DETERMINATION OF TRACE ELEMENTS IN LICHEN SAMPLES BY INSTRUMENTAL NEUTRON ACTIVATION ANALYSIS

[1]MITIKO SAIKI, [1]LIDIA K. HORIMOTO, [1]MARINA B.A. VASCONCELLOS, [2]MARCELO P. MARCELLI, [3]NAIRO M. SUMITA, [3]PAULO H. N. SALDIVA

[1]Instituto de Pesquisas Energéticas e Nucleares, Caixa Postal 11049, CEP 05422-970, São Paulo, SP, Brazil.
[2]Instituto de Botânica, Seção de Micologia e Liquenologia, Caixa Postal 4005, CEP 01061-970, São Paulo, SP, Brazil
[3]Laboratório de Poluição Atmosférica, Faculdade de Medicina da USP, Av. Dr Arnaldo 455, CEP 01246-903, São Paulo, SP, Brazil

Abstract:

Samples of Canoparmelia texana lichen collected in different sites of São Paulo and Paraná States, Brazil, were analysed by neutron activation analysis in order to obtain preliminary information on the air quality in these regions and also to select a region of interest for biomonitoring studies. Also Tadescantia pallida plant has been analysed in order to study the viability of using this specimen in environmental pollution monitoring. Lichens samples were collected from tree barks which were also collected to investigate the contribution of substrate derived elements to elements present in lichens. Young and old leaves of T. pallida were collected separately in order to study the leaf age effects on their elemental levels. The samples were cleaned, washed with distilled water, dried and ground for the analyses. Samples and standards were irradiated at the IEA-R1m nuclear reactor for short and long periods and concentrations of the elements Al, As, Ca, Cd, Cl, Co, Cr, Cs, Fe, Hf, Mg, Mn, Rb, Sb, Sc, Ti, Th, U, V, Zn and lanthanides were determined. Preliminary results obtained for T. texana lichen indicated that three sites (Ibiúna, Botanical Garden and Parque de Vila Velha) present low concentrations of the most elements analysed. Therefore lichens from these regions could be analysed to establish baseline levels of elements for monitoring purposes. Samples collected in open areas presented high concentrations of some elements probably due to the accumulation of elements originating from soil and from heavy vehicular traffic. Elemental concentrations obtained in outer barks were similar or smaller than those results obtained for lichens. Results obtained for T. pallida indicated that concentrations of elements in old leaves of this plant are of the same magnitude or slightly higher than those presented in young ones.

1. SCIENTIFIC BACKGROUND AND SCOPE OF THE PROJECT

During the last decades, lichen analyses have played an important role in studies on environmental pollution monitoring. The accumulation of various air pollutants, including heavy metals by lichens is well documented and they are considered as useful monitors for air quality [1-3].

The advantages of using lichens as biomonitors, instead of direct measurement of pollutants in several materials of the environment such as water and air, are their easy sampling and their wide geographical distribution allowing comparison of metal concentrations from several regions and to draw more reliable pollution maps of a large area.

The occurrence of about 2,800 lichen species in the Brazilian territory has been published [4], however works with strictly ecological studies on communities of lichens are rare. This way, data on trace elements in lichens collected in Brazil as biomonitor of atmospheric particulate matter and deposition are also practically non-existing.

Consequently the development of this project is being of great interest due to the serious problems of pollution encountered here specially in big cities like São Paulo or in industrialised areas. Also this project is providing an opportunity to improve our knowledge concerning the validation of the use of plants as biomonitors of air pollution.

In this second year of this project, samples of the lichen *Canoparmelia texana* collected in different sites of States of São Paulo and Paraná, Brazil, were analysed by neutron activation analysis in order to obtain preliminary information on the air quality in these regions and also to select a region of interest for biomonitoring studies.

Also a plant named *Tradescantia pallida* is being analysed in this project in order to evaluate the viability of using this plant in the regions where lichens are not present. *T. pallida* was chosen for biomonitoring purposes due to its wide distribution in São Paulo city and its easy propagation, even in regions with high level of pollution, such as central area of São Paulo city. These conditions allow us to use *T. pallida* specimens specially cultivated for monitoring purposes or those spontaneously appearing in the interest areas.

