Section of Epidemiology and Preventive Medicine

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SYMPOSIUM ON WEATHER AND DISEASE

Mr. R. G. Veryard (Meteorological Office, Harrow):

Availability and Processing of Meteorological Data

There can be no disputing the fact that there is some kind of interrelationship, either direct or indirect, between many diseases to which man is susceptible and his geophysical and geochemical environment. The London "smog" disaster of December 1952 is a sad example. Yet in spite of the advances which have been made in medical and meteorological knowledge precise information is still lacking.

Now we all know that a little knowledge can be a dangerous thing, and this is particularly true of the science of Meteorology. I should therefore like to urge very strongly that the study of the relationship between weather and disease should be a joint effort on the part of experts in the various disciplines, meteorology, biology, physiology, &c.; the experts should work together as a team rather than as individuals. As an example, I can point to the joint efforts of the meteorologists and plant pathologists in the study of plant disease—efforts which have resulted in the issue, with a high degree of accuracy, of warnings of the outbreak of potato blight.

For the study of the relationship between weather and disease what meteorological data are available and how best can these data be used? First, I should mention that in this country, as in most other countries, meteorological observations are made mainly to meet forecasting requirements. By international agreement, surface observations are made at standard hours, 0, 3, 6, 9, &c. G.M.T. from a network of stations about 75–100 miles apart and upper air observations at the standard hours, 3, 9, 15 and 21 G.M.T. from a more open network of stations, about 150–200 miles apart. At many official stations, especially at airfields, additional surface observations are made every hour. To facilitate the processing of data by machine methods special forms have been devised for tabulating observations so that the information can be punched directly from the forms on to Hollerith cards. Now it is important for climatological purposes that observations be obtained from a much closer network than is needed for forecasting purposes—from a network that will include stations representative of the climatic characteristics of all types of terrain. To achieve this, the Meteorological Office has recruited about 500 co-operating stations—stations maintained by local authorities, research institutions, schools, colleges, and quite a few by private individuals. Most of these stations make observations once a day, at 9 G.M.T., and send in returns to the Meteorological Office at the end of each month. Then there are stations which produce autographic records—records of rainfall, of wind, of sunshine—as well as of temperature and pressure. Finally, there are a small number of stations which make observations of solar radiation—the direct beam, the diffuse radiation on a horizontal surface and the total radiation on a horizontal surface. A few stations record illumination and at Kew Observatory the net flux of radiation is observed. No routine observations are made of ultraviolet or of infra-red radiation: from the medical point of view this may be a pity as the ultraviolet in particular, and maybe the infra-red also, are believed to have an important bearing on human health.

In the archives of the Meteorological Office there is now a wealth of data available for research purposes. But it must be remembered that for many investigations, e.g. for the study of insect life, standard meteorological observations are of little use and it is necessary to make special observations with special instruments; the Meteorological Office has already carried out many micro-meteorological studies and can thus give useful advice regarding instrumentation for such work. It should also be borne in mind that it is misleading to think of climate in terms of averages. When considering questions of health and fitness, especially in a country which experiences such variable weather conditions as ours, extremes are important—especially extremes of radiation, temperature and humidity; but probably the greatest factor of all is the frequency and degree of the changes from day to day. There seems to be little doubt that most people react to changes of weather but it is still not known why, other things being equal, we should feel better in some weather conditions than in others. Maybe it is the cooling power of the atmosphere, maybe it is the ozone content, maybe it is the electrical state acting through the nervous system, or through.
changes in the blood stream; but to determine what the factors really are careful scientific research is necessary.

Broadly speaking, there are three ways of carrying out bioclimatological and biometeorological studies—but it may be necessary to combine one method with another, or to use all three methods. The first is the purely statistical approach—the method of correlation, either to test some preconceived physical relationship, or to obtain some clue to a physical relationship. There has been an enormous amount of statistical work in the field of bioclimatology and biometeorology and, if I may say so, a large amount of this work has been quite fruitless—either because of misuse of statistics or misuse of data. For example, there is the misuse of long period meteorological records either because the data are not strictly homogeneous on account of changes in the "exposure" of the observing station (e.g. urbanization at Kew) or of climatic fluctuations, or because of the effect of "persistence". Moreover, meteorological factors do not operate as simple variables; each of several factors may influence animal response in a multi-variable manner.

