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Comparative Study on the Use of a Moss Species,*Barbulalambaranensis* C. Mull and leaves of a Vascular Plant, *Peperomiapellucida* (L.) Kunth for Biomonitoring Heavy Metal Pollution Around Some Major Roads in Ado-Ekiti, Nigeria.

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ABSTRACT

The bioaccumulation capacities of two bioindicators, a moss species, *Barbulalambaranensis* and leaves of a vascular plant, *Peperomiapellucida*for heavy metals were investigated and compared. Samples of the moss and leaves of*Peperomiapellucida* were collected around seven major roads in Ado-Ekiti, Ekiti State, Nigeria. In each location, three subsamples were taken. Samples were then subjected to wet digestion and the concentrations of Pb, Cd, Cr, Fe, Ni and Cu in the digested samples were analysed using a Flame Atomic Absorption Spectrophotometer. The results of the study showed variations in the concentrations of the heavy metals among the locations. Pb, Cd and Cr were below detection limits in the leaves of *Peperomiapellucida* while Cd was below detection limit in moss samples. Pb was below detection limits in mosses collected from some locations. The concentrations (mg/kg) of Fe, Ni and Cu in the leaves of *Peperomiapellucida* varied from 360.73-1930.33, 0.45-3.12 and 22.05-28.03 respectively while the concentrations of Pb, Cr, Fe, Ni and Cu in moss samples varied from 1.02-2,07, 0.75-6.13, 1118.67-7480.05, 1.80-6.28 and 14.79-28.03 respectively. The present study showed that the moss species,*Barbulalambaranensis* was more suitable than the leaves of the vascular plant, *Peperomiapellucida* in monitoring atmospheric heavy metal pollution in the study area.

Keywords: moss species, vascular plant, biomonitoring, heavy metals, Ado-Ekiti

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INTRODUCTION

Mosses are cryptogams that thrive in a humid climate. There are about 15000 species of mosses known worldwide, growing on a variety of substrates in different ecosystems [1]. The method of utilizing mosses as bioindicators was applied more than three decades ago [2] and today, it is a widely accepted method for estimation of atmospheric depictions of metals [3]. They possess many properties that make them suitable for monitoring air pollutants [4]. Some of these include ability to obtain nutrients from wet and dry deposition, lack of real roots which make them depend solely on the atmosphere for minerals, possession of weakly developed cuticle which promotes nutrient uptake from the atmosphere (this makes it easy for metal ions to penetrate the cell wall), large surface to weight ratio and their ability to grow in groups. Other properties include a slow growth rate, small size, ease of sampling and handling, lack of vascular bundles which limits transport of minerals between segments, perenniality, wide distribution, ability to survive in highly polluted environment, minimal morphological changes during their lifetime and possibility of determining concentrations in the annual growth segments [5, 6]. Several researchers have successfully used mosses to assess heavy metal distribution [7-9].

Peperomiapellucida is an annual, shallow-rooted herb usually growing to a height of about 15 to 45 cm. It is characterized by succulent stems, shiny, heart-shaped fleshy leaves and dot-like seeds attached to several fruiting spikes. The use of higher plants, especially different parts of trees (leaves and barks) for monitoring air pollution is becoming more and more widespread. The main advantages include greater availability of the biological material, ease of species identification, sampling and treatment and the ubiquitous nature of some genera which makes it possible to cover large areas. Higher plants also have greater tolerance to environmental changes which is very important for monitoring areas with elevated anthropogenic influences [10]. Leaves of higher plants have been used for heavy metal biomonitoring since 1950s [11]. The use of leaves as bioindicators of environmental pollution has been studied more frequently to assess their suitability, to assess the effect of a particular pollution source, to differentiate between background and polluted sites and to assess the level of pollution in an area [12].

Monitoring and management of air pollution have been carried out for a long time and remain prevalent [13]. Presently, the main tools used to assess air pollution in urban areas are chemical monitoring and biomonitoring. Chemical monitoring is an active technique is an active method that gives an idea of trace – element atmospheric pollution only during the sampling time. It requires long- term sampling at a large number of sampling sites, hence, large number of deposition collectors are deployed. Also, the measurements require sophisticated equipment which is expensive.Moreover, there is lack of sufficiently sensitive and inexpensive techniques that permit the simultaneous measurement of many air contaminants [14]. In most remote areas, it is usually difficult to use air samplers due to lack of electricity. Thus, bio monitoring is the one and only solution.Biomonitoring methods in combination with chemical analyse have been extensively researched in recent years [15 - 17].

