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SHORT CONTRIBUTION

Chemistry of monsoon rain water at Delhi

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ABSTRACT

Rain water samples collected from various localities in Delhi throughout the monsoon of 1978 were analysed for Na, K, Ca, Mg, Cl, HCO_3, SO_4, PO_4 and SiO_2, pH and conductivity were also measured. The alkaline rain water of Delhi has total dissolved solids (TDS) ranging from 35–170 p.p.m., depending on space and time. The variation and relationship among the major constituents have been qualitatively evolved and controlling factors briefly discussed.

1. Introduction

In geochemical cycling of elements, the atmospheric precipitation plays an important role in the transport of a number of elements (Subramanian, 1979). Extensive analytical data compiled by Junge (1972) indicate that the chemical composition of rain water varies very widely as a function of space and time. Hence an overall understanding of the chemical nature of rainfall over the landmass is difficult. At present, chemical studies over areas such as South Asia (a region of intense monsoon activities) are rather limited. Except for Handa (1969), available data for India are generally partial. This note presents some observations on monsoon precipitation at Delhi.

2. Methodology

During the monsoon period of 1978 (July–August), rain water samples were collected from a number of localities within a 15 km radius of the coal-based thermal power plant in the city. Samples were collected in polyethylene containers during the rainfall. Standard analytical techniques for fresh water (Subramanian, 1979) were followed in the laboratory after membrane filtration. Sample containers were generally placed in the shower immediately after it began and were withdrawn when the rain became less intense. pH, alkalinity and conductivity were measured within half an hour of collection while other parameters were measured within 1–2 days. Galloway and Likens (1978) have critically evaluated the dependence of the chemistry of rain on sampling techniques and the data presented in this paper suffers from the limitations they have so outlined. Table 1 and Fig. 1 summarize the analytical data (TDS values are rounded off) obtained in this work for a few selected stations.

3. Results

3.1. *Total dissolved salts (TDS) and pH*

Values of 10–70 p.p.m. TDS for India (Handa, 1969), 23–84 p.p.m. of TDS for several European rain waters (Junge, 1972), values of about 60 p.p.m. TDS for rain over North America (Junge and Werby, 1958) and more than 300 p.p.m. TDS values during summer for rain at Kampala in Africa (Visser, 1961) have been reported so far. In general, early monsoon showers have higher TDS values compared to the later ones, this agrees with the observations of Handa (1969) for rain at Calcutta.

pH values indicate that Delhi rain water tends to be alkaline, whereas Handa (1969) reports slightly

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Table 1. *Chemical composition of rain over Delhi during monsoon, 1978*

