

Traces of Harmattan Mineral Dust as Measured by Epiphytic Lichens in the Kassena-Nankana Municipality, Upper-East, Ghana

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Abstract: The lichen biomonitoring technique was used to study trace element atmospheric deposition in the Kassena-Nankana municipality of Ghana. Seven short and medium lived trace elements (Na, Al, K, Ca, V, Mn and Mg) were determined by instrumental Neutron Activation Analysis and subjected to statistical analysis. Principal component analysis was used to identify and characterize different sources of pollution. The results of linear regression correlation test and Principal component analysis points to harmattan mineral dust as the main source of atmospheric deposition in the area.

Keywords: Atmospheric depositions, epiphytic lichen, harmattan mineral dust, neutron activation analysis, principal component analysis, trace elements

INTRODUCTION

Lichen is one of the most suitable biomonitors of heavy metals in the atmosphere. Several studies have shown that Sulfur, nitrogen and metal concentrations in lichen tissue indicate air quality within a region or around a point source, providing a widely accepted monitoring method (Richardson, 1992; Nash and Gries, 1991; Stolte *et al.*, 1993; Nash and Gries, 2002). The evaluation of atmospheric deposition by lichen biomonitoring technique has been widely used for several decades and in Ghana, some of the recently conducted works include heavy metal pollution levels biomonitoring in an industrial town, forest zone and gold mining areas of Ghana (Dampare *et al.*, 2008; Nyarko *et al.*, 2006, 2004; Boamponsem *et al.*, 2010).

In this preliminary study epiphytic lichen combined with Instrumental Neutron Activation Analysis (NAA) is used to investigate trace metal pollution in the Kassena-Nankana municipality of Ghana. The region is part of Northern Ghana which is on the Sahelian belt known to be a region where atmospheric levels of suspended mineral dust are among the highest observed on Earth. The dry dusty air from the Sahara Desert blown by the cold North East Trade winds locally known as Harmattan is an important source of natural aerosol pollution. As a result of the intense heating over the Sahara Desert, sand and dust particles are uplifted into the atmosphere by convective forces to great heights estimated to reach 6.0 km above the surface and showed that large particles, 0.1-1mm in radius, are transported over a

distance of 6,000 km before being deposited on the surface (Utah *et al.*, 2005).

Harmattan aerosol has a great impact on the agriculture, micro-climate, health, visibility and the ecosystem of a large of West Africa and even on the global environment and therefore deserves much attention. The further north in West Africa you go, the more pronounced the harmattan and the weather conditions. Other possible sources of trace elements in the area are those emanating from agricultural activities, bush fires, emission from vehicles, cook stoves and small scale mining activities.

Multivariate statistical analysis was used to analyze the data obtained from lichen samples and NAA procedures. A linear regression correlation test was performed to investigate correlations between metal concentrations and Principal component analysis (factor analysis) was used to identify and characterize different pollution sources and to point out the most polluted areas.

MATERIALS AND METHODS

Sampling and sample preparation: The sampling was carried out in accordance with US Department of Agriculture-Forest Service Manual for Monitoring Air Quality Using Lichens on National Forests of the Pacific Northwest, Geiser (2004). Samples of epiphytic lichens were collected at ten different locations within the TANKARA forest reserve in May, 2013. The reserve is located along Navrongo-Kajelo road in the Kassena-

Nankana Municipality in the Upper East Region of Ghana, bordered by the Republic of Burkina Faso and the Bolgatanga, Bongo, Builsa, Sissala and Mamprusi West Districts. It lies between longitude 1°08W and latitudes 10°N and 10°80N. The Tankara forest reserve was established on 12 February, 1951 and the total area is 482 ha with a perimeter of 12.4 km. No admitted farm is located in the reserve.

In the laboratory, the samples were critically examined to remove extraneous materials or pieces of the bark collected with the thallus during the field sampling and afterwards washed in purified water to remove dust and sand. Each sample was blended to smooth powder using a mortar and pestle and homogenized. 200 mg each of the samples were weighed and wrapped in a transparent polyethylene film. The samples were further encapsulated into irradiation capsules and heat sealed for neutron activation (irradiation).

Analysis: The samples and the Certified Reference Materials (for both calibrations and validations) were irradiated in the Ghana Research Reactor-1 (GHARR-1) at the National Nuclear Research Center (NNRC), Ghana Atomic Energy Commission. GHARR-1 is operated at a half full power of 15KW which generate a thermal flux of $5 \times 10^{11} \text{ n-cm}^{-2}\text{s}^{-1}$. Two separate irradiations were performed based on element of interest and the half life of the radionuclide; two minutes and 1 h irradiation times were chosen for short lived radionuclide (s) and relatively medium lived radionuclide (s) respectively. The activated samples (short irradiation) were delayed within a period of 2-5 min and counted for 10 min in order to identify the short lived radionuclide (elements). In order to identify the Medium lived radionuclide (s) the activated samples were delayed for a maximum period of 24 h and counted for 10 min. Radioactivity measurement of induced radionuclide was performed by a PC-based γ - ray spectrometry set-up which consisted of an N-type HpGe detector (coaxial type) coupled to a computer based Multi-Channel Analyzer (MCA) via electronic modules. The relative efficiency of the detector is 40%. It energy resolution is 1.8keV at a γ -ray energy of 1332keV of ^{60}Co . The data acquisition and identification of γ -rays of product radionuclide were identified by their γ -ray energy (i.e.,) via ORTEC MAESTRO-32. Quantitative analysis was done via relative comparator method. The peak area determinations, processing and concentration calculation were done by multipurpose γ -ray spectrum analysis software; winSPAN-2010 version 2.10.

