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Research Article

Assessment of Transboundary Pollution from Colombo to Kandy on the Atmospheric Deposition of Heavy Metals Using Moss (*Hyophila involuta*)

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Abstract:

Kandy has been known to be one of the highest air-polluted cities in Sri Lanka even without lack of point anthropogenic sources other than the traffic congestion inside the city. Therefore, this study was done to assess the transboundary air pollution effect from Colombo to Kandy using Moss (*Hyophila involuta*) as a biomonitor. Atmospheric deposition of five heavy metals (Cu, Pb, Ni, Cr and Cd) was monitored using moss collected from Colombo and Kandy, from March 2013 to January 2014. The concentrations of Cu, Pb, Ni, Cr and Cd were analyzed by atomic absorption spectrometer (AAS) and the results obtained for both sampling were compared with the monsoon pattern of Sri Lanka. Cu accumulation in moss around Kandy has been influenced by the brass industries at Pilimathalawa. The cross-boundary effect from Colombo to Kandy during the southwest (SW) monsoon elevated the accumulation of Ni and Cr in moss around Kandy.

Keywords: Biomonitor, Air pollution, Moss, Anthropogenic sources,

1. Introduction

Cross-boundary pollution is the transportation of pollutants from one place to another and is more dangerous in the air, but international environmental laws are unable to establish air-like land by giving boundaries. Long-range transboundary air pollution is only one source of exposure to heavy metals like Hg, Cd and Pb in most remote regions in Europe and it has become a global problem as these heavy metals are persistence in the air for long periods of time and cause a wide range of diseases and a significant reduction of life expectancy in most of the population in Europe [1]. Pakistan has been affected by the emissions of coal power plants in India and China during the summer monsoons and trade winds and it is another example of international transboundary air pollution in South Asia [2].

Reduction of cross-boundary pollution has simultaneously improved public health in the destination cities and also leads to higher real estate prices in China [3] Transboundary pollution is the transportation of pollutants from one administrative region to another should be monitored initially before identifying the cross-boundary effect. Therefore, the identification of such kind of pollution sources and the level of pollution in Sri Lanka should be implemented to make policies. However, as a developing country with a middle income, cost-effective air monitoring techniques are needed like biomonitoring [4].

The use of terrestrial mosses as biomonitors of atmospheric contamination has become one of the commonly used tools for biomonitoring the air quality [5]. Because mosses obtain most of their nutrient supply directly from atmospheric deposition and have a great capacity to retain many elements [6]. European countries have been carried out moss biomonitoring for heavy metals every five-year interval since 1990 to assess any temporal or spatial changes in atmospheric deposition of heavy metals following the guidelines of the International Cooperative Programme on Effects of Air Pollution on Natural Vegetation and Crops [7,8].

Kandy has been known as a highly air-polluted city in Sri Lanka and some studies explained that as a result of the basin structure of Knuckles mountain range and the Hanthana mountain range which lies adjacent to the artificial Kandy Lake and the south of Udawatta Kele Sanctuary. Air quality condition (SO_2, NO_2 and O_3) of Kandy city is three times more polluted than that of Colombo city and the major air pollutants in the western province of Sri Lanka have been expected as the higher degree of a contributor to elevate the pollution level in Kandy during SW monsoon [9]. Air particulate matter ($PM_{2.5}$) analysis has been used for identification of heavy metal emission sources in Kandy and introduced five different sources by the factor analysis; the crustal elements, aged sea salt, automobile traffics, biomass burning and industry emissions [10].

Atmospheric deposition of trace elements in Kandy has been indicated using *Hyophila* sp. moss and about 73 % of the trace metals were by two factors: vehicular emission and transboundary pollution [11]. Even though transboundary pollution was suggested as one of the major contributors of heavy metal air pollution, consecutive biomonitoring in Colombo and Kandy has not been carried out yet for the justification of transboundary heavy metal pollution. Therefore, the current investigation was conducted to monitor the atmospheric deposition of heavy metals in Colombo and Kandy using moss *Hyophila involuta* as a biomonitor and to identify the heavy metals emission sources around Kandy including the transboundary air pollution effect.

