International Journal of Advances in Engineering and Management (IJAEM)
Volume 7, Issue 03 Mar. 2025, pp: 250-263 www.ijaem.net ISSN: 2395-5252

Assessment of Heavy Metals in Soil and Underground Water at Coal Camp Enugu Nigeria

Eze, Kenneth Afamefuna[1], Chukwu Tobechi Emmanuel[2], Udemba Chinenye Margaret[3]

[1] *Department of Chemical Engineering, Enugu State University of Science and Tech., Enugu State.*
[2,3] *Department of Chemical Engineering, Caritas University Amorji-NikeEmene, Enugu State.*

Date of Submission: 10-03-2025 Date of Acceptance: 20-03-2025

ABSTRACT
The investigation was focused on Coal Camp, Enugu, where the heavy metal concentrations in the soil and subsurface water were created by auto-mechanic activities. There was an analysis of soil and subterranean water samples from five local auto repair companies for certain heavy metals, including lead, cadmium, and chromium. We took three separate soil samples at different depths: 0–15, 15–30, and 30-45 cm. At five different locations around the region, water samples were taken from wells that had been cut. Using an atomic absorption spectrophotometer (AAS), the amounts of heavy metals were ascertained after the samples underwent conventional wet digestion. Typical concentrations of lead (Pb), cadmium (Cd), and chromium (Cr) in soil samples were between 0.2 and 90.0 mg/kg, 0.02 and 0.07 mg/kg, and 0.01 and 0.06 mg/kg, respectively. Comparison of these numbers with the control group's data made the pollution of these soils quite clear. While lead and cadmium were both below the detection limit in all samples, with less than 90.0 and 0.07 mg/kg, respectively, Cr was also below the limit. A pattern of increasing concentration for heavy metals was observed, with Pb>Cd>Cr. All the heavy metal values in the groundwater samples fell below the World Health Organization's drinking water threshold, except for Cd, which exceeded the limit in sample D. The temperature and pH ranges for groundwater were 23 to 29 °C, 7.79 to 8.28, 4.6 to 5.7 N.T.U., and 313 to 987 µs/cm, respectively, according to the results of the physicochemical parameters. Consequently, the study suggests moving the car market and implementing remediation strategies like phyto-remediation at coal camps, as well as enforcing other environmental protection legislation, to stop the buildup of toxic metals there..

Keywords: Heavy metals,Coal Camp, Enugu, soil, water, Assessment

I. INTRODUCTION

The poisoning of soil and groundwater with heavy metals is an increasingly common problem in the nation and around the globe. The world's increasing reliance on petroleum products as an energy source, together with factors like industrialization, fast population increase, and total disregard for environmental health, likely contribute to this.

When the atomic density of a metal or metalloid is more than 5.0 g/cm3, we say that it is a heavy metal (Duffus, 2002). Soils, rocks, water (both below and on the surface), and sediments all contain these elements naturally, but to varying degrees (Hutton and Symon, 1986). Because they do not break down in the body, heavy metals pollute our surface water and soil and can have devastating impacts on human health, with symptoms varying according to the metal and the amount consumed. The in decomposability of heavy metals is the root cause of their toxicity. Lead, chromium, cadmium, nickel, zinc, mercury, and copper are the most prevalent heavy metals discovered in polluted areas. Heavy metals are an ill-defined class of inorganic chemical dangers.

Southern Enugu is home to a 2-kilometer-long industrial market, also referred to as "coal camp" due to the fact that many small and medium-sized businesses (SMES) are located in the same areas where early coal miners first settled. Activities found in the coal camp area include foundry work, fabrication of motor parts, smelting

International Journal of Advances in Engineering and Management (IJAEM)
Volume 7, Issue 03 Mar. 2025, pp: 250-263 www.ijaem.net ISSN: 2395-5252

and fabrication of aluminum, woodworking and bricklaying, automobile mechanics, blacksmithing, and many more. The coal camp environment is also littered with dealers of various machines, spare parts, food, and household effects. Scientists have proven that the local industrial market is a major pollutant in the city's water supply, both beneath and on the surface(Chima, et al. 2009, Ekere, 2011).

When the concentrations of heavy metals in soils exceed the safe limits, this is known as heavy metal pollution and could have negative effects on local ecosystems. According to (Gazso, 2001), heavy metals can be found in nature, but they are mainly caused by human activities. These include mining for coal and metal ore, making chemicals, extracting and refining petroleum, generating electricity, smelting and refining metals, plating metal, and, to a lesser degree, domestic sewage. Heavy metals like copper, nickel, and zinc are necessary for life at extremely low quantities because they are used in enzymes, structural proteins, pigments, and cellular ionic equilibrium maintenance (Kosolapov et al., 2004). A lack of these or other trace elements, which are critical for healthy biological systems, can cause a variety of diseases. Pollution of water, soil, and air with heavy metals has the ability to build up in bio systems, making food chain pollution a major concern.

Metal pollution is an ongoing issue at many polluted sites; the chemical form of the metal determines its solubility, toxicity, and movement in subterranean water systems. Metal waste's origin, as well as the site's soil and groundwater chemistry, determine the metals' chemical form. Coal camp Enugu is both a mechanic village and a residential area; however, there is no research on this topic despite a dearth of studies on other Nigerian mechanic villages, such as Akure, Iwo, Port Harcourt, and places in the Imo river basin (Nwachukwu et al., 2010; Ilemobayo and Kolade, 2008; Ipeaiyeda and Dawodu, 2008; Iwegbue, 2007; Abidemi, 2011).

II. MATERIALS AND METHODS

Research Area

60°21′E and 70°30′E are the coordinates of Enugu State. Situated in southeastern Nigeria, Enugu serves as the capital of Enugu State. In 2006, according to the census (NPC, 2006), the population was 722,000. Humid tropical conditions Characterize Enugu urban, where rainforest savanna flora grows and where monthly temperatures range from 27 to 290 degrees Celsius average. Producing goods, fixing vehicles, dealing with metal, selling technical materials, and selling car parts are the key operations. Businesses often employ around five people, however the relatively more sophisticated manufacturing workshop has between 7 and 10 workers.

Figure 1 Map of Enugu showing the study area; Coal Camp

Soil Sampling

Five auto-mechanic workshops spread over coal camp were randomly selected for investigation. The WHO standard is used as a control. Soil samples were obtained in triplicates at each site at depths of 0 to 15; 15 to 30 and 30 to 45 cm using a depth calibrated soil auger. Each sample was placed into a well labelled fresh plastic bag and tightly sealed. All the samples were transported to the laboratory where on arrival, analytical procedure commenced in earnest.

Determination of ConcentrationPb, Cd,& Cr in the Soil.

