

## Trends of pH and aerosols in the precipitation at Srinagar, Mohanbari, Allahabad, Jodhpur, Nagpur and Minicoy during the period 1981-2001

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**सार** – वर्षा का स्वरूप क्षारीय है अथवा अम्लीय, यह जल में विलयशील प्रमुख अकार्बनिक गैसीय और उसी में घुलनशील मृदा से व्युत्पन्न कणों की सांद्रता पर निर्भर करता है। यदि धनायनों की सांद्रता ऋणायनों की अपेक्षा अधिक होती है तो वर्षा क्षारीय होती है और इसके विपरीत स्थिति में वर्षा अम्लीय होती है। पी. एच. एक प्रमुख प्राचल है जो वर्षा के स्वरूप को दर्शाता है।

0 से 14 के मध्य पी. एच. के पैमाने दोनों में यदि वर्षा जल का पी. एच. 5.65 से कम होता है तो यह अम्लीय है और 5.65 से अधिक है तो क्षारीय है। इस शोध पत्र में औसत आयनिक सांद्रता (मि.ग्रा./ली.) और उनकी प्रवृत्तियों का विश्लेषण किया गया है। 1981–2001 के दौरान श्रीनगर, मोहनबाड़ी, जोधपुर, इलाहाबाद, नागपुर और मिनिकाय को वर्षा के रासायनिक वर्षण का अध्ययन करने के लिए चुना गया है। 1981–87, 1988–94, और 1995–2001 के अंतरालों पर विभिन्न वायुविलयों की प्रवृत्तियों का विश्लेषण किया गया है। इन प्रवृत्तियों से पता चला है कि वर्षा में ऋणायनों की प्रतिशतता बढ़ी है जिससे अम्लीय गुण में वृद्धि हुई है। वर्ष 1995–2001 के अंतराल में नागपुर और मोहनबाड़ी के पी. एच. मान क्रमशः 5.16 और 5.47 पाए गए हैं जो कि अम्लीय हैं।

**ABSTRACT.** Nature of Precipitation - alkaline or acidic depends upon the concentration of major water soluble inorganic gaseous and soil derived particulates dissolved in it. If the concentration of cations is higher than that of anions the precipitations becomes alkaline and *vice versa*. pH is the main parameter indicating the nature of precipitation.

If pH of rainwater <5.65 it is acidic and >5.65, it is alkaline, both in the pH scale ranging between 0 and 14. In this paper average ionic concentration (mg/lit) and their trends have been analyzed. Srinagar, Mohanbari, Jodhpur, Allahabad, Nagpur and Minicoy have been selected for the study of chemical precipitation during the period 1981-2001. Trends of different aerosols have been analyzed at the intervals 1981-87, 1988-94 and 1995-2001. It has been observed that percentage of anions has increased which results in the increase of acidic character of the precipitation. During the interval 1995-2001, Nagpur and Mohanbari had pH values 5.16 and 5.47 respectively which were in acidic range.

**Key words** – pH, Anions, Alkaline and Precipitation.

### 1. Introduction

Importance of chemical analysis of rain water has been realized during last few decades since pollution has increased due to increase in population and industries. Changed land use pattern and excessive fossil fuel burning due to tremendous increase in vehicles have caused enormous amounts of aerosols in the atmosphere. India Meteorological Department maintains a network of GAW (formerly known as BAPMoN) stations which has the longest sampling record of precipitation in India. Since the establishment of network of 10 stations as shown in Fig. 1, under BAPMoN – WMO project (now GAW), chemical analysis of well mixed monthly rainfall

samples is being carried out regularly at the air pollution Laboratory, O/o ADGM(R) Pune to determine concentrations (mg/lit) of major cations and anions along with pH and conductivity. Krishnanand, (1986) pointed out that due to high quantity of natural suspended particulate matter, which is mainly alkaline in nature the pH of rainwater remains in the alkaline range in India. Mukherjee, *et al* (1986) found out that pH of rainwater over Indian Oceanic areas is also in basic range. Varma, (1989) studied the precipitation chemistry and concluded that NE India and East coast are highly sensitive to acid rain. In recent studies Naik, *et al.*, (2002) concluded that acid rains at Kalyan were found due to influence of sulphur and NO<sub>3</sub> from fossil fuel burning, vehicular traffic

