ABUAD Journal of Engineering Research and Development (AJERD)
Volume 1, Issue 3, 393-398

ISSN: 2645-2685

Longitudinal and transverse mobility of Some heavy metals on receiving soils of dumpsites in Niger State, Nigeria

John Jiya MUSA[1*], Jeremiah David BALA[2], Hassana Ibrahim MUSTAPHA[1], Elijah Tsado MUSA[3], Yahuza Ibrahim YERIMA[1], Sunday Enebojojo DANIEL[1], and Musa Paul AKOS[1]

[1]*Department of Agricultural and Bioresources Engineering, Federal University of Technology, P. M. B. 65, Minna, Nigeria*
johnmusa@futminna.edu.ng

[2]*Department of Microbiology, School of Life Sciences, Federal University of Technology, P.M.B 65, Minna, Nigeria*
jerrybrown316@yahoo.com

[3]*Central Research Laboratory, University of Ilorin, P M B 1515, Ilorin, Nigeria*
elijahtmusa@gmail.com

Corresponding Author: johnmusa@futminna.edu.ng

Date Submitted: 14/09/2018
Date Accepted: 12/12/2018
Date Published: 31/12/2018

Abstract*: Population growth and Industrialization have caused the introduction of toxic substances into the agricultural soil from manufacturing processes as waste. This study describes the longitudinal and transverse mobility of this waste containing heavy metals from dumpsites to the surrounding environment of Niger state, Nigeria. Soil samples were collected within the dumpsites at distance of 10 m and 20 m away at three depths (5 cm, 15 cm and 30 cm) to assess the concentration and mobility of Cr, Fe, Mn, Pb, Zn, Cu and Al. The results show that heavy metals are more concentrated in the topsoil with significant migration down the slope, thereby posing a threat to groundwater quality. In the fractions, the concentrations of the metals follow this sequence: Mn>Fe>Cu>Zn>Cr>Al. The mobility factors of the heavy metals are significantly high indicating high potential mobility and bioavailable forms of these heavy metals. The high concentrations of the heavy metals particularly Cr, as observed in the study is as a result of anthropogenic activities on the enrichment of natural soil with bioavailable heavy metals. Consequently, there is a need to be cautious in the way waste that is generated from heavy metals sources is added to the natural soil.*

Keywords*: Heavy metals, mobility, Borgu, Bida, Minna.*

1. INTRODUCTION

The recent increase in globalisation in the industrial sector, agricultural sector as well as domestic activities have led to the plaque associated with pollution within Nigerian territory, and thus, there is the problem or challenges of waste management [1]. However, the largest source littering is the town comprises of roadways, automobiles and areas of dumpsites which are mostly metal [2]. Due to increasing population growth in Nigeria, the environment is continually being degraded through agricultural activities, industries and urbanisation. Heavy metals are being released into the environment in the form of loss or waste from these anthropological activities to meet the everyday demand for life [3, 4]. Heavy metals can also occur naturally in the soil [5], they are sometimes found in the soil and water as a result of anthropogenic activities like mining, smelting, domestic waste and various industrial activities. The direct activities of mining, processing for industrial and consumer use contribute to the mobilisation of heavy metals into the soil. The biological systems require some of these heavy metals, but their lack or excess can lead to several glitches. Heavy Metals defined as elements in the periodic table having an atomic number more than 20 [6] or densities more than 5 g/cm^3 generally excluding alkali metals and alkaline earth metals [7]. These metals are all naturally occurring substances which are often present in the environment at low concentration [8, 9. 10]. The researchers further stated that mobility of these metals most likely occurs where there is the high disposal of sewage sludge made on sandy soils that are acidic with low organic matter receiving high rainfall or irrigation. The effect of the presence of some of these metals in such areas is their uptake by plants which are grown in such areas as a result of the soil fertility. The aim of this study is focused on the concentration of the selected heavy metals (Cr, Fe, Mn, Pb, Zn, Cu and Al) with respect to their longitudinal and transverse mobility in the interested dumpsite soils and to determine the longitudinal and transverse mobility of heavy metals in the soils at varying distances and depths.

2. MATERIALS AND METHODS

2.1 *Study Area*

Niger State is a north-central state of Nigeria, created in 1976 and covers a total land area of 76,363 km^2 it has a population of about 3,950,249 people with 729,964 households generating solid waste where 200,078 family dispose their trash in Public Approved Dump Site while 283,374 household disposes their waste in Unapproved Dump Site [11](NPC, 2006).

