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Analysis of heavy metal concentration in auto-mechanic dumpsites in Makurdi Metropolis, North Central Nigeria

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This research was carried out to assess heavy metals pollution in Makurdi auto-mechanic dumpsites in Kanshio (K), Northbank (NB) and Wadata (W). Atomic absorption spectrophotometer (PG990) was used to determine the heavy metals concentration. Results of the mean heavy metals concentrations (Cd, Cu, Pb and Zn) were found to be K (4.65, 137.12, 257.77 and 294.75), NB (1.97, 65.67, 162.88 and 223.23), and W (2.92, 85.27, 187.20 and 262.00 mg/kg), respectively, they were higher than their referenced maximum permissible level in the soil when compared to World Health Organization (WHO), United States Environmental Protection Agency (USEPA), Mean Shale Concentration (MSC) and World Surface Rock Average (WSRA) guidelines, indicating high level pollution. The high level of Cu, Pb and Zn, may be due to waste from welding activities, lead (Pb) battery repairs and coatings done in these area. The geo-accumulation index for Cd and Pb for the three dumpsites was found to exhibit moderately to strongly polluted character with values within 2-3, while Cu and Zn were from uncontaminated to moderately contaminated with values < 1. The contamination factor for Cd and Pb was found to be of very high contamination, while Cu and Zn were found to be in moderate contamination. The pollution load index for the three dumpsites were found to be highly polluted with values >1.

Key words: Heavy metals, auto-mechanic dumpsite, geo-accumulation index, contamination factor and pollution load index.

INTRODUCTION

Recently, the interests of researchers regarding heavy metals contamination in the environment have been on the increase, this may be due to their toxicity and persistence within the environment. Amo-Asare (2012)

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defined heavy metals as metals which have their densities five times higher than that of water and are poisonous at low concentrations even as elements having atomic number more than 20 or their densities more than 5 g/cm^3. One major source that increases heavy metal concentration in the ecosystems in Nigeria is the auto mechanic activities (Adewole and Uchegbu, 2010). These auto mechanic workshops are found in open plots of land in towns or cities (Nwachukwu et al., 2010, 2011). Within these workshops are people that specialize in electrical aspect of auto repairs, others engage in repairs of brakes and steering, automatic or standard transmission engine, spray painting, recharging of auto batteries, welding and soldering. Each of these activities generates various types of waste (gasoline, diesel, spent engine oil and paint) which are disposed by simply dumping in the surrounding areas. Heavy metals in these wastes includes; cadmium (Cd), nickel (Ni), copper (Cu), lead (Pb), arsenic (As), chromium (Cr), tin (Sn), zinc (Zn) and so on which ends up in the environment (Yahaya et al., 2009). Heavy metals are serious pollutants because of their toxicity, persistence and non-degradability in the environment. The increasing pollution of heavy metals in the environment has become a global phenomenon (Malik et al., 2010; Linnik and Zubenko, 2000). Heavy metals can bio-accumulate and bio-magnify via the food which are assimilated by humans resulting in adverse health effects. Some common health effects associated with heavy metal poisoning includes; kidney damage, blindness and breathing related problems (Agah et al., 2009). Pollution effects of mechanic site activities in Nigeria has received limited attention in the time past even though these activities have shown to produce harmful wastes. Therefore, there is need to continually monitor their nature, volume, direct harmful effects, current methods of disposal as well as potential impacts on the inhabitants of the environment. The objective of this research is to determine the concentration of Heavy metals in the soil from three auto-mechanic dumpsites, to assessed the site contamination using the criteria of Geo-accumulation index (I_{geo}), Contamination factor (CF), Pollution load index (PLI) and to compare their concentrations with world referenced standard upon which decisions about the site quality will be made.

