



# HEAVY METALS ACCUMULATION IN SOIL AND GROUND WATER FROM A WASTE DUMPSITE IN MAKURDI, NIGERIA USING COLD VAPOUR METHOD

*\*Musa O. W., Ishaq S. E., Wuana A. R. and Ogah E.*

*Department of Chemistry, University of Agriculture Makurdi, Benue State Nigeria*

*\*Corresponding Email: williamsombugus70@yahoo.com*

*Manuscript Received: 05/01/2018 Accepted: 06/06/2018 Published: December 2018*

## ABSTRACT

The safety of waste dumpsite situated within the heart of many developing cities of the world continues to be a source of worry within the scientific community. The extent of environmental pollution by Central Bank of Nigeria (CBN) waste dumpsite in Makurdi, Benue State was investigated by determining the concentrations of mercury (Hg) and selenium (Se) in 26 soil samples and 3 groundwater (GW) samples collected around the waste dumpsite. Environmentally available metals were acid extracted from soil and groundwater samples and determined using cold vapor method. Mercury (Hg) and selenium (Se) levels in soil ranged from (0.25-0.38), (0.01-0.11) and (0.23-0.35), (0.001-0.10)mg/kg for 25cm and 50cm depth respectively. The concentrations in the ground water were: Hg (0.27-0.33). These levels for mercury were far higher in varying degrees than background levels, suggestion serious anthropogenic influence from the landfill. The concentration of Hg in the soil and groundwater sample is higher than permissible limits indicating a common origin for the metals. Pollution and Geoaccumulation indices revealed pollution of soil and groundwater, therefore, an urgent attention to mitigate this menace is required by government and stakeholders.

**Key words:** *Heavy metals contamination, soil, ground water, cold vapour method waste dumpsite.*

## INTRODUCTION

Contamination of soil and ground water source by leachate from landfills have been recognized for a long time (Alloway and Ayres, 1997). Industrialization and population increment results in changes in the composition and quality of waste generated. This is one of the main causes of environmental pollution and degradation in many cities of the developing world, (Musa and Tukura 2017). Poor waste management poses a several challenges to the well-being of the city residents, particularly those living adjacent the dumpsite due to the potential of the waste to pollute water, food sources, land, air and vegetation (Wuana *et al.*, 2011). Dumping of solid waste without proper separation increases the concentration of heavy metal, these metals when present in solid waste have been known to produce the major environmental impacts (Musa and Tukura, 2017).

The contaminations of soil, water and air with heavy metals even at low concentrations are known to have potential impact on environmental quality and human health; these metals also pose a long-term risk to groundwater and ecosystem in general (Eneji *et al.*, 2011). Reports further indicate that these metals are toxic or poisonous even at low concentrations and create definite health hazards when they enter the ecosystem (Lenntech *et al.*, 2007). Physical, chemical and biological processes which take place in solid waste dumpsite also results in waste decomposition and production of leachates (Oladunni and Tejumade, 2013). Disposal of solid waste in major cities of Nigeria in the last two decades has posed serious environmental and public health problems. This has become a source of worry for urban planner in Makurdi, the second most populous city in North Central Nigeria because of the explosive population growth and urbanization (Wuana *et al.*, 2012). Most Landfills which were sited at the outskirts are now within the heart of the city.

Leachate from dumpsite is of particular interest when it contains potentially toxic heavy metals. These metals are known to bioaccumulate in soil and have long persistence time through interaction with soil component and consequently enter food chain through plants or animals (Adedosu *et al.*, 2011). The study was carried out to assess the distribution of heavy metals present in the soil and ground water around the dumpsite, using cold vapor method and comparing these levels around the dumpsite with that from control site close to water dam.

## MATERIALS AND METHODS

Makurdi, the Benue State Capital located on latitude 7°44'N and longitude 8°32'E situated in a valley in north central Nigeria. 100m above sea level. As at

the year 2007 Makurdi has an estimated population of 500.791 people with a total land area of about 200km<sup>2</sup> (Aloysius *et al.*, 2013). The study Area (Fig. 1) is located along University of Agriculture Road Makurdi. The study area is surrounded by two communities namely Ate-Akee community in the West, Mennee community in the East and a water dam 500 meter adjacent to it. The population of the area is about one hundred to one hundred and fifty persons, most of whom are peasant farmers. Figure 2 shows a picture of the open waste burns in the dumpsite.