Iwegbue (2007) outlined the procedure used to calculate the total metals in the soil, which

International Journal of Advances in Engineering and Management (IJAEM)
Volume 7, Issue 03 Mar. 2025, pp: 250-263 www.ijaem.net ISSN: 2395-5252

are listed above. In an open container, the soil was digested using nitric acid and 30% hydrogen peroxide. A 100 cm3 pyrex beaker was filled with 1g of soil sample, 10 cm3 of 1+ 1 nitric acid solution, and a watch glass. The beaker was then covered and heated on a steam bath to 99^0C. After one hour of digestion at 99^0C, the sample was released. The next step was to take the sample out and let it cool for twenty-five minutes. After heating the sample to 99^0C, 3 cm3 of 30% hydrogen peroxide was added to it. Hydrogen peroxide was added in increments of 10cm3 and heated until no further reaction was observed; no more than 10cm3 of peroxide was utilized. The slurry was heated for 15 minutes after adding 5 milliliters of concentrated hydrochloric acid. After removing the sample, it was given time to cool. Finally, 50 cm3 of de-ionized water was added to the cooled solution, and it was filtered through Whatman 41 filter paper to remove insoluble particles. Subsequently, the buck scientific 210 VGP Atomic Absorption Spectrophotometer was used to determine the heavy metals.

Water Sampling and Analysis.

Sampling and analysis were done following the method of (Ekere 2011).

A total of 5 samples from each water source were collected from the sampling site. The control (background) samples were obtained from World Health Organization (WHO 2008) standards. Water samples were collected using sterilized 1.5L plastic bottles. All samples were placed in an 'ice chest' in ice packs and transported to the laboratory. To every 1.5L of sample for metal analysis, 5 ml of Conc. HNO_3 was added. This treatment was used to minimize adsorption of metals on the container walls. All the wells were between 3 and 15 meters in depth. The environmental sanitation condition and the human activities around the water sources were noted.

DETERMINATION OF SOME PHYSICO-CHEMICALPROPERTIES OF THE WATER SAMPLES.

Determination of temperature.

The temperature was determined with a thermometer at room temperature (AOAC, 1990)

Determination of Turbidity.

The turbidity was determined photo electrically using photometer 7000 (AOAC, 1990).

Determination of Conductivity.

The conductivity of water was determined with a conductivity meter Model720 (AOAC,1990)

Determination of PH.

PH of water was determined with a pH meter Model Digital pH meter335 (AOAC, 1990).

III. RESULT AND DISCUSSION

Results

3.1 Physicochemical Parameters

Table 3.1Physio-chemical parameters of ground water samples

Ground water Sample	Conductivity (µS/cm)	Turbidity (NTU)	pH	Temperature ^{0}C
A	566	5.5	7.84	23
B	412	4.8	8.15	26
C	313	5.0	7.79	25
D	987	5.7	8.28	29
E	772	4.6	8.20	24

International Journal of Advances in Engineering and Management (IJAEM)
Volume 7, Issue 03 Mar. 2025, pp: 250-263 www.ijaem.net ISSN: 2395-5252

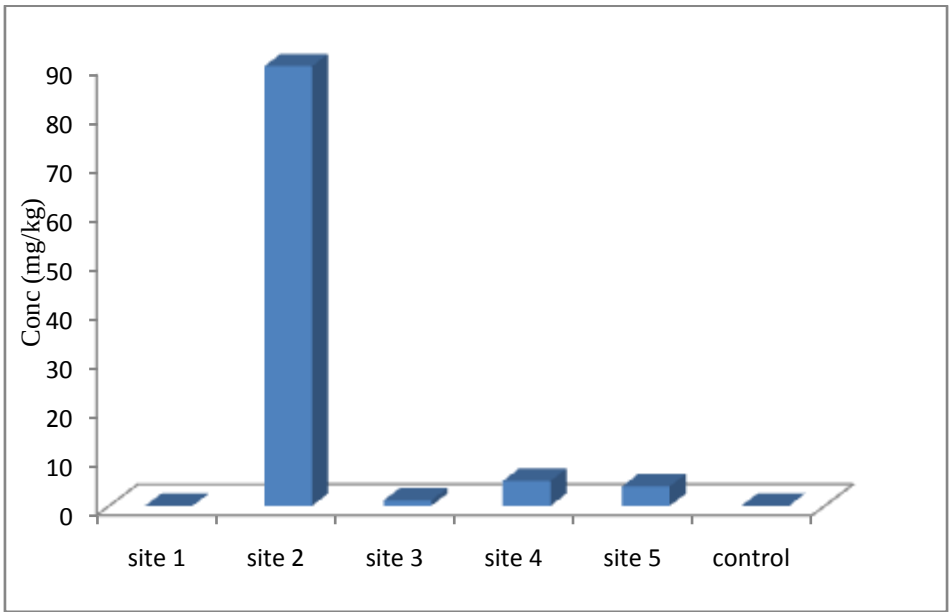

Fig 3.1 A plot of Pb concentration vs sample site at 0 - 15 cm depth

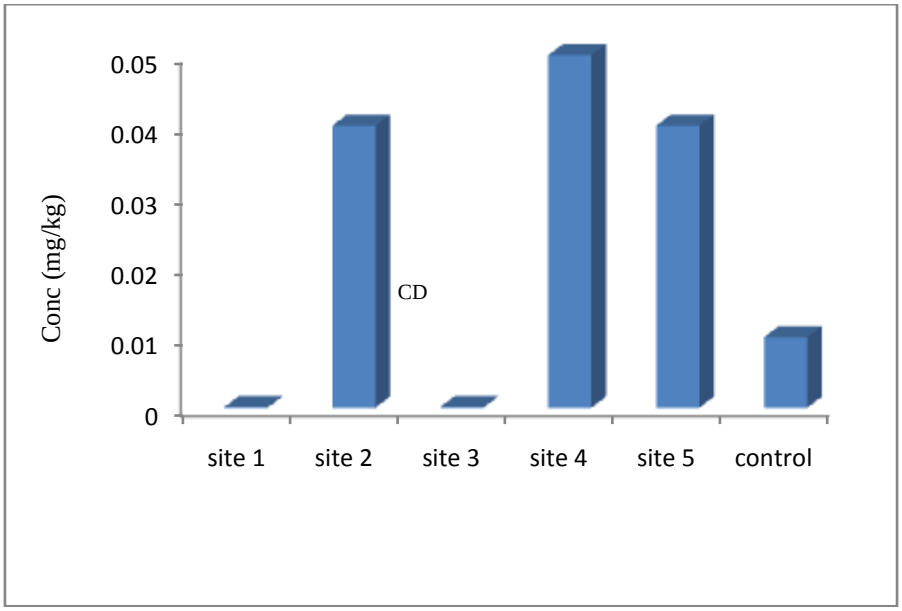

Fig 3.2 A plot of concentration vs sample site at 0 - 15 cm depth

International Journal of Advances in Engineering and Management (IJAEM)
Volume 7, Issue 03 Mar. 2025, pp: 250-263 www.ijaem.net ISSN: 2395-5252

