BIOMONITORING OF HEAVY METALS USING *Polytrichum commune* AS A BIOINDICATOR IN A MACROENVIRONMENT, LAGOS STATE, SOUTHWESTERN - NIGERIA

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Abstract: Mosses plants have proven to be excellent indicators of atmospheric pollution, as they reflect metals concentration gradient and sources of deposition. The major objective of this study is to investigate the concentrations of some metals (Zn, Pb, Cd, Ni and Cu) content in moss plant (*Polytrichum commune)* collected at different microenvironments within Yaba College of Technology Campus, Lagos state, Southwestern – Nigeria. The samples of the plant were collected randomly between September and November, 2016 at 10 different locations at the Campus between 2 - 2.5 metres high from unplastered buildings in Lagos state. The samples were properly cleaned from all the debris, weighed and digested with a mixture of $HN0_3$ and H_2O_2 for 35 min. The concentrations of heavy metals were analyzed by Atomic Absorption Spectrophotometer (AAS) Perkin Elmer AA 200. Results show that the average concentrations of the heavy metals at Yaba College of Technology Campus were Zn 12.711µg/g, Pb 1.174 µg/g, Cu 9.095 µg/g, Ni 3.626 µg/g, and Cd 0.086 µg/g. The most polluted site is Students affairs unit (6.532 µg/g) while the least polluted is Bakassi hostel (1.031 µg/g). The levels of some of the heavy metals were present in concentrations greater than WHO threshold limiting values.

Keywords: Anthropogenic, bioaccumulation, bioindicator, concentration, environment, **s**pectrophotometer

Introduction

Mosses are living organisms of the *plantae* kingdom and classified in the phylum *bryophyta.* They grow in forests, on rocks, on trees, bare soil, cracks of concrete side walls, on burnt bricks on abandoned automobiles, and uncompleted buildings (Adie *et al.*, 2014). They are effective atmospheric pollution bioindicators as they take up nutrients and pollutants directly from the atmosphere since they have no root (Ruta and Dainius, 2010). Some plant species have developed specialized mechanisms of accumulate and regulate metals in their parts. These plants are generally used as biomonitor for air pollution monitoring, because they can indicate the presence of elements and their concentration gradients.

Previous research works have shown that mosses have proven to be better bioindicators of pollution because they are more sensitive to atmospheric pollution (Kulartene and Defreitas, 2013). For example, Adebiyi and Oyedeji (2012) investigated using mosses grown in the localities as possible bioindicators to determine the level of heavy metals deposition in Ido-Ekiti, a sub-urban town and Ipere-Ekiti, a rural town. In another study, Ekpo *et al.* (2012) carried out a comparative study of the levels of trace metals in moss species in some cities of the Niger Delta Region of Nigeria where twelve trace metals were revealed. Their levels showed significant variation from metal and from location to location. This probably shows differences in the kind of anthropogenic activities in the region. Fatoba *et al.* (2012) assessed the particulate metals deposition around Lagos and Ogun states, Southwest Nigeria by passive bio-monitoring of the concentrations of elemental pollutants with the use of mosses. There are several mechanisms by which plants takes up metals from the atmosphere. These include accumulation in cell walls through ion exchange processes and metabolically controlled passage into the cells (Chakrabortty and Paratkar, 2006), association with pectin and chelation with oxalate crystal in the plant tissues.

Meanwhile, atmospheric metals pollution in Nigerian cities has been reported Ojiodu *et al.* (2016) reported that the atmosphere of Owode - onirin in Lagos - state, Southwestern, Nigeria is highly polluted with the heavy metals: Zinc Zn (66.01%), Lead Pb (15.99%), Copper Cu (12.79%), Chromium Cr (2.89%), Nickel and Ni (2.25%). A considerable number of other regional studies on heavy metal and other element concentration have been carried out using mosses, primarily in Europe (Reimann *et al.*, 2001; Grodzinska *et al.*, 2003) and in North America. Lambe *et al.* (2013) studied air pollution in Macedonia and reported the increasing trends in the elemental content in mosses are connected with anthropogenic sources, such as Cd, Pb, Ni and Zn, in the period from 2000 to 2005 except for Cr. Unfortunately, monitoring of air quality in major cities is becoming expensive, as the cost of air samplers is becoming unaffordable. Similarly, electricity supply in most parts of the country is erratic electricity. Therefore, there is need for alternate sampler that is of low cost, affordable, specific, sensitive and reliable. Moss plants have been selected for monitoring in this study because of its abundance in the environment. Heavy metals are important indicator of air pollution, because their concentrations correlate well with anthropogenic sources.