Ado-Ekiti, the capital of Ekiti State is not much industrialized hence the major sources of heavy metals particularly along the roadsides are likely to be automobiles and fossil fuel combustion. Other likely anthropogenic influences may include pockets of small scale industrial activities and incineration of domestic wastes. The major roads would therefore be suspected to have been contaminated by heavy metals commonly associated with the aforementioned sources. However, whether mosses or vascular species are more applicable in monitoring air pollution in Ado-Ekiti has not been determined.

Consequently, this study was designed to compare the bioaccumulation capacities of two bioindicators, a moss and leaves of a vascular plant around some major roads in Ado-Ekiti, Nigeria.

MATERIALS AND METHODS

Collection and Identification of Samples

Barbulalambaranensis and *Peperomiapellucida* were collected from seven major roadsides in Ado-Ekiti, Ekiti State, Nigeria. The two plants were found growing in very close association in all the locations. The characteristics of the sample locations are shown in Table 1. The plants were authenticated at the Herbarium of the Department of Plant Science and Biotechnology, Ekiti State University, Ado Ekiti, Nigeria. In each location, three subsamples were collected. The moss, *Barbulalambaranensis* is the most abundant moss species in Ekiti State [18]. Moss samples and leaves *of Peperomiapellucida* were stored in separate and sterilized nylon bags, labelled accordingly and taken to the laboratory for analyses.

Table 1: Sample locations and characteristics

Location	Longitude/E	Latitude/N	Altitude (m)
Fajuyi road	7^{0}30'2280.49	5^{0}12'775.47	466
Ajilosun road	7^{0}36'2205.65	5^{0}13'804.43	450
Irona road	7^{0}37'2222.07	5^{0}13'782.50	463
Odo Ado road	7^{0}37'2238.90	5^{0}13'812.45	458
Adebayo road	7^{0}39'2355.83	5^{0}13'842.28	412
Old garage	7^{0}37'2238.90	5^{0}13'812.45	458
Basiri road	7^{0}35'2240.45	5^{0}12'738.31	447

Chemicals

All chemicals used in this study were of analytical grade.

Sample Pretreatment and Digestion

Litters, dead materials and soil particles were manually removed from the moss samples. The green or greenish-brown parts of the moss samples as well as the leaves of *Peperomiapellucida* were then cleaned of dust particles with deionized water. Samples were then oven-dried to a constant weight for 48 hours at 40^{0}C. They were then ground into fine powder in a mill.Wet digestion of the samples was applied as follows: 1 g of the ground sample was weighed into a pyrex beaker and 10 ml of conc. HNO_3 was added and allowed to soak for 30 mins. Then, 3 ml of 60% perchloric acid was added. This was placed on a hot plate and heated at 350^{0}C until frothing stopped and HNO_3 almost evaporated. Then, a watch glass was placed on the beaker and heating continued until the sample turned light straw in colour. This was then removed from the hot plate and cooled. Then, the watch glass was rinsed into the sample and it was filtered into 100 ml volumetric flask and made up to the mark with distilled water.

Determination of Heavy Metals in Digested Samples

Digested samples were analysed for Pb, Cd, Cr, Fe, Ni and Cu using Atomic Absorption Spectrophotometer, Buck Scientific Model 210 equipped with a continuum source background correction and attached to a computer. These metals were chosen according to the significance of their presence in environments [19].

RESULTS AND DISCUSSION

The ranges of the heavy metal concentrations in the moss species, *B. lambaranensis* and the leaves of the vascular species, *P. pellucida* are presented in Tables 2 and 3 respectively. In moss samples, Pb ranged from 1.02 to 2.07 mg/kg with a total mean value of 0.61 mg/kg. It was however below detection limits in some locations. Cr ranged from 0.88 to 6.13 mg/kg with total mean value of 2.21 mg/kg. The concentration of Fe was between 1118.67 and 7480.05 mg/kg and its total mean value was 3409.05 mg/kg. Ni concentration ranged between 1.80 and 6.28 mg/kg and its total mean value was 3.56 mg/kg while Cu concentration varied between 14.79 to 28.03 mg/kg with a total mean of 20.37 mg/kg. The concentration of Cd was below detection limits in all the locations. In the leaves of *P. pellucida*, the concentrations of Pb, Cd and Cr were below detection limits in all the locations while the concentrations (mg/kg) of Fe, Ni and Cu ranged between 360.73-1930.33, 0.45-3.12 and 22.05-28.03 respectively. The total mean values of Fe, Ni and Cu were 784.24 mg/kg, 1.32 mg/kg and 25.75 mg/kg respectively. These ranges were lower than reported ranges [20, 21]. The major source of these heavy metalswas suspected to be traffic emissions sinceall the samples were collected from roadsides. However, there could also be contributions from other anthropogenic activities such as fossil fuel combustion, incineration of domestic wastes, bush burning and pockets of small scale industrial activities along the roadsides. It has been reported that the introduction of heavy metals into the environment results from different domestic and industrial activities, automobiles, fossil fuel combustion, power stations,dead and decomposing animals, as well as fall out of atmospheric particulates [22 - 25]. Cd mainly spread to the environment through emissions from metal industry [26]. The absence of such industry in the study area may be responsible for the absence of Cd reported in this study.

