment (Liu, *et al.*, 2013). However, as a result of the disturbance and acceleration of the naturally occurring geochemical cycle of metals by anthropogenic activities and natural causes, most of the soils of the rural and urban environments are contaminated with one or more heavy metals to the extent that it posed a high risk to human health, animals, plants, ecosystems and other media (Jagaba et al., 2019; Ikpesu and Dickson, 2016)..

* Corresponding author:
zakariyyazango4@gmail.com (Zakariyya Uba Zango)
Published online at http://journal.sapub.org/re

Access to sufficient amounts of safe and nutritious food is paramount to sustaining life and promoting good health. However, unsafe or contaminated food can cause health-related issues such as food poisoning, diarrhoea, and cancers. Food contaminations impede socioeconomic development by straining health care systems, harming national economy, tourism and trade. It is noteworthy that the factors responsible for foodborne diseases have often been underestimated, this could be due to negligence, underreporting and difficulty to establish fundamental relationships between food contamination and the resulting illness or cause of death. Thus, it grossly affects public health, welfare, and economy (World Health Organisation, 2015).

Basically, we do understand that vegetables serve as a major source of our daily diets which are regarded as an economic crop and a viable template for nutrients such as protein, vitamins, and minerals. It is essential to state that the vegetable fields around Katsina metropolis are greatly affected by the increasing presence of heavy metals concentration which is resulting from various forms pollution routes such as sewage irrigation, metal works (operating near the farmland), vehicular emission, fertilizers (being applied regularly), etc. A sector like Lambun Sarki which is situated in the heart of Katsina metropolis and being it one of the largest and reliable sources of Vegetables in the City, when contaminated with various toxic chemical species will affect the safety and quality of the food as well as the health status of the populace in focus (Jagaba 2018; Abubakar et al., 2016; Shi, *et al*., 2011). Hence it is vital to investigate the soil in which these vegetables are being grown.

Heavy metals are often referred to as a special group of the element that has the potential to become toxic when present at high concentrations (Imam and Zango, 2018). While it is quite difficult to list or specify all the heavy metals found in soils as there exist over 50 of such elements, scientifically, those within the range of Vanadium (atomic mass 50.9) to Uranium (atomic mass 238) constitute the group of natural heavy metals and metalloids, except for halogens and the noble gases, which are non-metals (Vodyanitskii, 2016). Amongst them are seven heavy metal which includes Zn, Cd, Cu, Hg, Ni, Cr, and Pb, which is considered to be the most commonly found in contaminated areas (Garba 2015; Galadima 2012).

Heavy metals occur through anthropogenic activities and it is naturally present in the soil through processes such as weathering, erosion of parent rocks, atmospheric deposition and volcanic activities but their concentration is rarely at toxic levels (Khan, et al., 2013; Ikpesu and Dickson, 2016). Often, most of the heavy metals accumulated in the soil are washed by heavy rain and consequently ends up into the water bodies such as ponds, river, sea and ocean where they exert toxic effects to living organisms (Jagaba et al., 2020). The excess of these heavy metals in soils is toxic to humans and other animals. The continuous uptake of heavy metals is associated with harmful effects on both human beings and animals (Lai et al., 2010; John and Andrew, 2011). This is because the toxicity of heavy metals can cause damage to the central nervous system, mental problems, reduced energy levels and damage to blood composition, kidneys, lungs, liver and other vital organs in the body while a chronic exposure affects the physical functions and muscular processes. It has been reported that long-term contact with some cancer-causing heavy metals or their compounds may eventually lead to cancer (Ikpesu and Dickson, 2016).

