LECTURES, REPORTS, LETTERS, AND PAPERS ON SANITARY QUESTIONS

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ROBERT RAWLINSON

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LETTERS, AND PAPERS

ON

SANITARY QUESTIONS.

BY

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1876.

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TO

EDWIN CHADWICK, Esq., C.B.,

AS THE

CHIEF PROMOTER

OF

MODERN SANITARY WORKS AND APPLIANCES

BY

THE AUTHOR.

London, 1876.

SANITARY ENGINEERING.

A LECTURE ON METEOROLOGY delivered in the month of November, 1868, before the Royal Engineers, at their Establishment, Chatham.

In the construction of many important works, engineers find that they have to contend with much hostile action of the elements; consequently it is absolutely necessary that the technical education of engineers should include a study of Meteorology—the science which (in addition to other phenomena) treats of the evolution of heat and moisture, of evaporation and condensation, of tornadoes and calms, of wind and rain, of ocean waves, river currents, land absorption, and land floods.

For the purposes of this lecture, it appears desirable to omit detailed notices of abtruse meteorological questions concerning the origin of storms and electric phenomena, such as the formation of cumulous clouds, hail, tornadoes, and water-spouts. Considerations such as these, which are powerfully affected both by general causes and by local influences; would, on the present occasion, have a tendency rather to bewilder than to give information. To certain specific facts connected with the science of Meteorology, as applicable to works of water supply and drainage, this introductory lecture will, therefore, be devoted; and these facts will be set forth in simple language; my purpose being to lead you onwards, from first principles and elementary facts, to those conclusions which eventually I shall place before you.

This earth consists, on its surface, of ocean and dry land, the relative areas of the two being about in proportion of 7 to 3. Assuming, therefore, the entire surface of the earth to be 200 millions of square miles, then the ocean has an area of about 140 millions of square miles, leaving an area of about 60 millions of square miles to the dry land.

Thus constituted at its surface, the terrestrial globe is enveloped with an atmosphere composed of oxygen and nitrogen gases, nearly in the proportion of two atoms of the latter gas to one of the former; and, in combination with these two gases there also exists a fractional per centage of carbonic acid gas. In this atmosphere water is present in the form of vapour.*

The one main source of heat to the surface of the earth and atmosphere, and of electric action, is the sun. By the action of the sun, also, is produced all those phenomena of Meteorology which we have to consider.

That great reservoir of water, the salt ocean, is the prime source of all "fresh water," wherever and however it may be present, either upon the surface of the land, or within the stratafied crust of the globe. And it is through the process of evaporation that all "sweet" or "fresh water" is obtained from the salt waters of the ocean.

If the heat emitted from the sun were, year by year, uniformly the same, there would, necessarily, be uniformity of evaporation; and this would imply a corresponding annual uniformity in precipitation of vapour in the form of dew, snow, hail, or rain. On the other hand, the reverse of these statements will be equally true: that is to say, irregularity in the emission of heat from the sun must be attended with a corresponding irregularity in the volume of ocean-water evaporated, which last irregularity must also in the same degree affect the volume of fresh water obtained by precipitation. Whether the heat of the sun, year by year, be uniform, or whether it is subject to fluctuating variations, it may be assumed as certain, that the heat-giving action only varies within certain limits, and so conforms to every other known operation of nature; for we observe the grand phenomena of the elements obeying a law which, out of apparent irregularity and inequality, brings forth equality and order, just as a pendulum ever beats true time in its swing, however great or however slight may be its motion; such variety pervades nature's working, and such is the type of variety in the transmission of solar heat to this earth; that so, in a series of years, an average temperature is determinable, to which may be referred all those complex and wonderful changes that are perpetually taking place on the surface of the globe.

The leading facts to be recognised by engineers are consequently these: there is evaporation from the ocean caused by the heat of the sun; and in proportion to this heat is the volume of water that in each year is evaporated; this vapour, whatever its volume carried into the atmosphere, must again be precipitated in the form of fresh-water. These grand evolutions of the elements can be brought under no control by human power.

