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A study on the environmental background values in the Mt. Namjagbarwa region, Tibet

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Abstract—A study on the elemental composition of aerosol, water and soil in the Mt. Namjagbarwa region, Tibet, was carried out in the period of 1982 to 1984. Samples of aerosol particles were collected by cascade impactor and analyzed for 10 elements by PIXE. Samples of ice, snow and water were collected and analyzed for trace metals, major cations and anions. The pH values of water were at quasi-neutrality or neutrality, and the hardness of water was low. Contents and physico-chemical composition of 20 elements in the major types of soil were determined by physico-chemical methods. Levels of elements in soil varied with soil type and their parent materials. Contents of some elements were higher in the substratum soil derived from in situ than in the surface soil. The region was in a remote area with negligible pollution and could be considered as a good location for measuring the baskground value of environmental sample.

Keywords: aerosol; water; soil; background value.

INTRODUCTION

Concern over environmental protection has recently led to a investigation to determine natural elemental composition of aerosol, water and soil in pollution-free regions. Efficient long range transport of atmospheric pollutants contributed greatly to contamination of many rural areas, and safe pollution-free areas for background composition measurement can scarcely be found. As Mt. Namjagbarwa is a remote, sparsely populated region, and measurement of background value, representative of the region, is of importance, it has brought to the increasing attention of many scientists. For this purpose, survey and sampling were taken from 1982 to 1984 for three times, which were based on natural conditions, climate and human activities, samples of water, soil and aerosols were collected and analyzed, using several multi-element methods.

METHODS

Sitting

Mt. Namjagbarwa, 7782m sea level, is the highest in the east Himalaya Mountain Range. The piedmont belt is enclosed by the great bend gorge at the Yarlung Zangbo River. The site chosen for sampling is located at latitude 29°37′51″ N, longitude 95° 03′31″ E in East Tibet. The area consists of four counties (Mainling, Linzhi, Medog and Bomi) with an area of about 10 thusand km^2 and sparse human habitation as shown in Fig. 1. Being a monsoon type of

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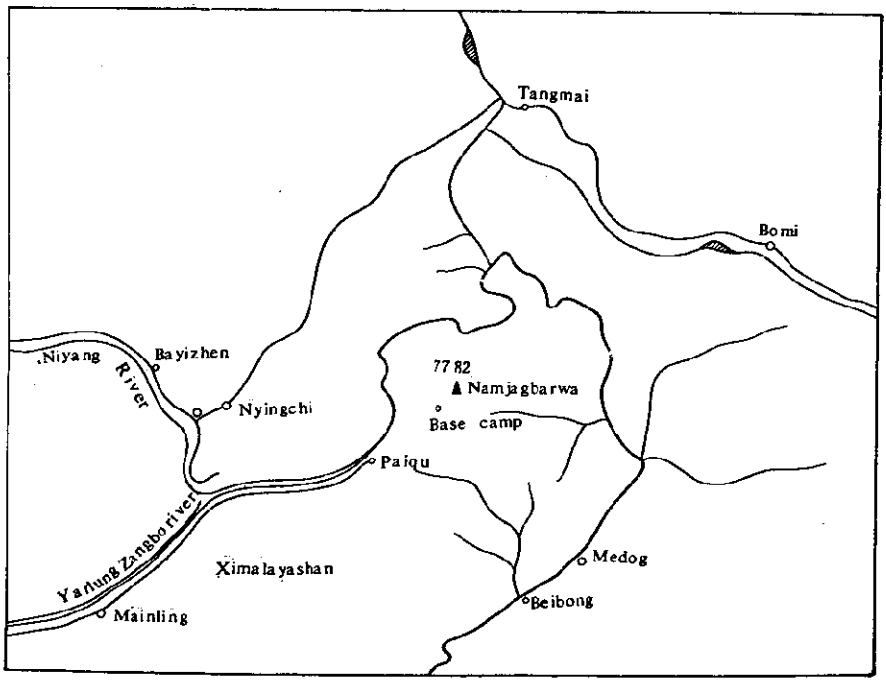

Fig. 1 Sketch of Mt. Namjagbarwa rigion

weather due to the Indian Ocean, the climate is moist and rainfall is aboundant. About 95% of the ground is covered by vegetation.

