STUDY OF AIR POLLUTION IN CHILE USING BIOMONITORS

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Abstract:

A project has been undertaken within the framework of a Co-ordinated Research Programme (CRP) supported by the International Atomic Energy Agency (IAEA) to carry out a long term study on atmospheric air pollution in Chile using biomonitors. The present paper describes the activities undertaken within the framework of this project. Sampling of different lichens species has been performed in clean areas (native forest), preparation of such samples has been done under controlled, cryogenic conditions and analysed by neutron activation analysis. Participation in an intercomparison run organized by the IAEA for the determination of trace and minor elements in two lichens samples, has also been carried out. Transplant of lichens collected in clean areas has been done in Santiago.

1. INTRODUCTION

Chile in general and Santiago, its capital city, in particular have serious air pollution problems [1,2]. During winter time the air pollution in Santiago increases to levels which might be detrimental to elder and children. A number of studies have identified the main sources of this pollution. It has been determined that the main problem is the airborne particulate matter coming from fixed and mobile sources, in particular buses and cars. In 1992 the catalytic converter has been requested to all new cars but this has also contribute to an increase in the ozone levels in the city, not only in winter but also, and more remarkably in summer [3,4]. Since 1995, the Chilean Nuclear Energy Commission (CCHEN) has worked closely with The Metropolitan Commission for the Environment (COREMA) and international research institutions (i.e., The University of Sao Paulo, Brazil, USP) to determine the main sources of the contamination. The role of CCHEN has been the sampling of airborne particulate matter using Gent type PM-10 samplers provided by the IAEA, and the analyses of samples by NAA and ion chromatography. The data evaluation and interpretation were jointly carried out by staff of COREMA, CCHEN and USP [5-13]. Recently, the so-called "Decontamination Plan for the Santiago Metropolitan Area" has been extensively review and modified accordingly to make it more effective. The authorities have realized that the air pollution problem is being extended to areas outside the city limits and would extend their monitoring network to zones outside the Metropolitan area.

Some of the new target areas do not have an adequate infrastructure for operation of traditional air samplers (i.e., electricity) and other ways of monitoring the levels of pollutants are becoming relevant. Among these alternatives are the use of passive tubes for the collection and identification of gases and biomonitors for minor and trace elements. The present project will help in the identification of the more suitable biomonitor for such purpose and the possibility of doing transplants to areas where there suitable biomonitors do not exist. The possibility of "planting" appropriate monitors in suspected areas or near sources of pollutants is quite interesting and can help to detect the origin of contaminants for control and surveillance purposes.

The experience on biomonitoring at CCHEN started in 1996 when a project on the determination of reference levels of elements of environmental importance in the sea, using different molluscs and sediments [14-16]. This project, carried out jointly with the National Commission for the Environment (CONAMA), established the "natural or background" concentration levels of some elements in given matrices for regulatory and control purposes. A sample preparation laboratory has been implemented for handling the samples in a contamination free environment. Available is a class 100 clean room, several laminar flow fume hoods, cryogenic mills, a large capacity freeze-drier and homogenizers. This laboratory prepares all samples for analyses by the different analytical techniques at CCHEN and also plays an important role in the preparation of reference materials.

The present project, as originally planned, aims at (I) the study of the applicability of biomonitors to monitor elemental air pollution, (ii) to determine the concentration levels of elements in the atmosphere of cities and rural areas using PM-10 samplers, (iii) to determine the concentration levels of those toxic elements on the membrane filters and in the selected biomonitors using NAA, complemented by AAS, (iv) to establish correlations, if any, between the concentration levels of trace elements in airborne particulate matter and those in the biomonitors, (v) to determine the sources of pollutants and (vi) to determine the applicability of biomonitors to study air pollution in large areas, using indicators either naturally grown or transplanted to the region under examination.

