PRICE SIXPENCE.

LECTURE

BY

W. ARNOLD EVANS, ESQ., M.D.,

Medical Officer of Health for Bradford,

ON

WATER SUPPLY,

Delivered in the

COURT HOUSE, WAKEFIELD,

On SATURDAY, APRIL 30th, 1892,

Being the eighth of a series of Twelve Lectures on Sanitary Subjects.

Under the Auspices of the Sanitary Institute, the Yorkshire College, the Boroughs of Halifax, Huddersfield, and Sheffield, and the West Riding County Council.

Published by AMOS FIRTH, WONDER STREET, WAKEFIELD.

WAKEFIELD:

C. W. CARR, "Herald" Offices, Westgate.

LECTURE BY
W. ARNOLD EVANS, ESQ., M.D.,
ON
"WATER SUPPLIES."

SYNOPSIS OF LECTURE.

Quantity required, and for what purposes—Sources—Rainfall—Surface Waters—Springs—Wells (Shallow, Deep, Artesian)—Rivers—Characters of each and their respective liability to Contamination—Hard and Soft Water—Public and Private Supplies—Constant and Intermittent Service—Inspection of Water Supplies—Taking Samples—Value of Analysis—Relation to Disease—Lead Poisoning—Preventive Measures—Means of Purification—Filters.

The eighth of the series of lectures on Sanitary Science was delivered in the Court House, at Wakefield, on Saturday, April 30th, 1892, under the presidency of Colonel Mackie, J P., of Heath Common, who was supported on the "platform" by Dr. Kendell, Dr. Whitelegge, Mr. Trevor Edwards, Dr. Wright, and Mr. Massie.

The CHAIRMAN, in commencing the proceedings, said:—Gentlemen, my duty is a very simple one this afternoon. I have not had an opportunity of attending any of these lectures previously, but I have had the privilege of reading some of them, and certainly must conclude that they are not only highly interesting, but exceedingly instructive. I have the pleasure of introducing this afternoon Dr. Evans, the Medical Officer of Health for Bradford, and I am sure we shall all listen with the greatest interest and attention to what he has to say upon the subject before us—that of "Water Supplies."

Dr. EVANS then gave his lecture. He said:— Mr. Chairman and Gentlemen, the subject of my lecture, namely, the supply of water, being one that can only be considered in an elementary and somewhat superficial manner in the course of an hour or so, I shall not detain you with any prefatory remarks, but at once ask for your serious attention while I describe many interesting facts in connection with it, and explain a few others with regard to which opposite opinions are held by different authorities.

USES OF WATER.

Water is a prime necessity of life; its uses are numerous and varied. It is necessary for drinking, for the cooking of food, for the preparation of drinks for man and beast, for personal ablution, for washing utensils, clothes and habitations, for the removal of sewage and the flushing of drains, for cleansing streets and extinguishing fires, and for various trade purposes which we need not consider in detail. What, then, under ordinary circumstances is the amount which individually is required? In estimating the supply and consumption of water, engineers are in the habit of stating the amount per head of the population, which figure is got by dividing the total number of gallons supplied by the number of people using the water. Let us consider the various uses of water *seriatim*. The quantity used for drinking depends greatly upon the climate, temperature, and the amount of work done. However, in this country, and under ordinary circumstances, an average man of 12 st. in weight takes daily about 80 ozs. of water, much of which is contained in the solid food, leaving only two pints or thereabouts to be taken in liquid form. For cooking, the quantity consumed is liable to considerable variation, but the amount is generally not less than three-quarters of a gallon to one gallon daily. Taking all ages and sexes together, the smallest amount that may with safety be put down for drinking and cooking purposes is one gallon per head per diem. For the washing of household utensils and dishes, a certain amount of water is required, and this, though by no means a fixed quantity, cannot be less than that which is requisite for cooking, so that one gallon is perhaps a fair estimate. For cleansing the house and yard another two gallons would perhaps suffice, so that if the two last items be added together, as is usually the custom, three gallons may be allowed. Another three gallons would be wanted for the washing of clothes, and in most houses where the washing is done at home, probably more. In the matter of personal cleanliness it is also necessary to make an estimate; and here much depends on the habits of the individual. In houses where general baths are taken daily, the consumption will be much greater than in those in which only sponge baths are used, or where a general bath is a somewhat rare occurrence. Assuming, however, that each person has a sponge bath every day, or a general bath once a week, about five gallons would be added to the daily consumption. It will thus be seen that for domestic purposes, leaving out of consideration such luxuries as baths, twelve gallons per head is the least amount, compatible with cleanliness, that should be allowed; but if the washing is sent out, then nine gallons would suffice. An additional quantity must be provided for water closets in those places where a water carriage system of sewerage exists, and five gallons per head is the usual estimate. This amount may at first, sight appear to err on the side of extravagance, but on account of numerous leakages in connection with some closets and the repeated flushings necessary in many others, I think it is little enough. A margin on account of inevitable waste also enters into the calculation—leaking water mains, defective taps, and burst service pipes are matters of every-day occurrence, and three gallons per head are usually estimated by engineers as being due to "unavoidable waste." Municipal purposes also claim their share in the distribution of water, and the amount generally given is five gallons per head. I refer, of course, to the watering of streets, extinguishing of fires, flushing of drains, &c. We thus see that the daily allowance of water per head of the population in non-manufacturing towns is about 25 gallons, but in districts where mills and factories abound, a further allowance of five gallons per head must be granted. The quantities may be tabulated:—

