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Research article

Ectohydric moss, *Thuidium tamariscellum*, monitors atmospheric Lead (Pb) pollution in Baguio City, Philippines

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Abstract: This is the first study in the Philippines which adopted the standard moss monitoring procedure to address Lead (Pb) contamination in the ambient air of Baguio City. Pb is considered as one of the seven criteria pollutants by United States Environmental Protection Agency. Analysis of exposed moss tissues was performed using Flame-Atomic Absorption Spectrophotometry by Baguio Water District. There is high metal loading observed on the tissues of *Thuidium tamariscellum* (Müll. Hal.) Bosch & Sande Lac. after exposure along and in between major road intersections in the city.There is no significant variation in Pb concentration in the exposed moss as revealed by One-Way Analysis of Variance. This study reports the presence of Pb in the ambient air of Baguio City and the lack of monitoring is harmful to people and environment. Nevertheless, this study offers cost-effective air monitoring method that can be adopted in cities as newer available technology.

Keywords: Air pollutants - Flame-Atomic Absorption Spectrophotometry (AAS) - Heavy metal - Ectohydric moss - Lead (Pb) - *Thuidium tamariscellum* (Müll. Hal.) Bosch & Sande Lac.

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INTRODUCTION

Standard German Moss Monitoring Procedure was put in place to determine the quality of air and as basis in drafting laws on air quality standards in European countries (Martin & Coughtrey 1982, Fernandez & Carballeira 2000, Schilling & Lehman 2001). According to Yunus *et al.* (1996), current metal fluxes from the atmosphere to the biosphere are significantly increased as a product of various anthropogenic inputs such as, combustion of fossil fuels, agricultural dust, and metallurgy. *Thuidium* B.S.G. is genus of ectohydric mosses which belong to the group of Subclass Bryidae - "the jointed toothed mosses" (Schofield 1985). The properties of *T. tamariscellum* (Müll. Hal.) Bosch & Sande Lac. such as the absence of cuticle, high surface area to volume ratio and absence of stomata make it a good candidate for monitoring air pollutants. Mosses draw negligible amounts of water and minerals from the soil and rely mostly on the input of atmospheric nutrients by wet and dry deposition (Schilling & Lehman 2001). Mosses have high cation exchange capacity (CEC) making them efficient hyperaccumulators of metals present in the atmosphere. They also lack well developed vascular tissue so that there is minimal translocation of the bioaccumulated metals in its tissues (Ruhling & Tyler 1968).The main objective of this study is to evaluate the dry-deposition of Pb, one of the hazardous criteria pollutants as indicated by the National Ambient Air Guideline System of the Philippine Clean Air Act (RA 8749) in the tissues of bioindicator organism, *T. tamariscellum*, exposed along and in between major road intersections in Baguio City.

MATERIALS AND METHODS

Moss Collection and Exposure

Mosses were collected in Busol Watershed at Barangay Aurora Hill, Baguio City. Disposable latex gloves were worn during the collection and the mosses were placed in a zip lock plastic bag. Professor Roland Hipol of the University of the Philippines Baguio identified the moss as *T. tamariscellum* (Müll. Hal.) Bosch & Sande Lac. (Fig. 1A,B).