Station No.	Date	Conductivity $\mu ohm^{-1}\,cm^{-1}$	pH	Ca^{++}	Mg^{++}	Na^{+}	K^{+}	Cl^{-}	HCO_3^{-}	SO_4^{--}	H_4SiO_4	PO_4^{---}	TDS
				p.p.m.									
1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	15 July	110.0	7.38	2.0	1.0	3.4	2.5	3.5	32.5	88.5	0.6	0.51	136
	16 Aug.	81.0	7.4	2.0	2.0	2.9	1.3	1.26	24.5	11.5	1.9	0.02	81
	28 Aug.	72.0	7.45	2.0	1.5	2.9	1.9	2.92	25.07	12.5	2.26	0.03	51
2	15 July	62.5	7.55	2.5	1.0	3.0	1.0	2.0	30.05	62.0	0.61	0.08	102
	16 Aug.	74.5	7.4	2.0	1.25	2.9	1.15	2.09	24.5	22.5	3.45	0.06	60
	28 Aug.	73.0	7.35	2.5	1.5	3.1	2.1	2.21	16.5	20.5	2.25	0.02	51
3	18 July	25.2	7.05	0.5	0.5	0.3	1.0	1.5	30.05	74.0	1.0	0.04	110
	16 Aug.	34.0	7.3	0.5	0.75	2.3	—	1.26	24.5	7.0	0.02	0.01	36
	28 Aug.	73.2	7.55	2.5	1.5	3.1	2.3	1.68	16.5	6.5	2.45	0.02	37
4	16 July	38.0	7.4	1.0	0.25	2.7	1.5	2.0	31.0	64.0	0.80	0.28	104
5	21 July	82.5	7.55	2.0	—	4.2	—	2.1	37.0	65.0	0.85	0.02	111
	28 Aug.	125.0	7.85	8.5	—	8.2	10.5	10.2	20.05	59.0	0.50	0.03	117
6	25 July	195.0	7.0	4.5	5.5	8.2	9.5	14.0	50.05	75.0	2.6	0.38	170
	28 Aug.	69.9	7.75	2.5	1.0	2.7	—	0.41	34.0	24.0	4.55	0.02	69
7	28 Aug.	75.0	7.65	2.0	3.0	3.1	1.15	4.21	25.0	48.0	1.45	0.02	88
8	16 Aug.	85.0	7.35	—	—	3.3	—	1.26	39.0	24.0	2.0	0.02	76
9	16 Aug.	190	7.55	—	—	2.1	0.3	11.62	36.5	4.5	4.6	0.04	60
10	9 Aug.	32.5	7.3	1.0	1.5	2.7	—	5.6	63.0	65.0	0.03	0.01	163
11	11 Aug.	72.5	7.2	3.0	1.5	3.4	1.6	3.0	44.5	85.0	3.5	0.09	146
12	17 July	59.5	7.6	4.5	2.0	10.4	6.0	12.5	32.5	60.0	1.0	—	129
	16 Aug.	290.0	8.4	13.0	1.5	6.9	4.25	9.5	32.5	74.0	1.3	0.05	143
13	18 July	29.0	7.2	0.5	0.25	3.0	1.9	17.0	24.0	24.0	0.1	0.45	72
14	28 Aug.	88.0	7.5	2.0	1.5	5.0	0.8	7.36	17 5	22.5	0.95	0.05	58
Weighted average rain water		54.37	7.4	2.11	1.25	2.76	0.74	5.47	50.51	58.34	0.71	0.05	129
World average rain water, Carroll (1972)		—	5.5	1.42	0.39	—	0.35	3.5	—	2.19	—	—	—

acidic waters for Calcutta and Dehra Dun monsoon rain. Padmanabhamurthy and Kachare (1975) report pH 5–10 for Poona (Western India) rain water and they suggested that pH is directly proportional to wind speed and phase of the rain. Visser (1961) suggested that in alkaline rain water, mechanisms in addition to those of the CO_2—H_2O system influence rain water pH.

3.2. *Major cations*

The total of cations is generally less than the total of anions in all the samples, though cations are generally more numerous than anions due to the presence of organic matter in the rain. Cation variations are erratic and, in general, various cation and cation–anion ratios differ from the expected values for inland rain water derived from the sea. Selenzneva (1972), Seqoeva and Kelkar (1978) and Handa (1969) have shown that both cations and anions increase inland due to the addition of salts from natural or anthropogenic sources. Khemani and Ramanamurthy (1968) observed values of less than 1 p.p.m. of Ca, Na and K for monsoon rain at Delhi, while Seqoeva and Kelkar (1978) observed excess Ca (in excess of that expected for a rain water) throughout India even in unpolluted stations.

3.3. *Major anions*

Variation among Cl, SO_4 and HCO_3 is responsible mainly for the erratic relationship between the TDS and conductivity values given in Table 1. The present high values, compared to earlier reports on low SO_4 in rain water in India (Seqoeva and Kelkar, 1978), cannot at present be satisfactorily explained. A high value of 42 p.p.m. SO_4 and 9 p.p.m. Cl for Europe (Junge, 1972), and 36 p.p.m. of SO_4 and 7 p.p.m. Cl for Africa (Visser,