2. BIOMONITORING AIR POLLUTION

Various monitor materials have been used in trace-element air monitoring programs, including lichens, mosses, ferns, grass, tree bark, tree rings, tree leaves and pine needles [19-21]. Evaluation of the criteria mentioned above for the various biomonitor materials, leads to lichens and mosses as the best suitable monitors. For all biomonitors used, the mechanisms of trace element uptake and retention are still not sufficiently known. For monitors other than lichens and mosses, the contribution from sources other than atmospheric, such as soil have to be taken into account. Where comparisons have been made, lichens and mosses show consistently higher metal levels than higher plants which simplifies the analytical process for the determination of trace-element. According to some authors, differences between element concentrations in bark on different trees are often significant to the trace elements levels in lichens. Some lichen species exist in large geographical areas, occurring more abundant in rural zones than in urban and industrial areas. The morphology of lichens and mosses does not vary with seasons, thus accumulation can occur throughout the year. Lichens and mosses usually have considerable longevity, which led to their use as long-term integrators of atmospheric deposition.

3. SELECTION OF STUDY SITES

Sampling sites and areas of study remains the same as originally planned taking into account the special characteristics of the country (Fig. 1) and the real possibilities for field work: (i) Santiago city, the capital, (ii) Valparaiso, the main port of Chile and (iii) Talca, a city at about 300 km south of Santiago (Fig. 2). The reasons for the selection of these places are explained in the Report on the First Research Co-ordination Meeting (RCM, 28 September-1 October 1998, Vienna, Austria) for this CRP.