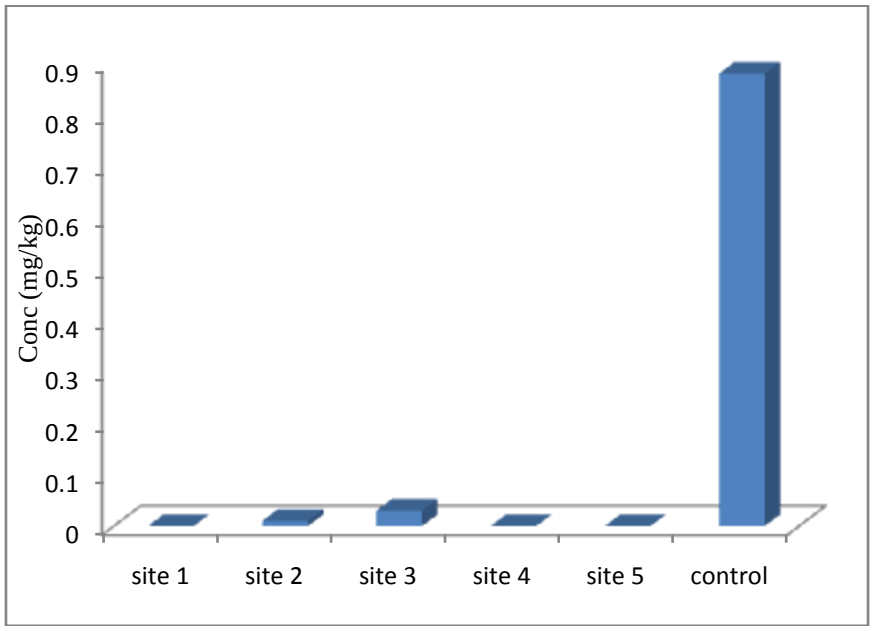

Fig 3.3 A plot of concentrationvs sample site at 0 - 15 cm depth

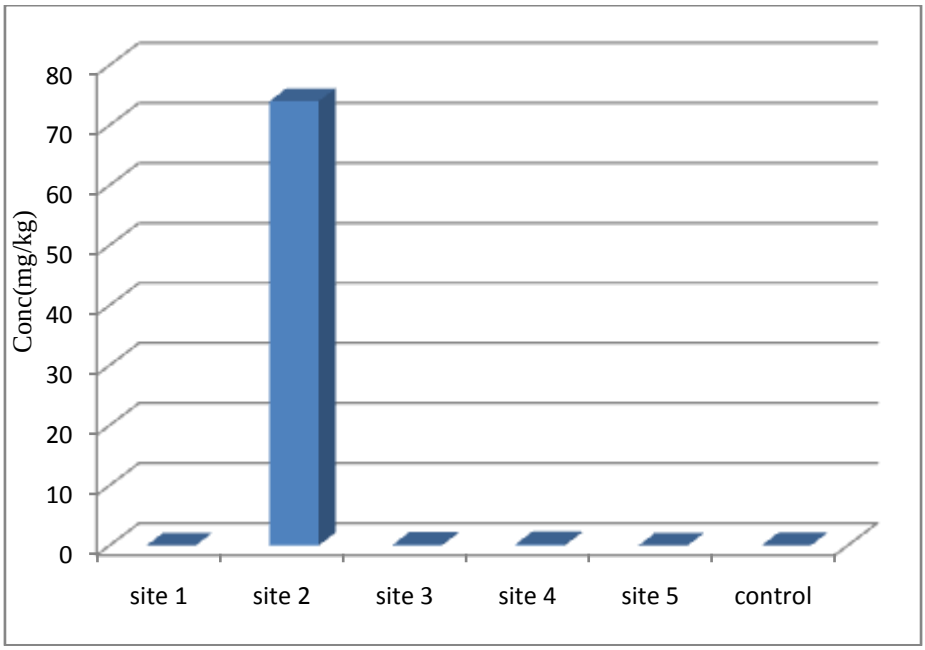

Fig 3.4 A plot of Pb concentrationvs sample site at 15 - 30 cm depth

International Journal of Advances in Engineering and Management (IJAEM)
Volume 7, Issue 03 Mar. 2025, pp: 250-263 www.ijaem.net ISSN: 2395-5252

