LECTURES TO SANITARY OFFICERS.

WATER SUPPLY FOR DOMESTIC USE.

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THE plentiful supply of water for domestic purposes of good quality is of paramount importance, as we now know that many diseases, cholera and typhoid fever especially, may be spread by drinking foul water.

As all sources of water supply are derived from rainfall, a short consideration of this interesting subject will be necessary before proceeding to the various sources of supply themselves.

The amount of rainfall varies in different parts of the world, and even in different parts of England. The average rainfall over England may be taken at 30 inches per annum, equivalent to 3,000 tons per acre. In parts of India, however, more than this amount has fallen in one day.

It will be useful and instructive to explain here how rainfall is measured. The apparatus for measuring rainfall is called a rain-gauge, and the size usually adopted is 8 inches in diameter. The most generally useful pattern is made of copper, in two parts, and consists of a lower cylindrical part and an upper deep funnel part, with a strong truly-turned rim of brass, leading by a small pipe into a bottle within the copper cylinder, so placed as to be protected from breakage by frost and from evaporation. A small graduated glass of an area one-tenth of the mouth of the funnel is used to read off the amount of rainfall direct in inches and decimals of an inch.

The rainfall over the British Isles varies considerably, and the best way of studying its distribution is from the map prepared by Mr. J. G. Symons, F.R.S., for the Sixth Report of the Rivers Pollution Commission.

Upon this map rainfall contours or lines of equal rainfall are shown, and the spaces between or areas of equal rainfall are

sources of
water.

rainfall Evapo-
ration and Per-
colation.

Fig. 1.

SEASONAL VARIATION
OF
FLOW OF UNDERGROUND WATER.

Fig. II.

Fig. III.

Fig. IV.

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coloured blue. The light blue are the area of light rainfall, and the darker blue tints the areas of heavy rainfalls.

On looking at the map, it will be seen that the rainfall upon the area east of a line from Newcastle to Reading has an average of less than 25 inches. The portion west of this imaginary line has a rainfall of 30 inches and 40, while the Welsh and Cumberland mountains and Dartmoor have 75 inches, and Sty Head Pass in Cumberland has as much as 175 inches.

The amount of rainfall varies also with the seasons. The districts having a low average rainfall, 20 to 25 inches, have the greater part of the rain in summer, and, generally, districts with a rainfall over 30 inches have most of it in winter.

The following is a useful approximate rule.

The fall in the driest year is one-third less than the mean fall.

The fall in the wettest year is one-third more than the mean fall.

Continual evaporation is going on from the surface of land and sea, and this is eventually returned to the earth as rain, dew, or mist. The amount of evaporation depends upon the temperature of the air, the higher the temperature the more the evaporation. It has been stated that from tropical seas 100 inches per annum are evaporated. Evaporation.

The water which falls as rain or snow upon the earth is disposed of in three ways. A certain portion runs off the surface to the streams and rivers, another portion sinks into the ground or percolates and forms the vast "underground waters," of which we shall have something to say later on, and a third portion is evaporated and absorbed by vegetation. Percolation.

It has been stated that:—

One-third of the rainfall flows off the surface.

One-third percolates forming the "underground waters."

One-third evaporates.

This, however, is only an approximation to the truth, as the proportions differ enormously in different seasons of the year and under different conditions.

The sources of water supply to which we shall direct our attention are as follows:— The various sources of water supply.

- 1.—Gathering grounds.
- 2.—Streams and rivers.
- 3.—Springs.
- 4.—Wells.
- 5.—Rain-water from roofs.

The waters which drain off uncultivated lands in hilly districts not manured, or only slightly manured, are often impounded, Upland Surface Water.

and the water supplies of some of our large manufacturing towns in Yorkshire and Lancashire form notable examples of such works. For example, the water supplies of Liverpool, Bradford, and Bolton. The city of Dublin is also supplied with water from the Wicklow Mountains, 26 miles distant.

These impounding reservoirs or lakes are formed by building a dam across the neck of a valley suitable to contain a supply of some months even in the driest year.