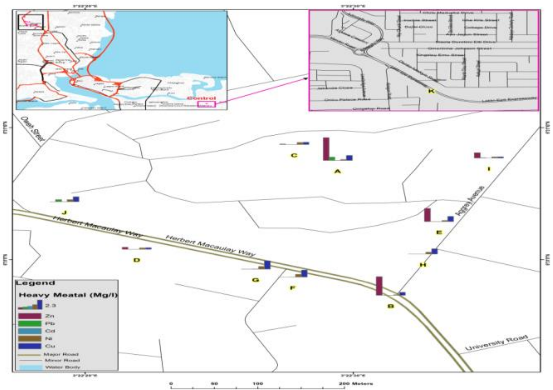
The objectives of this research are to investigate the distributions of some metals (Ni, Cu, Pb, Cr and Zn) in *Polytrichum commune* plants in microenvironments of Yaba College of Technology Campus. This is to establish uptake and bioaccumulation of metals by *Polytrichum commune* plant, thereby evaluate their potential use as indicator of air quality metal pollution in the atmosphere. It is hopeful that the study will provide baseline data on bioaccumulation of heavy metal (Ni, Cu, Pb, Cr and Zn) and determine whether there is a significant difference in the levels of heavy metals from one location to another within the study area.

Materials and Methods

Study area

Yaba College of Technology, the center for this study, is a cradle of higher education in Nigeria is situated in Yaba Local Government Area of Lagos State. It is located on longitude 03^0 22E and latitude 06^0 30N and bounded to the North by Fadeyi, to the South by Fola Agoro, to the East by Shomolu and to the West by Herbert Macaulay Way. The present students population is about 15,000 while the total staff (both Academic and Non- Academic) strength is about 1600. The Campus is structured into Academic and Residential areas, with facilities such as Banks, Eatries,

Business Centres, Dry Cleaning shops, Automobile workshops, Residential Buildings, Bukertaria, etc.
Ten sampling sites were carefully chosen in the area, to reflect activities in the areas and based on the following criteria: accessibility, availability of open spaces and of course areas with minimal influence from traffic as well as industrial activities. The sampling points were at least 300 m from main roads and 100 m from minor roads. The geo-referencing was carried out by using Garmin GPS MAP 76S.



A= Student affairs unit, **B =** Old bursary building, **C=** Bakassi hostel, **D=** Science complex, **E =** New environmental building; **F=** Administrative block; G= Automobile workshop, H= New food tech building, I = Medical centre; J =Staff residential quarters, K= Oniru (control).

Fig. 1: GIS map of Yaba College of Technology Campus showing the concentrations of heavy metals in *Polytrichum commune*

Sample collection

Airborne particulate

Suspended particulate matters were collected using SKC sidekick sampling pump 224 - 50. This instrument use Whatman membrane filters of 25 mm with a pore size of 3.0 um for filtration. The sampler operates at a nominal flow rate of 0 - 10.0 Lmin-1. A total of 1500 L/10 hr air was sampled for each sampling day. The loaded filters were stored in polyethene bags and taken to the laboratory for sample preparation and elemental analysis by Atomic Absorption Spectrophotometer.

Polytrichum commune

Samples of *Polytrichum commune* were collected from 10 sites within the studied area at least 10 metres apart, from September to November, 2016. Sampling and samples handling of mosses *Polytrichum commune was* carried out using hand gloves and polyethylene bags. The moss plant was chosen because it is widespread across Yaba College of Technology Campus and can be found in all parts of the study Area. Sampling below canopy of shrubs and large-leafed herbs was avoided (Plate I). Moss species were collected randomly between 2 - 2.5 metres high from unplastered perimeter fences within the sample area. The samples were collected using stainless steel trowel into polyethylene bags, labelled accordingly and transported to the laboratory for analysis.