Sampling

The aerosol samples were collected by cascade impactors. In this device the particulate matter is separated into eight different size fractions corresponding nominally to aerodynamic diameters of > 11, 7.7-11, 5.0-7.7, 3.5-5.0, 2.3-3.5, 1.2-2.3, 0.7-1.2 and < 0.7μm (stages 1-8 respectively). Stages 1-7 are all Mylar film with vaseline, stage 8 is Millipore filter with 0.45μm pores. Ten groups of samples were collected at a flow rate of 2 L/min. The air volume pumped was 1.0-1.3 m^3 for each group of samples. Two ice samples and five snow samples were collected from different elevations. Twenty water samples were collected from Yarlung Zangbo River, Pa Long Zangbo River and Ni Yang River, major streams and mountain lakes. The soil samples included the major types of soil and the parent materials of soil in the region and were kept from contamination from all possible pollutant sources. One hundred and sixteen soil samples (52 profiles) were collected.

Sample analyses

Aerosol samples were analyzed by using Proton Induced X-ray Emission (PIXE). The samples were put in a target-holding frame dirven by a step by step motor for measurement. Counting rates were limited to 2000 counts per second by changing proton beam current (3-15nA). X-ray produced from the sample was deterected by a Si (Li) detector with an energy resolution of 185 eV at 5.9 KeV. A multichannel analyzer (ND-76) with PDP 11/23 microcomputer was applied. Several analytical techniques were employed to dertermine a number of trace and minor constituents in the water samples. The elements Cd, Cr and Pb in water were determined by flameless atomic absorption spectrophotometry. Inductively Coupled Plasma-Atomic Emission Spectroscopy (ICP) was used for the determination of Mn, Sr, Al, Fe, B and Ba, ion chromatography for HCO_3^-, SO_4^{2-}, NO_3^-, Cl^-, Na^+, K^+, Ca^{2+} and Mg^{2+}, gas chromatography for Se and microwave induced plasma spectrometry for Hg.

Concentrations of elements Ca, Co, Cu, K, Mg, Zn, Al, Fe, Na, Ni, V, Sr, Ba, Mo, Rb, Ga

and Sc in soil samples were determined using ICP. Determination of elements Zr and Y were also performed by X-ray fluorescence analysis.

RESULTS AND DISCUSSION

Aerosol composition

Elemental concentrations: The elemental concentrations in aerosol samples are listed in Table 1. It is shown that the concentrations of Pb, As, Se, Ni, Br and Cr in aerosol were very low, about 10 μg / m^3. The average concentration of mercury in aerosol was as low as 4.4 μg / m^3 (Liu Quanyou, 1984). The sulfur concentrations were different at different sites. It is thought that they might be derived from the gas or hot mineral spring containing H_2S. The high concentrations of Cl was probably related to geochemical and climatic conditions.

Table 1 Elemental concentrations in aerosol in the Mt. Namjagbarwa region (μg / m^3)

Element	Camp (2)	Base camp	Paiqu	Bomi	Bayizhen	Beibong
Si	8.09	5.86	5.28	1.04	0.58	0.63
S	0.55	0.77	0.55	1.12	0.38	0.02
Cl	5.29	1.78	3.14	6.58	2.30	5.79
K	0.44	0.24	0.41	0.60	0.13	0.21
Ca	0.47	0.19	0.38	0.36	0.13	0.20
Ti	0.08	0.05	0.04	3× 10	4× 10	5× 10
Mn	0.02	0.03	0.02	5× 10	4× 10	7× 10
Fe	0.51	0.56	0.47	0.13	0.05	0.10
Cu	0.12	0.19	0.10	7× 10	1× 10	7 × 10
Zn	0.15	0.08	0.07	0.01	0.01	7× 10
Pb	0.16	7× 10	0.06	< 10	< 10	< 10
As	0.04	< 10	< 10	< 10	< 10	< 10
Se	0.07	< 10	< 10	<10	< 10	< 10
Ni	< 0.10	< 10	0.14	< 10	< 10	< 10
Br	< 10	< 10	0.02	2.14	0.07	0.05
Cr	< 10	< 10	0.04	7× 10	0.01	0.03
Hg	2.00	2.80	4.25	6.90	8.30	2.10

