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Lichens as Bio-Identity Tool for Monitoring Atmospheric Heavy Metal Deposition in Industrial and Urban Environment

Obiakor, M.O[1]* and Ezeonyejiaku, C.D[2]

[1]GreenPlanet Integrated Resources, Lagos, Nigeria.
[2] Departments of Zoology, Nnamdi Azikiwe University, PMB 5025, Awka, Anambra, Nigeria.

*Corresponding Author: maxiugobiks@yahoo.com

Abstract: Heavy metal pollution has been a major concern to the society. The rate of exposure to this pollutant is alarmingly on the increase with its attendant public health risk. The aim of the study was to investigate the atmospheric deposition of heavy metals in an important semi-industrialized and sparsely populated area of Okpuno Awka, Southeastern Nigeria using lichens as biomonitor. The area being close to a traffic highway has also been on extensive differential stress of the highway rehabilitation and reconstruction for nearly five years now. Epiphytic foliose-lichens of family Parmelia were sampled from four different representative stations of various landuses covering industrial, small-scale agriculture, and urban areas (residential and roads). The lichen samples were analyzed for Hg, Pb, As, Cd, Cu, Cr, and Zn using atomic absorption spectrophotometer. Hg was not detected in all the stations observed. As was observed to be highest in concentrations compared to other metals. Appreciable quantities of some heavy metals detected in the lichens indicated atmospheric contamination. The study clearly demonstrated the effectiveness and low cost validated methodology of using lichens as biomonitor in atmospheric environmental monitoring and calls for proper implementation of environmental plans to reduce the accelerating trend of dangerous metals in the atmospheric environment. Further work is encouraged on determining the levels and distributions of heavy metals especially As, Cd, Cr, and Zn in the air as the present concentrations raise alert code.

Keywords: Foliose-epiphytes, Biomonitor, Air pollution, Bioaccumulation

INTRODUCTION

Lichens have been defined as 'permanent control system' for air pollution assessment [1]. Because of high sensitivity and ability to store contaminants/ pollutants in their biological tissues, lichens and other epiphytic cryptogams are defined as effective biomonitors of atmospheric depositions. Lack of root systems and surface morphology in lichens make its contaminant contents depend on surface absorption [2]. Characteristically, lichens are slow-growing and long-lived, and they have an extremely broad distribution [3], an ideal suitable to provide environmental insight.

Environmental monitoring of heavy metals has bordered largely on water and wastewater making airborne types apparently less important. Direct exposure to air increases the impact risk of these atmospheric contaminants to the living organisms but the complexity in evaluating the quantities and potential harm to biological systems validate the use of effective ubiquitous bioindicators. In the context of pollution monitoring, which uses naturally occurring lichens at monitoring sites, measuring the bioaccumulation of the pollutants in the thallus provides the environmental quality status[1].

According to studies of Kansanen and Venetvaara [4], lichens and mosses are the most effective indicators for low and moderate level of metal deposition in polluted areas. It was found that concentrations of Pb, Fe, Cu, Cr, and Zn in lichen (Hypogymnia physodes) correlated strongly with annual average atmospheric deposition [5]. Accordingly, Balabanova et al. [6] while biomonitoring the air of a copper mine vicinity of eastern part of the Macedonia using lichen species, Hypogymnia physodes and Evernia prunastri, reported high Cu content of 130mg/kg. The authors further documented that lichen thallus showed high retention power of accumulation of the sampled elements compared to moss species. Kapu et al. [7] found that the heavy metal content of foliose- epiphytic lichens was related to the highway aerial dispersion and residential emissions in Zaria of Northern Nigeria.

Taking into account the above literature reports, the current study attempts to assess the atmospheric deposition of heavy metals in a semi-industrial and sparsely residential environment based on lichen survey.

MATERIALS AND METHODS

Study Area: The study was developed in semi-industrial and residential area of Okpuno, Awka South of Ananmbra State located at the Southeast of Nigeria (Figure 1). The area has important industrial facilities such as plastic and pharmaceutical plants. The area is sparsely populated with most residential buildings located far inland from the industrial segment, though scanty clusters of residential buildings were notices around it. The residential houses could be spotted in the area with network of roads. Below are the spatial characteristics of the various sampled stations at the study area during the experimental tour;

Station 1: This site encompasses huge plastic industries of various products and wastes ranging from wastewater to atmospheric input. Smoke could be notices billowing into the air from the smoke-stacks and surrounding attached mini plants.

