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ANALYSIS AND SPATIAL DISTRIBUTION OF HEAVY METALS IN DUMPSITES OF OKENE METROPOLIS, KOGI STATE, NIGERIA

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ABSTRACT

Heavy metals analysis of soils at the nine (9) dumpsites: Idoji (ID), Okene (OK), Ikuehi (IK), Oboroke (OB), Uhuoze (UH), Ozuri (OZ), Nagazi (NA), Kabba Junction (KJ), Obehira (AC) and a control site (CTR) were investigated by standard procedures and methods. The mean concentration ranges of Mn in the dumpsite soils for the wet and dry seasons were 0.035 (AC) to 1.523 mg/kg (IK) and 0.050 (AC) to 1.733 mg/kg (IK) mg/kg respectively. Similarly, the concentration ranges for Cr during the wet and dry seasons across the dumpsites were: 0.031 (OK) to 1.367mg/kg (IK) and 0.038 (OK) to 2.097 mg/kg (NA) respectively. Furthermore, the concentrations of Zn in the wet and dry seasons were 49.465 (AC) to 566.611 mg/kg (NA) and 12.193 (NA) to 887.366 mg/kg (UH) respectively. The concentrations of Pb during the wet and dry season were 1.147 (ID) to 6.357 mg/kg (IK) and 10.616 (OK) to 81.596 mg/kg respectively. The concentration ranges of Ni in the wet and dry season were 0.400 (UH) to 1.977 mg/kg (OK) and 1.010 (OK) to 7.106 mg/kg (ID) respectively. The concentrations of Cu during the wet and dry seasons were 1.303 (OZ) to 70.200 mg/kg (OB) and 1.100 (OK) to 919.634 mg/kg (KJ) respectively. Lastly, the concentrations of Cd across seasons and dumpsites were 0.900 (OZ) to 3.060 mg/kg (KJ) and 0.372 (OK) to 3.280 mg/kg (OZ) respectively. The results from the dumpsite soils generally indicated that there was serious threat of Cd, Pb and Zn accumulation to immediate inhabitants of the dumpsites because their mean concentrations were above WHO permissible limits for safe soils. However, Cu, Ni, Cr and Mn do not pose any immediate threat to the dumpsite residents. Adequate solid waste disposal technique should be adopted by the appropriate agencies to forestall this threat to Okene metropolis environment.

Keywords: Heavy metals, soil, Okene metropolis, dumpsites, pollution

INTRODUCTION

The impact of pollution on congested cities due to industrial effluents and automobile discharge has reached a worrying magnitude and is arousing public awareness [1]. An extreme level of pollution has caused a lot of harm to human and animal health, also to plants as well as the tropical rain forests and the wider environment [2]. Pollution and ensuing contamination of the environment by poisonous heavy metals are of immense worry due to their sources, well-known distribution and several effects in the ecosystem [3]

Heavy metals are elements of elevated molecular masses, most of which belong to the transition elements [3-5]. Studies have shown that soils of refuse dumpsites include different kinds and concentrations of heavy metals [1-6]. In recent times, it has been reported that these elements build up and persist in soils at an environmentally dangerous levels [7, 8].

Poor waste management poses several challenges for the well-being of the city residents, particularly those living near to the dumpsites due to the potential of the waste to pollute the water, food sources, land, air and vegetation [9]. Dumping of solid wastes without proper separation increases the concentration of heavy metals such as arsenic (As), cadmium (Cd), chromium (Cr), copper (Cu), lead (Pb), mercury (Hg) and zinc (Zn). These heavy metals when present in solid wastes have been known to produce major environmental impacts [10].

Due to low level of development, some developing countries such as Nigeria, Ghana, Ivory Coast and Gambia consider economic growth, social and educational development and industrialization as key development priorities, while protection of the environment has not been given the same importance. The cities of the third world countries are growing at very rapid rates compared to those in the developed nations. For instance, a United Nations habitat report observed that Africa is the fastest urbanizing continent having cities like Nairobi, Cairo, Lagos and Kinshasa, among others, growing at fast rates that would make them triple their current sizes by the year 2050 [11, 12]. The increasing growth of cities has implication for municipal waste management among other social services required in the urban communities. Data from many of the cities show inadequacy in the social services like shelter, provision of safe drinking water and efficient management of solid waste. The cities are, therefore, littered with mountains of rubbish in the landfills and open waste dumps which are covered with flies and thus serve as breeding grounds for rodents and mosquitoes which are carriers of diseases [12].

Heavy metals have been referred to as common pollutants which are widely distributed in the environment with sources mainly from soils, and human activities [13, 14]. According to Chiroma et al [15], there exists transfer of heavy metals from contaminated soil to plants and from plants to animals with the subsequent transfer through the food chain up to man.

It is worrisome that from available literature research on heavy metals distributions in dumpsites and waste management in Okene metropolis has been very scanty. Hence, the urgent and immediate need for this research.

The aim of this study is to assess heavy metals and their spatial distribution in selected dumpsites of Okene metropolis of Kogi State, Nigeria, between 2019 and 2021.