Plate I: *Polytrichum commune*

Sample preparation and analysis

Samples of mosses (11) were cleaned from all debris (soil, leaves, and needles). In order to remove the moisture content of mosses, the samples were dried at 45^0C to a constant weight. After removal of moisture, samples were weighted again in order to calculate the real mass of sample (Blagnyte and Paliulis, 2010). Sample of the mosses (0.50 g) was mixed with a mixture of 10ml nitric acid (65%) and 2 ml of hydrogen peroxide (30%) and digested using hot plate for 35 min. After mineralization, samples were left to cool under room temperature for one hour, poured into 50 ml flasks and finally make-up with distilled water (Baltrenaite *et al.*, 2011).
Mineralization conditions do not allow the total digestion of mineral particles, therefore filtration was necessary. The heavy metal contents in the filtrate were determined by flame atomic absorption spectrophotometer (Perkin Elmer AA 200) using an air- acetylene flame. The analytical wavelengths used were 357.9 nm for Cr, 324.7 nm 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 *Polytrichum commune* were evaluated by analysis of variance (ANOVA) together with mean, standard deviation of each metal; T-test (IBM SPSS 23) was also performed to check the significant variation between metals and sites (Table 1).

Table 1: Concentration and standard errors of heavy metals (μg/g) in Polytrichum *commune* at Yuba College of Technology Campus and Oniru

Location	No.	Zn	Pb	Cd	Ni	Cu
		Mean + SD	**Mean + SD**	**Mean + SD**	**Mean + SD**	**Mean + SD**
Student Affairs Unit	6	4.628 + 0.365^{f}	0.676 + 0.227^{c}	0.011 + 0.001^{be}	0.051 + 0.078^{a}	0.898 + 0.417^{cd}
Old Bursary Building	6	3.786 + 0.226^{e}	0.001 + 0.001^{a}	0.001 + 0.0001^{a}	0.124 + 0.021^{ab}	0.617 + 0.470^{bc}
Bakassi Hostel	6	0.122 + 0.0122^{a}	0.001 + 0.0004^{a}	0.001 + 0.0001^{a}	0.428 + 0.184^{de}	0.325 + 0.352^{ab}
Science Complex	6	0.418 + 0.226^{b}	0.001 + 0.0005^{a}	0.005 + 0.003^{ab}	0.297 + 0.193^{bcd}	0.321 + 0.425^{ab}
New Environmental Building	6	2.671 + 0.226^{d}	0.001 + 0.001^{a}	0.001 + 0.0001^{a}	0.214 + 0.127^{abc}	1.055 + 0.054^{de}
Administrative Block	6	0.003 + 0.002^{a}	0.001 + 0.001^{a}	0.018 + 0.011^{c}	0.556 + 0.247^{e}	1.418 + 0.360^{ef}
Automobile Workshop	6	0.005 + 0.004^{a}	0.001 + 0.0004^{a}	0.043 + 0.016^{d}	0.543 + 0.217^{e}	1.706 + 0.158^{f}
New Food Tech Building	6	0.005 + 0.003^{a}	0.001 + 0.0004^{a}	0.001 + 0.0002^{a}	0.394 + 0.166^{cde}	1.088 + 0.497^{de}
Medical Centre	6	0.939 + 0.598^{c}	0.058 + 0.038^{a}	0.001 + 0.0004^{a}	0.241 + 0.112^{abcd}	0.241 + 0.079^{ab}
Staff Residential Quarters	6	0.005 + 0.004^{a}	0.426 + 0.128^{b}	0.007 + 0.004^{ab}	0.420 + 0.128^{de}	0.845 + 0.372^{cd}
Oniru	6	0.005 + 0.004^{a}	0.001 + 0.001^{a}	0.001 + 0.0003^{a}	0.213 + 0.118^{abc}	0.131 + 0.133^{a}
Test statistics		**$F_{10,55}$ = 302.095; p = 0.000**	**$F_{10,55}$ = 49.329; p = 0.000**	**$F_{10,55}$ = 27.957; p = 0.000**	**$F_{10,55}$ = 6.710; p = 0.000**	**$F_{10,55}$ = 13.593; p = 0.000**