2. Material and Methods

Moss sampling was carried out in eighteen sampling stations around the Sapugaskanda oil refinery and the Kelanitissa power plant to represent the Colombo sampling location and twenty sampling stations around the Kandy Municipal council. For the Colombo, sampling sites were located in the west coast of Sri Lanka within the range of latitude from 6° 56′ N to 6° 58′ N and the range of longitude from 79° 52′ E to 79° 58′ E with temperate climate influenced by the southwest monsoon (late May to September) and the northeast monsoon (November to March) that results in heavy rainfall to the state. The area is generally fairly temperature and humid throughout the year. Sampling sites were selected areas around the Sapugaskanda oil refinery which is known to be as biggest industrialized area and the area around the Kelanitissa power station which is close to the commercial capital of Sri Lanka. For the Kandy, sampling sites were located in the central province of Sri Lanka within the range of latitude from 7°15′ N to 7°19′ N and the range of longitude from 80°33′ E to 80°39′ E with two types of distinct seasons in this area namely the monsoon season (from May to November) and the dry season (December to April). Sampling sites were selected from the area of the artificial Kandy Lake and the area around the transport network with the huge traffic congestion surrounding the city of Kandy.

The sampling technique and related procedures were based on the Scandinavian guidelines and were described in more detail in the protocol for the 2010 survey [12]. Moss species *Hyophila involuta* were collected between March 2013 and January 2014. The distance of moss sampling areas was not evenly distributed because of geographical problems and the availability of the particular moss species that have been chosen in this study. The geographic coordinates were determined using GPS. The sampling sites were also located at least 300 m distant from main roads and at least 100 m away from other roads and settlement areas. Most of the moss samples were collected in an open area. On each sampling site on average 5 subsamples were taken within an area of 50 ×50 m^2 and a collective sample was taken into a plastic bag and carefully closed to prevent contamination during transportation and the samples were transported to the laboratory at 8 ºC using a cooled box. Plastic gloves were used when picking up the mosses thought out the sampling and analysis.

All kinds of foreign materials adhering to the surface of the samples such as tree bark, lichens, soil dust, and dead materials were removed thoroughly in dry conditions. For the analysis, only the green and greenish-brown parts of the moss plants were used, as they generally are intended to represent a period of about 3–5 years of growth. Their metal content is generally considered to reflect the atmospheric deposition during that period [7] Following the removal of adhering material the samples were then washed with deionized water and oven-dried at 60 °C for 24 h to constant weight [13]. The representative samples of each moss species were prepared in triplicates.

The glass and Teflon material for sample digestion was cleaned by immersion in 10% HNO_3 (24 h) followed by profuse rinsing with deionized water. Representative moss samples (500.0 mg) were placed in a Teflon vessel, 10 mL concentrated nitric (Sigma Aldrich, ACS reagent ≥ 69%) was added, and digested using a microwave accelerated reaction system (CEM Mars 6). Digestion conditions of the microwave system were 20 min and 15 min ramp and hold time at 200 ºC respectively. The digested sample was filtered through filter paper (MN 617≡ No. 4). The filtrate volume was transferred to a volumetric flask (25 mL) and made up to volume by deionized water. Blank was performed in the same procedure. The samples were transferred to polypropylene bottles (50 mL) and kept in a refrigerator at 8 ºC until analysis. The soil samples were treated in the same manner as the moss samples. The metal contents Cu, Pb, Ni, and Cr in the filtrate were determined by atomic absorption spectrometry (GBC 932 plus) using an air-acetylene flame. Cd in the filtrate was determined by graphite furnace atomic absorption spectrometry (analytikjena novAA 400 P) using N_2 as an inert gas. Consequently, the National Institute for Standards and Technology Standard Reference Martial (NIST SRM 1575a pine needle) was used as a reference to determine the metal recoveries. Statistical comparisons and correlations were performed using the statistical package Minitab17, USA.

3. Results and Discussion

Concentrations (mg/kg) of atmospheric deposition of heavy metals in moss were determined by dry weight basis, and the average concentration of heavy metals and standard deviation of heavy metals for two sampling locations; Colombo and Kandy are summarized in Table 1.