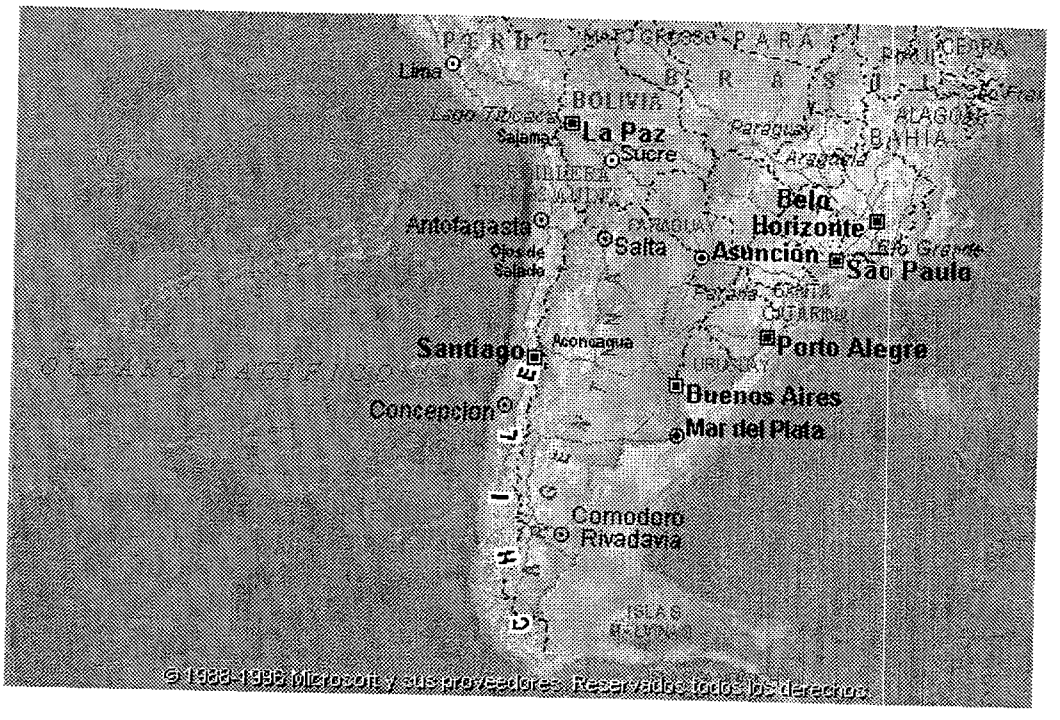


Fig 1. Location of Chile in South America

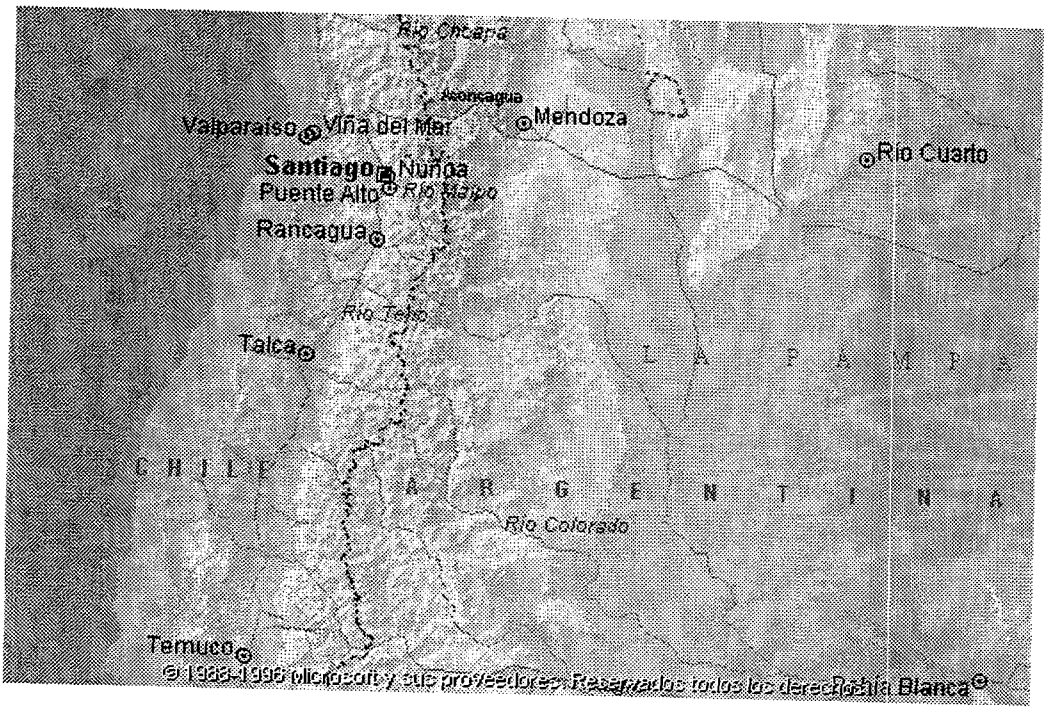


Fig. 2. Location of the areas of interest for air pollution studies

4. SAMPLING AND SAMPLE PREPARATION

Sampling has taken place in the mountain area near Talca, in a native forest at about 1100 m above sea level. This first sampling campaign had two purposes: (i) to establish the working group for this project, integrating botanists and chemists to exchange experience and information about lichens species, procedures for collecting samples (without contamination) and analytical methodologies, and (ii) to collect samples of lichens to select the appropriate one for monitoring purposes. Collection has been done following procedures described in the literature and adapted to our possibilities and limitations [18]. A list of the sample collected, as well as their substrate is shown below in Table I.

TABLE I. SPECIES OF LICHENS AND THEIR SUBSTRATE COLLECTED IN THE AREA OF TALCA

Specie	Date	Substrate	Location
Hypogymmia	26 Mar 1999	Árbol Donbeyi	Altos de Vilches.
Plalismatia glauca	26 Mar 1999	Arbol Dombeyi	Altos de Vilches
Usnea	26 Mar 1999	Arbol Dombeyi	Altos de Vilches
Plalismatia glauca	26 Mar 1999	Árbol Donbeyi	Altos de Vilches
Plalismatia glauca	26 Mar 1999	Árbol Donbeyi	Altos de Vilches
Parmelia caperata	26 Mar 1999	Obligua Var Macrocarpa	Altos de Vilches
Parmelia perlata	26 Mar 1999	Obligua Var Macrocarpa	Altos de Vilches
Usnea flenda	26 Mar 1999	Obligua Var Macrocarpa	Altos de Vilches
Hypogymmia	26 Mar 1999	Obligua Var Macrocarpa	Altos de Vilches

A second sampling campaign was carried out in a valley in the Andean Mountains, known as Laguna del Maule. There is little vegetation and lichens are not abundant, however, it was possible to collect some samples which are indicated in Table II.

