Original Articles.

FORECAST OF THE PROBABLE MAJOR VARIATIONS IN CHOLERA, SMALL-POX AND PLAGUE IN INDIA DURING 1930, BASED ON THE METEOROLOGY OF 1929.

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As the result of three very laborious years' study of some sixty years' sanitary and meteorological records for all parts of India, I showed that the major epidemics of small-pox, cholera and plague are dependent on antecedent meteorological variations which makes it possible to forecast them several months before their development with a fair degree of accuracy. Such a correct forecast based on my methods was actually made by the sanitary officer in the Southern Deccan in the case of the cholera epidemic of 1927, and that in Sind in 1929 so clearly followed very deficient rainfall during the previous monsoon and winter months, that I presume it was also foreseen by the sanitary authorities in accordance with the previous similar sequence of events in 1885 and 1892, pointed out in my memoir on cholera incidence (*Indian Jour. Med. Research*, 1928).

Working in London I am handicapped by receiving the vital statistics and meteorological data some two months later than they are available in India, but in order to put my theories to a very rigid test I propose to publish forecasts of the probable major variations of the three great epidemic diseases of India, in the hope that should they prove in any degree correct during the next three years or so, the method may subsequently be taken up under the more advantageous conditions obtained in India itself. That such forecasts may be of great practical value is proved by the fact that in the case of the South Deccan cholera epidemic of 1927 the divisional sanitary officer warned the authorities some time before the appearance of any cholera in his districts that on the rules laid down by me in 1926 the failure of the previous monsoon rains, combined with the high degree of susceptibility due to the practical absence of cholera from that area during the previous two years, rendered an epidemic of cholera very probable. Moreover, as soon as the first few cases appeared he advised the prohibition of a local pilgrimage, but the authorities decided that it was too late to do so, and severe cholera broke out at this fair, and although subsequent fairs were prohibited, a widespread epidemic followed, which was apparently the origin of an outbreak in the Persian Gulf soon after, which, but for our presence in Iraq, would probably have spread to Europe with appalling results in Russia, as happened in 1851—53. My full memoir had not then been published or it would have been possible to foresee the South Deccan outbreak with practical certainty at least a month before its occurrence by the exceptionally favourable 1927 high spring absolute humidity in the South Deccan as shown on page 105 of my memoir, and it is of great interest to record that I was fortunate enough to meet the head of the first infected district, who agreed with me that had he received longer warning based on the high absolute humidity data, he could have prohibited the incriminated fair in time to check the outbreak. This example should suffice to convince the sanitary authorities in India that my methods are at least worthy of their attention.

Meteorological data of 1929 *unfavourable for forecasts.*—Fortunately for India the monsoon rains of 1929 were remarkably well distributed, for the only material defect in the British Provinces, with which alone I deal, was the moderate deficiency of 16 per cent. in the United Provinces, and the only significant excess was due to heavy rains on the North-West Frontier and in Sind in July, which is less important from my present point of view than in the later monsoon months. My forecast this year will therefore be mainly of a negative character, but not necessarily less valuable, should a forecast of the absence of epidemics over most of India prove correct.

CHOLERA INCIDENCE.

Factors influencing.—These were fully described in my memoir and are briefly: (1) Low monsoon and winter rains of the previous year, (2) a high degree of susceptibility due to absence of recent epidemic prevalence, and (3) a favourable absolute humidity of about 0.400 and over at the time of the usual seasonal increase of cholera in the particular area. The first two sets of data are available some months before an outbreak, the third is only known shortly before, so only the first two can be used in this forecast, although the third is also important to watch in some areas. In my memoir I showed that no less than 40 out of 41 epidemics in India during 45 years had been preceded by deficient rains, and the one exception was due to high spring absolute humidity in a twelve-yearly Allahabad Kumbh Fair year, which Fair has recurred once more in 1930. I also showed that cholera does not spread in periodic waves from Bengal as held for a century, for the yearly incidence curves over 45 years are different in Assam, Eastern Bengal, Western Bengal and in Bihar, as well as in the East and the West of the United Provinces, which forms one huge north-eastern endemic area, while South-East Madras and the West Coast of Bombay are distinct endemic areas from which cholera also spreads as in 1875. Smaller areas than provinces

