Transactions on Ecology and the Environment vol 66, © 2003 WIT Press, www.witpress.com, ISSN 1743-3541

Tourist use and moss contamination at Torres del Paine National Park, Chile

G.B. Wiersma, J.B. Wiersma & J.A. Elvir
Department of Forest Ecosystem Science, University of Maine U.S.A.

Abstract

Lead (Pb) contamination in mosses at Torres del Paine National Park in Chile was examined using data from samples collected in 1984, 1985, 1988, 1997 and 2001. Due to its remote location and protected status, Torres del Paine remains one of the last ecosystems in the world with the minimum anthropogenic influence, providing one of the most suitable environments for studying natural processes. Monitoring sites were established in 1983 as part of a global network of baseline environment monitoring sites and were located in the unique *Nothofagus pumilio* forest ecosystems. Atmospheric samples collected in the park in 1983 showed some of the lowest pollutant loadings recorded on the planet. Only atmospheric samples reported from Antarctica have lower concentrations than those reported in the atmospheric sampling from Torres del Paine research. Data from 1984 showed that Pb concentrations in *Acrocladium auriculatum* moss were some of the lowest reported in scientific literature. However, moss Pb concentrations have increased since 1984. Lead concentrations in 1984 were less than 0.3 PPM but by 1997 and 2001 concentrations were up to 2 PPM. Lead concentrations in moss from these monitoring sites were strongly correlated with tourist usage and vehicle traffic in the park. Tourism has increased from less than 4,000 visitors in 1983 to over 60,000 in 2001. The number of vehicles entering the park increased from less than 1500 in 1983 to over 9,000 in 1998. The data suggest that increasing gas exhaust emission from leaded gas run engines as a result of the increasing tourist traffic could explain the dramatic increase in moss Pb contamination.
Keywords: lead, tourism, Nothofagus pumilio, anthropogenic influence, pollution, Acrocladium auriculatum, Torres del Paine, Chile.

1 Introduction

Torres del Paine National Park is located in a remote area of southern Chile. The park was established in 1959, and encompasses approximately 180,000 hectares including the Cuernos del Paine Mountains. These mountains serve as the front door to the great southern ice fields, which bisect Chile and extend to the north for 1000 miles. This area, also known as Patagonia, is home to more than 40 mammals including the Guanaco, Puma, and Patagonian Grey Fox. Some of the world's rarest bird species–the Andean Condor, Crested Cara Cara, Pink Flamingos, and the Black Vulture among them–are found in Torres as well.

In 1978 UNESCO gave the park Biosphere Reserve status, recognizing it as a location especially valuable of international recognition. In 1983, Torres del Paine National Park was first established as a candidate site for United Nations Environment Program, Global Environment Monitoring System [2, 12, 13]. This park was chosen because of its unique *Nothofagus* forests ecosystem and its remote and protected location from anthropogenic influences.

Atmospheric samples collected in the park in 1983 and subsequent years showed some of the lowest pollutant loadings recorded on the planet [10]. Only atmospheric samples collected in Antarctica have lower concentrations than those reported in the atmospheric sampling from Torres del Paine research. Also, Pb concentrations in mosses including *Acrocladium auriculatum* and lichens, which are excellent natural accumulators for atmospheric deposited particles [4, 5], sampled from the park were some of the lowest reported in scientific literature [11, 12].

In 1997, *Acrocladium auriculatum* moss samples were collected again from Torres del Paine National Park. Results showed that moss Pb concentrations had risen by a factor of ten. From previous research, it is known that this park is almost completely unaffected by long-range atmospheric deposition. Therefore, it was hypothesized that the dramatic increase in pollution must be from a local source, and that the source might be the significant increase of tourism usage of the park.

The objective of this study was to re-sample *Acrocladium auriculatum* moss for 2001 and to compare levels of Pb found in previous years. Also to analyze moss Pb concentrations to statistics on vehicle usage in the park in order to establish a correlation between increasing levels of Pb in our samples and the increase in tourism in the park.

2 Study site

The permanent sampling site established in 1983, called Zapata A, (noted as "reference stand" in Figure 1) is located along the Rio Zapata in the Rio Pingo valley in the western side of Torres del Paine National Park, Chile (51°05'S, 73°12'W). The elevation of the site is about 400 m a.s.l. with a north-northwest exposure. Zapata A plot is a pure mature *Nothofagus pumilio* forest more than 150 years old. *Nothofagus pumilio* occurs from 35°35' to 55° S in the Andean

Range and the Coastal Range of Chile and Argentina [7]. *Nothofagus pumilio* and *Nothofagus antarctica* are some of the rare deciduous hardwood species that form upper treelines in the Southern Hemisphere [3]. Zapata A has served as the original sampling site, and mosses have been collected here since 1984.