TABLE II. SPECIES OF LICHENS AND THEIR SUBSTRATE COLLECTED IN THE AREA OF LAGUNA DEL MAULE

Specie	Date	Substrate	Location
Rhizoplaca melanophthalma	27 May 1999	Laguna del Maule	3ra. Parada
Umbilicania	27 May 1999	Laguna del Maule	3ra. Parada
Rhizoplaca melanophthalma (de) Leuck	27 May 1999	Laguna del Maule	4ra. Parada
Usnea acmomelana stirt	27 May 1999	Laguna del Maule	5ra. Parada
Rhizoplaca melanophthalma	27 May 1999	Laguna del Maule	5ra. Parada
Umbilicania	27 May 1999	Laguna del Maule	5ra. Parada

One of the most important aspects of this study is the use of biomonitors for air pollution studies in large cities. Therefore, a third sampling campaign was performed in Santiago to identified species of potential use as biomonitors. However, no lichens were found in the city despite an studied carried out in 1988 were a number of species were identified in several zones of the city. Only few species, in very bad conditions were found in a park in a rather remote area. This means that the environmental conditions of the cities has damaged al lichens living there 12 years ago. A list of the samples collected in this area is in Table III.

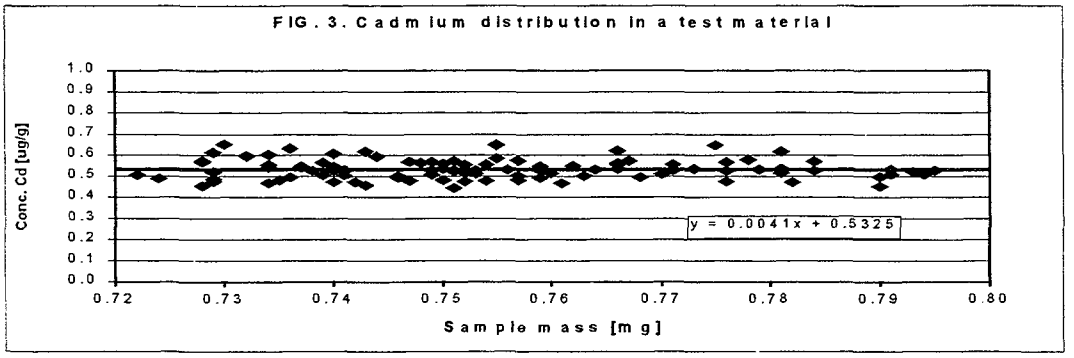
TABLE III. SPECIES OF LICHENS AND THEIR SUBSTRATE COLLECTED IN THE METROPOLITAN AREA OF SANTIAGO

Specie	Date	Substrate	Location
Mosses	27 Jun 1999	Saxícola	P. Muni. De La Reina
Ramalina	27 Jun 1999	Litraca caustica	P. Muni. De La Reina
Teloschistes chrysophthalmus	27 Jun 1999	Acacia caven espino Maulino	P. Muni. De La Reina
Ramalina striatula ecklonii	27 Jun 1999	Acacia caven espino Maulino	P. Muni. De La Reina
Parmelia	27 Jun 1999	Saxícola	P. Muni. De La Reina

At the botanical laboratory at the University of Talca the species of lichens where identified and then transported to the CCHEN laboratories. There, the samples were cleaned, using only clean plastic materials, milled at liquid nitrogen temperature and freeze dried. The solid material was then re-homogenized and stored at low temperature.

5. ANALYSIS AND QA/QC

The samples were analysed by INAA and a few elements were determined using radiochemical NAA. Some of the samples were also analysed by solid atomic absorption spectrometry, with direct introduction of the solid sample in the graphite furnace. This technique has recently been implemented in the laboratory and is planned to be mainly used for homogeneity studies in sample preparation procedures as well as in the preparation of reference materials. This technique require minimum sample mass of around 1-2 mg or less with the advantage that it does not require sample treatment before the instrumental measurement. This technique has already been used to study the homogeneity of some test materials. One example of the determination of the homogeneity, homogeneity factor and minimum mass for analysis, is shown in Table IV and Figures 3 and 4.