	Gallons.
Domestic Supply	12
General Baths	5
Water Closets	5
Unavoidable Waste	3
Total House Supply	25
Municipal Purposes	5
Trades and Manufactures	5
	35

For farmhouses, dairies, stables, mistals, and the keeping of cattle, I am unable to give an estimate, but, suffice it to say, the supply should be unstinted and as much used as is necessary to keep premises and animals in a clean condition. The average supply to the various towns sometimes exceeds the amount above stated, and often falls below it. The quantities consumed in some of the largest towns are as follows:—

	Gallons per head daily.
London	40
Manchester	21
Norwich	14.5
Bradford	24
Glasgow	50
Paris	44

New York	83
Middlesborough	140

These figures refer to large and populous centres only. In rural districts, when the inhabitants have not the advantage of being supplied by a good Water Company or by the Corporation of a neighbouring town, but have to draw their water from wells, so large a supply for domestic purposes as 25 gallons per head daily is seldom obtained, nor indeed is it necessary. If there be no drains to flush and no water closets to supply, the amount per head is materially reduced; and if, as happens in some rural localities, the water has to be carried for any distance, the "unavoidable waste" is reduced to a minimum. It is commonly stated that the extremely small quantity of three or four gallons per head daily is the average consumption in places where water is difficult to obtain, but this state of things is, I should imagine, incompatible with ordinary cleanliness.

SOURCES.

Let us now consider the sources whence we obtain that amount of water which is so essential to cleanliness and healthy living. All water as met with on the earth's surface comes to us in the form of rain. Enormous quantities of water are continually being absorbed by the atmosphere from the surface of the sea. In tropical climates it is computed that no less than 52 gallons yearly are evaporated from each square foot of sea, or $2\frac{1}{4}$ million gallons per acre, most of which ultimately returns to the earth's surface in the form of rain not very far distant from the place whence it was taken up in the shape of vapour. But in this part of the world evaporation does not occur with such rapidity and on so large a scale, consequently the rainfall, although perhaps spread over a long period of time, does not attain the proportions that one meets with in some other latitudes.

RAINFALL.

Stated briefly, and somewhat roughly, the rainfall in the British Islands, as ascertained by means of the rain-gauge, averages about 30 inches per annum, but showing great variations in different years, even at places situated at about the same altitude above the sea level. In Ireland and on the West coast of Scotland and Wales the rainfall is much above the average for that of the country generally, reaching as high a figure as 154 inches on an average of six years at Seathwaite, in Borrowdale, a village 422 feet above the sea level. On the other hand, in some of the Eastern counties of England the rainfall occasionally descends much below the average. We can, however, each year rely on a certain amount of rainfall, and from a large number of observations it has been found that the fall in the wettest year is a little more than double that of the driest year; consequently, for the purposes of water-supply, engineers adopt the rule that the fall in the driest year will be one-third less than the mean fall, and the fall in the wettest year will be one-third more than the mean fall. The amount of rain falling differs also with the season of the year. As a general rule, those districts (*e.g.*, the Eastern counties of England) which have a small annual rainfall receive the greater part of it during the summer, and those districts with a large annual record receive the major part of their rain in the winter months. On the West Coast of the British Islands the wettest month is January, but a second maximum is reached in October; and on the East coast the October rise is the chief maximum. The difference between the various months as regards rainfall in London is not great, the wettest month (October) giving 2·74 in. on an average of 60 years, and the driest month (viz., February) giving 1·50 in.

Now the water which falls in the form of rain is ultimately disposed of in several ways. One part of it, namely, that which runs off the surface, *i.e.*, "surface water," eventually joins our streams and rivers, unless intercepted and impounded in some storage reservoir. This portion of the water often becomes seriously polluted, especially if flowing over cultivated land; another part of the water is lost by evaporation, or taken up by trees and plants to form part of their tissues; the third part percolates into the earth, and joins that immense but invisible reservoir, the "ground water," reappearing in the form of springs perhaps at some very distant point. The proportion of water disappearing in each of the above-mentioned ways has been differently stated by different observers, but the relative amounts must vary according to the nature of the soil, the contour of the land, and the season of the year. Rain falling upon a highly porous material, like gravel, sand, or chalk, will rapidly disappear by sinking into the ground; but if the district be largely composed of hard rock or stiff clay very little will percolate into the subsoil. In hot climates more water will be lost by evaporation than in colder regions, and even in the same district evaporation will be greater in summer than in winter. A glance at the following table shows the influence of soil and climate on the amount of water lost by percolation. It is seen that the percolation is much greater in winter than in summer, and, conversely, that evaporation is more active in summer that in winter; also, that the quantity of water disappearing into the subsoil varies with the permeability of the subsoil itself.

		Dalton Soil. 3 years.	Evans Chalk. 7 years.
		Inches.	Inches.
WINTER— October to March	Rain	14 2	11·9
	Percolation	5·8	6·9
	Difference or Loss	8·4	5·0
SUMMER— April to September	Rain	19·4	14·6
	Percolation	2·6	3·0
	Difference or Loss	16·8	11·6
ENTIRE YEAR—	Rain	33·6	26·5
	Percolation	8·4	9·9
	Difference or Loss	25·2	16·6

These figures have been arrived at by experiments on artificial gauges, and not by calculating the amount of percolation from the variation in the yield of springs; but there is every reason to suppose they are fairly accurate. As I have already stated, the amount of percolation varies in different years. If the greater part of the rainfall occurs during a hot summer, and in small quantities at a time, a relatively large quantity will be lost by evaporation, and the amount sinking into the ground very small; but if, on the other hand, the rainfall be heaviest in winter, the percolation will be correspondingly great.

