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Distribution of Metal in Precipitation in Kanazawa City in a 15-Month Period

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From May 1992 to August 1993, rain water and snow samples taken from the Kanazawa suburbs were analyzed to determined the metal concentration and pH and to clarify the distribution of metals. A negative correlation between the quantity of precipitation and quantity of trace elements was noted for some metal elements, and it is speculated that they originated from soil, sea water, or artificial contamination.

Key words —— metal, rain, snow, distribution, correlation

INTRODUCTION

The trace substances found in rain water or snow are present during the cloud formation process, or absorbed from the air as the moisture is released from clouds in the form of rain or snow. By analyzing these trace substances, it is hypothesized that the extent of pollution in the local atmosphere can be determined.[1)]

Analysis of trace substances in precipitation has mainly been performed as part of research into rain or snow acidification, concentrating on alkaline metals, alkaline-earth metals, organic acids, and inorganic anions in rain water.[1,2)] It is hypothesized that the main reason for acidification is the incorporation of atmospheric inorganic anions, such as sulfuric acid ion and nitric acid ion, into rain or snow. Previously, the author's group took dry samples and precipitation samples monthly, and found a seasonal variation in the amount of trace elements using ingredient analysis. It was found that the geographical features of the sampling site and weather systems such as the monsoon had a marked effect on the variation. However, some studies have suggested that when such rain falls on soil, changes also occur in river water and groundwater, which are sources of drinking water or water for agricultural use, and metals such as aluminum and cadmium are eluted from the soil.[3)] It is possible that heavy metals in water and soil can not only affect the growth of agricultural products and the quality of drinking water but also human health.[3–7)] Since it is thought that such metals are naturally present in precipitation, this study focuses on analyzing the trace metal contents in rain water and snow in Kanazawa city during the 15-month period from May 1992 to August 1993. Based on the results of analysis, the correlation between the amount of precipitation and trace substances was investigated.

MATERIALS AND METHODS

Sampling of Rain Water and Snow —— Rain water and snow were sampled at every precipitation on the first floor roof of the Kanazawa University Pharmacy Department. A polyethylene funnel (diameter 12 cm) was installed perpendicularly at a predetermined fixed point on the roof, and the rain water and snow were collected in a polyethylene container and measured. To prevent movement of the equipment by the wind and to prevent pollution from the concrete floor, a plastic guard container fixed with sandbags was placed around it. The period of precipitation was defined as from when rain or snow started until two hours after it had stopped. The container and the funnel were changed daily regardless of the weather and rinsed and dried with Milli-Q water after immersion in detergent and diluted nitric acid.

Pretreatment —— After sampling, pH was measured immediately using a pH meter (YOKOGAWA PH82 type) and 0.1 M acidity was established with the addition of concentrated nitric acid after suction filtration with a membrane filter (FUJI FILM FM-45) with pore size of 0.45 μm. Samples were stored in a cool dark place.[2)] The volume of rain and snow was measured in the scalpel cylinder at the time of filtration. Measurement of metal contents was performed twice or more, using the following methods.

Determination of Metal Concentration —— Metals were measured using an HITACHI Z-8000-type

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atomic adsorption spectrophotometer. Eleven elements were measured: aluminum (Al); zinc (Zn); cadmium (Cd); calcium (Ca); chromium (Cr); copper (Cu); sodium (Na); lead (Pb); magnesium (Mg); manganese (Mn); and nickel (Ni). Measurements were performed in the order Al → Mn → Pb → Cd → Cu → Cr → Ni → Zn → Mg → Ca → Na based on the likely contamination from the surrounding environment and the concentration contained, and the measuring method (atomization mode). The fixed-quantity range was as follows: Al, 0.5–100 ppb; Cr, 0.2–25 ppb; Mn, 0.2–50 ppb; Pb, 2–50 ppb; Cd, 0.05–5 ppb; Cu, 0.5–50 ppb; Ni, 1–25 ppb; Zn, 50–1000 ppb; Mg, 10–1000 ppb; Ca, 50–5000 ppb; and Na, 10–5000 ppb. Samples deviating from the fixed-quantity maximum were measured again after dilution with 0.1 M nitric acid. The other main conditions are shown in Table 1.