3 Methodology

In May of 2001, 10 *Acrocladium auriculatum* moss samples were collected in Zapata A site according to procedures established and described in Wiersma et al, [9, 11]. Samples were collected using sterile powder free gloves changed for each sample. Samples were placed in sterile inert plastic bags. Bags with samples were sealed and transported for chemical analyses. Chemical analyses were performed by the Analytical Laboratory of the Maine Agricultural and Forest Experimental Station at the University of Maine. Samples were pre-dried in a Stabil-Them laboratory oven at 70-degree C for 36 hours and ashed at 450-degrees C using standard EPA procedure #3050. Samples were analyzed for Pb and aluminum (Al) and values were given in parts per million (PPM) dried weight. Details in analytical laboratory techniques can be found in Weber and Wiersma et al. [8].

Transactions on Ecology and the Environment vol 66, © 2003 WIT Press, www.witpress.com, ISSN 1743-3541

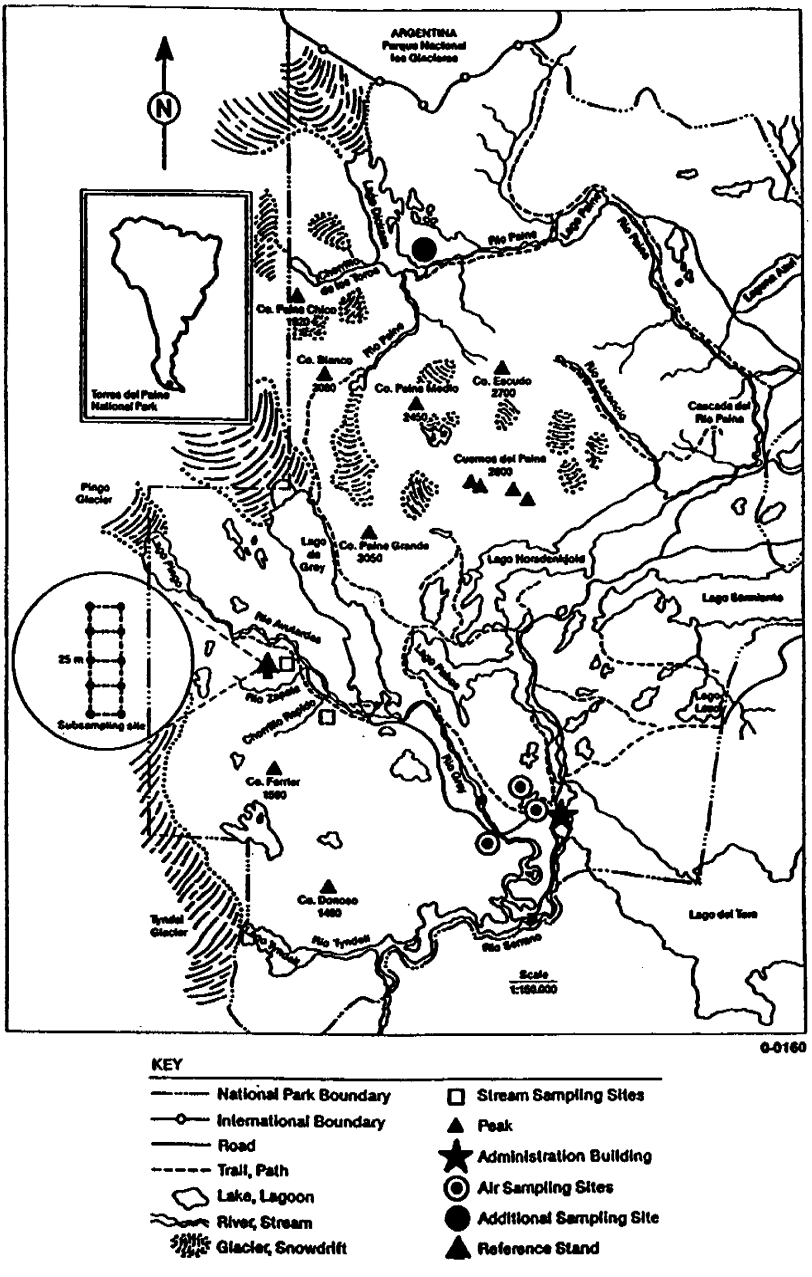

Figure 1. Zapata A site (Reference Stand) at Torres del Paine National Park, Chile

4 Results and discussion

Results from analytical laboratory analysis of moss samples confirmed results from 1997. Lead levels in *Acrocladium auriculatum* moss samples collected in 2001 have remained high relative to data from 1984-1988. Table 1 shows the average Pb concentrations for 2001 and for previous years.