Peaty matters are frequently present in upland surface water, giving it a decided colour. Filtration through beds of sand is sometimes made use of to remove peaty matters and discolouration.

Waters supplied from natural lakes, such as Glasgow from Loch Katrine 34 miles distant north of the city, may also be considered as upland surface water. This Loch Katrine supply took the place of the much-polluted Clyde water, and the construction of the works was due to the genius of the late J. Frederick Bateman, F.R.S., Civil Engineer.

For engineering purposes in estimating the water supply from a catchment area the least rainfall has to be considered, as this is the crux of the question.

The rainfall which flows directly off the surface forms rivulets, which join to form the streams, which again flow to the river systems.

The rivers and streams were formerly the usual source of water supply, and London is the most notable example of a city supplied by river water. The city and county of London is supplied by eight water companies, five of which draw their entire supply from the River Thames above Teddington. It has been stated in evidence that during the summer of 1887 more than one-third of the entire flow of the river was taken for the water supply of London.

The water supply from rivers has been abandoned to a great extent, on account of the pollution of rivers by raw sewage, and this brings me to say a few words about the deplorable pollution of many of our beautiful rivers.

Unfortunately, the Public Health Act of 1848 encouraged the emptying of raw sewage into rivers. It is certain that, unless a more workable Act can be obtained, most of our rivers will become not only polluted but will be in many instances a danger to health.

The existing Rivers' Pollution Prevention Act has been adverted to in the late Royal Commission on London Water Supply by Dr. Ashby, Medical Officer of Health for Reading, as "more or less a dead letter."

We have seen already that the source of all water supply is from rainfall. Of the rain descending upon the ground, part percolates into the soil and descends through it to a level where it is held up by an impervious stratum, such as many of the clay beds. The amount of percolation has been measured by what are called percolation gauges, the earliest form being that of Dr. Dalton, of Manchester.

Springs and the flow of underground water.

Extensive experiments have also been made by Sir John Lawes and Sir H. Gilbert upon percolation gauges of an area of $\frac{1}{1000}$ of an acre.

In order to bring before you in a graphic manner the relation between the rainfall and the rise and fall of the underground water, a diagram has been made which is from the one prepared by Mr. Rogers Field and the author for the article on "Water" in "Our Homes,"* and is, as far as the author is aware, the only attempt to show graphically the connection between rainfall percolation and the rise and fall of the underground water.

It is commonly known to those who have to draw water from deep wells by means of a bucket and rope, that they have to wind up more rope in autumn than in winter; or to express this more carefully would be to state that the level of the water in the well is at its lowest in October and November, and then rises rapidly until February and March, when it is as a rule at its highest level, and then it gradually sinks through the summer to the autumn low level.

Referring now to the diagram, Fig. I., which is drawn out for ten years, it will be noticed that lines divide each year into four parts, and the divisions of winter and summer are also marked. The upper part of the diagram shows the heights of the underground water in the chalk, as measured at Chilgrove, Sussex, by Mr. Woods, and are plotted in feet above the bottom of the well, which is taken as the datum. The lower part of the diagram shows the rainfall and percolation in inches, the percolation amounts being the black portion. The rainfall is from the record kept at Chilgrove, and the percolation in the chalk is from the records kept at Nash Mills, Hemel Hempstead.

Now the first thing which will be noticed on examining the diagram is that the bulk of the percolation is in the winter (except in the year 1879), when the ground is already saturated, and that there is none in the summer, because of the evaporation and absorption by vegetation. The next noticeable feature is that the underground water is highest in the early part of the

* "Our Homes and how to make them healthy." Cassell & Company.

year, January and February, and lowest in October and November, and that it follows the amounts of percolation.

