Elemental composition analysis in lichens transplanted to the western region of Catamarca, Argentina

Raquel Clara Jasan

Técnicas Analíticas Nucleares,
Comisión Nacional de Energía Atómica,
Av. del Libertador 8250,
(1429) Buenos Aires, Argentina
Email: jasan@cae.cnea.gov.ar

Carolina Beatriz Mohaded Aybar,
Alejandra Irupé Ocampo,
Luis Iraúl Palomeque and
Martha Susana Cañas*

Cátedra de Química,
Facultad de Tecnología y Ciencias Aplicadas,
Universidad Nacional de Catamarca,
Maximio Victoria 55,
(4700) San Fernando del Valle de Catamarca, Argentina
Email: cmohaded@hotmail.com
Email: aiocampo@hotmail.com
Email: iraulpalomeque@yahoo.com.ar
Email: marthacanas@tecno.unca.edu.ar
*Corresponding author

Abstract: Thalli of the lichen *Parmotrema austrosinense* were collected in their natural non-polluted habitat and transplanted to 18 monitoring sites within an area of the western region of Catamarca province (Argentina) where fruticose lichens are absent. This region is going through a reactivation phase, owing to large-scale mining development and agricultural expansion. The concentrations of 25 elements were determined in the thalli by instrumental neutron activation analysis. In general, the elemental accumulation of *P. austrosinense* was low when transplanted to the study area. By means of factor analysis it could be inferred that elements of soil and rock have influence over air quality in the study zone. The presence of uranium and arsenic in two separate factors was related to natural sources of these elements present in the region.

Keywords: air quality; arsenic; environment; lichen; load factor; neutron activation analysis; trace elements; uranium.

Reference to this paper should be made as follows: Jasan, R.C., Mohaded Aybar, C.B., Ocampo, A.I., Palomeque, L.I. and Cañas, M.S. (2011) 'Elemental composition analysis in lichens transplanted to the western region of Catamarca, Argentina', *Int. J. Environment and Health*, Vol. 5, No. 4, pp.304–317.

Biographical notes: Raquel Clara Jasan graduated in Chemistry in 1997 from the Universidad del Salvador, Buenos Aires, and as a Specialist in Radiochemistry in 2001 from the Universidad Tecnológica Nacional – Instituto de Estudios Nucleares (CNEA). Since 1998, she has been working at the Nuclear Analytical Techniques Group of the Argentine Atomic Energy Commission, which got accredited in 2001, on the application of neutron activation analysis in air pollution studies by biomonitoring and direct sampling including evaluation and interpretation of the data.

Carolina Beatriz Mohaded Aybar graduated in Biochemical Sciences in 1999 from the Universidad Nacional de Córdoba, Argentina. Since 2004, she has been working at the Universidad Nacional de Catamarca (Argentina) as an Assistant Professor of General Chemistry. She obtained a fellowship of the Secretaría de Ciencia y Técnica of the Universidad Nacional de Catamarca for the study on the biomonitoring of air quality in Catamarca (Argentina) using lichens. She is doing a master in Environmental Management and Conservation. She works as a collaborator in research projects headed by Martha Susana Cañas.

Alejandra Irupé Ocampo graduated in Pharmacy in 1995 from the Universidad Nacional de Córdoba, Argentina. Since 2001, she has been working at the Universidad Nacional de Catamarca (Argentina) as an Assistant Professor of General Chemistry. She works as a collaborator in research projects headed by Martha Susana Cañas.

Luis Iraúl Palomeque graduated in Biochemical Sciences from the Universidad Nacional de Córdoba, Argentina, and subsequently obtained a Master in Environmental Management and Conservation in the Universidad Nacional de Catamarca (Argentina). Since 2004, he has been working at this university as an Assistant Professor of General Chemistry. He works as a collaborator in research projects headed by Martha Susana Cañas.

Martha Susana Cañas graduated in Biological Sciences and subsequently obtained a PhD in Biological Sciences from the Universidad Nacional de Córdoba, Argentina. Since 2002, she has been working as a Professor of General Chemistry for Engineering and Geological Sciences in the Universidad Nacional de Catamarca (Argentina), where she has continued her researches on the chemical response of lichen and tree species to air pollution. She is also serving as Environmental Chemistry Professor for the Environmental Management and Conservation Master and for the Geological Science Doctorate. Her research projects focus on the assessment of the air quality in urban, rural and mining areas in the northwest of Argentina through the use of biosensors.