MATERIALS AND METHODS

Figure 1 shows the digitalized map of Okene Metropolis, Kogi State with the nine (9) sampled dumpsites; Idoji (ID), Okene (OK), Ikuehi (IK), Oboroke (OB), Uhuoze (UH), Ozuri (OZ), Nagazi (NA), Kabba Junction (KJ), Obehira (AC) and a control site (CTR). Soil samples were collected from each dumpsite with the aid of an auger stainless spoon at 0 – 20 cm profile and the samples were placed in polythene bags and labeled. About 5.0 g of the soils were weighed into 100 ml beaker and 10 ml concentrated nitric acid were added. The mixture in the beaker was covered with lid and heated to dryness. Exactly 5 ml *aqua-regia* was added and the mixture was again evaporated to dryness. Then 10 ml 1 mol/dm^3 nitric acid was added and the suspension filtered. The filtrate was then diluted to volume with distilled water in a 50 ml volumetric flask. Triplicate digestions of each sample together with blank were carried out [16]**.** Soil samples across selected dumpsites were collected between November, 2019 and January 2021 from the study area [16. 17]. The digests were analysed for heavy metals (Cd, Cu, Ni, Pb, Zn, Cr and Mn) using atomic absorption spectrophotometer (Model AA320N).

Data Analysis

Statistical analysis was carried out using SPSS Package 20.0 and spatial analysis of the heavy metals in the soil was carried out using arcGIS 3.0 software (version 2021).

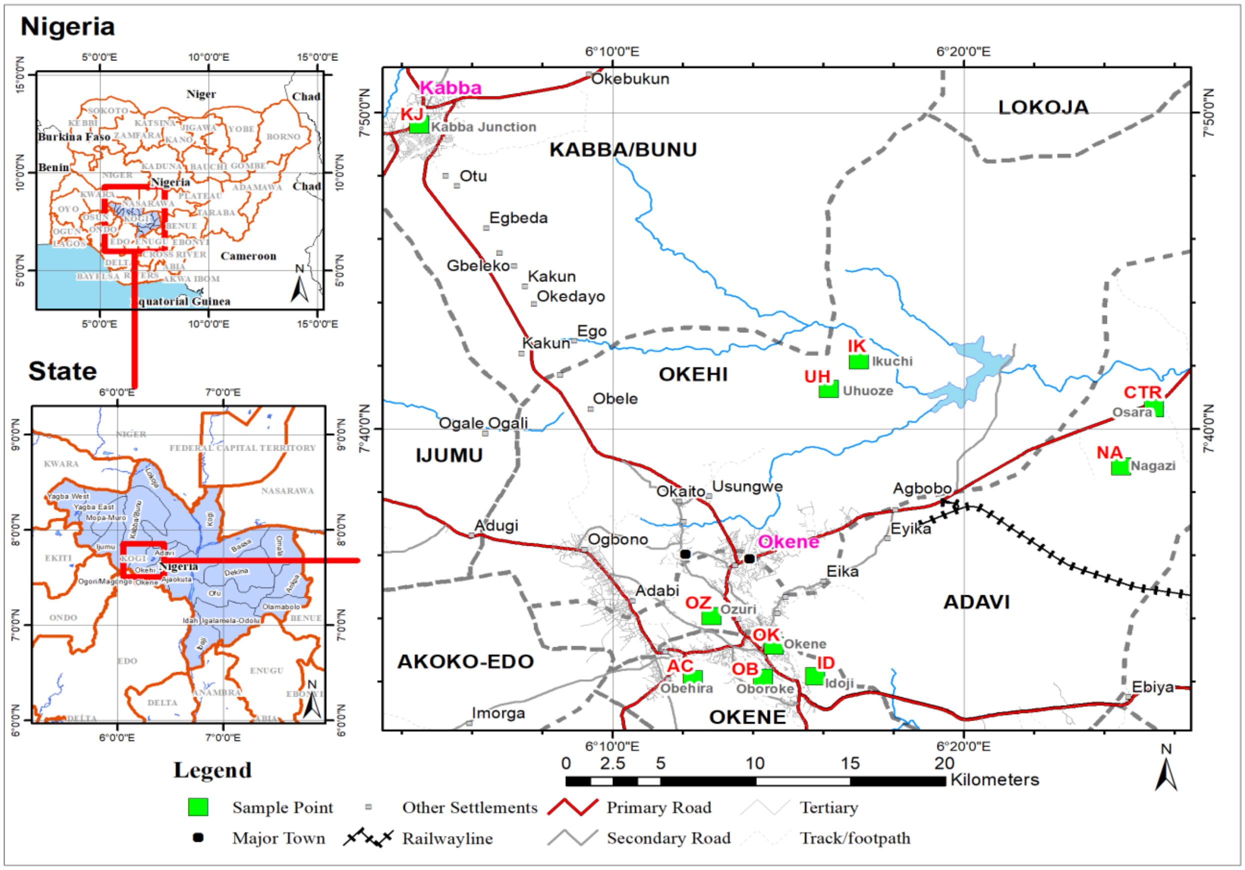

Figure 1: Digitalized map of Okene metropolis showing the sampling points

RESULTS AND DISCUSSION

Table 1 showed the mean concentrations of Mn in the dumpsite soils for dry season. The concentration ranges of Mn in the dumpsite soils for dry seasons were 0.063 (OK) to 1.733 mg/kg (IK) mg/kg while CTR recorded 0.023 mg/kg. Similarly, Table 2 showed the mean concentrations of Mn in the dumpsite soils for wet season. The concentration ranges of Mn in the dumpsite soils for wet seasons were 0.035 (AC) to 1.470 mg/kg (ID) mg/kg while CTR recorded 0.011 mg/kg. The mean concentration ranges for Cr (Table 1) during dry seasons across the dumpsites were 0.038 (OK) to 2.097 mg/kg (NA) as compared to 0.014 mg/kg (CTR) while in the wet season according to Table 2, the concentration ranges for Cr were 0.031 (OK) to 1.937 mg/kg (NA) as compared to 0.024 mg/kg (CTR).