MATERIALS AND METHODS

Study area description

Makurdi is the capital city of Benue State, North Central Nigeria. The city is located along the Benue River bank on latitude 7.44°N and longitude 8.32°E, situated in the Benue valley 100 m above sea level as shown in Figure 1. As at 2007, Makurdi had an estimated population of 500,791 people with a total land area of about 820 km^2. Human activity in Makurdi metropolis include irrigational farming, extraction of sharp sand for building, fishing activity, market activity and auto-mechanic workshops which serves as one of the point sources of heavy metals in Makurdi (Adamu et al., 2003). Three sampling sites were identified within Makurdi town namely: Kanshio Auto-Mechanic dumpsite, an area well known for repairing and maintaining automobiles with a large clientele. It is located along Makurdi-Otukpo road opposite the National Open University, Makurdi. The second sampling site selected for the study was the Wadata new garage dumpsite, which is famous for repairs of motor body parts as well as mechanical and electrical motor repairs. The third sampling site was the North Bank area.

Sample preparation and digestion

The samples were collected at three different sites in Makurdi (Kanshio, North bank and Wadata), in uniform depth of between 5.5 and 10 cm in triplicates. Method of preparation used was adopted from Okereke et al. (2019). The soil samples were air-dried in the laboratory for four days and transferred to an oven for complete dryness. After drying, the samples were sieved using 0.5 mm particle size mesh, in order to obtain fine particles. The sieved soil was properly grounded using an agate mortar to enhance oxidation of the soil samples. After which, 2 g of the finely ground soil was accurately weighed, then transferred to a beaker and 30ml of the acid mixture (4 parts H_2SO_4, 2 parts HCl and 1 part HNO_3) was added for digestion. The mixture was heated gradually at first and then more strongly until white fumes no longer evolved. The viscous mass was mixed with hot dilute HCl acid and filtered in line with method of Oladeji (2016). The insoluble fraction, which consists of unchanged mineral and the silica liberated from the silicates, was washed with diluted HCl acid and hot water. The filtrate was made up to 100 ml in volumetric flasks before being transferred to a well labeled 120 mL bottles. The same procedure was repeated for the remaining soil samples. Blanks were prepared at concentrations between 0.00 and 10.00 mg/L and calibration curves plotted to check for background contamination by the reagents used. The concentrations of elements of interest (Cd, Cu, Pb, and Zn) were determined using the atomic absorption spectrometer (PG990) model. The spike recovery for each metal was > 97.5%.

Assessment of heavy metal contamination

Geo-accumulation index (I_{geo})

The index of geo accumulation (I_{geo}) actually enables the assessment of contamination by comparing the current status and pre-industrial concentrations originally bottom sediments (Yerima et al., 2018). The method assesses the degree of metal pollution in terms of seven enrichment classes based on the increasing numerical values of the index (Table 1). The index of geo accumulation was calculated using the Equation 1.

$$I_{geo} = log_2(\frac{C_n}{1.5\times Bn}) \quad (1)$$

Where, Cn is the measured concentration of the element in soil or sediment and Bn is the geochemical background value. The constant value, 1.5, is back-ground matrix correction factor due to the lithological variations. The geo-accumulation index (I_{geo}) values are shown on Table 1.

Contamination factor (CF)

The contamination factor (CF) gives an indication of the degree of contamination in the soil. The level of contamination factor of sediment by metal is expressed by Equation (2). C_{Sample} is the given