The procedure started with a reconnaissance survey to the study area, soil and water samples were collected at different points from the downstream to the upstream. Soil samples from each of the twelve points were collected at two depths ( 25cm and 50cm ) respectively and in two rows. Soil sample were also collected 500m away from dumpsite area as control. A total of twenty-six soil samples were collected. Polyethylene bags were used for the collection of the soil samples from various samples location. Groundwater samples were collected from three different boreholes around the dumpsite, while the fourth water sample was collected 500m away from the dumpsite area.. The samples were appropriately labeled and acidified with concentrated HNO<sub>3</sub> (1mL/L of water sample) in order to keep the pH of the samples low, subsequently preventing precipitation of the metal (Omotunde *et al.*, 2011). The soil samples were air dried in a clean room to avoid contamination and ground to fairly uniformed size to pass through 0.5mm sieve and stored in polyethylene bags for analysis.

Exactly 1.0g of dried and sieved soil samples was weight into a 25mL conical flask. 12mL of freshly prepared aqua – regia (3mLHNO<sub>3</sub> + 9mL HCl i.e. ratio 1:3) was added. The flask was covered with a filter paper to enable the digestion to take place under constant volume (Adedosu and Adewuyi, 2013). The content was heated for 1 hour on the medium heat of a hot plate. The mixture was allowed to cool and then filtered through a Whatman No.42 filter paper into a 50mL standard volumetric flask. The filtrate was diluted to 50mL with de-ionized distilled water. The procedure was repeated for all the soil and control samples.

To ensure the removal of organic impurities from the samples and thus prevent interference in analysis, the samples were digested with concentrated nitric acid. 50mL of the water sample was measured and 10mL of nitric acid was added to the water sampler in a 250mL conical flask. The mixture was evaporated to half it's volume on a hot plate after which it was allowed to cool and then filtered with Whatman No. 42 filter paper. The filtrate was diluted

to 50mL with de-ionized distilled water. A blank solution was prepared according to standard method (Eneji *et al.*, 2011).

All extracts from soil and ground water samples were analyzed for Hg and Se using cold vapour method. The settings and operational conditions of the instrument were in accordance with the manufacturer's specification. The instrument was calibrated with analytical grade standard metal solution.

Three different assessment indices were used to assess the extent of pollution of soil and water around the dumpsite. The quantification of the anthropogenic inputs, the pollution index and geoaccumulation index (Muller, 1969) were adopted. Pollution index (PL1) assesses pollution level by considering the joint effect of all the polluting metals in soil or water.

Equation used for Quantification of the anthropogenic input heavy metals in the soil

$$\text{Anthropogenic metal} = \frac{X - X_c}{X} \times 100\% \quad \dots (1)$$

Where x = average concentration of the metal in the soil  
 $X_c$  = average concentration of the metal in the control sample.

The study site was evaluated for the extent of metal pollution by employing the method based on the pollution load index (PL1) developed by Thomilsom *et al.*, (1980) as follows:]

$$PL1 = (CF1 \times CF2 \times \dots \times CF_n)^{\frac{1}{n}} \quad \dots (2)$$

where n is the number of metals studied and CF is the contamination factor calculate as follows: -

$$CF = \frac{C_m \text{ sample}}{C_m \text{ Background or control}} \quad \dots (3)$$

Where the contamination factor  $CF < 1$  refers to low contamination  $1 \leq CF < 3$  means moderate contamination:  $3 \leq CF \leq 6$  indicates considerable contamination and  $CF > 6$  indicates very high contamination.

The PL1 provides simple but comparative means for assessing a site quality, where a value of  $PL1 < 1$  denote perfection:  $PL1 = 1$  present that only baseline levels of pollutants are present and  $PL1 > 1$  would indicate deterioration of site quality Mmolawa *et al.*, (2011).

