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URBAN AND RURAL BULK PRECIPITATION CHEMISTRY IN BANGALORE REGION

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ABSTRACT

Bulk precipitation is a combination of wet precipitation and dry fallout, which was compared at an urban Bangalore site and nearby rural areas in order to examine the influence of emissions within a large urban area on local precipitation chemistry. During the study period, samples were collected from June to September 2005 on weekly basis and analysed for pH, conductivity, major cat ions (Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}, NH_4^{+}) and anions (Cl^{-}, SO_4^{2-}, HCO_3^{-}, NO_3^{-}, NO_2^{-}, PO_4^{3-}). Rural precipitation chemistry of Bangalore region in which the suburban site was upwind of the urban site and most urban emissions may be affected. Precipitation quality is a function of its contents of both acids and bases (alkaline), and any attempt to understand the processes causing acid precipitation must deal with the potential acid neutralizing capacity of alkaline materials. The objective of the present study is to establish the chemical composition of bulk precipitation samples collected from rural precipitation of Bangalore region and to assess variability in concentration between the areas. Attempt has been made to identify the predominant ions, which decide the quality of rain. It revealed that acidic pH of bulk precipitation samples were caused by H_2SO_4.

INTRODUCTION

Precipitation is an efficient pathway for removing the gases and particles from atmosphere. It also plays a significant role in controlling the concentration of these species. The precipitation provides important information from which the deposition of water soluble gases and aerosols bound constituents can be estimated. Precipitation, however, has unique scavenging properties, which makes it a useful indicator of ambient pollution levels.

Urban/suburban environment attracts more people from rural areas, and it is these urban areas which have traditionally been subjected to high concentration of air pollutants. The effects of acid deposition and its precursors can often be seen in the urban environment. Recently, acid rain problem has become common in urban areas because of significant increase in the atmospheric emissions from industries and automobiles. Rural and urban precipitation studies should be conducted using number of sampling stations. Acid precipitation is generally defined as precipitation with pH less than 5.60 (Likens 1976). In other words acid rain means the presence of excessive acids in rainwater.

Oxides of nitrogen constitute an additional major source of rainfall acidity from combustion processes. Nitric oxide is formed at high temperature by reaction of N_2 and O_2 to produce NO, which can then be oxidized to from NO_2 in either the combustion zone or in the atmosphere. The NO_2 can be hydrolysed in presence of water to form respective ammonium or calcium nitrite or nitrate salts. Other constituents present in the fuels can also affect the acidity levels of rainfall once the materials are emitted to the atmosphere. Trace metals present in coals such as Fe, Cu, Mg, and others can act as catalyst to promote the oxidation of sulphite to sulphate ions in solution, or of nitrite to nitrate ions.

Other constituents present, particularly in the fly ash released from combustion, are Ca, Al or Si etc. which are associated with carbonate, silicate or oxide, and can contribute to the alkalinity of rainfall. The NH_3 present in the atmosphere from natural sources or from oil combustion can also act as a weak alkaline constituent.

World Metrological Organization (WMO) established 10 BAPMON (Background Air Pollution Monitoring Network) stations to monitor background trends of pH. The BAPMON stations and data are presented in Fig. 1 (Varma 1989). The author concluded that the probable region for higher pH in precipitation in north-west India may be due to incursion of sand/dust particles into these areas from the adjoining Thar desert of Rajasthan. The Bangalore region precipitation had an average of 6.61 for the years 1974-1984. The study concluded that the overall probability of occurrence of acid rain was 2% in Indian BAPMON. Shivashankara undertook the monitoring of bulk precipitation in Bangalore in the year 1996-1998.

The analysis of precipitation chemistry consists of ten monitoring sites and shows that Bangalore precipitation changes from alkaline to acidic nature. The purpose of chemical analysis of precipitation at an urban site is to determine the quality of precipitation in the region and the temporal trends caused by rapid urbanization and industrialization. The main objective of the present study is to characterize the pH of Bangalore city, Devanahalli, Kanakapura and Ramanagaram towns of Bangalore district and chemical composition of precipitation in Bangalore.