The harmful effects of environmental pollution caused to *T. pallida* have been evidenced by micronucleus assay by several researchers [5-7]. The nuclei of plant DNA molecules which were submitted to high pollution levels are split in micronuclei so that the *T. pallida* might used as an indicator of environmental pollution. The number of micronuclei raises with the air pollution increase, that is, the more DNA molecules are split, the more polluted is the air.

Also *T. pallida* is considered an ideal plant for air monitoring and testing and this species has been used to test for mutagenicity of radioisotpes - contaminated air after nuclear accident and monitoring around power plants [8].

The analytical methodology used in the analyses of *C. texana* lichen and *T. pallida* plant was the instrumental neutron activation analyses (INAA).

2. MATERIALS AND METHOD

2.1. Collection and preparation of the samples

2.1.1. Collection of lichen samples and sampling points

C. texana *(Tuck) Elix & Hale is an epiphytic lichen species of the family Parmeliaceae. This foliose lichen with large thallus (5 to 20 cm in diameter) and radial growth was collected from the tree barks. The samples were carefully removed using a titanium knife and placed in a paper bags. Plastic bags were not adequate for storing lichen samples because of the their humidity and the mould formation. They were collected at the following sampling sites*:

- Site Nr.1 – Ibiúna city, SP, that is a part of the green ring (horticultural and touristical region) located in the country about 100 km from São Paulo city, 850 meters above sea level, and it is a region considered not polluted, originally covered by a Mesophyllous Forest however not far from Serra do Mar.
- Site Nr.2 – Alto da Serra, Paranapiacaba, São Bernardo do Campo city, SP is a region supposed to be clean, located in a high place near the top of the Serra do Mar, about 720 meters above sea level, rounded by Tropical Rain Forest.

- Site Nr.3 – Jardim Casqueiro, Praça Independência, Cubatão, SP. Cubatão is a city situated in a coastal region, in a place originally covered by mangroves, about two meters above sea level. Cubatão is well known as one of the most polluted cities of the world however, the lichen samples were collected in a clean place located before the south winds cross the industrial part of the city.
- Site Nr.4 – Campo Limpo Paulista town, SP, situated about 100 Km from São Paulo city, 750 meters above sea level. The lichen sample was collected near a not paved road and in a place particularly submitted to heavy dust from the soil. This region was originally covered by Cerrado vegetation.
- Site Nr.5 – Botanical Garden, SP, that is situated 15 km far from downtown of São Paulo city, inside the urban zone, 680 meters above sea level.
- Site Nr.6 - Instituto de Pesquisas Energéticas e Nucleares (IPEN), SP, located at the Campus of the São Paulo University, in the urban zone of São Paulo city, with vehicular traffic.
- Site Nr.7 - Campus of São Paulo University, SP, situated about 650 meters above sea level and with heavy vehicular traffic and building contructions.
- Site Nr.8 – Parque Vila Velha situated in Ponta Grossa city, Paraná State, is an open field with great rock formations and it is a not polluted area in the countryside, 950 m above sea level.

2.1.2. Treatment of the lichen samples

In the laboratory the thalli were examined under an Olympus stereoscopic microscope model SZ4045 and they were cleaned in order to remove substrates or other adhered material. Then the samples were washed in distilled water where the samples remained immersed for about 5 minutes to remove dust and sand. Next the samples were freeze-dried for 16 hours under a pressure of about 4.10^{-2} mbar. A fine powder of the lichen sample was obtained by manual grinding in an agate mortar.

2.2. Samples of *Tradescantia pallida* plant

Tadescantia pallida (Rose) Hunt. Cv purpurea is an indigenous popular ornamental plant, which is widely grown in the garden, roadside and streets of São Paulo city. This plant was cultivated in vases by researchers of Medicine School of São Paulo University to investigate the suitability of *Tradescantia* micronucleus bioassay to detect the toxicity of environmental pollutants and also to use this plant as biomonitor of toxic elements. The same lot of soil sample was used in all vases and they were kept in three sites of different levels of air pollution:

- Bandeirantes Avenue – is one of most polluted avenues from São Paulo city, SP.
- Medicine School of São Paulo University, one polluted area of São Paulo city, and
- Caucaia, SP is a clean region of the countryside situated about 50 km from São Paulo central area. Caucaia was considered as a control region and the vases of these plants were kept in a green house.