To assess the intensity of metal contamination in the soil around the CBN dumpsite, the geochemical accumulation index (I-geo) was calculated using the

equation as follows:

$$I\text{-geo} = \log_2 \left| \frac{C_m \text{ Sample}}{1.5 \times C_m \text{ background}} \right| \dots (5)$$

This method assesses the metal pollution in terms of the seven (0 to 6) enrichment classes ranging from background (control) concentration to very heavily contaminated. The factor 1.5 is introduced in this equation to minimize the effect of possible variations in the background (control) value.  $C_m$  background, which may be attributed to lithogenic variation in soil.

## RESULTS AND DISCUSSION

The mean concentration of mercury from the 25cm depth is 0.31mg/kg, standard deviation 0.050mg/kg and the control site is 0.006mg/kg while at 50cm depth the mean concentration is 0.29mg/kg, standard deviation 0.04mg/kg and the concentration at the control site is 0.003mg/kg. The mercury concentration level at the control site is very low compared to the concentrations level obtained at the sample site. The concentration levels at the two selected depth were below the maximum allowable limit set by countries (Kabata Pendias, 1995).

The low concentration of mercury obtained in this study is in agreement with that of a similar study by Ahmed *et al.*, (2010) whose mean concentration was 0.29mg/kg in India. The anthropogenic distribution of mercury in this location could be attributed to the disposal of batteries, fluorescent bulbs, thermometer, electrical gear and waste mercury compounds in the dump. Mercury is not commonly found in plant products but it can enter human bodies through vegetables and other crops. Significantly high exposure to mercury could cause nervous, brain and kidney damage, lung irritation, eye irritation, skin rashes, vomiting and diarrhea (Wuana, 2011).

Selenium Concentration in this study was the lowest among the two metals. The mean concentration of selenium at 25cm depth is 0.04mg/kg with standard deviation value of 0.04mg/kg. The mean concentration at 50cm depth is 0.04mg/kg with standard deviation 0.4mg/kg. The value of selenium is below the approved maximum allowable limits for heavy metal in soils regulated by various countries, which suggest that for now there is little anthropogenic contribution (Kabata Pendias, 1995).

Table 1: Statistics of Physiochemical Properties of Soil at Two Selected Depths

Parameters	At 25cm depth			At 50cm depth		
	Range		Mean + S.D	Range		Mean + S.D
	Min.	Max.		Min.	Max	
PH	5.10	6.00	5.60 + 0.40	5.05	6.11	5.63 + 0.41
CEC (meq/100)	5.71	7.14	6.30 + 0.50	5.63	7.22	6.41+0.65
OM(%)	10.5	12.51	11.30 +0.58	10.50	12.00	11.321+0.38

Table 2: Mean of heavy metal concentrations (mg/kg) in the soil at selected depths first and second row around CBN dumpsites

Element	At 25cm depth			At 50cm depth		
	Range		Mean + S.D	Range		Mean + S.D
	Min.	Max.		Min.	Max	
Hg	0.25	0.38	0.31+0.05	0.23	0.35	0.29 + 0.04
Se	0.01	0.11	0.04 + 0.04	0.001	0.09	0.04 + 0.04

The results of ground water sample analyses around the Central Bank of Nigeria (CBN) dumpsite are shown in Table 3 and 4. The concentration of the detected heavy metals in water sample shows that in the three sampling location mercury (Hg) exceeded the WHO and EU standard limits expect selenium (Se) which was not detected in the three water samples. The control water sample has very low concentration for all the metals compared to those of the study area. The presence of mercury in the control water sample which is 500m away from the study area is attributed to water with contaminant that permeates down from the bottom of the dam into the control area.

Table 4 shows the statistics of heavy metals concentration in ground water of the study area. The result shows that the ranged concentration of the examined Hg (0.27-0.33mg/L) while Se was not detected in the samples. Among the two examined heavy metals parameters, mercury (Hg) recorded the highest value (0.133mg/L). The result obtained is in agreement with that of Eneji *et al.*, 2011 and Adamu *et al.*, 2009 in their work similar to this in Makurdi, established the presence of Hg in both surface and ground water. Further, the World Health Organization (WHO), European Union Commission (EU) and Nigerian environmental protection Agence (FEPA) standard limit for drinking water quality adopted to adjudge the suitability of the ground water for human drinking showed that examined mercury was found to be highly above the maximum permissible limit for drinking water (Lenntech, 2011). The result of the control water samples shows that the concentration of mercury (0.002mg/L) analyzed is slightly above the WHO maximum concentration limit in drinking water of 0.001mg/L.