Results of the present study revealed significant variations in the concentrations of the heavy metals among the locations. This could be attributed to variations in anthropogenic influence particularly traffic density around the locations [27, 28].

The total average abundance of each metal in the moss samples was in the following order: Fe>Cu>Ni>Cr>Pb>Cd while it was Fe>Cu>Ni>Pb, Cr, Cdin the leaves of *P. pellucida.*This abundance may be attributed to the level of their concentrations in the atmosphere or variations in the uptake efficiency of mosses for different metals [29].

In the present study, it was revealed that the concentration of Pb and Cr were below detection limits in the leaves of *P. pellucida* while they were detected in the moss samples. Furthermore, the concentrations of Fe and Ni were significantly higher in mosses than in the leaves of *P. pellucida* though there was no significant difference in the concentration Cu between the two plants (Table 4). A comparison between the concentrations of Fe, Ni and Cu between the moss samples and leaves of *P. pellucida* is shown in Fig 1 & 2. The foregoing is an indication that the accumulation capacities of heavy metals by the moss were stronger than the leaves of the vascular species. This tends to be in consonance with a previous study in which heavy metals, Fe, Zn, Cu, Ni, Cd and Pb concentrations followed the order bryophytes> lichens > vascular plants [30]. Higher mean concentrations of heavy metals and some selected pollutants were also found in moss samples than other bioindicators such as soil, lichens and barks of pine trees [31 - 33]. The results obtained in the present study also agreed with this.

Table 2: Mean concentrations (mg/kg) of heavy metals in a moss species, *B. lambaranensis* collected at some major roads in Ado-Ekiti, Nigeria

Location	Pb	Cd	Cr	Fe	Ni	Cu
Fajuyi road	BDL	BDL	0.88e	5618.33b	3.02d	20.89c
Ajilosun road	BDL	BDL	0.75f	1639.67f	2.10f	22.03b
Irona road	1.02	BDL	6.13a	1118.67g	2.40e	18.00f
Odo Ado road	BDL	BDL	4.19b	2560.01d	4.20c	18.79e
Adebayo road	2.07	BDL	1.43c	3173.67c	5.12b	20.03d
Old garage	1.17	BDL	1.22d	7480.05a	6.28a	28.03a
Basiri road	BDL	BDL	0.88e	2273.03e	1.80g	14.79g
Mean±S.D.	0.61±0.81	0.00	2.21±2.02	3409.05±2187.50	3.56±1.60	20.37±3.89

BDL – BelowDetection Limit

Means with the same letters are not significantly different at $p< 0.05$

Table 3: Mean concentrations (mg/kg) of heavy metals in leaves of *P. pellucida* collected at some major roads in Ado-Ekiti, Nigeria

Location	Pb	Cd	Cr	Fe	Ni	Cu
Fajuyi road	BDL	BDL	BDL	1019.33b	1.20c	28.03a
Ajilosun road	BDL	BDL	BDL	440.06d	0.98d	26.04b
Irona road	BDL	BDL	BDL	1930.33a	2.10b	28.03a
Odo Ado road	BDL	BDL	BDL	382.33e	0.60f	24.02c
Adebayo road	BDL	BDL	BDL	430.21d	0.45g	26.04b
Old garage	BDL	BDL	BDL	360.73e	3.12a	22.05d
Basiri road	BDL	BDL	BDL	927.67c	0.76e	26.05b
Mean±S.D.	0.00	0.00	0.00	784.38±544.73	1.32±0.91	25.75±2.02

BDL – Below Detection Limit

Means with the same letters are not significantly different at $p < 0.05$

Table 4: t-Test

Fe	Group level	N	Mean	SD	Df	t-cal	Pr> t
	Leaves	21	784.2381	544.73	22.47	-5.336	<.0001
	Mosses	21	3409.048	2187.50			
Cu	Group level	N	Mean	SD	Df	t-cal	Pr> t
	Leaves	21	25.74952	2.024	30.07	5.622	<.0001
	Mosses	21	20.36571	3.894			
Ni	Group level	N	Mean	SD	Df	t-cal	Pr> t
	Leaves	21	1.315714	0.9139	31.77	-5.576	<.0001
	Mosses	21	3.56	1.6022			