Results and Discussion

The most polluted site is the Students affairs unit 6.532 µg/g while the least polluted site is the Bakassi hostel 1.031 µg/g (Fig. 2). Student affairs unit had the highest mean concentrations for Zn 4.628 µg/g and Pb 0.676 µg/g (Table 2). This is because it is exposed to constant heavy traffic and air pollution from car exhaust pipes and from the generator powering the hostels. It is not surprising that the Automobile workshop had the highest mean concentrations of Cd 0.043 µg/g, since automobile repairs and servicing are carried out here on a daily basis and fuel spillages are experienced. The high concentration of Copper 9.095 µg/g is associated with release from corroding metal parts derived from engine wear, brushing and metal bearing and also from lubricating oil, used automobile batteries (Table 2). The Administrative block (1.993 µg/g) also witnesses a variety of anthropogenic activities ranging from continuous vehicular movement from major road just behind the school fence, release of fume from generator sets all of which results in the high emission of these metals in the air. The most polluted heavy metal in the study area is Zinc (12.711 µg/g) while the least polluted is Cadmium (0.086 µg/g) (Table 2). The presence of Zinc is due to large deposit of weared brakes/tyre alloys, alloys of Zinc composite, corrosion of galvanized steels, scrap iron bars and improper disposal of waste and sewage in the study area. Similarly, the presence of Cadmiun and Nickel in these areas arises from combustion of fossil fuels, smelting of metals, vehicular emission, traffic congestion and various old paint chips. The mean value of Zinc measured at the Staff residential quarters, New food technology building, Administrative building, Automobile workshop and Bakassi hostel were not significantly different ($p \geq 0.05$) from Oniru site, while its value in all other locations were significantly different from that of Oniru site (Fig. 1). The mean value for Lead at the Student affairs unit and Staff residential quarters were significantly different from the Oniru while all other locations were not significantly different from it.

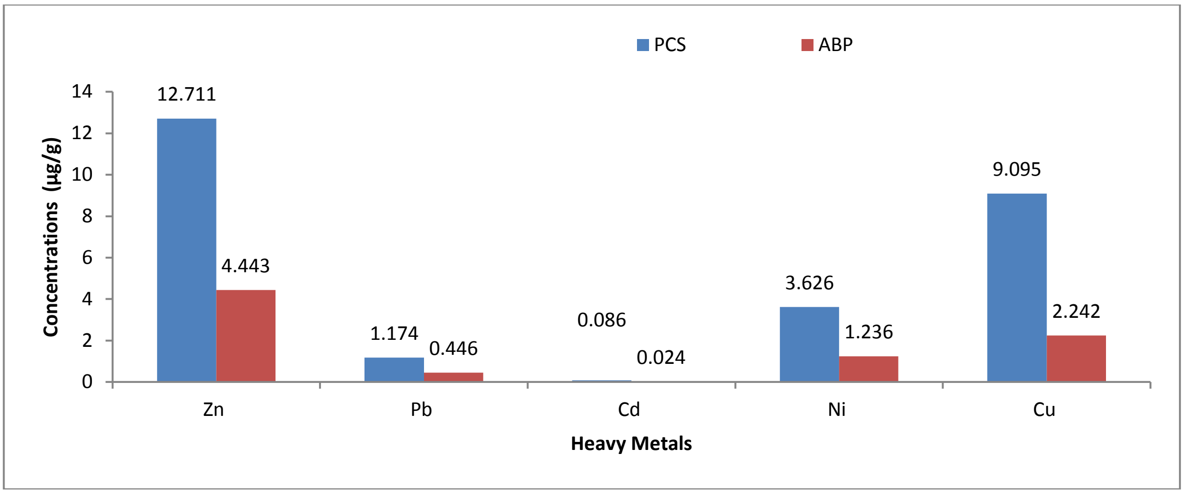
Table 2: Concentrations of heavy metals (µg/g) in *Polytrichum commune* specie at different locations of Yaba College of Technology Campus