A second method of investigation, which is common in meteorological and other physical sciences, is the dynamical or "energy balance" approach. A good example of this method, as applied to the field of biology, is a recent paper by Mr. C. H. B. Priestley, a meteorologist (1957). He shows how the heat balance of a sheep or other animal may be studied within the framework of a simple equation (to which Mr. E. N. Lawrence will refer later). The analysis carried out by Priestley largely separates the external or physical heat factors from the internal or physiological heat factors and thus facilitates the collation of experimental results and eases the burden on the field investigator.

This leads to the third line of attack on bioclimatological problems—the experimental approach, either in the laboratory or in "the field". A very good example of this is the work being carried out by physiologists attached to expeditions now in Antarctica who are studying the degree of acclimatization which man can acquire when he moves into a Polar region. The latter investigation has been described by Dr. Otto Edholm (1957).

One of the most neglected chapters in British climatology is the study of the health values of our climate. Fig. 1 (reproduced by kind permission of English Universities Press Ltd., from "The English Climate" by Dr. C. E. P. Brooks, 1954) shows what are called the "bracing" and "relaxing" areas of England and Wales and is based on the assessments obtained by a medical expert, Dr. E. Hawkins (1923). Maybe a meteorologist would have produced a similar map based on cooling power—I don't know. Anyway, I am sure a medico and a meteorologist working together would have produced a more reliable map!
Mr. E. N. Lawrence (Meteorological Office, Harrow):

The Application of Meteorological Data to Medical Problems

The problems here discussed arose mainly from enquiries received by the Climatological Services Division of the Meteorological Office. They are dealt with by meteorological or medical personnel or jointly.

Mr. Veryard has emphasized that “standard” meteorological observations cannot readily be used for micro-climatological study. Their limitations are well appreciated when trying to answer the common lay question “where to live?”—perhaps in connexion with some specific disease and stating interests or requirements such as low incidence of fog, low humidity or mild temperatures. This question can be answered broadly by describing regional climates, but the effects of local or micro-topography should not be ignored.

A mere pimple of a hill, 100 feet high in an otherwise plain area, may experience significantly different minimum temperatures, wind regime and ground conditions. In an industrial area, an elevated site may receive considerably more sunshine; in hilly areas, sites sheltered from wind may experience more valley fogs, mist and frost. I have found a gradient of several degrees Fahrenheit per 100 feet of height in the temperatures at one to four feet above the ground around Elstree Hill—and similar gradients elsewhere in the country. To summarize, one should realize that micro-climatic or local differences can be just as important as regional differences.

Site selection concerns not only those seeking a healthy retreat but also local councils and the Ministry of Housing when planning satellite towns. Site selection and architectural and engineering design must allow for infrequent meteorological phenomena such as strong winds, tornadoes, tidal waves and floods, and the more general conditions upon which health depends, as, for example, the limits of wet and dry bulb temperatures, the requirements for treating certain diseases and, in some regions, the climates of insect-breeding areas (e.g. rain-made breeding pools for mosquitoes) and wind direction relative to insect habitats. Health depends also on sensory comfort, and psychological or aesthetic factors.

Thermal comfort conditions are illustrated by data from Kip and Courtice (1945) for the East Indies. The data show that slight air movement produces a marked shift of the comfort zone towards higher temperatures. Referring to visual comfort, one must distinguish between hot dry climates with glare from bright ground and sunlit buildings, and hot humid climates where discomfort is caused mainly by bright sky glare. Olfactory comfort and air pollution are closely related to wind direction and atmospheric stability. Regarding acoustical comfort, wind greatly influences noise dispersion. The speed of sound equals a constant times the square root of the absolute temperature plus the “following wind” component. Sound waves tend to be refracted downwards when wind increases with height and therefore also when temperature increases with height. Thus prevailing wind direction during temperature inversion may be considerably important in avoiding noise.

An interesting investigation by the Australian Meteorological Service, in connexion with the Olympic Games held at Melbourne during November and December 1956, compared the most likely weather conditions at Melbourne during those months with conditions at previous Olympic Games and conjectured whether athletic performance would be more or less favoured than hitherto. The full investigation is described in a paper called “Weather and the Olympic Games” (published by the Bureau of Meteorology of the Commonwealth of Australia) against the background of the heat balance equation:

\[ \text{M} + \text{S} + \text{H} = \text{E} + \text{R} + \text{C} \]

where M stands for metabolism, S for storage, H for short-wave radiative gain and E, R and C the evaporative, long-wave radiative and convective losses.