Table 1: Average Pb levels in moss samples 1984-2001 at Torres del Paine National Park

month/year	Pb (mg/kg)
November, 1984	0.3
March, 1985	0.4
April, 1988	0.7
May, 1997	3.9
May, 2001	1.9

Pb levels found in moss samples from 2001 were significantly higher than those reported from the 1980's. However 2001 levels were lower than those reported in 1997. This might be attributed to unpredicted weather conditions during the 2001 field sampling. Samples were collected during the middle of a major snowstorm, which might have washed off some Pb from samples before collection.

4.1 Enrichment Factor

Enrichment factor was used to help determine possible sources of Pb found in moss. The enrichment factor normalizes data with respect to a geo-chemical reference. Aluminum is traditionally used as a reference element. The following equation compares moss Pb concentrations to crustal Pb concentrations [11].

$$\mathbf{EF} = \frac{\dfrac{[\mathrm{Pb}]_{\mathrm{moss}}}{[\mathrm{Al}]_{\mathrm{moss}}}}{\dfrac{[\mathrm{Pb}]_{\mathrm{crustal}}}{[\mathrm{Al}]_{\mathrm{crustal}}}}$$

Using average crustal values taken from standard geochemical tables [6] for ($[\mathrm{Pb}]_{\mathrm{crustal}}/[\mathrm{Al}]_{\mathrm{crustal}}$), the enrichment factor of Pb in the terrestrial moss samples was determined. In general, an enrichment factor greater than 10 indicates that the element has potential anthropogenic sources [1]. Table 2 shows the results of calculations for enrichment factors of Pb in moss samples relative to crustal Pb concentrations.

Table 2: Enrichment factor (EF) for moss (*Acrocladium auriculatum*) collected at Torres del Paine National Park (1984-2001). Using average Taylor [6] crustal values

month/year	EF (Pb)
November, 1984	0.5
March, 1985	0.5
April, 1988	0.9
May, 1997	47.0
May, 2001	10.2

Enrichment factors of terrestrial moss sampled between the years of 1984-1988 showed almost no enrichment, thus indicating no anthropogenic influence. However, in 1997 and 2001, enrichment factors were 47 and 10.2 respectively. Those enrichment factors (>10) indicate the presence of an anthropogenic influences. Although the enrichment factor in 2001 was lower than that in 1997, it confirmed the presence of the anthropogenic influence first noticed in 1997.

The increased Pb contamination might be coming from a local source within the park due to the park's remote location that protects it from long-range atmospheric pollution. We hypothesize that this local source is from the increase in tourism and automobile usage in the park throughout the last twenty years. Table 3 and 4 show the record of tourism and of vehicles respectively entering the park from 1986-2001 (Data provided by Guillermo Santana, Superintendent of Torres del Paine National Park).

Table 3: Five-year averages of number of visitors to Torres del Paine National Park (1976-2001)

Years	annual average # of visitors
1976-1980	3,949
1981-1985	7,061
1986-1990	14,578
1991-1995	29,964
1996-2001	59,390

Tourist use is growing at an exponential rate, doubling every five years. Although this increase in tourists certainly creates a financial burden on the park by increasing operating and maintenance costs, it is the externalities associated with tourists (mainly automobile usage) that perpetuate the increase in pollution. Automobile use in Torres del Paine has also been increasing exponentially in conjunction with the number of visitors to the park (Table 4). Data suggest that the increasing trend in Pb concentrations in moss from 1980's to 2001 might be attributed to the increasing contamination enhanced by increase vehicular traffic within the park. Vehicles in Chile still run on leaded gasoline.