The study area is bounded by the several states of Nigeria and is in the center of the country. The State climate falls under tropical region with alternate dry and wet seasons. The dry season usually lasts from November to March and the rainy season starts in April and continues through till October. The majority of the state populace are farmers while others are involved in vocations such as white-collar jobs, business, craft and arts [12].

2.2 *Sample Collection*

A random sampling of waste and soil samples with direct field survey methods was adopted for a gathering of data around the dumpsite. Samples were collected from three major towns of the State. At each dumpsite, transverse samples were collected at 5 cm depth to represent topsoil, 15 cm depth and 30 cm which represents the root zone of most perennial crops after clearing off solid waste covering the agricultural soil [13, 14, 15]. The longitudinal samples were collected within the dumpsite at 10 and 20 m away from the centre point. A sample was obtained at a reference point of the study locations. All samples were tightly sealed in a fresh plastic bag and sent to the laboratory for analysis within twenty-four hours.

2.3 *Analytical Techniques and Laboratory Analysis*

Atomic Absorption Spectroscopy (AAS) was used for the examination of heavy metals in the sampled soils. The samples were further analysed for some physical parameters for various depths at the laboratory of the Department of Soil Science, Federal University of Technology Minna. Method of analysis included the dispersion of the soil and separation of soil particles into size groups. The soils were pre-treated to remove organic matter and salts to allow it disperse completely. The soil triangle was then used to convert particle sizes into the recognised texture classification of sand silt and clay percentages.

3. RESULT AND DISCUSSION

The analysed samples were found to contain the following heavy metals, Cr, Fe, Mn, Zn, Cu, and Al in different concentrations. Table 1 gives a summary while figures 1 to 6 shows a representation of how the transverse/longitudinal mobility of these heavy metals occurs from the results obtained in this study.

Table 1: Heavy metals concentration in different dump site locations (mg/kg).

Parameters		Locations		
		Borgu	Bida	Minna
Cr^{2+}	Range	12-18	18-22	19-26
	Mean ± S.D	15.33±3.05	20±2.0	22±3.61
Fe^{2+}	Range	51-79	66-81	66-81
	Mean ± S.D	66±14.11	44±3.0	74±7.55
Mn^{2+}	Range	106-176	50-131	78-86
	Mean ± S.D	149±37.64	92.67±40.67	82.33±4.04
Zn^{2+}	Range	19-21	19-28	12-26
	Mean ± S.D	20±1	23±4.58	20.33±7.37
Cu^{2+}	Range	32-36	10-24	31-62
	Mean ± S.D	33.67±2.08	15.67±7.37	50.33±16.86
Al^{3+}	Range	5-6.8	9.8-16.3	10.8-13.6
	Mean ± S.D	5.7±0.96	12.8±3.28	11.87±1.51
Pb^{2+}		ND	ND	ND

SD; Standard Deviation, ND; Not Detected

3.1 *Chromium (Cr)*

The transverse and longitudinal mobility of Cr presented for the three locations shows that at the dumpsite depth 5 cm recorded higher concentration of between 20-30 mg/kg, which is below the threshold value of ≤90 mg/kg [16]. The area that is most affected by Cr mobility both vertical and horizontally is from the ranges of (0-15 cm) and (5-20 m) respectively while the least migration was at 15-30 cm and 20 m respectively as presented in figure 1 below. This conforms with the study of [17].

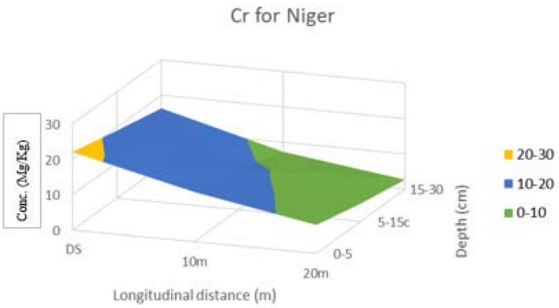

Fig. 1: Cr concentrations at Niger state Dumpsites by depth.