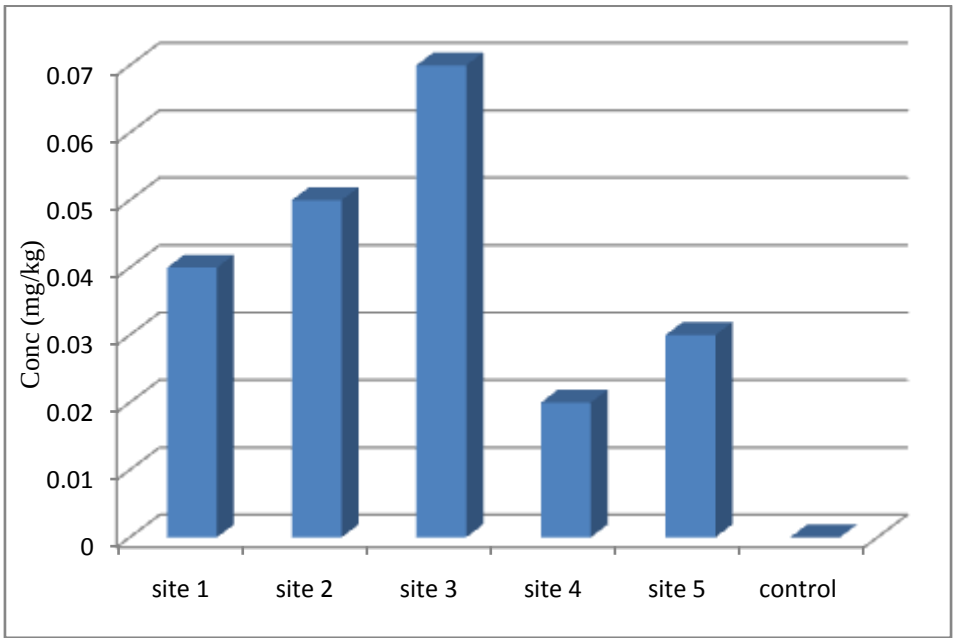

Fig 3.5 A plot of concentrationvs sample site at 15 – 30 cm depth

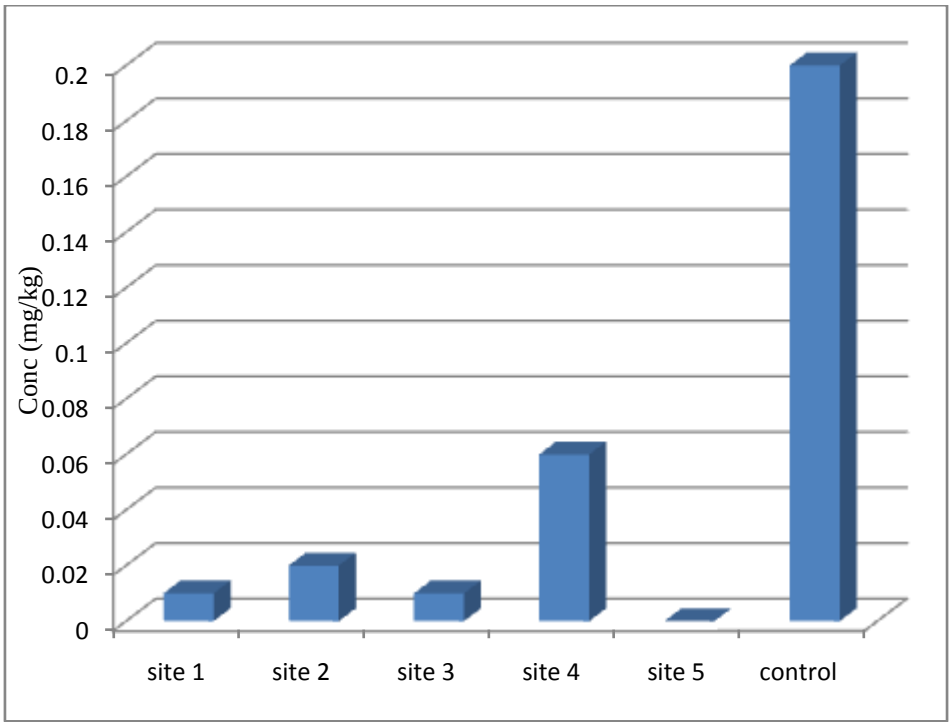

Fig 3.6 A plot of Cr concentrationvs sample site at 15 – 30 cm depth

International Journal of Advances in Engineering and Management (IJAEM)
Volume 7, Issue 03 Mar. 2025, pp: 250-263 www.ijaem.net ISSN: 2395-5252

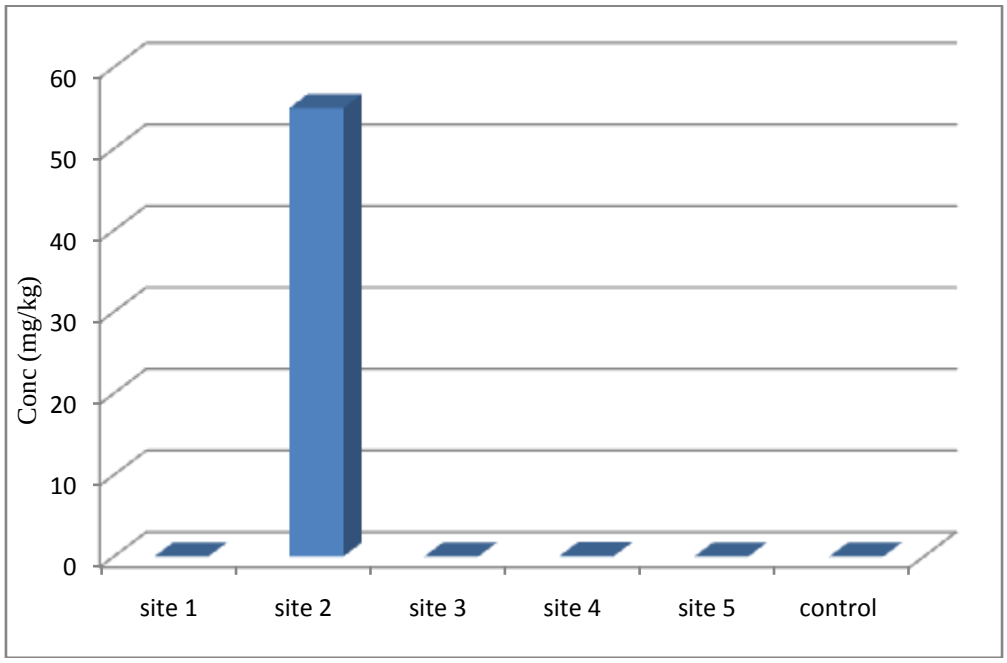

Fig 3.7 A plot of Pb concentrationvs sample site at 30 -45 cm depth

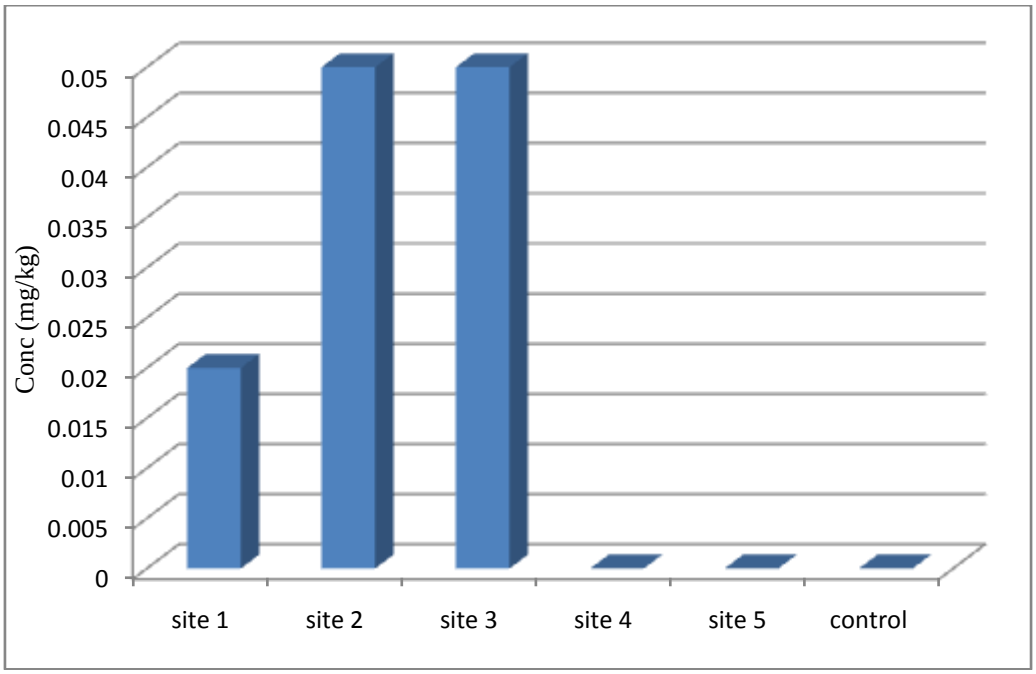

Fig 3.8 A plot of concentration vs sample site at 30 -45 cm depth

International Journal of Advances in Engineering and Management (IJAEM)
Volume 7, Issue 03 Mar. 2025, pp: 250-263 www.ijaem.net ISSN: 2395-5252

