Table 6

Element	**Sample 1 (mg/l)**	**Sample 2 (mg/l)**	**Sample3 (mg/l)**
Si	132	244	56
Fe	9.8	15.8	12.3
Na	10.5	15.1	3.5
Al	2.6	22.4	1.9
Ca	8.1	102	17.3
Pb	19.5	10.6	6.9
Ni	12.8	19.5	2
K	7.7	12.2	1.9
Cr	25	36.7	2.4
F	608	115	62.1
Cl	4360	8540	1570
SO4	45.3	244	28

The composition of the condensate was compared with *averaged* lake water, normalised to the lake water Na^+ concentration, in order to establish where the concentrations of fluoride and chloride were enhanced relative to what would be expected from the lake water only. Cation composition on this basis is generally quite similar to the lake water, indicating that some of the liquid collected is physically-generated aerosol. Silica, lead, nickel and chromium are all enhanced, but the latter two elements are undoubtedly contamination from the stainless steel components of the sampling device. The high levels of lead may originate from the crater lake, but the transfer mechanism is a matter for conjecture; the silica is probably from wind transported volcanic dust particles. The severity of the acid conditions in the gas cloud was recognised from the health aspects, but was not sufficiently well identified prior to selecting the materials for constructing the sampling device.

Of the anions, chloride and fluoride are enhanced in the condensate, while sulphate is found in about the same relative concentration as in the lake water. Chloride is enhanced by up to 8 times and fluoride by about 4 times. It therefore appears that most of the HCl and HF in the aerosol over the lake come from *volatilisation* at the lake surface, followed by dissolution into the aqueous aerosol. Earlier calculations suggested that if complexation of fluoride by Al^{3+} in the lake were ignored, then HF would be about 2 times – 4 times as volatile as HCl. However, it is found that HCl concentrations in the aerosol are enhanced by a larger factor than HF. This is consistent with a high degree of complexation in the lake as indicated earlier.

The fact that sulphate is not significantly enhanced in the condensate suggests that production of aerosol acidity by dissolution and oxidation of SO_2 is quite small relative to the direct transfer of HCl and HF. However, because H_2SO_4 is not volatile, as the aerosol drifts away from the volcano the HCl and HF will probably evaporate and disperse more readily, especially under dry conditions, leaving the non–volatile H_2SO_4. There is therefore still about 2×10^{-3} M H_2SO_4 in the aerosol to precipitate further away from the volcano, and this concentration will increase as the aerosol moves away to drier conditions and the water evaporates.

4.2.3 Diffusion samplers

The blank control tubes were emplaced in the Bajos del Toro some six kilometers from Poas summit, and the others in locations where they would receive constant exposure, subject to the prevailing winds The tubes were left in place for 600 hours, almost half as long again as in the earlier experiment. All data obtained are shown in Table 7, the November 1991 data being included for comparison.

Table 7

Location	**March'92 ($\mu g\ SO_2/m^3$)**	**Nov'91 ($\mu g\ SO_2/m^3$)**
Control Tubes	4	0.4
Cajon	249	250
San Luis	730*	299
Trojas	124	60
Farm	499*	314
Mirador	156	117

* Approximate data only due to normal tube capacity being exceeded

The enhanced levels of SO_2 observed at certain locations are very pronounced, even the control area of the Bajos del Toro exhibiting an order–of–magnitude increase. The release of acid gases and aerosols into the environment is much greater during the drier months, due principally to the loss of the beneficial *scrubbing* effects of rainfall near the summit source. Local farmers complained of aggravated respiratory problems during the dry season, and also damage to cash crops such as coffee. WHO guideline values are 30 μg/m^3 for plants and 50 μg/m^3 for humans (annual average), and 100 μg/m^3 for plants and 125 μg/m^3 for humans (24-hour average). Therefore it can be seen that the recommended levels are being routinely exceeded, in some locations by substantial margins.

4.2.4 Impregnated Papers

The use of simple chemical absorption techniques was considered appropriate to monitor the short-term variation of gas dispersion at certain locations around the crater (Figure 1). During the March 1992 visit, 1 litre volumes of air were pumped through individual filter papers impregnated with sodium formate, at pre-determined intervals over a period of four hours, during which time aerial SO_2 concentration was monitored. The papers were then sealed in polyethylene bags and returned to the laboratory for analysis. Each paper was cut into two pieces, one being leached with distilled water for chloride and sulphate determination, and the other with a special buffer solution to extract the fluoride. The results are shown in Table 8.

Table 8

Sample No	F^- (mg/l)	Cl^- (mg/l)	SO_4 (mg/l)	Aerial SO_2
1	0.15	nd	0.64	3.0
2	0.11	nd	0.53	0.4
3	0.10	nd	0.42	0.4
4	0.09	nd	0.87	0.6
5	0.10	nd	0.54	0.2
6	0.10	nd	0.66	0.2
7	0.15	nd	0.54	0.4
8	0.22	nd	0.56	0.3
9	0.20	nd	0.55	0.6
10	0.25	nd	1.79	1.5
11	0.31	nd	1.63	1.0
12	0.29	nd	1.76	0.8
13	0.32	nd	1.99	1.8
Lava Dome	0.40	nd	3.65	10.0
Lava Dome	0.50	nd	7.87	15.0–20.0

nd = not detected

It is to be expected that there would be an gradual increase in both fluoride and sulphate content, which is consistent with the general overall increase in the measured aerial SO_2 concentration. The papers were kept sealed until used, and therefore contamination is easily ruled out. The reason for there being no detectable HCl at this point is unknown, but may either be due either to the specificity of the sodium formate used to impregnate the papers, or that little or no HCl was reaching the sampling point. The latter seems unlikely as fluoride species were present, and HF is more soluble in water than is HCl, and would therefore be presumed to be *scrubbed* more efficiently by atmospheric water vapour. Two further 1 litre volumes of air were sampled on the top of the lava dome within the crater, at aerial SO_2 concentrations of 10–20ppm. Significant fluoride and sulphate were measured, but again there was no indication of HCl (Table 8). Short–term diffusion tube measurements at this point indicated 10ppm HCl, and therefore the inference is that the sodium formate with which the papers were impregnated was only collecting the fluoride and sulphate. The variability of the data is directly related to the localised movement of air masses within the crater.

The four larger diameter filter papers laid on polyethylene sheets for one hour on the top of the lava dome were each used to determine pH, fluoride, chloride and sulphate. Subsequent analysis of a distilled water leachate from one these papers indicated an acidic pH of 5.4, against a blank value of 6.4. Other leaching solutions were used to extract the anions, but of these only fluoride and chloride were present in any significant quantities at approximately 35ppm and 500ppm respectively. This is at variance with the data from the pumped papers, and appears to indicate that immediate localised fallout of HCl as hydrochloric acid is occurring close to the point of generation.

During January 1993 these experiments were repeated using, additionally, papers impregnated with potassium hydroxide. The collection and preservation of both fluoride and sulphate were successful, but again the chloride did not seem to be retained using either sodium formate or potassium hydroxide. This seems inconceivable, and it must therefore be assumed that chloride is present either in very low atmospheric concentrations, which is unlikely, or in such a form that it is being rapidly removed from the air before reaching the sampling stations. This requires further investigation.

4.2.5 Vegetation

The samples of wood from the decaying trees were weighed, broken into smaller fragments where possible, and allowed to soak in deionised water for up to four days. The solutions were then filtered, diluted to volume in a volumetric flask, and 5ml portions removed for the determination of the retained sulphate concentration. Results varied between 33mg/kg and 330mg/kg, and contradicts earlier work which showed that sulphate only seemed to concentrate in living tissue. However, these new data may be a feature of dry season conditions which allow acid precipitation products to accumulate in vegetation without being leached by continuous rainfall. A much wider study, incorporating other types of vegetation, is necessary to substantiate these findings e.g. dead and living vegetation and inter–species comparisons.

5. CONCLUSIONS AND RECOMMENDATIONS

It has been shown that there is a wide variation in the amounts of acid contaminants dispersing into the environment from Poas crater lake. The damage to vegetation is readily visible immediately downwind of the volcano, but there are undoubtedly potentially more serious effects of the emissions at greater distances from the summit, and from the health aspect, invisible to the naked eye. The principal agricultural and epidemiological problems are likely to arise from acid precipitation of both HCl and HF, both of which readily disperse from the source during the dry season because of their high volatility. However, sulphur species measured as sulphur dioxide have been monitored at least seven kilometers from the summit, and may therefore cause more severe health problems in the long term. This is due ultimately to higher strength sulphur acids being formed through evaporation of water during vapour transport. The formation of acid aerosols has long been suspected, and these preliminary measurements have indicated that although the amounts may be small, they are a pathway through which acid gases escape to the environment.