RESULTS AND DISCUSSION

The quantities of rain water and snow measured are shown in Table 2. The distribution of metal was as follows: Al, 0.61–124.52 (mean ± S.D. = 20.65 ± 20.48) ppb; Cr, 0.20–3.43 (0.54 ± 0.58) ppb; Mn, 0.39–43.38 (8.15 ± 7.98) ppb; Pb, 2.00–41.01 (6.81 ± 5.74) ppb; Cd, 0.050–1.170 (0.199 ± 0.173) ppb; Cu, 0.61–26.93 (3.68 ± 3.77) ppb; Ni, 1.00–13.04 (3.42 ± 3.03) ppb; Zn, 51–412 (112 ± 82) ppb; Mg, 16.2–1856.4 (354.6 ± 396.6) ppb; Ca, 54–9615 (1017 ± 1183) ppb; and Na, 29–11639 (2551 ± 2724) ppb. In smaller quantities of rain water, the metal concentration tended to be higher. This was because elements were washed out by the initial precipitation and then diluted by subsequent precipitation.[8,9]

Linear regression analysis between the concentration of elements containing a hydrogen-ion density showed a high correlation (r = 0.5 or more) between Al–Mn–Cd, Zn–Ni, or Ca–Mg–Na (Table 3).[10] The first elements in these combinations exists mainly in soil, and the second elements result from artificial pollution, such as a car exhaust fumes. The third elements are found mainly in sea water. Rain sample (no. 92, 98, *etc.* in Table 2) with high pH that fell at the beginning of spring was probably due to the yellow sand contents. Monsoons blowing from the westerly direction were responsible for the high calcium concentration during some periods of rainfall.[2,11]

Long-term continuous measurements of precipitation are useful to determine changes in pollution in an area, based on the concentrations of suspended particles.[12] Moreover, since metal contents in water can affect humans, it is suggested that the determination and continued investigation of the metal content in the atmosphere are important in the future.

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Table 1. Conditions for Atomic Adsorption Spectrophotometry of Precipitation Samples

Element	AAS mode	Wavelength (nm)	Slit (nm)	Measurement order
Aluminum (Al)	Flameless with nonpyrolytic tube	309.3	1.3	1
Manganese (Mn)	Flameless with nonpyrolytic tube	279.6	0.4	2
Lead (Pb)	Flameless with nonpyrolytic tube	283.3	1.3	3
Cadmium (Cd)	Flameless with nonpyrolytic tube	228.8	1.3	4
Chromium (Cr)	Flameless with pyrolytic tube	359.3	1.3	5
Copper (Cu)	Flameless with pyrolytic tube	324.8	1.3	6
Nickel (Ni)	Flameless with pyrolytic tube	232.0	0.2	7
Zinc (Zn)	Flame with air-C_2H_2	213.8	1.3	8
Iron (Fe)	Flame with air-C_2H_2	248.3	0.2	9
Magnesium (Mg)	Flame with air-C_2H_2	285.2	1.3	10
Calcium (Ca)	Flame with air-C_2H_2	422.7	1.3	11
Sodium (Na)	Flame analysis with air-C_2H_2	589.0	0.4	12

