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Electrical conductivity of monsoon rain water

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ABSTRACT. Electrical conductivities of some samples of monsoon rain water were measured at Jadavpur, Calcutta. In some cases it was found that there was no systematic variation of conductivity while in a few other cases conductivity was observed to decrease with progress of rain and increase only at the end when the intensity of rain became very low. Conductivity was also seen to increase and intensity of rain decrease steadily with progress of rain. In the last case the dependance of conductivity with intensity of rain is found to be expressible by the relationship : conductivity $\propto$ (intensity)$^{-m}$, where m is a positive constant. Explanations for these variations have been suggested.

1. Introduction

The whole process of formation of rain is similar to distillation. Water is evaporated from sea surface and is precipitated in the form of rain at different places. Physico-chemical properties like electrical conductivity etc should, therefore, give the values of those of pure water. But, since salts and other hygroscopic materials act as condensation nuclei and are also washed out by rain drops from the part of atmosphere through which they fall, value of conductivity will be higher than that of pure water. The concentration of dissolved substances in rain water being very low, we can regard the same to be at infinite dilution in the sense used in electro-chemistry. Again we know that at infinite dilution, specific conductivity of a solution is proportional to the concentration of the electrolyte dissolved in it. Thus, a study of electrical conductivity in rain water will give us an idea about the concentration of dissolved electrolytes.

2. Measurement

Samples of rain water were collected at the College of Engineering and Technology, Jadavpur, Calcutta (22° 30′ N, 88° 22′ E) and experiments were made at the Physical Chemistry Laboratory of the College. Rain water was collected in a Jena glass bottle using a 10-cm Pyrex glass funnel from 29 July to 18 August 1955. Later on it was collected in a big porcelain basin placed on a tripod stand and the water thus collected was transferred to dry Jena glass bottle without using any funnel. Quality of water collected was found to be good as may be noticed from the figures. Conductivity was measured immediately after the collection of the samples.

Measurement of the resistance was carried out with Phillips Universal Conductivity Bridge fitted with magic eye and logarithmic scale, like Kohlrausch's bridge, using alternating current of 1000 cycles per second. Output voltage was 2 volts.

Double distilled water prepared by standard method was used for cleaning and washing the bottles, funnel and the porcelain basin.

The cell constant was determined by using an N/50 KCl solution at 28°C. Its value was found to be 0·7302. Temperature of the collected rain water ranged from 27·5° to 29·0°C at the time of measurement. Volume of water collected was measured by pouring water in a dry measuring cylinder after other measurements were over.

The details of the observations are given in Table 1.

3. Discussion

From the data in Table 1 it is found that on 10 and 13 September 1955 there is only one value of specific conductivity for each

TABLE 1

Date (1955)	Collected during (IST)	Interval (min)	Amount collected (cc)	Sp. conductivity (mhos)	Remarks
29 Jul	1000—1130	90	30	$3{\cdot}17\times10^{-5}$	No thunder
	1130—1300	90	25	1·50 ,,	
	1300—1500	120	22	3·17 ,,	
6 Aug	1100—1115	15	30	1·30 ,,	No thunder
	1125—1130	15	32	1·04 ,,	
	1130—1200	30	35	0·66 ,,	
	1200—1230	30	30	0.66 ,,	
	1230—1400	90	29	1·03 ,,	
18 Aug	1135—1145	10	25	3·72 ,,	No thunder
	1145—1200	15	25	1·43 ,,	
	1200—1220	20	27	2·42 ,,	
19 Aug	1020—1030	10	50	1·62 ,,	Thundershower
	1030—1040	10	52	1·32 ,,	
	1040—1050	10	50	1·30 ,,	
	1050—1100	10	55	1·04 ,,	
	1100—1110	10	45	0·66 ,,	
	1110—1130	20	37	0·84 ,,	
30 Aug	1030—1037	7	70	1·33 ,,	Thundershower
	1037—1044	7	68	1·12 ,,	
	1044—1051	7	68	1·06 ,,	
	1051—1058	7	65	1·00 ,,	
	1100—1125	25	50	1·22 ,,	
7 Sep	1200—1205	5	30	2·52 ,,	No thunder
	1205—1211	6	32	1·72 ,,	
	1211—1221	10	58	1·46 ,,	
10 Sep	1305—1315	10	35	$8{\cdot}94\times10^{-6}$	No thunder
11 Sep	1400—1410	10	40	$2{\cdot}12\times10^{-5}$	Loud thunder
	1410—1430	20	30	3·20 ,,	
	1430—1455	25	25	3·84 ,,	
	1455—1525	30	23	4·06 ,,	
13 Sep	1455—1510	15	33	$2{\cdot}18\times10^{-6}$	Loud thunder
18 Sep	1400—1410	10	60	7·72 ,,	Loud thunder
	1410—1430	20	60	8·84 ,,	
	1430—1445	15	30	$1{\cdot}02\times10^{-5}$	
	1445—1505	20	30	1·05 ,,	

