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Full Length Research Article

BIOMONITORING OF HEAVY METALS POLLUTION IN THE UNIVERSITY OF LAGOS, AKOKA CAMPUS ENVIRONMENT USING THE MOSS *DICRANIUM SCORPARIUM* HEDW

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ABSTRACT

The level of atmospheric heavy metal deposition in University of Lagos, Akoka campus was investigated using the moss *Dicranum scorparium* Hedw. Moss samples were collected from unplastered perimeter walls and rock surfaces at ten sampling sites labeled A-J: UBA Park (A), Ransome Kuti (B). Makama Hall (C), Faculty of Law (D), Moremi Car Park (E), Medical Centre (F), Ozoluwa BQs (G), High Rise Buildings (H), Honors Hall (I), Lagoon Front (J). A control sampling was done at First Estate, Amuwo-Odofin LGA. The concentrations of Cadmium (Cd), Lead (Pb), Nickel (Ni), Copper (Cu) and Zinc (Zn) were determined using Atomic Absorption Spectrophotometer (AAS) Perkin Elmer AA 800. The results obtained confirmed the presence of heavy metal in this order Zn > Pb > Cd > Cu > Ni. The concentration of Zn, Cd and Pb were greater than the FME and UNEP threshold limiting values. The analysis of the anthropogenic influence of the pollutants on the environment revealed that Zn (4.24mg/L) despite its highest abundance is a moderate contaminant in the study locations. Contamination factor (CF) suggests that locations B, D, F, G and J are seriously contaminated (C5) while locations A, C, E, H, and I are extremely contaminated (C6). The index of geo-accumulation revealed that all the studied locations are in the $I_{geo}7$ category indicating extremely pollution with the assayed metals. The difference in the occurrence of anthropogenic activities was seen to be the major factor responsible for the variations in the concentration of heavy metals accumulated by the mosses.

Keywords: Biomonitoring, Heavy metal, Air pollution, Geo-accumulation index, Contamination factor.

INTRODUCTION

Over the past decades, industrialization is growing at a fast pace, increasing the demand for exploitation of the Earth's natural resources and thus causing a lot of environmental pollution (Briffa *et al.* 2020). Atmospheric pollution is one of the sources of deteriorating living conditions for the inhabitants of densely populated and residential areas in the world. This has been one of the most important issues of air quality due to its concerted effects on the environment and human health (Cowden et al. 2015). Particulate matters such as heavy metals are suspended into the atmosphere by a variety of natural sources and anthropogenic activities (Ozaki *et al*. 2004). Although heavy metals are naturally occurring elements, anthropogenic activities such as agricultural use of metallic compounds, industrial production as well as mining and smelting of natural resources contribute to environmental contamination and human exposure to pollutants (Tchounwou, 2012). In addition, natural phenomena such as weathering and volcanic eruptions contribute significantly to heavy metal pollution. Industrial sources include metal processing in refineries, coal burning in power plants, petroleum combustion amongst others (Tchounwou, 2012). At very low concentrations, some of these metals such as iron, zinc, copper, and manganese are essential for life but can lead to harmful effects in humans, plants, and animals at higher concentrations (Furini, 2012). At higher concentrations in the environment, they will inevitably find their way into the human body. Similarly, non-essential metals will induce toxicity once certain concentrations are reached (Yatim & Azman, 2021). The presence of heavy metals in the environment beyond the acceptable threshold limit has been of serious concern to environmentalists (Yushin et al. 2020). Atmospheric heavy metal contamination has been a major environmental problem in the world. Emissions from energy generation, automobiles, industries, vehicular traffic, combustion of fossil fuel, and poor waste management strategies has equally become a significant worry in Lagos-State, South-Western Nigeria (Ojiodu & Elemike, 2018; Ojiodu *et al.* 2016). It has thus become expedient to determine and monitor the level of heavy metal concentration in an environment to avert detrimental impacts of these metals.