The enhanced levels of sulphur dioxide measured at some localities are very conspicuous, and emphasise the problems created when a change in wind direction discretely alters the fallout zone of the volcanic plume. During the wet season, many areas seem to be protected from the effects of the acidity, presumably because rainfall effectively *scrubs* the main components close to their source. This is adequately demonstrated by the differences in data obtained for the diffusion tube measurements in the control area. In the Bajos del Toro, sulphur dioxide showed an order-of-magnitude increase in background levels in the dry season (April 1992) over those obtained during the wet season (November 1991). The release of acid gases and aerosols into the environment is therefore *apparently* much greater during the drier months. Local farmers complained of aggravated respiratory problems during the dry season, and also damage to important (for Costa Rica) crops such as coffee. Visible foliar damage to coffee plantations and other vegetation several kilometers from the summit of Poas was indeed apparent on each of the field trips, and therefore invisible damage to soil profiles may also be expected, with obvious consequences for plant health. World Health Organisation guideline values for SO_2 are 30 $\mu g/m^3$ for plants and 50 $\mu g/m^3$ for humans (annual average), and 100 $\mu g/m^3$ for plants and 125 $\mu g/m^3$ for humans (24-hour average). Therefore by reference to Table 7 it is obvious that the recommended levels are being exceeded by significant margins in some locations monitored.

Analogous to the escape of gases into the environment there is also that of acid waters into the Rios Agrio and Desague. These waters potentially pose a much greater threat, in that they can directly contaminate groundwater supplies, with a consequential threat to the health of fauna and flora. Fluorine is well documented as being beneficial to the formation of skeletal tissue at low dose rates, but is equally well known to be injurious to health when present in excess. Waters containing high acid concentrations can mobilise many potentially toxic trace elements, and it is to be hoped that studies prior to the decision to site the reservoir on the NW side of Poas volcano took this aspect into account.

It should be emphasised that this has only been a pilot study, and there is an urgent need for much longer-term monitoring to establish *baseline* information. It is therefore recommended that:

(a) The sampling of fumarole gases should be repeated to substantiate the limited datasets available from past exercises. OVSICORI-UNA staff should be trained to undertake these analyses as part of their routine monitoring. Apart from gas sampling bombs, the remainder of the equipment necessary is believed to be available in-house. The situation relating to staff suitable for training is unknown as it is recognised that some new staff have been recruited recently.

(b) Although it was anticipated that the monitoring of gas emissions, using passive sampling techniques, would be carried out on a routine basis through a CEC-funded collaborative project with Costa Rica, this has not been possible to date. It is important to obtain reliable data for several cycles of wet and dry seasons, in order to monitor the mean fallout at selected locations relative to the source emissions. The uncertainties relating to the collection and determination of chloride species need to be resolved.

(c) A co-ordinated sampling exercise should be mounted to determine the amounts of acid components being retained by various types of vegetation and soils around the volcano, to ascertain the areal extent of the contamination. The continued monitoring of rain and river waters for pH, fluoride, chloride and sulphate by OVSICORI-UNA is therefore an important aspect of this.

(d) The successful preliminary experiment to condense aqueous vapour from the gas cloud above the crater lake should be repeated, using a device constructed solely from inert materials, to minimise sample contamination. Only then will it be possible to obtain completely reliable data for aerosol composition. This sampling and analysis could then be continued by OVSICORI-UNA as part of their routine monitoring of the volcano.

(e) Only by understanding the magnitude of the problem, by establishing a comprehensive database of information through the constant monitoring of source gases and waters, and the principal pathways through which these contaminants disperse in the environment, will it eventually be possible to suggest improved measures to combat the principal effects of the secondary volcanic processes. It may even be feasible ultimately to predict long and short-term changes in the activity related to the changing chemistry of the gases and waters. These techniques might then be applicable to similar situations elsewhere in the world, where secondary volcanic activity is raising environmental issues.

6. ACKNOWLEDGEMENTS

Many people contributed to both the fieldwork and laboratory investigations for this project, and it is not practicable to acknowledge everybody individually. Due appreciation has been paid to those with significant inputs, by inclusion in the list of authors. However, this list could easily have been extended to include Eduardo Malavassi and Erick Fernández from OVSICORI–UNA, both of whom gave either assistance with field investigations and/or helpful advice. Similarly Barbara Vickers and other colleagues in the Analytical Geochemistry Group undertook multifarious chemical determinations, without which much of the above study would have been impossible. The late Professor Geoff Brown, and his colleague Dr Hazel Rymer, from the Open University also helped considerably by introducing us to the field area, and by providing geological information based on their personal experiences over many years working on Poas Volcano. Dr Peter Brimblecombe from the University of East Anglia contributed much to the research, by virtue of his extensive experience on atmospheric contaminants. Thanks are due to all those concerned. In addition, the comments of Dr John Bennett and Doug Miles on the text of this report are gratefully acknowledged.

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POAS LAKE WATERS 1992/93

Date	7/2/92	13/3/92	3/4/92	6/5/92	1/6/92	24/6/92	24/7/92	21/8/92	18/9/92	7/10/92	19/11/92	10/12/92	23/1/93
Element	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
Sr	16	17	14	12	14	17	17	17	18	20	23	18	29
Cd	1.1	2.5	3.9	3.3	2.6	1.4	1.6	1.3	1.7	0.6	0.9	1.3	1
Ba	0.3	<0.2	0.9	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	0.3	0.2	0.2	<0.2
Si	280	720	640	400	720	720	980	980	670	900	980	570	320
Mn	38	96	136	155	114	61	70	58	74	23	34	56	41
Fe	1190	3230	5140	4740	3580	1980	2400	1990	2540	930	1130	2090	1440
P	38	114	166	178	151	78	89	70	94	34	44	70	53
B	40	108	158	176	147	83	103	77	100	35	52	78	59
Mg	560	1450	2080	2480	1820	970	1120	900	1190	380	560	890	690
V	9.6	25.5	37.1	41.7	31.6	17.5	19.6	15.7	20.8	7	9.9	15.6	11.7
Na	610	1370	2010	1940	1850	1060	1190	970	1280	410	610	970	740
Mo	2.8	7.2	10.4	8	6.2	3.4	3.7	2.9	4	1.3	2	3.1	2.2
Al	2800	8200	12100	15000	11300	6000	6800	5500	7400	2200	3300	5600	4000
Be	0.06	0.14	0.2	0.02	0.02	0.01	0.01	0.01	0.01	<0.005	0.005	0.01	0.005
Ca	1160	380	260	150	240	580	430	570	660	1560	1200	970	1330
Zn	6.5	17.3	25.3	26.2	19.5	11.1	12	10.4	13.8	3.9	5.9	11	8.1
Cu	1	7.5	14.7	17.9	12.8	6.2	6.5	4.5	6.7	1.8	2 6	4.6	3.9
Pb	8.3	18.6	30.9	34	26.1	14.6	16.4	13	17.3	6.4	8 5	13.2	9.8
Li	<0.3	0.5	0.7	0.8	0.6	0.4	0.4	0.3	0.4	<0.3	<0.3	0.3	0.3
Zr	4.7	13.2	19	20.3	15.9	9.3	11	8.7	10.8	3.6	6	8.1	6.3
Co	1	1.9	3.6	3.6	2.7	1.5	1.7	1.2	1.7	0.6	0.9	1.3	0.9
Ni	<1	1.4	1.8	6	1.3	<1	<1	<1	<1	<1	<1	<1	<1
Y	0.6	1.1	0.7	0.7	1	0.6	0.9	0.7	0.7	1	0.7	4	0.9
La	<0.7	1	<0.7	0.9	0.9	0.7	0.8	0.7	0.7	0.8	0.9	0.8	1
K	400	870	1390	920	700	800	760	730	960	310	460	740	570
Cr	<1	1.4	2.2	2.3	1.7	1	1.1	<1	1.2	<1	<1	<1	<1
F	3700	8800	11000	11200	10700	7140	8260	6870	8390	5060	5720	6490	4510
Cl	32900	87400	102100	94100	80300	53100	67800	63300	74430	71600	73000	58500	54000
SO4	41600	119000	147300	171900	132400	78700	94200	78900	93100	52400	38400	69300	56100
TOC	44	159	192	26	24.6	23.5	23	21.7	21.1	21.4	19.1	17	19.9
TIC	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1

GEOCHEMICAL DATA ON WATERS FROM POAS VOLCANO, COSTA RICA (1992)