GROUND OR SUB-SOIL WATER.

Passing from the consideration of percolation, I now come to consider the matter which is to a great extent dependent upon and closely associated with it, namely, the ground water, or water contained in the sub-soil. It is only by obtaining a clear knowledge of the movements of the ground water that the apparently anomalous conditions of wells and springs, of which I shall presently speak, can be understood, and I must first of all ask you to carefully distinguish between moisture in the soil and "ground water." The distinction is clearly defined by Dr. Parkes in the following words—" When air, as well as water, is present in the interstices of the soil it is merely moist. The ground water must be defined as that condition in which all the interstices are filled with water; so that, except in so far as its particles are separated by solid particles of soil, there is a continuity of water." From this definition it follows that under ordinary conditions the superficial layers of the soil, although always moist, do not contain the ground water, but that the moisture in their uppermost layers, especially after seasons of drought, is derived from the sub-soil water by the forces of capillary attraction and evaporation. It is by these agencies, assisted by the rise and fall of the ground water itself, that the soil in most parts of the world is constantly kept damp. As a matter of fact, the level of the ground water is liable to great variations; it rises or falls at different rates in different places, and at any place depends to a large extent on the rainfall and amount of percolation. In Munich, according to Professor Pettenkofer, the highest level during the year is one foot, and the lowest ten feet below the surface of the ground. An inspection of the diagram before you indicates a close relationship between the ground water level and the amount of rainfall disappearing by percolation into the ground. If the level of the water in a deep well in any porous stratum, *e.g.*, chalk, be regularly observed during a series of years it will be found the water attains its lowest level in October or November and then gradually rises till the end of the following February or beginning of March, falling again in the Autumn. The greatest amount of percolation takes place in winter, and scarcely any in summer; also the rise in the water level of the well closely follows the increase in percolation, and a short interval intervenes, *e.g.*, when the percolation commences in October the level of the well water rises in November, and if the percolation is greatest in January the water in the well attains its maximum in February or March. In exceptional years, such as 1879, with an unusually large amount of summer percolation, it was noticed that the rise in the level of the water followed the amount of precolation, and that two maxima were obtained instead of one. This annual rise and fall of the ground water is known as the "seasonal variation," and its extent depends chiefly upon the porosity or permeability of the geological strata; in chalk the seasonal variation of the ground water level is often fifty feet, and occasionally more; in sandstones and impermeable formations it is considerably less. But in addition to its seasonal variation in level the ground water is possessed of another movement. It is constantly, though slowly, moving towards the nearest outcrop of the impervious stratum which holds it, making its appearance in the form of springs, either in some valley, river-bed, or on the sea coast. A section of the watershed of any two rivers would show the sub-soil water to possess not a flat or perfectly level surface, but a curved one, the highest part of the curve being generally at a point equidistant from the two water-courses, but depending to a certain extent on the compactness of the soil and its inclination The presence or absence of forests influences to a large extent this movement of the underground water, for large quantities are absorbed and held back by the roots of trees. After the clearance of wooded districts in the upper reaches of a river, flooding of the low lying land further down has frequently occurred. Observations taken on the height of water in wells also show that the level of the sub-soil water rapidly falls as it approaches any natural outlet, such as a river bed or a series of springs, consequently the difference in the summer and winter level of those wells situate at a great distance from the outlet will be greater than that of those placed near a river or the sea coast where there is practically no seasonal variation in the height of the ground water. You will thus see that the question of the under-ground water is of vital importance from a sanitary point of view, both as regards the amount of water procurable from wells and springs, and, as I shall presently show, as regards the danger of pollution of water obtained from these sources. Many diseases have from time to time been attributed to the existence of a high or low level of the ground water, and we can imagine its rise and fall to act prejudicially upon health in two ways, viz., by causing a permanently damp condition of the soil above it, as happens in retentive soils, *e.g.*, clay, and, in the second place, by forcing organic emanations out of the ground during a rapid rise, or by leaving the soil in a moist condition during its subsidence after reaching an unusual height. Of the diseases affected by the ground water it was unquestionably proved years ago by Sir Geo. Buchanan that the occurrence of wasting diseases of the lungs, *e.g.*, Phthisis, bore a constant relation to the height of the underground water. He showed that in many English towns the mortality from these diseases had fallen about 30 to 50 per cent. since the introduction of a system of sewerage and the draining off of the ground water; and other observers have noticed the same facts. The development of malarious fevers, too, in those countries where they exist is doubtless influenced by the rise of the ground water which produces the amount of moisture in the soil necessary for their production. Numerous cases proving this have been put on record by army surgeons and others living in the malarious parts of India and other tropical countries. This idea of the prejudicial action of a rise in the subsoil water in malarious countries receives strong confirmation in the fact that in the fen districts of Lincolnshire, where the level of the ground water has been permanently lowered by drainage, the malaria which at one time was very rife has now almost disappeared. Other diseases, notably Diphtheria and Diarrhœa, seem to be to some extent dependent on the moist condition of the soil, which is again influenced by the height of the subsoil water. The influence of the subsoil water on health is well stated by Dr. Parkes in the following words :—

> "A uniformly low ground water, say 15 to 20 feet, is most healthy, but a uniformly high ground water, say 3 to 5 feet, is preferable to one that is fluctuating, especially if the limits be wide. It must, however, be borne in mind that it is not the ground water itself that is the cause of disease, but the impurities in the soil which the varying level of the ground water water helps to set in action."