Not only is the level of the underground water rising and falling as we have seen, but it is always moving slowly through the strata containing it with a definite gradient towards certain outlets, sometimes to a river, sometimes to the sea level, the latter case is well shown by the Brighton section, see Fig. II. The general notion prevails that a well has only to be sunk at some desirable spot, and if you are fortunate you find water in some such way as you might find a nugget of precious metal, but a moment's consideration will show that this is not the case. Where water is found by sinking a well you are drawing from the general underground water. This is a very important point, as we shall see further on. The upper and lower dotted lines in the diagram, Fig. II., show the high water and low water levels, from which it will be seen that great seasonal variations exist, the water in the wells B, C, D, E, rising and falling considerably. In the autumn months the underground water level would be along the dotted line on the diagram A, G, but in the winter it would have risen along the line A, D, E, F, the water standing in the wells at a higher level, and the gradient being much steeper towards the outlet A. In chalk districts the seasonal variations are from 50 to 100 feet.

In districts where an impermeable stratum underlies permeable or porous strata, such as the gravel "outliers," upon the clay around London, wells sunk into the porous strata will yield water at depths varying considerably according to circumstances. The distinction between shallow wells and deep wells is not very clearly defined, but, speaking generally, wells sunk into superficial beds are called shallow wells, and wells sunk into geological formations and deep beds are called deep wells. Such, for example, as the deep wells in the New Red Sandstone at Liverpool, and the deep wells in the chalk around London.

In some cases, owing to the position of the water-bearing strata, the water rises to the surface, and in some instances considerably above the surface, as at the celebrated well at Grenelle, near Paris, and many in our own country. These wells, the water from which rises above the surface, are called Artesian wells, so named from the province of Artois, where they have been long in use.

Tube wells, or Abyssinian wells, form a simple means of reaching water-bearing strata at moderate depths, and have much to recommend them from a sanitary point of view. They have in many instances yielded good supplies on a small scale.

Rain water collected from roofs in rural districts gives an excellent supply on account of its great softness. It is, how-

Wells—
allow wells,
deep wells,
artesian wells,
tube wells.

Rain-Water
from Roofs.

ever, quite insufficient under many circumstances, but where earth-closets are used it may sometimes be made sufficient. Great care should be taken to prevent leaves, soot, and refuse from entering the storage tank. The best way is to have a rough filter, constructed in two portions, one merely as a settling chamber, and the other a rough filter of small washed stones.

With reference to the quantity of water obtainable from roofs, this is entirely governed by the rainfall of the district in the driest year, and the area of the collecting roof. In the West of England the average rainfall may be assumed as 36 inches, and the fall in the driest year as 24 inches. Taking the loss from evaporation and absorption at two inches, we have 22 inches of rain left as available. In the East of England the average rainfall would be 24 inches, and the minimum 16 inches, and taking a loss of two inches as before, we have 14 inches as the available rain in a dry season.

There is a very simple rule by which the available quantity of rain-water may be calculated approximately. It is as follows: Multiply the area covered by the roof in square feet by the average annual rainfall, also in feet, and divide the result by 100, will give the average supply in gallons per diem for a very dry year.

The next most important point with reference to rain-water collection is to have sufficient storage or a tank of sufficient capacity to tide over the longest droughts. The simplest way is to calculate the capacity of the tank from the roof area, and it has been found by practical experience that two gallons for every square foot of roof area must be allowed for in constructing the tank.

Much interesting and useful information on the collection of rain-water from roofs will be found in a pamphlet by Mr. Rogers Field, International Health Exhibition Handbook, 1884.

As rain-water has the quality of great softness care must be taken not to use any lead pipes or connections in pumps or fittings. Cases have been known of water pollution caused by a piece of lead pipe being used to join the iron suction pipe to the pump barrel, in fact, the ordinary piece of lead pipe supplied with hand pumps.

When water is pumped from a well the effect is first of all to lower the surface of the water in the well, and afterwards to lower the underground water for a distance around the well, and if the stratum is fairly homogeneous this depression will be equal around the well, and will extend in a circle drawn with the well as a centre. In some cases, however, the figure would be more or less irregular and would not be a circle.

Depression of the Under-ground water caused by pumping.

This depression has been likened to an inverted cone, as was

The Liverpool Corporation took measures to induce the Local Sanitary Authority to carry out a system of sewerage, and divert the drainage of the houses from the cesspools, and by these measures the quality of the water in the deep well was so improved that pumping was resumed, and the water from the deep well was again used for the supply of Liverpool.