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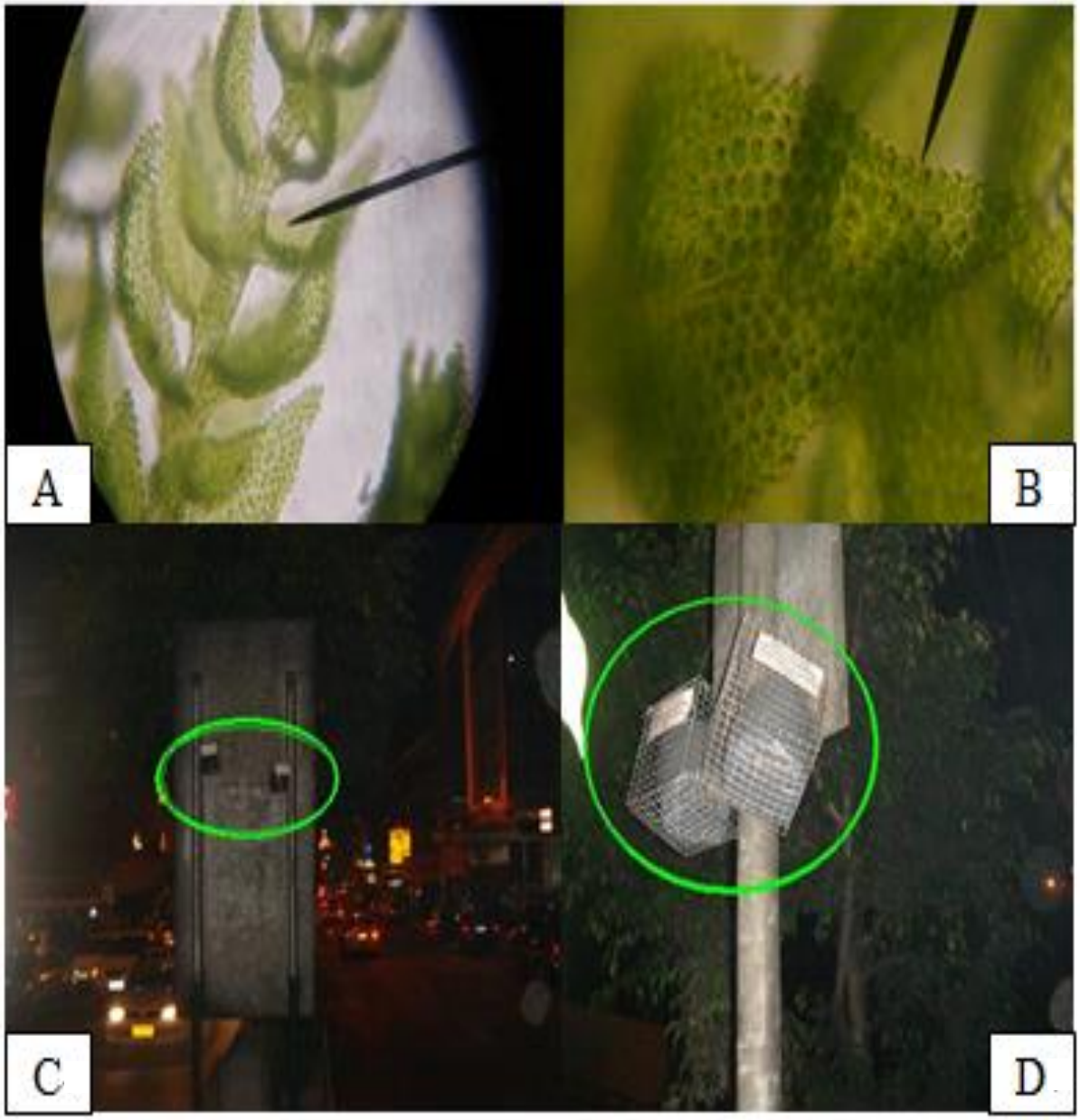

Figure 1. *Thuidium tamariscellum*; **A,** with numerous papillose cells; **B,** viewed under H.P.O, 400x; **C–D**, Actual specimen exposed along and in between road intersections in Baguio City.

The moss samples with equal dry weights of five grams were transplanted in polyethylene bags. Replicates of moss bags were installed at a height of at least two meters from the ground. Moss bags were installed along and in between major road intersections in Baguio City (Fig. 1C,D). The moss bags were exposed for a period of about three months or 12 weeks.

Acid digestion of exposed moss tissues

After the exposure period of 12 weeks, the moss bags were collected with disposable latex gloves and were placed in zip lock plastic bags. The samples were oven-dried for 24 hours, and crushed using mortar and pestle. The crushed samples were subjected to a mixture of concentrated HNO_3 and $HClO_4$ (4:1 v/v), and boiled in 250 ml beaker at 130°C until the organic material is oxidized and the solution is evaporated to dryness. The pellets were dissolved in HNO_3 and demineralized H_2O (1:4 v/v) and stored in 250 ml Erlenmeyer flask (Folkeson 1979).