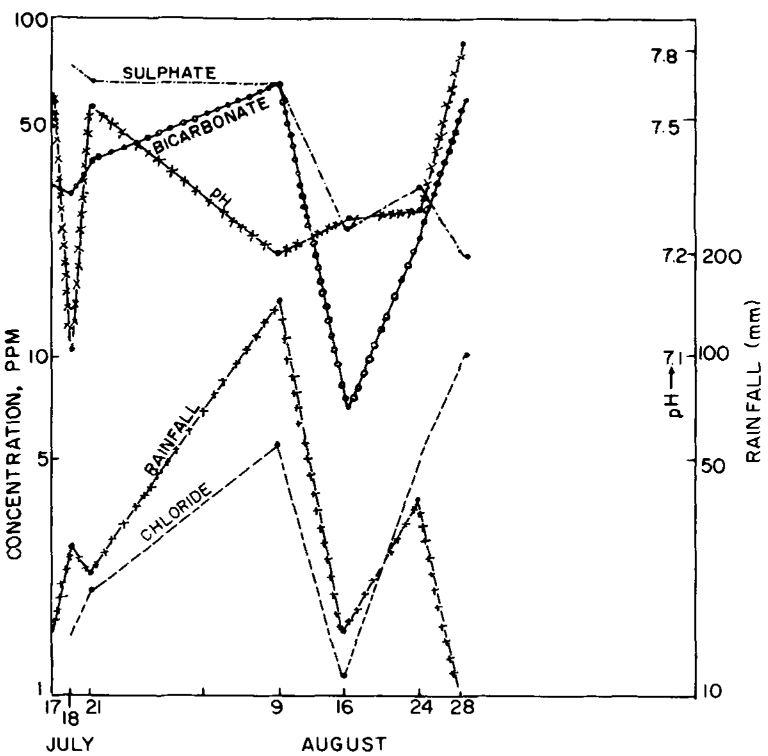

Fig. 1. Variation in pH, SO_4, HCO_3, Cl and rainfall intensity during the monsoon period of Delhi, 1978. Values correspond to station no. 5. Note the different vertical scale for anions, pH and rainfall intensity. Mg and K were not analysed for this station due to loss of sample. Rainfall scale is mm of rainfall per day.

1961) suggest that anion values vary widely over the continents. The first three stations for which sampling was done throughout the monsoon indicate that all the three major anions decrease with time, and that the excess anions accumulated in the atmosphere from local sources before the monsoon (natural or anthropogenic) are washed out by the initial rain.

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REFERENCES

Carroll, D. 1972. Rain water. In *Encyclopaedia of environmental geochemistry and environmental science* (ed. Fairbridge). Van Nostrand Ltd.

Galloway, J. N. and Likens, J. E. 1978. The collection of precipitation for chemical analysis. *Tellus 30*, 71–82.

Handa, B. K. 1969. Chemical composition of rain water in some parts of North India. *Indian J. Met. Geophys. 20*, 144–148.

Junge, C. E. 1972. Atmospheric chemistry. *Adv. Geophys. 4*, 1–106.

Junge, C. E. and Werby, R. T. 1958. The concentration of chloride, sodium, potassium, calcium and sulphate in rain water over United States. *J. Met. 15*, 417–425.

Khemani, C. K. and Ramanamurthy, B. M. V. 1968. Chemical composition of rain water and rain characteristics of Delhi I. *Tellus 20*, 284–291.

Padmanabhamurthy, B. and Kachare, S. D. 1975. Chemical characteristics of precipitation at two regional background stations in India. *Pre-Pub. Sc. Report No. 226*, I.M.D., Poona, India. 12 pages.

Selezneva, E. S. 1972. Estimation of background contamination of the atmosphere from the chemical composition of precipitation. *Tellus 24*, 122–126.

Seqoeva, R. and Kelkar, D. 1978. *J. appl. Met. 17*, 7–18.

Subramanian, V. 1979. Chemical and suspended sediment characteristics of rivers of India. *J. Hydrol. 44*, 37–55.

Visser, S. 1961. Chemical composition of rain water in Kampala, Uganda and its relation to meteorological and topographical conditions. *J. geophys. Res. 66*, 3759–3766.