Station 2: This position has pharmaceutical industries in it. Atmospheric discharges were also witnessed from the premises.

Station 3: Here, some residential buildings were sighted and retreat center located. Road networks were observed leading to various houses and inland.

Station 4: This is a stretch of road leading to a popular 'Y' junction. Small scale agricultural landuses were noticed and few grass covers along the roads observed. The road stretches along to in-residential areas through station 3. Vehicles were consistently notices plying the road. Heavy traffic was noticed in the evening the proximity of station 1 and 2 to the state's major traffic highway is between 20-30 meters.

Collection of Lichen Samples: Samples of foliose lichen species of the family Parmeli were collected along the study area at various stations from trees and roof-tops. These lichen species are characteristic for the flora of the area and can be effectively used as biomonitors for the atmospheric history of the location.

The lichen sampling protocol was performed according to the set standard rules for collection of such samples and was performed in the following order: one sampling station /spot was formed by collecting five subspots in an area of 50 x 50 m2. Lichen samples were collected using polyethylene gloves to prevent any further sample contamination. The collected material was stored in paper bags. After it was cleaned from other plant species and soil, individual plant samples were separated and air dried for several days [8]. Lichen samples were collected at four stations. Five composites of the epiphytic foliose lichen samples were taken from each station. The sample preparations and analysis were carried out according to method described by Kapu et al. [7]and slightly modified in the present study.

Samples Preparation and Analysis

6g of the lichen samples were dried to constant weight at 600C in a hot air oven and cooled in desiccators. The dry material (3g) was then ashed in a muffle furnace for 6 hrs at 4600C, and the ash was cooled in desiccators for 24 hrs. The ashed samples were digested for 3 hrs on a hot plate at 850C using 20ml of a 1:1 (w/v) hydrochloric acid: water mixture. The digests were extracted using deionized water and filtered into 25ml polyethylene bottles. The concentrations of Hg, Pb, As, Cd, Cu, Cr, and Zn (ppm) were determined in triplicate by atomic absorption spectrophotometer (Perkin model). Standards containing known amount of these metals and blank samples were subjected to the same procedure to estimate recovery rates and to check for contamination. The average recovery was 96-97%. Standard solutions of metals were prepared by dilution of 1000 mg/L.

Statistics: Descriptive statistics were employed to show the distributions of the heavy metal concentrations at different station of the study area. To compare the mean of the heavy metal values in lichens, one-way analysis of variance in completely randomized design was evaluated and separation of means done using Duncan’s Multiple Range Test (DMRT). Significant level was accepted at the alpha error of 0.0.5.