Enrichment factors of elements in the coarse particles:

Enrichment factor may be useful in distinguishing the elemental sources for aerosol particles from each other. In this study aerosol crust enrichment factors ($E.F.$) were calculated for elements (X) in coarse mode ($> 11\mu m$) by the equation:

$$E.F. = \frac{(X/Fe)_{aerosol}}{(X/Fe)_{crust}}, \tag{1}$$

where iron is used as a reference element. The average concentration of crust rock as reported by Mason is used (Mason, 1966). The results are summarized in Table 2. It is found that non-enriched or negligibly enriched elements such as Si, Ca, K, and Ti are considered to be crust-derived. The $E.F.$ for S, Cl, Cu and Zn in coarse particles were higher in this region, but lower than in north China (Winchester, 1981). The $E.F.$ values observed here for S and Cl can be compared with those obtained at Mt. Chacaltaya by Adams et al. (Adams, 1977). E.F. for S, Cl and Pb in the coarse particles at Mt. Chacaltays were 97, 130 and 51, respectively.

Enrichment factors of elements in the fine particles:

The fine modes of elements show relative large enrichments as compared with fine mode Fe. The composition of fine particles was compared with the Antarctic aerosol (Admas, 1977). From the concentrations of elements in fine particles ($< 1.2\mu m$), the values of $E.F.$ and X/Fe were calculated and shown in Table 3. It is found that Cl/Fe and Zn/Fe in the Namjagbarwa

were higher than in the Antarctic, contrary quite the S/Fe was. The values of E.F. were different between coarse and fine particles in the Mt. Namjagbarwa region. Thus the enrichment status for elements may be correlated to long-range transport of the pollutants and the environmental conditions in this region.

Table 2 Enrichment factors of elements in the coarse particles

Element	Concentration, $\mu g / m^3$	X/Fe, Namjagbarwa	X/Fe, Crust Rock	*E.F.*
Si	0.881	10.208	5.500	1.856
S	0.071	0.827	0.005	165.4
Cl	0.345	4.026	0.003	1342
K	0.668	0.703	0.520	1.352
Ca	0.050	0.527	0.720	0.732
Ti	0.021	0.222	0.088	2.523
Mn	0.031	0.032	0.019	1.684
Cu	0.027	0.310	0.011	28.182
Zn	0.012	0.141	0.001	141.0
Fe	0.086	1.000	1.000	1.000

Table 3 Enrichment factors of elements in the fine particles

Element	Concentration, $\mu g / m^3$	X/Fe, Namjagbarwa	X/Fe, the Antarctic	*E.F.*
Si	0.685	7.780	—	—
S	0.115	1.310	80.00	0.016
Cl	1.804	20.500	4.200	4.881
K	0.086	0.977	1.100	0.888
Ca	0.076	0.864	—	—
Ti	0.071	0.193	—	—
Mn	0.004	0.045	0.021	2.143
Cu	0.037	0.420	0.047	8.936
Zn	0.123	1.398	0.053	26.377
Fe	0.088	1.000	1.000	1.000

Concentrations of elements in water

Levels of major cations and anions in water: Results of water quality analyses are listed in Table 4. As shown the impurity level of water is low in the region.

Table 4 Concentrations of major ions (mg/L), alkalinity and hardness of water

Water	HCO_3^-	SO_4^{2-}	NO_3^-	Cl^-	Na^+	K^+	Ca^{2+}	Mg^{2+}	Alkal., *mmol/L*	Hard.
Stream	2.94	15.3	0.26	0.91	4.41	4.58	14.0	1.06	0.48	2.18
River	38.2	24.7	0.23	1.07	4.15	5.30	22.1	2.41	0.70	3.51