Let me now pass on to consider our different sources of water supply in some detail, commencing with

RAIN WATER.

In country districts rain water generally forms an important part of the water supply, and in those districts in which the water of springs and wells is very hard, a supply of rain water is exceedingly useful for such domestic purposes as washing and cooking. It is soft and well ærated, and when not contaminated during its fall, or by defective methods of collection or storage, is the purest of all waters. But in the vicinity of towns it receives many impurities from the atmosphere, including organic matters, sulphurous and sulphuric acids, which give it an acid reaction and large quantities of tarry and carbonaceous matter derived from the combustion of coal. Near the sea it generally contains chlorides and sulphates in small though appreciable quantities. In its passage through the atmosphere rain-water becomes well ærated, and the gases contained in solution are oxygen, nitrogen, carbonic acid, and ammonia, with occasionally a trace of nitric acid, particularly after thunderstorms. The quantity of rain water available can be calculated by taking into consideration the average rainfall in the district and the area of the collecting surface. Speaking generally, the following rule gives results which are liable only to an error of about 4 per cent. The area of the collecting surface in square feet, multiplied by one quarter of the rainfall in inches, gives the amount of water obtainable in gallons. As a rule, two or three gallons per head daily can be obtained by collecting the rain from the roofs of cottage houses—a quantity which must be a very useful addition to the supply obtained from wells in hard water districts. Sanitary Inspectors in rural districts may do good work and materially lessen the consumption of contaminated well water by recommending the collection and careful storage of water falling on the roofs of cottage houses. Unfortunately, this valuable supply is in many instances allowed to run to waste, and in others completely ruined by storage in filthy water-butts and cisterns.

SPRINGS.

Of these there are two varieties, generally known as "main springs" and "land springs." The latter arise from a superficial bed of sand or gravel lying upon an impermeable stratum of clay or rock, consequently their flow is very irregular and immediately dependent on the rainfall, the effect of a heavy shower being at once apparent in the augmented flow. These springs are usually dry during the summer. A main spring, on the contrary, is one which derives its supply from some deep-seated water-bearing stratum, such as chalk, greensand, or other definite geological formation; its flow, although liable to variation during the dry season, is more constant than that of a land spring, and the deeper the stratum from which its supply is obtained the more regular is the flow. But even the deep-seated springs are liable to a seasonal variation, their yield being at its lowest in October or November, and gradually increasing till the following February or March, when the maximum is reached. The water of superficial springs is liable to contamination by organic matter, and frequently contains impurities derived from the surface layers of the soil. If situated near cultivated land or in the neighbourhood of a graveyard it should not be used for drinking purposes. Very recently I was called upon to investigate an outbreak of a troublesome disorder, the chief symptoms of which were diarrhœa and dyspepsia. I could only attribute the epidemic to contamination of the drinking water, which was procured from a superficial spring situate in close proximity to a cemetery. As soon as drinking water was obtained from another source the complaint disappeared. Deep spring water, on the other hand, is generally bright and sparkling, owing to the quantity of gas, especially carbonic acid in solution, and is palatable and wholesome. The organic impurities which might have been originally imparted to it in passing through the soil have either been filtered out by the various geological strata which it has traversed, or oxidised and converted into nitrates.

WELLS.

For classification, wells are divided into two varieties, viz., shallow and deep wells, the distinction being that the former are entirely contained in a superficial bed of gravel or sand, and the latter sunk into a definite geological formation, *e.g.*, chalk or sandstone; so that the distinction between the two kinds is very similar to that between land springs and main springs. An examination of a diagram in Dr. Whitelegge's book on "Hygiene and Public Health" will show you that a well completely contained in a superficial stratum of sand or gravel may be actually deeper than a so-called "deep" well, which has pierced a regular geological stratum—in other words, the shallow well may have a greater depth from the surface of the ground than a deep well. Nevertheless, in the Sixth Report of the Rivers' Pollution Commissioners, the shallow wells examined were under 50 feet in depth, and the deep wells generally over 100 feet deep. A variety of the deep well is the Artesian well, formed by tapping a water-bearing stratum which creeps out some distance away at a higher level. Artesian wells are usually very deep, so that the water when reached is under great pressure, and quickly rises, sometimes with great force, to its own level. The water obtained from these wells, although varying in its constitution according to the strata traversed, generally contains more salts than spring water, but is not so well ærated, and, consequently, less palatable.

Good water may be obtained from a shallow well, provided that precautions are taken to prevent contamination by surface washings. The sides of the well should be lined by a layer of brickwork, well set in cement, outside which there should be a layer of puddle extending for about two-thirds the depth of the well; and in order to prevent rubbish from falling in at the mouth the brickwork should be carried two or three feet above the level of the ground. It is advisable, also, to put a few flags around the mouth of the well, so sloped that the overflow water will immediately be carried away. The top should be covered over, and the water drawn by means of a pump, the supply pipe to which should not be made of lead but of enamelled iron. But in spite of all precautions, wells both of the shallow and deep variety may become seriously polluted if placed near cesspools or other accumulations of filth. Any leaky cesspool must necessarily pollute the underground water, which may carry the offensive matters into some well in its onward course. But much depends on the direction of the flow of the ground water. It is clearly evident that if the ground water is flowing from the cesspool towards the well any soakage from the former will contaminate the water supplied by the latter, so that if the cesspit contains the microbes of any infectious disease, such as Typhoid Fever, it is highly probable that the well water will acquire dangerous properties. But if the ground water flows in the contrary direction, *i.e.*, from the well towards the cesspit, then the former may escape contamination, although the ground water becomes afterwards seriously polluted. An unusually heavy rainfall may pollute a well situate near a cesspit. In dry seasons the surface of the ground-water may be considerably below the cesspit, which, although not water-tight at every point, may not contaminate the ground water. But a wet season, bringing a rise in the level of the ground water, causes it to be contaminated, so that at times of flood the ground water may convey noxious material from the cesspit to the well.