The varied values of Mn and Cr obtained in this study across dumpsites and seasons were attributed to dumpsite composition. However, concentrations of Cr and Mn were significantly different at $p < 0.05$ for dumpsite soils and were below the tolerable limits of 100 mg/kg [18].

The mean concentrations of Zn in the dry seasons was 12.193 (NA) to 887.366 mg/kg (UH) while CTR recorded 7.832 mg/kg (Table 1) while the mean concentrations of Zn in the wet seasons was 49.465 (AC) to 566.611 mg/kg (NA) while CTR recorded 128.595 mg/kg (Table 2). The total mean value obtained for Zn metal in the studied dumpsites was attributed to leaching activities and dumpsite composition. The concentrations of Zn were also significantly different at $p < 0.05$ for dumpsite soils and were above the WHO tolerable limits of 300 mg/kg [18] across the seasons except for ID, OK, OB, UH, OZ and KJ dumpsites. Also, the levels of Zn obtained in this work were below the reported levels of Zn [19, 20].

The mean concentrations of Pb during dry season were 10.616 mg/kg (OK) to 81.596 mg/kg as compared to 1.845 mg/kg recorded for CTR (Table 1) while in the wet season, the mean concentrations of Pb (Table 2) were 1.250 mg/kg (OK) to 3.190 mg/kg (AC) as compared to 1.140 mg/kg recorded for CTR. The mean concentrations of Pb across the dumpsites across seasons were attributed to dumpsite compositions and leachates migrations of Pb at the dumpsites. Generally, the concentrations of Pb recorded across the dumpsites were below WHO permissible limit of 100 mg/kg [18]. The concentrations of Pb reported in this study were above the reported levels [20, 21] but higher than the levels recorded by Ebong et al [22] in a similar research.

The concentration ranges of Ni in the dry season were 1.010 (OK) to 7.106 mg/kg (ID) which were higher than 0.530 mg/kg for the CTR (Table 1). Similarly, during the wet season, the concentration ranges of Ni in the wet season were 0.400 (UH) to 1.977 mg/kg (OK) which were higher than 0.030 mg/kg for the CTR (Table 2) and were all below WHO permissible limit of 67.9 mg/kg [18] at most dumpsites.

Table 1: Total metal concentrations (mg/kg) of the dumpsite waste soils during the dry season

Metal	ID	OK	CTR	IK	OB	UH	NA	OZ	KJ	AC
Cd	1.750 ± 0.134	0.372 ±0.630	0.155 ±0.046	2.433 ± 0.306	2.136 ±0.006	2.336 ±0.025	2.853 ±0.031	3.280 ±0.020	3.013 ± 0.110	2.270 ± 0.061
Cu	2.553 ±0.050	1.100 ±0.000	1.033 ±0.306	15.113 ±0.093	11.173 ±0.388	3.953 ±0.032	1.038 ±0.020	1.303 ±0.006	919.634 ±0.436	7.893 ±0.031
Ni	7.106 ± 0.006	1.010 ± 0.010	0.530 ±0.312	2.046 ± 0.006	1.433 ± 0.006	2.036 ± 0.006	2.106 ±0.029	2.646 ±0.015	1.933 ± 0.012	2.063 ± 0.015
Pb	17.613 ± 0.480	10.616 ± 0.505	1.845 ± 0.385	29.053 ± 0.136	25.196 ±0 374	16.506 ± 0.101	29.446 ±0.175	18.690 ±0.488	81.596 ± 0.295	34.993 ± 0.258
Zn	382.230 ± 4.075	343.820 ± 0.306	7.832 ±0.216	260.157 ± 0.056	426.940 ± 1.161	887.633 ± 2.000	12.193 ±1.679	371.72 ±6.653	442.710 ±1.285	251.873 ± 0.771
Cr	0.813 ± 0.011	0.038 ± 0.012	0.014 ±0.003	1.440 ± 0.017	0.915 ± 0.003	1.563 ± 0.060	2.097 ±0.091	0.934 ±0.003	1.137 ± 0.021	0.932 ±0.013
Mn	1.606 ± 0.012	0.063 ± 0.001	0.023 ±0.002	1.733 ± 0.025	0.628 ± 0.008	0.079 ± 0.002	0.812 ±0.002	0.513 ±0.005	1.403 ± 0.049	0.050 ± 0.002

Table 2: Total metal concentrations (mg/kg) of the dumpsite waste soils during the wet season