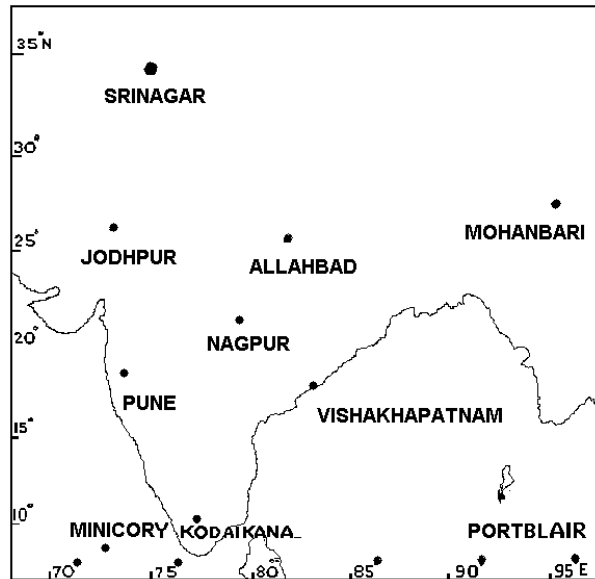


Fig. 1. Background air pollution monitoring network (BAPMoN) stations in India

and the other industries. Shende, *et al.* (2007) concluded that lowest pH values were at Mohanbari (3.77) and Nagpur (4.12) both in acidic range. Jodhpur recorded highest pH value in alkaline range indicating influence of soil derived alkaline particulates. Among cations,  $\text{Ca}^{2+}$  has shown its dominance. In the present study an attempt has been made to find out trends of pH and the concentrations of different aerosols during the periods 1981-87, 1988-94 & 1995-2001 covering the total period of 21 years in respect of Srinagar, Mohanbari, Jodhpur, Allahabad, Nagpur and Minicoy. Mukhopadhyay *et al.*, (1992) concluded that there is a major decreasing trend in pH of rainwater as one travels from west to east; Jodhpur recording the highest pH while Mohanbari the lowest.

## 2. Data and methodology

Collection, preservation and analysis of precipitation samples are described by Shende *et al.*, (2007). In this paper data collected from National Data Centre for the period 1981-2001 of Srinagar, Mohanbari, Jodhpur, Allahabad, Nagpur and Minicoy were analysed.

## 3. Results and discussions

### 3.1. pH measurements

pH of precipitation depends on various water soluble constituents. These constituents are of two types- soil derived and gaseous. Which can be of marine and anthropogenic origin such as soil dust picked up by winds, smoke from man-made fires, pollens from forests, gases or particulates from volcanoes, sea spray, combustion of fossil fuel and soil erosion etc.

### 3.2. Composition of major ions in rainwater

Rain water consists of cations and anions which decide its pH.  $\text{NO}_3^-$ ,  $\text{SO}_4^{2-}$  and  $\text{Cl}^-$  form anions and  $\text{Ca}^{2+}$ ,  $\text{Na}^+$ ,  $\text{Mg}^{2+}$ ,  $\text{K}^+$  &  $\text{NH}_4^+$  contribute to form cations. Water soluble soil derived and gaseous aerosols present in the atmosphere washed out by rain are responsible for the nature of rainfall- alkaline or acidic at each location.

### 3.3. Calculation of $\text{H}^+$

Concentrations of  $\text{H}^+$  in Moles/lit have been calculated from the pH of rain samples by using formula as given below.

$$\text{Since } \text{pH} = -\log [\text{H}^+]$$

$$\text{H}^+ \text{ (Moles/lit)} = 1/\text{antilog pH}$$

For example given pH = 6.36 (pH of Nagpur in Table 1)

$$\begin{aligned} \text{H}^+ &= 1/\text{antilog } 6.36 \\ &= 0.43 \times 10^{-6} \text{ Moles/lit.} \\ &= 0.43 \text{ E-06 Moles/lit.} \end{aligned}$$

### 3.4. Comparison of data

Average ionic concentration of major water soluble inorganic constituents of precipitation having pH in alkaline range  $>5.65$  and acidic range  $<5.65$  are given in Tables 1, 2 & 3 for the period 1981-87, 1988-94 and 1995-2001 respectively. pH values of all the stations as shown in tables are decreasing from Tables 1 to 2 except Jodhpur and from Tables 2 to 3 except Jodhpur and Allahabad. But anions' concentrations have increased in respect of all the stations from Tables 1 to 2 and from Tables 2 to 3 which show the acidic character of the precipitation. This can be further attributed to increase in  $\text{NO}_3^-$  and  $\text{SO}_4^{2-}$  caused by automobiles and thermal plants which release NO and  $\text{SO}_2$  respectively.