TABLE 1 (*contd*)

Date (1955)	Collected during (IST)	Interval (min)	Amount collected (cc)	Sp. conductivity (mhos)	Remarks
24 Sep	1400—1403	3	50	$7\cdot16\times10^{-6}$	No thunder
	1403—1406	3	50	5·17 „	
	1406—1409	3	30	5·41 „	
	1409—1412	3	30	9·42 „	
	1412—1415	3	30	4·87 „	
	1415—1418	3	30	6·64 „	
	1418—1421	3	30	3·48 „	
	1421—1424	3	30	10·66 „	
29 Sep	1400—1402	2	60	5·62 „	Loud thunder
	1402—1406	4	100	5·92 „	
	1406—1412	6	90	7·66 „	
	1412—1422	10	30	12·12 „	
30 Sep	1000—1002	2	80	6·37 „	Strong gusty winds, No thunder
	1002—1004	2	80	5·15 „	
	1004—1006	2	70	3·24 „	
	1006—1010	4	50	5·21 „	
	1010—1014	4	50	3·24 „	
	1015—1020	5	40	4·71 „	
	1020—1025	5	40	2·51 „	*
	1210—1213	3	50	5·80 „	Strong gusty winds, No thunder
	1213—1216	3	50	5·21 „	
	1216—1219	3	50	5·62 „	
	1219—1223	4	50	5·64 „	
	1223—1227	4	50	3·03 „	
	1227—1231	4	30	5·21 „	
	1231—1235	4	30	2·70 „	
	1235—1239	4	30	2·71 „	
	1239—1246	7	32	6·35 „	
	1246—1253	7	30	2·98 „	
	1253—1300	7	30	3·32 „	
	1300—1307	7	30	2·61 „	
1 Oct	1000—1003	3	80	10·00 „	No thunder
	1003—1006	3	80	9·15 „	
	1006—1009	3	80	4·06 „	
	1009—1012	3	60	3·84 „	
	1012—1015	3	40	4·27 „	
	1015—1018	3	30	5·04 „	
	1018—1021	3	50	2·15 „	
	1021—1031	10	30	5·40 „	

* Rain stopped at 1030 IST and started suddenly at 1205 IST

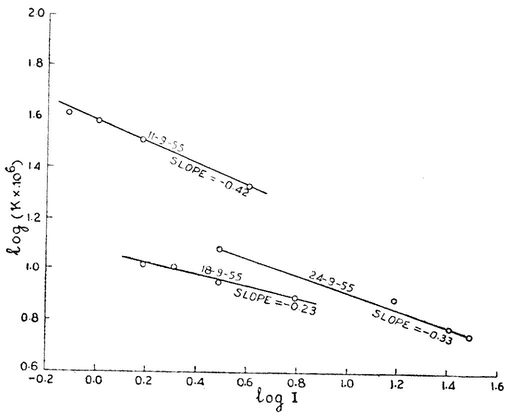

Fig. 1

day's rain. As such, they are not suitable for further analysis. Data for other days can be classified into three types.

1. Unsystematic variation of conductivity as observed on 24 and 30 September and 1 October 1955. The reason for such variation is not understood.

2. Decrease in conductivity with progress of rain on 29 July, 6, 18, 19 and 30 August, and 7 September 1955 and then, as we can observe in most of the cases, there is increase in specific conductivity towards the end when intensity of rain becomes too low and amounts to drizzling.

3. Decrease in intensity of rain and simultaneous increase in conductivity of rain water with progress of precipitation on 11, 18 and 29 September 1955.