Comparing the contamination level of Hg from the control water sample with that obtained from the study site, one can established that the borehole water

in the study site is contaminated with mercury. This may be as a result of percolation of leachate down into the ground water table (Duruibe *et al.*, 2007; Momodu *et al.*, 2010). These metals are leached out from the up stream of the dumpsite to down stream due to sloppy nature of the area. These results are of great concern because the borehole water around the CBN dumpsite cannot be use for domestic and human consumption since it is hazardous to human health.

There are low levels of variation in the investigated soil and ground water with standard deviation shown by Hg and Se low variation show more or less homogenous distribution of metals in the soils and ground water (Alosius *et al.*, 2013). In order to assess the impact of toxic trace metals in soil, a methodology adopted where in various indices such as (i) anthropogenic metal quantification (ii) contamination (pollution) load index (PL1) (iii) index of geo-accumulation (I-geo)

Results from the calculation of Geo-accumulation index (I-geo) in soil are also presented in table 5 the contamination status of the metals in the environment expressed in terms of geo-accumulation indices showed that the environment is highly contaminated with mercury (Hg). The zero values of selenium (Se) are indication that the soil is not contaminated by selenium.

The Quantification of heavy metals obtained from the soil of the study site shows that the degree of anthropogenic contamination of Hg was high. (95% at 50cm depth and 98% at 100cm depth) Selenium (Se) 0%. The result clearly indicated that Mercury pollution in the study site derived from the waste generated from the CBN dumpsite.

The pollution (contamination) load index (PL1) was applied, on the sample concentration from the study site. The pollution load index (PL1) is aimed at providing a measure of the degree of overall

contamination at the sample site. The result of the two metals studied at two selected depth 50cm and 100cm read 2.0 and 1.0 respectively. Meaning that the soil of the study area is moderately contaminated with heavy metal at 50cm depth and at 100cm the contamination is base line level. Similarly, the contamination load index for borehole water in the study site shows a

value of 1.5 indicating that the ground water around the CBN dump site is slightly contaminated with Mercury. When the PLI value is less than one ( $PLI < 1$ ) it denote perfection and when it equals one ( $PLI = 1$ ) it present that only baseline levels of contamination are present and when PLI value is greater than one ( $PLI > 1$ ) it means that the site is contaminated.

Table 3: Physicochemical parameters of borehole water sample

Sample location	pH	Temp °C	TDS (mg/L)	DO mg/L	Total Hardness mg/L	EC mg/L mS/cm
WBH1	6.68	33.68	345.0	3.49	20.00	536.0
WBH control	6.78	34.02	366.0	4.86	15.00	513.0
WHO STD	6.5-8.5	25 – 27	500	7.5	200	500

Table 4: Statistics of heavy metal concentrations (mg/L) in borehole water samples

Element	Range		Mean + S.D	W.H.O Std.	EU Std.
	Min.	Max.			
Hg	0.27	0.33	0.31+0.03	0.001	0.001
Se	N.D	N.D	-	0.01	0.01

Table 5: Geo-accumulation index (I-geo), quantification of contamination and background (control) concentration (mg/kg) of heavy metals in soil around CBN dumpsite

	I-geo		Quantification contamination (%)		Background (control) mg/kg		PLI of soil/ ground water	
	50cm	100cm	50cm	100cm	50cm	100cm	50cm	100cm
Hg	1.54	1.81	95	98	0.006	0.003	2	1
Se	0	0	0	0	N.D	N.D	PLI of ground water 1.5	

where  $PLI < 1$  denote perfection,  $PLI > 1$  indicate contamination of site.