 ISSN: 2645-2685

If the accumulation of Cr in these dumpsite increases significantly, this may lead to contamination of soil and water with Cr causing harm to both plant and humans. This result was above the results of the research carried out in Niani and Bandh dumpsite in India [18]. They took samples at depths of 0-15 cm, 15-30 cm and 30-45 cm respectively and recorded the concentration of Cr to be 3.2 mg/kg, 2.8 mg/kg and 1.4 mg/kg respectively in Niani dumpsite and 3.0 mg/kg, 2.6 mg/kg and 1.2 mg/kg respectively in Bandh dumpsite. All the mean values of Cr in table 4.4 falls within the target and intervention value of [18] which is 20 mg/kg and 240 mg/kg.

3.2 Iron (Fe)

The concentration of Fe in Minna was observed to be maximum with value of 81.0mg/kg closely followed by that of Borgu with 79.0 mg/kg. The minimum value of Fe concentration for the dumpsite was recorded at Bida. This was below WHO limit of 4720 mg/kg as reported by [19] and [20]. All the mean values in table 1 fall within the target and intervention value of [18].

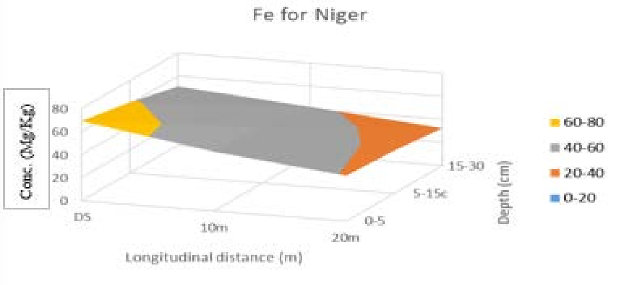

Fig. 2: Fe concentrations (mg/kg) at Niger state Dumpsites by depth.

The mobility of Fe in Figures 2 shows that movement is higher at the topsoil with the concentration of 60-80 mg/kg at the various dump sites, this may be due to the high organic matter at the topsoil, while the least mobility concentration was at 20 m in all depths. All the results are above the findings of [21] conducted at Otamiri hilltop and Valley dumpsite in Owerri Imo State where they took the depths of 0-20 cm, 20-40 cm and 40-60 cm, they recorded the concentrations of 0.30 mg/kg, 1.80 mg/kg and 0.70 mg/kg at the valley dumpsite while the hilltop had the concentrations of 1.30 mg/kg, 0.30 mg/kg and 1.20 mg/kg respectively, and [22] which had values from 1.084 mg/kg to 6.542 mg/kg in their study conducted around paint industries in Kaduna.

3.3 Manganese (Mn)

The mobility of Mn from figure 3 below shows that Mn has the highest movement at the dumpsite with 176 mg/kg and the lowest was at the 5.0 mg/kg which is far above the results of [23] in their study conducted in Maiduguri. This is similar to Cu and Fe; the concentration of Mn was also observed to be accumulated at the surface (5 cm) depth.

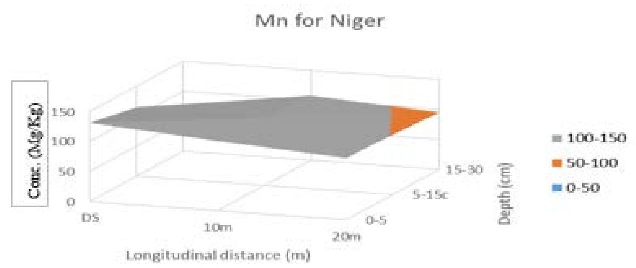

Fig. 3: Mn concentrations at Niger state Dumpsites by depth.

The mobility of Mn presented in Figures 3 reveals that movement was higher at all the three depths and distances, while the rest portion from the dumpsite to a range of 20 m away for the depth of 20 cm recorded the concentration of 50-100 mg/kg. From the result of this study it was found that as distance increases from the dumpsite, the migration of heavy metals decreases, this is in agreement with the findings of [24] and [25] Conducted in New Dehil India.

3.4 Zinc (Zn)

Table 1 showed that the highest concentration of Zn is 61 mg/kg which is below the threshold value for [16] which is ≤100 mg/kg and that of [26] which is 2800mg/kg. The result was found to be higher than that reported by [23] in a similar study conducted in Maiduguri, Nigeria, which they recorded the highest mean concentration of Zn at dumpsite B (1.80±0.01 mg/kg). It is observed that Zn shows almost constant concentrations in the study area. This is similar to the findings of [27] conducted at Otamiri hilltop and valley in Owerri and [22] in their study carried out around paint industries in Kaduna.