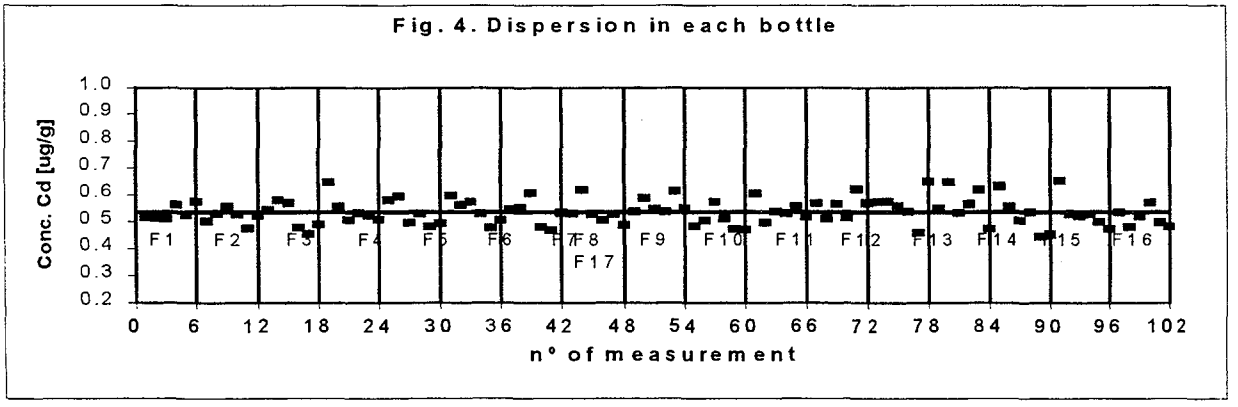


TABLE IV. DESCRIPTIVE STATISTICS OF THE HOMOGENEITY OF TEST MATERIAL

Descriptive Statistics	
Average	0,536
Typical error	0,005
Median	0,530
Mode	0,5695
Standard Deviation	0,047
Variance of the sample	0,0022522
Kurtosis	-0,097530
Coefficient of asymmetry	0,48131
Range	0,2079
Minimum	0,4444
Maximum	0,6523
Addition	54,6334
Counts	102
Confidence level (95,0%)	0,00932
Results	
S%	8,86
He	7,697
M[mg]	11,82

Emphasis have been placed in quality control and quality assurance of the analyses. This is routinely done using appropriate reference material. The NAA laboratory also took part in the Intercomparison Run for the Determination of Minor and Trace Elements in Two Lichen Samples organised by the IAEA. The laboratory performed well and most of the results are within the confidence intervals of the averaged calculated for all participating laboratories. Table V shows the results of the laboratory as well as the overall average of all participating laboratories.

TABLE V. RESULTS OF AN INTERCOMPARISON RUN FOR THE DETERMINATION OF TRACE AND MINOR ELEMENTS IN TWO LICHENS SAMPLES

Analyte	Intercomparison sample L-1				Intercomparison sample L-2			
	Our data	Unc.	Overall mean of lab. aver.	Std. Dev.	Our data	Unc.	Overall mean of lab aver.	Std. Dev.
Al	1100		1065	252	700	14	634	134
As	0.85	0.028	0.97	0.1	0.65	0.025	0.68	0.07
Ba	28	1.3	26.1	1.81	7.4	0.68	7.1	0
Br	17	0.58	18.9	1.51	12.2	0.24	11.8	1.15
Ca	3560	54	3927	316	2400	180	2489	194
Cd								
Ce	1.5	0.38	1.76	0.26	0.98	0.057	1.23	0.2
Cl	2540	26	2438	206	2160	59	1964	181
Co	0.4	0.037	0.36	0.05	0.34	0.016	0.29	0.04
Cr	6.4	0.59	6.04	1.71	1.13	0.096	1.05	0.26
Cs	0.35	0.025	0.39	0.04	0.113	0.0022	0.122	0.02
Cu								
Eu	0.03	0.0036	0.03	0	0.024	0.0013	0.025	0
Fe	800	67	902	92	415	28	444	42
Hg	0.27	0.026	0.31	0.03	0.15	0.019	0.167	0.01
K	3100	170	3138	266	1900	120	1814	197
La	0.87	0.027	0.9	0.13	0.68	0.024	0.63	0.05
Mg								
Mn	54.4	0.12	52.6	1.6	69	3	64	7
Na	109	3.9	124	9.4	325	9.5	303	24
Ni								
Pb								
Rb	20	1.2	20.9	1.42	1.8	0.18	1.73	0.07
Sb	0.41	0.03	0.46	0.06	0.071	0.0044	0.085	0.01
Sc	0.22	0.019	0.25	0.02	0.161	0.0085	0.169	0.02
Ti								
V	3.54	0.085	3.58	0.34	1.4	0.1	1.45	0.2
Zn	109	8.6	112	6.4	33	1.9	31.9	1.94

6. RESULTS OF THE ANALYSIS

Table VI present the results of the analyses of the samples of lichens collected during the first three sampling campaigns. These results have been obtained using NAA.

