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Studies on chemical constituents of precipitation over India

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सार – वर्ष 1979 में भारत में उद्योगों एवं शहरों से प्रभावित न होने वाले वायुदूषण मॉनीटरिंग संजाल के स्टेशनों को वर्षण के रासायनिक अवयवों के लिए विश्लेषित किया गया है । दी हुई तालिका में क्लोराइड, सल्फेट, नाइट्रेट, सोडियम, पोटेशियम एवं कैलसियम के सान्द्रण को दर्शाते हैं । चूंकि मानसून अवधि (जून से सितम्बर) के पर्याप्त आंकड़े उपलब्ध हैं, इसी अवधि के उपरोक्त अवयवों का कुल सांद्रण निकाला गया है । मानसून अवधि का क्लोराइड और सोडियम के सांद्रणों के अनुपात के माध्यमान को भी निकाला गया है । विश्लेषण के परिणामों की चर्चा की गई है ।

ABSTRACT. The rainwater samples collected at Background Air Pollution Monitoring Network stations in India during the year 1979 are analysed for the chemical constituents of precipitation. Tables given, show the concentration of Chloride, Sulphate, Nitrate, Sodium, Potassium and Calcium. As sufficient data for monsoon period (June to September) are available total concentration of above constituents for the above period have been worked out. The mean value of ratio Chloride to Sodium concentrations for monsoon period have also been worked out. The results of analyses are discussed.

1. Introduction

The investigations of chemical composition of precipitation began a long-time ago. However, only since last two--three decades they have been widely used in connection with various scientific and applied problems. Recently the investigation of precipitation composition has attracted attention because of problem of growing air pollution.

The World Meteorological Organization has established a global network of Background Air Pollution Monitoring (BAPMoN) stations. Under this, a network of ten Background Air Pollution Monitoring stations has been established in India. It is the aim of the network to know the current level of pollution to identify the long term trends in the concentration of significant constituents which may affect the environment. However, in this paper an attempt has been made to study the chemical constituents of rainfall over India during the year 1979.

The precipitation samples were manually collected with precipitation collector (WMO 1978) on each rainy day. Some portion of collected precipitation was used to measure pH and conductivity of the samples. The samples were stored in a polyethylene bottle which kept in dark and cool place. One litre of well-mixed portion of precipitation is sent to the Central Chemical Laboratory, Pune for every month, where the samples were analysed for chemical constituents such as Sulphate, Nitrate, Chloride, Sodium, Potassium, Calcium etc. Since sufficient data for southwest monsoon period (June to September) are available, the total concentration of the constituents for the above period are discussed in details during the study.

2. Analytical methods

Electrical conductivity and pH were measured immediately after the samples were collected at BAPMoN stations. Measurement of pH was done with pH meter using two electrode system. Standardization were made with buffer solutions of pH 4, 7 and 9.2 standards. Conductivity was measured according to standard methods using a conductivity bridge standardized with 0.01 N KCl solution. Sulphate, Chlorides and Nitrate were measured by Barium Iodate, Turbidimetric and Brucine Sulphate methods respectively. Sodium, Potassium and Calcium were analysed by Atomic Absorption Spectrophotometry using an air-acetylene flame and instrument settings recommended by the instrument manufacturer. Automiser times and voltage setting for each metal followed recommendation of the manual.

3. Discussions

It can be seen from Table 1 that Chloride is one of the predominant anions of rainwater

