



Assessment of Heavy Metals Content in Soil and Groundwater within the Vicinity of Automobile Mechanic Workshops in Yola and Jimeta Towns, Adamawa State, Nigeria

*¹VINCENT, F; ²MANU, JM; ¹CHESSSED, G; ¹VANDI, P; ¹FRANCIS, S; ¹NORAH, S

¹Department of Zoology, Faculty of Life Sciences, Modibbo Adama University, Yola, Adamawa State, Nigeria

²Department of Science Laboratory Technology, Faculty of Life Sciences, Modibbo Adama University, Yola, Adamawa State, Nigeria

*Corresponding Author Email: ferdinandvincent89@gmail.com; Tel: +234 806 340 4672

Co-Authors Email: jomaitandu@yahoo.com; godlychessed@gmail.com; vandiphilips@mau.edu.ng; donkene02@mail.com; simmonnorah@mail.com

ABSTRACT: Although heavy metals are naturally occurring elements that are found throughout the earth's crust, anthropogenic activities such as mechanic workshops are a source of concern for heavy metal contamination. This paper assessed the heavy metals content in soil and groundwater within the vicinity of automobile mechanic workshops in Yola and Jjimeta Towns, Adamawa State, Nigeria using standard methods. Heavy metals were determined using AAS model 210 VGP while pH was determined by electronic JENWAY glass electrode pH meter (Model 3510). Data obtained revealed that, the pH of the sample ranged from 7.52 to 5.19 (provide the average pH levels in the soil and groundwater). From the study conducted, (provide the mean of the heavy metals here) it can be seen that the level of heavy metals found in the soil is in the order of Zn>Ni>Fe>Pb>Cd. While heavy metals found in the ground water of automobile mechanic locations is in the order Ni>Fe>Zn>Cd>Pb. The levels of metals found in the present study were generally below the Department of Petroleum of Petroleum Resources target values for metals in soils.

DOI: <https://dx.doi.org/10.4314/jasem.v26i11.3>

Open Access Policy: All articles published by **JASEM** are open access articles under **PKP** powered by **AJOL**. The articles are made immediately available worldwide after publication. No special permission is required to reuse all or part of the article published by **JASEM**, including plates, figures and tables.

Copyright Policy: © 2022 by the Authors. This article is an open access article distributed under the terms and conditions of the **Creative Commons Attribution 4.0 International (CC-BY- 4.0)** license. Any part of the article may be reused without permission provided that the original article is clearly cited.

Cite this paper as: VINCENT, F; MANU, J. M; CHESSSED, G; VANDI, P; FRANCIS, S; NORAH, S (2022). Assessment of Heavy Metals Content in Soil and Groundwater within the Vicinity of Automobile Mechanic Workshops in Yola and Jimeta Towns, Adamawa State, Nigeria. *J. Appl. Sci. Environ. Manage.* 26 (11) 1749-1755

Keywords: Heavy metals; Soil contamination; groundwater contamination; mechanic workshops

Heavy metals are defined as metallic elements that have a relatively high density compared to water (Aloysius *et al.*, 2013). With the assumption that heaviness and toxicity are inter-related, heavy metals also include metalloids, such as arsenic, that are able to induce toxicity at low level of exposure (Alao *et al.*, 2010). Although heavy metals are naturally occurring elements that are found throughout the earth's crust, most environmental contamination and human exposure result from anthropogenic activities such as mining and smelting operations, industrial production and use, and domestic and agricultural use of metals and metal-containing compounds (Alao *et al.*, 2010). Environmental contamination can also occur through metal corrosion, atmospheric deposition, soil erosion of metal ions and leaching of heavy metals, sediment re-suspension and metal evaporation from water resources to soil and ground water (Lenntech, 2011).