2.2.1. Treatment of T. pallida samples for analysis

Young and old leaves of *T. pallida* were collected separately in plastic bags. In the laboratory they were previously washed using distilled water, dried in an oven at 37°C during 48 hours and then they were ground in an agate mortar to obtain the samples in a powder form. A loss weight percentage of about 93% was obtained in this drying process.

2.3. Preparation of Standards

Multielement standards were used for the INAA determinations. Stock solutions of elements were provided from Spex Chemical or they were prepared by dissolving high purity metals, oxides or salts in high purity reagents or distilled water. Single or multielement solutions were prepared by using appropriate amounts of these stock solutions and they were then pipetted onto a sheets of Whatman 42 filter paper. After drying these sheets in a desicator, they were placed in polyethylene bags that were heat sealed for irradiation together with the samples.

2.4. Instrumental neutron activation analysis

The samples, ranging in mass from 100-180 mg, were weighed in polyethylene envelopes. Short irradiations of 5 minutes were carried out using a pneumatic transfer system of the IEA-R1m nuclear reactor and under a thermal neutron flux of $4\ 10^{11}$ n cm^{-2} s^{-1} for the determinations of Al, Cl, Mg, Mn, Na, Ti and V. Longer irradiations of 16 h under thermal neutron flux of about 10^{12} n cm^{-2} s^{-1} were carried out for As, Br, Ca, Cd, Co, Cr, Cs, Fe, Hf, K, lanthanides, Rb, Sb, Sc, Th, U and Zn determinations.

After adequate decay times, gamma ray measurements were performed using a Canberra GX2020 hyperpure Ge detector which was coupled to Model 1510 Integrated Signal Processor and System 100MCA Card, both from Canberra. The detector used had a resolution (FWHM) of 0.9 keV for 122 keV gamma rays of ^{57}Co and 1.78 keV for 1332 kev gamma rays of ^{60}Co. Samples and standards were measured at least twice and the sample-to-detector distances of 3.0 and 0.5 cm were used for first and second measurements, respectively. The gamma-ray spectra were processed using VISPECT software[9] that evaluates peak areas (counting rates) and gamma ray energies. The standard comparative method was used for calculating the elemental concentrations.

Certified reference materials IAEA 336 Lichen and NIST 1570 Peach Leaves were irradiated with the samples and analysed to control the quality of the results. The accuracy and the precision for most of elements were, generally, found to be within 11%.

3. RESULTS

Table I presents results obtained in the samples of *C. texana* collected in seven sites of São Paulo State and one site of Paraná State. In all these samples, Ca was found in higher concentrations at levels of percentages. The elements Al, Br, Cl, Cr, Fe, K, Mg, Mn, La, Ce, Nd, Na, Rb, Ti, V and Zn are present at the levels of $\mu g\ g^{-1}$ and the elements As, Cd, Co, Cs, Hf, Sm, Eu, Tb, Lu, Sb, Sc, Se, Th and U at the levels of $\mu g\ kg^{-1}$.

The number of analytical results presented here is not sufficient to have a final conclusion however some observations could drawn. A preliminary comparison between the results obtained for samples collected in different sites indicates that lichens from Ibiúna, Botanical Garden and Parque de Vila Velha present low concentrations for most elements analysed. These results indicate that samples from these regions should be analysed to establish baseline levels of elements in *C. texana* for monitoring purposes.

As expected, low concentrations of elements were obtained in samples collected in regions considered clean. The concentrations of several elements in the lichens collected in the open places like Campus of São Paulo University were higher than those found in lichens from clean region of Parque Vila Velha and Ibiuna, presumably due to accumulation of elements originating from heavy vehicular traffic and from soil. Also sample from Campo Limpo presented high levels of Hf, Th, Sc and lanthanide elements probably due to the air contamination by elements present in the soil and sample from this site was collected along a not paved road.