Experience has demonstrated that in different countries and climates the annual volume of rain which falls is subject to con-

* The permanent gases of the atmosphere are nitrogen, oxygen, and carbonic acid. The first two are always found in nearly unvarying proportion of 80 per cent. of nitrogen and 20 per cent. of oxygen, with carbonic acid in a fractional proportion—from 3·7 to 6·2 in 10,000 parts.

siderable variations. In the equatorial regions, for example, where the sun's heat is greatest and most powerful, evaporation is necessarily most copious and the rainfall is heaviest; and, as we approach either pole, with decreasing solar heat evaporation decreases and the rainfall is in a proportionately diminished volume. But in no region of the earth's surface does evaporation cease. Vary as it may, evaporation is general and constant. It takes place incessantly, wherever the ocean extends. Even icebergs and the broad floes of the polar oceans evaporate. In tropical regions, as well as in the colder zones of the earth's surface, vapour is constantly passing into the atmosphere, again to be condensed and become fresh-water; and at all temperatures (boiling or freezing) this act of evaporating water implies the absorption of *latent* heat, which heat is again given out, sometimes accompanied by lightning and thunder, when invisible vapour is condensed into water, as tornado, water-spouts, deluging sheets of water, gentle rain, snow or hail.

The fall of rain is determined by the amount of invisible vapour which is carried up into the atmosphere, as also by terrestrial causes, such as latitude, the relative position of land and water, plains, valleys, mountains, and air-currents (winds) which all act and re-act upon the process of precipitating vapour into rain. This may be illustrated simply by what takes place year-by-year in our own country. In England the annual average fall of rain is from 30 to 36 inches. The distribution of this rainfall is, however, singularly arbitrary, as the average fall of rain in one portion of the Lake districts is not less than 150 inches in each year; and even 300 inches of rainfall has been experienced at Styehead. In contrast with this, on a portion of the eastern coast of England the average yearly fall of rain does not exceed 20 inches; and, in a dry season, it sinks down to 14 inches. In the Thames valley, the average yearly fall is 27 inches. On the western coast of England, as also on the southern, the rain which regularly falls year by year considerably exceeds in volume the rainfall on the eastern coast. This result is produced by a greater local prevalence of the south-west wind, which brings in the vapour-laden atmosphere from the Atlantic Ocean, and much of this vapour, as it sweeps towards and over the backbone ridge of our island, becomes condensed, and precipitates heavy rains in the districts that lie towards the south and the west.

During the actual descent of the heaviest rain over any area of fall, the process of evaporation is maintained. Recent researches have led to the discovery that, in England, the amount of constant evaporation is greater than previously had been supposed. [There do not appear to exist any certain data which may be accepted as determining accurately the comparative amount of evaporation in the tropics.] But, if we take the valley of the Thames, which contains an area of about 5,000 square miles, and where the yearly average rainfall amounts to 27 inches, we find something nearly approaching to two-thirds of the entire fall of rain re-evaporates and passes again, in the condition of invisible vapour, into the atmosphere.

That is to say, about two-thirds of the entire volume of the rain that falls upon the area of the Thames valley, and is there measured in the rain-gauge, is not measurable in the river or in any of its numerous springs and feeders; nor could this large proportion of the whole yearly rainfall be admitted by an engineer into his calculations for any works to be constructed by him for water-supply in the valley of the Thames. He could really rely only upon one-third of the measured rainfall, and of that third one-half now passes away in floods, and the other half by perennial river flow. Once more: take the valley of the Lee, a tributary of the Thames, having an area of 500 square miles. Four-fifths of the rain-fall is not measurable to the river—a fact which has been determined by accurate gaugings taken during the last twenty years. It has been demonstrated that four-fifths of this rainfall passes away through re-evaporation.

I now desire to direct your attention to some important considerations in connection with "averages." In questions of water-supply engineers have been in the habit of considering that they have to deal with averages. It is necessary that you should distinctly understand when and how averages are liable to be fallacious. An average is useful when an appeal is made to it to indicate the *general* difference that exists between one district and another district. But if averages of annual rainfalls in any particular locality, for however long a period taken, are accepted and adopted as giving the true basis upon which either sewers or works for providing a water-supply should be projected, subsequent experimental test of use and supply would be certain to show that the engineering works had been designed and built upon misleading data. The engineer, in such a case, would find that the averages to which he had trusted had misled him. This arises from the fact that his averages had made no provision for encountering and dealing with exceptional circumstances and *occasional excesses*—excesses, probably, which may occur only at long intervals, but which, when they do occur, may be both sudden in their appearance and violent in their operation. Averages extending over a period of one hundred or more years would be required, in order to secure their including and accounting for occasional excess; and even then an average would fail to indicate the amount of precaution that would be required to meet and provide against maximum excesses.

The average fall of rain for the entire surface of the earth may be assumed at 150 inches; and if we apply the rule of ⅓ loss for a dry season, and ⅓ more for a wet season, the dry season would give 100 inches, and the wet season 200 inches. If any such variation can be even approximately settled, we may then conclude that there is a corresponding annual variation in the heat and evaporating power of the sun.

Some districts of the earth's surface are rainless, and other districts are exceptionally wet. Some mountain ranges are so lofty as to prevent vapour passing over, whilst all ranges and