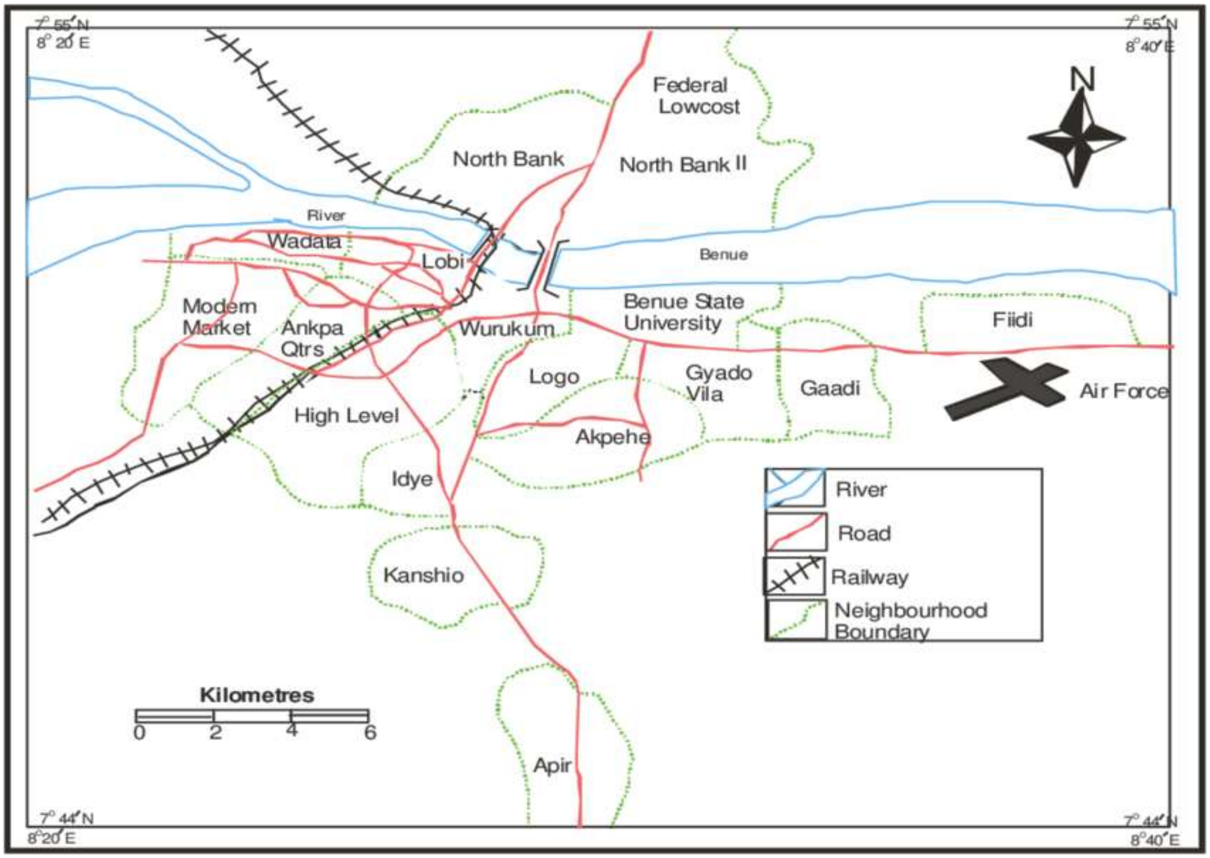

Figure 1. Map of Makurdi metropolis showing the study areas.
Source: Ministry of Lands and Survey, Makurdi (2015).

Table 1. Classification for geo-accumulation index (I_{geo}).

I_{geo} value	Class	Sediment quality
≤0	0	Unpolluted
0 - 1	1	From unpolluted to moderately polluted
1 - 2	2	Moderately polluted
2 - 3	3	From moderately to strongly polluted
3 - 4	4	Strongly polluted
4 - 5	5	From strongly to extremely polluted
>6	6	Extremely

Source: Muller as adopted by Yerima et al. (2018).

metal in shore sediment; $C_{Background}$ is the background value of the metal(Emmanuel et al., 2018). The $C_{Background}$ values are their world surface rock average (WSRA).

$$\mathrm{CF} = \frac{C_{sample}}{C_{Background\quad value}} \tag{2}$$

CF < 1, refers to low contamination; CF values between 1 and 3 indicates moderate contamination; CF values between 3-6 indicates considerable contamination and CF > 6 indicates very high contamination(Otene and Alfred-Ockiya, 2019).