The use of bioindicators and biomonitors have become an important part of air pollution measurements (Radziemska et al. 2019). Species abundantly available and capable to provide qualitative and quantitative information about environmental quality are employed for biomonitoring activities. They can effectively determine levels of air pollutants and their impact on the environment and therefore used to complement instrumental measurement methods (Vergel *et al.* 2019).

Mosses are useful bioindicators of a wide range of pollutants and have been employed for air quality assessments (Vergel et al. 2019). They are resistant against many highly toxic substances and can accumulate pollutants due to their nutrient use and uptake systems (Fernandez *et al*. 2013; Jiang *et al*. 2018). As compared to other plant groups, mosses are excellent biomonitors of atmospheric depositions (Bargagli, 2016; Jiang *et al.* 2018). They are plentiful and extensively distributed; they lack protective cuticle and thick cell walls. Their numerous cell wall possess negatively charged groups; due to their lack of internal roots to store water, mineral nutrition is obtained mainly from wet and dry depositions (Yatim & Azman 2021). Since the 1960s, in different parts of the world, mosses has been extensively utilized to monitor and map atmospheric deposition of contaminants, especially heavy metals; due to the high bioaccumulation correlation between deposition

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rates and levels of contaminants in moss tissues (Markert *et al.* 2003; Yatim & Azman 2021). This study therefore aims to assess and evaluate atmospheric deposition of heavy metals in the University of Lagos, Akoka campus using the moss *Dicranium scorparium* as a bioindicator.

MATERIALS AND METHODS

Study Area

The survey was carried out at on the University of Lagos, Akoka campus (6˚31'0" N 3˚23'10" E), located on 802 acres of land in Akoka, the North-Eastern part of Yaba, Lagos state. It was a survey-type research based on primary data collection. This involved the stratification of the sample area. The ten sample sites were selected based on the accessibility to the moss plant, availability of open spaces as well as areas with influx of vehicles as well as industrial activities. A control sampling was done in First Estate, Amuwo Odofin LGA; a strictly residential area with minimal vehicular traffic, commercial activities and alternative electricity sources. Georeferencing of the study sites was done using Garmin GPS MAP 76S. Detailed information of the sampling sites is provided in Table 1 and Figure 1.

Table 1: Sample location and characteristics

Site code	Location	Coordinates	Description
A	UBA Park	6°31´04.1" N 3°23´10.3" E	A strictly recreational site recently converted into a car parking lot. Adjacent to a major busy road.
B	Ransome Kuti	6°30´48.8" N 3°23´15.7" E	A residential area.
C	Makama Hall	6°31´10.0" N 3°23´31.9" E	A student residential area with high commercial activities.
D	Faculty of Law	6°31´13.6" N 3°23´56.6" E	A site with staff offices, lecture halls and commercial activities.
E	Moremi Car Park	6°31´04.6" N 3°28´50.3" E	A major bus stop and car parking lot with high commercial activities.
F	Medical Centre	6°30´54.2" N 3°23´18.8" E	A site with offices, laboratories, medical equipment rooms, pharmacy etc.
G	Ozolua BQs	6°30´46.1" N 3°23´47.2" E	A strictly residential area
H	High Rise Buildings	6°30´19.1" N 3°23´48.5" E	A strictly residential area
I	Honors Hall	6°30´38.5" N 3°23´24.7" E	A residential area with a few commercial activities
J	Lagoon Front	6°31´07.7" N 3°24´04.3" E	A strictly recreational area with dense vegetation.
Ctrl	First Estate (Control)	6°28´31.6" N 3°18´18.7" E	A strictly residential area. Little or no commercial activities. Behind it is a major busy highway.