	BOTOS									POTRERO				PELON							
Date	4/04	24/07	21/08	4/09	18/09	7/10	16/10	30/10	10/12	18/09	7/10	30/10	10/12	24/07	7/08	4/09	18/09	7/10	16/10	30/10	10/12
Element	μg/l	μg/l	μg/l	μg/l	μg/l	μg/l	μg/l	μg/l	μg/l	μg/l	μg/l	μg/l	μg/l	μg/l	μg/l	μg/l	μg/l	μg/l	μg/l	μg/l	μg/l
Sr	22	4	<2	<2	2	2	<2	2	7	<2	<2	<2	<2	4	<2	<2	2	3	2	3	4
Ba	50	5	<2	<2	7	5	<2	2	6	<2	5	<2	2	119	8	12	37	109	8	15	12
Si	2240	<2	77	<2	148	39	27	<2	614	<2	<2	<2	180	1750	309	326	752	887	682	1220	2280
Mn	20	<5	<5	<5	7	7	<5	<5	12	<5	<5	7	32	<5	5	<5	<5	<5	<5	<5	5
Fe	<10	<10	13	<10	13	16	<10	<10	11	<10	<10	<10	26	<10	22	22	13	<10	72	131	535
P	<30	<30	109	<30	<30	<30	<30	<30	<30	<30	<30	<30	<30	<30	<30	<30	<30	<30	<30	<30	<30
Mg	540	64	42	76	59	53	53	42	128	<30	<30	<30	<30	80	64	52	38	43	62	72	87
Na	580	180	268	360	163	34	110	75	285	46	61	75	86	154	243	217	75	49	334	225	308
Al	120	96	<30	<30	146	143	100	45	346	40	55	<30	112	810	257	258	559	547	181	501	833
Be	<0.5	0.8	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Ca	2600	534	135	238	308	357	199	162	1110	62	74	143	213	153	478	276	217	413	1550	1780	498
Zn	10	65	19	10	28	12	<5	<5	39	8	<5	7	10	362	74	56	23	34	192	200	234
Cu	<7	15	<7	<7	<7	<7	<7	<7	<7	<7	<7	<7	9	<7	<7	<7	<7	<7	<7	9	7
K	300	235	285	702	182	243	229	197	669	<100	<100	105	210	<100	<100	<100	<100	<100	102	566	161
F	90	130	20	40	450	350	150	30	800	70	90	30	530	600	510	590	590	430	1200	1350	2870
Cl	2000	3250	<2000	3570	7910	6580	3460	3190	1660	3960	3630	2810	10100	6880	8840	9710	9230	6510	22400	25900	49300
SO4/ICP	8600	3170	1450	1710	1900	3100	1040	1050	13100	1350	1870	1050	600	4720	4000	3860	3130	5050	4300	6480	5500
SO4/IC	7780	4370	2580	2830	3130	4300	2010	2040	12900	2520	3100	2190	1950	5470	5220	5140	4500	6090	5290	7110	6490
TOC	1160	1030	1080	1660	1250	910	1120	900	1720	1010	1500	900	950	800	630	260	520	660	1570	2150	1230
TIC	690	240	210	210	170	130	200	190	250	220	200	240	380	230	150	190	<100	180	160	<100	<100

GEOCHEMICAL DATA ON WATERS FROM POAS VOLCANO, COSTA RICA (1992)

	MIRADOR								EDIFICIO								BORDE ESTE				
Date	24/07	7/08	21/08	18/09	7/10	16/10	30/10	10/12	24/07	7/08	21/08	4/09	18/09	7/10	30/10	10/12	4/09	18/09	7/10	16/10	10/12
Element	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l
Sr	<2	<2	<2	3	<2	2	<2	2	<2	<2	<2	<2	<2	<2	<2	4	<2	<2	2	<2	<2
Ba	3	<2	14	2	<2	<2	<2	2	9	<2	<2	8	4	<2	<2	2	<2	8	2	<2	2
Si	35	<2	<2	405	84	244	<2	258	<2	35	<2	<2	51	133	<2	798	<2	514	412	<2	562
Mn	<5	<5	<5	5	<5	<5	<5	7	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	6	<5	<5
Fe	<10	<10	<10	23	<10	<10	<10	18	<10	<10	<10	<10	39	39	<10	275	<10	83	230	<10	16
P	<30	<30	<30	<30	<30	<30	<30	<30	<30	<30	<30	<30	<30	<30	<30	<30	<30	<30	<30	<30	<30
Mg	36	30	32	<30	<30	35	<30	46	30	<30	<30	32	<30	<30	<30	<30	67	73	84	39	<30
Na	138	107	99	82	25	105	77	114	173	113	52	95	84	65	82	151	418	207	114	103	124
Al	67	68	55	134	85	196	37	158	64	54	36	54	151	114	41	232	153	373	489	62	196
Be	<0.5	<0.5	<0.5	1.6	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Ca	136	100	105	119	75	194	62	213	194	108	92	89	113	159	102	472	244	210	343	56	286
Zn	133	18	13	19	<5	8	<5	13	142	123	18	9	55	37	35	42	22	22	27	<5	31
Cu	<7	<7	<7	<7	<7	<7	<7	<7	<7	<7	<7	<7	<7	8	<7	<7	<7	<7	8	<7	<7
K	<100	<100	408	<100	<100	<100	106	243	113	<100	<100	<1000	<100	<100	<100	<100	137	128	<100	<100	<100
F	360	80	110	1110	570	300	90	770	130	50	40	80	350	360	60	1500	90	1470	1500	210	1320
Cl	4410	3120	2970	16500	8170	4940	3610	12600	3910	3660	2650	3480	6180	5820	3100	25200	4180	23600	19400	3940	20300
SO4/ICP	2630	1460	1960	3920	3410	1250	1660	2630	2090	1250	1650	1600	2160	3300	1340	2990	2510	4290	7180	641	1215
SO4/IC	3500	2520	2890	4890	4390	2430	2720	3650	2950	2190	2620	2590	3300	4240	2450	4020	3430	5190	7730	<2000	2340
TOC	1010	1010	1130	980	1110	820	840	830	1030	1230	980	880	1200	1690	870	1940	1000	1350	720	860	1010
TIC	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	240	220	230	240	<100	<100	180	<100	<100