Low concentrations of major ions were found in water. The ranges for C_a^{2+}, HCO_3^- and SO_4^{2-} in water were 0.90-50.2, 12.0-66.0 and 0.50-90.0 mg/L respectively. Levels of Na^+ K^+ and Mg^{2+} were less than 10 ppm, but the contents of NO_3^- and Cl^- were lower than 5 ppm. The similar order of concentrations for major ions in ice and stream water indicated that the supplement of stream water was closely related to the melt of ice and the thaw of snow in the region. The alkalinity of water was 0.2-0.8 ($\times 10^{-3}$) mol/L. The hardness of water was 0.1-7.9 but mostly lower than 4. The pH values of water were quasi-neutral or neutral with a range from 6.7 to 7.7. The minerality of neutral with a range from 6.7 to 7.7. The minerality of water in the region was 25-100 mg/L. There is a remarkable correlation between minerality

and concentrations of HCO_3^- and Ca^{2+}. The regressive equations are found to be [minerality] (mg/L) =2.10 [HCO_3] (mg/L)-1.91 (n=17, R=0.95), and [minerality] (mg/L) =3.68 [Ca^{2+}] (mg/L) + 20.36 (n=17, R=0.98).

Average concentrations of elements in water: The comparison of the Mt. Namjagbarwa region water with world river (Garrels, 1975) is listed in Table 5.

Table 5 Comparison of elements in water of Mt. Namjagbrwa with world river (ppb)

Element	Mt. Namjagbarwa		World river (1)
	Range	Mean concentration	
Al	54-2090	810	400
B	2-147	38.7	10
Ba	4-32	14.9	20
Be	< 0.01	–	–
Cr	0-4.4	3.6	1
Cu	2-18.1	5.3	7
Fe	31-2950	1045	670
Hg	< 0.02	–	0.04
Mn	2-123	47.5	7
Pb	0-10.6	4.1	3
Se	< 0.1 – 0.35	0.17	0.02
Sr	6-155	50.1	70
Zn	6-79	19.4	20

(1) date from Garrels, 1975

As shown in Table 5, the concentrations of Al, Fe and Mn in water of Mt. Namjagbarwa were found to be higher, but the concentrations of Sr and Ba were lower than those in the world river water. The contents of trace elements, such as Cu and Mn, in ice, snow and stream water, were found to be much lower than in the river water. The levels of B, Cd and Cr in ice collected from 4200, 4800 and 6000m above sea level decreased with the increase in height.

Composition of soil.

Physico-chemical compositions of elements in major types of soil: The pH values of mountain brown soil and mountain meadow soil are at quasi-neutrality or neutrality and the other types of soil are acidulous. The contents of organic matter in soils varied from 1.8 to 16.2%, the total exchangeable base was 3.8-29.7 meq/100g (soil). The contents of coarse particles are more than fine particles (less than 10%).

Concentrations of elements in major types of soils: the average concentrations of twenty elements in major types of soil in the Mt. Namjagbarwa region are listed in Table 6.

It is well known that the soil element contents are strongly dependent on the soil type and their parent materials. In Table 6, the contents of K, Mg, Mn, Zn, Fe, Mo, Rb and Ga are higer in alpine meadow soil than in other soils, while the contents of the other elements are nearly the same for all soils. The elements Mn, Zn and Ga are enriched in sub-alpine scrubby meadow soil. Ca, Cu, Zn, Mn, Mg, K and Sr, have a strong mobility and obvious loss by leaching, while Sc, Zr and Y are enriched in mountain podsolic soil. The concentrations for most of trace elements were found to be higher in mountain brown soil than in mountain podsolic soil generally. Except for Mn, the leaching loss of other elements, such as K, Na, Ca, Mg and Y, in yellow latosol were found.

Background values of elements in soil: Average concentrations of elements in soil from the region are listed in Table 7. The levels of 20 elements determined in the region were found to be roughly the same as those in world soil (Bowen, 1979), indicating that soil in the region has no contamination from pollution sources. The mean concentrations of elements are suitable to represent the background values in soil of the region.