Trends in increasing percentage from 1981-1987 to 1995-2001 in respect of anions ( $\text{Cl}^-$ ,  $\text{SO}_4^{2-}$  &  $\text{NO}_3^-$ ) are as follows.

Stations	Srinagar	Mohanbari	Allahabad	Jodhpur	Nagpur	Minicoy
(%) Increase	60	60	77	89	71	67

Maximum percentage increase in the anions has been found at Jodhpur and Minimum at Srinagar and Mohanbari. On comparison among Tables 1, 2 & 3 it was found that % anions increased more from Table 1 to 2 than from Tables 2 to 3. It clearly indicates that % anions increased more during the period 1988-94 causing towards acidic character in the precipitation.

TABLE 1

Average ionic concentrations (mg/lit) of major inorganic components of precipitation 1981-1987

Elements	Nagpur	Allahabad	Jodhpur	Mohanbari	Minicoy	Srinagar
Cl	0.58	0.78	3.25	0.40	0.53	1.45
SO <sub>4</sub>	0.80	0.96	1.95	1.00	0.66	1.41
NO <sub>3</sub>	3.07	4.59	3.31	2.64	0.73	4.10
<b>Sum of anions</b>	<b>4.45</b>	<b>6.33</b>	<b>8.51</b>	<b>4.04</b>	<b>1.92</b>	<b>6.96</b>
Ca	3.49	5.21	10.99	2.11	0.66	6.04
Na	0.84	1.96	5.05	0.54	0.72	1.57
K	0.80	1.85	2.27	.67	0.40	2.15
Mg	0.97	2.39	0.13	0.58	0.57	0.09
NH <sub>4</sub>	0.28	0.21	0.10	0.46	0.31	0.55
<b>Sum of cations</b>	<b>6.38</b>	<b>11.62</b>	<b>18.54</b>	<b>4.36</b>	<b>2.66</b>	<b>10.4</b>
<b>Sum of anions &amp; Cations</b>	<b>10.83</b>	<b>17.95</b>	<b>27.05</b>	<b>8.40</b>	<b>4.58</b>	<b>17.36</b>
H (Moles/lit )	0.43 E-06	0.09 E-06	0.04 E-06	0.39 E-06	0.41 E-06	0.04 E-06
pH	6.36	7.02	7.38	6.41	6.39	7.36
<b>% Anions</b>	<b>41.09</b>	<b>35.26</b>	<b>31.46</b>	<b>48.10</b>	<b>41.92</b>	<b>40.09</b>
<b>% Cations</b>	<b>58.91</b>	<b>64.74</b>	<b>68.54</b>	<b>51.90</b>	<b>58.08</b>	<b>59.91</b>

TABLE 2

Average ionic concentrations (mg/lit) of major inorganic components of precipitation 1988-1994

Elements	Nagpur	Allahabad	Jodhpur	Mohanbari	Minicoy	Srinagar
Cl	0.92	2.48	3.20	0.93	0.96	1.44
SO <sub>4</sub>	1.07	2.25	2.93	1.73	0.76	1.46
NO <sub>3</sub>	12.77	15.32	8.09	11.10	1.27	6.53
<b>Sum of anions</b>	<b>14.76</b>	<b>20.05</b>	<b>14.22</b>	<b>13.76</b>	<b>2.99</b>	<b>9.43</b>
Ca	3.11	3.42	6.30	1.35	0.40	6.77
Na	1.71	4.35	3.75	0.79	0.75	1.50
K	1.26	2.73	1.54	0.65	0.50	2.45
Mg	0.99	2.21	1.59	0.21	0.14	0.65
NH <sub>4</sub>	1.35	0.61	0.05	1.06	0.38	0.47
<b>Sum of cations</b>	<b>8.42</b>	<b>13.32</b>	<b>13.23</b>	<b>4.06</b>	<b>2.17</b>	<b>11.84</b>
<b>Sum of anions &amp; Cations</b>	<b>23.12</b>	<b>33.37</b>	<b>27.45</b>	<b>17.82</b>	<b>5.16</b>	<b>21.27</b>
H (Moles/lit )	1.2 E-06	0.27 E-06	0.02 E-06	2.7 E-06	0.45 E-06	0.06 E-06
pH	5.90	6.56	7.54	5.56	6.34	7.25
<b>% Anions</b>	<b>63.68</b>	<b>60.08</b>	<b>51.80</b>	<b>77.22</b>	<b>57.95</b>	<b>44.0</b>
<b>%Cations</b>	<b>36.32</b>	<b>39.92</b>	<b>48.20</b>	<b>22.78</b>	<b>42.05</b>	<b>56.0</b>