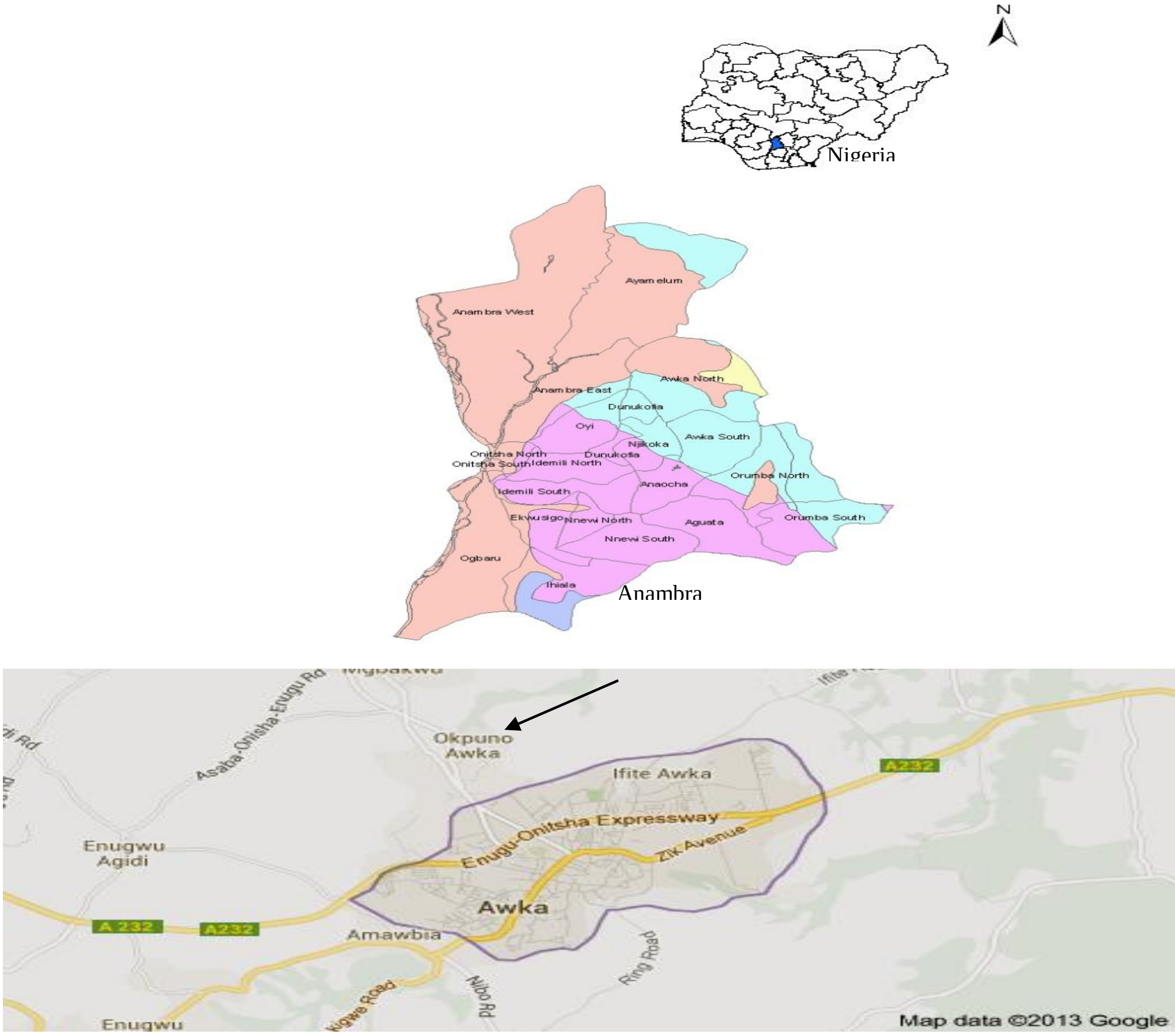

Figure1: Map of Awka showing the study location (arrow)

RESULTS

Table1presents the concentrations and distributions of heavy metals measured in lichen samples at different stations of the study location. There were random variations in the concentrations of the heavy metals observed. Hg was not detected in all the sampled stations.

Table 1. Concentrations and distributions of heavy metals measured in lichen samples at different stations of the study location

Stations	Heavy Metals (ppm)					
	Pb	As	Cd	Cu	Cr	Zn
1	ND	9.400^{d} ± 1.052	2.769^{a} ± 0.684	0.475^{b} ± 0.037	0.487^{b} ± 0.028	4.987^{c} ± 0.699
2	0.01 + 0.005	5.536^{c} ± 0.540	0.630^{b} ± 0.039	0.840^{a} ± 0.051	0.784^{a} ± 0.023	9.523^{a} ± 0.608
3	ND	18.940^{b} + 0.253	0.189^{c} ± 0.043	0.163^{c} ± 0.026	0.446^{b} ± 0.064	7.970^{b} ± 0.623
4	ND	28.612^{a} ± 0.697	ND	0.090 ± 0.024	ND	6.916^{b} ± 1.175

Mean values with superscripts along the same column are significantly different (P<0.05). ND: Not Detected