Metal	ID	OK	CTR	IK	OB	UH	NA	OZ	KJ	AC
Cd	2.140 ± 0.035	1.060 ±0.050	0.032 ±0.006	1.373 ± 0.032	1.817 ±0.006	2.253 ±0.031	2.670 ±0.8573	0.900 ± 0.040	3.060 ±0.0529	2.447 ±0.002
Cu	8.757 ±0.042	5.643 ±0.004	1.673 ±0.080	6.643 ±0.045	70.200 ±0.040	38.473 ±1.986	42.670 ±0.857	1.303 ±0.006	19.103 ±0.635	57.106 ±1.371
Ni	0.963 ± 0.006	1.977 ± 0.006	0.033 ± 0.006	0.693 ± 0.001	0.580 ± 0.010	0.400 ± 0.017	0.673 ± 0.012	0.827 ±0.0057	1.487 ± 0.012	0.623 ±0.006
Pb	1.147 ± 0.012	1.250 ± 0.026	1.140 ±0.035	6.357 ± 0.049	3.460 ±0 020	4.747 ± 0.023	1.440 ± 0.035	1.900 ± 0.050	2.453 ± 0.002	3.190 ±0.108
Zn	180.840 ± 0.423	176.203 ± 0.096	128.595 ±0.130	137.902 ± 1.058	221.182 ±10.871	491.716 ± 4.178	566.611 ± 2.824	205.802 ± 1.162	236.312 ±7.927	49.465 ±0.336
Cr	0.722 ± 0.004	0.031 ± 0.001	0.024 ± 0.005	1.367 ± 0.045	0.667 ± 0.013	1.423 ± 0.025	1.937 ± 0.035	0.804 ± 0.006	0.870 ± 0.003	0.083 ±0.007
Mn	1.470 ± 0.010	0.051 ± 0.001	0.011 ± 0.002	1.523 ± 0.012	0.574 ± 0.003	0.046 ± 0.021	0.294 ± 0.381	0.351 ± 0.229	1.187 ± 0.006	0.035 ±0.007

The mean concentrations of Cu during the dry seasons were 1.038 (NA) to 919.634 mg/kg (KJ) while 1.033 mg/kg was recorded at the CTR (Table 1). In the same vein, the mean concentrations of Cu during the wet seasons were 1.303 (OZ) to 70.200 mg/kg (OB) while 1.673 mg/kg was recorded at the CTR (Table 2). The level of Cu recorded across dumpsite soils were below 100 mg/kg WHO permissible limits [18] with the exception of KJ dumpsite. This is attributed to the composition of the KJ dumpsite.

Lastly, the concentrations of Cd across seasons and dumpsites were 0.372 (OK) to 3.280 mg/kg (OZ) and 0.155 mg/kg was recorded at (CTR) site (Table 1). Similarly, during the wet season, the concentration ranges of Ni in the wet season were 0.900 (OZ) to 3.060 mg/kg (KJ) which were higher than 0.032

mg/kg for the CTR (Table 2), Overall, the concentrations of Cd recorded across the many of the dumpsites and seasons were above the limit of 3.0 mg/kg [18]. The concentrations of Cd recorded in this study were higher than the reported ranges [24, 25]. The value of Cd in this study was lower than 2.15 – 6.18 mg/kg reported by Okoronkwo et al [20] in dumpsite soils.

Spatial distributions of heavy metals of selected dumpsites of Okene metropolis

The spatial distribution map of mean Cd determined in selected dumpsites of Okene metropolis is shown in Fig. 2. According to the map legends, during the dry season, UH, ID and AC dumpsites were located in the high Cd concentration region while NA and KJ dumpsites also showed very high Cd concentration. Low Cd concentrations were found in the IK, OZ and OK dumpsites while OB dumpsite was in the region of medium Cd concentrations. The control located in the North-East of the map showed very low Cd concentrations. Overall, North-West, North-East and South-West of Okene metropolis showed medium Cd concentration while South-East of Okene metropolis showed high Cd concentrations. Similarly, in the wet season, majority of the Okene metropolis recorded high Cd concentrations as depicted by the map legends (Fig 2). UH, IK, OB and AC dumpsites showed high mean Cd concentrations while OZ, OK, KJ, and NA dumpsites showed very high mean Cd concentrations. The control located in the North-East of the map showed very low Cd concentrations while ID dumpsite showed Medium Cd contamination.

The spatial distribution map of Cu in the dry season showed that all regions of Okene metropolis were highly contaminated by Cu (Fig. 3). Dumpsites such as UH, NA, KJ, AC and OB were very contaminated by Cu while IK, OZ, OK and ID Cu contamination ranged from high to very high (Fig. 3). The Cu contamination of the control site ranged from very low to high (Fig. 3). Likewise, during the wet season, regions of the spatial distribution map shows that CTR, NA, UH, OX, OK and ID had very low Cu contaminations (Fig. 3) while IK and KJ dumpsites recorded high to very high Cu contaminations. Overall, North-west, South-east and South-west of Okene metropolis recorded low Cu contaminations during the wet season (Fig. 3).

The spatial distribution map of Ni during wet and dry seasons (Fig. 4) showed that in the dry season, UH and CTR recorded very low while KJ had medium Ni contaminations. All other dumpsites that were analysed for Ni showed low accumulation with the exception of OK dumpsite that recorded high Ni contaminations. Overall, North-east region of Okene metropolis recorded very low Ni contamination (Fig. 4). Similarly, in the wet season, most of the dumpsites recorded very high Ni concentrations (Fig 4) with the exceptions of CTR, OB and OK dumpsites that had medium-high Ni contaminations.

The spatial distribution map of mean Pb determined in selected dumpsites of Okene metropolis is presented in Fig. 5. According to the map legends, during the dry and wet seasons, UH and IK dumpsites recorded low-medium Pb concentrations while NA, CTR, ID and OK showed very low Pb concentrations. Overall, Okene metropolis as showed by the map in Fig. 5 recorded low Pb contaminations. Similarly, in the wet season, majority of the Okene metropolis showed high very high Pb concentrations as indicated with the exception of CTR and OK sites that showed medium- high Pb contamination (Fig. 5).

The spatial distribution map of Zn in the dry season with the aid of the map legends showed that majority of Okene metropolis recorded low Zn contaminations (KJ, ID, OB, OK and OZ dumpsites) while CTR, IK and AC were within the very low Zn contamination area (Fig. 6). UH and NA dumpsites show high Zn contamination as illustrated on the map (Fig. 6). Similarly, in the wet season, Zn contamination ranges from very low (CTR and NA) to medium (OZ, OK, OK, ID, OZ and KJ); and low (AC and IK) to very high (UH) as shown on Fig. 6.