WATER SAMPLES FROM THE VICINITY OF POAS VOLCANO, COSTA RICA

Location/Date	Sr	Cd	Ba	Si	Mn	Fe	P	B	Mg	V	Na	Mo	Al	Be	Ca	Zn	Cu	Pb	Li
	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l
Agrio (Rio) 4/92	902	30	7	48920	3535	64660	781	590	83450	314	68490	102	179420	3	98480	258	23	345	32
Agrio (Rio) 1/93	850	23	10	50000	3140	49100	390	590	70000	136	58200	85	154000	1	88000	231	11	186	24
Anoños (Rio) 4/92	120	<5	4	21620	<5	<10	<30	<20	4200	9	4920	<10	30	<0.5	14980	<5	<7	<30	<3
Anoños (Rio) 1/93	136	<5	7	23500	<5	11	34	<20	4220	<5	4980	<10	<30	<0.5	15500	<5	<7	<30	<3
B D Toro (DW) 4/92	114	<5	9	26740	<5	<10	134	<20	4310	10	9310	<10	<30	<0.5	13200	785	<7	<30	3
B D Toro (DW) 1/93	114	<5	5	27600	<5	<10	87	<20	4130	11	9010	46	<30	2	12300	<5	<7	<30	<3
Cariblanco (Rio) 1/93	64	<5	2	21800	<5	<10	<30	<20	2620	<5	4450	<10	<30	<0.5	10700	<5	<7	<30	<3
Cajon (DW) 4/92	112	<5	8	27960	<5	<10	47	<20	4550	9	4170	<10	<30	<0.5	11430	<5	<7	<30	<3
Cajon (Rio) 4/92	91	<5	8	21800	<5	<10	<30	<20	4370	<5	4150	<10	<30	<0.5	9580	<5	<7	<30	<3
Desague (Rio) 4/92	230	<5	18	33360	178	<10	<30	30	7980	6	10180	<10	1780	<0.5	30970	12	37	30	3
Desague (Rio) 1/93	223	<5	18	33300	160	24	<30	<20	6870	<5	9110	<10	2590	<0.5	27600	10	<7	<30	3
El Angel (Rio) 4/92	99	<5	8	23040	<5	<10	<30	<20	3420	<5	5580	<10	57	<0.5	12720	<5	<7	<30	<3
El Angel (Rio) 1/93	81	<5	6	20900	<5	<10	<30	<20	2600	<5	4270	<10	43	<0.5	9770	<5	<7	<30	<3
Farm (DW) 4/92	167	<5	10	28260	<5	<10	<30	<20	3970	7	6300	<10	38	<0.5	16580	<5	<7	<30	<3
Farm (DW) 1/93	167	<5	6	29700	<5	<10	<30	<20	3760	<5	6020	25	<30	1	15500	<5	<7	<30	<3
Gata (Rio) 4/92	155	<5	20	25340	140	<10	<30	34	9330	<5	11120	<10	358	<0.5	28680	<5	<7	<30	3
Gata (Rio) 1/93	121	<5	8	23200	79	<10	34	21	6750	<5	8440	<10	136	<0.5	21000	<5	<7	<30	<3
Gorrion (Rio) 1/93	74	<5	4	16800	<5	14	31	<20	2500	<5	3110	<10	<30	<0.5	8190	<5	<7	<30	<3
San Luis (DW) 4/92	144	<5	8	28820	<5	<10	39	<20	4790	<5	4850	<10	<30	<0.5	13470	<5	<7	<30	<3
San Luis (DW) 1/93	152	<5	17	29400	<5	<10	50	<20	4680	<5	4590	<10	<30	<0.5	13400	7	<7	<30	<3
San Luis (Rio) 1/93	133	<5	15	25400	<5	<10	<30	<20	3920	<5	4200	<10	<30	<0.5	11700	<5	<7	<30	<3
La Paz (Rio) 4/92	67	<5	<2	20180	<5	<10	45	<20	4280	8	4210	<10	<30	<0.5	9350	<5	<7	<30	<3
La Paz (Rio) 1/93	64	<5	3	19900	<5	<10	65	<20	3660	9	3450	<10	<30	<0.5	8350	<5	<7	<30	<3
La Paz 1 (Rio) 4/92	50	<5	<2	14480	<5	<10	<30	<20	2030	<5	2760	<10	<30	<0.5	5270	<5	<7	<30	<3
La Paz 1 (Rio) 1/93	48	<5	2	13300	<5	<10	<30	<20	1850	<5	2240	<10	<30	<0.5	4810	<5	<7	<30	<3
Poasito (Rio) 4/92	93	<5	5	25300	<5	<10	34	<20	5100	12	5230	<10	42	<0.5	14610	<5	<7	<30	<3
Poasito (Rio) 1/93	92	<5	4	26900	<5	<10	70	<20	4740	10	4890	<10	<30	<0.5	13600	<5	<7	<30	<3
Trojas (Rio) 4/92	170	<5	4	25500	<5	<10	169	<20	8120	<5	6350	<10	<30	<0.5	17530	<5	<7	<30	<3
Trojas (DW) 4/92	105	<5	4	33380	<5	<10	<30	<20	5650	7	5160	<10	<30	<0.5	13400	<5	<7	<30	<3
Vigia (Rio) 4/92	104	<5	7	19800	<5	<10	<30	<20	5080	<5	3820	<10	<30	<0.5	10080	<5	<7	<30	<3

WATER SAMPLES FROM THE VICINITY OF POAS VOLCANO, COSTA RICA

Location/Date	Zr	Co	Ni	Y	La	K	Cr	F	Cl	SO4/ICP	SO4/IC	TOC	TIC	pH
	μg/l	μg/l	μg/l	μg/l	μg/l	μg/l	μg/l	μg/l	μg/l	μg/l	μg/l	μg/l	μg/l	
Agrio (Rio) 4/92	9	18	30	25	40	20000	28	34300	566000	1456300	1540000	2080	840	2.34
Agrio (Rio) 1/93	<5	<10	<10	19	14	15900	38	34400	497000	1250000	1200000	1090	260	
Anoños (Rio) 4/92	<5	<10	<10	<2	<7	1990	<10	420	7250	31300	29200	670	5290	7.32
Anoños (Rio) 1/93	<5	<10	<10	<2	<7	1750	<10	430	10300	35100	32900	790	4410	
B D Toro (DW) 4/92	<5	<10	<10	<2	<7	2640	<10	140	2580	6700	5990	1010	14400	7.14
B D Toro (DW) 1/93	<5	<10	<10	<2	<7	2420	<10	150	3890	6500	6860	<0.1	15100	
Cariblanco (Rio) 1/93	<5	<10	<10	<2	<7	2210	<10	200	4150	19400	18000	720	6780	
Cajon (DW) 4/92	<5	<10	<10	<2	<7	1870	<10	270	4250	21700	20100	760	6820	7.39
Cajon (Rio) 4/92	<5	<10	<10	<2	<7	1740	<10	220	4490	13400	13000	1850	6710	7.09
Desague (Rio) 4/92	<5	<10	<10	3	8	3310	<10	1020	21500	105800	105000	1090	300	5.09
Desague (Rio) 1/93	<5	<10	<10	2	8	2720	<10	1130	22500	97300	94100	780	270	
El Angel (Rio) 4/92	<5	<10	<10	<2	<7	2370	<10	330	3760	39500	40800	1310	3310	7.06
El Angel (Rio) 1/93	<5	<10	<10	<2	<7	1720	<10	260	9300	29000	27000	880	3400	
Farm (DW) 4/92	<5	<10	<10	<2	<7	2660	<10	330	6070	32900	31600	740	7170	7.49
Farm (DW) 1/93	<5	<10	<10	<2	<7	2410	<10	310	8020	32600	30200	650	7150	
Gata (Rio) 4/92	<5	<10	<10	<2	<7	4120	<10	970	22100	95400	93300	1660	800	5.86
Gata (Rio) 1/93	<5	<10	<10	<2	<7	3060	<10	880	15400	68200	67500	750	1920	
Gorrion (Rio) 1/93	<5	<10	<10	<2	<7	1220	<10	140	4350	8800	8460	630	6520	
San Luis (DW) 4/92	<5	<10	<10	<2	<7	2130	<10	340	6680	31800	31800	1100	5290	7.21
San Luis (DW) 1/93	<5	<10	<10	<2	<7	1870	<10	390	12700	30800	22800	530	4950	
San Luis (Rio) 1/93	<5	<10	<10	<2	<7	1640	<10	320	11300	27300	25100	1050	3650	
La Paz (Rio) 4/92	<5	<10	<10	<2	<7	2360	<10	190	2690	7800	7980	820	9420	7.40
La Paz (Rio) 1/93	<5	<10	<10	<2	<7	1890	<10	130	3430	5700	5810	800	9480	
La Paz 1 (Rio) 4/92	<5	<10	<10	<2	<7	1140	<10	70	1890	4300	4480	1210	5690	7.26
La Paz 1 (Rio) 1/93	<5	<10	<10	<2	<7	879	<10	50	3100	3910	4790	1040	5190	
Poasito (Rio) 4/92	<5	<10	<10	<2	<7	3030	<10	230	3020	26500	26200	20400	9540	7.46
Poasito (Rio) 1/93	<5	<10	<10	<2	<7	2620	<10	210	9010	25400	24000	740	9180	
Trojas (Rio) 4/92	<5	<10	<10	<2	<7	2790	<10	180	3220	11500	11200	1690	17200	7.03
Trojas (DW) 4/92	<5	<10	<10	<2	<7	1480	<10	120	2660	18500	18200	740	10400	7.18
Vigia (Rio) 4/92	<5	<10	<10	<2	<7	1740	<10	150	3440	8300	7430	1070	8960	7.09