In the equation, M, S, E and H may be measured and from this R + C may be calculated.

The possible values of the heat balance terms are quoted in the paper. Unfortunately, the experimental work obtaining the results was enacted indoors under controlled conditions and with a very low rate of air movement, 0·2 mile an hour, and the factor representing air movement is open to doubt, as no work has been carried out (at least until recently) beyond an air speed of 6 m.p.h.

Below are some examples of work done by the British Climatological Services Division:

- Following the London smog disaster of December 1952 detailed information on air temperature, vapour pressure and the number of hours of “thick” and “dense” fog (over
a period of eight years) was supplied to the Statistical Unit of the Medical Research Council for use in investigations on atmospheric pollution.

Study of weather conditions during certain periods of noticeable damage to laundry supplemented chemical with meteorological evidence in an investigation to ascertain the source or sources of atmospheric pollution.

A further enquiry came from a research worker desiring to relate humidity to respiratory disease. The evaporation rate inside the respirator apparatus may be estimated from the difference between inhaled and exhaled air. Let ingoing air have an absolute temperature \( T \), a vapour pressure of \( e \) millibars and a volume \( V \) cubic metres per hour and exhaled air a temperature of 95° F. (308° A.), a relative humidity of 95%, and hence a vapour pressure of 53.5 millibars, and a volume of 308 V/T cubic metres per hour. The inhaled air will contain 216.7 e/T grams of water vapour per cubic metre or 216.7 eV/T grams per hour and the exhaled air will have \( \frac{216.7 \times 53.5 - 308}{T} \) grams per hour and the difference

\[
\frac{308}{T}
\]

between these values, i.e. 216.7 V (53.5-e)/T grams per hour represents the rate of loss of moisture. This expression indicates that the relevant "humidity" element is vapour pressure. In January, moisture loss is 25% greater than on an average day in July. On the coldest winter day, evaporation may be from 50 to 75% greater than on a sultry day in summer.

A further avenue of investigation concerns poliomyelitis. Briefly, much attention has been given to temperature and humidity (or some measure of atmospheric moisture content). The writer has computed (Lawrence, 1956) the correlations of maximum weekly notifications and total annual notifications with annual "accumulated degree-weeks" (computed from the weekly mean temperature in England and Wales) from a base of 60° F., and obtained values of 0.85 and 0.83 respectively, which are indeed rather striking. These results do not preclude a close relationship between poliomyelitis and some measure of evaporation or atmospheric "drying power", for the function of accumulated temperature employed is indicative of the atmospheric "drying power" of a particular summer in Britain.

REFERENCES


Dr. P. J. Lawther (Medical Research Council Group for Research on Atmospheric Pollution, St. Bartholomew's Hospital, London):

*Climate, Air Pollution and Chronic Bronchitis*

The clinical condition of patients with chronic bronchitis may vary markedly from day to day. The influence of weather is commonly recognized and the serious effects of gross urban pollution have been manifest in various smog episodes. Recrudescence of infection is, of course, another important factor. In towns climate and air pollution are closely linked and both merit attention as possible aetiological factors in the production of chronic bronchitis as well as causes of exacerbation. It is important to recognize the separate nature of these divisions of the problem. Likewise it must be realized that the chemical and physical nature of polluted air is extremely complex and as yet ill-understood; pollution varies widely in both quality and quantity. Recent analytical work (Waller and Lawther, 1955, 1957) has shown that it is dangerous to regard smog as a specific miasma compounded of smoke and fog; it is wiser to regard fog and pollution as having more independent lives of their own, though obviously their coincidence is of chemical and clinical importance (Fig. 1).

![Fig. 1.—Concentration of smoke and occurrence of fog in London during a "smog" period in January 1956.](From Brit. med. J. (1957) ii, 1478; by kind permission)
Smog is better referred to as acute urban pollution and it ought to be regarded as a rare and freakish occurrence. It is not merely a quantitative variant of the day-to-day airborne dirt. The effects of air pollution and various climatic factors may be investigated by two complementary techniques: the experimental approach involves the exposure of subjects to isolated factors under controlled conditions and the effects must be interpreted with due recognition of the limitations of the method. The epidemiological approach consists of the observation of the undisturbed patient in his carefully defined environment. Elaborate techniques are necessary only if the truth of the matter is deeply hidden, and the crude method described here illustrates the value of a simple initial approach to the problem of the separate effects of weather and pollution.

