

FEATURES OF RAINFALL OF STATIONS WITHIN 200 KM OF A STEEL INDUSTRY

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A preliminary analysis of rainfall of four stations around the Burnpur-Jamshedpur steel mills complex, which had been reported by the authors earlier, suggested decreases in rainfall after establishment of the steel-mills complex. Using additional procedures of analysis the problem has been further examined. The decreases in rainfall noted in the earlier study are corroborated.

INTRODUCTION

Steel mills release large amounts of heat and moisture affecting the local atmospheric stability conditions. Also, particulate effluents from them are known to possess ice-nucleating property (Telford 1960; and Langer 1968). Large cumulus clouds have been occasionally found to develop over the steel mills (Lyons & Olsson 1973). Cloud streets are observed to undergo enhancement when aligned with the industrial plumes. On other occasions, decks of supercooled stratocumulus clouds have been noted to develop large clear areas downwind of the mills, presumably, due to the effect of "overseeding" with ice nuclei (Lyons 1974).

Rainfall changes over 30 per cent have been reported in U.S.A. in the downwind region of an industrial complex (Changnon 1968) due, probably, to altered microstructure of clouds by the effluents from steel mills. Weickmann (1972) has noted precipitation apparently caused by steel mill effluents in the Buffalo area, coincident with attempts at advertent cloud seeding of lake snow squalls.

A preliminary study of rainfall of four stations around the Burnpur-Jamshedpur steel mills complex in this country made by the authors (Ramana Rao & Ramana Murty 1973) has suggested decreases in rainfall after the establishment of the steel industry in the region. Using additional procedures, the same data have been further analysed in the present study. Also, concentrations of ice-forming nuclei near one of the steel mills have since been measured on a few days. Results of the analysis and measurements are presented.

STEEL MILLS, RAINGAUGE STATIONS AND DATA

Two steel mills are present in the region of the study—one at Burnpur (23° 41'N, 86° 59'E) and the other at Jamshedpur (22° 49'N, 86° 11'E), which went into production from 1892 and 1912 respectively. The four raingauge stations in the region considered for the study are Berhampore (24° 08'N, 88° 16'E), Midnapore (22° 25'N, 87° 18'E), Chaibasa (22° 33'N, 85° 49'E) and Hazaribagh (23° 59'N, 85° 22'E).

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The data analysed are the monthly rainfall data of February and August (to represent winter and monsoon conditions respectively) for the period 1872-1955.

TARGET AND CONTROL STATIONS

The station, downwind of the steel mills complex, receiving the effluents is the target. The station upwind of the complex and, therefore, unlikely to receive the effluents, is the control. The steel mills at Jamshedpur and Burnpur have been considered as one single entity for the purpose of delineating the target and control stations.

Chaibasa and Midnapore lie in the downwind sector for minimum number of days in February and August respectively. For this reason, these two stations have been considered respectively to be the control in February and August. As a target station could not be determined uniquely, the rest of the three stations put together, i.e., Hazaribagh, Berhampore and Midnapore in February and Chaibasa, Hazaribagh and Berhampore in August, have been considered as the corresponding targets.

RESULTS OF AN EARLIER STUDY

February rainfall showed significant changes. The rainfall patterns, during February, of all the stations have indicated statistically significant negative trend in the latest 21 year industrial period, namely, 1935-1955. The target-to-control rainfall ratios, both during February and August have, in general, not shown significant trends either in the pre-industrial or in the industrial period.

PRESENT ANALYSIS

The analysis in the earlier study was done considering the entire period of 84 years into 4 discrete units of 21 years each and also into 2 discrete units of 21 years and 63 years. The stratification of the data period thus considered assumes that changes, if any, would have taken place beginning from 1892 when the establishment of the steel mills at Burnpur started. It did not, however, provide scope for locating the precise time periods when those changes would have taken place. In the present study this aspect has been examined. For this purpose, the whole temporal length of the data has been scanned with the help of one of the statistical tests (Mann-Whitney), employed earlier, for significant disparities in the rainfall regimes. The fine-structure resolution of the test statistic has been investigated rather than the data itself.

Two different fine-structure variations of the z -statistic of the above test are obtained to locate periods of significant disparities in the rainfall ratio series of the 84 years. This is done by testing: (a) each pair of successive 21 year periods—for example, the ratios of target-to-control rainfall from 1872 to 1892 are tested with those from 1893 to 1913, those from 1873 to 1893 are tested with those from 1894 to 1914, and so on; and (b) a progressively increased initial period of ten years with the rest of the entire period, in steps of one year—for example, the ratios from 1872 to 1881 are tested with the ratios from 1882 to 1955, those of 1872 to 1882 are tested with those of 1883 to 1955 and so on. It is anticipated that, if steel mills influenced the rainfall of the region, the absolute value of z -statistic, which

defines probability levels, should be maximum for the pair of periods partitioned around 1892 in both the cases. Further, it is anticipated that such changes should be also visible for periods around 1912, the date of establishment of the second industry.

RESULTS

The spectrum of the z -statistic for successive pairs of 21-year period are presented in Fig. 1, and that for progressively increased initial period in Fig. 2. The 10 per cent probability level of significance for one-tailed testing is shown in the diagram, with areas of spectrum exceeding this reference line hatched.