Plate 1

Gas–plume sampling equipment
prior to deployment

Plate 2

Rio Gata photographed
from road bridge

Plate 3

Sampling condensate from
crater fumarole

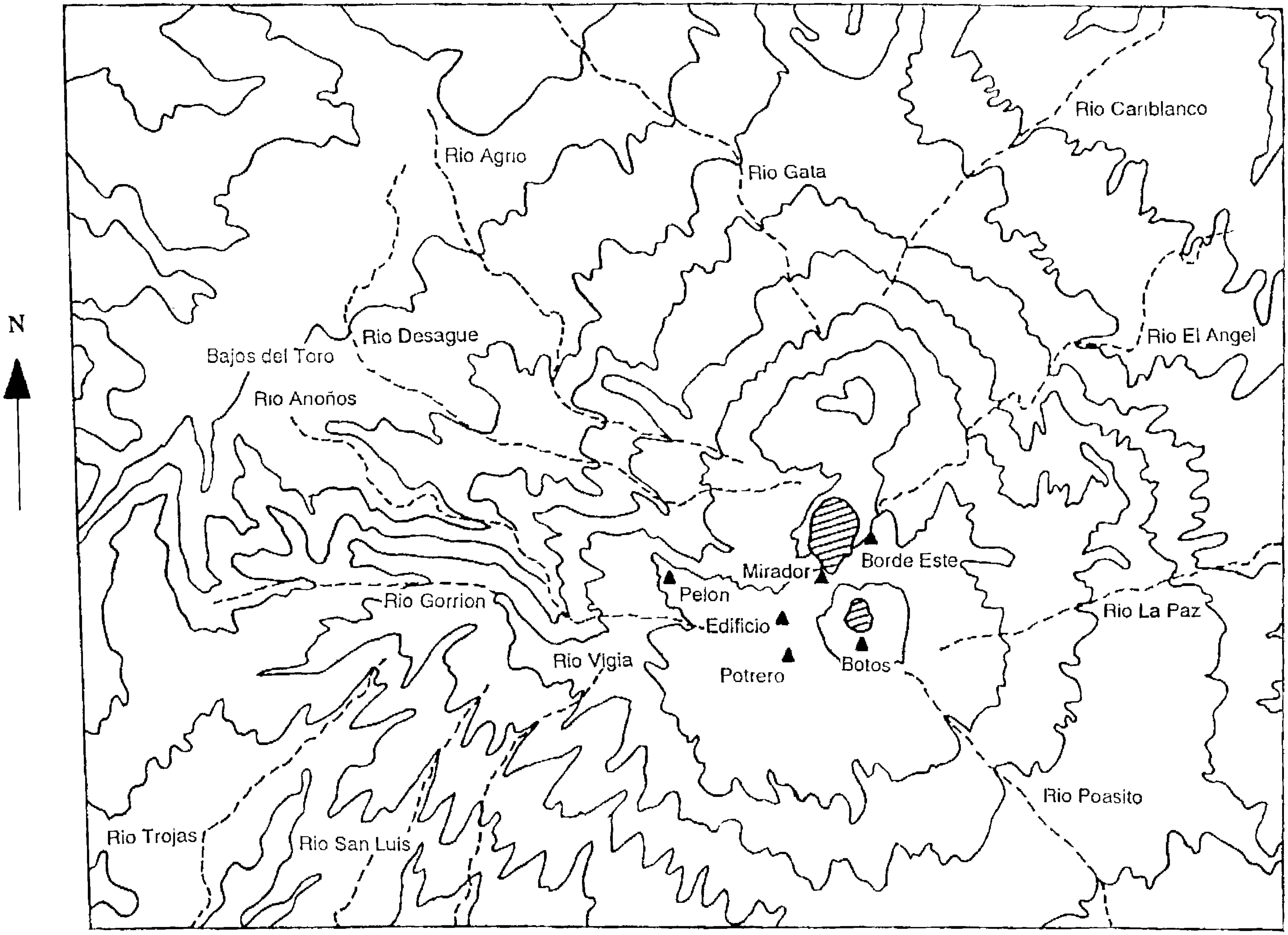

N
Rio Agrio
Rio Gata
Rio Cariblanco
Rio Desague
Bajos del Toro
Rio El Angel
Rio Anoños
Borde Este
Mirador
Pelon
Rio Gorrion
Rio La Paz
Edificio
Rio Vigia
Potrero
Botos
Rio Poasito
Rio Trojas
Rio San Luis

Figure 1

CONCENTRATIONS OF FLUORIDE, CHLORIDE AND SULPHATE IN POAS LAKE WATERS DURING 1992/93

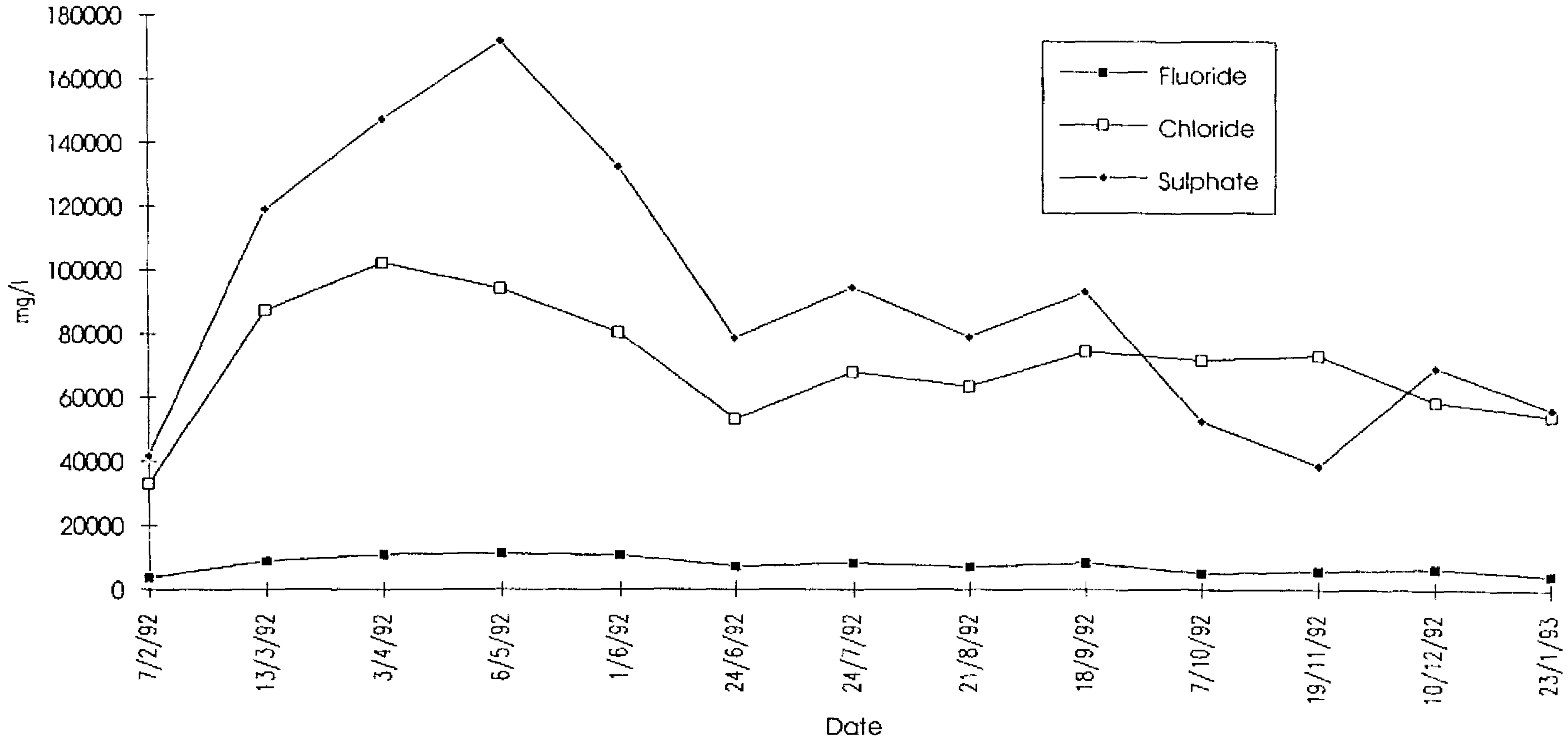


Figure 2

CONCENTRATIONS OF FLUORIDE, CHLORIDE AND SULPHATE IN RAINWATERS (MIRADOR)