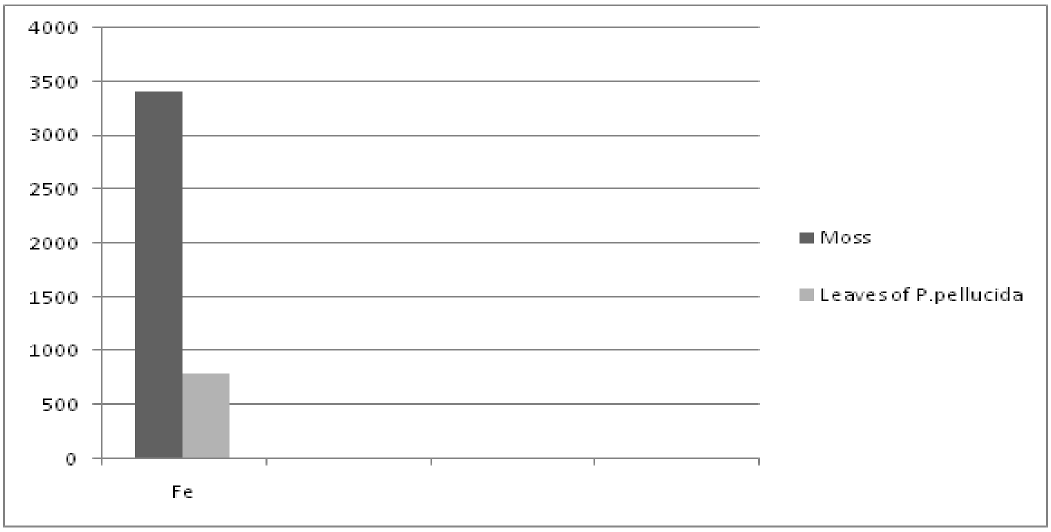

Figure 1: Comparison of Fe concentration (mg/kg) in moss and leaves of *P. pellucida*

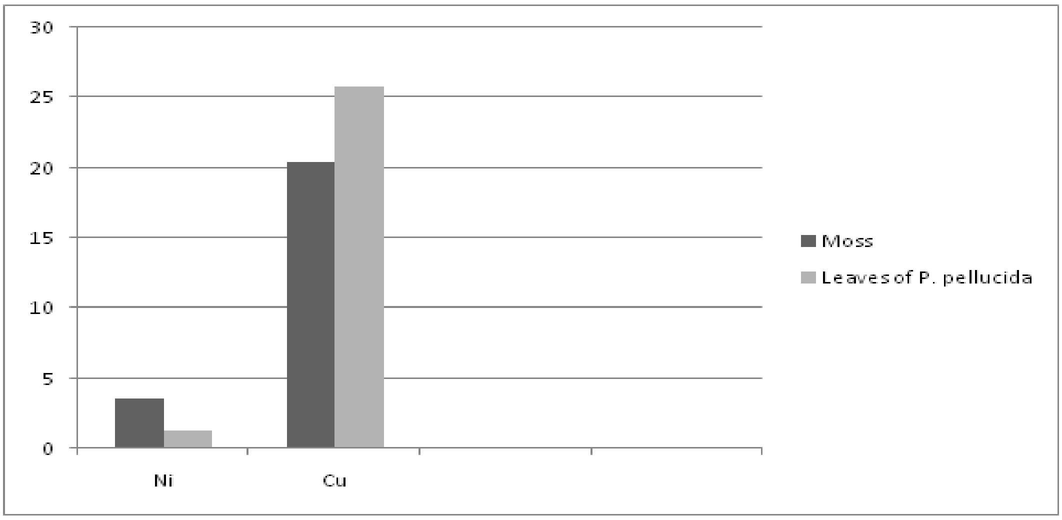

Figure 2: Comparison of Ni and Cu concentrations (mg/kg) in moss and leaves of *P. pellucida*

CONCLUSION

The results of the present investigation confirm the presence of heavy metals around the major roads in Ado Ekiti, Nigeria particularly in the atmosphere as revealed by moss analysis.This suggests pollution as they are supposed to be in the soil in form of their salts. Higher metal concentrations were observed in the moss species, *B. lambaranensis* than the leaves of the vascular species, *P.pellucida*. This indicated the heavy metal accumulation capacity of mosses. This result indicated that the moss species was more suitable than the leaves of the vascular plant for monitoring atmospheric heavy metal pollution in the study area.

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