The spatial distribution map of Cr during wet and dry season (Fig. 7) showed that in the dry season, only NA-dumpsite showed medium to high Cr contamination. CTR, OK and AC-dumpsites showed very low while other selected dumpsites recorded low to medium Cr accumulation. Similarly, in the wet season, most of the dumpsites recorded low to medium Cr contamination with the exception of CTR, AC and OK dumpsites that showed very low Cr contaminations (Fig. 7).

From the spatial distribution map of mean Mn determined in selected dumpsites of Okene metropolis (Fig. 8) during the dry and wet seasons, it can be explained that UH, OK, CTR and OK dumpsites recorded very low Mn concentrations while IK, ID and KJ dumpsites indicated high to very high Mn contaminations. Many of the regions on the map in the dry season showed low to medium Mn contaminations (Fig. 8). Likewise, in the wet season, UH, OK, CTR and AC dumpsites recorded very low Mn concentrations while IK, ID and KJ dumpsites indicated high to very high Mn contaminations.

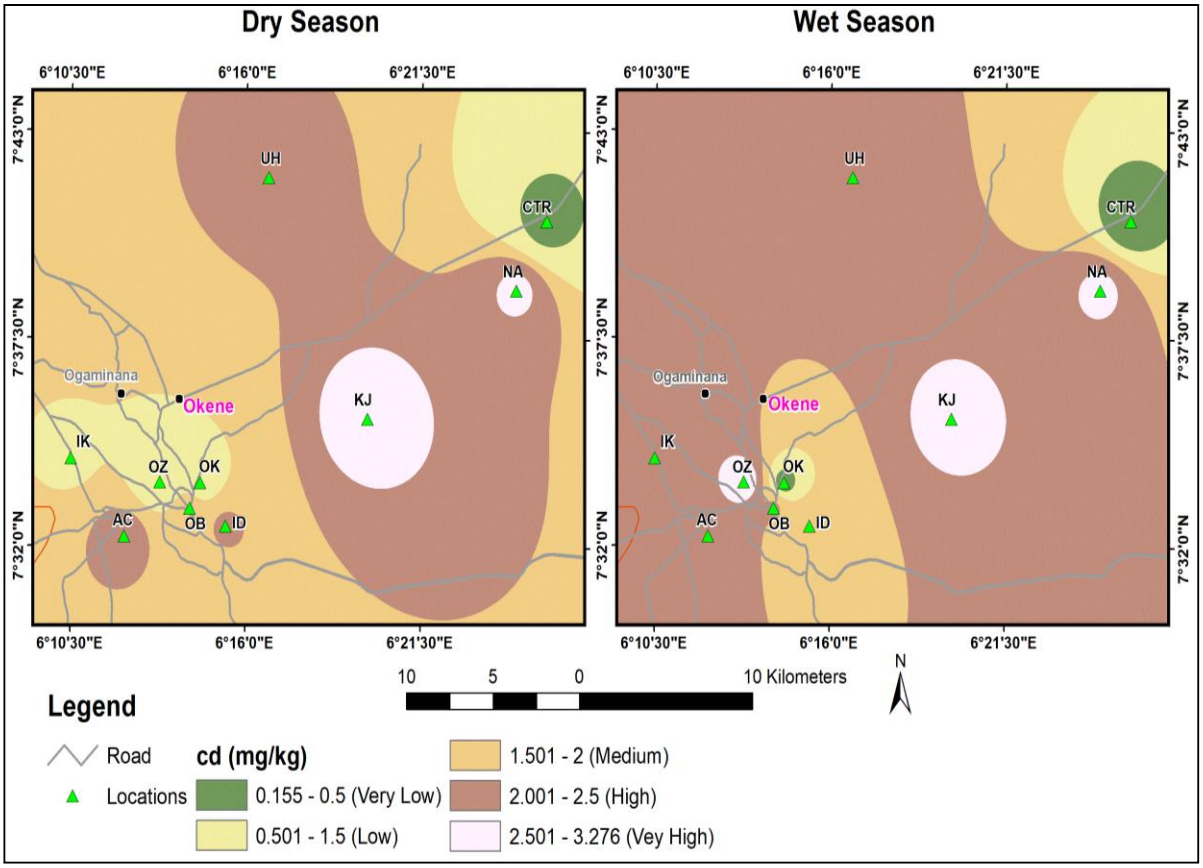

Fig. 2: Spatial distribution of Cd in the study area between dry and wet seasons

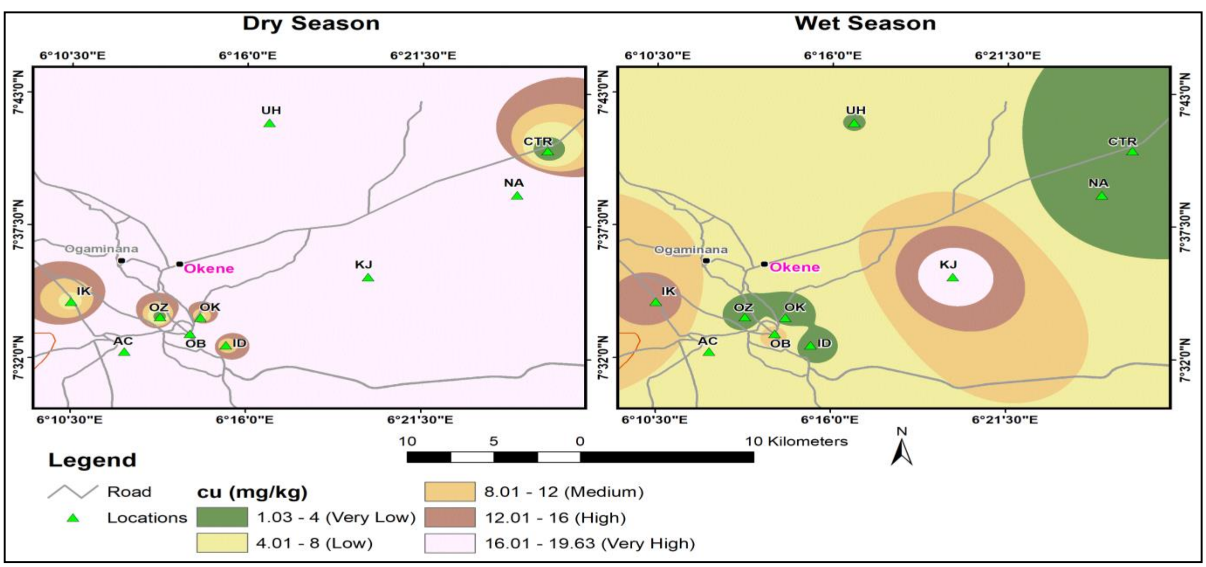

Fig. 3: Spatial distribution of Cu in the study area between dry and wet seasons

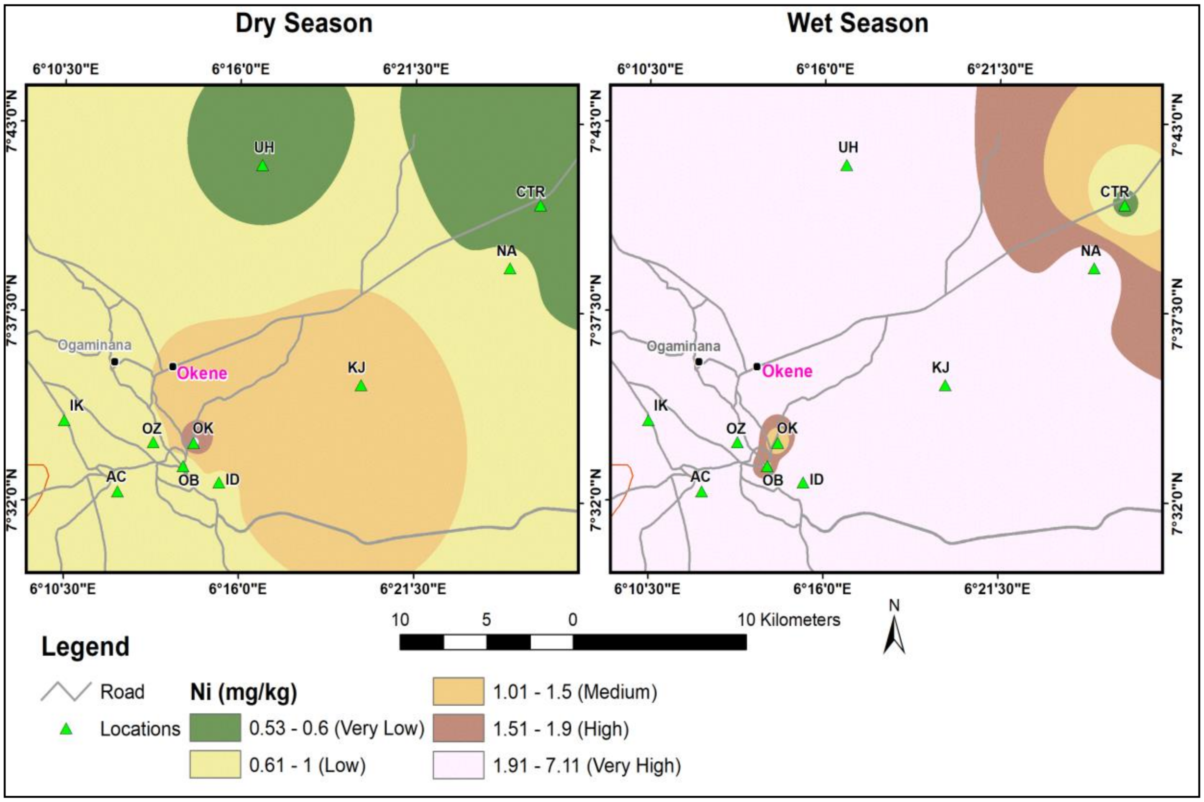

Fig. 4: Spatial distribution of Ni in the study area between dry and wet seasons

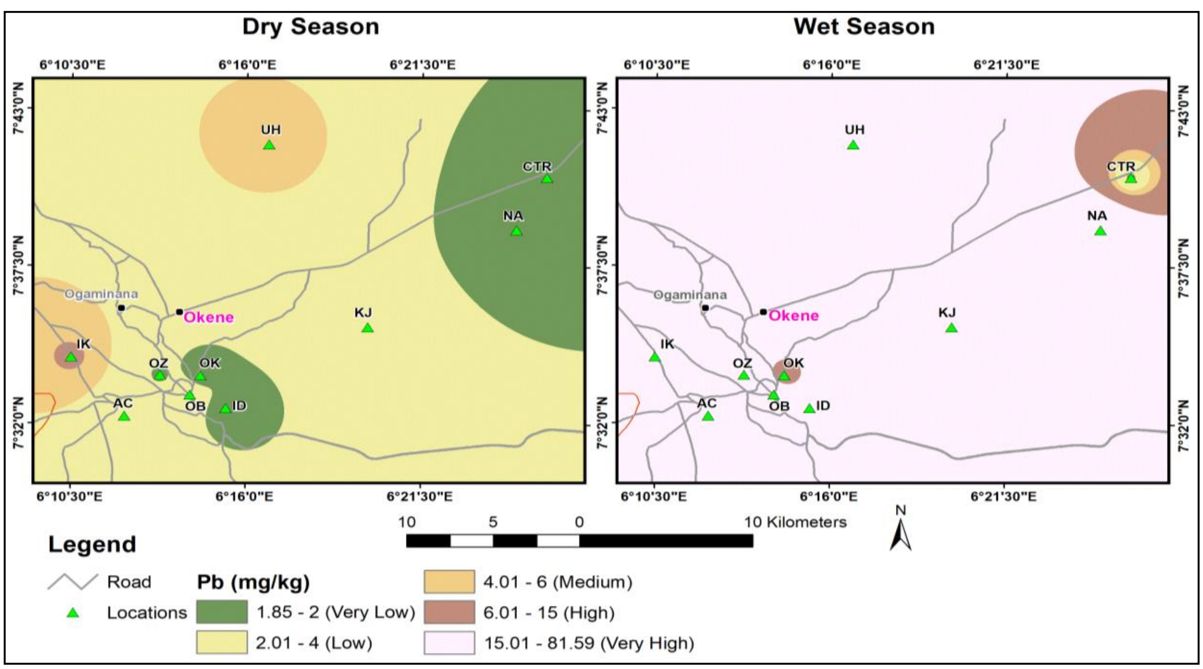