Generally, considering the non-biodegradable nature of heavy metals in the soil, they are known to persist for a very long time thereby resulting in accumulation beyond tolerance and permissible limit, thus their toxic nature affects our ecosystem (Khan, et *al.,* 2010). The soil of Lambun Sarki has been under cultivation regularly for over some decades, the system of farming in the area is still regarded as local because most of the farmers utilize this area as a means producing food crops for income and livelihood. Activities being carried out around the area of interest includes inappropriate application of fertilizer, disposal of toxic materials (batteries, petrochemical waste, metallurgical waste) and industrial effluents immensely poses a huge threat and it is a matter of concern for the safety of the people. In order to avoid the possible negative effect of consuming vegetables with high concentrations of heavy metals, it is paramount to investigate and report the findings to the appropriate authorities in Katsina metropolis. This is aimed towards creating awareness about the risk posed by the presence of heavy metals at dangerous levels in our society.

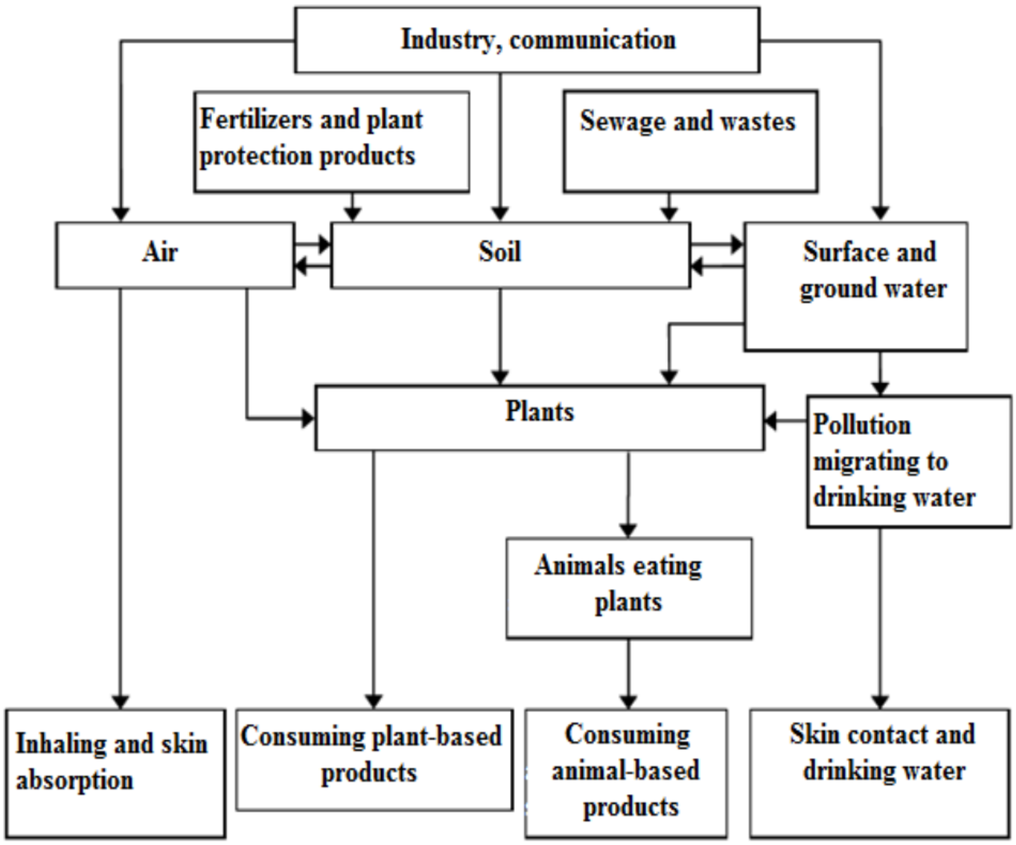

Figure 1. Flow Chart showing the mode of contamination caused by heavy Metals in various matrices. Source: (Kosek-Hoehne, et al., 2017)