The recent case at Worthing is another striking instance of the water in a deep well becoming polluted by sewage escaping from leaky sewers and drains.

In diagrams showing the pollution of water in wells by sewage, it is generally indicated by streams of sewage matter issuing from the sides of the well, indicating a direct passage of sewage from drains and cesspools into the well. Although as you are well aware this is sometimes the case, it is by no means the most usual mode of pollution.

The usual cases met with in practice are much less apparent, as the pollution is effected by the sewage passing into the underground water and not into the well direct.

The polluted underground water may reach the well in two ways. 1st—by the natural movement or flow of the underground water. 2nd—by the polluted water being drawn towards the well by the influence of pumping.

The diagram No. IV. has been prepared to show the first-mentioned case, where AA indicates the level of the underground water in permeable strata, BB being impermeable strata holding up the water. A porous cesspool at C is allowing sewage matter to percolate until it reaches the underground water. At X and Y are wells sunk into the underground water.

Now it has been previously explained that all underground water has a slow movement towards some outlet, and it therefore depends which way the underground water is supposed to be moving whether the wells are polluted or not. If the movement is from X to C no pollution takes place unless depression by pumping causes it. If on the other hand the movement is from C to X pollution must take place whether there is pumping or not.

Sending the sewage into a porous cesspool in permeable ground near a river will not prevent the river from being more or less polluted, inasmuch as the underground water will be polluted, and this will flow by its natural movement into the river.

The second case of polluted underground water reaching a well is shown by the diagram No. III. before referred to. If the well is pumped down to A it will not draw the water from beneath the cesspool, but if pumped down deeper to A' it will

influence the underground water to a greater distance, and pollution will be drawn into the well from the cesspool.

Another important consideration will be seen from the diagram, viz., that a well which gives good water when only slightly used may become seriously polluted if drawn upon largely so as to extend its sphere of influence to cesspools which were outside the sphere of influence when only slightly drawn upon; for instance, a well might give quite a good water for the supply of a house where a bucket or hand-pump is used, but if steam-pumping were resorted to for the supply of a village the water might become contaminated.

Composition of
water from
various sources.

It is not proposed in treating of this part of our subject to go into the question of chemical analyses, but simply into the quality of water as affected by the gathering ground or the strata through which it passes. When rain has descended upon the earth it depends obviously upon the character of the gathering ground and the strata through which it passes for its hardness and impurities. The length of time also in which it is in contact with those surfaces, calcareous and magnesian soils or strata cause water passing over them to be hard.

The evils arising from the use of hard water are very apparent, not only in cooking and washing, but in hot-water apparatus for heating and hot-water supply, and also in steam boilers.

It has been calculated that a saving of £36,000 per annum in soap alone was effected in the city of Glasgow by the introduction of the soft water supply from Loch Katrine.

Water may be softened by distillation, by carbonate of soda, by boiling the water, and by the lime process of Dr. Clark. The first and second methods are effective but too expensive on a large scale. The third and fourth are efficient only with certain classes of water. The fourth, however, is cheap and applicable to large town supplies. Carbonates of lime or magnesia (temporary hardness) can be removed by Dr. Clark's process. The process known as the Porter-Clark process is largely used for softening water for manufacturing purposes, for ice making, and for use in locomotive engines on railways.

The quantity of
water required
for various
purposes.

From a return made to Parliament in 1879 of the water supply of every urban sanitary district, the amount used was shewn to be from five gallons per head per diem to 50 gallons per head per diem.

The quantities of water supplied to various towns is as follows:—

London (average) 31.19 gallons, according to the recent Report of the Royal Commission on Metropolitan Water Supply.

Manchester 21·00, proposed to be 50 to 60 gallons when new works are finished.

Norwich 14·50.

Glasgow 50·00.

Ancient Rome is calculated to have been 300·00 gallons per head per diem.