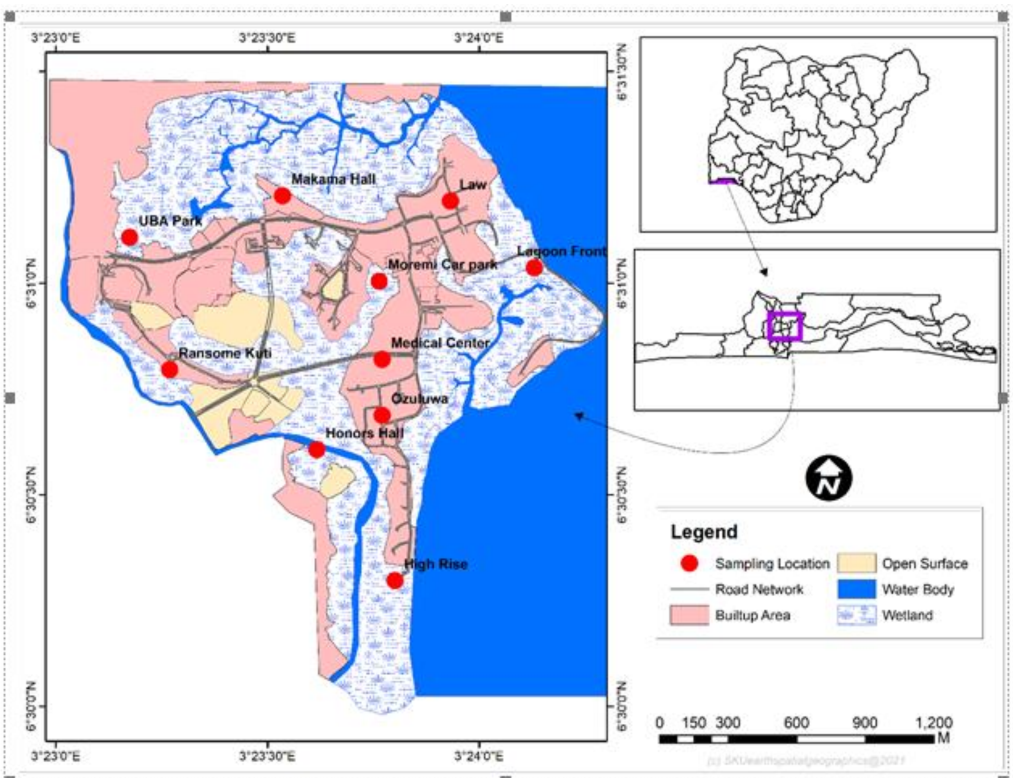

Figure 1: GIS map of the study area showing sampling sites
Source: Remote Sensing & GIS Lab, Department of Geography, University of Lagos

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Sample collection and identification

Samples of the moss plant were collected from the selected sites within the study area at least 20m apart and 1-2m high from the wall of perimeter fences within the study area, in July 2021. Collection was done using a plastic spatula into plastic sample bottles, labelled accordingly and transported to the laboratory for further analysis. Collected moss samples were taken to the laboratory and identified by a bryologist at the University of Lagos. The moss species was identified to be *Dicranium scorparium* based on the leaf structure. *Dicranum* is a genus of haplolepideous mosses (Dicranidae). They are acrocarpous, forming loose to dense, upright tufts of unbranched or irregularly branched leaves. Shoots are commonly glossy-green in appearance. Stem leaves appear to be tapering to a long, fine tip. The plant height when outstretched appears to be about 5cm long and the stem leaves are about 5mm long. Individual leaves are falcate-secund, lanceolate-shaped and usually unistratose. They have entire to serrate leaf margins. It is characterized by the keeled leaf apex and its costa with 4 serrate ridges in the upper part of the leaf (Stagg *et al.* 2014).