To help in the selection of the more appropriate monitors, an attempt to find similar behaviour between the similar and different species was made. Figure 5 shows a clear relation, as regards the content of trace elements for the same specie. Figure 6 presents a graphical relationship between the same species, collected in different zones from the same substrate.

TABLE VI. PARTIAL RESULTS OF THE ANALYSES OF LICHENS SAMPLES COLLECTED DURING THE FIRST, SECOND AND THIRD SAMPLING CAMPAIGN (1)

Specie	Substrate	Location	Al	Al-abs	As	As-abs	Br	Br-abs	Ca
Hypogymmia	Arbol Donbeyi	Altos de Vilches 2da. Par.	2600	390	1.9	0.1	13.3	1.1	93000
Plalismatia glauca	Arbol Dombeyi	Altos de Vilches, 2do. Puente	3200	522	1.6	0.1			3800
Usnea	Arbol Dombeyi	Altos de Vilches	1000	150	2.6	0.2	3.9	0.3	3400
Plalismatia glauca	Arbol Donbeyi	Altos de Vilches 2da. Par.	2800	199	2.1	0.2			3500
Plalismatia glauca	Arbol Donbeyi	en cabezas 2da. Par.	3300	495	2.6	0.2	7.1	0.6	3000
Parmelia caperata	Obligua Var Macrocarpa	Altos de Vilches pie. Tac.	5200	780	3.4	0.3	5.3	0.4	27000
Parmelia perlata	Obligua Var Macrocarpa	Altos de Vilches	1900	285	3.1	0.2	7.0	0.6	7700
Usnea flenda	Obligua Var Macrocarpa	Altos de Vilches	630	95	1.3	0.1	1.6	0.1	4700
Hypogymmia	Obligua Var Macrocarpa	Altos de Vilches	3900	585	2.3	0.2	13.8	1.1	22900
Rhizoplaca melanophthalma	Laguna del Maule	3ra. Parada	9800	470	2.2	0.2			28000
Umbilicania	Laguna del Maule	3ra. Parada	3470	42	1.8	0.1			1900
Rhizoplaca melanophthalma (de) Leuck	Laguna del Maule	4ra. Parada	10300	577	3.4	0.3			7000
Usnea acmomelana stirs	Laguna del Maule	5ra. Parada	1700	119	2.3	0.2			840
Rhizoplaca melanophthalma	Laguna del Maule	5ra. Parada	8400	336	2.9	0.2			3100
Umbilicania	Laguna del Maule	5ra. Parada	4800	341	2.5	0.2			970
Musgo	Saxicola	P. Muni. La Reina 860m S.M.M.	34500	1208	6.3	0.5			17400
Ramalina	Litraca caustica	P. Muni. La Reina	6410	64	4.7	0.4			4810
Teloschistes chrysophthalmus	Acacia caven espino Maulino	P.Muni. De la Reina	18300	2745	6.8	0.5	6.3	0.5	6600
Ramalina striatula ecklonii	Acacia caven espino Maulino	P.Muni. De la Reina	3700	555	4.7	0.3	3.3	0.3	2500
Parmelia	Saxicola	P.Muni. De la Reina	13800	2070	5.5	0.4	8.2	0.7	19300

(1) "abst' means absolute 2s standard deviation

TABLE VI. PARTIAL RESULTS OF THE ANALYSES OF LICHENS SAMPLES COLLECTED DURING THE FIRST, SECOND AND THIRD SAMPLING CAMPAIGN (1)