Natural phenomena such as weathering and volcanic eruptions have also been reported to significantly contribute to heavy metal pollution (Lenntech, 2011). Industrial sources include metal processing in refineries, coal burning in power plants, petroleum combustion, nuclear power stations and high tension lines, plastics, textiles, microelectronics, wood preservation and paper processing plants (Pam, 2013). Soils may become contaminated by the accumulation of heavy metals and metalloids through emissions from the rapidly expanding industrial areas, mine tailings, disposal of high metal wastes, leaded gasoline and paints, land application of fertilizers, animal manures, sewage sludge, pesticides, wastewater irrigation, coal combustion residues, spillage of petrochemicals, and atmospheric deposition. The increase in automobile repairs/workshops and their activities in Nigeria are partly due to the ever-

*Corresponding Author Email: ferdinandvincent89@gmail.com

increasing demand for personal vehicles, most of which are used "Tokunbo" vehicles. These have contributed remarkably to the problem of soil contamination in most cities. Automobiles used oil (waste) contains oxidation products, sediments, water and metallic particles resulting from machinery wears, used batteries, organic and inorganic chemicals used in oil additives and metals (Stevens *et al.*, 2010). Soil Percolation of leachates from these materials poses threats to groundwater. Unfortunately, information on the impact of automobile mechanics' activities on the ecosystem is still very unavailable. The co-existence of toxic heavy metals and hydrocarbons (HCs) at many of the mechanics contaminated sites all over Nigeria and in other developing countries pose a severe threat to the environment. In fact, the presence of trace elements in soil is increasingly becoming an issue of global concern especially as soil constitutes a crucial component of rural and urban environment (Okoro *et al.*, 2013). Hence, the objective of this paper is to assess the heavy metals content in soil and groundwater within the vicinity of automobile mechanic workshops in Yola and Jjimeta Towns, Adamawa State, Nigeria

MATERIALS AND METHODS

Study Area: The study was conducted in Yola and Jimeta towns under Yola North and Yola South Local Government, where the influx of personal cars, tricycles as well as taxis troop in for their repairs. Yola is the capital of Adamawa State, Nigeria, usually referred to as Jimeta-Yola. The old town of Yola is where the traditional ruler (Lamido) resides and therefore is known as the traditional city. But the new city which is about 5km north-west Yola is Jimeta. It lies between latitude 70° and 110° N of the Equator and between longitudes 110° and 140° E of the Greenwich Meridian. It shares boundary with Gerei Local Government Area at the North and Yola South Local Government at the East, West and South. It is the administrative and commercial headquarters of Adamawa State. The artisan activities at both areas (mechanic workshops), include panel beating, welding and metal fabrication, vulcanizing, automobile mechanics.

Sample collection and Preparation: All the chemicals and Reagents used were of analytical grade (AR), manufactured by British Dry House Chemicals limited pool England or Merck Germany. No further purification of the reagents were carried out before use. Distilled water was used throughout the research work. All glass wares, plastic containers, crucibles, mortar and pestle were washed thoroughly. Glasses were washed with liquid soap, rinsed with distilled

water and then soaked in 10 % HNO₃ solution for 24 hours (Fasae, 2011).

Soil samples collection: Soil samples from six (6) automobile mechanic workshops was collected from Jambutu, fire service, barrack road, opposite abattoir (Yola road), Bekaji and Tashan Sani.

Within a location, samples were collected from three different point at a depth of 0 -15cm and 15 -30cm which is referred to as top soil and sub-soil respectively (Awofolu, 2005). About 500g soil sample (from the two depths each) were collected from each artisan location using a pre-cleaned stainless steel hand trowel. The samples were put in polythene bags and transported to the laboratory where stones and other extraneous matter were removed and the sample were air-dried. The dried sample were then sieved through a 2 mm mesh stainless steel sieve, mixed thoroughly, sub-sampled for analysis and then stored in appropriately labelled polythene bags.

The soil was spread on a clean plastic sheet placed on a flat surface and air-dried in open air in the laboratory under room conditions for 24 hours. Afterwards, the soil was sieved on a 2 mm sieve and 5g sample was taken from the sieved soil and put in a beaker. 10ml of nitric/chloric acid, ratio 2:1 was added to the sample.

This sample was digested at 105°C. Next, HCl and distilled water, ratio 1:1 was added to the digested sample and the mixture transferred to the digester again for 30 mins. The digestate was then removed from the digester and allowed to cool to room temperature. The cooled digestate was washed into a standard volumetric flask and was made up to the mark with distilled water. Determination of the heavy metals was done in an atomic absorption spectrophotometer (AAS model 210 VGP) after calibrating the equipment with different standard concentrations.

Determination of pH: pH which was determined with an electronic JENWAY glass electrode pH meter (model 3510).