Table 2. Metal Concentrations (ppb) in Rain Water and Snow

Sample No.	Date	Vol. (mL)	pH	H+ (μM)	Al	Cr	Mn	Pb	Cd	Cu	Ni	Zn	Mg	Ca	Na
	'92														
1	5/13	18.5	4.57	26.92	7.98	1.86	7.18	4.01	0.160	2.93	<1	67.2	150.6	1235	2310
2	5/17	27.0	4.12	75.34	18.41	0.85	7.96	8.93	0.110	2.22	<1	<50	198.3	1420	332
3	5/18	18.0	3.95	112.98	36.48	0.70	10.56	7.60	0.308	2.77	1.26	60.3	290.7	2106	140
4	5/22	22.0	3.80	159.59	124.52	0.94	32.95	19.37	0.590	6.20	<1	100.4	511.1	3381	1998
5	5/25	7.0	4.61	24.55	17.85	0.33	7.05	6.31	0.135	2.28	<1	51.4	379.4	1083	2367
6	5/27	9.0	3.63	234.42	95.42	1.09	23.48	17.99	0.750	12.47	3.23	169.7	364.7	2155	1590
7	6/1	62.0	3.89	127.94	28.17	0.38	13.88	5.02	0.134	2.61	<1	<50	77.4	551	29
8	6/8	95.0	5.27	5.41	2.17	<0.2	4.43	<2	<0.05	1.25	<1	<50	98.5	306	161
9	6/14	2.0	4.67	21.53	48.22	3.43	25.20	4.21	0.380	9.35	13.04	399.7	—	—	—
10	6/18	41.0	4.15	71.29	11.46	0.26	6.79	3.01	0.174	2.95	<1	86.3	77.3	810	223
11	6/19	12.0	4.42	38.28	12.78	0.61	7.49	<2	0.093	2.05	<1	<50	249.2	671	1589
12	6/20	11.5	4.53	29.51	45.90	0.40	14.55	4.38	0.258	4.99	<1	74.6	210.1	2052	807
13	6/21	96.0	4.21	61.66	9.55	<0.2	3.48	2.13	0.063	1.32	<1	<50	126.0	337	529
14	6/22	49.0	4.91	12.22	0.81	0.20	1.65	<2	<0.05	<0.5	<1	<50	158.4	247	1054
15	6/24	2.0	4.54	29.17	33.79	0.93	25.56	8.87	1.170	17.60	12.84	412.2	—	—	—
16	6/27	40.0	3.90	125.89	25.79	<0.2	28.62	5.56	0.270	12.39	1.03	<50	97.7	946	147
17	7/9	6.5	4.07	84.53	72.17	<0.2	24.99	4.93	0.530	10.86	3.85	155.1	264.4	2669	1339
18	7/10	20.0	3.97	107.15	40.17	<0.2	14.24	3.44	0.250	6.50	1.24	63.9	127.1	1607	367
19	7/12	55.0	5.05	9.02	1.82	<0.2	2.30	<2	0.080	0.79	1.55	<50	24.7	478	<10
20	7/13	25.0	4.02	94.84	21.32	<0.2	7.40	6.67	0.240	3.11	2.13	<50	175.7	764	1085
21	7/14	10.5	3.91	124.45	25.39	<0.2	26.02	5.03	0.260	5.82	5.76	74.4	128.5	1397	1157
22	7/17	141.0	4.41	39.17	3.91	<0.2	2.06	4.46	0.095	<0.5	1.52	<50	16.2	171	<10
23	7/20	150.0	4.49	32.36	9.62	<0.2	4.36	<2	0.190	0.80	1.07	<50	41.6	446	<10