Behaviour of the second type can be explained in the following way. Rain washes out salt from air between the cloud and the ground, and wind replenishes it. In case the rate of replenishment of the salt is less than the rate at which it is being washed out, concentration of salt, or any other electrolyte that may be present in air, will decrease with progress of rain. Evaporation of rain drops will, however, increase the concentration of the salts to some extent and the effect is greater with the smaller rain drops.

Thus we see that at first the salinity of rain water and hence the specific conductivity, will decrease with progress of rain. But when the drops become smaller and smaller the effect of evaporation increases and the decrease in salinity may be checked at a certain stage after which it may increase. Moreover, towards the end, cloud base usually lifts up and the rate of replenishment of salts by wind in the rainy area increases rapidly. Both these factors will cause an increase in salinity towards the end of precipitation when rain becomes very light and it practically drizzles.

Of the samples studied, those of 19 and 30 August 1955 were from thundershowers and most probably rain was initiated in these cases by Bergeron-Findiesen process. In such cases the above explanation for the changes in conductivity seems to be possible. In case of non-freezing clouds, which may be the case with rain on 29 July, 6 and 18 August and 7 September 1955, there may be some complicated mechanism as suggested by Turner (1955) that "saline nuclei play a basic role in formation of warm rain".

In all the cases where the third type of behaviour was observed there was thundershower from well formed Cumulonimbus clouds. The precipitation was probably initiated by Bergeron process and further growth of rain drops might have been by accretion process as suggested by Houghton (1951). The increase in conductivity of rain water with decrease in intensity in rain can be understood if we assume that there was continuous supply of salts (most of which are highly soluble) in the rainy area.

Following Turner (1955), we plotted log K (conductivity which is proportional to concentration) against log I (amount of water collected per minute) and observed that there is a linear relationship between them as can be seen from Fig. 1. Thus, in cases where conductivity is found to increase with decrease in rainfall intensity we get the relationship—

$$\text{Conductivity} \propto (\text{intensity of rain})^{-m}$$

where m is a positive constant.

If we assume that the number of drops falling on a unit area were the same and that the variation of intensity of rainfall was due to the variation of rain drop size, we get

$$\text{Conductivity} \propto (\text{radius})^{-n}$$

$$\text{or} \qquad \text{Salinity} \propto (\text{radius})^{-n}$$

This relationship was also obtained by Turner (1955)*.

Purity of rain water—Turner observed that some of the rain drops collected by him were very dilute, more dilute than the best distilled water available. In our experiment we got samples of rain water with very low conductivity, as low as $2 \cdot 15 \times 10^{-6}$ mhos.

If we assume that only sodium chloride is present in rain water, we can calculate the amount of NaCl from the formula

$$\Lambda_\infty = 1000\ K/C$$

where Λ_∞ =equivalent conductivity at infinite dilution and C = concentration of the salt in molarity, *i.e.*, number of gm-moles of salt per litre of solution.

From such calculations we get that the NaCl content of rain water varied within the range of 0·3 to 17·3 parts per million.

4. Acknowledgement

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REFERENCES

Houghton, H.G.	1951	*Compendium of Meteorology*, p. 178.
Mukherjee, A. K.	1956	*Indian J. Met. Geophys.*, **7**, 1, p. 84.
Turner, J. S.	1955	*Quart. J.R. met. Soc.*, **81**, **349**, p. 418.

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*With the same assumption we can derive the relationship by an approximate method. We know that most of the salts that are washed out by rain are highly soluble. It has been shown by the author (1956) that in case of continuous supply of salts in rainy area, the concentration of the washed out salt (C) is inversely proportional to the intensity of rain (I). Again intensity of rain is proportional to $4/3\ \pi\ r^3$, provided number of drops falling per unit area remain constant.

$$\text{Hence,} \quad C \propto 1/\tfrac{4}{3}\pi\, r^3$$

Again, concentration of the salt tends to increase by its evaporation which in turn is proportional to the surface area of the rain drops.

$$\text{Or,} \quad C \propto 4\,\pi\, r^2$$

Hence, when both the factors vary, we get

$$C \propto \frac{1}{\frac{4}{3}\pi\, r^3} \times 4\,\pi\, r^2, \quad \text{Or } C \propto 3/r, \quad \text{Or } C \propto 1/I^{\frac{1}{3}}$$

In Fig. 1, plotting $\log K$ against $\log I$, we find that the slope lies between 0·23 and 0·43. Of course, the slopes are all negative,