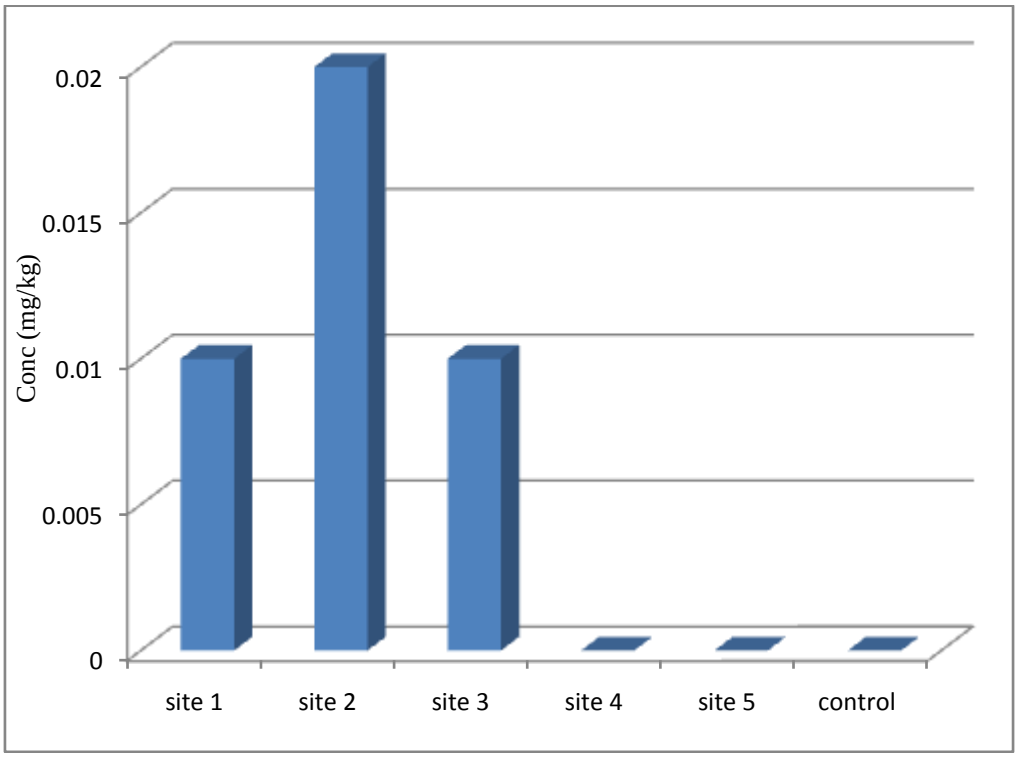

Fig 3.9 A plot of Cr concentrationvs sample site at 30 – 45 cm depth

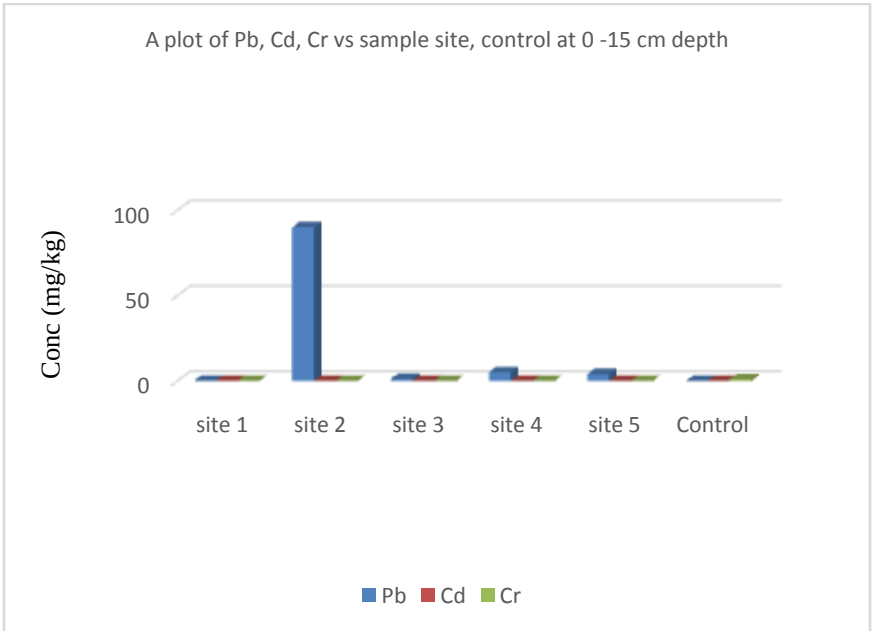

Fig 3.10A plot of Pb, concentration, Cr vs sample site, control at 0 -15 cm depth

International Journal of Advances in Engineering and Management (IJAEM)
Volume 7, Issue 03 Mar. 2025, pp: 250-263 www.ijaem.net ISSN: 2395-5252

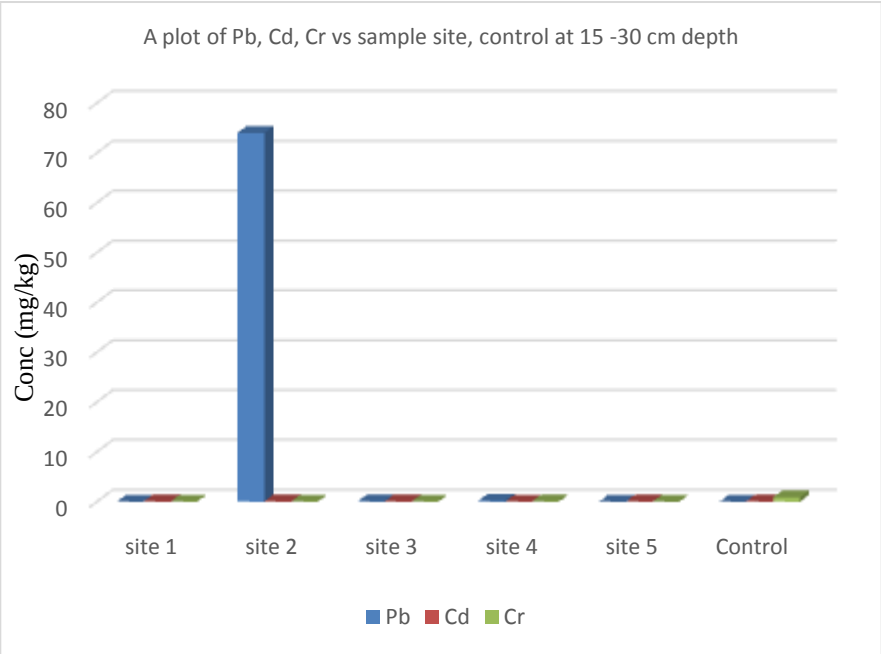

Fig 3.11A plot of Pb, concentration, Cr vs sample site, control at 15 -30 cm depth