1 Introduction

The capability to accumulate chemical elements from the atmosphere leads to the use of lichens as air quality biomonitors (Freitas et al., 1999; Nimis et al., 2000; Garty, 2001; Pignata et al., 2007). Most works on elemental accumulation in lichens have been focused on urban and industrial pollutants, with a lesser number about areas with scarce or null anthropogenic activity. Nevertheless, these studies are important, not only for establishing baseline levels for an area but also for detecting other pollution sources at rural areas (Palomeque et al., 2007).

Transplant techniques have been used to monitor air pollution in areas where lichens are scarce or absent (Adamo et al., 2003; Bergamaschi et al., 2007; Sorbo et al., 2008). Among them, the bags technique (Adamo et al., 2003) is commonly used to monitor urban air pollution in the centre of Argentina (González and Pignata, 1999; Carreras and Pignata, 2002; Bermudez et al., 2009).

In this sense, thalli of lichen *Parmotrema austrosinense* were collected in their natural non-polluted habitat and transplanted to different sites within an area in the West of Catamarca province (Argentina) where fruticose lichens are absent. This region is going through a reactivation phase, owing to the large-scale mining development and agricultural expansion. Since environmental conditions greatly influence ecosystem vulnerability, it is probable that the economic growing process results into ecological and environmental problems (Morlans, 1997). Thus, large masses of dust of unknown origin are more and more frequent and this phenomenon could be related to some factors of environmental degradation.

In this work, results of multi-element analysis in the transplanted *P. austrosinense* are presented, in order to contribute to the evaluation of air quality of the western region of Catamarca. *P. austrosinense* is a conspicuous species growing in Argentina, that has proved to be a good response indicator when transplanted to urban and industrial sites (Cañas et al., 1997; Cañas and Pignata, 2003), as well as to rural (Palomeque et al., 2006; Mohaded Aybar et al., 2008a) and mining areas (Mohaded Aybar et al., 2008b).

2 Materials and methods

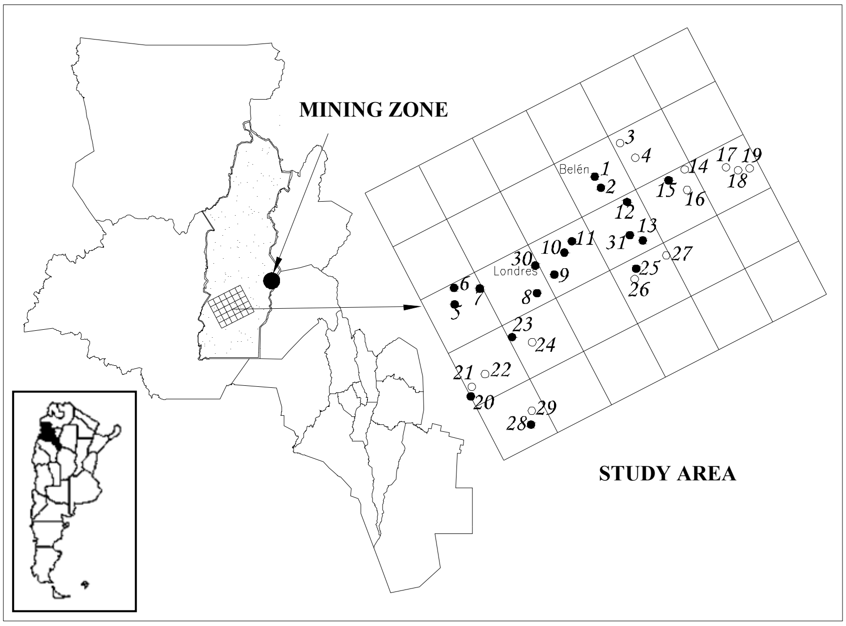
2.1 Study area

The study area of about 600 km^2 (Figure 1) is located at the western area of the so called 'Bolsón de Pipanaco'. This inter-mountain depression (bolsón) is at the Central-West of Catamarca province, among the coordinates 27° 30' N, 66° 12' E, 28° 30' S, and 67° 12' W, as part of the morphostructural unit of Northwestern Pampean Ranges. Geologically, it consists of a basement of pre-Palaeozoic rocks (González Bonorino, 1972), covered mainly by quaternary alluvial deposits. In the region, there are important Au, Ag, Cu and Mo deposits currently under exploration. An open-pit copper-gold mine (Argentina's first large-scale mining operation) is located 53 km NE of the study area.