The results reflect statistically significant disparities in the target-to-control rainfall ratios of February for the pair of periods around 1892 (*vide* curves for February in Figs. 1 and 2). The significant disparities noted extended from 1892 to 1900 in the successive period spectrum (Fig. 1). They extended from 1887 to 1894 in the progressive period spectrum (Fig. 2). The results do not, however, reveal significant changes in February rainfall around 1912 corresponding with the advent of the second industry.

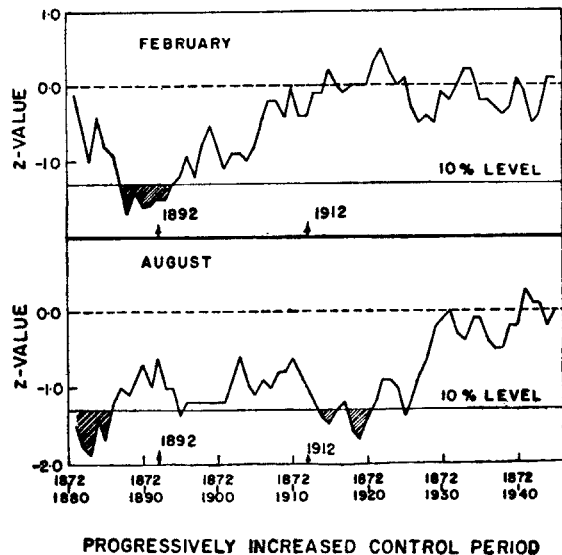
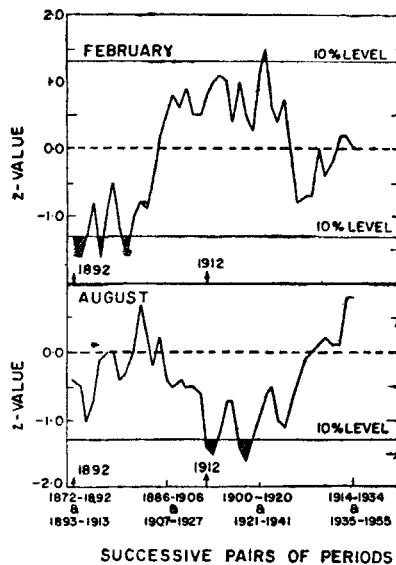


FIG. 1. Spectrum of z -statistic for successive pairs of periods.

FIG. 2. Spectrum of z -statistic for progressively increased control periods.

Statistically significant disparities in the target-to-control rainfall ratios of August rainfall were suggested around 1912. Such disparities were also noted from 1872 to 1886 in the progressive period spectrum (*vide* curves for August in Fig. 2).

MEASUREMENTS OF ICE-FORMING NUCLEI

Using the Millipore filter technique (Bigg *et al.* 1963), the concentration of ice-forming nuclei, active at -15°C , was measured at different times of day on 9 days at Jamshedpur. The concentration was also measured at different times of day at two

nearby stations (i) Chaibasa and (ii) Ghatsila on 2 days and 3 days respectively. Ghatsila, which is not a station considered for rainfall analysis, is situated approximately 30 miles southeast of Jamshedpur. The measurements were made in the later half of February 1971. The mean concentrations at the stations during the periods of measurement are shown in Table I. The level of significance of the concentration at Chaibasa and Ghatsila with respect to the concentration at Jamshedpur, as determined by the Mann-Whitney test, are given in the Table.

TABLE I
Average concentrations of ice-forming nuclei, active at -15°C

Station	Period	Number of measurements	Concentration (Number per cubic meter)	Level of significance
Jamshedpur	18-2-71 to 23-2-71 and 26-2-71 to 28-2-71	37	199	—
Ghatsila	23-2-71 to 25-2-71	12	121	0.01
Chaibasa	25-2-71 to 26-2-71	10	136	0.06

Note : The levels of significance of the concentrations at Ghatsila and Chaibasa with respect to the concentrations at Jamshedpur are given.

The winds at Jamshedpur (not presented) as noticed from pilot balloon observations, on all the days of measurement, were variable. The concentration of ice-forming nuclei at Jamshedpur was slightly but definitely higher than that at Chaibasa and Ghatsila. Though it is known that the concentration at a station can vary by two or more orders of magnitude within a short period (Bigg & Meade 1959), the small increase noticed in the concentration at Jamshedpur is statistically significant.

DISCUSSION

The February rainfall in the region of the study underwent significant changes after the establishment of steel industry at Burnpur. Advent of the second steel industry at Jamshedpur seemed to have caused little change. On the other hand, August rainfall showed significant changes only after the establishment of the industry at Jamshedpur. If the statistically significant changes evidenced in 1892 in February rainfall and in 1912 in August rainfall are to be ascribed to the steel mills, it is unlikely that such effects would be totally absent in 1912 in February rainfall and in 1892 in August rainfall. It is likely that the effects were present but they were relatively weak. The control stations are not totally uninfluenced by the mill effluents. They lie downwind of the mills for definitive periods than never. It is not clear whether and, if so, to what extent this aspect would have been contributed for the suggested preferential responses as above.

Significant increase was noticed in the ice-forming nuclei concentration at Jamshedpur. This feature helps to point out that the steel mill at the station is a

source of those nuclei. It is considered that increase in the concentration of such nuclei in the air would help to increase the rainfall. But, the decreases suggested in the rainfall in the present study are intriguing. Measurements of the ice-forming nuclei of cloud levels, when available, may help to throw light on the aspect of over-seeding.

CONCLUSION

The winter rainfall as well as the monsoon rainfall, in the Burnpur-Jamshedpur region, seemed to have undergone changes with the advent of the steel industries in that region.

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