The lichen sample from Cubatão presented a relatively high level of Mn and that from Paranapiacaba presented slightly high levels of Fe, Se and lanthanides. This high level of elements collected in these samples may be explained due to the air contamination by the smoke from the industries and refineries of the highly polluted areas of Cubatão city. Regarding to lanthanide elements, their biological effects of long exposure even at low concentrations are unknown and should be matter of concern. The highest concentrations of Na and Cl were expected for lichen collected in Cubatão since this city is situated at coastal region, however the their concentrations were not so high.

Elemental concentrations obtained in lichen and their respective substrates are presented in Table II. These results indicate that elemental concentrations of outer barks depend on the tree substrate but the outer bark is not significant source of metals for *T. texana*. As it can be seen in Table II, concentrations of elements obtained for outer barks were similar or smaller than those results found for lichens.

Table III shows the mean values obtained in the analyses of ten samples of young and old leaves of *T. pallida* plant cultivated in vases and kept in the same place. These results exhibited inter-vase variability as well as the concentrations of Ce, Co, Cr, Fe, La, Sb, Sc and Zn in old leaves were slightly higher than those presented in the young ones and for the elements Ca, Cl, K, Mn, Rb and Sr there was no difference related to the leaf age.

4. FUTURE PLANS

During the next few years our laboratory will concentrate in the following activities concerning biomonitoring of trace elements:

- Collection and analysis of lichen samples collected mainly near the industries (car battery industry and mercury recycling plants). This work will carried out in collaboration with Companhia de Tecnologia de Saneamento Ambiental (CETESB), a governmental institution responsible for quality control of São Paulo State
- Analyses of *T. pallida* plant cultivated in vases and kept in tree regions of different levels of pollution
- Analyses of the soil utilised in the *T. pallida* cultivation.
- Treatment of data and interpretation

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TABLE I. ANALYSES OF LICHEN SAMPLES COLLECTED IN SEVEN DIFFERENT SITES FROM SÃO PAULO STATE AND ONE SITE OF PARANÁ STATE.

Element	Samples from the sites							
	Nr.1 Ibiuna	Nr.2 Paranapiacaba	Nr.3 Cubatão	Nr.4 Campo Limpo	Nr.5 Bot. Garden	Nr. 6 IPEN	Nr. 7 Campus USP	Nr.8 Parque V. Velha
Al, $\mu g\ g^{-1}$	2747 ± 44	1164 ± 33	930 ± 20	306 ± 9	426 ± 17	789 ± 24	7129 ± 137	733 ± 22
As, $\mu g\ kg^{-1}$	411 ± 14	708 ± 9	450 ± 6	786 ± 9	274 ± 7	469 ± 11	1057 ± 14	343 ± 6
Br, $\mu g\ g^{-1}$	39.40 ± 0.07	11.00 ± 0.05	6.59 ± 0.01	5.70 ± 0.03	1.3 ± 0.4	23.0 ± 3.8	24.80 ± 0.05	3.30 ± 0.01
Ca, %	4.67 ± 0.08	4.79 ± 0.08	1.90 ± 0.02	1.68 ± 0.03	1.96 ± 0.06	2.67 ± 0.02	4.13 ± 0.07	5.74 ± 0.03
Cd, $\mu g\ kg^{-1}$	459 ± 59	139 ± 5	266 ± 36	600 ± 15	799 ± 43	640 ± 105	3917 ± 209	665 ± 122
Cl, $\mu g\ g^{-1}$	639 ± 14	308 ± 17	946 ± 43	601 ± 24	449 ± 11	529 ± 21	284 ± 39	665 ± 15
Co, $\mu g\ kg^{-1}$	219 ± 4	358 ± 6	353 ± 5	584 ± 8	- (*)	295 ± 4	1063 ± 14	110 ± 2
Cs, $\mu g\ kg^{-1}$	117 ± 4	356 ± 7	185 ± 12	276 ± 5	213 ± 1	155 ± 4	1016±9	95 ± 3
Fe, $\mu g\ g^{-1}$	1033 ± 6	4276 ± 19	1351 ± 12	1637 ± 7	366 ± 3	540 ± 3	4135 ± 21	540 ± 3
Hf, $\mu g\ kg^{-1}$	378 ± 3	182 ± 4	103 ± 7	639 ± 4	-	120 ± 2	1464 ± 5	100 ± 2
K, $\mu g\ g^{-1}$	1892 ± 116	1957 ± 468	1262 ± 4	682 ± 249	1491 ± 72	2516 ± 87	3849 ± 233	96 ± 42
La, $\mu g\ g^{-1}$	1.454 ± 0.006	8.31 ± 0.03	2.096 ± 0.004	38.7 ± 0.1	0.936 ± 0.004	1.238 ± 0.005	7.05 ± 0.05	0.77 ± 0.04
Ce, $\mu g\ g^{-1}$	3.30 ± 0.02	15.8 ± 0.04	3.07 ± 0.01	11.82 ± 0.03	1.70 ± 0.01	2.89 ± 0.01	16.58 ± 0.04	1.85 ± 0.01
Nd, $\mu g\ g^{-1}$	1.62 ± 1.09	6.87 ± 0.07	1.47 ± 0.03	4.05 ± 0.05	0.65 ± 0.05	1.53 ± 0.15	6.52 ± 0.21	0.66 ± 0.02
Sm, $\mu g\ kg^{-}$	180.7 ± 0.4	842.8 ± 1.2	203.0 ± 0.3	523.2 ± 0.7	113.1 ± 1.4	117.3 ± 0.3	1055 ± 1	102.6 ± 0.3
Eu, $\mu g\ kg^{-1}$	39.4 ± 2.4	218.6 ± 2.5	39.2 ± 0.7	108.2 ± 1.4	15.8 ± 0.4	26.9 ± 0.9	181 ± 2	21.9 ± 0.6