The climate of the bolsón is arid; precipitations are very scarce, only about 150–300 mm per year, with a strong summer concentration (about 60–70% of the total precipitation) and dominant winds are from NE, S and SE. Phytogeographically, it is located in the Monte Phytogeographic Province in the Chaqueño Domain of the Neotropical region (Morlans, 1995). At the alluvial cones of the western foothill where the rainfall is relatively higher, the vegetation is more conspicuous compared to the central area of the bolsón.

The study area is sparsely populated and the most important localities are Belén (11,003 inhabitants; the fourth city in the Province) and Londres (2134 inhabitants, according to a 1991 census). There is a small-scale agricultural activity centred in walnut trees (mainly at Londres's surroundings), aromatic herbs and vegetables. Livestock farming consists extensive grazing on natural vegetation, without management or control practices.

Figure 1 Location of the study area at Belén, Catamarca province. Numbers show transplant sites and full circles correspond to those sites with analytical results



2.2 Sampling procedure

Lichen *P. austrosinense* (Zahlbr.) Hale was used as biomonitor. Thalli were collected from a clean site near Coneta (central valley of Catamarca). Part of this freshly picked material was also analysed to get a baseline level to compare the transplants analysis results. Lichen bags were prepared and transplanted, following the methodology described by González and Pignata (1994).

Transplant sites were selected based on a geo-referenced satellite image, dividing the study area into 5 km × 5 km squares. Within each square, transplant bags were exposed at two or three different points for three months (October 2005–January 2006). Although 30 sample squares had been originally proposed, it was possible to sample only 12 due to geographical factors that determine the inaccessibility to some sample points (lichens could only be transplanted at foothill sites). From a total of 31 transplant bags, only 18 were recovered after the exposure period.

2.3 Multi-elemental analysis

Instrumental Neutron Activation Analysis (INAA) was used to determine elemental composition. Samples were ground in a Spex CentiPrep 6750 cryogenic mill and lyophilised for 24 hours. About 300 mg of lyophilised material was pelletised and wrapped-up in aluminium foil for irradiation together with two certified reference materials, NIST SRM 1633b Coal Fly Ash and IAEA Lichen 336, for calibration purposes. Irradiations were done at the RA-3 reactor (thermal flux 3×10^{13} $cm^{-2}s^{-1}$, 8 MW) of the Argentine National Atomic Energy Commission (Ezeiza Atomic Centre) for 4 hours. Two measurements were performed after 7 and 30 day-decay using GeHP detectors (30% efficiency, 1.9 keV resolution for 1332.5 keV ^{60}Co peak) coupled with an Ortec 919E multi-channel buffer module. Concentrations of As, Ba, Br, Ce, Co, Cr, Cs, Eu, Fe, Hf, K, La, Lu, Na, Nd, Rb, Sb, Sc, Se, Sm, Ta, Th, U, Yb and Zn were calculated using a software developed at the NAA laboratory. GBW07405 Soil was used as control sample and the results obtained are summarised in Table 1. For all determined elements, experimental values showed good agreement with those in the material's certificate.

Table 1 Quality control results (μg g^{-1}) obtained in the analysis of GBW07405 (Soil) by Neutron Activation Analysis (NAA)