Pollution load index (PLI)

The Pollution Load Index (PLI) is used in evaluating the pollution level in an environment (Emmanuel et al., 2018). It is obtained as degree of overall contamination using the concentration factors (CF). This is as shown in Equation 3:

$$\mathrm{PLI} = (CF_1 \times CF_2 \times CF_3 \times \ldots \times CF_n)^{1/n} \tag{3}$$

Where, CF = contamination factor, n = number of metals investigated, C_{metal} = metal concentration in polluted soil or sediments,

Table 2. Heavy metals concentration (mg/kg) in auto-mechanic dumpsites and some referencevalues.

Metal	K	NB	W	World surface rock average	Mean Shale concentration	WHO	USEPA
Cd	4.65	1.97	2.92	0.2	0.3	6	0.6
Cu	137.12	65.67	85.27	32	11.2	25	16
Pb	257.77	162.88	187.20	16	20	-	40
Zn	294.75	223.23	262.00	127	95	123	110

K =Kanshio, NB =Northbank and W =Wadata
Source: Adopted by Emmanuel et al. (2018).

$C_{Background\ value}$ = background value of that metal. If PLI value is >1 it means polluted, while PLI value < 1 indicates no pollution (Salah et al., 2012).

RESULTS AND DISCUSSION

The results of the heavy metal analysis carried out using Atomic absorption spectrophotometer (PG990) are tabulated in Table 2.

Assessment of heavy metals concentrations

The heavy metals investigated in this study include cadmium (Cd), copper (Cu), lead (Pb) and zinc (Zn). These metals were determined and analyzed from the sediment samples of three auto-mechanic dumpsites collected from Kanshio (K), Northbank (NB) and Wadata (W) respectively in Makurdi, Benue State. The heavy metals concentrations were measured, the variation in their mean concentrations compared with each other and with the reference values of World Health Organization (WHO), United States Environmental Protection Agency (USEPA), Mean Shale Concentration (MSC) and World Surface Rock Average (WSRA) shown in Table 2.

For Kanshio (K), the mean heavy metal concentrations determined for (Cd, Cu, Pb and Zn) were (4.65, 137.12, 257.77 and 294.75) mg/kg respectively. With Zn having the highest value of 294.75 mg/kg, and Cd lowest with value 4.65 mg/kg. For Northbank (NB) dumpsite, the mean heavy metal concentrations determined for (Cd, Cu, Pb and Zn) were found to be(1.97, 65.67, 162.88 and 223.23) mg/kg respectively. Wadata (W) was also found to be (2.92, 85.27, 187.20 and 262.00 mg/kg) for Cd, Cu, Pb and Zn respectively. From the results in Table 2, sites pollution was observed in the order of K > W > NB indicating K to be more polluted. The highest concentration observed in K wasan indication of high dumping activities carried out in this site. From the result it was also observed that the low concentration of Cd for the three dumpsites may be due to the ban of Cd-Ni batteries in most countries where electronics are manufactured, for instance, the sale of Cd-Ni batteries had been banned in the European Union where these batteries are import from, except for medical use (Waalkess, 2000). When not properly recycled, Cd could leach into the soil, harming microorganisms and disrupting the soil ecosystem. The inhalation of cadmium (Cd) causes severe damage to the lungs and kidneys (Jarup et al., 1998). Acute exposure to Cd fumes causes flu-like symptoms of weakness, fever, headache, chills, sweating, and muscular pain, lung cancer, kidney damage, pulmonary emphysema and bone disease (osteomalacia and osteoporosis) (Adriano, 1986). The concentration of Cd was observed in the order of K > W > NB with values higher than the United States Environmental Protection Agency (USEPA),Mean Shale Concentration (MSC) and World Surface Rock Average (WSRA), but lower than the World Health Organization (WHO).