have therefore to be dealt with in making a forecast, and the most important of these are shown in Table I, in which a — sign indicates previous low cholera incidence and low monsoon rainfall respectively, which are favourable to increased cholera, and + signs have the opposite significance. Two signs, such as — —, indicate high degrees and single signs, such as —, only moderate departure from the normal, and it is only the major degrees that indicate severe epidemics, and it will be noted that they are practically absent as regards rainfall from Table I owing to the favourable 1929 monsoon. A + — sign indicates no material variation from the normal. As in Assam and Bengal the cholera season commences during the last three months of the year, the forecast relates to the period from October 1929 to September 1930 and in South-East Madras from December to November. Table I will allow the data regarding previous cholera prevalence and the 1929 monsoon rainfall in each area and their probable influence on 1930 cholera incidence to be seen at a glance, and in view of the practically normal rainfall in most of them affording little likelihood of great departures from the average it is unnecessary to discuss them all in detail. An increase over the average of the last ten years may be expected in the Surma Valley of Assam, and low prevalence in Sind after last year's epidemic, due to failure of the 1928 monsoon and the ensuing winter rains. With the important exception of Bihar and the United Provinces, no great departure from the average of the last ten years is to be expected in the other areas dealt with, although I have ventured to indicate the direction which such slight variations may be expected to take, although I recognize that in view of the slight departures from the normal monsoon rains there is only a reasonable probability of their being fulfilled. The deficiency of the latter part of the monsoon rains in the West of the United Provinces is of greater importance than usual owing to the Allahabad Kumbh Pilgrimage in January and February 1930, for although I pointed out in my memoir this occurrence does not usually seriously infect the western United Provinces divisions owing to its occurring when the absolute humidity is too low for epidemic cholera in the west, yet should the epidemic prevalence of cholera in the east of the United Provinces, which has followed each of the four previous Allahabad Kumbh Fairs from 1882 to 1918, recur in 1930, the western divisions are more likely to be infected on account of their 1929 low rainfall. Should the winter rains be deficient in the United

TABLE I.

Forecast of probable cholera incidence in India in 1930.

Area.	Previous Prevalence. Monsoon 1929.					Forecast.
	1927.	1928.	1929.	6—9.	10.	
E. Bengal	+	?	— —	+	—	About average incidence.
W. Bengal	+	?	—	—	+	do.
Assam Valley	+—	— —	— —	++	+	Average to somewhat low.
Surma Valley	+	—	—	—	—	Moderate increase over average.
Orissa	+—	+	+—	++	—	Average to somewhat low.
Bihar	—	++	+—	— —	++	Climatic conditions normal. Allahabad Kumbh Fair will cause considerable excess.
E. United Provinces ..	+—	+	+—	+—	+—	Low September rains favour cholera. Allahabad Kumbh Fair will cause excess. This may be great if winter rains fail or if February and March absolute humidity is in excess as in 1894.
W. United Provinces ..	+—	+—	—	— —	+—	Deficient monsoon rains favour cholera, so excess following that in E. United Provinces to be feared.
Punjab	++	—	—	+—	—	Moderate increase over average.
N. W. F. P.	— —	— —	—	++	+—	No excess unless Punjab much infected.
E. Central Provinces ..	+—	—	—	++	+—	Good rains. Average to low unless infected by Allahabad Kumbh Fair.
W. Central Provinces ..	+—	++	—	+—	—	Average to low unless infected from Bombay Deccan.
Bombay Deccan ..	++	—	—	—	+—	Average to some excess.
do. Konkan ..	+—	—	—	+—	+	Average to low.
do. Gujerat ..	—	—	—	+—	+—	Average unless infected from Deccan.
do. Sind	—	—	++	++	+—	Low after 1929 epidemic and good monsoon.
Madras Deccan	+—	++	—	—	+—	Average to some excess.
N. E. Madras	+—	+	—	+—	+	Average to low.
S. E. Madras	+—	+—	+—	—	—	Average to some excess.

Provinces the danger will be enhanced in both parts of the province.