Plate 1: The Moss plant (*Mnium hornum*)

Sample preparation and analysis

Moss samples were prepared for laboratory analysis by trimming the life-green portions of the total amount of moss harvested. The moss was dried in a thermostatic dry machine for 24h at 40^{0}C to remove its excess moisture content and ground it into a homogenous powder. Mineralization of moss tissue was done by subjecting the sample to three different acids (65% HNO_3, 37% HCl and 70% $HClO_4$) to identify the most appropriate digestion method to determine the content of Cd, Cu, Pb, Ni and Zn. To 1g of the powdered moss, 9ml of freshly prepared acids was added and boiled gently over a water bath at 95^{0}C for 4 – 5 hours until the sample had completely dissolved. During the digestion procedures, the inner walls of the beakers were washed with 2mLof deionized water to prevent loss of the sample. After mineralization, samples were left to cool to room temperature for one hour and filtered using Whatman filter paper into a 50mL flask and finally made up with distilled water (Baltrenaite *et al.* 2011).

The absorption metal contents of Cd, Cu, Ni, Pb, and Zn in the filtrate were determined by a Perkin Elmer atomic absorption spectrophotometer A Analyst 800 at the University of Lagos Central Research Laboratory. The analytical wavelengths used were 357.9nm for Cd, 324.7nm for Cu, 232.0 nm for Ni, 283.3 nm for Pb, and 213.9 nm for Zn.

Statistical Analysis

The data for heavy metal accumulation in *D. scorparium* were evaluated by descriptive analysis and presented using charts and tables. All analysis was done using IBM SPSS v. 27 (IBM Corp., NY, USA). The anthropogenic influence of the pollutants on the environment was calculated using the contaminant factor and geo-accumulation index.

Contaminant factor

The contamination factor (CF) is used to express the level of metal contamination. It is the ratio between the metal content in the samples to the background value of the metal. It is effective for monitoring the pollution over a period of time and calculated as follows:

$$CF = \frac{C_{heavy\ metal}}{C_{background}}$$

Where C_{moss} is the measured concentration of the metal in the plant sample in a sample site while $C_{background}$ is the plant samples collected from a clean site (control site). The scale for interpretation of results consisted of various categories according to the CF values as described by Jiang *et al.* (2018): C1 (CF < 1) indicating none contaminated; C2 (CF: 1–2) indicating contamination suspected; C3 (CF: 2–3.5) indicating slightly contaminated; C4 (CF: 3.5–8) indicating moderately contaminated; C5 (CF: 8–27) indicating seriously contaminated; C6 (CF > 27) indicating extremely contaminated.

The index of geo-accumulation, I_{geo}, was calculated using the following formula below:

$$I_{geo} = \frac{C_{moss}}{1.5C_{background}}$$

where $C_{moss}/C_{background}$ is the contamination factor. The factor of 1.5 is introduced to minimize the effect of possible variations in the background (Okedeyi *et al.* 2014). The scale for interpretation of results consisted of various categories according to the I_{geo} values as described by Yushin *et al.* (2020): I_{geo} <0 no contamination (I_{geo} 1); 0–1 slightly polluted (I_{geo} 2); 1–2 moderately polluted (I_{geo} 3); 2–3 moderately to severely polluted (I_{geo} 4); 3–4 severely polluted (I_{geo} 5); 4–5 severely to extremely polluted (I_{geo} 6); and I_{geo} > 5 extremely polluted (I_{geo} 7).

RESULTS

Distribution of Heavy metal in samples found in locations evaluated

The *Dicranum scoparium* species used in this research exhibited significant variation in the average levels of the metals across various sites in the study areas and the control location (Fig. 2). The most abundant heavy metal is Zn (11.950mg/L) followed by Pb (3.772 mg/L) while the least abundant heavy metal is Ni (0.558mg/L) (Table 2). The highest concentration of Zn was recorded at Ransome Kuti (25.65mg/L) while the least concentration was recorded at Lagoon Front (3.21mg/L). The highest concentration of Pb was recorded at UBA Park (5.72mg/L) and Honors Hall (5.66mg/L) whereas the least concentration was