Water sampling and analysis: Water samples were obtained from each of the sites following standard water sampling procedure. Each sample was directly collected into a factory-fresh 1.5 L plastic bottle, with cap securely tightened. After collection the bottles were placed inside ice coolers for transportation to the laboratory where they were then transferred to the refrigerator. Laboratory analysis commenced the same day. The methods used are all detailed in APHA, AWWA, WPCF (1998).

RESULTS AND DISCUSSION

The pH recorded for groundwater and soil at both depth (0-15cm and 15-30cm) showed that the highest pH for groundwater (7.52) was recorded in Tashan Sani, while the least (6.74) was recorded in Bekaji. The soil pH recorded at different depths showed that the highest (6.50) was recorded in Jambutu at 15-30cm, while the least (5.19) was recorded in Fire service mechanic workshop at a depth of 15-30cm (Table 1). The data on heavy metals analyzed in the soil samples collected in the study areas is captured in Table 2 Tashan Sani (0-15cm) had the highest (0.390 mg/Kg) concentration of Cadmium recorded. While,

opposite abattoir (15-30cm) had the lowest concentration of Cadmium (0.006 mg/Kg) recorded among the soil samples collected. Concentration of Iron in the soil samples ranged from 0.143 mg/Kg at Bekaji (15-30cm) to 7.827mg/Kg level of concentration at opposite abattoir (0-15cm). Nickel concentration at barrack road (0-15cm) from the sample collected had the highest value 6.772mg/Kg, while the concentration at Jambutu (15-30m) was the lowest 1.441mg/Kg from the samples collected. Lead concentration was highest from the sample collected at Fire service (0-15cm) with 5.249mg/Kg and lowest at Tashan Sani (15-30cm) sample with 0.72mg/Kg concentration.

Table 1: pH of Groundwater and Soil Samples from the Study sites

Samples Location	Ground water	Soil (0-15cm)	Soil (15-30cm)
Opp. abattoir	7.30	6.47	6.20
Barrack Rd	6.92	5.30	5.29
Bekaji	6.74	6.09	5.83
Jambutu	7.19	6.33	6.50
Fire Service	6.84	5.72	5.19
Tashan Sani	7.52	6.04	6.29

Table 2: Heavy Metal Concentrations of Soil Samples Obtained from study sites

Sample Location	Heavy Metal Concentrations (mg/kg)				
	Cd	Fe	Ni	Pb	Zn
Opp. Abattoir (0-15)	0.108	7.827	4.301	1.661	8.334
Opp. Abtr (15-30)	0.006	7.132	2.167	0.798	6.161
Barrack Rd (0-15)	0.240	2.309	6.772	2.132	4.299
Barrack Rd (15-30)	0.010	0.739	2.246	1.625	3.895
Bekaji (0-15)	0.017	0.819	4.327	2.709	7.398
Bekaji (15-30)	0.029	0.143	4.237	1.513	3.701
Jambutu (0-15)	0.262	3.191	2.619	3.129	6.430
Jambutu (15-30)	0.202	2.077	1.441	1.628	5.519
Fire Service (0-15)	0.333	4.173	3.732	5.249	2.847
Fire Service(15-30)	0.304	2.279	0.873	2.178	1.560
Tashan Sani (0-15)	0.390	3.450	5.550	1.583	4.376
Tashan Sani (15-30)	0.145	0.814	3.317	0.072	3.006

Zinc concentration in the studied soil samples ranged from 1.560 mg/Kg at fire service (15-30cm) to 8.334mg/Kg at opposite abattoir (0-15cm). From the study conducted, it can be seen that the level of heavy metals found in the soil is in the order of Zn>Ni>Fe>Pb>Cd. The concentration of some heavy metals such as Cadmium, Lead, Nickel, Zinc and Iron present in the water samples obtained in the study area is indicated in Table 3. Cadmium concentration was below detection limit in water samples from Bekaji and Fire service but had the highest concentration in

sample from Jambutu with 0.011mg/Kg. In Jambutu and barrack road, lead was found to be 0.001mg/Kg and 0.002mg/Kg respectively in concentration. It was below detection limit in other samples of the study. Nickel was found in all water samples. Zinc was below detection limit in water samples from Bekaji and fire service but had the highest concentration in water sample from barracks road. Iron concentration was lowest in the sample from Bekaji and highest in the sample collected from abattoir.