A supply of from 20 to 25 gallons per head per diem is sufficient for ordinary houses with baths and water-closets, but for horses a separate allowance should be made. If water be required for watering a garden or for ornamental purposes it must be reckoned separately.

In country places if earth-closets are adopted less water would be required, 15 to 20 gallons per head per diem would be ample. In cottages with earth-closets still less supply would be required, and there 10 gallons a head per diem would suffice.

The allowance generally made for various purposes is as follows:—

Domestic	...	...	...	...	9 gallons.
Water-closets	...	...	...	...	5 "
Baths	...	...	...	...	5 "
Washing	...	...	...	...	3 "
Waste	...	...	...	...	3 "
Town Purposes	...	...	...	...	5 "
Trades	...	...	...	...	5 "
Total					35 "

By the term constant supply is meant that water is continuously supplied to the house, *i.e.*, that the service pipes to the houses are always kept full under pressure so that water may be drawn by the taps at any time direct from the main.

Constant and
Intermittent
supplies.

By intermittent supply is meant that water is only turned on to the house at stated intervals, necessitating the use of cisterns to store the water.

The chief advantage of the constant system is that the water can be drawn direct from the mains without storage in cisterns, so that the pollution which so often takes place in cisterns can be avoided. This pollution occurs in a number of ways well known to you, *viz.*, the connection of the overflow pipe of the cistern direct with the sewer; by dirt collecting in cisterns; or by rats, mice, or birds. As an instance of the latter pollution, a friend tells me that a bird entered his cistern through the overflow pipe, and the bird died there as it was a covered cistern, and caused pollution to the water. The subsidiary

advantages of the constant supply is that water may be drawn fresh and cool direct from the main. The cost of storage cisterns is avoided, and only flushing cisterns are required for W.C.'s.

Also the water is constantly on all the branch mains in case of fire.

The advantage of the intermittent supply was supposed to be prevention of waste of water, but recent experience has shown that the constant supply is as economical as the intermittent.

The intermittent was formerly the usual method of supply, but the constant supply is now being adopted, and even in London, the most striking instance of intermittent supply, the constant system is being largely introduced.

Water meters are in England generally only used for trade and manufacturing supplies, the domestic supply being charged according to the rateable value of the house, with certain extras.

In Berlin and other places on the continent the whole supply is charged for by meter.

Where service reservoirs are in the neighbourhood of towns there is evidently always danger of the water in them being contaminated, and they should therefore always be of covered construction.

In the case of water mains it would at first sight appear that it is impossible for the water in them to become polluted, as if there were a bad joint or hole in the pipe, or even a broken pipe, water would escape under pressure and there would be no tendency for extraneous matter to enter the water main. This is not true even when the pipes are kept constantly full of water, as under certain conditions, which, however, do not often occur, the water rushing past a hole may create an insuction.

In practice, however, even with a constant supply, the pipes are not always kept full of water, as they have to be emptied for repairs and for making new branches, and when emptied an entirely new condition is introduced. A vacuum is often then created, so that there is a powerful insuction into the pipes through any opening there may be.

If the main therefore passes through polluted ground, which is generally the case in towns, polluted matter will be sucked in, and when the water is turned on again into the mains it will become distributed with the general supply.

Many outbreaks of fever have been traced to contamination of the water supply in this way.

Waterworks filter beds generally consist essentially of a thick layer of sand over coarse gravel, in which porous pipes are laid to convey the filtered water to a storage reservoir. A film of

Supply of water
by meter.

Contamination
in reservoirs and
water mains.

Filters.

glutinous silt collects on the top of the sand, which gradually chokes the filter, and this has to be cleaned off at intervals.

Waterworks filters if properly managed are very efficient, but it is very different in the case of domestic filters. These require cleaning and renewal as much if not more than the waterworks filters, but as a matter of fact they do not receive the proper attention, in fact, they are frequently not attended to at all. Consequently, they often collect so much objectionable matter that they make the water passing through them worse instead of better.

This is especially the case when animal charcoal is used, as the pores become clogged with putrescible organic matter, which forms a breeding ground for living organisms.