Heavy Metal Analysis

Heavy metal analysis was done as described in the protocol of Environmental Management Bureau-Cordillera Administrative Region (EMB-CAR). One hundred ml of acid preserved sample was transferred into

clean 150 ml beaker. Three ml of concentrated nitric acid was added slowly. The beaker was placed on a hot plate, and the sample was evaporated to less than five ml. The sample was not allowed to boil and that no area at the bottom of the beaker was allowed to go dry. The sample was cooled. Another three ml concentrated nitric acid was added; the beaker was covered with watch glass and returned to the hotplate. The temperature of the hotplate was increased so that a gentle reflux action occurs. Heating is continued and acid was added as necessary until digestion is completed (indicated by a light colored residue). A 1:1 HCl (about five ml) was added and heated for 15 minutes to dissolve any residue. The beaker and watch glass was rinsed with distilled water and filtered to remove insoluble materials. The final volume was adjusted to 100 ml with distilled water. The digested samples were submitted to the Baguio Water District (BWD) for the aspiration process. The samples were examined using Flame Atomic Absorption Spectrophotometry (AAS).

Data Analysis

Lead concentration before and after exposure were statistically analyzed using T-test (one-tail right test) to determine whether there is an observable increase in the concentration of Pb in the tissues of exposed mosses. One-Way Analysis of Variance (ANOVA) was used to determine whether there is a significant variation on the bioaccumulated heavy metals on the different exposure sites.

Table 1. Intersite comparison of dry-deposition of Pb.

Exposure Site*	Conc. of dry-deposited Pb (µg.m^3)	Difference between before and after exposure conc. of Pb (µg.m^3)	Heavy Metal Loading (%)
Before exposure	0.21	-	-
1	2.14	1.93	90.2
2	1.94	1.73	89.2
3	2.36	2.15	91.1
4	2.26	2.05	90.7
5	1.88	1.67	88.8

*The five exposure sites includes the (1) Intersection of Magsaysay Road and Session Road where the Continuous Automatic Ambient Air Quality Monitoring System of EMB-CAR is located, (2) Intersection at the upper Session Road, (3) Intersection at Quirino Highway (Bokawkan-Naguillian), (4) Intersection at the Baguio Center Mall and Magsaysay Road, (5) Harrison Road and Governor Pack Road Intersection.

RESULT

The difference between Pb concentration before and after exposure was presented in table 1.One-tailed T-test at 5% α level of significance showed that the Pb concentration in the five sites after exposure is greater than the concentration before exposure.

DISCUSSION

Evaluation of T. tamariscellum

The availability and abundance of *T. tamariscellum* in Baguio City is the main reason why it was used in the study. The initial concentration of Pb (0.21 µg.m^3) measured in the control sample is associated by the leaching process from the *Pinus* canopy where the moss samples were collected (Schilling & Lehman 2001). As observed in the high metal loading (88–91%) in the tissues of *T. tamariscellum*, the efficiency of these organisms to hyperaccumulate metal present in the air as reported in earlier studies is strongly supported (Schilling & Lehman 2001).

Analysis of Pb dry-deposition

The standard tolerable limit of Pb in the ambient air set by the National Ambient Air Guideline System (NAAGS) of the Philippine Clean Air Act (RA 8749) and National Ambient Air Quality Standards (NAAQS) set by US EPA is 1.5 µg.m^3 per three months exposure period. The data showed that the dry-deposited Pb in the exposed samples exceeds the standard tolerable limit. In the Intersection of Magsaysay Road and Session Road where the monitoring station of EMB-CAR is located, the level of Pb is about 2.14 µg.m^3. This concentration exceeds the tolerable limit in the ambient air as indicated by NAAGS and NAAQS. The Continuous Ambient Air Monitoring Station in Baguio city only measures sulfur dioxide, ozone and toluene. This monitoring station does not measure Pb which is one of the criteria pollutants along with ozone (O_3), carbon monoxide (CO), nitrogen dioxide (NO_2), sulfur dioxide (SO_2), total suspended particles, photochemical oxidants. Pb is largely

contributed by the combustion of fossil fuels and exposure to this toxic gas is detrimental to the health of young children (US EPA).

CONCLUSION

The use of *T. tamariscellum* in determining the dry-deposition of Pb offers inter-site comparison of heavy metal contamination in different road intersections in Baguio City. This study revealed that there is aggravation of Pb level from the tolerable limit set by US EPA and this is attributed to the growing number of vehicles in the city. The assumption that Pb is not to be found in the ambient air by merely banning the use of leaded gasoline poses more harm than good. Nevertheless, the use of *T. tamariscellum* was observed to be effective bioaccumulator of heavy metal such as Pb as observed on the high metal loading after exposure. The use of moss to monitor air quality offers cost-effective and allows inter-site comparison of air pollution scenario which cannot be done with a single monitoring station.

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