Table 6 Concentrations (ppm) of elements in major types of soil from the Mt. Namjagbarwa region

Soil type	Ca	Co	Cu	K	Mg	Mn	Zn	Al
Alpine meadow	4289	38.35	26.68	20535	24184	1695	265.9	80717
Sub-alpine scrubby meadow	19395	23.98	30.78	10192	12236	877	148.2	47107
Mountain podzolic	16651	26.76	36.32	9841	11515	686	178.8	44816
Mountain brown	20150	24.90	32.68	14255	12145	918	120.4	47450
Mountain yellow brown	24401	18.95	33.39	15165	16267	852	283.8	60252
Mountain meadow	32336	15.92	19.92	17227	18474	892	140.6	58296
Mountain latosol	18995	28.75	57.52	10895	11591	1130	191.6	53122
Soil type	Fe	Na	Ni	V	Sr	Ba	Mo	Rb
Alpine meadow	78794	17806	57.02	212.2	431.9	518	17.67	10337
Sub-alpine scrubby meadow	49883	15456	41.62	147.8	154.5	244	8.14	314
Mountain podzolic	54007	21379	38.02	144.9	137.6	235	9.90	281
Mountain brown	42709	14336	40.48	107.2	134.1	317	9.08	331
Mountain yellow brown	48679	18172	54.47	115.0	153.7	356	7.20	268
Mountain meadow	42119	17935	44.50	94.9	244.7	392	9.29	230
Mountain latosol	51111	14320	46.42	127.5	230.5	423	10.66	314
Soil type	Ga	Sc	Zr	Y	Progile	Sample		
Alpine meadow	66.84	19.05	258.0	31.79	1	2		
Sub-alpine scrubby meadow	30.49	12.15	335.0	27.46	4	9		
Mountain podzolic	28.70	11.83	292.0	26.11	7	15		
Mountain brown	30.48	10.23	430.0	35.20	23	55		
Mountain yellow brown	29.84	13.55	372.0	33.29	4	8		
Mountain meadow	30.80	12.00	376.0	33.38	6	12		
Yellow latosol	34.17	9.57	215.7	25.44	7	15		

Table 7 Mean values (ppm) in 95% confidence internal of elements in soil from the Mt. Namjagbarwa region

Element	Mean concentration	Standard deviation	95% confidence internal	Median world soil
Ca	21829	0.413	19485-24489	15000
Co	23.97	0.424	21.31-21.98	8
Cu	29.84	7.73	10.53-110.8	30
K	13173	0.398	11802-14712	14000
Mg	12499	658.2	10673-14325	5000
Mn	910	307	824.9-995.9	1000
Zn	145	0.552	51.01-411.6	90
Al	50193	1815.5	45157-55229	71000
Fe	47463	9789	32298-77221	40000
Na	14868	0.409	13279-16647	5000
Ni	42.27	0.515	36.63-48.76	50
V	122.4	0.331	111.6-134.1	90
Sr	147.6	0.446	130.5-167.1	250
Ba	316.4	0.405	282.9-354.0	500
Mo	9.33	0.503	3.41-25.53	1.2
Rb	303.1	141.6	51.4-535.2	150
Ga	32.10	8.20	13.33-77.41	20
Sc	10.10	3.81	9.04-11.16	7
Zr	349.9	106.0	320.3-379.5	400
Y	30.83	6.60	16.06-50.31	40

CONCLUSIONS

The samples of aerosol, water and soil collected from the Mt.Namjagbarwa region were analysed. Among the elements detected in aerosol, Si, Ca, K and Ti were non-enriched or negligibly enriched, but E.F. values for S, Cl Cu and Zn were found to be higher in coarse particles. The water has a pH value of quasi-neutrality or neutrality with low hardness and weak mineralization. The levels of Ba, Cr , Cu, Pb, Zn, Hg, Se and Be in the river water were close to the mean values in the world, while Sr was found to be at low level and Al, Fe and Mn at high level in the region. The impurity content in water was found to be low. Thus water in the region was excellently fresh water. Most of soils in the region showed acid-reaction. The contents of clay particle-size (< 0.001 mm) were found to be less than 10% generally. The concentrations of elements in soil were dependent on soil types, parent materials and geographic conditions. The soil contents of Na and Mg were found to be higher than those of other regions, which may be related to high concentration of these elements in the local parent rocks. No anomalous value was found in the ranges of elements concentrations in the region.

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