Fig. 5: Spatial distribution of Pb in the study area between dry and wet seasons

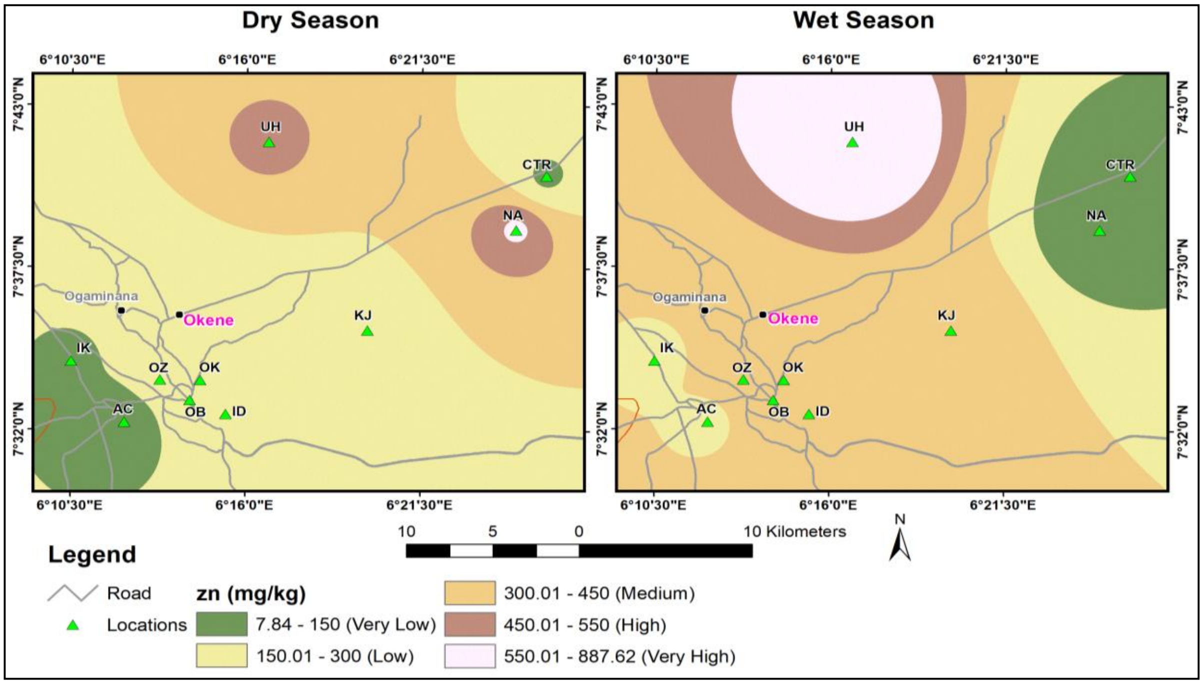

Fig. 6: Spatial distribution of Zn in the study area between dry and wet seasons

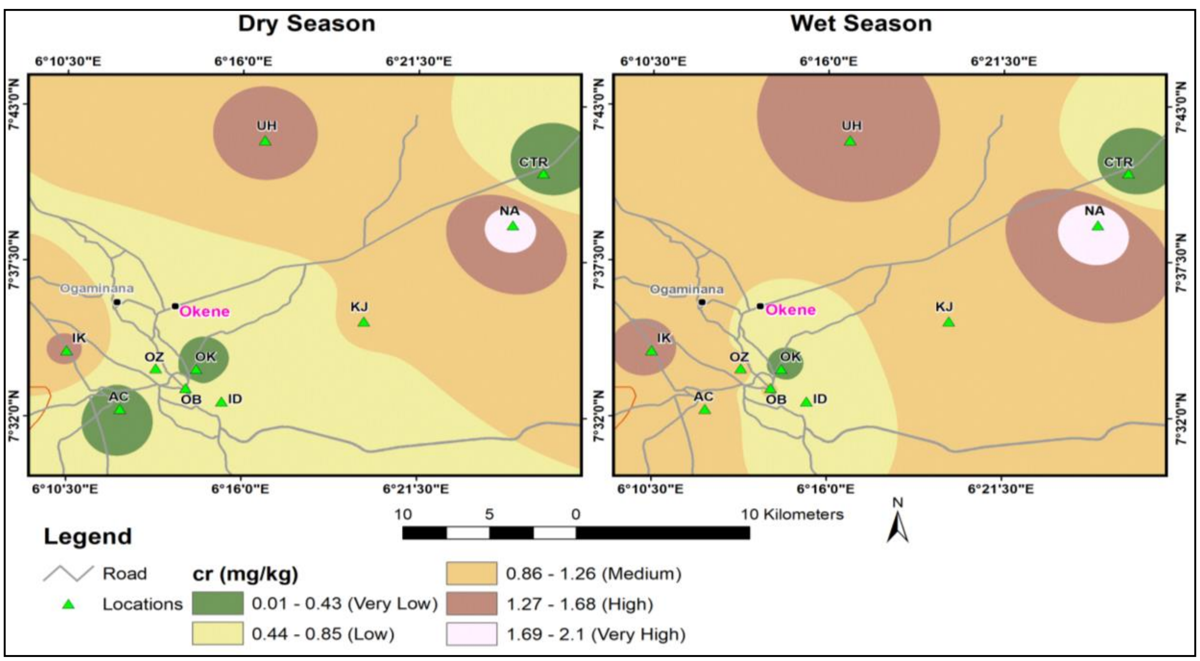

Fig. 7: Spatial distribution of Cr in the study area between dry and wet seasons

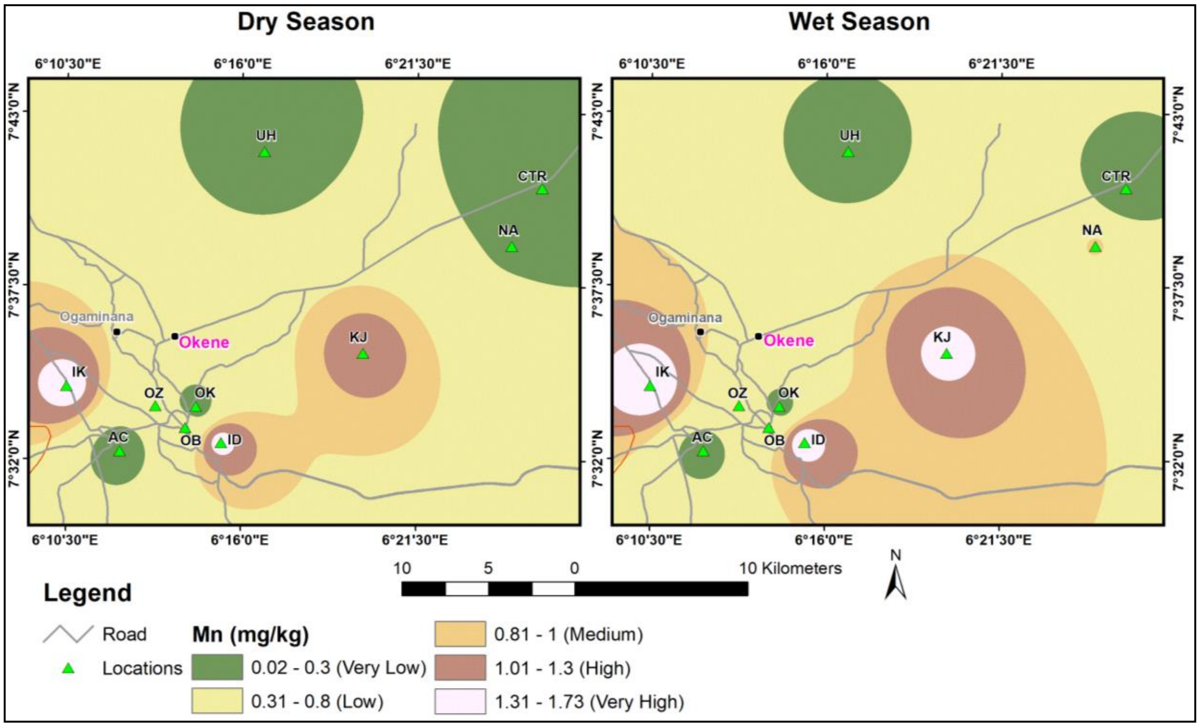

Fig. 8: Spatial distribution of Mn in the study area between dry and wet seasons

CONCLUSION

From the results, the aim and objectives of the research have been achieved because the selected dumpsites in Okene metropolis was found to have Cd and Zn concentrations above the WHO permissible limits with the exception of the control site while all the dumpsites were not contaminated by Cu, Ni, Pb, Cr and Mn. It can be deduced that higher concentrations of heavy metals in the dumpsite soils could be due to improper disposal of refuse as a result of leaching that took place on the soil at the dumpsites and human activities. Therefore, the presence of the dumpsites is harmful to neighborhood inhabitants. There is an urgent need to construct a standard environmental sanitary dumpsite and encourage recycling of refuse around the dumpsites. It is also recommended that the Ministry of Environment should make policies on monitoring, treatment and protection of the environment and people a priority.

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