Quality control: The quality of the analytical results was evaluated by analyzing two certified reference materials, IAEA-336 (1999) Lichen and NIST 1547 (1993) Peach leaves provided by the International

Atomic Energy Agency (IAEA) and the National Institute of Standards and Technology (NIST), respectively. These reference materials were used alternatively for calibration and validations where appropriate by applying the same experimental conditions used in lichen analyses.

RESULTS AND DISCUSSION

The Neutron Activation Analysis (NAA) was done for short and medium lived radionuclide (elements). The long lived radionuclide may take more than three months to analyze depending on the half life of the radionuclide. Seven elements, Na, K, Mg, Al, Ca, V, Mn were obtained after the NAA procedures (Table 1) and subjected to statistical analysis.

A linear regression correlation test was performed to investigate correlations between metal concentrations. The values of correlation coefficients between metal concentrations are given in Table 2. The correlation between two variables that yield values greater than 0.5 is said to be highly correlated, there is a high positive correlation between Mg and K. There is also a high negative correlation between Ca and Al.

Principal component analysis (factor analysis) was applied to determine possible sources of trace element deposition in the lichen samples in the Kassena-Nankana municipality. Although seven factors have

Table 1: Level of trace metals as mg/kg in lichen species

	Mean	SD	N
Na	2026.480	270.3330	10
K	8588.750	1168.344	10
Mg	8035.130	1098.093	10
Al	1.74E4	2224.564	10
Ca	1.13E4	1338.936	10
V	22.430	4.521000	10
Mn	363.350	48.09200	10

N = Number of samples

Table 2: Correlation between metal concentrations in lichen samples

	Na	K	Mg	Al	Ca	V	Mn
Na	1.0000						
K	-0.325	1.000					
Mg	-0.404	0.521	1.000				
Al	0.349	0.235	-0.046	1.000			
Ca	-0.282	0.112	0.376	-0.523	1.0000		
V	-0.451	0.472	0.381	-0.116	-0.324	1.000	
Mn	0.247	-0.307	0.076	0.204	0.0760	-0.189	1.000

Table 3: Factor analysis of NAA data on lichen samples from Navrongo

	Factors		
	1	2	3
Mg	0.844		
K	0.834		
V	0.627		-0.536
Na	-0.525	0.4590	0.423
Ca		-0.877	
Al		0.829	0.370
Mn			0.814

been computed, it is obvious that not all the seven factors will be useful in representing the list of seven variables. Three factors that explain almost 77% of the total variance in the data set was retained based on the criterion for retaining factors. These three factors account for 34.907, 23.992 and 17.539% of the total variance respectively. The interpretation (major sources) of the three factors based on the knowledge of elements composition of each factor and values of loadings are as follow:

Factor 1: which contributed the greater percentage of the total variance has high values of Mg, K and V. Mg and K are commonly found in soil dust. The presence of vanadium is normally as a result of industrial activities or oil combustion sources but there are no major industries in the municipality, therefore the accounted for source would be oil combustion from agricultural activities which the main occupation of the people in the area. Vanadium presence may also be due to motor cycles which the main means of transport in the area. From Table 3 Vanadium recorded insignificant concentration of 22.430 mg/kg in the lichen sample. The most probable source contributing to this factor is soil dust which is also highlighted by the positive correlation between Mg and K.

Factor 2: Recorded a significantly high loading of Al and relatively high loading of 0.459 value for Na. Aluminum is the most abundant metal in the earth's crust and probably supplied to the lichen by windblown soil dust. Al and Na are also found in coal combustion and motor vehicles. Soil dust and oil combustion were mostly responsible for this factor.

Factor 3: Contained very high loading of Mn which clearly reechoed the significant contribution of soil dust to atmospheric pollution in the municipality. The low loadings of Na and Al in this factor also indicate motor vehicles as a likely source of pollution.

The elements Mg, K, Na, Ca, Al and Mn obtained in this our preliminary study on the traces of harmattan mineral dust have been reported in recent studies on the composition, characteristics and effects of harmattan particulate in Sub-Saharan Africa (Chineke and Chiemeka, 2009; Ifeanyi *et al.*, 2012).

CONCLUSION

In conclusion, the results showed that using factor analysis, epiphytic lichens might be used as indicators of air quality and as well as, biomonitors for assessing harmattan mineral dust deposition. The Atmospheric pollutants as measured by lichen element content are mainly due to harmattan mineral dust.

This study is just a part of ongoing research that would cover the whole northern Ghana and it seeks to provide a less expensive method of detecting and

identifying sources of heavy metal pollution in these harmattan prone regions of Ghana.

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