While other results for Cu, Pb and Zn was observed in the order of K > W > NB. These results shows a higher concentration compared to the referenced maximum permissible level in soil of World Health Organization (WHO), United States Environmental Protection Agency (USEPA),Mean Shale Concentration (MSC) and World Surface Rock Average (WSRA) shown on Table 2, thereby indicating high pollution. The elevated level of Cu, Pb and Zn, may be due to the dumped auto-mechanic waste of welding activities, lead (Pb) used in lead (Pb) battery cells, painting and coating done in these areas (Chinwe et al.,2010).

Research have shown that Cu could help in regulation of water, seed production, disease resistance in plants, and in animals to maintain the central nervous system, production of blood haemoglobin and prevention of anaemia (Bernard and Ayandeji, 2020). But excess of Cu may result in liver and kidney damage, stomach and intestinal irritation and brain tumors (Wuana and Okieimen, 2011).The high concentration of Pbcouldbio-accumulate in plant via uptake from the soil and then enters into the food chain, which when consumed could result into Pb poisoning, chronic neurological disorders in foetus, hypertension and other respiratory difficulties in humans (Okereke et al., 2019).Also, excessive intake of Zn by humans may cause pancreatitis, vascular shock, dyspeptic nausea, vomiting, diarrhea and damage of hepatic parenchyma (Bernard and Ayandeji, 2020). At high concentration Zn cannot be adsorbed by plants and

Table 3. Geo-accumulation index (I_{geo}) of heavy metals in auto-mechanic dumpsite in Makurdi, Benue State.

Heavy metals	Kanshio	Northbank	Wadata
Cd	3.369	2.130	2.698
Cu	1.023	-0.0397	0.337
Pb	3.103	2.441	2.641
Zn	1.050	0.664	0.897

Table 4. Contamination factor (CF) of heavy metals in auto-mechanic dumpsite in Makurdi, Benue State.

Heavy metals	Kanshio	Northbank	Wadata
Cd	15.500	6.566	9.733
Cu	3.047	1.459	1.895
Pb	12.889	8.144	9.360
Zn	3.103	2.349	2.758

so prevent the activities of microorganisms and earthworms, therefore bringing about reduced decomposition of organic matter (Salah et al., 2012; Bernard and Ayandeji, 2020). The accumulation pattern of these heavy metals in the soil were found in the order of; Cd< Cu<Pb<Zn. Similar results were obtained by Iwegbue et al. (2006), study on automobile mechanic waste dumps in Port Harcourt.

Assessment of site contamination

It is important to compare the mean heavy metal concentrations in soil or sediment with their world guideline limit values before informed decision about the site quality could be made. In this study, site contamination was assessed using geo-accumulation index (I_{geo}), Contamination factor (CF) and Pollution load index (PLI). The geo-accumulation index (I_{geo}), contamination factor and pollution load index of the heavy metals were calculated, using Equation 1, 2 and 3, as shown in Tables 3 to 5.

Geo-accumulation index (I_{geo}) is a quantitative measure of the degree of contamination in soil sediments (Chukwu and Oji, 2018). The geo-accumulation indexes for the heavy metals accumulation in the studied areas are presented in Table 3. The I_{geo} for the three studied areas sediments were found to vary from metal to metal and site to site. The $I_{geo}$for Cd and Pb in Kanshio (K), Northbank (NB) and Wadata (W) auto-mechanic dumpsites were found to be Cd(3.369, 2.130 and 2.698) and Pb (3.103, 2.441 and 2.641) respectively. These values are high and may impose serious health risks in future. From the geo-accumulation index (I_{geo}) values on Table 3, it could be deduced that Cd and Pb for the three dumpsites were moderately to strongly polluted having values within 2-3, with the highest value of 3.369(Salah et al., 2012). The I_{geo} values for Cuwere found to be (1.023, -0.0397 and 0.337) and Zn (1.050, 0.664 and 0.897) for Kanshio, Northbank and Wadata, respectively. These values showed that Cu and Zn are uncontaminated to moderately contaminated having values<1(Yerima et al., 2018). The results on Table 3 showed the order of pollution to be K > W > NB. From the results it can be implied that the three auto-mechanic dumpsites can cause harm to the inhabitants of environment by excessive exposure which may cause weakness, fever, headache, sweating, and muscular pain, lung cancer, kidney damage, pulmonary emphysema and bone disease (Adriano, 1986).