Igeo value 0 – 1 uncontaminated, Igeo 1 – 2 moderately contaminated

## CONCLUSION

The study has confirmed that heavy metals contamination of ground water and soil is an issue of environmental concern. The results reveal the presence of significant concentration of heavy metals mercury (Hg) and selenium (Se) in soil in all the sample points, except for selenium (Se) which was not detected in the three water boreholes. Mercury (Hg) had the highest concentration in both soil and water, with selenium lowest concentration in soil sample.

The metals concentration investigated in the soils and water in this study area have been found to be higher than their control (background) collected 500m away from the CBN dumpsite indicating a clear case of pollution, equally suggesting anthropogenic influence from the dumpsite. The concentration of all the heavy metals in the soil were lower than permissible limit set by other countries, in the other hand the concentration of Hg in groundwater were higher than permissible limit for drinking water set by WHO, EU and Nigeria Standard and guideline for

drinking water. The whole results strongly suggest leakage of the leachate from the CBN dumpsite to surround environment, which would pause great danger to human health living in the surrounding environment.

Rehabilitation of the CBN dump sites is recommendable as soon as possible to prevent deterioration of the surrounding environment. Awareness of the pollution statuses of soil and ground water in and around the CBN dumpsite need to be urgently created especially among people living in the surrounding environment to avert health related problem from drinking water and consuming plant from this vicinity.

## ACKNOWLEDGEMENT

The Authors are grateful to the Authorities of Golden Year limited, Port Harcourt Nigeria for Assisting with Laboratory facility to analyze the data. We are further grateful to Professor Rufus Sha’Ato for mentoring and always encouraging us to write.