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recorded at Lagoon Front (0.62mg/L). The highest concentration of Cu (1.66mg/L) was recorded at UBA Park while High Rise had the least concentrations of copper (0.13mg/L). The highest concentration of Ni was recorded at Faculty of Law (0.97mg/L) while Campus Car Park has the least concentration (0.11mg/L). Cadmium had its highest concentration at Moremi Car Park (9.25mg/L) and its least concentration at Ransome Kuti and Lagoon Front (0.43mg/L). The recorded heavy metal concentrations from the study sites were greater than concentrations at the control location. Comparing these values within each sampling site, the most polluted site in University of Lagos is Moremi Car Park with 35.488mg/L; 18.48% of heavy metals while the least polluted site was Lagoon Front with 5.650mg/L; 2.94% in this order Moremi Car Park (18.48%) > Ransome Kuti (16.46%) > Makama Hall (11.61%)> Honors Hall (9.72%)> Medical Center (9.40%) > Faculty of Law (9.26%) > UBA Park (7.88%)> Ozoluwa BQs (7.52%) > High Rise (6.64%) > Lagoon Front (2.94%) (Figs. 3&4). The recorded concentration of heavy metals are higher than the recommended limits of the United Nations Environmental Programme (UNEP) threshold permissible levels of heavy metals (Fig. 2) in all the study sites except Ni which was within the limit.

Table 2: Concentrations (mg/L) of some heavy metals in moss sampled in University of Lagos

Metal/Site	Cd	Pb	Ni	Cu	Zn
A	1.47	5.72	0.51	1.66	5.79
B	0.43	3.91	0.84	0.79	25.65
C	3.58	4.11	0.32	0.39	13.93
D	0.63	4.72	0.97	0.15	11.32
E	9.25	1.87	0.11	0.81	23.45
F	0.73	2.99	0.22	0.54	13.58
G	0.54	4.38	0.27	0.44	8.91
H	2.33	3.74	0.76	0.13	5.8
I	3.92	5.66	0.87	0.36	7.86
J	0.43	0.62	0.74	0.65	3.21
Ctrl	0.03	0.06	0.07	0.06	2.62