The 1930 *Allahabad Kumbh Fair and Cholera in Bihar and the Eastern United Provinces.*—In Chart XIII of my memoir I demonstrated that the cholera incidence curves during 35 years in Bihar and the Eastern United Provinces ran closely parallel owing to main rises occurring in the Allahabad Kumbh Fair years, and in those with very deficient monsoon rains affecting both areas. Moreover, I showed that the extent of the Kumbh epidemics from 1882 to 1918 was dependent on the rainfalls and the January to March absolute humidity, and not on the excellent sanitary measures at the fairs since 1894, which only deal with two or three square miles out of some 100,000 square miles of the endemic cholera area of the two provinces, through whose insanitary villages and towns some 3,000,000 pilgrims pass to and from the Fair. The fact that the 1882 Fair, with no proper sanitary precautions at the Fair site, caused less cholera than the next three fairs, with good sanitation at the camp, suffices to prove this obvious inference. I also showed that the high cholera incidence in 1894 as compared with that of 1882 was due to the exceptionally high and favourable absolute humidity at the time in 1894 compared with exceptionally low readings in 1882 (*see* p. 129 of my memoir). The extent of the 1930 epidemic will largely depend on whether the absolute humidity in Western Bihar and Eastern United Provinces is well below the critical level of 0.400 in January to early March this year as in 1882, or whether it approaches that level, as in the bad cholera year 1894, as well as on whether the winter rains are good and so less favourable to high cholera incidence. These data are not yet available in London at the time of writing in the last week of January, but they will be available to the sanitary authorities by the time this forecast appears, so this crucial point is referred to in Table I and will largely determine the extent of the cholera epidemic, which is apparently inevitable in Bihar and the Eastern United Provinces this year, and which may affect to a less extent the West. Owing to the favourable monsoon rains in the Eastern United Provinces and Bihar, unless the absolute humidity in January to March is in excess of the normal, the cholera epidemic due to the Kumbh Fair of 1930 is likely to be less severe than in 1894, 1906 and 1918.

Small-Pox.

Factors influencing yearly incidence.—A comprehensive study of the monthly provincial small-pox variations in India in relation to meteorology during 48 years was published by me in No. 106 of the *Special Report Series of the Medical Research Council.* I there showed that the yearly decline in the disease during the rains in the seven provinces most affected by the south-west monsoon was related to the high absolute humidity at that season, and that the small-pox epidemics which occur mainly in the north-west and central part of India are related to comparatively low monsoon absolute humidity due to partial failure of the monsoon rains in the previous year, but in the less affected damp areas of Bengal, Assam and Madras low autumn absolute humidity favours subsequent increased small-pox prevalence. Another important factor is the prevalence of the disease during the previous few years, as in a year immediately following an epidemic, favouring low absolute humidity will have comparatively little effect in causing another rise; on the other hand after a series of four or more years of low small-pox a considerable rise may occur, due to the accumulation of susceptible persons, in the absence of specially favourable low absolute humidities. Only considerable variations from the average absolute humidities are of value in forecasting epidemic increases.

Meteorological conditions during 1929.—The remarkably well distributed monsoon rains of 1929 naturally resulted in only slight variations in the monsoon absolute humidity in most of the provinces of India, consequently few material variations from the average small-pox prevalence in 1930 are to be expected. The monthly distribution of the rains, as well as their totals, affect the average absolute monsoon absolute humidities; it is for this reason that the humidity data are the more important in making forecasts. The provincial variations of the 1929 absolute humidities which mostly affect the next year's small-pox are given in Table II, together with the small-pox incidence of recent years, and their probable bearing in the incidence of the disease in 1930 is indicated.

Discussion.—Only variations of about 0.030 to 0.050 and over from the average absolute humidities are closely related to small-pox variations in any particular province, so in absence of very high degrees in any of the data, which are based on the figures of a representative place in each province, no severe epidemic of small-pox is likely to occur in India during 1930. Bihar and Orissa, the North-West Frontier Province and the Central Provinces show moderately low absolute humidities, which are liable to be followed by some increase of small-pox over the average of the ten years 1919—28 given in Table II, but in the case of the North-West Frontier the fact that small-pox has been fairly prevalent in three out of the four previous years makes it unlikely that the increase, if any, will be material. The same remark applies to Bihar and Orissa, and the year as a whole presents unusually indefinite data on which to base a reliable forecast.