S/N	Samples location	Zn	Pb	Cd	Ni	Cu
A	Student affairs unit	4.628	0.676	0.011	0.19	1.027
B	Old bursary building	3.786	<0.001	<0.001	0.124	0.616
C	Bakassi hostel	0.12	<0.001	0.001	0.428	0.482
D	Science complex	0.418	<0.001	0.005	0.297	0.317
E	New environmental building	2.671	<0.001	<0.001	0.214	1.06
F	Administrative block	<0.005	<0.001	0.019	0.556	1.418
G	Automobile workshop	<0.005	<0.001	0.043	0.543	1.709
H	New food tech building	<0.005	<0.001	<0.001	0.394	1.087
I	Medical centre	1.088	0.068	<0.001	0.247	0.262
J	Staff residential quarters	<0.005	0.43	0.007	0.42	1.01
K	Oniru (control)	<0.005	<0.001	<0.001	0.213	0.106
	Total	**12.711**	**1.174**	**0.086**	**3.626**	**9.095**

Table 3: Concentrations of heavy metals (µg/g) in airborne particles at different locations of Yaba College of Technology Campus

S/N	Samples location	Zn	Pb	Cd	Ni	Cu
A	Student affairs unit	2.236	0.239	0.004	0.061	0.037
B	Old bursary building	1.287	<0.001	<0.001	0.044	0.205
C	Bakassi hostel	0.037	<0.001	<0.001	0.116	0.110
D	Science complex	0.128	<0.001	<0.001	0.073	0.106
E	New environmental building	0.453	<0.001	<0.001	0.071	0.325
F	Administrative block	<0.001	<0.001	<0.004	0.174	0.436
G	Automobile workshop	<0.001	<0.001	0.019	0.178	0.503
H	New food tech building	<0.001	<0.001	<0.001	0.113	0.301
I	Medical centre	0.297	0.022	<0.001	0.087	0.075
J	Staff residential quarters	<0.001	0.177	0.002	0.148	0.033
K	Oniru (control)	<0.001	<0.001	<0.001	0.171	0.031
	Total	**4.443**	**0.446**	**0.024**	**1.236**	**2.242**

Furthermore, the mean values of Cadmium at Old bursary building, Bakassi hostel, Science complex, New environmental building, New food technology building, Medical centre and staff residential quarters were not significantly different from that of Oniru while the rest were (Table 1). The mean value of Nickel at Bakassi hostel, Administrative block, Automobile workshop and Staff residential quarters showed significant difference from the Oniru while values for the other locations were not. Also, the mean value of Copper at Belasis hostel, Science complex and Medical centre did not significantly differ from that of Oniru while the remaining locations were significantly different ($p \leq 0.05$). The mean value of Nickel at Bakassi hostel, Administrative block, Automobile workshop and Staff residential quarters showed significant difference from the Oniru while values for the other locations were not. Also, the mean value of Copper at Bakassi hostel, Science complex and Medical centre did not significantly differ from that of Oniru while the remaining locations were significantly different (Table 1). The *Polytrichum commune* specie used in this research exhibited significant variation in the average levels of the metals with various sites in the study areas (Plate 1). There were progressive increases in the levels of bioaccumulation from September to November (Table 2). This may account for the persistent anthropogenic activities within Yaba College of Technology Campus (Table 1). The average levels of Zinc, Lead, Cadmium and Nickel are significantly different in different sites ($p \leq 0.05$), while the average levels of Copper in each of the sites is not significantly different ($p \geq 0.05$) (Table 2). The total average abundance of each metal and in each location was in the following order: Zn > Cu > Ni > Pb > Cd (Table 2). To make clearer the picture of metal contamination, the contamination factor was calculated from the quotient of metal concentration in *Polytrichum commune* and at Oniru site. Table 4 presents the mean bioaccumulation quotient of metals, as observed in this study. This quotient which expresses the present situation in relation to an unpolluted condition revealed that all metals were above unity in all the studied sites (Table 3). As can be observed, Zn has the highest value. Fig. 2 depicts the concentrations of metals in airborne particles and in moss plants in our studied area. As can be observed the concentrations in moss plant is about 3 times higher than those in the airborne particles in all the sites (Table 2 and 3).