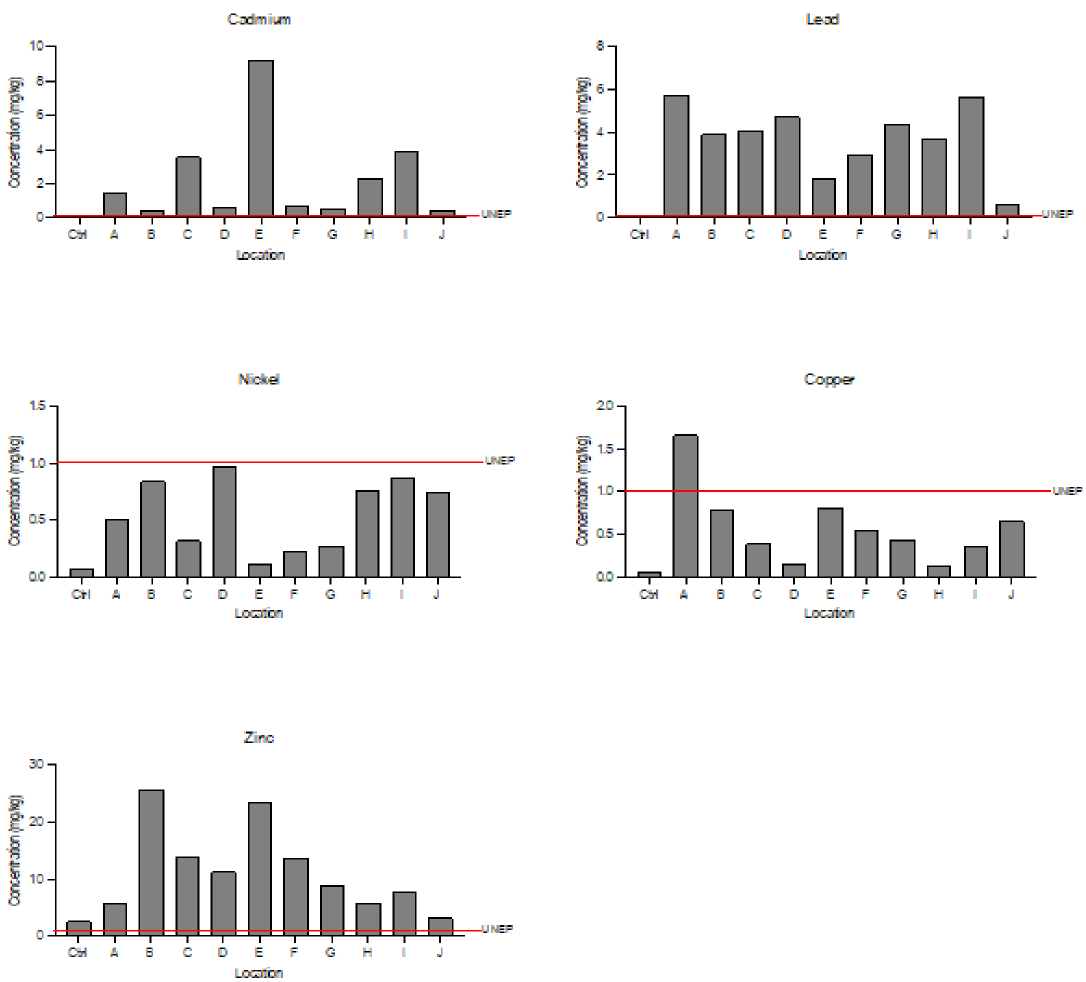

Figure 2. A comparison of heavy metals in mosses across the collection sites against control location (Ctrl= Control location, A=UBA park, B= Ransome Kuti hall, C=Makama hall, D=Faculty of Law, E=Moremi car park, F= Medical centre, G=Ozoluwa, H=Highrise bulidings, I=Honours hall, J= Lagoon front)

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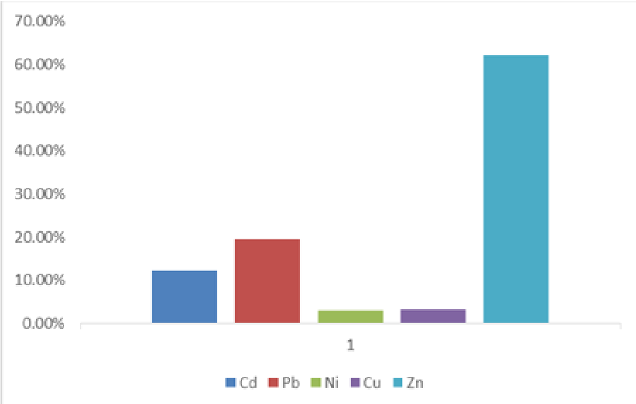

Figure 3: Percentage contribution of each heavy metal to the total atmospheric heavy metals in University of Lagos

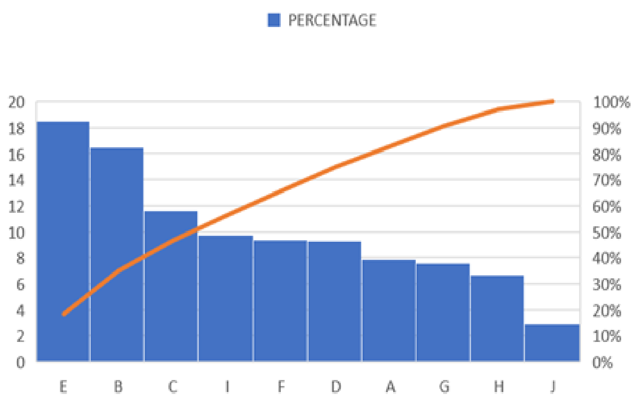

Figure 4: Percentage contribution of sites sampled to total heavy metals in University of Lagos

Contaminant Factor

The contaminant factor (CF_{moss}) of each metal in the studied locations is summarized in Table 3. Results revealed that Zn (4.24mg/L) despite its highest abundance is a moderate contaminant, Cu (9.37mg/L) is a severe contaminant while Pb (54.52mg/L) and Cd (78.58mg/L) are extreme contaminants in the studied locations. Comparing these CF values within the different study locations, locations B (Ransome Kuti), D (Faculty of Law), F (Medical centre), G (Ozoluwa) and J (Lagoon front) are seriously contaminated in the C5 category while locations A (UBA park), C (Makama hall), E (Moremi car park), H (High rise buildings), and I (Honors hall) has a CF value in the C6 category, indicating extreme contamination.