DISCUSSION

The current findings have validated epiphytic lichens as suitable biomonitor for aerial heavy metals and air quality. The random variations in the heavy metal concentrations detected in lichens sampled could be better explained by considerable number of factors associated with the site where lichens are growing, which may change the concentrations of the pollutants in the organism [9,10]. These factors are quality of the deposition (form of occurrence, composition, pH), climate (composition of precipitation, temperature, wind, drought, length of the growing period) and local environmental factors (vegetation, quality of the substrate, dust derived from soil and altitude of area). The biological nature and species of lichens might attest to their absorption capacities of elements and support the concentrations of the heavy metals observed in the present study. Balabanova et al. 6 had earlier reported the thallus of lichens absorbing higher quantity of the heavy metals sampled. Furthermore, in alternative hypothesis, unpredictable aerial dispersions of the pollutants might throw light on the observed accumulation and random variations in concentrations of the heavy metals at different stations of the study area.

Though we observed appreciable quantities of some heavy metals in current study but the concentrations of Pb, Cr, Cu, and Zn obtained were much lower than those reported by Augusto et al. [11] in Setubal Peninsula, one of the most industrialized and densely populated areas of Southern Portugal. The Cu values from the current study was lower than the values reported by Balabanova et al. 6 in copper mine vicinity of Macedonia Republic. The main source of Pb in the atmosphere is the automobile fuel, batteries industries and their use in pesticide manufacturing. In this study the Pb was accumulated in very less quantities in the lichen samples.

Apart from the industries (plastic and pharmaceuticals) located at the study area, other factors could be adding the pollutants to the atmosphere. Supporting this, Cu, and Cr measured in lichens, are known to be vehicle emission indicators [12, 13, 14]. Consequently, the area is close to the traffic highway (Onitsha-Enugu Express way, see Figure 1) linking important towns of Onitsha through Awka to Enugu State. Aerial fallout could accelerate the pollution load of the surrounding atmosphere. However, the highway has been under intense rehabilitation and reconstruction for nearly five years with attendant high particulate pollution from the site construction over the bordering areas and towns. Several studies are ongoing to ascertaining the impacts of these constructions on the environmental systems.

The concentrations of as measured, compared to other heavy metals were highest. This quantity might be as a result of the industries located in the area and additionally, its proximity to traffic highway. Rajesh et al. [15] had earlier reported concentrations of as in lichen Pyxine cocoes (Sw.) growing in the vicinity of coal-based thermal power plant at Raebareli, India. The fact that highest concentrations of As were obtained at the stations (3 and4) not directly close to the traffic highway and industries could be wind and its direction are probable agents for dispersion of this element, away from the source. According to Garty [16], dispersion of metals depends on the gravity of a particular metal along with speed and direction of wind.

Earlier studies carried out elsewhere has shown that As can also be present in air and a major source of threat to living organisms including man and it is classified as group I carcinogen [17]. Its severe health effects have been observed in populations all over the world over long period [18]. The element is mainly associated with water pollution but these days it is also found in air (EPA, 2006). The areas in the neighborhood of the industrial complex, mining and vehicular activities exhibit significant increase in the concentration of As 15. Koch et al. [19]recorded that fungi and lichens collected from Yellowknife Canada, an area affected by past mining activities, exhibited elevated arsenic levels.

Conclusion

In view of the survey, the results demonstrated the validity of epiphytic lichens in biomonitoring air quality from airborne heavy metals. With the accelerating anthropogenic activities and respective heavy metal pollution, low cost validated methodologies using site biomonitors are crucial for effective monitoring than the conventional mechanisms with detection limits for toxicants. Integrating the use of environmental biomonitor like lichens in decision support system (DSS) for environmental management will ultimately provide a sustainable environmental future. The heavy metal concentrations observed with regards to As, Zn and Cd is worrisome owing to the human exposure. It should be noted that the part of the study area is dominated by residential occupants. As and Cd are carcinogenic and constant exposure poses a great danger to human. Further comparative methodological investigations to determining the levels of these metals in the air should be done with a view to averting potential harm to the entire functioning ecosystem.

REFERENCES

1. Conti, M.E. & Cecchetti, G. (2001). Biological Monitoring: Lichens as Bioindicators of Air Pollution Assessment-a Review. Environmental Pollution, 114 (3), 471–492.