PCS= Heavy metals in *Polytrichum commune;* ABP= Heavy metals in Air borne particles

Fig. 2: A comparison of the metal concentrations in airborne dust sample and the moss plant in the area

Table 4: Mean bioaccumulation quotient of the heavy metals (µg/g) in *Polytrichum commune* at Yaba College of Technology Campus

Sites	Zn Mean±SD	Pb Mean±SD	Cd Mean±SD	Ni Mean±SD	Cu Mean±SD
Student affairs unit	2.922 ± 1.22	1.274 ± 0.34	0.186 ± 0.74	0.826 ± 1.67	0.285 ± 2.56
Old bursary building	2.713 ± 0.65	1.190 ± 2.23	0.086 ± 1.99	0.626 ± 0.43	0.105 ± 1.08
Bakassi hostel	2.323 ± 23.98	1.076 ± 0.05	0.067 ± 2.97	0.420 ± 2.52	0.095 ± 3.98
Science complex	2.712 ± 0.78	1.180 ± 1.32	0.087 ± 0.45	0.624±1.87	0.095 ±0.02
New environmental building	2.565 ± 1.25	1.118 ±0.04	0.077 ± 0.099	0.622±1.93	0.066±0.01
Administrative block	2.456±0.58	1.121 ±0.04	0.075±0.089	0.620 ±0.95	0.072±0.02
Automobile workshop	2.643±0.67	1.232±0.06	0.089±0.091	0.627± 0.25	0.076±0.03
New food tech building	2.564±1.23	1.344±0.05	0.084±0.070	0.619±0.83	0.087±0.02
Medical centre	2.332±1.09	1.1111±0.04	0.083±0.01	0.611±1.34	0.077±0.01
Staff residential quarters	2.345±1.11	1.2333±0.05	0.082±0.01	0.601±0.48	0.073±0.01
Oniru (control)	1.000 ±0.01	1.000±0.01	1.000±0,01	1.000±0.01	1.000±0.01

This finding is similar to that of Sa'idu (2015) and Ojiodu *et al.* (2016) who reported that the atmosphere of Owode-onirin in Lagos- state, Southwestern, Nigeria is highly polluted with the heavymetals: Zinc Zn (66.01%), Lead Pb (15.99%), Copper Cu (12.79%), Chromium Cr (2.89%) and Nickel Ni (2.25%). The trend in the levels of total atmospheric heavy metals in the study were: Student affairs Unit > Old bursary building > New environmental building > Automobile workshop> Administrative block > Staff residential quarters > Medical centre > New food tech building > Science complex > Bakassi hostel > Oniru (Fig. 1). All concentrations of the metals detected were higher than the Oniru site (Table 1). Levels of Zn, Pb, Cd, Ni and Cu were present in concentrations greater than WHO (2001) threshold limiting values. However, some of the heavy metals were within. Furthermore, the levels of Zn, Pb, Cd, Ni and Cu in all the sites 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. There is a significant difference in the level of each heavy metals within each of the sites ($P_{value} < 0.05$) (Table 1).

Conclusion

Since, Zn, Pb, Cd, Ni and Cu contributes 47.62, 4.40, 0.30, 13.59 and 34.08% to the atmosphere of Yaba College of Technology Campus. It is evident that the atmosphere of Yaba College of Technology Campus is highly polluted with heavy metals. The high concentration of this heavy metal could be attributed to the presence of large number of petrol and diesel generators, improper disposal of waste and sewage, vehicular and commercial activities within and around Yaba College of Technology Campus. Therefore, there is need for constant environmental monitoring, safety and management of atmosphere of Yaba College of Technology Campus.

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