In districts where the conditions are such that cesspits become a necessity the danger may be avoided by placing the well above the cesspit, the direction of the flow of the underground water being ascertained from the situation of the nearest river or water-course, towards which the ground-water always flows. The interior of every deep well should of course be lined by brickwork, in exactly the same way as I described when speaking of shallow wells. Where the yield of a well is not sufficient for the number of houses which depend on it for their supply, or even in dry seasons if the yield be generally ample, the large quantity of water withdrawn reduces the level of the well water, the consequence of which is that the ground water falls for some distance around the spot from which the water is taken, and if the pumping be continued the area supplying water becomes larger and larger, until at last the well is the centre of a large circle of land which is practically drained into it. Now this is a very different state of affairs from that in which the well is supplied by ground water flowing from one direction only, for in this case we know the direction of the flow, and by allowing no accumulations of filth on the weather side of the well, can guard against pollution; but, in the second case, water is drawn from all sides, and cesspits and manure heaps, which were considered to be in a safe position, may now contribute liquid refuse to the contents of the well. The distance, too, from which water is drawn by sinking the level of the well water is very considerable, and is usually expressed in terms of the depression. It has been ascertained by experiment that in chalk this distance amounts to fifty-seven times the depression, so that if the water level be reduced one foot the influence of the pumping extends to a distance of fifty-seven feet in every direction ; in coarse gravel the distance affected is said to be one hundred and sixty times the depression ; and I should think that in fissured rocks it might be much greater.

RIVERS.

The water of rivers is composed of upland surface waters, of land drainage, and water derived from springs in the river bed and watershed. It contains more salts than upland surface water, but less than spring water, and consequently occupies an intermediate position as regards mineral constituents and hardness. But it is liable to serious pollution, especially in populous districts. Not only may the sewage of towns and villages be emptied into the river, but it may also receive refuse from manufactories, mills, and dyeworks, which render the water quite unfit to be a source of supply. It is partly on account of the filthy state of rivers that moorland waters and the headwaters of rivers have to be taken to supply our great centres of population—although I believe that until recently the City of Wakefield was supplied with water from the Calder purified by filtration. Provided the pollution of a river with sewage or organic matter is not great, natural purification eventually takes place through the process of oxidation, and the influence of aquatic plant life, but any river after receiving the sewage of towns and villages, in my opinion, becomes a questionable source of supply, although fairly good water can often be obtained by means of filtration. Such water is, however, always liable to the danger of specific infection, and many epidemics of typhoid fever have been traced to the contamination of river-water by the sewage of one or more villages situate higher up the stream, where cases of the disease were known to have previously occurred. The various waters have been classed as regards wholesomeness and palatability by the Rivers Pollution Commissioners as follows :—

Wholesome	1. Spring-water	Very palatable.
	2. Deep well water	
	3. Upland surface water	Moderately palatable.
Suspicious	4. Stored rain water	
	5. Surface water from cultivated land	Palatable.
Dangerous	6. River water to which sewage gains access	
	7. Shallow well water	

The three first kinds of water are wholesome, but the upland surface water is not so palatable as the spring and deep well water on account of its containing a very small quantity of salts in solution. Where seen in bulk the water from moorland and peaty ground is brownish in colour, whilst that from springs and deep wells is generally bright and sparkling. Stored rain water, although soft, and after æration not disagreeable to the taste, is apt to become fouled by faults in collection or storage, and can only be classed as suspicious. Surface water from cultivated land is always liable to contamination by material washed from freshly manured fields, and occasionally such water has become specifically polluted and given rise to serious epidemics. Polluted river water and shallow well water are both dangerous, and should not be used if any other supply is available.

COLLECTION AND STORAGE.

In sparsely-populated districts situate at a great distance from the conducting mains of a large town, water is obtained from springs and wells or from some natural watercourse in the neighbourhood ; frequently country houses are supplied from a private well on the premises. In searching for such a supply of water the boring should be taken through the superficial bed of gravel or drift and continued through some impervious stratum—in other words, a deep and not a shallow well should be made and the boring such as will extend below the summer level of the ground, or in dry seasons the supply may fail. A good method of reaching water is to excavate an ordinary well in the superficial stratum and then to drive in Norton's tubes, which are jointed iron pipes in sections, the lowest of which is perforated and pointed at the end. As soon as the water-bearing stratum is tapped the water rises in the tube to a certain level from which it can easily be pumped. The yield of a well can be ascertained by lowering the level of the water to a known distance and noting the time required for re-filling. In hilly districts the yield of springs is generally fairly constant, but in a flat country the supply is liable to fail in seasons of drought unless the spring has its source in some stratum at a great depth from the surface. In limestone districts springs are often very constant and are sometimes fed from underground reservoirs made by the solvent action of the carbonic acid of the water on the rocks. There are usually few springs or streams on chalk formations, and wells sunk into them are apt to become dry in seasons of drought. On the other hand, deep wells in old or new sandstone yield a plentiful supply.