Tb, μg kg^{-1}	20.7 ± 1.9	73.5 ± 3.5	14.8 ± 1.2	60.7 ± 2.5	11.2 ± 0.7	11.1 ± 1.6	203.6 ± 3.2	14.6 ± 1.4
Yb, μg kg^{-1}	53.1 ± 4.1	120.0 ± 7.6	36.8 ± 3.3	134.2 ± 6.2	28.0 ± 3.0	44.7 ± 1.6	346.6 ± 6.7	53.3 ± 1.0
Lu, μg kg^{-1}	10.8 ± 0.4	17.5 ± 0.4	10.5 ± 0.7	23.3 ± 0.3	3.4 ± 0.2	9.9 ± 0.3	60.1 ± 0.5	10.7 ± 0.3
Mg, μg g^{-1}	251 ±13	865 ± 96	855 ± 151	122 ± 18	570 ± 54	781 ± 76	3540 ± 437	699 ± 77
Mn, μg g^{-1}	37.8 ± 0.9	73.2 ± 1.3	366 ± 9	115 ± 2	11.4 ± 0.2	138 ± 2	164 ± 1	62.7 ± 0.6
Na, μg g^{-1}	77.2 ± 0.1	132.8 ± 11.2	81.8 ± 0.1	96.0 ± 7.1	33.9 ± 0.8	53.0 ± 0.5	422.9 ± 0.5	20.6 ± 0.3
Rb, μg g^{-1}	6.0 ±0.1	9.1 ± 0.2	7.7 ± 0.3	13.8 ± 0.2	9.1 ± 0.1	12.9 ± 0.2	20.2 ± 0.2	1.1 ± 0.1
Sb, μg kg^{-1}	280 ± 6	192 ± 2	250 ± 6	177 ± 2	191 ± 1	200 ± 2	2000 ± 10	57.7 ± 0.8
Sc, μg kg^{-1}	315 ± 1	306 ± 1	161 ± 1	568 ± 2	56.9 ± 0.2	125.7 ± 0.7	1190 ± 3	163.1± 0.7
Se, μg kg^{-1}	201 ± 18	873 ± 29	283 ± 11	278 ± 22	104 ± 9	141 ± 17	665 ± 24	98 ± 15
Th, μg kg^{-1}	327 ± 2	412 ± 4	198 ± 1	802 ± 4	83 ± 1	278 ± 2	1933 ± 5	133 ± 2
Ti, μg g^{-1}	195 ± 39	64 ± 11	37 ± 7	171 ± 25	47 ± 7	342 ± 77	510 ± 89	114 ± 32
U, μg kg^{-1}	55 ± 6	128 ± 4	45 ± 5	152 ± 4	-	64 ± 2	190 ± 9	27 ± 3
V, μg g^{-1}	1.5 ±0.3	3.9 ± 0.2	3.5 ± 0.2	0.40 ± 0.03	1.26 ± 0.08	2.7 ± 0.2	14.0 ± 0.9	1.9 ± 0.1
Zn, μg g^{-1}	137.0 ± 0.5	72.8 ± 0.4	58.0 ± 0.2	73.0 ± 0.3	66.1 ± 0.2	97.8 ± 0.4	145.7 ± 0.5	31.9 ± 0.2