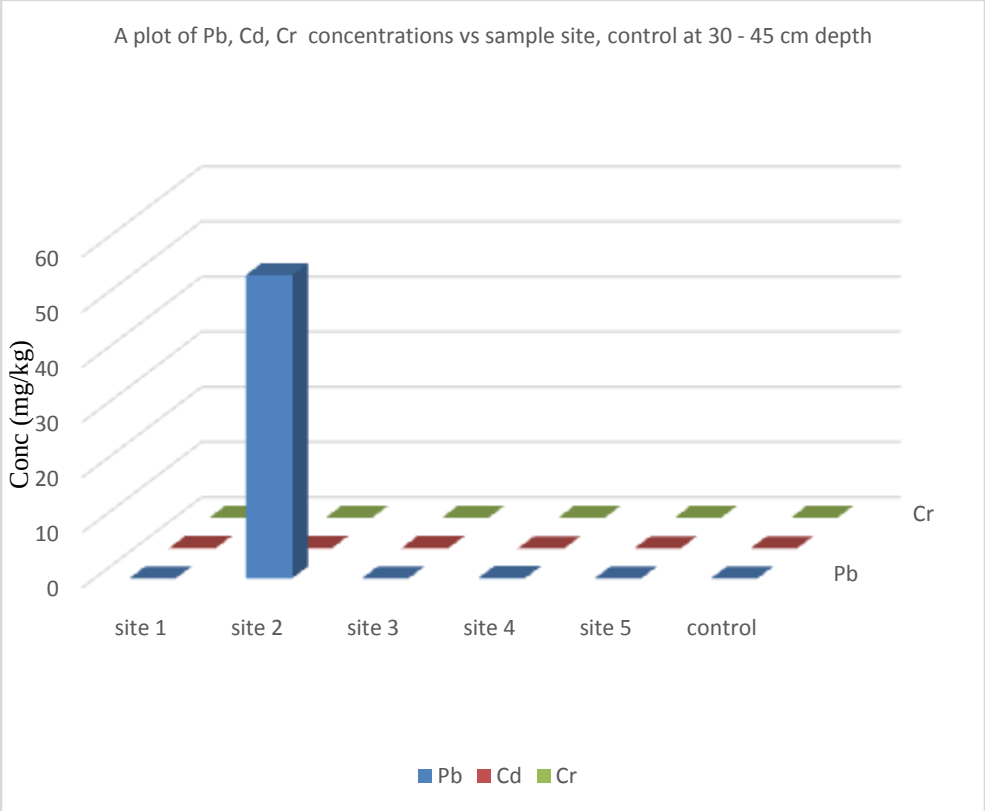

Fig3.12. A plot of Pb, Cd, Cr vs sample site, control at 30 – 45 cm depth

International Journal of Advances in Engineering and Management (IJAEM)
Volume 7, Issue 03 Mar. 2025, pp: 250-263 www.ijaem.net ISSN: 2395-5252

Graphical representation of Table 4.2

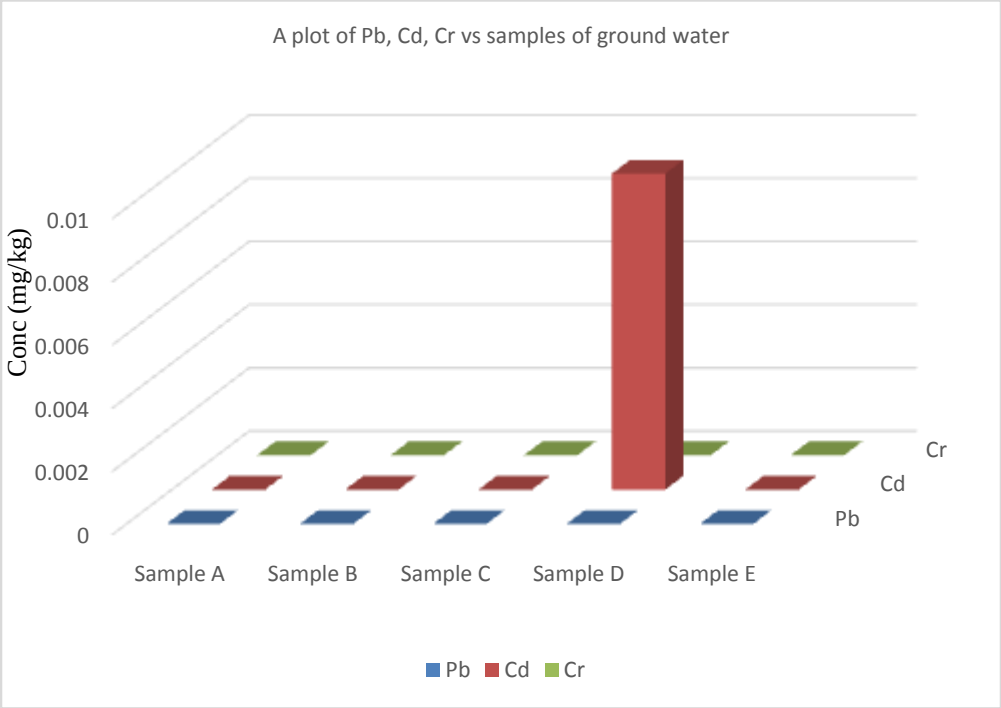

Fig 4.13 A plot of Pb, concentration, Cr vs samples of ground water

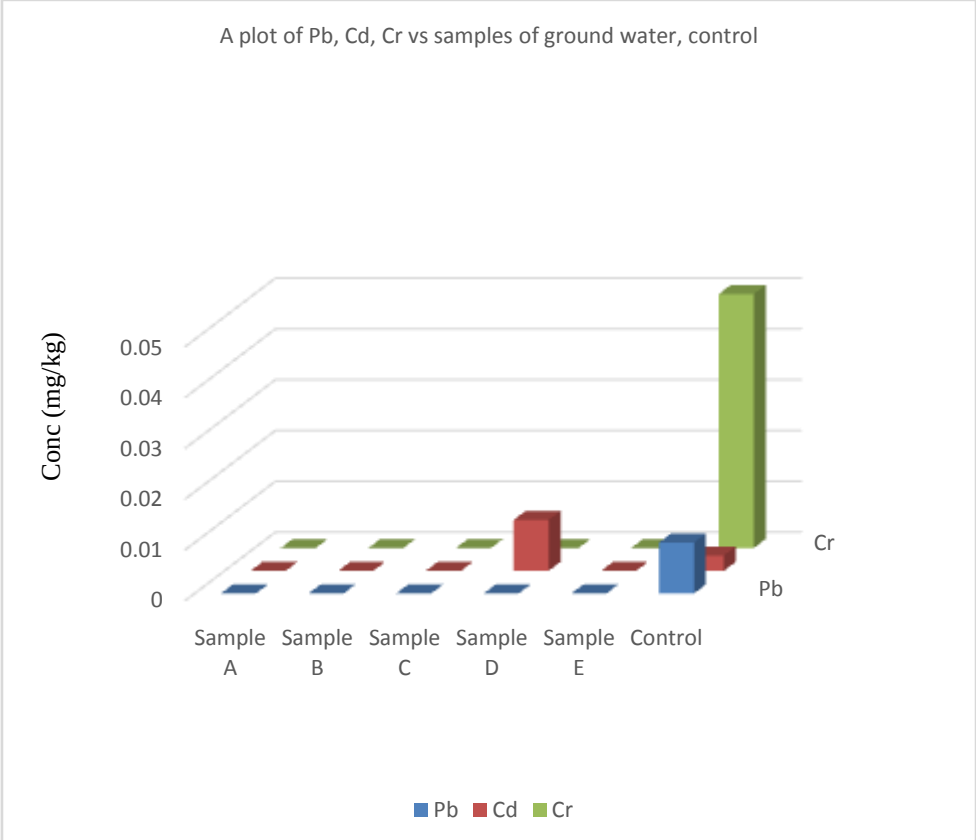

Fig 3.14A plot of Pb, concentration, Cr vs samples of ground water, control

International Journal of Advances in Engineering and Management (IJAEM)
Volume 7, Issue 03 Mar. 2025, pp: 250-263 www.ijaem.net ISSN: 2395-5252