According to the previous study, the contamination of the soil by heavy metals is a result of increasing use of the metals due to industrialization and urbanization which facilitate pollutants containing these metals into our environment (Jagaba et al., 2020; Najib, *et al.*, 2012). Conventionally, there exists the presence of heavy metals in agricultural soil with their concentration set at minimal or negligible when compared to relevant standards. However, as a result of anthropogenic activities taking place around us, the concentrations of the heavy metals in an area can be increased to a significantly high extent which becomes a focus of concern (Guo, *et al.*, 2013). If heavy metals are present in a particular agricultural soil, it can affect the soil function which will subsequently affect the plant growth on the soil, thus leading to the transfer of the heavy metals to the plants cultivated on the soil. This poses a risk to human life, as such it should be taken seriously. It is on this basis that the present study which entails investigating the soil in Lambun Sarki area (Katsina state, Nigeria) for the quantification of heavy metals concentration. This study will help to reveal the nature of the soil and ascertain the safety of food cultivated in the farming areas of Lambun Sarki. **Figure 1** depicted various modes in which contamination due to heavy metals occurs and how it gets into human system.

The accumulation of heavy metals in plants is dependent on certain factors such as plant species, soil properties and the absorption efficiency which is evaluated by either the plant uptake or soil-plant transfer factors of the metal. Aktaruzzaman et al (2013), carried out a study on leafy vegetables, they reportedly found that the vegetables cultivated in areas contaminated by heavy metals accumulated higher amounts of it compared to those grown in uncontaminated soil. This clarifies to us that the pathway through which toxic pollutants can enter into the human system is the food chain.

Chemically, the detection of heavy metals can be aided by a variety of instruments which include Atomic Absorption Spectroscopy. This instrumental method (AAS) is widely applied concerning the quantitative analysis and determination of Heavy metals in water samples (Tareen et al., 2014). Yusuf et al., (2015) conducted research to investigate the concentrations of some heavy metals (Fe, Cr, Cd, Zn, and Pb) in soil from Illela garage in Sokoto state of Nigeria using Atomic Absorption Spectroscopy (AAS). The results obtained indicated that Fe was higher than all other metals. Also, in Selangor of Malaysia, a study was carried by Jasima, et al., (2014) to determine the level of heavy metals (Pb, Cr, Mn, Cu, and Zn) present in different parts of Universiti Kebangsaan Malaysia (UKM). The Diplazium esculentum is a widely used medicinal fern in Malaysia and other regions worldwide. According to their findings, heavy metals were found to be highly accumulated in the roots of the D. esculentum. Hence, this serves as a vital reason why heavy metals distribution in soil and plant samples should be monitored to help prevent environmental pollution which affects soil quality and safety of plants.

Therefore, this work is aimed at exploring the presence of heavy metals in various soil samples of Lambun Sarki garden in Katsina metropolis, Nigeria. The soil samples were collected and digested before performing the analysis.

1.1. Description of Study Area

In terms location, the Lambun Sarki area is a vegetable garden located in Kofar Marusa, Katsina metropolis of Katsina state, Nigeria with latitude of 12°59'18.60"N and a longitude of 7°37'1.86"E. Initially, it was a small garden in which a small stream originating from far outside the town around the steel rolling company passes through the area as "sewage sludge". This was used to provide water for irrigation in the garden. As time elapse, soil erosion and sewage disposal increase as a result of the rise in the population which led to the widening of the stream, hence plenty of water became available in the area for irrigation. It then flows through the town of Katsina thereby serving as a sludge in which contaminants are deposited on a regular basis such as industrial waste, mechanic waste, vulcanizers waste, and metal moulders wastes which are located adjacent to the garden (Lambun Sarki). All these serve as the main source of contamination in the Lambun Sarki area. The dominant farming activity in the area includes the cultivation of vegetables such as Cabbage, Carrot, Cress, Spinach, Lettuce, Cucumber, Tomato, Pepper, Onions, Horseradish Tree, and Waterleaf. Other plants grown in the area include fruits likes Mango, Banana, Orange, Lime, and Dates.