24	7/24	6.0	4.21	61.66	60.28	<0.2	22.86	6.44	0.485	26.93	6.00	142.4	491.5	3583	2889
25	8/9	147.5	5.33	4.68	<0.5	<0.2	3.64	<2	<0.05	2.92	<1	<50	644.7	634	4860
26	8/10	1.5	4.49	32.36	4.98	<0.2	2.87	<2	0.133	4.78	7.04	—	—	—	—
27	8/13	309.0	4.62	23.99	6.79	<0.2	2.91	<2	<0.05	2.29	<1	<50	33.8	170	<10
28	8/14	3.5	3.84	146.22	33.13	0.27	4.39	22.50	0.157	4.96	4.60	136.7	180.1	1263	51
29	8/24	169.0	4.58	26.30	8.86	<0.2	11.77	<2	<0.05	2.96	<1	<50	102.0	710	<10
30	8/25	151.5	4.67	21.38	7.59	<0.2	3.39	<2	<0.05	4.31	<1	<50	44.6	452	<10
31	9/3	100.0	4.17	67.61	10.30	<0.2	2.95	4.32	<0.05	5.13	<1	<50	60.5	276	<10
32	9/3	3.5	3.89	130.32	23.43	<0.2	4.66	6.96	0.239	5.34	7.74	219.1	288.1	166	—
33	9/4	3.5	4.36	43.65	32.24	0.29	7.49	8.64	0.051	7.20	2.76	100.7	449.5	2067	—
34	9/10	95.0	3.98	104.71	21.93	0.20	5.70	5.89	0.145	3.26	<1	100	203.0	798	1030
35	9/14	56.5	5.65	2.22	<0.5	<0.2	2.58	<2	<0.05	2.75	<1	<50	194.9	467	1349
36	9/15	26.0	4.56	27.54	18.44	<0.2	6.72	<2	0.082	4.09	<1	52.5	133.8	976	495
37	9/19	9.0	4.49	32.36	<0.5	—	—	—	—	—	—	—	—	—	—
38	9/21	6.0	5.62	2.40	13.06	0.24	10.12	<2	0.276	9.87	<1	99.3	981.5	2932	6590
39	9/25	13.5	5.44	3.63	5.62	<0.2	10.94	<2	<0.05	6.87	<1	<50	154.0	1180	392
40	9/25	241.0	5.50	3.16	<0.5	<0.2	2.71	<2	<0.05	3.70	<1	<50	181.9	514	1113
41	9/26	77.5	5.21	6.17	<0.5	<0.2	0.54	<2	<0.05	2.69	<1	<50	643.9	353	5069
42	9/29	154.0	4.93	11.75	6.39	<0.2	4.58	<2	<0.05	1.49	<1	<50	194.6	850	1092
43	9/30	7.5	4.37	42.66	4.97	<0.2	2.67	<2	0.097	2.31	<1	<50	379.5	1136	—
44	10/5	79.0	4.22	60.26	15.20	<0.2	7.18	2.00	0.142	1.95	<1	<50	563.7	569	4008
45	10/6	2.5	4.54	28.84	11.68	<0.2	10.30	4.61	0.189	8.07	2.68	103.7	578.6	—	—
46	10/9	215.5	5.66	2.21	<0.5	<0.2	1.54	<2	<0.05	<0.5	<1	<50	30.1	242	<10
47	10/12	11.5	4.61	24.55	10.46	<0.2	7.48	5.83	0.255	3.66	<1	212	667.8	1175	6287
48	10/14	11.0	4.61	24.55	7.47	<0.2	23.40	4.11	0.132	3.39	<1	69.2	289.7	913	2007
49	10/15	58.0	4.66	21.73	<0.5	<0.2	2.35	<2	<0.05	1.73	<1	<50	29.1	187	185
50	10/20	18.0	3.73	186.21	66.65	0.33	43.38	8.63	0.273	6.41	<1	89.5	252.3	1069	1244