In 1954 patients who regularly attended a special clinic at St. Bartholomew's Hospital for chronic bronchitis and emphysema were given diaries in which they were asked to record their own assessment of their condition by means of a simple code

A. Condition BETTER than usual.
B. Condition THE SAME as usual.
C. Condition WORSE than usual.
D. Condition MUCH WORSE than usual.

The state of the group was plotted against pollution and climatic data and the value of this technique was quickly established when it was seen that an episode of acute pollution in the absence of fog resulted in marked clinical deterioration of the patients (Fig. 2).

![Graph showing effect on 29 bronchitic patients (St. Bartholomew's Hospital) of high pollution without fog.](image)

**Fig. 2.**—Graph showing effect on 29 bronchitic patients (St. Bartholomew's Hospital) of high pollution without fog.

[From Brit. med. J. (1955) ii, 1356; by kind permission]

A method of scoring was applied to subsequent results, from which was derived a figure called the "degree of illness":

\[ A = -1; \quad B = 0; \quad C = 1; \quad D = 2. \]

Then Mean Score = \[ \frac{\text{Sum of scores for all patients}}{\text{Number of patients}} \]

The mean score provides a measure of the "degree of illness" of the group as a whole, ranging from 0 to 1 in winter and falling below 0 in summer.
In the winter of 1955 the scheme was extended (with the kind help of Dr. C. M. Fletcher and other chest physicians) to five centres in London and others in the provinces. It was hoped that in the event of a smog disaster it would be possible to correlate the diary results with special tests made by the Department of Scientific and Industrial Research. These tests proved to be of limited value but the diary results yielded very valuable information. 180 diaries from patients in the London area were examined and the degree of illness of this population plotted against pollution and climatic data measured in central London (Fig. 3).

![Diagram showing degree of illness of a group of 180 patients in Greater London with chronic bronchitis, plotted with smoke and SO₂ concentrations, temperature and humidity.](image)

**Fig. 3.—Graph showing degree of illness of a group of 180 patients in Greater London with chronic bronchitis, plotted with smoke and SO₂ concentrations, temperature and humidity.**

[From *Instrument Practice*, 1957, 11, 611; by kind permission]

The degree of illness is seen to be more closely related to pollution than to any other factor during the winter months but this connexion disappears when pollution falls in the spring. It is noteworthy that decreases in visibility do not always correspond to a worsening of the condition of the group and this strengthens the suspicion that fog itself may play a less important part than was formerly thought. These results do not imply any direct causal relationship between smoke and SO₂ and the clinical state of the patients, but show that pollution, of which these substances are at least indicators, is probably causally involved. The scheme has again been extended and further analytical data, including sulphuric acid measurements, are being collected. The interpretation of these results is as yet very incomplete, but they provide for the first time evidence that chronic bronchitis is influenced markedly by day-to-day variations in urban atmospheric pollution.

**REFERENCES**


**Dr. B. B. Waddy** (London School of Hygiene and Tropical Medicine):

*Atmospheric Humidity and Air-borne Epidemics*

The countries bordering on the south and east of the Sahara experience cerebrospinal meningitis (c.s.m.) in a way with which no other part of the world compares. For example, c.s.m. was epidemic in the United Kingdom in 1940 and 1941; adding together the figures for the two years the attack rate was roughly 1 : 10,000. Ordman (1932) gave an attack rate of 3 : 1,000 as the greatest he found in an exhaustive historical survey of the disease in southern Africa. In contrast to these figures, in a large area of Northern Nigeria the
mortality rate in a single season was estimated at 33 : 1,000, and in the cycle of epidemics in the western Northern Territories of Ghana with which I was concerned the total attack rate was 81.9 : 1,000. Lobar pneumonia also is an epidemic disease there.

Epidemics of this severity occur only during the dry season, and only in the dry savannah areas of the Sudan, Nigeria, Ghana and the intervening French territories. All epidemics end at the same time, the end of April. When c.s.m. is first introduced into a susceptible area the epidemic seldom gets under way until about the middle of February, half-way through the dry season. The first epidemic, therefore, is usually not a very big one. There are never more than occasional sporadic cases during the rains, but in its second dry season in an area the epidemic may start at the very beginning of the dry season—the turn of the year. With seven or eight weeks longer in which to develop, the second season's epidemic in an area tends to be the enormous one, and apparently leaves local mass immunity.