Table 3: Contamination Factor (CF) and different categories of contamination (as defined by the mean CF) for each heavy metal

Metals (mg/L)/ Site	Cd	Pb	Ni	Cu	Zn	Mean	Category
A	54.44	90.79	7.73	28.62	2.21	36.76	C6
B	15.93	62.06	12.73	13.62	9.79	22.83	C5
C	132.59	65.24	4.85	6.72	5.32	42.94	C6
D	23.33	74.92	14.70	2.59	4.32	23.97	C5
E	342.59	29.68	1.67	13.97	8.95	79.37	C6
F	27.04	47.46	3.33	9.31	5.18	18.46	C5
G	20.00	69.52	4.09	7.59	3.40	20.92	C5
H	86.30	59.37	11.52	2.24	2.21	32.33	C6
I	145.19	89.84	13.18	6.21	3.00	51.48	C6
J	15.93	9.84	11.21	11.21	1.23	9.88	C5
Mean	78.58	54.52	7.82	9.37	4.24		
Category	C6	C6	C4	C5	C4		

Index of Geo-accumulation

The I_{geo} results indicate different levels of contamination in the different study locations (Table 4). Zinc despite its highest abundance (2.82 mg/L) is the least contaminant while Cd (52.38 mg/L), Pb (36.35 mg/L), Ni (5.21 mg/L) and Cu (6.25 mg/L) are extreme pollutants in the study locations. In comparison, the index of geo-accumulation of heavy metal pollution in all the study locations are in the $I_{geo}7$ category indicating extreme pollution with the determined elements.

Table 4: Index of geo-accumulation values of the studied locations

Metals (mg/L) / Site	Cd	Pb	Ni	Cu	Zn	Mean	Category
A	36.30	60.53	5.15	19.08	1.47	24.51	$I_{geo}7$
B	10.62	41.38	8.48	9.08	6.53	15.22	$I_{geo}7$
C	88.40	43.49	3.23	4.48	3.54	28.63	$I_{geo}7$
D	15.56	49.95	9.80	1.72	2.88	15.98	$I_{geo}7$
E	228.40	19.79	1.11	9.31	5.97	52.91	$I_{geo}7$
F	18.02	31.64	2.22	6.21	3.46	12.31	$I_{geo}7$
G	13.33	46.35	2.73	5.06	2.27	13.95	$I_{geo}7$
H	57.53	39.58	7.68	1.49	1.48	21.55	$I_{geo}7$
I	96.79	59.89	8.79	4.14	2.00	34.32	$I_{geo}7$
J	10.62	6.56	7.47	7.47	0.82	6.59	$I_{geo}7$
Mean	52.38	36.35	5.21	6.25	2.82		
Category	$I_{geo}7$	$I_{geo}7$	$I_{geo}7$	$I_{geo}7$	$I_{geo}4$		

DISCUSSION

Moss plant is an important plant material that can accumulate heavy metals from the atmosphere (Cowden & Aherne, 2015; Jiang *et al,* 2018). *Dicranum scorparium* used in this research exhibited significant variation in the average levels of the metals in various sites in the study area. It can therefore be used for quantification and removal of heavy metals from the environment Graciela *et al.* (2013). The result of this research agrees with the results obtained in some Nigerian cities and showed that concentration of heavy metals depends on the nature of activities in the sites (Kakulu, 1993; Ite *et al.* 2014; Batagarawa, 2015; Ojiodu *et al.* 2016; Ojiodu & Olumayede 2018). The high significant levels of Zn, Pb and Cd obtained in the samples from the study locations of the University of Lagos Akoka campus is an indication of heavy metals presence in the atmosphere which could be as a result of both vehicular activities within and around the Campus, generator fumes, paint