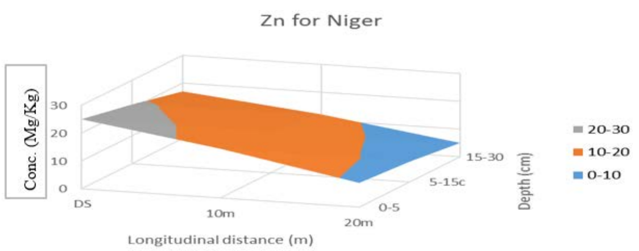

Fig. 4: Zn concentrations at Niger state Dumpsites by depth.

It was discovered that the mobility of Zn at the subsoil is higher with the concentration of 10-20 Mg/Kg which is below [16] limit which is 50 mg/kg. It is assumed that the subsoil is considerably less influenced by soil-forming processes and anthropogenic supply than the topsoil. This is in agreement with the study of [28] conducted at Alaba International Market in Lagos.

3.5 Copper (Cu)

The result shows a steady downward decrease in Cu concentration in all the dumpsite soils. The highest Cu concentration of 62 mg/kg was observed at 5 cm depth in Minna dumpsite which is above the threshold value for [16] which is ≤ 35 mg/kg and below the [26] limit of 1500 mg/kg. The result of this study is also above finding of [23] conducted in Maiduguri Nigeria, which has the highest concentration at 100 cm in dumpsite B (1.65±0.35 mg/kg).

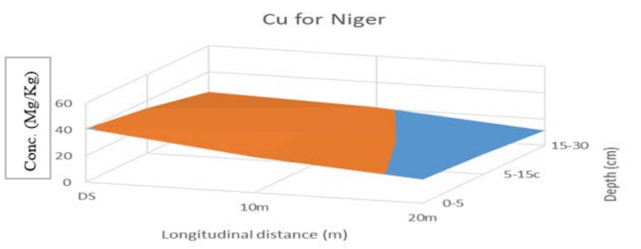

Fig. 5: Cu concentrations at Niger state Dumpsites by depth.

From figure 5 above it was observed that the mobility of heavy metals is higher at the top soil and subsoil across the depths with a notable concentration range of 70-40 Mg/Kg, this may be as a result of mobility by surface and sub-surface runoff and leaching into surface and sub-surface soil and waters in its soluble or precipitated form. This agrees with the findings of [29, 30] conducted in Makurdi Benue State.

3.6 Aluminium (Al)

The concentration means for Al is presented in decreasing order as follows 12.8 mg/kg, 11.8 mg/kg and 5.7 mg/kg for Bida, Minna and Borgu respectively. The high concentration of Al in Bida may be due to the inhabitant engaged in the craft of bronze and brass into different equipment, while that of Minna might be due to a large number of mechanic and battery charger concentrated in the area.

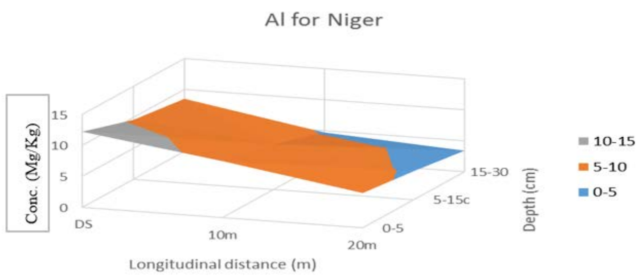

Fig. 6: Al concentrations at Niger state Dumpsites by depth.

The mobility of Al was found to be low at the surface but higher at the subsoil and the longitudinal distances 7-20 cm across the three depths, this may be due to the reason earlier stated by [29, 30] conducted in Makurdi Benue State.

3.7 Correlation Analyses

Heavy metal pollution is frequent and complicated pollution to practice. Correlation analyses can be used to assist in revealing the relationship between transverse/longitudinal mobility and heavy metals. Inter-metal concentration correlation analysis was conducted using Pearson correlation coefficient (r) values, to determine the level of association of pairs of metals across the different depth levels.