The contamination factor (CF) for the three sites are presented in Table 4. The CF for Cd was found to be within the ranges of (6.566 - 15.500), Cu (1.459 - 3.047), Pb (8.144 - 12.889) and Zn (2.349 - 3.103) for Kanshio, Northbank and Wadata, respectively, which some are similar to those reported by Emmanuel et al. (2018), study on assessment of heavy metals concentration in shore sediments from the Bank of River Benue, North-Central Nigeria. According to Otene and Alfred-Ockiya (2019), CF < 1, refers to low contamination; CF values within 1-3 indicates moderate contamination; CF values within 3-6 indicates considerable contamination and CF > 6 indicates very high contamination. From results on Table 4, Cd is said be of very high contamination having value > 6, Cu as moderate contamination having values between 1 and 3, Pb as of very high contamination having values > 6 and Zn to be moderately contaminated having Values between 2 and 3 (Otene and Alfred-Ockiya, 2019). These results showed the contamination factor of Cd, Cu, Pb and Zn for the three sites in the order of K >

Table 5. Pollution load index (PLI) of heavy metals in auto-mechanic dumpsite in Makurdi, Benue State.

Index	Kanshio	Northbank	Wadata
PLI	6.593	3.679	4.671

W > NB indicating K to be more polluted. This simply means that the soils in these dumpsites are not safe for planting since these metals can bio-accumulate via uptake in plant and cause harm to food chain (Salah et al., 2012).

The PLI investigated in this study was quite high compared with the values recorded by Emmanuelet al. (2018), study on heavy metals along the bank of river Benue. In their studies, the PLI ranges from 0.4173 - 1.5928. The PLI values presented on Table 5 showed Kanshioto have (6.593), Northbank (3.679) and Wadata (4.671) respectively indicating K to more polluted as compared with other sites in the order of K > W > NB.According to Emmanuel et al. (2018), PLI values >1 means polluted and those values< 1 indicates no pollution. These indicates that the three dumpsites are heavily polluted with values>1. The results obtained in this study, showed that there is high contamination at these auto-mechanic dumpsites and therefore can cause health risk to the inhabitants of these environments (Salah et al., 2012).

Conclusions

This study shows that auto-mechanic waste dumps in Kanshio (K), NorthBank (NB) and Wadata (W) are significant sources of heavy metal pollution to soils in the studied sites. This can lead to increase in heavy metals concentrations that can cause harm to the environment and pose serious health risks to its inhabitants. From the study, it was observed that the concentrations of Cd, Cu, Pb and Zn metals studied are in the decreasing order of K > W > NB with almost all their values higher than the World Health Organization (WHO), United States Environmental Protection Agency (USEPA), Mean Shale Concentration (MSC) and World Surface Rock Average (WSRA) except for Cd whose values were less than the WHO limit. The pollution criteria of, Geo-accumulation index (I_{geo}), Contamination factor (CF) and Pollution load index (PLI) also showed that the sites were highly polluted. The accumulation pattern of the heavy metals in the soil was found to be in the order of; Cd< Cu<Pb<Zn. Therefore there is need for effective legislation on these dumping sites to reduce human risk exposure to these heavy metals in the environment. National and international organizations should formulate appropriate legislations to prevent heavy metal contamination and pollution in these sites. Also new technology should be developed and encouraged in the recycling of these solid wastes or extraction of these metals from liquid wastes before dumping them.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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