Table 3: Heavy Metal Concentrations of Water Samples Obtained from study sites

Sample Location	Heavy Metal Concentrations (mg/L)				
	Cd	Pb	Ni	Zn	Fe
Opp. Abattoir	0.006	B.D.L	0.186	0.051	0.129
Barrack Rd	0.001	0.002	0.068	0.104	0.074
Bekaji	B.D.L	B.D.L	0.014	B.D.L	0.004
Jambutu	0.011	0.001	0.213	0.030	0.044
Fire Service	B.D.L	B.D.L	0.003	B.D.L	0.011
Tashan Sani	0.004	B.D.L	0.117	0.053	0.020

B.D.L=Below Detection Limit

From the study conducted, it can be seen that the level of heavy metals found in the ground water of automobile mechanic locations is in the order Ni>Fe>Zn>Cd>Pb. Heavy metals in Soil samples: These Sites contains considerable amount of potentially harmful substances including heavy metals like Fe²⁺, Zn²⁺, Ni²⁺, Pb²⁺. FAO (1985) has permissible limit of Cadmium at 0.01 µg ml⁻¹, 5.0 µg ml⁻¹ for Lead, 2.0 µg ml⁻¹, for Zinc, 0.20 for Nickel and 0.5-50 for Iron. The concentrations of the heavy metals in the soil layers in the present study differ from the reports of Adelekan and Abegunde, (2011), who reported that Pb generally has the highest while Cd generally has the least and the order observed for this study is Pb > Cu > Cr > Ni > Cd. Some exceptionally high values of lead have also been reported in the literature and most were in one way or the other connected to manufacturing sites of vehicle batteries. Adie and Osibanjo (2009) found a range of 243 to 126,000 mg.kg⁻¹ in soils from the premises of a battery manufacturing plant. Nwoko and Egunjobi (2002) found Pb concentrations which were described as being highly elevated in soil and vegetation in an abandoned battery factory site. Oyeleke *et al.* (2015), reported Pb concentration ranged from 5.0 mg/kg to 182.0 mg/kg with an overall mean concentration of 59.13 mg/kg. The highest concentration obtained in the present study is even far below the highest Pb concentration obtained by Onianwa and Fakayode (2000) and Ogundiran and Osibanjo (2009) in the surrounding soils of battery factories in Ibadan, Nigeria. Other authors recorded higher values of Pb, which include; 17.07-8469 mg/kg by Yaylali-Abanuz (2011), obtained in surface soil around Gegze industrial area, Turkey, 14.13 mg/kg reported by Babatunde *et al.* (2014) in soil in the vicinity of an oil depot in Jos, Nigeria and 47.8 mg/kg by Srinivas *et al.* (2009) in soil within an industrial area, and 18 mg/kg reported by Iyaka and Kakulu (2012) around a ceramic and pharmaceutical industrial sites in Suleja and Minna, Nigeria. In this present study the elevated Pb levels in some of these urban soils are definitely due to activities in these auto mechanic villages. The mean level of Fe in the soil of the study location is lower when compared to the permissible limit of 50mg/kg, it is safe to say that the soil is safe for use. The mean of Zinc in soil samples of the present study is more than the permissible limit of Zn in soils (0.30mg/kg), Štofejová *et al.* (2021), also recorded a higher value of 52.00–113.00 mg/kg. The level of Pb in the soil samples of the study area is more than the permissible limit of lead in soils (0.10mg/kg), and is not similar to the findings of Štofejová *et al.* (2021), that recorded that the average lead content was at the level of 29.92 mg/kg in 2019 and 28.90 mg/kg in 2020. Therefore, the level of Pb in the study area is hazardous. Nickel

manifested a lower range in the present study when compared with the report of Adelekan and Abegunde, (2011), who recorded a range of 2.0 to 25.0 mg.kg⁻¹. The maximum value is well within the limits set for Ni in all the countries with the exception of Netherlands, and Denmark (ECDGE, 2010). Both countries set a limit of 15 mg.kg⁻¹ for Ni. Whereas the mean level of Ni in soil of the present study area is above the permissible maximum level of Ni in soil just as in Štofejová *et al.* (2021) where the average nickel content in the soil in 2019 was 32.58 mg/kg, and 31.92 mg/kg in 2020. Ni is therefore in excess in the study area.