2. Materials and Method

Analysis of the soil was performed using Atomic Absorption Spectrophotometer (AAS), Nitric acid (HNO_3 99.0% purity) and Hydrogen peroxide (H_2O_2 99.0% purity) were obtained from M&B and BDH respectively. Hydrochloric acid (HCl 99.0 %) was purchased from Kermel. Other laboratory apparatus utilized include drying oven (Gallenkamp UK), pH meter 3017 (Jenway UK), while hot plate, measuring cylinder, beakers, pipette, conical flask, glass rod, burette are all Pyrex model glass from England. The chemicals utilized were of analytical grades and used without further purification. Distilled water was utilized for washing.

Soil samples were obtained from the Lambun Sarki area of Katsina state, in Nigeria. The sampling was done in triplicate from four different areas of the irrigation site and was labeled as LA1, LA2 & LA3 (1st sampling), LB1, LB2 & LB3 (2nd sampling), LC1, LC2 & LC3 (3rd sampling) and LD1, LD2 & LD3 (4th sampling). A reference sample was obtained from a non-polluted area of the same locality and it is referred to as "Normal", hence it is labeled as LN1, LN2 & LN3. In total, there were 15 samples collected from the site at a depth of 0 – 5cm and stored in polyethylene bags.

2.1. Samples Preparation and Digestion

The Soil samples were air-dried, then followed by oven drying in order to ensure the removal of moisture. The samples were repeatedly crushed by the aid of mortar and piston and sieved with a 2mm mesh sieve to obtain the fine particles. 2 g of the soil samples were weighed into a beaker, followed by the addition of 20 cm^3 of aqua-regia and 10 cm^3 of 30 % H_2O_2. The addition of H2O2 was done slowly in order to avoid any possible overflow that could lead to loss of material. Afterward the beakers were covered with a watch glass and heated at a temperature of 90℃ for 2 h. The sample was filtered in order to separate the insoluble solid from the supernatant liquid, this was followed by making up the volume to 100 cm^3 using distilled water and the digested sample was analysed for presence of heavy metals with the aid of an AAS instrument.

3. Results and Discussions

Table 1. Results of the Heavy Metals determined from the different sampling locations

		Concentrations of the heavy metals (mg/L)				
S/N	Location	Cadmium	Lead	Copper	Chromium	Zinc
1	LN1	0.0126	0.0130	0.0081	<0.0001	2.1330
2	LN2	0.0036	0.0056	0.0117	<0.0001	1.8610
3	LN3	<0.0001	0.0172	0.0661	0.0261	1.2621
4	LA1	0.0310	0.0188	0.1201	0.0177	1.9026
5	LA2	0.0226	0.0177	0.1530	0.0026	0.3721
6	LA3	0.0010	0.0090	0.0930	0.0070	1.7721
7	LB1	<0.0001	0.0250	0.0310	0.0133	1.2621
8	LB2	0.0560	0.0073	0.0934	0.0010	0.6120
9	LB3	0.0414	0.0270	0.0531	0.0216	0.3740
10	LC1	0.0021	0.0285	0.0818	0.0360	0.6123
11	LC2	0.0601	0.0370	0.0194	<0.0001	0.7203
12	LC3	0.0070	0.0103	0.0090	0.0007	1.5310
13	LD1	0.0515	0.0060	0.0217	0.0212	0.5510
14	LD2	0.0313	0.0113	0.0076	<0.0001	1.0201
15	LD3	0.0180	0.0213	0.1061	0.0146	3.3621

Table 2. Mean concentrations (mg/L) of heavy metals from different locations

Sample locations	Chromium	Cadmium	Lead	Zinc	Copper
LA	0.0091	0.0182	0.0152	1.3489	0.1220
LB	0.0120	0.0325	0.0198	1.3330	0.0592
LC	0.0123	0.0231	0.0253	0.9545	0.0367
LD	0.0120	0.0336	0.0129	1.6444	0.0451
LN	0.0088	0.0054	0.0119	1.7520	0.0286
Permissible Values (WHO/FEPA)	2.0000	0.0030	0.0100	3.0000	1.0000

NB: LA, LB, LC, and LD are sampling points in Lambun Sarki area; LN stands for Reference sample and WHO/FEPA is the World Health Organisation and the Nigerian Federal Environmental Protection Agency standards for heavy metals in soil respectively.