In Madras and Burma the small-pox incidence is most closely related to the absolute humidity from November to January which is not yet available.

TABLE II.

Forecast of probable small-pox incidence in India in 1930.

Province.	10 years' average.	Previous Prevalence.			Absolute Humidity.			Forecast.
		1927	1928	1929	Months.	Average.	Variation from normal.	
Assam	0.42	0.76	1.23	0.09*	10—11	0.675	— 0.008	Average to low.
Bengal	0.42	0.9	0.25	0.1*	10—11	0.726	— 0.007	Average to low.
Bihar and Orissa ..	0.40	1.0	0.4	0.1*	10—11	0.588	— 0.038	Average to some excess.
United Provinces ..	0.12	0.17	0.07	0.13*	10—11	0.519	— 0.001	Average to some excess.
Punjab	0.37	0.48	0.43	0.18*	6—9	0.833	— 0.023	About the average.
N. W. F. P. ..	0.30	0.08	0.27	0.24*	7—9	0.708	— 0.045	Above the average.
Central Provinces ..	0.18	0.20	0.10	0.06*	6—9	0.710	— 0.037	Above the average.
Bombay	0.24	0.27	0.27	0.46*	6—10	0.676	— 0.006	About the average.

* The 1929 rates are based on the available figures from January to November with the estimated prevalence in December. They are not likely to vary from the actual data by more than a point or two in the second decimal place.

PLAGUE.

Factors influencing annual incidence.—I recorded in 1928 the results of an elaborate analysis of the incidence of plague in relation to climate during thirty years in different areas of India (*Proc. Royal Soc.*, B., Vol. 103, p. 42). This paper, as well as those already mentioned on cholera and small-pox, were sent to all the Directors of Public Health in India. The climatic factors which showed the closest relation to plague incidence proved to be the average mean temperatures in the hot and rainy seasons, and the saturation deficiencies at all four seasons of the year, making six yearly data to be studied, four of which are available before the annual increase of the disease about December in North and Central India, but in the Bombay Deccan the rise of plague occurs during the later monsoon months owing to the mean temperature being then too low to inhibit the disease in that area. Only northern India and the Central Provinces can therefore be dealt with in this forecast, and as the disease is absent or negligible in Assam and Bengal this leaves Bihar and Orissa, the United Provinces, the Punjab and the Central Provinces. The four climatic factors of the previous year which mainly influence the disease in any year in these areas are the monsoon temperatures, and saturation deficiencies of the hot weather and monsoon seasons, and that from October to December, but only the first two months' figures of the last are available at the time of writing. Saturation deficiency is obtained by deducting the monthly absolute humidity from the saturation point at the mean monthly temperature; it is a measure of the drying power of the atmosphere, high degrees of which, as well as high temperatures, are inimical to the life of the rat-flea carriers of plague infection. The average monthly figures I worked out for thirty years of these data enables the degree of excess or deficiency to be calculated for any year, and as high temperatures and high saturation deficiencies, indicated by + signs in Table III, are unfavourable to subsequent high plague incidence, and *vice versa,* a considerable preponderance of + signs indicates the likelihood of low subsequent plague, and a series of — signs indicates the probability of subsequent increase of plague over the average of recent preceding years. Two + + and two — — signs respectively indicate a well marked variation from the normal, and a single + or — sign only a moderate variation of much less significance, so that unless some double signs appear in the table no great change in the plague incidence is to be expected. The climatic data as far as they are available for 1929 are given in this manner in Table III and the deductions from them are indicated. It must also be remembered that, just as with small-pox, after a year or two of high plague incidence any factors favouring high plague incidence will have less effect than after some years of low incidence. Owing to the multiplicity of the factors, plague forecasting is more complicated and difficult than that of cholera and small-pox and my full paper should be studied by any one attempting this task.

Forecast.—It will be seen from Table III that in no province during 1929 were the climatic conditions very favourable or unfavourable to plague prevalence during 1930, such as was shown by a great preponderance of — or + signs in years of high and low incidence in the tables in my former paper. There is only then

TABLE III.