The concentrations of Ni found in this study are compatible with those reported in the literature. For instance, Lenntech (2009) pointed out that the nickel content in soil can be as low as 0.2 mg.kg⁻¹ or as high as 450 mg.kg⁻¹ although the average is about 20 mg.kg⁻¹. The UK Soil and Herbage Survey found total nickel concentrations in the range 1.16 to 216 mg.kg⁻¹ for rural UK soils, with a mean value of 21.1 mg.kg⁻¹. Urban UK soils were found to contain nickel concentrations in the range 7.07 to 102 mg.kg⁻¹, with a mean value of 28.5 mg.kg⁻¹ (Environment Agency, 2007). A survey of soils in Scotland (Berrow and Reaves, 1986) reported a geometric mean concentration of Ni in soil of 27 mg.kg⁻¹; and a survey of soils in England and Wales by McGrath and Loveland (1992) reported a geometric mean concentration of 20 mg.kg⁻¹. Therefore, soils from these auto-mechanic sites in Jimeta metropolis do not appear to contain abnormally high values of Ni. Global input of nickel to the human environment is approximately 150,000 and 180,000 metric tonnes per year from natural and anthropogenic sources respectively, including emissions from fossil fuel consumption, and the industrial production, use, and disposal of nickel compounds and alloys (Kasprzak *et al.*, 2003). The Cd content in the present study was lower when compared to the findings of Adelekan and Abegunde, (2011), who recorded below the detection limit and the situation was found to spread through all the locations and at various depths of their research. Two possible reasons may be ascribed to this kind of situation of low occurrence of Cd in soil. The first is that the aggregate Cd levels in the sludge applied to soil may be low. However, since these are auto mechanic workshops which have existed for several years, the possibility of that is remote. The other explanation is the mobility of Cd through the soil layers. Cadmium tends to be more mobile in soil systems than many other heavy metals (Alloway, 1995). Contamination sources of Cd include industrial site contamination, mine waste dumps, and corrosion of metal structures. It therefore indicates that the level

of Cd in soil of the study area are safe for use and this can be attributed to no mining activities. (IARC 1993). Only the United Kingdom and Luxembourg have Cd limit of 3 mg.kg⁻¹ while the rest have a lower limit. Only 2 of the measured values in this study are above 3.0 mg.kg⁻¹. A soil Cd limit of 1 mg.kg⁻¹ is set in Norway (Reimann *et al.*, 1997), Germany, Ireland, Spain and Portugal (ECDGE, 2010). Switzerland set a value of 0.8 mg.kg⁻¹ for Cd (FOEFL, 1987) while Sweden set 0.4 mg.kg⁻¹ (ECDGE, 2010). The measured values of Cd in this present study were below 1 mg.kg⁻¹. Several of these findings find support in a study by Kabala and Singh (2006) which investigated the vertical distribution of Cd as well as its potential mobility in soil profiles exposed to copper smelter emissions. It found that Cd ranged from 1.06 to 1.40 mg.kg⁻¹ overall.

Heavy metals in ground water samples: Groundwater is the principal natural water resources for both drinking and agricultural purposes. Nowadays one of the most important environmental issues is groundwater contamination. In areas where population density is high and human use of the land is intensive, groundwater is especially vulnerable. Virtually any activity whereby chemicals or wastes may be released to the environment, either intentionally or accidentally, has the potential to pollute groundwater. When ground water becomes contaminated, it is difficult and expensive to clean up. Industrial waste and the municipal solid waste have emerged as one of the leading cause of pollution of surface and ground water. In many parts of the country available water is rendered non-potable because of the presence of heavy metal in excess. Patil *et al.* (2012)

World Health Organization (1996) set the maximum permissible limits of heavy metals in drinking water as follows; Cadmium (0.003 mg/l), Lead (0.01 mg/l) and Nickel (0.02 mg/l). All water samples analysed in the present study cut across these limits and therefore posed some degree of danger to consumers as far as these specific heavy metals are concerned but Adelekan and Abegunde, (2011), reported that all heavy metals were within the these recommended maximum permissible limits and therefore poses no danger. The deleterious health effects of excessive levels of heavy metals in water vary (WHO, 1996, 2004). It can be seen that the mean level of Cd in water samples in the present study is within the permissible limits of Cd for drinking water and irrigation water, this does not agree with Yusuf *et al.* (2018) where the mean concentration of Cadmium across all the samples was 0.07mg/l as against the WHO, (2011) permissible limit of 0.03mg/l and 0.003mg/l respectively. Iron concentration in the present study is lower when compared to the concentration of