As earlier mentioned, the soil samples were digested by aqua regia acid and the determination of heavy metal with the aid of atomic absorption spectrophotometry was performed, hence the results obtained indicated certain levels regarding the metal of importance. The data obtained from the 15 different sampling points are presented in **Table 1**, while the mean concentration of the heavy metal of focus from the different sample points is shown in Table 2. The heavy metal of interest was Cr, Cd, Pb, Zn, and Cu, the mean concentration levels for each of the metals were compared with the reference sample and World Health Organisation/Nigerian Federal Environmental Protection Agency standards respectively.

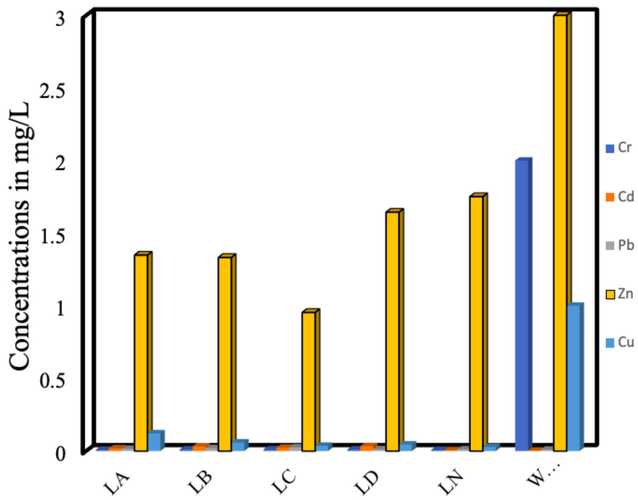

Figure 2. Average concentrations of the heavy metals from the different locations compared with WHO and FEPA standard

The contamination of soil by heavy metals is a vital environmental issue, and its detection can be aided by several conventional analytical techniques such as spectroscopic, separation and electrochemical techniques. Considering the results obtained, the mean concentration for the heavy metals of interest as tabulated in table 2 above clearly indicates the Zn metal to have the highest concentration with a value of 1.6444 mg/L. Although, this level is in conformity when compared to the permissible limit of WHO and FEPA (3.0000 mg/L) and that of the reference sample which has a value of 1.7520 mg/L. The amount observed could be due to the extensive application of local manures and fertilizers to the farmlands, this has a tendency of changing the natural composition of the soil. However, sufficient amount of Zn is very important for normal body functions but when it is consumed in excess, it can become toxic (Muhammad et al., 2011). Hence, it is worthy to note that lower level of heavy metal in soil is key, thus it is vital to prevent the steady increase in the concentration of these metals.

Also, the average concentrations obtained for Lead (Pb) is between the ranges of 0.0129 mg/L to 0.0253 mg/L in Lambun Sarki farmland. As shown in Table 2 and further represented in figure 2, it can be clearly seen that the values obtained are higher than the concentration of Pb in the reference sample and that of WHO/FEPA standards when compared. This red-shift in terms of concentration values could be due to emissions resulting from the vehicles passing by the farmland and also the presence of Pb based materials such as batteries in the irrigation water. Also, the local fertilizers which are collected from dumpsites to serve as manure for the plants can definitely contribute to the increase in Pb level. The presence of Pb in the soil has serious negative effects and hence it poses a great risk to human health. It is evident that when small amounts are consumed, it could cause brain damage and behavioural disturbances in children (Kosek-Hoehne, *et al.,* 2017).