SAMPLING LOCATIONS AND METHODOLOGY

The samples of bulk precipitation were collected during monsoon season of 2005 at five stations in Bangalore district, namely Bangalore South (Jayanagar), Bangalore North (Hebbal), Devanahalli, Kanakapura and Ramanagaram. Description of sites is as follows.

Bangalore-Urban: The metropolitan city of Bangalore is a continental, highly polluted site. The precipitation study at Bangalore will be useful for understanding the contribution due to anthropogenic pollution as well as dust particle interface (which may be partly natural and partly of anthropogenic origin). The Bulk collectors were placed at two stations in Bangalore-Urban.

Bangalore South (Jayanagar-residential area): It is situated at latitude 12°55’ N and longitude 77°34’E, and is major residential area of Bangalore.

Bangalore North (Hebbal industrial area-mixed area): It is situated at latitude 13°3’ N and longitude 77°35’E, and is a major industrial belt of Bangalore, which is connected to national highways.

Bangalore-Rural: The bulk collectors are placed at three stations in Bangalore-rural areas. They are:

1. Ramanagaram: (12°43.5′ N and 77°17.5′ E, at 704.435 M.S.L.) Hilly area with agricultural background, dry land. Located at Ramanagaram, which is an internationally famous township for silk and silk products, 45 km from Bangalore on the Bangalore-Mysore highway. The Township spreads on both banks of the River Arkavathi.

2. Kanakapura: (13°33′ and N 77°25′ E) Kanakapura, a taluk headquarter town of Karnataka, is situated at a distance of 50 km from Bangalore. The town is surrounded by agricultural belt.

3. Devanahalli: (12°8′ N and 77°37′ E) Devanahalli, a taluk headquarter, is situated at a distance of 55 km from Bangalore. The town is surrounded by agricultural belt. This town is downstream of Hebbal industrial area Bangalore.

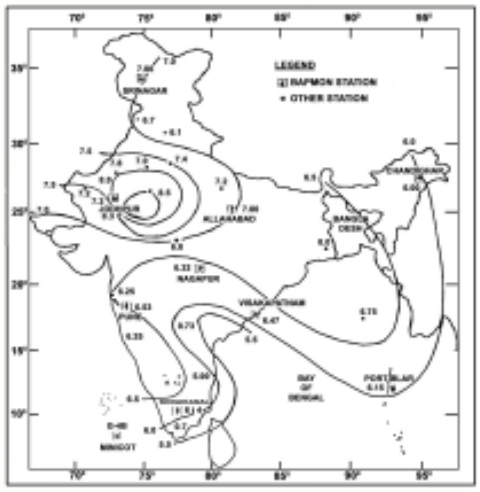

Fig. 1: Rainfall weighted mean pH at BAPMON stations and other stations in India and Iso-pH curve. (Varma 1989).

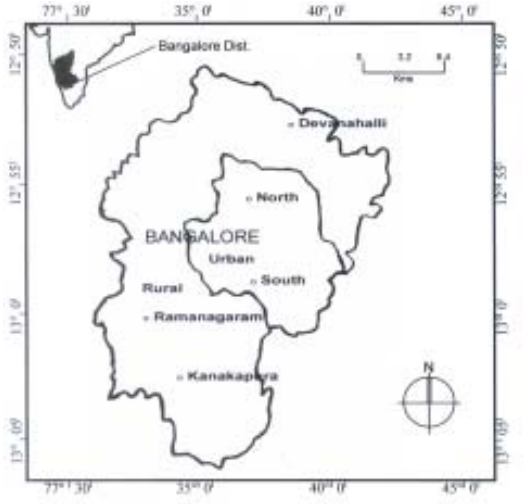

Fig.2: Map showing the sampling stations at Bangalore district (Rural and urban).