Forecast of plague incidence in 1930 *in North and Central India; saturation deficiencies.*

Province.	Monsoon Temperature.	In Hot Season.	In Monsoon Season.	October—November.	Forecast.
Bihar and Orissa ..	+—	++	++	+—	Below the average.
United Provinces ..	+—	+	+—	+—	About the average.
Punjab	+—	+	— —	+—	Average to slight excess.
Central Provinces ..	+—	++	+—	++	Below the average.

Note.—High saturation deficiency in January to March and high mean temperatures in March and April lessen the incidence of plague, and *vice versa*. The above forecast will be influenced by any material departures from the normal in these respects in the climatic conditions in the early months of 1930.

a fair degree of probability of moderate variations of plague during 1930 in the directions indicated in the table, namely rather low incidence in Bihar and Orissa, and especially in the Central Provinces, and possibly slight excess in the Punjab.

As a whole 1930 is likely, if my forecast is fairly correct, to be one of no very great variations of cholera, small-pox and plague in India from the average incidence of the last decade, except the regularly recurring twelve-yearly Allahabad Kumbh Fair cholera one in Bihar and the United Provinces.

THE *ANOPHELES STEPHENSI* PROBLEM IN CALCUTTA.*

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THE seasonal prevalence of *Anopheles stephensi* Liston has been studied in Calcutta for one year, viz., from July 1928 to June 1929, in an area almost one square mile in extent in Central Calcutta, with a view to studying this complex problem and the best methods of control of this notorious malaria carrier species of anopheline in Calcutta, the second city of the British Empire. The area under survey is bounded on the north by Mechuabazar Street and Cotton Street; on the south by Bowbazar Street, Lalbazar Street and Dalhousie Square North; on the east by Amherst Street; and on the west by Charnock Place and Clive Street. It consists of ward 8, and parts of wards 7 and 9. According to the latest census in 1921 the population and number of occupied houses in this area were as follows:—

	Population.	Number of houses occupied.
Ward 7 ..	32,959	4,550
Ward 8 ..	38,510	7,125
Ward 9 ..	69,670	15,115

* Being a paper read at the Medical and Veterinary Research Section of the Indian Science Congress, Allahabad January, 1930.

The prominent places of public importance in this area are the Bengal Secretariat buildings, the premises of the Calcutta School of Tropical Medicine, the Medical College and allied hospitals, Calcutta University, the Presidency and

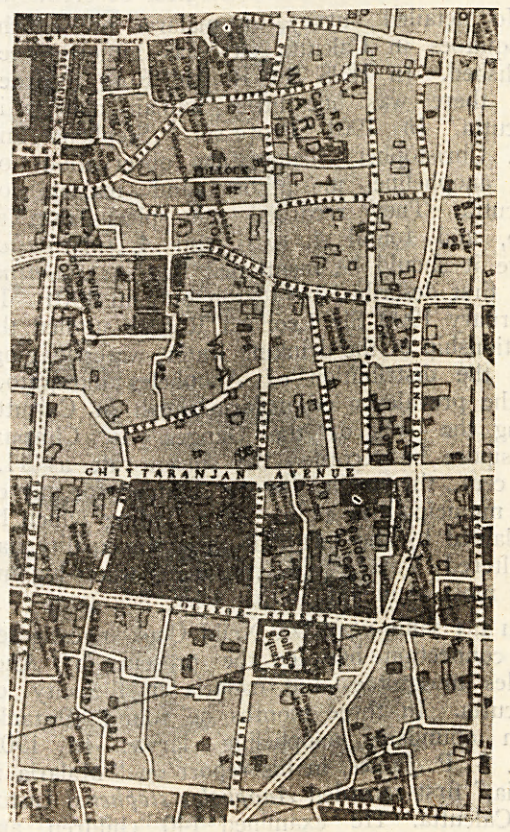

Fig. 1.—Sketch map of the area of Calcutta surveyed.

Sanskrit Colleges, the Marwari Hospital, the Indian Association for the Advancement of Science, the Royal Exchange, and a large number of banks and mercantile offices. Fig. 1 gives a map of the area in question.

The land may be considered to be more or less flat, though it has a very slight slope towards