The intake of Cadmium in foods is associated with the possibility of postmenopausal breast cancer and kidney damage (Kosek-Hoehne, *et al.,* 2017; Sanusi, *et al.,* 2017). As per our analysis, the cadmium means concentration level was found to be highest at 0.0336 mg/L and lowest at a value of 0.0182 mg/L for the sampling points in Lambun Sarki. The reference sample has a value of 0.0054 mg/L and the WHO/FEPA permissible limit of Cadmium in soil is 0.0030 mg/L. This clearly shows that the concentration of cadmium in all the sampling locations is higher when compared to the reference area and the permissible limit depicting that the soil of Lambun Sarki is contaminated with cadmium. This could be attributed to the effluents of the steel rolling industry and waste from the metals works that are discharged into the sewage water used for irrigation purposes around the farmland. Its presence can also be associated with the extensive use of phosphorous based fertilizers, municipal solid waste as manure and combustion of fossil fuels.

Chromium contamination can cause liver diseases, lung cancer, abnormal thyroid artery and polycythaemia problems (Martin & Griswold, 2009). From table 2, the lowest mean value for chromium is 0.0091 mg/L and the highest value of 0.0123 mg/L in Lambun Sarki, which were found to be higher than that of the reference area (0.0088 mg/L). However, all the concentrations detected were less than the permissible limit of WHO/FEPA (2.0000 mg/L), hence it is in conformity. The concentration of chromium in Lambun Sarki is found to be higher than that of the reference area even though it does not exceed the permissible limit. This could be due to the metallurgical process around the farmland and the deposition of materials containing chromium such as paints, cement, papers, rubbers, etc. which are found in local fertilizers.

The mean value copper concentration found in the soil sample is within the ranges of 0.0367 mg/L to 0.1220 mg/L in Lambun Sarki and the reference area was found to contain about 0.0286 mg/L as shown in table 2. The WHO/FEPA permissible limit for Copper is 1.0000 mg/L, hence this clearly shows that the soil of Lambun Sarki is not contaminated with copper because the values conform to the standard. However, the concentration of copper detected in Lambun Sarki is higher than that detected in the reference area. Copper occurs generally in soil, sediments, and air, and is a microelement that is essential in plant growth. The concentration of copper differs according to the soil type and pollution source. However, it can be as a result of the metal works along the farmland and from local fertilizers containing materials made of copper such as electrical wires. The accumulation of Copper can cause mental diseases such as Alzheimer's (Ogundele, *et al.,* 2015).

In general, the mean concentration value of Chromium, Zinc, and Copper in all the sampling points in Lambun Sarki and the reference area were all below the permissible limits of WHO/FEPA. While the concentrations of Lead and Cadmium in all the sampling points are higher than the permissible values. Concentrations of all the metals with the exception of Zinc in the farmland (Lambun Sarki) are higher than of the reference area, indicating that there is a gradual increase in the concentration of the heavy metals in the area. Although the concentration of zinc in the reference sample area is less than the threshold value, it is found to be slightly higher when compared to that of Lambun Sarki.

4. Conclusions

Summarily, the concentration of five heavy metals (Cr, Cd, Cu, Pb, and Zn) in soil samples taken from Lambun Sarki in Katsina metropolis, Nigeria were investigated using AAS. All the selected heavy metals were detected in the sample. Concentrations of Pb and Cd were found to be higher than the background values of WHO/FEPA while the concentrations of Cr, Cu, and Zn were below the range of the maximum permissible limits of WHO/FEPA. The findings in this study showed that the soil of Lambun Sarki is contaminated with Pb and Cd as a result of the anthropogenic activities around the area. It also indicates the gradual rise in the level of these metals which is subject to concern. These heavy metals have the tendency of becoming toxic when they surpass the threshold level of relevant standards. It poses a great risk to human health as they will eventually be transferred to the plants which are sequentially consumed by humans and animals.

REFERENCES

[1] Abubakar, S., Latiff, A., Lawal, I.M., Jagaba, A.H., 2016. Aerobic treatment of kitchen wastewater using sequence batch reactor (SBR) and reuse for irrigation landscape purposes. American Journal of Engineering Research (AJER) 23–31.