Sample collection and analysis

During the study period, 80 bulk precipitation samples were collected from the five sampling stations in the urban and rural areas of Bangalore district using bulk precipitation collectors. The bulk precipitation (wet + dry) collectors in the study were designed by Likens (1976) and cited by Ramalingaiah (1985) and Shivashankara et al. (1998, 1999). The collector consists of a polyethylene funnel (18cm diameter) connected to a five litres polyethylene reservoir. The reservoir was attached to a vapour trap, and a vapour barrier using tygon tubing which was provided with a loop to prevent the gas exchange between the atmosphere and the sample, and evaporation from the reservoir. A filter was used in the funnel to avoid contamination by insects and litter. The samples, collected from the various stations, were analysed for pH, cations (Ca^{2+}, Mg^{2+}, Na^{+}, K^{+} and NH_4^{+}) and anions (Cl^{-}, SO_4^{2-}, HCO_3^{-}, NO_2^{-}, NO_3^{-} and PO_4^{3-}) as per the standard methods (APHA 1995).

RESULTS AND DISCUSSION

pH of the precipitation and their variations: Table 2 shows the pH of bulk precipitation at different locations in Bangalore district. Review of data in Table l shows that for entire Bangalore city pH was 5.40, which is lower than 5.60. The pH data indicate that during 2005 monsoon period, mean was in acidic range. The pH of 5.40 when compared with the reported value of pH 6.61 for the city during the period between 1974 and 1984 by Varma (1989), clearly established that the city's precipitation pH has decreasing trend. The probable reasons for decreasing trend of pH in the Bangalore city from alkaline to acidic rain during the last two and half decades can be attributed to rapid industrialization, urbanization and also the increasing number of automobiles. The pH of Devanahalli was 6.5, Kanakapura 6.6, and Ramanagaram 6.5, which were alkaline in nature but not in the category of acid rain.

The chemical composition of bulk precipitation data is presented in Table 2 for the 2005 monsoon season. It indicates that SO_4^{2-} was the most abundant anion in bulk precipitation, which accounted

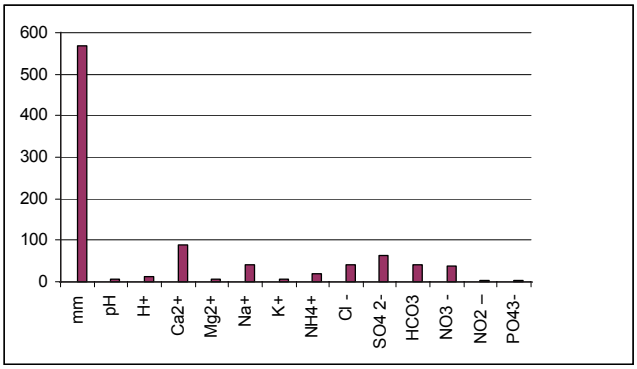

Fig. 3: Graphical presentation of volume weighted mean (VWM) of pH and major ions (μeq.$L^{-1)}$ of bulk precipitation at Bangalore city (2005).

for 33% (64.2 μeq.L^{-1}) of total anions, followed by HCO_3^- (21%); Cl^- (22%), NO_3^- (20%), PO_4^{3-} (2%) and NO_2^- (2%). Calcium (Ca^{2+}) was the most dominant in the city's bulk precipitation, since it accounted for 25% of total ions followed by SO_4^{2-} (18%), HCO_3^- (11%), Cl^- (12%), Na^+ (12%), NO3– (11%), NH_4^+ (5%) Mg^{2+} (3%), K (2%), PO_4^{3-} (1%) and NO_2^- (1%).