Table 1: Average concentration of heavy metal (mg/kg) in moss collected from Colombo and Kandy

	Heavy metal accumulation in moss (mg/kg)	
	Colombo	**Kandy**
Cu	26.45 ± 14.50	31.66 ± 16.80
Pb	27.70 ± 17.48	21.26 ± 18.18
Ni	33.49 ± 17.69	29.99 ± 12.11
Cr	27.37 ± 16.27	23.42 ± 14.62
Cd	0.44 ± 0.23	0.24 ± 0.14

Even though the concentration of SO_2, NO_2 and O_3 has been recorded three times in Kandy than in Colombo, the heavy metal accumulation did not show that relationship according to the results given in Table 1 [9]. All the results obtained for Colombo and Kandy were summarized in Table 1 and it showed a high standard deviation due to the variation from site to site and month to month. Therefore, the change of concertation of Cu in a single sampling site at Colombo with the sampling month is shown in Fig. 1 to show the month-to-month deviation.

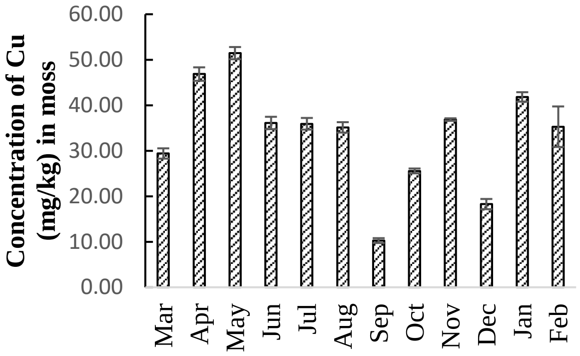

Fig. 1. The monthly accumulation of Cu (mg/kg) in moss for a single at Colombo

The average and the standard deviation obtained for the above site was 33.58 ± 11.5 mg/kg within the range of 10.26–51.45 mg/kg. Similarly, accumulation of other four heavy metals in moss also deviated month to month. Further, deviation from site to site is also affected to increase the standard deviation of the results given in Table 1.

Even though standard deviation is high, the order of mean concentrations of heavy metals in moss (Cu > Pb > Ni > Cr > Cd) is compatible with the order of the average concentration of trace metals in moss in *Hyophila sp.* (Fe > Al > Zn > Mn > Cu > Pb > Cr > Ni > Cd) using inductive Coupled Plasma-Mass Spectrometry [11].

A sampling site that is close to the Pilimathalawa which is popular for traditional brassware was identified as a highly Cu-polluted site (250.4 ± 11.5 mg/kg) during the first sampling month. Thereafter the number of sampling sites around this identified sampling site was increased to confirm the results further and the range of concentration of Cu in moss was 107.6–437.4 mg/kg at Pilimathalawa during the studied period. The atmospheric depositions of heavy metal concentrations in moss around Kandy are summarized by avoiding extremely high concentrated Cu contained Pilimathalawa sampling site. The factor analysis carried to identify the $PM_{2.5}$ sources around Kandy has revealed the metallurgical industries (brass and other metal products) are the larger contributor for one of the factors with the transition metals V, Cr, Mn, Fe, Co, Cu, Zn, and Pb [10]. Further, the higher concentration of Ca, Zn and Cu has been recorded in household dust samples in the Kandy Municipal area due to anthropogenic activities like the construction industry and traffic activities [14]. The mosses do not have a cuticle and they have a great capacity to sorption and retain heavy metals through both wet and dry deposition [15]. Therefore, the adhere of dust on the surface of the moss seems to be also affected to increase the Cu accumulation in moss in Kandy.

Even though point anthropogenic sources present around Kandy are lesser than in Colombo, the heavy metal accumulation of moss in Kandy is similar to the results obtained for Colombo. As the data are not normally distributed, median concentrations of heavy metals in moss were used to compare the monthly correlation between the two sampling locations of Colombo and Kandy. The correlation studies done using the Pearson correlation test ($p < 0.01$) and Spearman rho correlation test ($p < 0.01$) showed a significant correlation between Kandy and Colombo for the heavy metals Ni and Cr. The concentrations of these two elements were also highest in May 2013 which showed the maximum monthly rainfall during the studied period.

Further monthly comparison between Colombo and Kandy for Ni and Cr accumulation in moss was compared by the non-parametric Mann-Whitney test ($p < 0.05$) and there was not a significant difference for the months from May to September which belongs to the SW monsoon period. The concentration of Ni and Cr was significantly higher in Colombo than in Kandy for the months that do not belong to SW monsoon and results are illustrated in Fig. 2 and 3.