2. Szczepaniak, K. & Biziuk, M. (2003). Aspects of the Biomonitoring Studies Using Mosses and Lichens as Indicators of Metal Pollution. Environmental Research, 93 (3), 221–230 .
3. Wolterbeek, H.Th., Garty, J., Reis, M.A. & Freitas, M.C. (2003). Biomonitors in Use: Lichens and Metal Air Pollution, In: Bioindicators and Biomonitors, B.A. Markert, A.M. Breure, & H.G. Zechmeister, 377-419, Elsevier, ISBN 0080441777, Oxford.
4. Kansanen, P. & Venetvaara, J. (1991). Comparison of biological collectors of airborne heavy metals near ferrochrome and steel works. Water, Air & Soil Pollution, 60 (3-4), 337-359 .
5. Sloof, J. E (1995). Lichens as quantitative biomonitors for atmospheric trace-element deposition using transplants. Atmos. Environ. 29, 11–20.
6. Balabanova, B., Stafilov, T., Šajn, R.& Baèeva, K (2012). Characterisation of heavy metals in lichen species Hypogymnia physodes and Evernia prunastri due to biomonitoring of air pollution in the vicinity of copper mine. Int. J. Environ. Res., 6(3), 779-794.
7. Kapu, M.M., Ipaye, M.M., Ega, R.A.I., Akanya, H.O., Balarabe, M.L., and Schaeffer, D.J (1991). Lichens as biomonitors of aerial fallout of heavy metals in Zaria Nigeria. Bull. Environ. Contam. Toxicol., 47: 413-416.
8. Tuba, Z., Csintalanm, Z., Nagy, Z., Szente, K. &Takács, Z. (2007). Sampling of terricolous lichen and moss species for trace element analysis, with special reference to bioindication of air pollution. In Markert, B., (ed.), Environmental Sampling for Trace Analysis. Wiley-VCH Verlag GmbH, Germany.
9. Brown, D.H. (1991). Lichen mineral studies – currently clarified or confused. Symbiosis, 11, (2-3), 207-223.
10. Garty, J. (2000). Environment and Elemental Content of Lichens, In: Trace elements – Their Distribution and Effects in the Environment, B. Markert & K. Friese (Eds.), 33-86, Elsevier Science, ISBN 0444505326, Amsterdam.
11. Augusto, S., Pinho, P., Branquinho, C., Pereira, M.J., Soares, A., & Catarino, F. (2004). Atmospheric dioxin and furan deposition in relation to land-use and other pollutants: a survey with lichens. Journal of Atmospheric Chemistry 49, 53-65.
12. Ormrod, D.P (1984). Impact of trace metal pollution on plants, in M. Treshow (ed.), Air Pollution and Plant Life, Wiley, New York, pp. 291-319.
13. Saquid, M., Alam, I., El-Mubarek, A., & Al-Mohdar, H.M (1989). Preliminary evaluation of metal pollution from wear of auto tires. Bull. Environ. Contam. Toxicol. 42, 743-748.
14. Ward, N.I (1989). Multielement contamination of British motorways environments, in J.P Vernet (ed.): Heavy Metals in the Environment, vol. 1, CEP Consultants, Edinburgh, pp. 174-176.
15. Rajesh, B., Upreti, D.K., & Nayaka, S (2010). Accumulation of arsenic and fluoride in lichen Pyxine cocoes (sw.) nyl., growing in the vicinity of coal-based thermal power plant at Raebareli, India. Journal of Experimental Sciences 1(4), 37-40.

16. Garty, J. (2001). Biomonitoring atmospheric heavy metals with lichens: theory and application. Critical Review in Plant Science 20(4), 309-371.
17. IARC (2004). Monograph: Some drinking water disinfectants and contaminants including arsenic related nitrosamine, 84.
18. EPA (2006). Office of ground water and drinking water. http://www.epa.gov/OGWDW/arsenic/basicinfirmation.html.
19. Koch, I., Wang, L., Reimer, K.J. & Cullen, W.R. (2000). Arsenic species in terrestrial fungi and lichens from Yellowknife, NWT, Canada. Applied organometallic chemistry 14, 245-252.