For the needs of large centres of population it is necessary to impound the yield of springs and the head waters of rivers. Although large supplies are often taken from deep wells in water-bearing strata, *e.g.*, the supply of Guildford and that of the East Kent Company in London. The easiest method of storing the water of a stream is to construct an embankment across the valley through which it flows and so form a reservoir. Such an embankment will be required to withstand great pressure from the large volume of water held back, and must be of great strength. It usually contains a centre of clay puddle, and is covered on the inner surface with stone, and on the outer with turf. In cases, especially in moorland districts, the water of springs and streams is collected by means of a conduit and conducted to the storage reservoir. By means of a by-wash facilities are afforded for allowing turbid and impure water in times of flood to escape. From such a reservoir the water is conducted to the aqueduct by a pipe so arranged that only the purest water from the centre of the whole mass is taken. The aqueduct in the first part of its course is generally an open channel of stone-work, but afterwards a large iron pipe is substituted, lined with an anti-corrosive material, and wherever bent provided with apertures for cleansing at its lowest points, and air-vents at the summits. The aqueduct delivers the water into small service reservoirs, from which it is sometimes pumped into other reservoirs at a higher level in order to obtain the fall necessary for its distribution by gravitation. It now enters the iron mains and is laid on to the various streets and roads of the district supplied, precautions of course being taken to prevent any leaky main from absorbing soakage from a defective sewer. Houses are supplied from the mains by service pipes controlled by stop valves, which pipes are usually made of lead owing to the ease with which this material can be bent and turned in any direction required, but if the water has any solvent action upon this metal other materials should be used.

If the service of water be *constant*, *i.e.*, the pipes always full at high pressure, and whenever possible this system should be adopted, no temporary storage of water in houses is required; but in places where the intermittent system is in operation, water being turned on only at certain hours of the day, cisterns are necessary in order to store sufficient for consumption during the intervals. Now, cisterns in houses are apt to become sources of contamination, and great care should be taken to have them made of the proper material. Lead and zinc, or any combination of those metals, ought not to be used, on account of their liability of solution. Iron cisterns are objectionable, unless their inner surface is protected by some anti-corrosive material; if this precaution is not taken, the metal soon becomes corroded, and large quantities of it dissolved, giving a red colour to the water and staining any clothes that are washed in it. The best material for cisterns is slate, put together with non-metallic cement. They should be covered to prevent the entrance of impurities, and protected against frost. They should also be placed in such a position as will admit of easy inspection, and be regularly cleaned out. It is highly important that no water-closet be supplied directly from them, but each closet should have a separate cistern and a water-waste preventer, and under no circumstances should any tap be attached to the cistern supplying the water-closet by means of which any water could be withdrawn for drinking or cooking. The over-flow pipe from the storage cistern ought always to be taken through the house wall and end over a gully communicating with the drain, and not be directly connected with any trap or house drain. If this is not done, foul gases will ascend from the drain and be absorbed by the water in the cistern. Cases of diarrhœa and enteric fever have frequently been caused by the neglect of this obviously simple precaution. Another danger connected with the intermittent service is that, owing to the pipes being alternately full and empty, impurities are apt to be sucked into any leak that may exist; so that if there be any broken drainpipe within the influence of such suction-power the water will very likely be contaminated. Outbreaks of fever arising from this cause have been described by Sir George Buchanan. Briefly stated, the disadvantages of the intermittent system of water service are:—

1. That it necessitates the storage of water in house cisterns.
2. That such cisterns, owing to faulty construction or connection with W.C.s or house drains, cause pollution of the water.
3. That there is danger of sewage finding admittance through any crack in the water pipe on account of the suction produced by the alternate filling and emptying.
4. That the interior of the pipes being exposed to the influence of both air and water are liable to corrode and undergo solution.
5. That it is not more economical than the constant system, provided fittings of the latter are efficient.

We have seen, then, that before the water reaches the consumer it may receive impurities at various points. It largely owes its original composition to the geological strata through which it passes, and it is not always possible from a consideration of the geology of the district to say what will be the constituents of a water, for it may have been contained in some hidden stratum before reaching the spot where it is collected. Water from such rocks as granite or millstone grit is very pure, containing only a small quantity of minerals in solution and an infinitesimal amount of organic matter. Limestone and dolomite waters are clear and bright in appearance; they contain the sulphates of calcium and magnesium in large quantities, and, consequently, possess a high degree of permanent hardness; such waters, therefore, are not good for manufacturing purposes, and should not be recommended as a domestic supply if a softer water can be obtained. Water collected from wells in the chalk is always sparkling and agreeable to the palate on account of the large quantity of carbonic acid in solution; it contains calcic carbonate often in large quantities, and is therefore hard, but softens considerably on boiling; it is a pleasant and wholesome water. Surface and subsoil water presents many variations in constitution, all depending on the nature of the ground where they are collected. The surface water from such rocks as the millstone grit, and from heaths and moorlands and uncultivated land, is generally pure, but if the gathering ground contain much peat it is of a brownish colour and occasionally acid in reaction. From cultivated and manured lands large quantities of organic matter may be found in solution, and even in the absence of organic matter nitrates, nitrites, chlorides, and phosphates are sure to be present, indicating some previous contamination with animal matter. Waters from graveyards and marshes are always dangerous as supplies; they contain organic matter in suspension or solution in addition to nitrates and nitrites. The characters of rain water I have already described; it cannot be used in towns on account of the impurities taken up from the atmosphere.