Table 2. Continued

Sample No.	Date	Vol. (mL)	pH	H+ (μM)	Al	Cr	Mn	Pb	Cd	Cu	Ni	Zn	Mg	Ca	Na
51	10/31	266.5	4.56	27.54	30.53	<0.2	10.41	5.00	0.218	1.41	<1	<50	1279.1	1862	9450
52	11/2	128.0	4.43	37.15	18.45	<0.2	6.47	5.85	0.184	<0.5	<1	<50	1856.4	1081	11639
53	11/4	79.5	4.08	83.18	17.68	<0.2	4.29	6.00	0.160	0.87	<1	61.9	305.0	620	2836
54	11/14	9.5	3.79	162.18	33.17	0.29	5.77	8.56	0.298	7.25	<1	89.8	439.0	1295	4264
55	11/16	158.0	4.05	89.13	25.99	<0.2	6.11	11.03	0.342	2.05	<1	63.2	277.5	491	2513
56	11/24	49.0	4.08	84.14	32.74	<0.2	5.28	5.42	0.136	1.55	<1	56.4	378.9	642	3667
57	11/27	489.0	4.55	28.18	22.50	<0.2	7.72	2.90	0.136	2.23	<1	<50	1096.6	1254	8846
58	12/2	121.0	3.81	156.68	45.38	<0.2	10.43	9.34	0.276	1.28	<1	53	1591.5	1278	10873
59	12/4	55.0	4.25	56.23	15.57	<0.2	5.10	3.69	0.085	1.85	<1	<50	332.4	550	3165
60	12/7	35.5	4.39	40.74	0.67	<0.2	3.17	2.76	<0.05	0.91	<1	<50	75.1	277	674
61	12/10	2.5	4.07	86.10	65.87	0.52	13.63	9.02	0.497	7.18	<1	281.4	204.1	—	—
62	12/28	168.0	4.14	72.44	3.36	<0.2	1.77	<2	0.092	1.87	1.14	<50	41.3	113	216
63	12/29	214.5	4.34	45.71	1.33	<0.2	1.23	2.01	0.086	1.02	<1	<50	38.5	54	273
64	12/30	38.5	4.27	53.70	1.61	<0.2	0.81	<2	<0.05	2.31	1.01	<50	370.8	254	2805
65	12/31	98.0	3.95	112.20	24.71	0.27	5.04	6.09	0.138	1.64	<1	<50	1168.1	992	7407
	’93														
66	1/1	23.5	3.98	104.71	38.40	<0.2	4.35	12.48	0.256	3.08	1.62	108.1	469.3	742	3768
67	1/4	135.0	4.02	95.50	25.18	<0.2	7.80	13.45	0.402	2.02	1.71	<50	757.1	744	5578
68	1/5	14.5	4.28	52.48	3.04	0.24	5.25	3.90	0.071	2.34	<1	<50	287.0	397	1891
69	1/5	35.5	4.56	27.54	1.70	<0.2	1.77	2.97	<0.05	0.87	<1	<50	424.9	251	3658
70	1/8	520.5	4.85	14.13	<0.5	<0.2	0.57	<2	<0.05	0.75	<1	<50	69.0	78	551
71	1/11	186.0	4.55	28.51	<0.5	<0.2	0.52	<2	<0.05	<0.5	<1	<50	105.9	76	858
72	1/16	168.5	4.33	46.77	3.99	<0.2	2.54	<2	<0.05	1.06	<1	<50	60.1	284	249
73	1/18	270.5	5.07	8.51	<0.5	<0.2	0.39	<2	<0.05	0.80	<1	<50	619.6	265	5308
74	1/25	4.5	4.16	69.18	28.91	0.78	24.51	5.23	0.142	9.61	2.33	122	489.8	3482	2733