IV. DISCUSSION OF RESULT

Fig.3.1-3.9 represent the heavy metal (mg/kg) in the soil samples after digestion. Lead concentrations in this study exceeded the WHO standard for the maximum permissible limit of Lead (Pb) in the soil althoughthey were lower than those reported in other studies by Adekunle and Abegunde (2011) from some mechanic villages in Ibadan. This may be due to lower amount of used automobile batteries - which are source of lead. 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 243-126,000 mg/kg 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. Elevated levels of lead in soils give environmental and health concern. An example is the reported case of 10,000 mg/kg found in top-soils in a village in Zamfara State, Nigeria (Purefoy, 2010). Elevated Pb values are due to on-going lead deposition in soils within the mechanic villages and its consequent retention in the soil upper layers. This is much more obvious when the Pb values are compared to those of the control site and this provides further evidence that Pb is gradually building up in the soil at coal camp as shown in Fig 3.10, and Fig 3.11.

Cadmium was detected in all the soils samples with concentration higher than the concentration in the control (WHO set limits of 0.01 mg/kg). According to (Jarup, 2003; Ebong, et al., 2008) the presence of Cadmium could be due to the dumping of PVC plastics, nickel-cadmium batteries, motor oil and disposal sludge in the auto-mechanic village. The presence of cadmium in automobile waste dump soils have also been reported by (Uba, et al., 2007) and (Myung, 2008).

Chromium was detected in most of the sampled soils for all sites and the level was below the control (WHO) limits for heavy metals in the soils. It is one of those heavy metals whose environmental concentration is steadily increasing due to industrial growth, especially the development of metal, chemical and tanning industries. Other sources through which chromium enters the environment are air and water erosion of rocks, power plants, liquid fuels, brown and hard coal, and industrial and municipal waste. Although there is no risk of chromium contamination on a global scale, local permeation of the metal to soil, water or the atmosphere might result in excessive amounts of this pollutant in biogeochemical circulation (Wyszkowska, 2002). As observed by (Ghosh and Singh, 2005) the non-biodegradability of chromium is responsible for its persistence in the environment; once mixed in soil, it undergoes transformation into various mobile forms before ending into the environmental sink (Bartlett and James, 1983). Although Cr toxicity in the environment is relatively rare, it still presents some risks to human health since chromium can be accumulated on skin, lungs, muscles fat, and it accumulates in liver, dorsal spine, hair, nails and placenta where it is traceable to various heath conditions (Reyes-Gutiérrez et al., 2007).

In other words, according to hierarchy of prevalence, Lead (Pb) is the most prevailing heavy metal followed by Cadmium (Cd) then Chromium (Cr) in the soil.

Table 3.1 show the physico-chemical properties of ground water samples.This study has shown that the temperature of all water samples from different sites, ranged from 23 to 29 ˚C. The temperature range were lower than the values observed by (Oni, 2000): (28 to 30°C and 27 to 30°C) of groundwater at Ibadan. Temperature of drinking water is often not of a major concern to consumers as it depends on individual taste and preference. It is noted that high water temperature enhances the growth of microorganisms and may increase taste, odor, color and corrosion problems.pH levels of all the water samples within the Coal Camp area were in the neutral region between 7.79 to 8.28 (Table 3.1). These pH values were in the range of the WHO standard for drinking water (6.5-8.5) (WHO 2008) thereby making it fit for drinking. Conductivity levels of the water samples in the study sites varied from 313 to 987 µS/cm. Conductivity levels were relatively low compared to WHO guideline limit of 1500 µS/cm. However, it is evident that, there is an influence from anthropogenic sources despite the low conductivity levels in the water samples (Ullah, et al., 2009; Nkansah, et al., 2011; Adefemi and Awokuni, 2010). An oil spill does not conduct electrical current very well, thus have a low conductivity when in water (USEPA, 2012).The turbidity of all water samples were within the WHO standard (5 NTU).

Fig 3.13 shows a plot of the heavy metals (Pb, Cd, and Cr) concentration in the ground water at different sites, having sample A – E. The figure shows the level of these heavy metals in ground water. While Fig 3.14 shows a plot of the heavy

metals (Pb, Cd, and Cr) concentration against the samples and control (WHO standards). It is obvious from the figure that the concentration of the heavy metals in ground water is below the WHO standard of maximum permissible concentration in water, except for Cd whose concentration is higher than the limit.

V. CONCLUSION

It was found that Pb has the highest concentrations in the soil samples while Cr has the least and the order observed for this study is Pb> Cd> Cr. The concentrations of Pb in soil as obtained in the study were higher than the values obtained by (Ilemobayo and Kolade, 2008), (Ipeayeida and Dawodu, 2008) and (Nwachukwu et al., 2010) in other auto-mechanic locations. The values of Pb obtained from this study were above the WHO permissible level for soils. Similarly, watersamples analyzed met the WHO (1993, 1996, and 2004) guideline values set for Pb, Cr, but exceeded the limit for Cd. The result of four physico-chemical parameters (Temperature, pH, Conductivity and Turbidity) of water show that pH of all the water samples was within the permissible limits set by WHO, whereas the values of electrical conductivity of all the collected water samples were relatively low compared to WHO guideline limit of 1500 µS/cm and the turbidity of all water samples were within the WHO standard.

REFERENCES

[1]. Abidemi, O. O. (2011). Levels of Pb, Fe, Cd and Co in Soils of Automobile Workshop in Osun State, Nigeria. J. Appl. Sci. Environ. Manage. 15 (2) 279 – 282.

[2]. Adefemi, S. O. and Awokunmi, E. E. (2010). Determination of physico-chemical parameters and heavy metals in water samples from Itaogbolu area of Ondo-State, Nigeria. African Journal of Environmental Science and Technology. http://www.academicjournals.org/ AJEST, 4(3):145-148.

[3]. Adepouju-Bello, A. A., and Alabi, O .M. (2005). Heavy Metals: A review. The Nig. J. Pharm., 37:41-45.

[4]. Adie G. U, and Osibanjo O (2009). Assessment of soil pollution by slag froman automobile battery manufacturing plant in Nigeria. Afr. J. Environ. Sci. Technol., 3(9): 239-250.

[5]. AOAC, (1990)Association of Analytical chemists. Official methods of Analysis. Helrich K. (Ed.). 15th ed. Inc.USA P777.

[6]. Bartlett R.J,and James B (1983). Behavior of Chromium in Soils: VII. Adsorption and Reduction of Hexavalent Forms. J. Environ. Qual., 12 (2): 177-181.

[7]. Begum A, Ramaiah M, Harikrishna, Khan I, Veena K (2009). Analysis of Heavy Metals Concentration in Soil and Litchens from Various Localities of Hosur Road, Bangalore, India. E-J. Chem., http://www.e-journals.net. 6(1): 13-22.