The uncertainties of the results were calculated using statistical counting errors of the samples and standards.

TABLE II. ELEMENTAL CONCENTRATIONS IN LICHENS SAMPLES AND THEIR RESPECTIVE SUBSTRATES

Element	Sample 1		Sample 2	
	Trunk 1	Lichen 1	Trunk 2	Lichen 2
Al, $\mu g\ g^{-1}$	728 ± 9	789 ± 24	846 ± 18	733 ± 22
Br, $\mu g\ g^{-1}$	1.90 ± 0.03	23.0 ± 3.8	5.6 ± 0.2	3.30 ± 0.01
Ca, %	0.246 ± 0.004	2.67 ± 0.02	5.37 ± 0.07	5.74 ± 0.03
Cd, $\mu g\ kg^{-1}$	681 ± 31	640 ± 105	158 ± 3	665 ± 122
Cl, $\mu g\ g^{-1}$	146 ± 9	529 ± 21	105 ± 2	665 ± 15
Co, $\mu g\ kg^{-1}$	277 ± 4	295 ± 4	158 ± 3	110 ± 2
Cs, $\mu g\ kg^{-1}$	33 ±2	155 ± 4	77 ± 3	95 ± 3
Fe, $\mu g\ g^{-1}$	285 ± 2	540 ± 3	191 ± 1	540 ± 3
Hf, $\mu g\ kg^{-1}$	326 ± 3	120 ± 2	96 ± 2	100 ± 2
La, $\mu g\ g^{-1}$	1.19 ± 0.01	1.238 ± 0.005	0.498 ±0.005	0.77 ± 0.04
Ce, $\mu g\ g^{-1}$	2.45 ± 0.01	2.89 ± 0.01	0.99 ± 0.01	1.85 ± 0.01
Nd, $\mu g\ g^{-1}$	1.49 ± 0.04	1.53 ± 0.15	0.61 ± 0.03	0.66 ± 0.02
Sm, $\mu g\ kg^{-}$	111.9 ± 0.9	117.3 ± 0.3	78.7 ± 0.4	102.6 ± 0.3
Eu, $\mu g\ kg^{-1}$	19.5 ± 0.6	26.9 ± 0.9	16.9 ± 0.6	21.9 ± 0.6
Tb, $\mu g\ kg^{-1}$	7.4 ± 1.3	11.1 ± 1.6	14.5 ± 1.9	14.6 ± 1.4
Yb, $\mu g\ kg^{-1}$	19.7 ± 2.1	44.7 ± 1.6	30.5 ± 4.5	53.3 ± 1.0
Lu, $\mu g\ kg^{-1}$	5.2 ± 0.4	9.9 ± 0.3	9.2 ± 0.3	10.7 ± 0.3
Mn, $\mu g\ g^{-1}$	122 ± 1	138 ± 2	73.0 ± 0.4	62.7 ± 0.6
Na, $\mu g\ g^{-1}$	67 ± 4	53.0 ± 0.5	12.6 ± 0.4	20.6 ± 0.3
Rb, $\mu g\ g^{-1}$	2.0 ± 0.1	12.9 ± 0.2	1.00 ± 0.08	1.1 ± 0.1
Sb, $\mu g\ kg^{-1}$	219 ± 5	200 ± 2	80.5 ± 6.8	57.7 ± 0.8
Se, $\mu g\ kg^{-1}$	143 ± 21	141 ± 17	98 ± 15	98 ± 15
Th, $\mu g\ kg^{-1}$	87 ± 1	278 ± 2	125 ± 2	133 ± 2
U, $\mu g\ kg^{-1}$	55 ± 6	64 ± 2	34 ± 4	27 ± 3
V, $\mu g\ g^{-1}$	2.6 ± 0.1	2.7 ± 0.2	1.2 ± 0.1	1.9 ± 0.1
Zn, $\mu g\ g^{-1}$	105.3 ± 0.3	97.8 ± 0.4	51.6 ± 0.2	31.9 ± 0.2