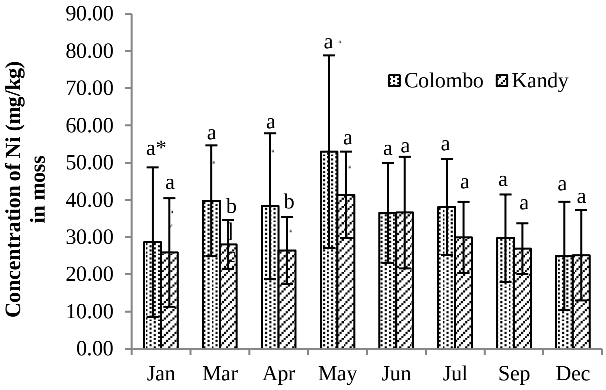

Fig. 2. Concentration of Ni (mg/kg) in moss in Colombo and Kandy for eight months (March 2013–January 2014)
*Different letters (a,b) indicate significant differences between medians based on the Mann-Whitney test ($p < 0.05$) for each month.

Considerable amounts of Cr and Ni are linked to the emissions from a power station, and to other industries where petroleum-derived products are burned [16] Sapugaskanda oil refinery and other local petrochemical-based industries operating around Colombo were identified as the Ni and Cr originate from the pollution around Colombo [17]. Seneviratne *et al,* indicated the influence of sea salt concentrations (Na and Cl) in Kandy during July and August by westerly monsoon winds as a result of transporting the marine aerosol from the west coast of Sri Lanka to Kandy [10]. Therefore, emission of Ni and Cr from the Sapugaskanda oil refinery and the power plants in Colombo seems to be influenced by the Ni and Cr pollution in Kandy during the SW monsoon of Sri Lanka.

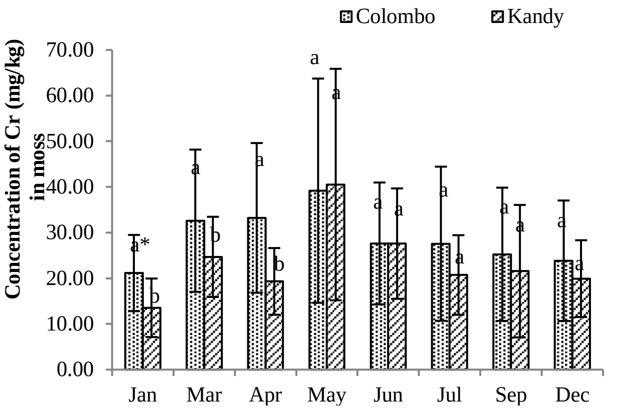

Fig. 3. Concentration of Cr (mg/kg) in moss in Colombo and Kandy for eight months (March 2013–January 2014)

*Different letters (a,b) indicate significant differences between medians based on the Mann-Whitney test ($p < 0.05$) for each month.

The average amount of Pb and Cd in Kandy Lake was recorded as 150 μg/L and 77 μg/L respectively due to the vehicular emissions and industrial waste matter than the geological materials [18]. The average of Pb and Cd in moss at the sampling points around Kandy Lake was 23.62 ($\pm$4.37) mg/kg and 0.24 ($\pm$0.14) mg/kg respectively and then it seems to be influenced mainly by the vehicular emissions around the Kandy town.

4. Conclusion

Vehicular emissions are one of the anthropogenic sources that influence the heavy metal accumulation in Kandy and Colombo. The concentration of Cu around Kandy is significantly higher than in Colombo and the brass industries around the Pilimathalawa are identified as a major anthropogenic source of Cu around Kandy. The sampling points selected from Colombo are around the Sapugaskanda oil refinery and Kelanitissa power plant. The concentration of Ni and Cr is high in these petroleum related-industries. The accumulation of Ni and Cr in Kandy during the SW monsoon season months is higher than the other months and there is a similar trend between Colombo and Kandy during these SW monsoon months. Therefore, the transboundary pollution from Colombo to Kandy mainly influences the accumulation of Ni and Cr in Kandy during the SW monsoon of Sri Lanka. Therefore, the monsoon pattern of Sri Lanka also affected to elevate the pollution level even without significant point anthrophonic sources in the surrounding area.

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