Table 4: Number of automobiles that entered Torres del Paine National Park 1986-1998

year	Automobiles (Thousands)
1986	1.603
1987	2.258
1988	2.951
1989	3.458
1990	3.818
1991	4.296
1992	4.666
1993	5.540
1994	6.420
1995	7.269
1996	8.918
1997	9.286
1998	9.267

5 Conclusion

Acrocladium auriculatum moss Pb concentration data indicated that contamination in Torres del Paine National Park is higher than the early sampling period in the mid 80's. Data from the 1980's established baseline levels of Pb in the park, and they showed to be some of the lowest reported in moss contamination studies in terrestrial ecosystems. Moss Pb concentrations found in 2001 still were significantly lower compared with other terrestrial ecosystems [8]. However, moss samples that were collected and analyzed in 2001 confirmed concerns from 1997 that this park may be under increasing air pollution levels. Enrichment factor analysis confirmed that enhanced air contamination might be derived from anthropogenic sources. Data suggested that increased vehicular tourist traffic within Torres del Paine National Park might be the local source of this enhanced pollution.

6 Acknowledgement

Our thanks to National Geographic Society for providing the funds necessary to continue our research in Torres del Paine National Park. We would like to extend a special thanks to the rangers and staff at Torres del Paine for their warm hospitality and tremendous support throughout the years.

References

[1] Alkezweeney, A.J., Laulainen, N.S., & Thorp, J.M., Physical, chemical and optical characteristics of a clean air mass over Northern Michigan.

Atmospheric Environment, **16**, pp. 2421-2430, 1982.

[2] Bruns, D.A., Wiersma, G.B. & Minshall, G.W., Ecosystem Monitoring at Global Baseline Sites. *Environmental Monitoring and Assessment*, **17(1)**, pp. 3-31, 1991.

[3] Levanic, T., Krusic, P., Hoffmann, S., Huffman, J., Pollmann, W., Ponton, S., & Vera, P., Regeneration Dynamics of *Nothofagus pumilio* in a High Elevation Forest of Southeastern Argentina, Online 2003. www.rmtrr.org/adef/regeneration.htm

[4] Pakarinen, P. & Tolonen, K., Regional survey of heavy metals in peat mosses (*Sphagnum*). *Ambio*, **5(1)**, pp. 38-40, 1976.

[5] Steinnes, E., Hanssen, J.E., Rambaek, J.P., & Vogt, N.B., Atmospheric deposition of trace elements in Norway: temporal and spatial trends studied In moss analysis. *Water, Air, Soil Pollution*, **74**, pp. 121-140, 1983.

[6] Taylor, S.R., Abundance of chemical elements in the continental crust: a new table. *Geochemica et Cosmochemica Act*, **28**, pp. 1272-1285, 1964.

[7] Veblen, T.T., Hill, R.S., & Read, J., The Ecology and Biogeography of Nothofagus forests. Yale University Press, New Haven and London, p. 403, 1996.

[8] Weber, K.A., & Wiersma, G.B., Trace Element Concentrations in Mosses Collected from a Treated Experimental Forest Watershed. *Toxicological and Environmental Chemistry*, **65**, pp. 17-29, 1998.

[9] Wiersma, G.B., Bruns, D.A., Finley, K., McAnulty, L., Whitworth, C. & Boelcke, C., Elemental Composition of Lichens from a Remote Nothofagus Forest Site in Southern Chile. *Chemosphere*, **24(2)** pp. 155-167, 1997.

[10] Wiersma, G.B., White, G.J., Bruns, D.A., & Serey, I., Atmospheric Trace Element Sampling at Torres del Paine National Park, Chile. *Toxicological and Environmental Chemistry*, **49**, pp. 253-264, 1995.

[11] Wiersma, G.B., Bruns, D.A., Boelcke, C., McAnulty, L., & Whitworth, C., Elemental Composition of Mosses from a Remote Nothofagus Forest Site in Southern Chile. *Chemosphere*, **20(5)**, pp. 569-583, 1990.

[12] Wiersma, G.B., O'Rourke, T.P., Bruns, D.A., Boelcke, C., Johnson, A., & McAnulty, L. Integrated Monitoring Project at Torres del Paine National Park-Chile: methodology and data report, 1984 through 1986. EGG-EES 7966. Idaho National Engineering Laboratory, EG&G Idaho, Inc., Idaho Falls, ID. 207 pp. 1988.

[13] Wiersma, G.B., Global Pollution: An early warning system. *Western Wildlands,* **11(3)**, pp. 17-19, 1985.