Statistical Analysis

Statistical analysis data presented in Table 3, clearly established that a significant positive correlation between H^+ and SO_4^{2-} (r = 0.43 at 1% level) and H^+ and NO_3^- (r = 0.18 at 5% level) indicate a decreasing trend of pH from 6.61 (1974-1984) to 5.20 (2005) due to SO_4^{2-} and NO_3^- in bulk precipitation samples. During the last two and half decades the pH of precipitation decreased by 1.21 pH (6.61-5.40). Positive correlation between NH_4^+ and SO_4^{2-} (r = 0.22 at 5% level) and Ca^{2-} and SO_4^{2-} (r = 0.41, 1% level) indicate that NH_4^+ and Ca^{2+} were acting as neutralizing ions. In other words, in the absence of these ions, pH reduction of the city's bulk precipitation may be much faster. The possible sources of NH_4^+ in bulk precipitation may be from animal sources, sewage plants and open drains in the urban and rural areas. The decrease of pH appears to be slow since significant ammonia was also present in bulk precipitation of the Bangalore region.

CONCLUSION

The total ionic composition of bulk precipitation established that Ca^{2+} and SO_4^{2-} were predominant ions. pH in bulk precipitation of the city show a decreasing trend from an alkaline precipitation to acidic precipitation. The pH value decreased from an average of 6.61 to 5.40 during last two and half decades. The study established through statistical analysis that positive correlation exists between H^+ and SO_4^{2-} and H^+ and NO_3^- in the bulk precipitation samples of the city. The decrease of pH in the precipitation of the city could be because of SO_4^{2-} and NO_3^- ions. NH_4^+ and Ca^{2+} were acting as neutralizing ions or in the absence of these ions the pH reduction of bulk precipitation may be much faster. The decreasing trend of pH in the precipitation in the city may be attributed to local emissions of SO_2 and NOx from urban activities. The pH of the Devanahalli, Kanakapura and Ramanagaram were in alkaline range, as these regions are influenced by neutralizing ions such as Ca^{2+} and NH_4^+.

Table 1: Volume weighted mean (VWM) of pH and major ions (μeqL^{-1}) of bulk precipitation in Bangalore city.

Station Bangalore	mm	pH	H^+	Ca^{2+}	Mg^{2+}	Na^+	K^+	NH_4^+	Cl^-	SO_4^{2-}	HCO_3	NO_3^-	NO_2^-	PO_4^{3-}
South	585	5.88	1.31	86.9	6.8	42.1	8.5	12.6	47.5	40.2	39.9	38.8	3.0	4.10
North	548	4.57	25.9	88.0	8.4	42.9	6.4	23.0	36.7	88.1	41.9	38.6	4.2	4.14
Complete data	567	5.40	13.16	88.5	7.6	42.5	7.5	17.8	42.1	64.2	40.9	38.7	3.6	4.10

Table 2: pH of Bulk precipitation at different locations.

Location	Period	pH
Bangalore (Present Study)	1974 - 1984*, 1996 - 1998 (Annual VWM for ten sampling stations)**	6.61 - 5.20
1. Bangalore	2005 (VWM for Two sampling stations)	5.40
2. Devanahalli	2005	6.50
3. Ramanagaram	2005	6.40
4. Kanakapura	2005	6.60

(Varma 1989)*, Shivashankara et al. (1999)**

Table 3: Correlation matrix between ions in bulk precipitation.

	mm	H^+	Ca^{2+}	Mg^{2+}	Na^+	K^+	NH_4^+	Cl^-	SO_4^{2-}	NO_3^-
mm	1									
H^+	-0.08	1								
Ca^{2+}	-0.65*	-0.12	1							
Mg^{2+}	-0.32**	-0.07	0.33**	1						
Na^+	0.55**	-0.08	0.43**	0.10	1					
K^+	-0.08	-0.17	0.11	0.17	0.21	1				
NH_4^+	-0.17	0.03	0.22*	0.23	-0.10	-0.03	1			
Cl^-	-0.42*	0.21	0.49**	0.19	0.01	-0.06	0.32**	1		
SO_4^{2-}	0.51**	0.43**	0.41**	0.21	0.22*	-0.05	0.22	0.29**	1	
NO_3^-	-0.15	0.18*	0.21*	-0.09	0.04	0.10	0.18	0.33**	0.21*	1

(*5%, **1% level).

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