Table 3: Correlation analysis

Locations	Parameters	Cr	Fe	Mn	Zn	Cu	Al
	Cr	1					
	Fe	0.9801*	1				
Niger	Mn	0.4419	0.5892	1			
	Zn	0.9804*	0.9896*	0.5516	1		
	Cu	0.963*	0.9951*	0.6482	0.9848*	1	
	Al	0.9804*	0.9737*	0.5282	0.9704*	0.9599*	1

Table 3 shows that a perfect positive correlation value (r = 0.9) was recorded in almost all the metals in the three States, while other metals show low (r = 0.4) to moderate (r = 0.6) level of association as their concentration's determination proceeded depth-wise, these metals are Mn and Cr in Niger State.

4. CONCLUSION

In summary, the transverse/longitudinal mobility of Cr, Fe, Mn, Zn, Cu and Al from the dump sites to the surrounding was evident with consequent potential dangers from heavy metals contamination of agricultural soils and groundwater quality resulting from human activities. This shows that wastes can supply the environment with reasonable soluble and mobile heavy metals that are of environmental concern. Mobility factors such as pH, organic matter and hydraulic conductivity were found to be high; this shows that heavy metals of anthropogenic origin have great potential to distribute and be bioavailable fast within the environment if not restricted. Hence, there is a need for concerted efforts against the introduction of wastes generated from heavy metals projects into the natural soil.

ACKNOWLEDGMENT

The authors are grateful to the Federal University of Technology Minna and Tertiary Education Trust Fund for providing grants to carry out this research work. They are also thankful to Laboratory Staff of Soil Science Department, Federal University of Technology Minna, Niger State and Chemistry Department, Ahmadu Bello University Zaria, Nigeria who assisted in carrying out soil analyses.

REFERENCE

[1] Oguzie, F. A. & Okhagbuzo G. A. (2010): Concentrations of heavy metals in effluent discharges downstream of Ikpoba river in Benin City, Nigeria. *African Journal of Biotechnology*, 9(3), 319-325,

[2] Olaniyan, T. A., Phillips, O. K., & Elesha, L. (2011). Hazards of heavy metal contamination on the groundwater around a municipal dumpsite in Lagos, Southwestern Nigeria. *International Journal of Engineering & Technology*, *11*(1), 61-69.

[3] WHO-World Health Organization, Europe. (2010). Environment and health risks: a review of the influence and effects of social inequalities. http://www.euro.who.int/pubrequest.

[4] EU - European Union Directive 86/278/EEC. (2000). Third Draft Working Document on sludge, (*ENV.E.3/LM*), Brussels, 10.

[5] USDA-United States Department of Agriculture (2000). Heavy Metal Soil Contamination-Soil Quality Institute Urban Technical Note No. 3. *Natural Resources Conservation Service*.

[6] Lyman, W. J. (1995). Transport and transformation processes", in Fundamentals of Aquatic Toxicology, G. M. Rand (Ed.), Taylor and Francis, Washington DC.

[7] Lozet, J. & Mathieu, C. (1991). Dictionary of Soil Science, 2nd ed., A. A. Balkema, Rotterdam.

[8] Bambara, L. T., Kabore, K., Cisse, O., Derra, M., Zougmoré, F., & Bentil, N. (2015). Assessment of Pollution in Agricultural Soil and Interrelationship between the Heavy Metals at Paspanga, Burkina Faso. *IOSR Journal of Environmental Science, Toxicology and Food Technology* (IOSR-JESTFT). 9(8), 84-90

[9] Eriyamremu, G.E., Asagba, S.O., Akpoborie A. & Ojeaburu. S.I. (2005). Evaluation of lead and cadmium levels in some commonly consumed vegetables in the Niger-Delta oil area of Nigeria. *Bulletin of Environmental Contamination and Toxicology*, 75, 278-283.

[10] Satarug, S., Haswell-Elkins, M.R. & Moore, M.R. (2000). Safe levels of cadmium intake to prevent renal toxicity of human subjects. *British Journal of Nutrition*, 84, 791-802.

[11] National Population Commission (NPC). (2006). *2006 Population Census of the Federal Republic of Nigeria: Analytical Report at the National Level*. National Population Commission.

[12] Musa, J. J., Adewumi, J. K., & Ohu, J. (2013). Comparing Developed Manning Coefficients for some selected soils in Gidan Kwano with exiting Values. *International Journal of Basic and Applied Science*. Vol. 01, No. 03, pp473-469.

[13] Nyangababo, J.T. & Hamya, J.W. (1986). The deposition of lead, cadmium, zinc and copper from motor traffic on Brachiaria enimi and soil along a major Bombo road to Kampala City. *International Journal of Environmental Studies*. 27(1-2), 115-119.