[8]. Chima, G.N., Ogbonna, C.E, Nwankwo, I.U (2009). Effects of urban wastes on the quality of Asata River in Enugu, South Eastern Nigeria. Global J. Environ. Sci. 8(1):31-39.

[9]. Duffus, J.H (2002) "Heavy Metals-A Meaningless Term". Pure and Applied Chemistry 74:793 -807.

[10]. Ekere, N.R (2011). Heavy metals contamination of Ground water in Industrial areas of Enugu Nigeria J. Appl. Sci. 14(1):9535-9542.

[11]. Ebong, G.A., Akpan, M.M. and Mkpene, V.N (2008). Heavy metal content of municipal and rural dumpsite soils and rate of accumulation by Carica papaya and Talinumtriangulare in Uyo Nigeria. E-Journal of Chemistry, 5(2): 281-290.

[12]. Gazso, L.G (2001). The Key Microbial Processes in the Removal of Toxic Metals and Radionuclides from the Environment. A review. Cent. Eur. J. Occup. Environ. Med., 7(3): 178–185.

[13]. Gosh, M. and Singh, S.P. (2005). "A review on phytoremediation of heavy metals, and utilization of it's by- products. Applied Biology and Environmental Research, 3 (1) 1-18.

[14]. Hutton M, Symon C (1986). The Quantities of Cadmium, Lead, Mercury and arsenic entering the UK. Environment from human activities. Science of the Total Environment, 57:129 - 150.

[15]. Ilemobayo O and Kolade I (2008). Profile of Heavy Metals from Automobile Workshops in Akure, Nigeria. J. Environ. Sci. Technol., 1: 19-26.

[16]. Ipeaiyeda AR, Dawodu M (2008). Heavy Metals Contamination of Topsoil and Dispersion in the Vicinities of Reclaimed Auto-repair Workshops in Iwo Nigeria. Bull. Chem. Soc. Ethiopia, 22(3): 339-348.

[17]. Iwegbue CM (2007). Metal Fractionation in Soil Profiles at Automobile Mechanic

Waste Dumps around Port Harcourt. Waste Manage. Res., 25(6): 585-593.

[18]. Jarup, L. (2003). Toxicity of heavy metals and sources in the environment. British MedicalBulletin 68: 167 – 182.

[19]. Kosolapov, D, Kuschk, P., Vainshtein, M; Vatsourina, G.A.V; Wiebner A; Kaestner, M and Ano Muller, R (2004). search yet. Microbial Processes of Heavy Metal Removal from Carbon-Deficient Effluents in Constructed Wetlands. Engineering in Life Sciences. 4(5), Pp403-410

[20]. Myung, C.J.(2008). Heavy metal concentrations insoils and factors affecting metal uptake by plants in the vicinity of a Korean, CU-W Mine. Sensors 8, 2413-2423.

[21]. Nkansah, M.A., Ofosuah J., and Boakye, S. (2011) Quality of Groundwater in the Kwahu West District of Ghana. Environmental Research Journal 5(2): 31-37.

[22]. Nwachukwu MA, Feng H, Achilike K (2010). Integrated Study for Automobile Wastes Management and Environmentally Friendly Mechanic Villages in the Imo River Basin, Nigeria. Afr. J. Environ. Sci. Technol., Available online at www.academicjournals.org/AJEST. 4(4): 234-249,

[23]. Nwoko, C. O., Egunjobi, J. K. (2002). Lead Contamination of Soil and Vegetation in an Abandoned Battering Factory Site in Ibadan, Nigeria. J. Sustain. Agric. Environ. 4(1): 91-96.

[24]. Ogunlaja, A, and Ogunlaja O.O. (2007). Physico-chemical Analysis of Water Sources in Ubeji Community and their Histological Impact on Organs of Albino Rats. Journal of Applied Sciences and Environmental Management 11(4):91-94.

[25]. Onianwa PC, Jaiyeola OM, Egekenze RN (2002). Heavy MetalContamination of Topsoil in the Vicinities of Auto-repair Workshops, Gas stations and Motor parks in a Nigerian city. J. Toxicol. Environ. Chem., 84(1-4): 33-39.

[26]. Oni AA (2000). Macrofaunal Diversity and Impact of Leechate from Landfills on Ground and Surface Waters in Three Locations in Ibadan. Unpublished M.Sc Thesis. p.113.

[27]. Purefoy C (2010). Lead clean-up in Nigerian Village is Life-or-Death Raceagainst Time. Cable News Network.

[28]. Reyes-Gutiérrez LR, Romero-Guzmán ET, Cabral-Prieto A, Rodríguez- Castillo R (2007). Characterization of Chromium in Contaminated SoilStudied by SEM, EDS, XRD and Mössbauer Spectroscopy. J. Miner. Mater. Characterization Eng., 7(1): 59-70.

[29]. Uba, S., Uzairu, A., Harrison, G.F.S., Balarabe, M.L.andOkunola, O.J. (2008). Assessment of heavy metals bioavailability in dumpsites of Zaria metropolis, Nigeria. African Journal of Biotechnology, 7(2): 122-130.

[30]. Ullah, R., Naseem, R., Qadir, A. (2009). Assessment of groundwater contamination in an industrial city,Siakolt,Pakistan.Afr.J.Environ.Sci.Technol.http://www.academicjournals.org/AJEST. 3(12):429-446.

[31]. United States Environmental Protection Agency (USEPA) (2012). Drinking Water from Household Wells. http//www.epa.gov/safewater/drinklink.html.

[32]. USGS (2009). What is Groundwater? U .S Geological Survey Open File Report. http:// pubs.water.usgs.gov/ofr93643. 93-643

[33]. U.S.G.A.O. (2000). Health Effects of Lead in Drinking Water: U.S. General Accounting Office Reports 2000.

[34]. Vanloon, G. W., Duffy, S. J. (2005). The Hydrosphere: In Environmental Chemistry: A Global Perspective. 2nd Edition. New York: Oxford University Press, 197-211.

[35]. World Health Organization, WHO (2004). The Guidelines for Drinking Water Quality, Third edition. www.who.int/water_sanitation_health/dwq/gdwq3rev.

[36]. World Health Organization, WHO (1993). World Health Organization. Guidelines for Drinking-Water Quality. 2nd Edn, Vol. 1, Recommendations, WHO, Geneva.

[37]. World Health Organization, WHO (1996). World Health Organization. Guidelines for Drinking-Water Quality. 2nd Edn, Vol. 2, Health Criteria and Supporting Information, WHO, Geneva.

[38]. WHO (2008). Guidelines for drinking water quality, World health organization, Geneva.GhanaDistricts.com, http://www.ghanadistricts.com/region/?r=2 assessed on March 21, 2016.

[39]. WHO (2012). Water, Sanitation and Health**.** World Health Organization, Geneva.
[40]. Wyszkowska J (2008). Soil Contamination by Chromium and itsEnzymatic Activity and Yielding. Polish J. Environ. Stud., 11(1): 79- 84.