TABLE 1

The chemical concentrations in precipitation values in mg/litre

Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Jun-Sep	Oct	Nov	Dec
						Chloride							
Pune			1.20		1.00	1.70	2.70	1.50	0.20	6.10	1.00	0.40	
Nagpur	0.70	0.50			0.90	0.60	0.50	0.30	0.10	1.50			1.10
Jodhpur		1.20			4.60	1.60	1.90	4.30	4.10	11.90	5.90		
Allahabad	0.50					0.90	0.50	0.30	0.50	2.20		0.30	
Mohanbari		4.30			0.30	0.30	0.50		0.90	1.70	1.10	1.70	1.10
Visakhapatnam				4.00	5.60	2.50	2.90	1.70	2.20	9.30		1.30	1.50
Kodaikanal		0.30	0.70	0.30	0.30	0.30	0.30	0.50	0.10	1.20	0.30	0.10	0.20
Srinagar		0.60	0.40	0.60	0 20	0.60	0.80	1.90	0.90	4.20		1.40	1.30
Minicoy			2.10	0.70	1.80	2.60	2.30	4.80	1.90	11.60	2.50	1.40	3.70
Port Blair				1.40	4.50	2.30	3.90	8.90	2.30	17.40	1.60		
						Sulphate							
Pune			0.10		0.00	0.30	0.01	0.05	0.41	0.77	1.05	0.28	
Nagpur	0.90	0.20			0.70	0.30	0.30	0.50	0.40	1.50			0.10
Jodhpur		0.80			3.90	1.50	0.10	0.10	0.10	1.80	1.70		
Allahabad	0.07					0.30	0.10	0.03	0.15	0.58		0.30	
Mohanbari		4.00	2.90		0.20	0.10	0.30		0.10	0.50	0.10	5.50	0.30
Visakhapatnam				20.0	0.30	0.60	1.60	0.10	0.10	2.40		0.50	0.10
Kodaikanal		0.20		0 10	0.10	0.20	0.30	0.10	0.10	0.70	0.20	0.10	0.50
Srinagar		0.20	0.30	0.20	0.07	0.57	1.10	0.10	0.01	1.78		0.06	0.02
Minicoy	0.80		0.20	0.15	0.13	0.03	0.30	0.50	0.10	0.93	0.20	0.20	0.10
Port Blair				0.40	0.30	0.30	0.10	0.30	0.30	1.00	0.40		
						Nitrate							
Pune					4.30	0.30	1.40	0.90	0.60	3.20	2.14	1.60	
Nagpur	0.45	0.51			0.10	0.85		0.30	0.70	1.85			
Jodhpur		0.50				0.60	0.10	0.03	0.30	1.03			
Allahabad	4.20					3.90	1.50	2.80		8.20		0.90	
Mohanbari		0.30	1.20			2.50	0.10		1.30	3.90	3.30	4.60	5.60
Visakhapatnam				10.20	2.10	5.30	6.10	2.80	1.40	15.60		0.60	2.20
Kodaikanal		1.40	1.40	2.20	1.90	0.90	0.30	1.90	0.60	3.70	0.20	0.10	0.20
Srinagar	0.60	0.30	0.40	2.60	0.50	1.70	3.30	3.50	4.30	12.80		2.30	4.40
Minicoy	0.20			0.60	0.40	0.40		0.50	0.30	1.20	0.20		1.50
Port Blair				0.80	0.80	0.20		0.10	0.10	0.40	0.10		
						Sodium							
Pune					1.10	1.80	1.98	1.84	0.3	5.97		0.36	
Nagpur	0.90	0.71					0.50	0.56	0.25	1.31			3.43
Jodhpur		1.63			8.88	4.24	2.27	0.65	0.67	7.83			
Allahabad	1.32					2.80	1.31	0.60		4.71		0.88	
Mohanbari				1.15	0.80	0.55	0.39		0.30	1.24	1.26	1.50	0.53
Visakhapatnam				9.36	5.71	1.87	4.80	1.95	2.74	11.36		1.65	1.59
Kodaikanal		0.72		0.72	0.34	0.47	0.34	0.46	0.20	1.47	0.19	0.14	

TABLE 1 (*contd*)

Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Jun-Sep	Oct	Nov	Dec
						Sodium							
Srinagar	10.50	0.92	0.40	0.52	0.26	1.00	1.38	1.59	1.07	5.04		0.98	0.66
Minicoy			3.02	0.81	2.84	2.53	3.75	5.68	2.27	14.23	3.12	1.38	3.82
Port Blair				1.75	4.40	3.18	3.42	7.70	1.65	15.95	1.17	5.92	
						Potassium							
Pune					0.47	0.38	0.30	0.25	0.16	1.09		0.24	
Nagpur	0.83	0.54					0.65	0.12	0.12	0.89			0.82
Jodhpur		1.94			1.55		0.56	7.80	8.50	16.86			
Allahabad	0.72					0.70	0.53	0.22		1.45		0.36	
Mohanbari				6.30	0.86	0.45	1.15		2.17	3.77	0.90	7.23	1.90
Visakhapatnam				4.40	0.87	0.84	1.49	0.47	0.80	3.60		0.64	0.78
Kodaikanal		0.15		0.71	0.48	0.58	0.17	0.29	0.26	1.30	0.26	0.22	
Srinagar	7.00	1.03	0.33	0.93	0.22	0.66	0.90	0.68	0.23	2.47		0.72	2.24
Minicoy			1.28	0.70	0.56	0.24	0.43	0.75	0.42	1.84	0.31	0.21	0.84
Port Blair				1.67	2.53	0.38	0.31	0.48	0.38	1.55	0.10	0.69	
						Calcium							
Pune					2.65	2.26	2.12	1.56	0.30	6.24		0.96	
Nagpur	0.42	0.74					1.50	0.26	0.23	1.99			0.28
Jodhpur		5.15			5.98	5.40	5.10	1.72	3.15	15.37			
Allahabad	2.64					1.68	2.62	1.54		5.84		4.11	
Mohanbari				2.40	1.25	0.37	0.12		0.30	0.79	0.86	0.53	0.97
Visakhapatnam				12.56	1.80	1.48	4.02	1.26	1.44	8.20		0.44	0.74
Kodaikanal		1.76		1.22	0.63	0.76	0.38	0.67	0.65	2.46	0.10	0.11	
Srinagar	13.68	4.11	1.93	2 75	1.97	4.70	5.20	7.60	4.69	22.19		4.66	2.86
Minicoy			2.42	1.06	1.84	0.67	1.07	2.72	1.05	5.51	1.04	0.33	1.02
Port Blair				2.03	2.04	1.39	1.06	1.67	0.23	4.35	0.21	0.73	

TABLE 2

Ratio of Chloride to Sodium concentration (Cl/Na)

Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Mean Jun-Sep	Oct	Nov	Dec
Pune					0.90	0.94	1.35	0.81	0.59	0.92		1.10	
Nagpur	0.78	0.70					1.00	0.53	0.40	0.64			0.32
Jodhpur		0.74			0.52	0.38	0.84	6.61	6.12	3.49			
Allahabad	0.38					0.32	0.38	0.50		0.40		0.34	
Mohanbari					0.37	0.54	1.28		3.00	1.61	0.87	1.13	2.07
Visakhapatnam				0.43	0.98	1.33	0.60	0.87	0.80	0.90		0.79	0.94
Kodaikanal		0.42		0.42	0.88	0.64	0.88	1.09	0.50	0.78	1.58	0.71	
Srinagar		0.65	1.00	1.15	0.77	0.60	0.58	1.19	0.84	0.80		1.43	1.97
Minicoy			0.69	0.86	0.63	1.03	0.61	0.85	0.84	0.83	0.80	1.01	0.97
Port Blair				0.80	1.02	0.72	1.14	1.15	1.39	1.10	1.37		

TABLE 3

Hydrogen ion concentration (in terms of 1×10^{-7} con/l) at different stations during 1979

Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Jun-Sep (Mean)	Oct	Nov	Dec
Pune	—	—	3.16	—	0.50	0.25	0.32	0.79	3.16	1.13	1.26	1.59	—
Nagpur	—	3.16	—	—	1.59	0.50	—	—	—	0.50	—	3.98	—
Jodhpur	—	0.20	—	—	—	0.79	0.50	0.79	—	0.70	0.63	—	—
Allahabad	0.16	0.40	—	0.16	—	0.16	0.25	0.79	0.63	0.46	—	0.13	—
Mohanbari	—	—	—	—	—	—	—	—	—	—	—	—	—
Visakhapatnam	—	—	—	1.26	1.99	0.06	0.25	—	3.16	1.16	0.63	0.79	6.31
Kodaikanal	—	—	—	—	—	—	—	—	—	—	—	—	7.94
Srinagar	0.63	0.79	0.50	—	—	—	—	0.32	0.50	0.41	—	0.50	0.10
Minicoy	1.26	0.32	1.26	1.26	3.16	3.16	1.99	1.26	0.79	1.76	1.59	5.01	
Port Blair	—	—	—	—	—	—	—	—	—	—	—	—	—

samples collected at BAPMoN stations. Port Blair and Minicoy are island stations and are expected to be affected by sea-spray. Visakhapatnam is a coastal station and is also surrounded by small industries. So the composition of rainwater samples are expected to be influenced by sea-spray as well as pollution from local sources.