Element	*Certified*	*Experimental*
As	412 ± 24	407 ± 12
Ba	296 ± 40	316 ± 100
Ce	91 ± 15	97.9 ± 4.5
Co	12 ± 2	12.40 ± 0.39
Cr	118 ± 10	117 ± 6
Cs	15 ± 2	15.0 ± 0.8
Eu	0.82 ± 0.06	0.86 ± 0.16
Fe	9.0E+04 ± 2.0E+03	8.6E+04 ± 1.1E+03
Hf	8.1 ± 1.7	7.71 ± 0.98
La	36 ± 6	37.4 ± 0.5
Lu	0.42 ± 0.07	0.423 ± 0.047
Na	890 ± 30	886 ± 96
Rb	117 ± 9	121 ± 9
Sb	35 ± 7	34.7 ± 0.4
Sc	17 ± 2	17.4 ± 0.1
Sm	4.0 ± 0.6	4.54 ± 0.22
Ta	1.8 ± 0.3	2.03 ± 0.45
Tb	0.7 ± 0.2	0.755 ± 0.071
Th	23 ± 2	23.4 ± 0.6
U	6.5 ± 1.1	7.07 ± 0.97
Yb	2.8 ± 0.5	2.60 ± 0.55
Zn	494 ± 39	493 ± 35

Note: Average of ten replicates.

2.4 Data analysis

Statistical analysis was performed on analytical data from 18 sampling sites, out of a total of 31 points in the study, using SPSS 16.0.

For elemental composition in *P. austrosinense* transplanted to each exposure site, a Load Factor (LF) was calculated according to Giordano et al. (2005):

$$LF = (C_{exposed} - C_{original})/C_{original}$$

where $C_{exposed}$ is the content of an element in lichen samples after exposure, while $C_{original}$ is the content of the same element determined in lichen samples before exposure.

Pearson's correlation coefficients were also calculated to study the relationships between the chemical elements. A preliminary factor analysis was performed using Principal Component Analysis and Varimax rotation.

3 Results and discussion

Table 2 shows the values of arithmetic mean, standard deviation (SD), minimum, maximum and coefficient of variation (CV = SD/mean), for each determined element in *P. austrosinense* transplanted to the study area. Comparison between elemental concentrations in this species with values observed in others from the same genus has been discussed before (Jasan et al., 2008). Concentration values of Br, Co, Cs, Hf, K, La, Rb, Sc, Se, Sm, U and Zn in *P. austrosinense* were similar to those reported by Bergamaschi et al. (2002) for Himalayan lichens, while those for As, Ce, Cr, Fe and Th were higher and Sb values were lower.

Pignata et al. (2007) also observed high As content in *Ramalina celastri* growing in the central region of Argentina and related this result with the presence of As in basic soils typical of the Pampa plains. For Catamarca province, Vilches et al. (2005) reported high As concentrations in surface and ground waters in areas corresponding to endorheic basins, such as the Bolsón de Pipanaco. For these areas, As origin is attributed to the presence of volcanic ashes in the soil, where they have formerly been carried from volcanic zones by aeolian action; as well as to igneous, sedimentary and metamorphic rocks meteorisation, that can release arsenic compounds (arsenites, arsenates or arsenic trioxide) of great mobility, able to migrate long distances from the source. For the province of Catamarca, it cannot be dismissed the possibility that As can be mobilised from different anthropogenic processes, such as mineral beneficiation that can lead to arsenic contamination phenomena (Vilches et al., 2005).

Although As content in *P. austrosinense* transplanted to Belén was similar to the values for other Argentine lichens (Pignata et al., 2007), most of the other determined elements showed higher concentrations. High values of Fe, Rb and rare earth elements were in accordance with the geochemical characteristics of the study area, as Fogliata and Ávila (2004) mentioned that the granitic rocks in the region are enriched in these elements.

In general, high values of coefficients of variation were obtained, if compared with previous works with other lichen species (Garty et al., 1996; Garty et al., 1998). According to Garty et al. (1977), CV analysis can provide information on the form of the elements absorbed/accumulated in the lichen thallus. Thus, different CVs indicate differences between dispersion of metal particles; that is, small CVs indicate a low variation in the air, due to a suspension of minute particles, while in contrast high CVs indicate the deposition of coarse particles.

Thus, high CV values obtained for *P. austrosinense* ($CV \geq 0.20$, except for As), would reflect the particulate form of the elements accumulated in the lichen thalli. Especially for Ba, Cr, Cs, Hf, Sb, Se, Ta and Th, CVs suggest intake of these elements from particles larger than those containing the rest of the determined elements.