Contamination may also take place in open collecting conduits; heavy rains may wash into them large quantities of debris and decaying vegetable matter. If collected from a ground dotted over with dwellinghouses or farmsteads sewage may find its way into the conduit, and if such sewage contain any specific poison it may seriously contaminate large volumes of water. Trade refuse, *e.g.*, the effluents from dyeworks, etc., would seriously pollute any water supply if allowed to soak into the land through which any stone work conduit is taken. Wells may easily be polluted with organic matter by surface washings and leaky drains. [The Lecturer here gave an instance (taken from an actual case) of how a leaking drain might contaminate a well.] Water contamination may also occur in the service pipes, especially in those made of lead, a metal on which certain waters are known to have a solvent action. This brings me to the subject of

LEAD POISONING,

upon which I will only detain you a few moments. Although much experimental work has of late years been devoted to the elucidation of this subject, the actual cause of the plumbo-solvent properties of certain water has not been satisfactorily explained. Some investigators attribute such action solely to the acidity which exists at certain times in the various waters they happen to have examined; others, including the late Dr. Tidy, thought the absence of a certain amount of silica from the water favoured its solvent action on lead; whilst Mr. Power suggests that some microphyte brings about those occult conditions in the water which impart to it its plumbo-solvent action. The waters which act most on lead are :—

1. The purest and most highly oxygenated, *i.e.*, rain water, and the water of upland streams.
2. Those containing nitrates, nitrites and chlorides, *i.e.*, water contaminated with sewage.
3. Waters containing a free acid; soft peaty waters, such as is supplied to some towns in Lancashire and the West Riding of Yorkshire.

Those waters which have the least action on lead are :—

1. Hard waters containing carbonates, phosphates and sulphates, especially carbonate of lime, which very soon deposit a protective coating on the lead pipes.
2. Those having in solution free carbonic acid, which protects lead piping by the formation and deposition of a basic carbonate.

According to Dr. Garrett, who has made numerous experiments on the plumbo-solvent properties of various waters, the first stage in the process of solution is the formation of an oxide of lead, which is readily dissolved by some waters; he certainly shows that when all access of oxygen to the water is cut off its solvent action ceases. In those waters which contain chlorides or nitrates a further chemical action ensues, resulting in the formation of nitrate or chloride of lead, both of which are soluble in water. In addition to the composition of the water there are other circumstances which influence the action of water on lead pipes. New lead-piping is of course more easily dissolved than that which has been in use for any length of time; it is perfectly obvious that a fresh clean surface of lead is more easily acted upon by any water capable of dissolving it than an old surface partially covered with deposit. But the quality of the lead must also be taken into account, and since the process of extracting from native lead that small amount of silver with which it is generally found alloyed has been introduced, the metal has been supplied in a purer but unfortunately a more soluble form. The length of time water is left to stand in the pipes influences the solution of the metal. Water which has been standing for hours in a lead pipe will contain a certain amount of lead in solution if such water have any, even the slightest, solvent power on the metal. In all districts supplied by water suspected to have any action at all on lead, the service pipes, if made of this material, should be as short as possible, and not be laid along devious paths, through gardens and grounds, as I have not unfrequently seen them, before being taken into the houses supplied; they should also be thoroughly emptied every morning before any water is taken for drinking or cooking; the water thus drawn off not being wasted but set aside for cleansing purposes Although the water supplied to some towns has a marked action on lead, which can be neutralised by the addition of chalk, yet I think too much responsibility in this matter has by many people been fixed on the Water Companies or whatever Corporation it may be that supplies the water. The fact that extensive lead-poisoning from certain classes of drinking water is quite a recent development should make us reflect and ask ourselves whether a change in the constitution of the lead as at present supplied for the manufacture of lead piping may not have something to do with the solvent power of certain waters. At all events, I am thoroughly convinced that if the simple precautions I have described were taken and systematically carried out we should hear less of those epidemics of lead-poisoning which every now and again attract so large a share of attention, but which, nevertheless, are a real danger to the public health. Other circumstances which affect the solution of lead are the temperature of the water and the pressure under which it exists in the pipes; an increase in either favours its solution.

CHEMICAL ANALYSIS.

The most convenient quantity of water to take as a sample for analysis is about half-a-gallon, or a Winchester quart; but if this amount cannot be obtained, the analyist must, of course, make the best of the small quantity sent him. Great attention must be paid to cleanliness, for the amount of organic matter in half-a-gallon of water being so small any carelessness in this particular would destroy the value of the analysis. The bottle should be rendered scrupulously clean by frequent washing with ordinary tap water, and a final rinsing with distilled water is perhaps advisable. Mr. Wanklyn advises a preliminary cleaning with strong sulphuric aid, but this is a proceeding I do not like to recommend. I think that if the bottle contains anything which requires such strong measures for removal as the addition of sulphuric acid it had better not be used. Before the actual sample is collected, the bottle should be washed out with some of the same water as is about to be analysed. If your sample is to be taken from a tap, the water should be allowed to run for a short time until the service pipe is cleared and a supply direct from the mains can be secured. When collecting from a well or pond, the bottle should be completely immersed, and the neck held a few inches below the surface of the water, any floating scum being carefully avoided. River water should be taken from the middle of the stream, at a safe distance from the entrance of a ditch or sewer; unless, for some purpose, you require a sample from a particular point. Having almost completely filled the bottle with the water to be analysed, a clean glass stopper is inserted, and fastened down with a piece of clean calico and string. The bottle is now labelled, the date, locality, name of collector, and any other necessary note being inscribed in legible writing. In the actual analysis, which should be made as soon as possible after collection, the first points to be noted are the appearance, colour, reaction, smell (if it has any) and taste of the water. If there be any turbidity or sediment, some of the water may be set aside in a conical glass, and the deposit, after settling, examined microscopically. All products of animal life may be met with in the deposit, viz., epithelial scales, bits of muscular fibre, &c. These unpleasant objects when occurring in drinking water afford strong evidence that such water is seriously polluted with animal products, and unfit for any domestic supply. Vegetable matters, such as pieces of cotton, linen, hemp, or woody fibre, indicate that refuse from human habitations finds its way into the water. The deposit in water taken from stagnant pools or the bed of rivers frequently contains many beautiful forms of diatomaceæ, and if your lens be strong enough different varieties of bacteria, including micrococci and bacilli, may be seen. Clusters of micrococci may be found in comparatively pure water, and I do not know that their presence is particularly significant; but large bacilli and wriggling spirilli have a certain import, for they can only live in water which contains organic matter in solution. The next point in our analysis is to ascertain the total amount of solid matter contained in the water, expressed in terms of grains per gallon.