For example, in case of Nagpur % anions increased from 41% to 64%, *i.e.*, 23% (From Tables 1 to 2) and it increased from 64% to 70%, *i.e.*, 6% (from Tables 2 to 3). Similar trend can be found for all other stations. On the contrary cations show decreasing trends due to neutralization of soil derived aerosols by acidic radicals

through rain at all the stations under study during the whole period 1981-2001.

During the period 1981-87 all the stations Srinagar Mohanbari, Allahabad, Jodhpur, Nagpur and Minicoy had alkaline pH. With the passage of time due to increase in

**TABLE 3**  
Average ionic concentrations (mg/lit) of major inorganic components of precipitation 1995-2001

Elements	Nagpur	Allahabad	Jodhpur	Mohanbari	Minicoy	Srinagar
Cl	2.39	3.01	9.84	0.65	0.60	2.14
SO <sub>4</sub>	9.29	6.22	10.28	2.70	1.65	4.12
NO <sub>3</sub>	11.47	11.32	17.47	8.42	2.25	9.33
<b>Sum of anions</b>	<b>23.15</b>	<b>20.55</b>	<b>37.59</b>	<b>11.77</b>	<b>4.5</b>	<b>15.59</b>
Ca	3.50	4.80	10.77	0.91	0.46	5.63
Na	1.59	3.14	6.03	.44	0.49	1.05
K	1.69	1.38	3.09	0.68	0.45	1.28
Mg	1.18	1.99	3.13	0.41	0.25	0.64
NH <sub>4</sub>	1.90	1.10	2.51	0.99	0.31	0.19
<b>Sum of cations</b>	<b>9.86</b>	<b>12.41</b>	<b>25.53</b>	<b>3.43</b>	<b>1.96</b>	<b>8.79</b>
<b>Sum of anions &amp; Cations</b>	<b>33.01</b>	<b>32.96</b>	<b>63.12</b>	<b>15.20</b>	<b>6.46</b>	<b>24.38</b>
H (Moles/lit)	6.9 E-06	0.14 E-06	0.02 E-06	3.4 E-06	1.7 E-06	0.28 E-06
pH	5.16	6.85	7.54	5.47	5.77	6.45
<b>% Anions</b>	<b>70.13</b>	<b>62.35</b>	<b>59.55</b>	<b>77.43</b>	<b>69.66</b>	<b>63.95</b>
<b>% Cations</b>	<b>29.87</b>	<b>37.65</b>	<b>40.45</b>	<b>22.57</b>	<b>30.34</b>	<b>36.05</b>

pollution Nagpur and Mohanbari turned with acidic pH during 1995-2001.

#### 4. Conclusions

(i) pH of all the stations except Jodhpur showed decreasing trend during the period 1981-2001. However concentrations of anions increased at all the stations. During the interval 1988-1994 only Mohanbari had acidic pH, but during the interval 1995-2001 Mohanbari and Nagpur had acidic pH. This may be due to industrialization and anthropogenic activities both at Nagpur and Mohanbari coupled with humid atmosphere particularly at Mohanbari throughout the year.

Humid climate cuts down on soil derived aerosols like Ca<sup>2+</sup> and Mg<sup>2+</sup>. These elements neutralize acidic aerosols and hence increases pH. But at Mohanbari and Minicoy concentrations of Ca<sup>2+</sup> and Mg<sup>2+</sup> were found very less in the period 1981-2001 due to humid climate. Therefore neutralization of acidic aerosols was also very less which resulted in reduction of pH.

(ii) Percentage of anions showed increasing trend at all the stations, which has resulted in reduction in pH.

(iii) Percentage of cations showed decreasing trend at all the stations hence decreased basic character of precipitation.

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