Table 2 Elemental concentration (mg kg^{-1}, dry weight) in *P. austrosinense* transplanted to Belén (Catamarca, Argentina) and in original material

	Mean ± S.D.	*Range (minimum – maximum)*	*C.V.*	*Original value*
As	2.40 ± 0.40	1.62 – 3.28	0.17	2.480
Ba	65 ± 26	30 – 132	0.41	0.950
Br	5.5 ± 1.6	2.6 – 8.0	0.28	6.400
Ce	20.3 ± 8.6	7.5 – 34	0.42	19.33
Co	1.69 ± 0.52	0.99 – 2.7	0.31	1.362
Cr	12.9 ± 5.4	6.4 – 27	0.42	10.82
Cs	2.31 ± 0.93	0.99 – 4.2	0.40	2.080
Eu	0.22 ± 0.06	0.13 – 0.36	0.29	0.1830
Fe	5200 ± 1900	2800 – 9000	0.36	4189
Hf	1.37 ± 0.65	0.45 – 2.69	0.48	0.890
K*	5900 ± 1600	3800 – 8600	0.27	4827
La	5.5 ± 1.5	3.5 – 9.5	0.27	3.637
Lu	0.073 ± 0.026	0.032 – 0.15	0.36	0.0441
Na	2700 ± 1000	1100 – 4900	0.38	970
Nd	5.3 ± 1.1	3.6 – 7.0	0.21	4.10
Rb	26 ± 10	11 – 46	0.38	18.6
Sb	0.195 ± 0.079	0.109 – 0.472	0.41	0.2010
Sc	0.86 ± 0.65	0.98 – 3.20	0.35	1.4970
Se	1.03 ± 0.47	0.39 – 1.8	0.45	0.750
Sm*	0.93 ± 0.22	0.63 – 1.34	0.24	0.6865
Ta	0.27 ± 0.11	0.13 – 0.49	0.42	0.166
Th	3.2 ± 1.4	1.2 – 5.7	0.44	2.597
U	0.53 ± 0.17	0.25 – 0.85	0.32	0.490
Yb	0.44 ± 0.13	0.25 – 0.71	0.29	0.263
Zn	44 ± 11	29 – 71	0.26	25.9

Notes: *n = 18 except for K (n = 10) and Sm (n = 17).

The amounts of trace elements intercepted by biomonitors during the entire exposure time (post-exposure to pre-exposure content) were compared after normalisation (as LF), by dividing their absolute values by the respective pre-exposure content, following Giordano et al. (2005). The chemical element LF values in *P. austrosinense* at the transplant sites are reported in Table 3. It may be noted that, with the exception of Na, element LF mean values were below 1. Moreover, most of the elements (except Na and Zn) had negative LF values in some transplant sites. These results could indicate a selective accumulation of Na and Zn in *P. austrosinense*.

Table 3 Element load factor (LF) in *P. austrosinense* transplanted to Belén (Catamarca, Argentina)

Sites	*As*	*Ba*	*Br*	*Ce*	*Co*	*Cr*	*Cs*	*Eu*	*Fe*	*Hf*	*K*	*La*	*Lu*
1	0.03	2.77	–0.59	0.54	0.97	0.95	0.79	0.95	1.15	2.02	0.79	1.62	–0.26
2	–0.06	1.43	–0.45	0.65	0.74	0.65	0.75	0.69	0.78	1.29	–	0.78	1.08
5	0.32	1.06	–0.34	–0.21	–0.07	0.10	–0.16	–0.10	–0.07	0.12	0.73	0.43	2.31
6	0.24	1.83	–0.45	0.73	0.97	1.46	1.01	0.85	1.04	1.53	–	0.94	1.08
7	–0.18	0.43	–0.30	–0.49	–0.03	–0.22	–0.34	–0.08	–0.11	–0.23	–	0.24	0.35
8	–0.14	0.74	–0.32	–0.45	0.09	–0.10	–0.24	0.00	0.05	0.15	–	0.33	0.86
9	–0.14	0.51	–0.22	0.13	0.10	0.19	0.15	0.12	0.14	0.42	0.03	0.47	0.35
10	–0.17	–0.03	–0.32	–0.61	–0.27	–0.40	–0.52	–0.28	–0.34	–0.49	–	–0.04	–0.04
11	–0.01	0.46	0.19	–0.47	0.03	–0.23	–0.33	–0.02	–0.06	–0.19	–	0.27	0.31
12	–0.01	0.69	–0.15	0.23	0.28	0.37	0.04	0.28	0.30	1.01	0.01	0.68	0.93
13	0.04	0.94	–0.09	–0.36	0.25	0.02	–0.16	0.15	0.21	0.39	–	0.58	0.93
15	0.13	1.91	0.04	0.29	0.53	0.28	0.45	0.40	0.66	1.34	0.19	0.94	1.19
20	–0.35	–0.11	–0.03	0.12	–0.24	–0.21	–0.07	–0.04	–0.30	–0.09	–0.22	0.05	–0.03
23	–0.19	–0.14	0.25	0.33	–0.14	–0.30	0.09	–0.03	–0.17	0.00	–0.12	0.16	0.22
25	0.05	0.77	0.05	0.54	0.53	0.76	0.49	0.51	0.60	1.22	0.23	0.64	0.83
28	–0.09	0.49	0.11	0.19	0.20	0.10	0.08	0.17	0.19	0.22	0.30	0.13	0.29
30	0.00	1.09	0.08	0.22	0.41	0.28	0.39	0.32	0.50	1.06	0.38	0.64	0.92
31	–0.02	0.51	–0.04	–0.49	–0.06	–0.23	–0.38	–0.08	–0.10	–0.12	–	0.31	0.66
Mean	–0.03	0.85	–0.14	0.05	0.24	0.19	0.11	0.21	0.25	0.54	0.23	0.51	0.67