TABLE III. ELEMENTAL CONCENTRATIONS IN YOUNG AND OLD LEAVES OF *TRADESCANTIA PALLIDA*

ELEMENTS	Young leaves		Old leaves	
	Mean ± s*	Range	Mean ± s	Range
Br, $\mu g\ g^{-1}$	42 ± 14	77 - 21	26.4 ± 6.8	36.5 – 14.8
Ca, %	2.5 ± 0.4	3.05 – 1.91	2.3 ± 0.3	2.7 – 1.9
Ce, $\mu g\ kg^{-1}$	471 ± 281	1174 - 281	974 ± 323	1396 - 251
Cl, %	0.88 ± 0.17	1.15 – 0.69	0.74 ± 0.23	1.12 – 0.41
Co, $\mu g\ kg^{-1}$	180 ± 91	376 - 73	245 ± 97	445 - 130
Cr, $\mu g\ kg^{-1}$	194 ± 125	502 - 94	254 ± 112	353 - 127
Fe, $\mu g\ g^{-1}$	84.5 ± 30.4	172 -70	124 ± 31	167 - 64
K, %	4.36 ± 2.43	10.9 – 2.2	3.12 ± 1.04	5.27 – 1.84
La, $\mu g\ kg^{-1}$	286 ± 205	806 - 136	568 ± 232	927 - 114
Mn, $\mu g\ g^{-1}$	140 ± 57	245 – 89	133 ± 70	248 - 51
Na, $\mu g\ g^{-1}$	50.7 ± 15.7	75.2 – 25.4	85.9 ± 42.1	163 - 35
Rb, $\mu g\ g^{-1}$	37.8 ± 14.9	66.0 – 13.5	23.0 ± 10.4	38.4 – 10.9
Sb, $\mu g\ kg^{-1}$	55 ± 45	173 – 17	136 ± 62	282 – 29
Sc, $\mu g\ kg^{-1}$	8.2 ± 5.4	23.0 – 4.3	15.3 ± 5.1	25.8 – 6.6
Sr, $\mu g\ g^{-1}$	286 ± 98	519 - 166	274 ± 65	392 - 211
Zn, $\mu g\ g^{-1}$	109 ± 61	278 - 63	149 ± 35	192 - 77

(*) – Arithmetic mean and standard deviation of results obtained in 10 samples cultivated in 10 different vases

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CO-ORDINATED RESEARCH PROJECT

ON

VALIDATION AND APPLICATION OF PLANTS AS BIOMONITORS OF TRACE ELEMENT ATMOSPHERIC POLLUTION, ANALYZED BY NUCLEAR AND RELATED TECHNIQUES

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TITULO DO TRABALHO: Determination of trace elements in lichen samples by instrumental neutron activation analysis

APRESENTADO EM: (informar os dados completos - no caso de artigos de conf., informar o título da conferência, local, data, organizador, etc..)

Report on Second Research Co-ordination meeting on Validation and application of plants as biomonitor of trace element ~~athm~~ atmospheric pollution, analyzed by nuclear and related techniques, Vienna Austria. 20 to 24 march, 2000

PALAVRAS CHAVES PARA IDENTIFICAR O TRABALHO: lichen, biomonitoring, instrumental neutron activation air pollution

ASSINATURA: Mitiko Saiki

DATA: 31 / 08 / 01

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