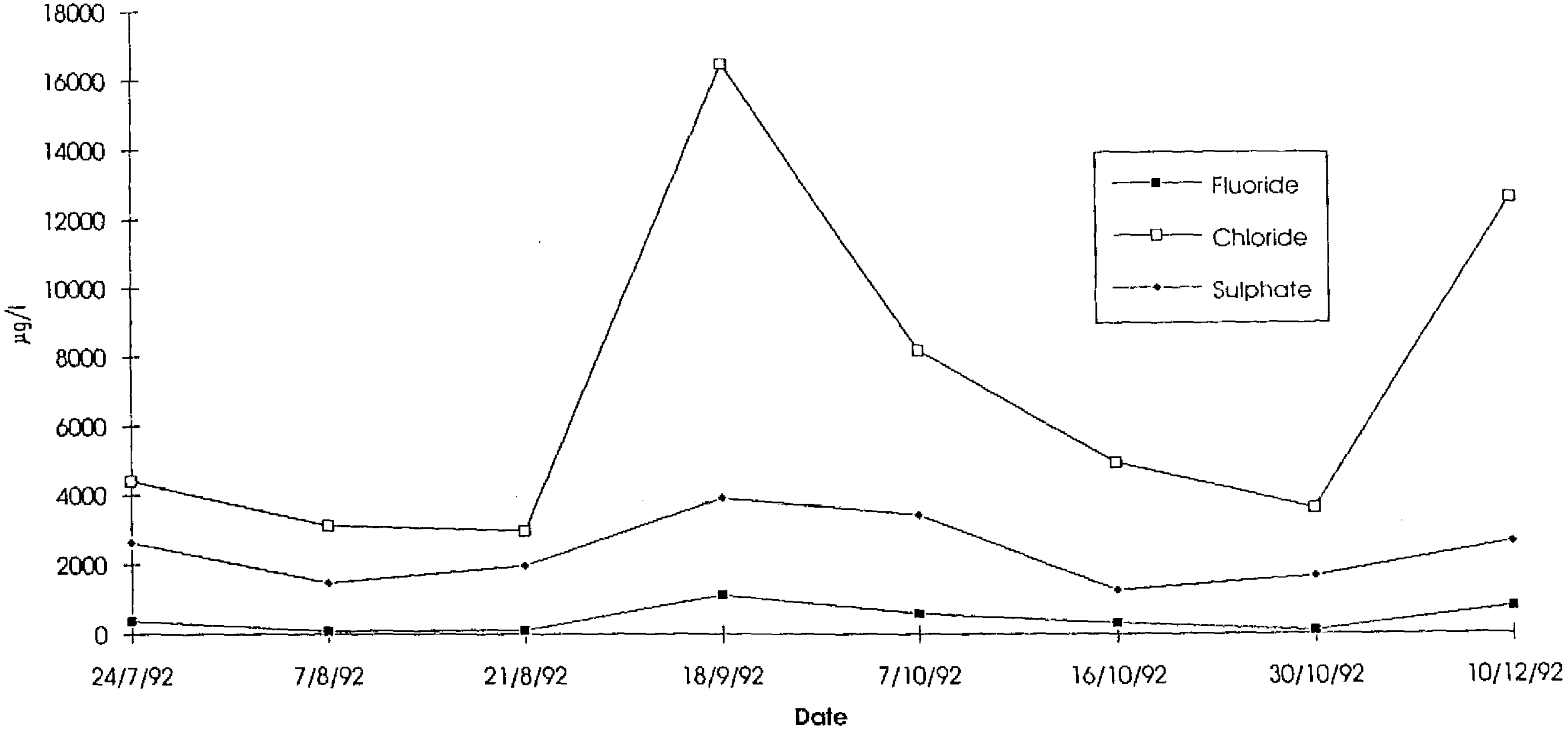
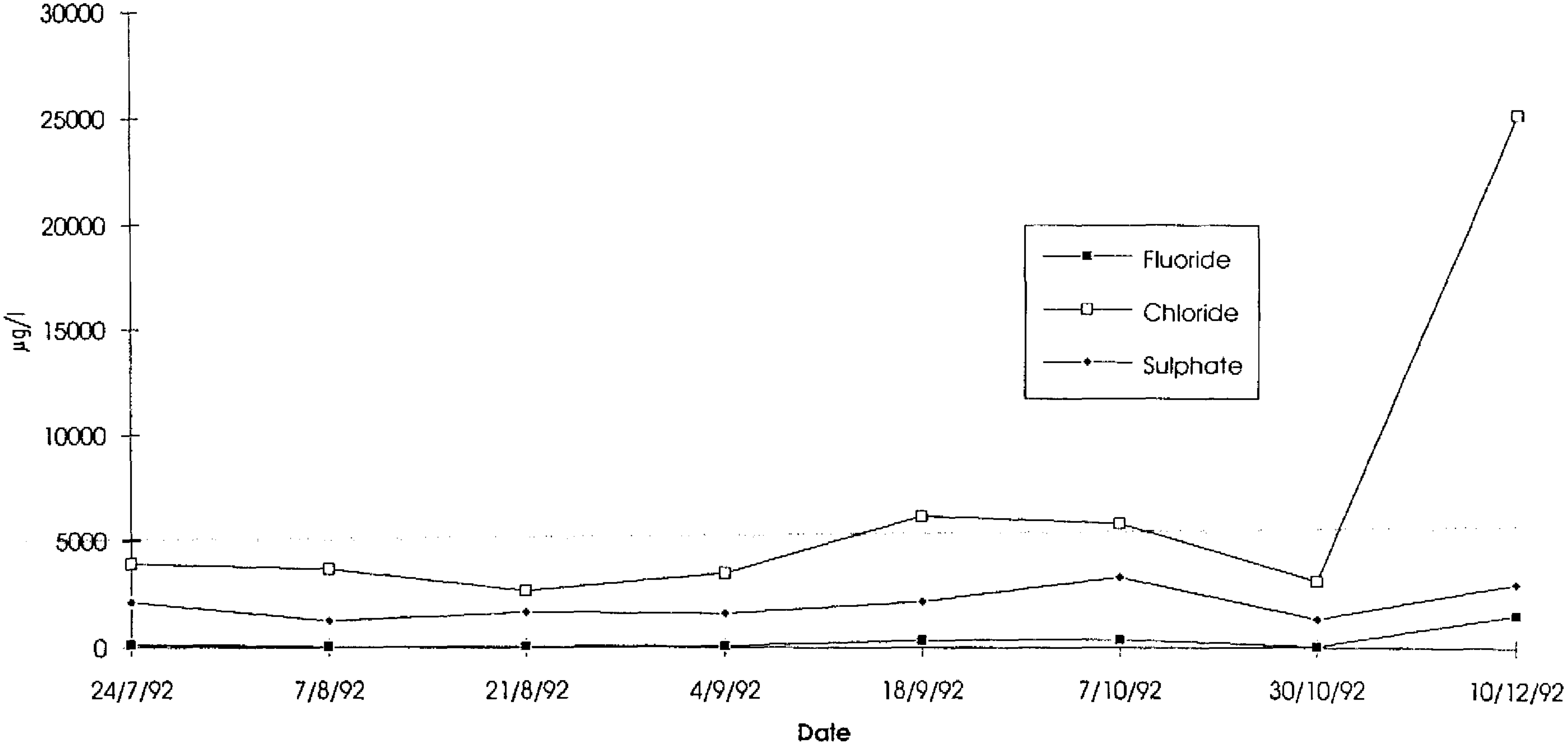


Figure 3

CONCENTRATIONS OF FLUORIDE, CHLORIDE AND SULPHATE IN RAINWATERS (EDIFICIO)



Fiigure 4

CONCENTRATIONS OF FLUORIDE, CHLORIDE AND SULPHATE IN RAINWATERS (BORDE ESTE)