Table 3 Element load factor (LF) in *P. austrosinense* transplanted to Belén (Catamarca, Argentina) (continued)

Sites	*Na*	*Nd*	*Rb*	*Sb*	*Sc*	*Se*	*Sm*	*Ta*	*Th*	*U*	*Yb*	*Zn*	*∑LF*
1	4.05	0.66	1.41	−0.09	1.13	0.12		1.97	1.08	0.32	1.69	1.73	25.82
2	2.10	0.63	1.15	0.07	0.72	1.37	0.89	1.13	0.90	0.65	1.21	1.55	14.25
5	0.73	0.27	−0.03	−0.16	−0.09	0.41	−0.08	0.34	−0.09	−0.11	0.40	0.65	6.35
6	2.82	0.71	1.46	1.35	1.06	1.21	0.97	1.42	1.19	0.73	0.61	1.04	25.81
7	2.23	0.08	−0.03	−0.29	−0.11	−0.35	0.23	−0.01	−0.37	−0.04	0.25	0.32	0.95
8	2.86	0.22	0.12	0.15	0.01	−0.19	0.35	0.30	−0.28	0.13	0.83	0.75	6.23
9	0.89	0.07	0.40	−0.24	0.17	0.57	0.34	0.62	0.30	0.10	0.37	0.61	6.45
10	0.70	−0.12	−0.41	−0.34	−0.35	−0.48	−0.01	−0.23	−0.54	−0.28	−0.04	0.29	−5.33
11	1.97	0.07	−0.07	0.19	−0.08	−0.33	0.28	0.11	−0.31	0.05	0.28	0.65	2.75
12	1.32	0.66	0.34	−0.19	0.26	1.07	0.12	0.83	0.47	−0.16	1.07	0.78	11.26
13	1.97	0.32	0.19	0.18	0.18	0.01	0.74	0.44	−0.09	0.39	0.91	0.19	8.34
15	2.28	0.61	0.78	0.12	0.66	1.11	0.26	1.29	0.74	0.05	1.29	0.86	18.21
20	0.10	0.00	0.17	−0.45	−0.22	−0.03	−0.03	−0.07	−0.01	−0.43	−0.06	0.12	−2.43
23	0.25	0.37	0.30	−0.42	−0.10	0.16	0.10	−0.13	0.07	−0.48	0.27	0.25	0.73
25	2.29	0.49	0.80	0.00	0.54	1.15	0.64	0.85	0.80	0.27	0.88	0.91	16.80
28	1.08	−0.05	0.33	−0.15	0.17	0.40	0.18	0.28	0.18	−0.23	0.24	0.42	5.25
30	2.82	0.32	0.78	−0.11	0.48	0.87	0.66	1.66	0.62	0.51	0.98	1.04	16.54
31	0.96	0.12	−0.15	−0.13	−0.13	−0.37	0.43	−0.06	−0.35	0.08	0.65	0.58	1.60
Mean	1.75	0.30	0.42	−0.03	0.24	0.37	0.36	0.60	0.24	0.09	0.66	0.71	