0.084mg/kg in reported by Musa *et al.* (2013), thus, it does not exceed the recommended limit for Fe in water 0.3ppm and irrigation water 5.00ppm. The level of Fe in underground water of automobile mechanic location is safe for use. But the mean level of Zn in the underground water is within the permissible limit of both drinkable and irrigation water, 5.0mg/kg and 2.0mg/kg respectively but does not tally with results from Musa *et al.* (2013) where zinc concentration ranges from 0.004mg/L to 0.066mg/L around Obajana, Kogi State. Thus, Zn is hazardous in the soil of the study areas and this can be as a result of the type of activities carried out in the region. Nickel is ubiquitous in the environment. Nickel is almost certainly essential for animal nutrition, and consequently it is probably essential to man. Nickel is a relatively non-toxic element; however, certain nickel compounds have been shown to be carcinogenic in animal experiments. FAO (2019). From the study, the mean level of Ni in underground water 0.0867mg/kg is above the maximum permissible Nickel limit just as Yusuf *et al.* (2018), where high concentration was observed at the entire location with mean value of 0.88mg/l as against both WHO, (2011) permissible limit of 0.02mg/l. When use for drinking and domestic purposes at high concentration, Nickel can cause carcinogenic diseases (National Academy of Sciences, 1999). The mean concentration of lead in underground water of study area 0.004mg/kg is within the permissible limit of both drinking water and irrigation water as against Yusuf *et al.* (2018) with the mean concentration values for Lead ion ranges from 1.186mg/l and 2.392mg/l in the study area.

Conclusion: The combined use of different approaches for evaluating soil and groundwater heavy metal contamination facilitates a comprehensive interpretation of the soil characteristics in terms of the background influences. The mechanic workshop environment is getting polluted, particularly with Pb, Ni and Cd based on the enrichment factor. This is a reflection of anthropogenic contribution which might partly result from the use of metal containing additives as lubricants. Based on the geo-accumulation index data, the soils can generally be classified as “moderately contaminated”

REFERENCES

- Adelekan, BA; Abegunde, KD (2011). Heavy Metals Contamination of Soil and Groundwater at Auto-Mobile Mechanic Villages in Ibadan Nigeria. *Inter. J. Phy. Sci.* 6: 1045-1058.
- Adie, GU; Osibanjo, O (2009). Assessment of soil pollution by slag from an automobile battery