Specie	Ca-abs	Ce	Ce-abs	Cl	Cl-abs	Co	Co-abs	Cr	Cr-abs	Cs	Cs-abs	Eu	Eu-abs	Fe
Hypogymmia	2790	2.10	0.16	770	123	0.68	0.07	1.69	0.33	0.23	0.02	<0,01		1700
Plalismatia glauca	232			1430	45	0.39	0.03	1.26	0.14			0.034	0.005	1360
Usnea	214	0.68	0.07	170	29	0.31	0.03	1.20	0.22	0.10	0.01	0.020	0.004	550
Plalismatia glauca	490			1280	47	0.52	0.03	1.97	0.21			0.038	0.005	1460
Plalismatia glauca	210	1.92	0.14	1200	180	0.70	0.07	2.24	0.39	0.33	0.02	0.051	0.009	1900
Parmelia caperata	972	3.13	0.23	110	24	1.01	0.10	3.15	0.53	0.47	0.03	0.073	0.013	3000
Parmelia perlata	1001	1.15	0.17	1030	185	0.44	0.05	<0,8		0.20	0.03	0.050	0.012	890
Usnea flenda	517	0.38	0.03	<60		0.13	0.01	0.39	0.08	<0,02		<0,001		190
Hypogymmia	802	2.65	0.19	980	147	0.78	0.07	2.35	0.39	0.23	0.02	0.072	0.013	2300
Rhizoplaca melanophthalma	1624			113	9	1.35	0.06	1.88	0.23			0.169	0.018	4720
Umbilicania	380			78	15	0.72	0.04	0.93	0.15			0.074	0.009	1730
Rhizoplaca melanophthalma (de) Leuck	161			130	26	1.49	0.07	1.70	0.21			0.168	0.018	4440
Usnea acmomelana stirs	151			170	11	0.24	0.02	0.90	0.12			0.060	0.007	780
Rhizoplaca melanophthalma	341			129	5	0.93	0.05	3.25	0.30			0.113	0.012	3140
Umbilicania	12			134	8	0.49	0.03	2.59	0.25			0.089	0.010	1530
Musgo	278			460	12	5.73	0.26	21.46	1.68			0.396	0.042	18300
Ramalina	96			170	4	1.35	0.06	7.65	0.62			0.095	0.011	4010
Teloschistes chrysophthalmus	436	9.34	0.66	250	45	3.96	0.37	18.93	3.04	1.10	0.08	0.257	0.044	12600
Ramalina striatula ecklonii	173	2.25	0.17	120	22	3.66	0.34	4.93	0.81	0.30	0.02	0.072	0.013	2900
Parmelia	869	8.53	0.60	210	40	2.92	0.27	12.93	2.09	0.73	0.05	0.229	0.039	9100

(1) "abst' means absolute 2s standard deviatio

TABLE VI. PARTIAL RESULTS OF THE ANALYSES OF LICHENS SAMPLES COLLECTED DURING THE FIRST, SECOND AND THIRD SAMPLING CAMPAIGN (1)

Specie	Fe-abs	Hg	Hg-abs	K	K-abs	La	La-abs	Lu	Lu-abs	Mg	Mg-abs	Mn	Mn-abs	Na
Hypogymmia	112	<0,22		2600	297	1.14	0.09	0.023	0.004	860	129	97	6	820
Plalismatia glauca	51			1800	432					840	54	155	5	470
Usnea	38	0.39	0.06	3000	277	0.40	0.03	0.026	0.006	690	104	94	6	144
Plalismatia glauca	55			2200	264					950	44	126	3	530
Plalismatia glauca	122	<0,15		3100	301	0.96	0.08	0.020	0.004	1100	121	114	7	670
Parmelia caperata	192	<0,18		4000	382	1.58	0.13	0.029	0.006	1700	156	270	17	860
Parmelia perlata	68	<0,35		5300	584	0.81	0.07	<0,01		<1200		360	24	270
Usnea flenda	14	<0,08		2900	259	0.20	0.02	<0,002		<490		95	7	71
Hypogymmia	146	<0,13		3300	304	1.31	0.10	0.024	0.005	1400	129	170	11	750
Rhizoplaca melanophthalma	160			2800	672					2610	31	125	6	2090
Umbilicania	63			2100	153					1100	150	49	2	790
Rhizoplaca melanophthalma (de) Leuck	151			3200	256					2380	83	125	4	2020
Usnea acmomelana stirs	31			1600	209					500	42	26	2	330
Rhizoplaca melanophthalma	108			3400	300					2200	107	88	3	2320
Umbilicania	56			3000	459					1200	24	53	2	1520
Musgo	609			10100	780					8400	656	473	3	6600
Ramalina	136			3400	340					1900	186	100	1	1380
Teloschistes chrysophthalmus	796	<0,29		7100	682	4.33	0.34	0.081	0.016	4800	346	200	13	4400
Ramalina striatula ecklonli	185	<0,17		4500	414	1.09	0.09	0.020	0.004	1500	113	57	4	890
Parmelia	576	<0,29		7400	681	4.09	0.32	0.080	0.016	3500	294	160	10	3400