In the present study, transplantation corresponded to the highest precipitation period (late spring to early summer) that occurs after a large drought seasons with rainfall below 20 mm. Most biomonitoring studies suggest that rain after a drought may cause the displacement of cations bound to negatively anionic sites in the cell wall and outer surface of the plasma membrane and the substantial wash-out of particles (Bargagli, 1998). Since precipitations were concentrated in January just before the end of the transplantation period, negative LF values could be indicating a washing effect of rainfall on most of the elements quantified in *P. austrosinense*. Due to the size of the study area, there are no differences in precipitations among sampling points, but there might be differences in wind direction combined presence of obstacles.

Data were used to compute a cumulative LF value (∑LF) in order to estimate the multi-element load of the exposure sites. Although differences in cumulative LF value (∑LF) between sites could be detected, in general *P. austrosinense* multi-elemental load during the survey period was low. The sites with the highest LF values are located at the Quebrada de Belén (site 1) and at El Shinkal NW of Londres (site 6), where the hills act as a geographical barrier that causes the deposition of particulate material carried by the wind from the SE area. An exploratory analysis showed that lichens transplanted to these inter-mountain areas (sites 1, 2, 5, 6 and 7) showed a multi-elemental load significantly higher than those transplanted to the remaining sites within the study area (ANOVA, $p < 0.1$). Individually, Ba, Co, Cr, Cs, Eu, Fe, K, La, Rb, Sc, U and Zn presented significantly high LF values in *P. austrosinense* transplanted to the Quebrada de Belén and El Shinkal.

To reduce the initial information through a lineal combination of variables, factor analysis was applied on the data matrix. Keeping the factors with eigenvalues over 1, a total of four factors were chosen that accounted for approximately 90% of the total variance, indicating that the results are statistically consistent (Table 4). Considering the contribution of the different chemical variables in each factor, it is possible to detect different geochemical associations that give account of the origin of the particles intercepted by the biomonitor.

Table 4 Factor analysis for analytical results of *P. austrosinense* transplanted to Belén (Catamarca, Argentina). The eigenvectors higher than 0.700 are in bold

	Communalities	*Component*			
		1	*2*	*3*	*4*
As	0.914	0.240	0.376	0.227	**0.815**
Ba	0.945	0.579	**0.720**	0.219	0.207
Br	0.444	–0.086	–0.632	–0.194	0.000
Ce	0.952	**0.967**	–0.082	0.094	0.014
Co	0.984	**0.770**	0.443	0.435	0.077
Cr	0.901	**0.771**	0.298	0.430	0.180
Cs	0.957	**0.911**	0.170	0.309	0.048
Eu	0.982	**0.846**	0.376	0.354	–0.012
Fe	0.989	**0.798**	0.454	0.372	0.081
Hf	0.985	**0.881**	0.395	0.204	0.109
K	0.837	–0.008	**0.850**	–0.024	0.336

Table 4 Factor analysis for analytical results of *P. austrosinense* transplanted to Belén (Catamarca, Argentina). The eigenvectors higher than 0.700 are in bold (continued)

	Communalities	*Component*			
		1	*2*	*3*	*4*
La	0.942	**0.706**	0.640	0.157	0.098
Lu	0.921	0.053	0.032	0.119	**0.950**
Na	0.848	0.347	**0.723**	0.446	–0.078
Nd	0.815	**0.787**	0.268	0.183	0.302
Rb	0.973	**0.885**	0.272	0.341	–0.020
Sb	0.834	0.248	0.129	**0.816**	0.302
Sc	0.987	**0.819**	0.424	0.364	0.060
Se	0.918	**0.838**	–0.148	0.178	0.403
Sm	0.883	0.388	0.125	**0.846**	0.045
Ta	0.913	**0.776**	0.497	0.225	0.115
Th	0.989	**0.947**	0.182	0.225	0.087
U	0.912	0.366	0.413	**0.760**	0.171
Yb	0.758	0.612	0.600	0.088	0.128
Zn	0.838	0.654	0.613	0.178	0.055
Variance (%)		46.093	20.415	14.289	8.875