[14] Eddy, N.O., Odoemelem, S.A. & Mbaba, A. (2006). Elemental composition of soil in some dumpsites. *Journal of Environmental Agricultural Food Chemistry*. 5, 1349-1365.

[15] Odai, S.N., Mensah, E., Sipitey, D., Ryo, S. & Awuah, E. (2008). Heavy metals uptake by vegetables cultivated on urban waste dumpsites: Case study of Kumasi, Ghana. *Research Journal of Environmental Toxicology*, 2, 92-99.

[16] World Health Organization (W.H.O) (2006): National water quality guidelines for domestic consumption.

[17] Dinesh M., Vishv K. M., Neeraj P., Niraj P., Indra S. T. & Shailendra K. (2015): The effect of solid waste dump on heavy metals levels, soil fertility and its agricultural implication in Allahabad, India. *Research Journal of Agricultural and Environmental Sciences*, 2(2), 31-35.

[18] DPR-EGASPIN (2002), Environmental Guidelines and Standards for the Petroleum Industry in Nigeria (EGASPIN), Department of Petroleum Resources, Lagos, Nigeria.

[19] Abdolhossein H. P., Vahid B., Abasali A. Z., & Ali H. (2015): Concentration, Distribution and Comparison of Total and Bioavailable Heavy Metals in Top Soils of Bonab District in Zanjan Province. *Open Journal of Soil Science*, 2012, 2, 123-132.

[20] Muchuweti, M., Birkett, J.W. Chinyanga, E. Zvauya, R. Scrimshaw, M.D. & Lester. J.N. (2006). Heavy metal content of vegetables irrigated with mixture of waste water and sewage sludge in Zimbabwe: implications for human health. *Agriculture, Ecosystem and Environment*, 112, 41-48.

[21] Inobeme, A., Ajai, A. I., Iyaka,Y. A., Ndamitso, M. & Uwem, B. (2014): Determination of Physicochemical and Heavy Metal Content of Soil Around Paint Industries In Kaduna. *International Journal of Scientific and Technology Research*, 3, 221-225.

[22] Bukar, L. I., Hati, S. S., Dimari, G. A., & Tijjani, M. (2012). Study of Vertical Migration of Heavy Metals in Dumpsite Soils. *ARPN J Sci Technol*, *2*(2), 50-55.

[23] USEPA. (2010): Land application of bio-solids for home vegetable gardens. USEPA clean water act title 40, section 503.13. http://ecfr.gpoaccess.gov.

[24] Krishna, A. K., Satyanarayanan, M., & Govil, P. K. (2009). Assessment of heavy metal pollution in water using multivariate statistical techniques in an industrial area: a case study from Patancheru, Medak District, Andhra Pradesh, India. *Journal of hazardous materials*, 167(1-3), 366-373.

[25] Eneje, R. C. & Lemoha K. T. (2012): Heavy Metal Content and Physicochemical Properties of Municipal Solid Waste Dump Soils in Owerri Imo State. *International Journal of Modern Engineering Research*, 2(5), 3795-3799.

[26] Olafisoye, B. A., Adefioye, T., & Osibote, O. A. (2012): Heavy Metals Contamination of Water, Soil, and Plants around an Electronic Waste Dumpsite. *Pol. J. Environ. Stud.*, 22(5), 1431-1439.

[27] Bolan, N., Kunhikrishnan, A., Thangarajan, R., Kumpiene, J., Park, J., Makino, T., Kirkham, M.B. & Scheckel, K. (2014). Remediation of heavy metal (loid) s contaminated soils–to mobilize or to immobilize? *Journal of Hazardous Materials*, *266*, 141-166.

[28] Ande, S., Famuyiwa, A., & Iorungwa, M. S. (2017). A Preliminary Assessment of Heavy Metals in Top Soils

around Wurukum Abattoir, Makurdi Benue State, Nigeria. *International Journal of Science and Research (IJSR)*. 6(9), 144-147.

[29] Odueze, J. Chibuzor, O. J., Nwakonobi, T. U., & Itodo, I. N. (2017). Influence of Physico-Chemical Characteristics of Soils on Heavy Metal Contamination in Makurdi, Benue State. *IOSR Journal of Environmental Science, Toxicology and Food Technology*, 11(5), 84-92.