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chips from walls of Buildings, use of cosmetics and metal dump (Ozaki *et al.* 2004; Adamiec *et al*. 2016). The low concentration of Cu and Ni suggest low contributing factors to their spread and as well as plant inability to preferentially accumulate these metals (Skorbiłowicz & Skorbiłowicz, 2019). The concentration of heavy metals in all the sites was higher than the control values. This may be due to the fact that the control environment is a swampy forest vegetation with little or no anthropogenic activity. In comparison with the locations surveyed, Moremi car park is the most polluted location this may be attributed to the high commercial, automobile and vehicular activities (Ozaki *et al*. 2004) in the area, spillage of petroleum products, smoking of cigarettes, paint chips from the walls of industrial buildings, careless discard of lead acid batteries used in automobiles, as well as the use of industrial grade and non-domestic waste from nearby construction. This result agrees with the work of Jiang *et al.* (2018) who reported that the least polluted location in the Huazhong Agricultural University (HZ) is exposed to minimal anthropogenic emission, surrounded by clear lakes and green hills with high vegetation cover. The concentration of heavy metals recorded in the study area were far greater than the recommended limits of the Federal Ministry of Environment (FME), European Communities (EC) and United Nations Environmental Programme (UNEP) permissible level for heavy metals in the atmosphere (EC, 2006). Since, there is a significant difference in the levels of heavy metals in the sampling sites; it shows that the heavy metals exert different influence on the atmosphere of the studied sites.

The use of geochemical indices such as contamination factor and geo-accumulation index is important for the assessment of the contamination status of an environment (Vergel *et al.* 2019; Rutkowski *et al,* 2020). The contamination factor (CF) helps to determine the contamination level of each metal in the location. The different categories of CF values indicate the level of pollutants in the environment. In this study, CF values ranged between C4 and C6 categories. Ni in Moremi car park was less than 2 indicating slight pollution. Conversely, the most abundant metal Zn is in the C4 category indicating moderate contamination. This can be ascribed to the multipurpose use of zinc in the form of zinc oxide present in paints, rubber tires, cosmetics, pharmaceuticals, wearing of brake lining, losses of oil and cooling liquids from automobile, corrosion of galvanized steels, scrap iron bars, and improper disposal of industrial waste in the area (Radziemska *et al.* 2019). Cadminium and Pb are the extreme pollutants in the environment. These results are at variance with Fernandez & Carballeria (2001) which indicated that Cu, Mn, Cd, Fe, Ni and Zn are associated with the C1 and C2 categories of contamination scales in Galicia North Spain. The Igeo data are somewhat correlating the CF values depicting all the examined locations are extremly polluted in the moss samples evaluated.

In conclusion, mosses have proven to be excellent indicators of atmospheric pollution, as they reflect metals concentration gradient and sources of deposition. The results of this investigation had shown that Zn, Pb, Cd, Cu and Ni contribute 62.22; 19.64; 12.13; 3.10 and 2.90% to the atmosphere of University of Lagos, Lagos State, Nigeria. Based on the results of the contamination indices (CF and I_{geo} values), the 10 selected study locations are severely to extremely polluted with the assay metals. It is therefore evident that the atmosphere of University of Lagos is highly polluted with the analyzed heavy metals. The high concentration of these heavy metals could be attributed to vehicular activities within and around the Campus, generator fumes, paint chips emanating from walls of buildings, use of cosmetics and metal dumps. Consequently, there is need for continuous environmental monitoring and management of the atmosphere of University of Lagos due to the high concentration of this metal pollution which could be very hazardous to the existence of humans and plants.

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