[2] Abubakar, S., Lawal, I.M., Hassan, I., Jagaba, A.H., 2016. Quality Water Analysis of Public and Private Boreholes (A Case Study of Azare Town, Bauchi, Nigeria). Am. J. Eng. Res. 5, 204–208.

[3] Aktaruzzaman, M., Fakhruddin, A. N., Chowdhury, M. A., Fardous, Z., & Alam, M. K. (2013). Accumulation of Heavy Metals in Soil and their Transfer to Leafy Vegetables in the Region of Dhaka Aricha Highway, Savar, Bangladesh. *Pakistan Journal of Biological Sciences, 16,* 332-338. doi:10.3923/pjbs.2013.

[4] Galadima, A., Garba, Z.N., 2012. Heavy metals pollution in Nigeria: causes and consequences. Elixir Pollut. 45, 7917–7922.

[5] Garba, Z.N., Bello, I., Galadima, A., Lawal, A.Y., 2016. Optimization of adsorption conditions using central composite design for the removal of copper (II) and lead (II) by defatted papaya seed. Karbala Int. J. Mod. Sci. 2, 20–28. https://doi.org/10.1016/j.kijoms.2015.12.002.

[6] Garba, Z.N., Ubam, S., Babando, A.A., Galadima, A., 2015. Quantitative assessment of heavy metals from selected tea brands marketed in Zaria, Nigeria. J. Phys. Sci. 26, 43–51.

[7] Guo, Y. B., Feng, H., Chen, C., Jia, C. J., Xiong, F., & Lu, Y. (2013). Heavy Metal Concentrations in Soil and Agricultural Products Near an Industrial District. *Pol. Journal of Environmental Studies, 22*(5), 1357-1362.

[8] Herk, A. V. (2012). Physicochemical Parameters in Soil and Vegetable Samples from Gongulon Agricultural Site, Maiduguri, Borno State, Nigeria. *International Journal of Chemistry, 01*, 21-36.

[9] Ikpesu, J. E., & Dickson, Y. (2016). Determination Of Heavy Metals In Soils In Nigerian Agip Oil Company Obiafor/Obrikom Environs. *Journal of Multidisciplinary Engineering Science and Technology (JMEST), 3*(2), 3995-4007.

[10] Imam, S.S., Zango, Z.U., 2018. Magnetic Nanoparticle (Fe_3O_4) Impregnated onto Coconut Shell Activated Carbon for the Removal of Ni (II) from Aqueous Solution. Int. J. Res. Chem. Environ. 8, 9–15.

[11] Jagaba, A.H., Kutty, S.R.M., Khaw, S.G., Lai, C.L., Isa, M.H., Baloo, L., Lawal, I.M., Abubakar, S., Umaru, I., Zango, Z.U., 2020. Derived hybrid biosorbent for zinc(II) removal from aqueous solution by continuous-flow activated sludge system. J. Water Process Eng. 34. https://doi.org/10.1016/j.jwpe.2020.101152.

[12] Jagaba, H.A., Abubakar, S., Lawal, I.M., Latiff, A.A.A., Umaru, I., 2018. Wastewater Treatment Using Alum, the Combinations of Alum-Ferric Chloride, Alum-Chitosan, Alum-Zeolite and Alum- < i & gt; Moringa Oleifera & lt; /i & gt; as Adsorbent and Coagulant. Int. J. Eng. Manag. 2, 67. https://doi.org/10.11648/j.ijem.20180203.13.

[13] Jagaba, A.H. Kutty, S.R.M. Hayder, G., Latiff, A.A.A., Aziz, N.A.A. Umaru, I., Ghaleb, A.A.., 2020. Sustainable use of natural and chemical coagulants for contaminantsremoval from palm oil mill effluent: A comparative analysis. Ain Shams Eng. J. https://doi.org/https://doi.org/10.1016/j.asej.2020.01.018.