- manufacturing plant in Nigeria. *Afr. J. Environ. Sci. Technol.* 3(9): 239-250.
- Alao, O; Arojojoye, O; Ogunlaja, O; Famuyiwa, A (2010). Impact Assessment of Brewery Effluent on Water Quality in Majawe, Ibadan. Southwestern Nigeria. *Res.* 2: 21-28.
- Alloway, BJ (1995). Cadmium. In: Heavy Metals in Soils, Second Edition (BJ Alloway, ed.). Blackie, New York, pp. 122-151.
- Aloysius, AP; Rufus, S; John, OO (2013). Evaluation of heavy metals in soils around auto mechanic workshop clusters in Gboko and Makurdi, Central Nigeria. *J. Environ. Chem. Ecotoxicol.* 5(11): 298 – 306.
- APHA, AWWA, WPCF (1998). Standard Methods for the Examination of Water and Wastewater, 20th Edn. Washington D.C.
- Awofolu, OR (2005). A survey of trace metals in vegetation, soil and lower Animals along some selected major roads in metropolitan city of Lagos. *Environ. Monit. Assess.* 105: 413-447.
- Babatunde, OA; Oyewale, AO; Steve, PI (2014). Bioavailable Trace Elements in Soils around NNPC Oil Depot Jos, Nigeria. *J. Environ. Sci. Toxicol. Food Technol.* 8(1):47-56.
- Berrow, ML; Reaves, GA (1986). Total Chromium and Nickel Contents of Scottish Soils. *Geoderma.* 37: 15-27.
- Department of Petroleum Resources, [DPR] (2002). Environmental guidelines and standards for the petroleum industry in Nigeria (revised edition). Department of Petroleum Resources, Ministry of Petroleum and Natural Resources, Abuja, Nigeria.
- Environmental Agency (2007). Environmental Concentrations of Heavy Metals in UK Soil and Herbage. UK Soil and Herbage Pollutant Survey. Bristol: Environ. Agency. p. 7.
- European Commission Director General Environment, [ECDGE] (2010). Heavy Metals and Organic Compounds from Wastes Used as Organic Fertilizers. Final Rep., July. WPA Consulting Engineers Inc. pp. 73-74.
- Federal Office of Environment, Forests and Landscape, [FOEFL] (1987). Commentary on the Ordinance Relating to pollutants in Soil. Ben: Switzerland. Greenpeace Int., (1991-93) Amsterdam: Netherlands.
- International Agency for Research on Cancer [IARC] (1990). Chromium, nickel and welding. IARC Monographs Evaluation on Carcinogenic Risks Human. 49: 1–648.
- Kabala, C; Singh, BR (2006). Distribution and Forms of Cadmium in Soils near a Copper Smelter. *Pol. J. Environ. Stud.* 15(2a): 90-97.
- Kasprzak, KS; Sunderman Jr FW; Salnikow, K (2003). Nickel Carcinogenesis. *Mutat. Res.* 533: 67-97.
- Lenntech, BV (2011). Heavy Metals <http://www.lenntech.com/processes/heavy/heavy-metals/heavy-metals.html>
- Lenntech, WT (2009). Chemical Properties, Health and Environmental Effects of Copper. Lenntech Water Treatment and Purification Holding B.V. www.lenntech.com/periodic/elements/cu.htm.
- Nwoko, CO; Egunjobi, JK (2002). Lead Contamination of Soil and Vegetation in an Abandoned Battery Factory Site in Ibadan, Nigeria. *J. Sustain. Agric. Environ.* 4(1): 91-96.
- Ogundiran, MB; Osibanjo, O (2009). Mobility and speciation of heavy metals in soils impacted by hazardous waste. *Chem. Spec. & Bio.* 21(2):59-69.
- Okoro, AC; Chukwuma, GO; Chukwuma, EC; Nwachukwu, PC; Ezeh, KA (2013). Investigating the Effects of Selected Heavy Metals on Topsoil at the Vicinities of Two Automobile Mechanic Villages, Owerri Municipal, Nigeria. *Int. J. Eng. Sci.* 2(9): 2319 – 1805.
- Onianwa, PC; Fakayode, SO (2000). Lead contamination of topsoil and vegetation in the vicinity of a battery factory in Ibadan. *Environ. Geochem. Heal.* 22: 211-218.
- Oyeleke, PO; Abiodun, OA; Salako, RA; Odeyemi. OE; Abejide, BT (2016). Assessment of some heavy metals in the surrounding soils of an automobile battery factory in Ibadan, Nigeria. *Afr. J. Environ. Sci. Technol.* 10(1): 1-8.
- Pam, AA; Sha'Ato, R; Offem, OJ (2013). Evaluation of heavy metals in soils around automechanic workshop clusters in Gboko and Makurdi, Central

- Nigeria. *J. Environ. Chem Ecotoxi.* 5(11):298-306.
- Patil, P; Sawant, DV; Deshmukh, RN (2012). Physico-chemical parameters for testing of water -a review. *Int. J. Environ. Sci.* 3. 1194-1207.
- Stevens, JJ; Graham, B; Walker, AM; Tchounwou, PB; Rogers, C (2010). The effects of arsenic trioxide on DNA synthesis and genotoxicity in human colon cancer cells. *Int. J. Environ Res Pub. Heal.* 7(5): 2018-2032
- Štofejová, L; Fazekáš, J; Fazekášová, D (2021). Analysis of Heavy Metal Content in Soil and Plants in the Dumping Ground of Magnesite Mining Factory Jelšava-Lubeník (Slovakia). *Sust.* 13: 4508-4517
- World Health Organization [WHO] (2011). WHO Guidelines for drinking water quality, 4th ed. World Health Organization, Geneva. 219-229.
- WHO (2004). The Guidelines for Drinking Water Quality, Third edition. www.who.int/water_sanitation_health/dwq/gdwq3rev.
- WHO (1996). World Health Organization. Guidelines for Drinking-Water Quality. 2nd Edn, Vol. 2, Health Criteria and Supporting Information, WHO, Geneva.
- Yaylali-Abanuz, G (2011). Heavy metal contamination of surface soil around Gebze industrial area, Turkey. *Microchem. J.* 99(1):82-92.