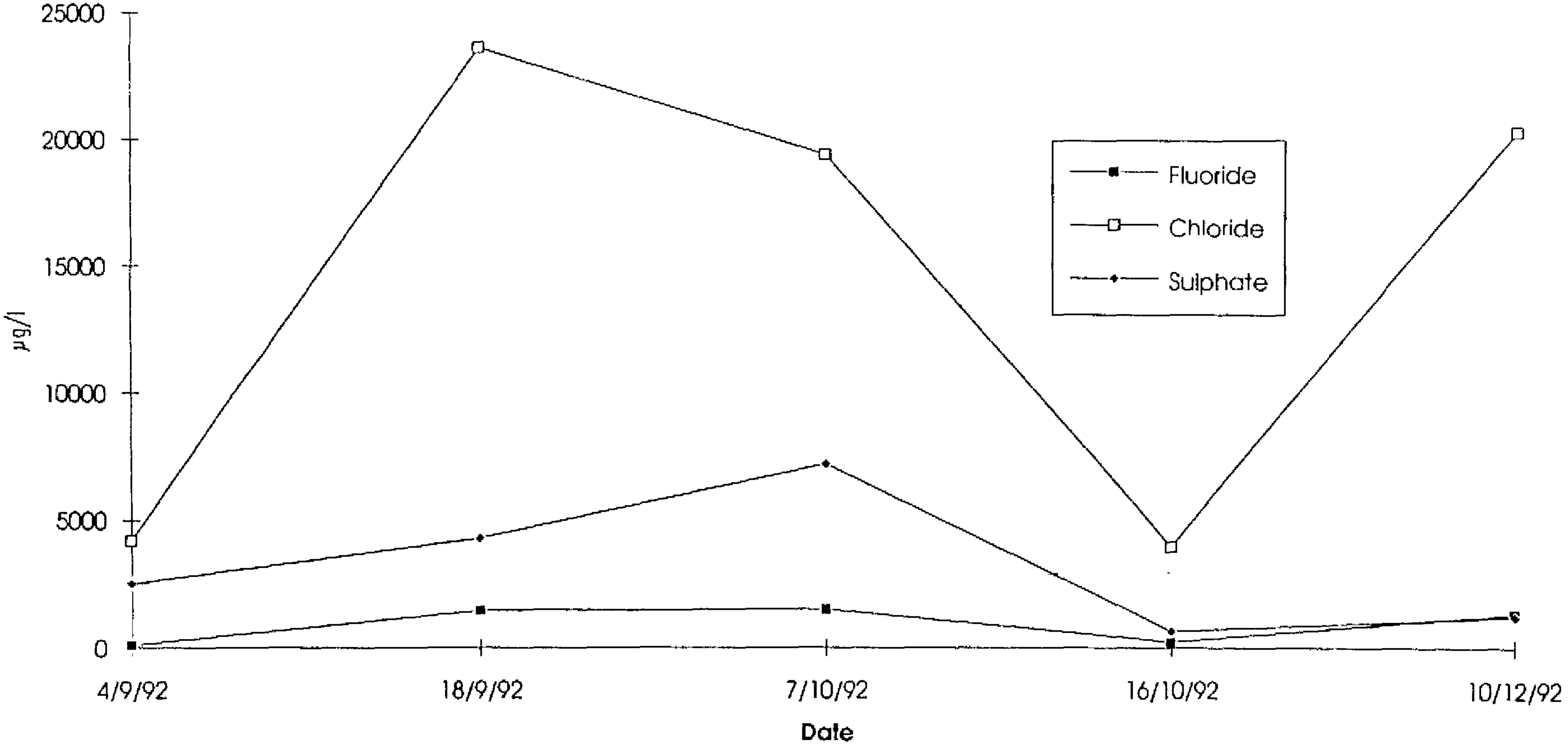


Figure 5

CONCENTRATIONS OF FLUORIDE, CHLORIDE AND SULPHATE IN RAINWATERS (BOTOS)

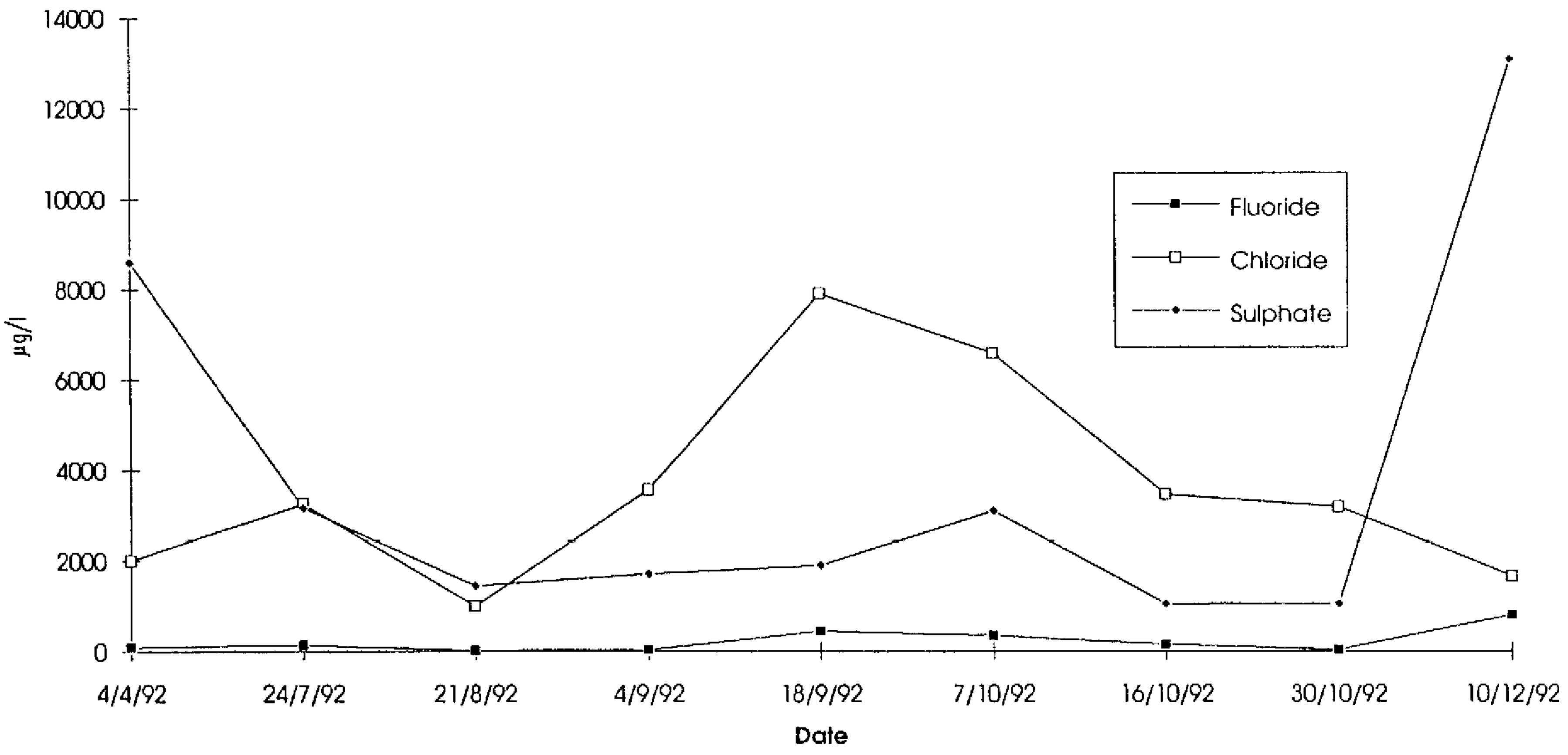


Figure 6

CONCENTRATIONS OF FLUORIDE, CHLORIDE AND SULPHATE IN RAINWATERS (POTRERO)

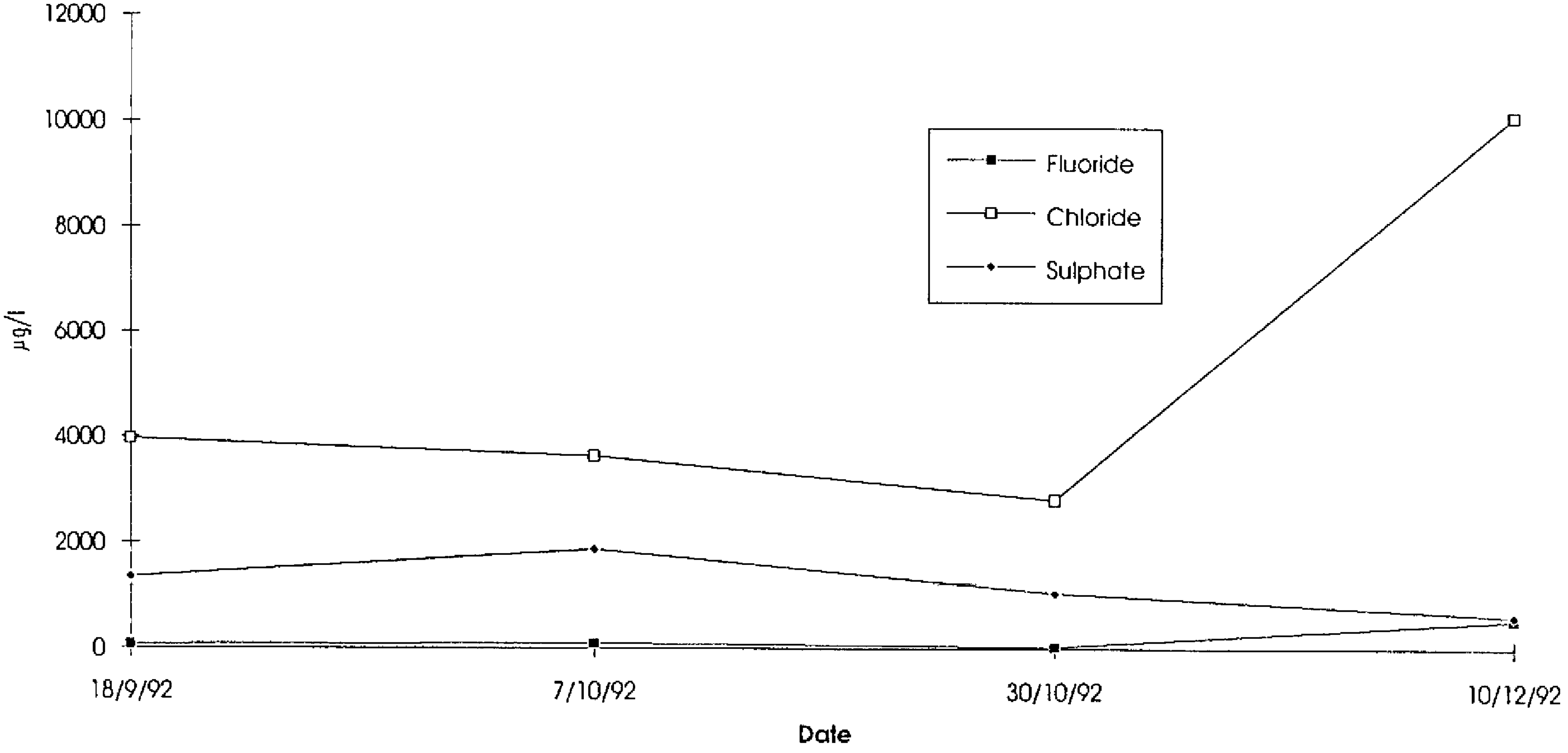


Figure 7

CONCENTRATIONS OF FLUORIDE, CHLORIDE AND SULPHATE IN RAINWATERS (PELON)