The total concentration of Cl^- at Port Blair, Minicoy and Visakhapatnam during monsoon were 17.4, 11.6 and 9.30 mg/l respectively. These concentrations are quite high when compared with concentrations at inland stations. Thus it could be inferred that the Bay of Bengal and the Arabian Sea are the major sources of Chloride of rainfall over India (Junge 1963).

The concentration levels of Cl^- at inland stations during monsoon period indicate that an advection of maritime air is responsible for presence of Cl^- in the samples of inland stations. The monsoon wind pattern is responsible for transporting the Cl^- from the sea to the inland stations of the country.

The concentration values of Cl^- during winter, pre-monsoon and post-monsoon periods at inland stations showed that it is also generated by anthropogenic processes.

It is interesting to see that although Jodhpur is far away from the coast, the Cl^- concentration at this place was 11.9 mg/l which is quite high as in the case of island stations and the Cl/Na ratio 3.41 (Table 2) is also higher than the ratio of seawater (1.8). This showed that the sufficient enrichment of Cl^- in the rainwater has been occurred from the salt particles available in the area surrounding the station. The salt particles are being transported and scattered over the station and neighbourhood, which are getting dissolved in the scanty rain of this region (Holland and Christie 1909) giving rise to a high concentration of Cl^- in rainwater.

There are interesting similarities between the distributions of Sulphate and Nitrate in rainwater, as well as differences. In general, the concentrations of Sulphate and Nitrate are lower than the concentrations of Chloride at all BAPMoN stations. The lowest value of total concentrations of Sulphate during monsoon period is 0.50 mg/l at Mohanbari and its highest value is 2.40 mg/l at Visakhapatnam indicating slight variation of Sulphate in precipitation. However, slightly more variation in Nitrate concentrations of precipitation have been observed during the monsoon period. It is not possible at present to identify the reasons of such variation. It is perhaps worth noting that both Sulphate and Nitrate concentrations are higher at Visakhapatnam than the concentrations at all other BAPMoN stations, indicating that the local sources of pollution are responsible for high concentration at Visakhapatnam.

Like Chloride, the Arabian Sea and the Bay of Bengal are the main sources for Sodium in the precipitation. It can be seen from Table 1 that total concentration of Sodium is higher at island and coastal stations than its concentrations at inland stations. It is also interesting to see that like Chloride the total concentrations of Sodium at Jodhpur is higher than its concentrations at other inland stations. This may also reflect the fact Sodium is also derived from the salt particles (NaCl) available in that region. The ratio Cl/Na (Table 2) of precipitation at BAPMoN station except at Jodhpur is lower than the ratio (1.8) in sea water (Oddie 1959).

The total concentrations of Potassium during monsoon period were between 0.89 & 3.77 mg/l at all BAPMoN stations execept at Jodhpur where is was 16.86 mg/l. It could be due to Kyanite mineral particles available in this region. The total concentrations of Calcium at BAPMoN stations varied from 0.79 to 8.20 mg/l. However, its concentrations at Srinagar and Jodhpur were 22.19 and 15.37 mg/l respectively. The high concentrations at above stations may be due to the Ilmenite and Gypsum mineral partcles available in this region.

It can be seen from Table 3 that the Hydrogen ion concentration was very low. The concentration range was between 0.4×10^{-7} and 1.8×10^{-7} g ion/l during the monsoon period.

4. Conclusions

From the analyses of rainwater samples it can be concluded that Chloride, Sodium, Sulphate, Nitrate, Calcium and Potassium are the major constituents of rainfall over India. Hydrogen ion concentrations in rainwater samples were very low at all BAPMoN stations.

The Bay of Bengal and the Arabian Sea are the major sources of Chloride and Sodium in rainwater samples.

The concentration values of the chemical constituents in rainwater during winter, pre-monsoon and post-monsoon indicate that the anthropogenic processes are also responsible to generate these constituents.

High concentration values of Chloride and Sodium at Jodhpur revealed that large number of salt particles are available in the neighbourhood of Jodhpur.

The highest values of Sulphate and Nitrate concentrations at Visakhapatnam indicate that the local sources are responsible for affecting the pollution level at Visakhapatnam.

The high concentration of Potassium and Calcium in precipitation at Jodhpur and Srinagar could be due to small particles of minerals such as Kyanite, Ilmenite and Gypsum which are available in the region.

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