(1) stabs" means absolute 2s standard deviatic

TABLE VI. PARTIAL RESULTS OF THE ANALYSES OF LICHENS SAMPLES COLLECTED DURING THE FIRST, SECOND AND THIRD SAMPLING CAMPAIGN (1)

Specie	Na-abs	Sb	Sb-abs	Sc	Sc-abs	Se	Sm	Sm-abs	Th	Th-abs	V	V-abs	Zn	Zn-abs
Hypogymmia	53	0.13	0.01	0.65	0.10	<0,33	0.20	0.01	4.8			0.9	47	3
Plalismatia glauca	17			0.55	0.01				0.20	0.02	4.1	1.1	20	1
Usnea	9	0.10	0.01	0.27	0.04	<0,19	0.07	0.01	1.8				33	2
Plalismatia glauca	20			0.58	0.01				0.22	0.02	4.5	0.3	20	1
Plalismatiaglauca	44	0.13	0.01	0.78	0.12	<O,23	0.19	0.01	5.8			1.0	35	3
Parmeliacaperata	56	0.21	0.02	1.01	0.15	<0,28	0.29	0.02	8.7			1.5	72	5
Parmelia perlata	18	0.10	0.01	0.33	0.05	<0,52	0.16	0.01	<1,2				46	3
Usnea flenda	5	0.04	0.00	0.10	0.02	<0,12	0.04	0.00	<0,3				28	2
Hypogymmia	49	0.13	0.01	0.81	0.12	<0,19	0.26	0.02	6.2			1.0	38	3
Rhizoplaca melanophthalma	77			1.95	0.04				0.78	0.05	18.9	0.6 <1,6		
Umbilicania	29			0.70	0.01				0.31	0.02	6.7	0.2 15		1
Rhizoplaca melanophthalma (de) Leuck	74			1.75	0.04				0.91	0.05	17.2	0.7 <1,5		
Usnea acmomelana stirs	12			0.50	0.01				0.23	0.02	2.2	0.2 5		0
Rhizoplaca melanophthalma	85			1.23	0.02				1.05	0.06	11.8	0.3 8		1
Umbilicania	57			0.72	0.01				0.93	0.05	5.0	0.3 21		1
Musgo	248			6.15	0.12				2.03	0.12	79.0	3.2 <1,3		
Ramalina	51			1.58	0.03				0.44	0.03	14.7	0.3	36	2
Teloschistes chrysophthaimus	285	0.99	0.08	4.37	0.66	<0,44	0.88	0.06	45.0			7.7	105	10
Ramalina striatula ecklonii	58	0.41	0.03	1.10	0.17	<0,20	0.23	0.02	8.8			1.5	48	4
Parmelia	220	0.71	0.06	3.32	0.50	<0,43	0.86	0.06	32.2			5.5	109	9

(1) "abs" means absolute 2s standard deviatio

7. TRANSPLANTS OF LICHENS

Since one of the main objectives of the project is the use of appropriate lichens in rather highly polluted cities an areas in the country, lichens collected in clean areas where transplanted to Santiago, one of the target cities. Samples of *Parmelia perlata* and of *Usnea* where collected and carefully placed into "envelopes" of nylon net. Two of such transplants where placed under a cover to protect the lichen from rain and distributed among colleagues of the Nuclear Centre living in the Metropolitan area and distributed throughout the city. The transplants were carried out in January 2000 and one "envelope" will be collected at the end of April 2000 (beginning of Fall) and the second at the end of September, when the winter is over. Figure 7 shows where the transplants were installed.

8. FUTURE ACTIVITIES

During the next period of this CRP, the collection and analyses of the transplanted lichens will take place. Also, a systematic collection of lichens will start in the more relevant cities and zones of the country where air pollution may be an important factor for the health of the persons. The determination of some elements which is not possible to be done using NAA will be carried out by solid atomic absorption spectrometry. In addition, the collection of airborne particulate matter using Gent type PM-10 samplers at the same location where the biomonitor(s) will be sampled (if electricity and other services are available) will continue as well as the preparation of analytical quality control materials to assure reliable and useful data.

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