In the Northern Territories of Ghana it has been possible to trace the complete epidemiological picture of c.s.m. since its first introduction there in 1906. Apart from being confined to the dry season, intense epidemics are also confined to only the western side of the Northern Territories. The only explanation of this lies in the different types of house in common use. In the epidemic-free areas the dwelling consists of thatched round-houses each with a door opening on to a central compound; in the epidemic area the houses have mud roofs; they may be enormous in size, with perhaps 300 rooms, and most of the rooms are reached by internal connexions from very few outside opening doors. Inside them, therefore, there is a complete absence of ventilation and impermeable darkness.

Epidemic lobar pneumonia has the same distribution and seasonal timing. Smallpox is not so strictly dependent on climate, but in the savannah smallpox epidemics invariably die out at the end of the dry season. Everything in this epidemiological picture is extremely clear-cut although no bacteriological work has been done. Glover's conception of the epidemic following in the train of an increased carrier rate would fit the observed facts of African c.s.m., if the carrier rate is dependent on dryness of the atmosphere. Initially, the carrier rate rises slowly from a small nucleus of migrant carriers, so that epidemic conditions take some weeks to ensue. At the end of the dry season carrier rate and epidemic die away rapidly and simultaneously, leaving a number of chronic carriers. These make a more widespread infective nucleus at the start of the next dry season, when the epidemic develops earlier.

In temperate climates, since the time of Hippocrates it has been known that air-borne epidemics tend to occur in late winter and after cold snaps, the change of weather taking about a month to take effect. Unless the epidemiology differs radically from that in the tropics, there must be something in common between the English home in February and the inside of a particular type of African house during the dry season. There are two such factors.

The first is a lack of daylight. Miller and Schad (1944) found that the meningococcus survived and kept its virulence for at least a week if kept dry and cool and in complete darkness, and that survival was roughly inversely proportional to the intensity and shortness of wavelength of light to which it was exposed. Field observations fit in with this finding. The incidence of the different types of house in Ghana is very striking. In England and Wales in 1940-41 there were higher attack rates in counties in which coal mining was the predominant occupation. In New Zealand, Dixon (1943) found an association with refrigerator workers. The common factor is darkness or artificial light.

The other factor is low absolute humidity (A.H.). In the epidemic zone of Africa, relative humidity (R.H.) drops extremely low during the dry season, and A.H. follows an exactly parallel course. In temperate climates A.H. is almost independent of R.H. and entirely dependent on temperature, being at its lowest in February and highest in July and August (Figs. 1 and 2). C.s.m. incidence in 1940 and 1941 showed obvious peaks at the nadir of the A.H. curve. In fact, the A.H. on a cold foggy day in England and a dry hot day in Africa are very much the same, 2 to 4 grams per cubic metre.

In Ghana in 1948 between case incidence and the A.H. of four weeks previous there was a correlation coefficient of —0:53, s.e. 0:20. In this country, the only prolonged series of carrier rates of which I know is that of Glover (1918). The correlation coefficient between carrier rate and A.H. of four weeks previous was —0.78, s.e. 0:29. The A.H. figures were outdoor ones, but experiments I made myself during the winter of 1947 showed that the indoor A.H. does not rise very much above that outdoors (Waddy, 1952).

Elsewhere in the tropics, Rogers (1926) correlated smallpox and lobar pneumonia with low A.H. The association of the three waves of the 1918-19 influenza pandemic with cold dry weather was noted both in this country and in France. More recently Thorburn (1957) correlated air-borne infections with low A.H. in southern Africa.

There is experimental evidence that air-borne organisms do live longer in conditions of low A.H. (de Ome, 1944; and Loosli et al., 1943). As far as is at present known, therefore,
bacteriological evidence supports field epidemiology. So does physiological evidence. The amount of water that has to be evaporated in the upper respiratory passages and added to the inspired air depends on the absolute, not relative humidity of the outside air. Looked at from this point of view, the saturated air of a February day, A.H. about 4 grams per cubic metre, is very much drier than that of a hot dry July day, A.H. about 11 grams per cubic metre. The evaporation of water produces also a cooling effect, and it is well known that ciliated epithelium does its job sluggishly when cooled. This may well apply specially when there has been a sudden change of weather, before physiological adaptation has taken place.

REFERENCES