75	1/27	240.5	7.12	0.08	23.63	0.46	2.17	<2	<0.05	1.19	<1	<50	570.7	2836	3992
76	1/29	324.0	4.21	61.66	24.23	<0.2	4.05	6.63	0.145	2.23	<1	<50	1105.3	795	7154
77	2/5	824.0	4.12	76.74	44.34	<0.2	11.48	6.84	0.297	1.90	<1	<50	1068.4	1472	6590
78	2/9	702.5	4.69	20.42	14.97	<0.2	8.23	3.82	0.126	1.08	1.45	<50	477.2	867	3806
79	2/10	41.5	4.31	48.98	4.94	<0.2	1.79	<2	<0.05	1.66	3.27	<50	113.2	246	876
80	2/15	460.5	4.24	58.21	21.03	<0.2	6.62	5.49	0.106	1.50	<1	<50	1115.6	865	7070
81	2/19	517.5	4.25	56.89	7.29	<0.2	2.33	2.49	<0.05	1.03	7.45	<50	536.0	414	4290
82	2/22	308.0	4.85	14.29	1.54	<0.2	1.45	<2	<0.05	0.82	<1	<50	169.8	395	1372
83	3/10	18.5	3.80	158.49	27.19	0.38	9.82	5.41	0.257	7.15	2.55	100.4	372.9	1410	2239
84	3/11	14.5	4.17	67.61	59.43	0.23	15.30	16.82	0.712	2.76	1.54	79.7	725.7	1506	5975
85	3/15	17.5	4.14	72.44	20.97	<0.2	6.99	8.92	0.193	1.82	<1	<50	101.3	837	408
86	3/17	45.5	4.20	63.10	20.78	<0.2	6.82	4.79	0.143	2.07	<1	<50	810.7	655	5943
87	3/17	13.5	4.68	21.13	5.20	<0.2	2.54	2.49	0.086	2.44	<1	<50	353.0	573	2786
88	3/18	1.5	5.75	1.78	25.40	<0.2	11.84	10.45	0.137	—	—	128.8	555.1	—	—
89	3/25	449.0	4.47	33.88	3.62	<0.2	1.87	2.65	<0.05	<0.5	<1	<50	41.3	176	157
90	4/2	127.0	4.96	10.96	43.57	<0.2	31.83	<2	0.176	2.12	1.56	<50	1823.2	3375	9192
91	4/7	50.5	4.49	32.36	35.50	<0.2	20.09	5.32	0.271	1.49	<1	61.2	1149.1	2122	7042
92	4/8	39.5	6.85	0.14	12.53	<0.2	27.64	<2	<0.05	0.69	<1	<50	1709.0	4862	8984
93	4/9	31.0	4.85	14.29	5.25	<0.2	4.62	<2	<0.05	<0.5	<1	<50	136.8	563	926
94	4/12	172.0	4.35	44.67	6.16	<0.2	3.60	3.16	0.072	0.65	<1	<50	91.5	319	554
95	4/12	5.0	3.88	131.83	37.39	0.32	6.40	6.72	0.164	8.50	8.04	93.8	495.6	1350	3909
96	4/14	118.0	4.21	61.66	44.21	<0.2	9.82	11.49	0.180	1.31	<1	<50	355.3	1206	2082
97	4/22	67.5	5.31	4.90	6.63	<0.2	7.92	<2	<0.05	0.82	<1	<50	120.7	614	6779
98	4/26	310.0	6.59	0.26	42.51	<0.2	21.34	<2	0.091	1.48	<1	<50	508.1	4316	2946
99	4/27	11.5	6.78	0.17	—	0.30	—	<2	0.174	5.21	1.57	<50	1481.5	9615	7882
100	4/30	390.0	5.53	2.95	7.04	0.52	10.43	<2	0.054	1.33	<1	<50	186.8	1071	781