[14] Jagaba, A.H., Shuaibu, A., Umaru, I., Musa, S., Lawal, M., Abubakar, S., 2019. Stabilization of Soft Soil by Incinerated Sewage Sludge Ash from Municipal Wastewater Treatment Plant for Engineering Construction. Sustain. Struct. Mater. 2, 32–44.

[15] Khan, S., Rehman, S., Khan, A. Z., Khan, M. A., & Shah, M. T. (2010). Soil and vegetables enrichment with heavy metals from geological sources in Gilgit, northern Pakistan. *Ecotoxicol. Environ. Saf, 73*, 1820–1827.

[16] Khan, K., Lu, Y., Khan, H., Ishtiaq, M., Khan, S., Waqas, M., . . . Wang, T. (2013). Heavy metals in agricultural soils and crops and their health risks in Swat District, northern Pakistan. *Food and Chemical Toxicology* (58), 449–458.

[17] Kosek-Hoehne, K., Panocha, B., & Śliwa, A. (2017). Heavy metals – a silent threat to health. *Journal of Education, Health and Sport, 7*(1), 121-132.

[18] Lai, H. Y., Hseu, Z. Y., Chen, T. C., Chen, B. C., Guo, H. Y., & 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*(3), 595–614.

[19] Liu, X., Song, Q., Tang, Y., Li, W., Xu, J., Wu, J., . . . Brookes, P. C. (2013). Human health risk assessment of heavy metals in soil–vegetable system: A multi-medium analysis. (C. Poschenrieder, Ed.) *Science of the Total Environment*, 530–540.

[20] Martin, S., & Griswold, W. (2009). Human Health Effects of Heavy Metals. *Environmental Science and Technology Briefs for Citizens*, 1-6. *MicroChem. J., 98*, 334–343.

[21] Muhammad, S., Shah, M. T., & Khan, S. (2011). Health risk assessment of heavy metals and their source apportionment in drinking water of Kohistan region, northern Pakistan.

[22] Najib, N. W., Mohammed, S. A., Ismail, S. H., & Ahmad, W. A. (2012). Assessment of Heavy Metal in Soil due to Human activities in Kangar, Perlis, Malaysia. *International Journal of Civil & Environmental Engineering, 12*(6), 28-20.

[23] Ogundele, D. T., Adio, A. A., & Oludele, O. E. (2015). Heavy Metal Concentrations in Plants and Soil along Heavy Traffic Roads in North Central Nigeria. *J Environ Anal Toxicol, 5*(6), 1-5.

[24] Shi, J. C., Yu, X. L., Zhang, M. K., Lu, S. G., Wu, W. H., & Wu, J. J. (2011). Potential risks of copper, zinc, and cadmium pollution due to pig manure application in a soil–rice system under intensive farming: a case study of Nanhu, China. *J Environ Qual, 40*(1), 695–704.

[25] Tareen, A. K., Sultan, I. N., Parakulsuksatid, P., Shafi, M., Khan, A., Khan, M. W., & Hussain, S. (2014). Detection of heavy metals (Pb, Sb, Al, As) through atomic absorption spectroscopy from drinking water of District Pishin, Balochistan, Pakistan. *International Journal of Current Microbiology and Applied Sciences, 3*(1), 299-308. Retrieved from http://www.ijcmas.com.

[26] Vodyanitskii, Y. N. (2016). Standards for the contents of heavy metals in soils of some states. *Journal Annals of Agrarian Science.*, 257-263.

[27] World Health Organisation. (2015). *Food safety: Fact sheets N°399.* WHO.

[28] Yusuf, A. J., Galadima, A., Garba, Z. N., & Nasir, I. (2015). Determination of some Heavy Metals in Soil Sample from Illela Garage in Sokoto State, Nigeria. *Research Journal of Chemical Sciences, 5(2)*(2231-606X), 8-10. Retrieved from www.isca.in.