---

## REFERENCES

- Abdul-Momen M. Ahmed, Salah M.A.H and Ahmed E. Eiadi (2011) Assessment of the Heavy Metals Around two Municipal Solid Waste (MSW) Dumpsite Egypt. *International Journal of Development and Sustainability* 1(2) 212-224.
- Abdus-Salam, N. (2009). Assessment of Heavy Metal Pollution in Dumpsites in Ilorin Metropolis *Ethiopia Journal of Environmental Studies and Management*. 1(2) 92-99.
- Adamu, C.I. & Nganje T.N. (2009) Assessment of Heavy Metals Pollution in Sediments and Surface Water of River Benue, Makurdi Nigeria. *Journal of Applied Science Engineering and Technology Volume 9* (3) 225-232
- Adedosu, H.O. & G.O. Adewuyi, G.U. (2013) Adie Assessment of heavy metal in Soil, Leachate and Underground water Samples Collected from the Vicinity of Olusosun Landfill in Ojota-Lagos-Nigeria-*Tranational Journal of Science and Technology*. 3 (6) ISSN 1857-8047.
- Ahmad Khusairi Bin Ayop (2011) Determination of Heavy Metal Concentration in top Surface and Subsurface soil Around Ulutu a-Lang closed Landfill. *Malaysia Journal of Environmental Studies* 2(3) 171-176.
- Aigbedion L.N. (2005). Environmental Pollution in the Niger Delta, Nigeria. *Inter-Disciplinary Journal Enugu Nigeria* 3(4): 205-210.
- Akoteyon, I.S. (2012); Evaluation of groundwater Quality using Contamination Index in Parts of Alimosho, Lagos-Nigeria *American Academic & Scholarly Research Journal Vol. 4*.
- Alloway B.J, Ayres DC (1997). Chemical Principles of Environmental Pollution, 2nd Ed. Blackie Academic and Professional, Glasgow, UK, pp. 10-30.
- Aloysius A. Pam, Sha’Ato Rufus, John O. Offem (2013) Contribution of Automobile Mechanic Sites to Heavy Metal: A case Study of North Bank Mechanic Village Makurdi, Benue State Nigeria *journal of Chemical, Biological and Physical Sciences*. 3(3); 2337-2347.
- Beetseh, C.I. and Num G. (2013) A Survey of the Presence of Heavy Metals in Water Source at and Around the Auto Mechanic Village at Lafia Junction, North Bank, Makurdi, Benue State. *Civil and Environmental Research Journal* 3(3) 20.
- Christensen, T.H. (1992). Attenuation of Leachate Pollutants in Groundwater, In: Land Filling of Wastes: Leachate (Christensen, T.H., R. Stegmann, Editors), London *Elsevier Applied Science* Pp 470-475.
- Duruibe, J.O, Oywegbu MOC (2007) Heavy Metal Pollution and Human Biotoxic Effect. *International Journal of Physical Science* 21(11) 112-118
- Eneji, I.S, Rufus Sha’Ato, Paul A. Annune (2011) An Assessment of Heavy Metals Loading in River Benue in the Makurdi Metropolitan Area in Central Nigeria. *Environment Monitoring Assessment Volume* 184(1): 201-207.
- European Union (2002). Heavy Metals in Wastes. European Commission on Environment (<http://ec.europa.eu/environment/lwas-te/studies/pdf/heavy-metalsreport.pdf>)
- Federal Environmental Protection Agency (FEPA) (1988) Guidelines and Standard for Environmental Pollution Control in Nigeria (1st Edition) Decree 58 of 1988. P. 108
- Kabata Pendias (1995) Agriculture Problem Related to Excessive trace Metal Contents of Soil in Heavy metal (Problems and Solutions). Springer Verlag Berlin, 4:3 – 18 (6th June 1995) Lenntech Water(‘Treatment and Air Purification (2004)»WaterTreatment, ‘Published by Lenntech, Rotterdamseweg. Netherland [www.e.xc.elwater.c.PmlthP/filtersWater Purification.htm](http://www.e.xc.elwater.c.PmlthP/filtersWater Purification.htm)).
- Lenntech, WHO/EU Drinking water standards Comparative table copyright 1998- 2014 Lenntech B.V. Email: [infro@lenntech.com](mailto:infro@lenntech.com)
- Mmolawa, K. B; Likuku A.S and Gaboutloe loe (2011) Assessment of heavy metal pollution in soils along major road side Area in Botswana. *African Journal of Environmental Science and Technology Vol.* 5(3). Pp 186 – 196
- Momadu, M.A. Anyakora C.A. (2010) Heaving Metal Contamination of Ground Water: the Surulere Case Study *Research Journal Environmental and Earth Science* 2(1) pg. 39-43.
- Muller G (1969) index of geoaccumulation in sediment of the Rhine river. *Geology Journal* 2(3) 108 – 118
- Musa, W. O and Tukura, B.W (2017) Evaluation of Heavy Metal Concentrations in Borehole Water Near Solid Waste Dumpsite *Journal of Natural and Applied Sciences Vol. 5* No 2 pp. 144 – 145
- Oladunni Bola Olafisoye, Tejumade Adefioye (2013), Heavy Metal Contamination of Water, Soil and Plants Around and Electronic Waste Dumpsite. *Pol. J. Environment Studies* 22(5) 1431-1439.

- 
- Omotunde, T.O., Adewale O.R., Adekemi M.B., Olusegun A.O., Adeleke A.A. (2011). Speciation of Heavy Metals (Cd and Pb) of some Dumpsites soil in Lagos state Nigeria Using AAS. *Advances in applied science Research*. 2(6) 247-253.
- Opaluwa, O.D., Aremu, M.O Ogbo (2012) Heavy Metal Concentration in soils, Plant Leaves and Crops Grown Around Dumpsites in Lafia Metropolis, Nasarawa State. *Advances in Applied Science Research*. 3(2): 780-784
- Thomilson D.C, Wilson D.J, Harris CR, Jeffrey D.W (1980) Problem in heavy metals in estuaries and the formation of pollution index. *Helgolwiss; Meeresuniter* 33(1 – 4): 566 - 576
- Wuana, R.A. and Okieimen, F.E. (2011): Heavy Metals in Contaminated Soils: A Review of Sources Chemistry, Risks and Available Strategies for Remediation *ISRN Ecology* 2011:1-20 International Scholarly Research Network.
- Wuana, R.A. Okieimen, F.E. Ogoh, B. (2012) Chemical Fractionation and Phyto Availability of Heavy Metals in a Soil Amended With Metal Salts or Metal Spiked Poultry Manure. *Communications in Soil Science and Plant Analysis* 43(20) 2615-2632