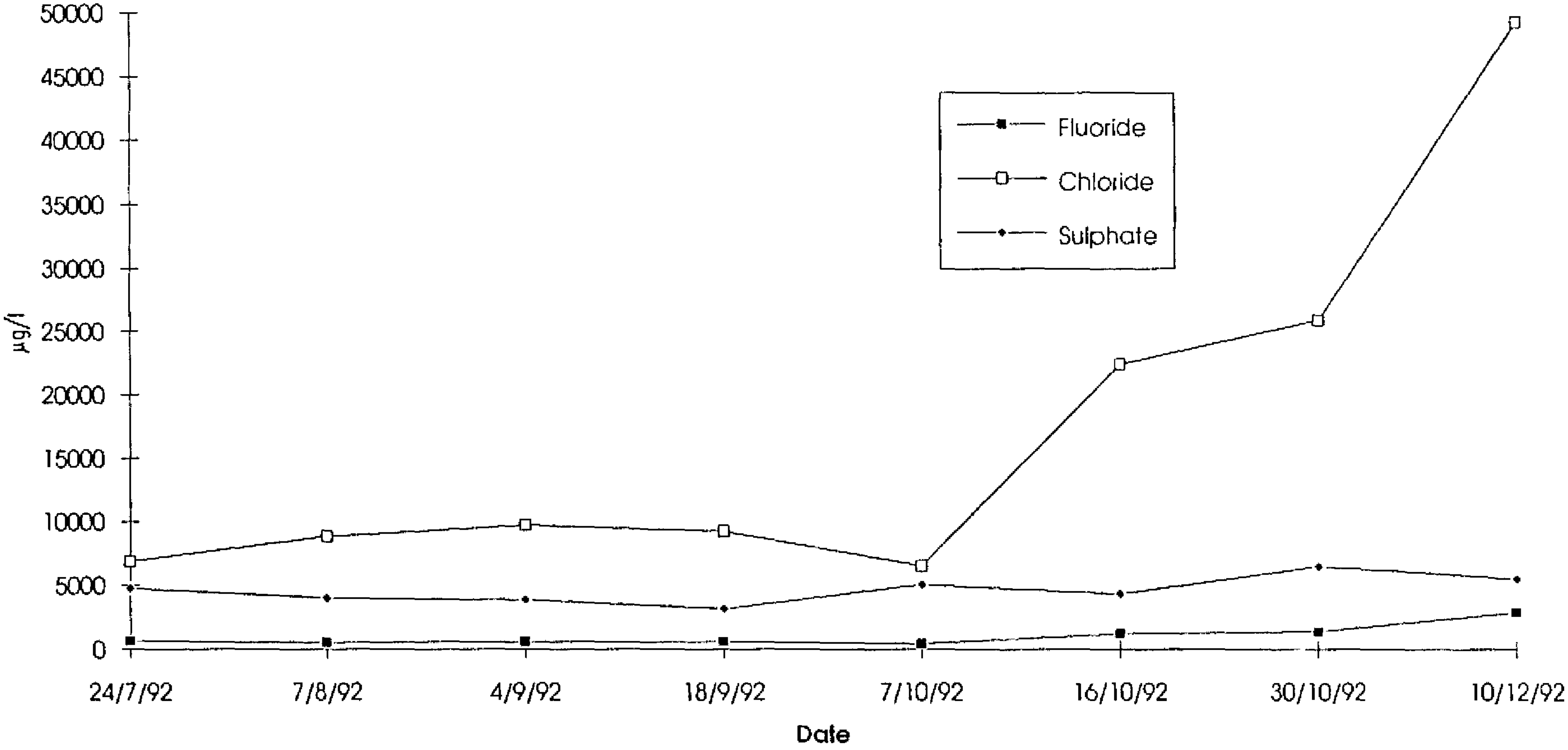


Figure 8

CONCENTRATIONS OF FLUORIDE, CHLORIDE AND SULPHATE IN PRINCIPAL RIVERS

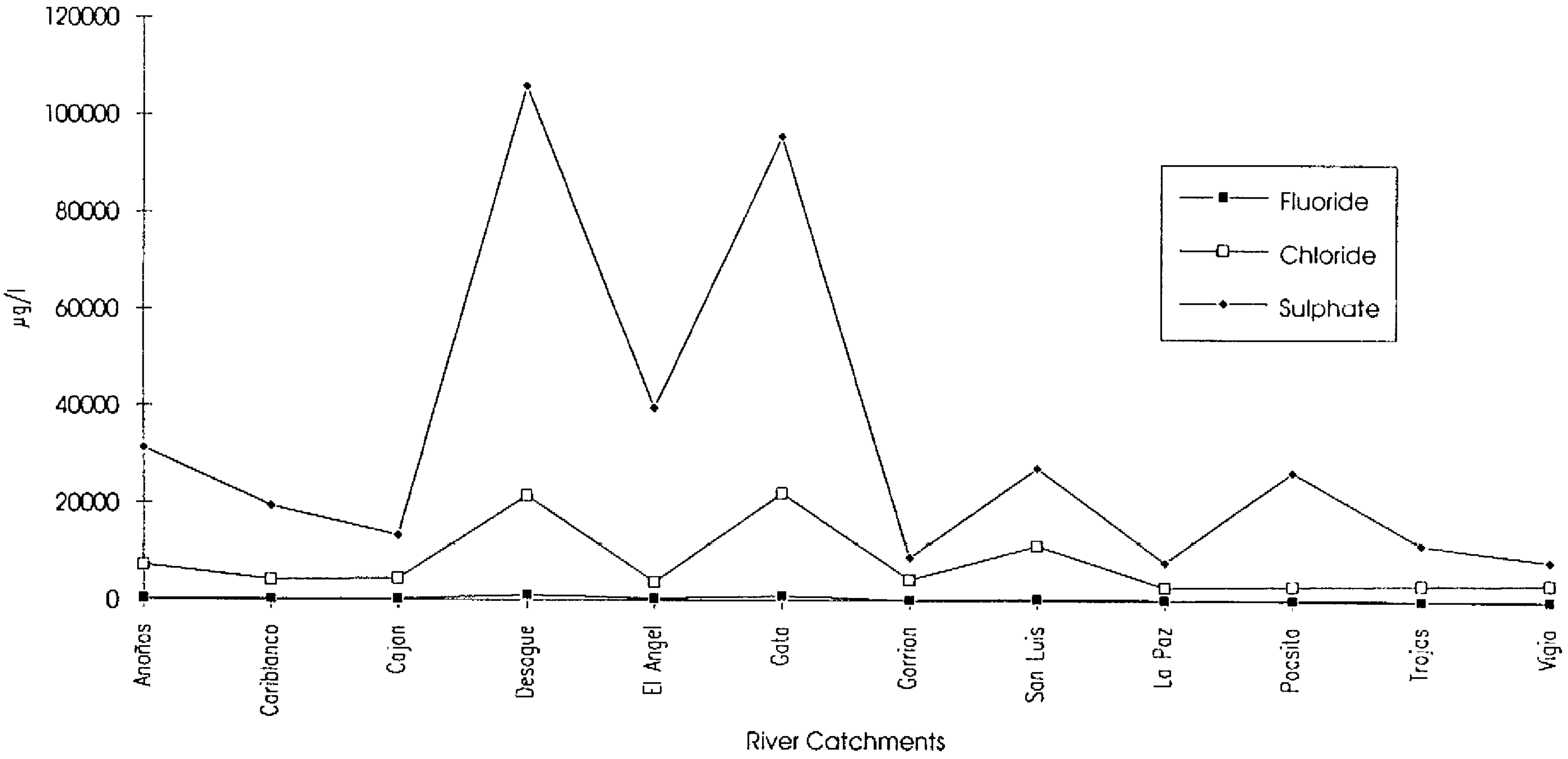


Figure 9