Factor 1 has high contributions of Ce, Co, Cr, Cs, Eu, Fe, Hf, La, Nd, Rb, Sc, Se, Ta, Th and can be assigned to lithogenic elements, which would indicate that soil and rocks are the principal source of metal and trace elements in the air. Co, Cr and Fe are associated to silico-magnesian ultrabasic rocks and gabbros present between Belén and Londres. Rare earths and their natural associates, Cs and Rb are normal in certain granitoid types and exhibit geochemically anomalous levels in radioactive granites as those found at Sierra de Belén and Zapata hills (included in the study area). It is a regional geochemical especialisation. Gabbros are intrusive plutonic igneous rocks.

Factor 2 has important contributions of Ba, K and Na and corresponds to lithophile elements (Goldschmidt geochemical classification; Rankama and Sahama, 1954); this is, elements that are present in the upper earth crust and have great affinity for oxygen. These elements are a characteristic association in hydrothermal mineralisations, abundant in the region. They are normally present in granitoid rocks. Ba (15–100 ppm) is present as a replacement in potassium feldspar.

Factor 3 has high loadings for Sb, Sm and U and can also be related to soil, although Sb is considered a semi-volatile element frequently associated with anthropogenic processes (Jasan et al., 2004; Pignata et al., 2007). The presence of U in Factor 3 indicates that this element provides a certain amount of variability to the data obtained in this study. Uranium contents in *P. austrosinense* (Table 2) was similar to those in other species used as passive biomonitor in other Argentine province (Pignata et al., 2007), and could be reflecting the presence of important uranium resources (still unexploited) in the region where the study area is located. Radioactive granites present in the region have U and Th associated to rare earth elements such as Sm. Nevertheless, Sb is associated to other kind of environment of low temperature hydrothermal mineralisations, present between Belén and Londres.

In Factor 4, Lu, a typical soil element, is associated to As. In Catamarca province, As origin is attributed to the presence of volcanic ashes in the soil, where they have formerly been carried from volcanic zones by aeolian action; as well as to igneous, sedimentary and metamorphic rocks meteorisation, that can release arsenic compounds (arsenites, arsenates or arsenic trioxide) of great mobility, able to migrate long distances from the source of origin. For the province of Catamarca, it cannot be dismissed the possibility that As can be mobilised from different anthropogenic processes, such as mineral beneficiation that can lead to arsenic contamination phenomena (Vilches et al., 2005). In the region there are acid Tertiary vulcanites with high As contents. At Londres area, the anomalous presence (geochemically speaking) is associated mostly to the presence of very abundant W-Sn-Mo-Bi-Ta-Cb mineralisations. There are cupriferous sulpharsenide and also, scarce arsenopyrite. For the area between Londres and Belén, As concentrations in normal rocks varies between 18 ppm and 85 ppm (representing granite-gabro as extreme terms). Lu is present in regional granites associated to Sn-Mo-W-Bi mines.

All factors correspond to natural geochemical associations, characteristic of different litologic formations present in the study area, as well as in the region where it is located. No emission sources other than natural ones have been detected, including windblown soil and sediments from Bolsón de Pipanaco basin, although they could be associated to overexploitation by shepherding or land clearing for agricultural purposes. No effect from the mine has been detected and this could be due to its location NE of the study area while predominant wind are mainly from the SE.

4 Conclusion

In general, *P. austrosinense* showed low elemental accumulation when transplanted to an area within Western Catamarca. Nevertheless, a differential behaviour could be detected for this species, both for individual element retention, and for multi-elemental accumulation at transplant sites.

From the elemental analysis of *P. austrosinense*, it could be inferred that elements from soil and rock have influence over air quality in the study zone. Particularly significant was the presence of As and U as important variables in the analysis.

Results presented in this work have to be considered as starting point for heavy metal and trace element monitoring using *P. austrosinense* transplants at Western Catamarca. It is necessary to deepen the study of this species accumulation capacity, considering different environmental conditions; as well as to enlarge the number of analysis of transplants, to be able to establish air quality levels for the region.

Acknowledgements

This study was supported by the Secretaría de Ciencia y Tecnología de la Universidad Nacional de Catamarca (SECyT). We thank to E.H. Peralta for his invaluable collaboration in the geochemical discussions.

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