Table 2. Continued

Sample No.	Date	Vol. (mL)	pH	H+ (μM)	Al	Cr	Mn	Pb	Cd	Cu	Ni	Zn	Mg	Ca	Na
101	5/11	555.5	5.28	5.25	6.06	<0.2	5.08	<2	<0.05	0.82	<1	<50	90.2	423	451
102	5/15	980.0	4.65	22.39	3.52	<0.2	2.16	<2	0.057	<0.5	<1	<50	33.0	105	91
103	5/18	41.5	4.72	19.05	11.29	<0.2	5.31	<2	<0.05	1.59	1.33	<50	78.0	531	373
104	5/24	111.5	4.87	13.49	7.47	0.20	9.44	<2	0.058	1.73	<1	<50	104.0	813	243
105	6/7	367.5	4.39	40.74	7.31	<0.2	2.65	<2	<0.05	1.07	<1	<50	410.9	356	3345
106	6/9	25.0	4.15	71.61	56.00	0.37	22.58	<2	0.115	5.44	1.30	53.4	254.3	1581	479
107	6/10	22.0	4.09	81.28	58.86	0.35	21.55	7.40	0.224	4.50	2.04	70.7	306.9	2022	2975
108	6/14	53.5	5.55	2.85	16.78	<0.2	8.12	<2	<0.05	3.29	<1	56.2	163.1	621	662
109	6/16	180.0	4.17	67.61	10.08	0.20	2.39	2.17	0.145	0.61	1.25	<50	36.1	182	156
110	6/18	20.5	4.48	33.11	12.16	0.23	6.19	<2	0.099	2.00	1.75	56.6	133.2	1016	324
111	6/21	28.5	3.99	103.51	15.32	0.25	5.23	5.59	0.221	1.96	1.94	<50	75.3	549	161
112	6/23	106.0	4.66	22.13	7.67	0.45	5.68	<2	0.062	1.42	1.00	<50	59.2	392	126
113	6/28	239.5	4.88	13.18	6.22	<0.2	3.36	<2	0.134	1.48	<1	<50	52.7	362	205
114	6/30	698.0	4.99	10.35	<0.5	<0.2	0.61	<2	<0.05	<0.5	<1	<50	<10	<50	69
115	7/3	411.5	4.51	30.90	<0.5	<0.2	1.85	<2	<0.05	<0.5	<1	<50	<10	144	979
116	7/5	356.0	5.13	7.41	<0.5	0.23	1.18	<2	<0.05	<0.5	<1	<50	<10	137	239
117	7/7	3.5	4.52	30.55	17.79	0.83	9.38	41.01	0.119	11.39	5.95	75.6	130.6	1251	4176
118	7/10	259.5	4.07	85.11	12.22	<0.2	3.12	3.70	0.079	1.96	<1	<50	23.6	308	576
119	7/16	22.0	4.16	69.18	7.03	<0.2	1.88	3.08	0.054	10.66	<1	<50	365.2	642	3069
120	7/19	209.5	4.16	69.18	6.46	<0.2	4.79	<2	0.064	3.03	<1	<50	21.2	135	158
121	7/20	14.0	4.17	67.61	14.19	0.23	7.12	4.21	0.171	9.59	1.89	59.2	158.2	867	850
122	7/26	27.5	4.57	27.23	1.16	<0.2	4.49	<2	0.051	2.80	<1	<50	84.2	454	1817
123	7/28	9.0	5.83	1.48	0.61	<0.2	4.27	<2	<0.05	2.92	<1	<50	140.1	837	2440
124	8/2	38.0	6.55	0.28	9.56	<0.2	4.50	<2	<0.05	3.22	<1	<50	310.7	713	2254
125	8/4	123.0	4.42	38.46	10.61	<0.2	7.88	3.20	0.059	3.58	<1	<50	76.2	483	1227
126	8/6	339.5	4.30	50.12	5.53	<0.2	6.55	<2	0.050	1.46	<1	<50	17.5	242	238
127	8/6	125.5	4.48	33.11	12.82	<0.2	4.96	<2	0.086	2.11	<1	<50	43.5	607	404
128	8/7	5.5	3.70	199.53	21.21	<0.2	8.22	3.50	0.214	5.87	6.90	83.7	175.0	1444	1034
129	8/9	74.5	5.24	5.75	<0.5	<0.2	2.22	<2	<0.05	1.18	<1	<50	42.9	346	181
130	8/19	9.0	4.34	45.71	2.99	<0.2	4.17	<2	0.070	1.26	3.77	<50	77.3	615	842
131	8/21	155.5	4.39	40.74	<0.5	<0.2	0.74	<2	<0.05	<0.5	<1	<50	<10	<50	60
132	8/23	160.0	4.50	31.62	4.88	<0.2	2.82	<2	<0.05	2.09	<1	<50	121.1	447	3426
133	8/30	114.0	4.86	13.80	<0.5	<0.2	3.57	2.46	<0.05	<0.5	<1	<50	286.7	463	6841

Table 3. Correlation Coefficients between Each Element

	Al	Cr	Mn	Pb	Cd	Cu	Ni	Zn	Mg	Ca	Na
H^+	0.385	0.066	0.339	0.253	0.340	0.288	0.063	0.077	0.006	0.049	0.055
Aluminum		0.441	0.520*	0.204	0.582*	0.490	0.257	0.255	0.042	0.295	0.131
Chromium			0.360	0.025	0.259	0.305	0.696*	0.600*	0.112	0.118	0.024
Manganese				0.206	0.526*	0.487	0.222	0.264	0.294	0.713*	0.155
Lead					0.296	0.237	0.041	0.016	0.033	0.292	0.060
Cadmium						0.552*	0.440	0.604*	0.203	0.318	0.190
Copper							0.465	0.469	0.001	0.351	0.045
Nickel								0.829*	0.017	0.011	0.083
Zinc									0.004	0.193	0.086
Magnesium										0.538*	0.917*
Calcium											0.379

*Strong correlation.

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