The following table, taken from Mr. Wanklyn's "Water Analyses," shows the quantity of solids contained in some of the largest water supplies in the country :—

	Grains per Gallon.
London, Thames Companies	18.5
,, New River	17.6
,, Kent Company	26.5
Manchester Water Supply	4.7
Glasgow, Lock Katrine	2.3
Bala Lake	3.2
Scarbrough Reservoir	28 7
Atlantic ocean	2688.0
Distilled Water	0.1

All these, with the exception of the last two, are wholesome waters, although the amount of total solids shows considerable variation. Provided the total solids do not exceed forty or fifty grains per gallon, the quantity of solid matter in itself is no objection to the adoption of the water as a domestic supply. A further point in the analysis of water is the determination of the amount of chlorine, not of course free chlorine, but chlorine in combination with some metal such as sodium, with which it is usually found combined in the form of sodium, chloride, or common salt. Although an excess of chlorine is in itself no serious fault in a water, provided it is not so excessive as to render it unpalatable, yet the presence of a large amount points to contamination with sewage ; the reason of this being that urine and sewage contain large quantities of sodium chloride, and the great majority of natural waters in an unpolluted state contain comparatively small amounts. If, therefore, the water analysed is found to be free, or almost free, from chlorine, it is unpolluted with sewage ; but if chlorides are present in quantity, animal matter has probably found its way into the water, and a more complete analysis is required. The absence or presence of chlorine, however, gives no information as to whether or not there is contamination by vegetable organic matter.

The following list taken from Mr. Wanklyn's book shows the quantity of chlorine in some waters analysed by him :—

	Grains of Chlorine per gallon.
Bala Lake	0·7
Ullswater	0·7
The Rhine at Bonn	0·6
Thames Companies in London	1·2
The Kent Company, London	1·75
Tunbridge Wells	3·7
London—Pump in Portland Place	2·2
Pump in Goodge Street	12·4
Pump in Oxford Market	33·2
Well in Windsor	6·9
Sample of Sewage	9·9

The next to be considered is the HARDNESS.

As this quality of certain waters is universally appreciated, there is no necessity for me to enter on any description of what is meant, but simply to say that hardness in water consists of two kinds, viz. :

1. Temporary or removable hardness.
2. Permanent or irremovable hardness.

Temporary hardness depends upon the presence of calcic and magnesic carbonates held in solution by carbonic acid, with which it is loosely combined. When the carbonic acid is drawn off, as it can be by boiling, the carbonates are precipitated and form a white deposit, giving rise to the "fur" so often found lining the interior of kettles and boilers. Another method of precipitating the carbonates is the addition of such an amount of lime water as will combine with all the carbonic acid in solution, and so throw down both the carbonates originally contained in the water, and those formed by the union of the carbonic acid and the added lime-water.

Permanent hardness is due to the presence of the sulphates of calcium and magnesium, and chlorides; also in a minor degree to iron, alumina, and free acid. This hardness cannot be removed by boiling.

The hardness of water is shown by its power of decomposing soap which consists of oleates, stearates, and palmitates of the fatty acids. As long as any undecomposed carbonate or sulphate remains in solution no lather can be produced, and in very hard waters a considerable quantity of soap must be used before the dissolved salts are combined as oleate, stereate, or palmitate, of the various bases in the water.

One grain of chalk, that is, calcic carbonate, wastes 8 grains of soap, so that if a family of 5 persons using 6 gallons per head daily for washing purposes are supplied with a water of 10 degrees of hardness, the yearly waste from hardness of water alone would amount to 130lbs. of soap. The economical advantages of soft water for washing are thus sufficiently obvious, and for manufacturing purposes soft water is equally necessary. It is estimated that the City of Glasgow by substituting the soft water of Loch Katrine for its former harder supply has effected a saving of no less than £36,000 per annum in soap.

The following table shows the degrees of hardness possessed by some public water supplies, most of which are copied from Mr. Wanklyn's book on water analysis :—

	Degrees of Hardness.
London, New River Co	15·0
London, Thames Co.	16·5
Leek, town water	3·8
Oxton, Birkenhead	11·9
Cockermouth, Cumberland	2·5
Kirby Shore, Westmoreland	25·0
Chatham	24·0
Darley Dale, Derbyshire, well	7·5
Manchester water	3·0
Bradford (high level)	3·68
Bradford (low level)	3·5

After discussing the significance of nitrates in drinking water, Dr. Evans proceeded :—Let us now sum up the various details considered, and deduce, if we can, a few general facts supplied by chemical analysis which can aid us in forming an opinion as to the suitability or otherwise of various waters for the supply of any community. First of all, it is to be noted that the water analysed is only a sample taken at a particular time, and, consequently, does not necessarily represent the constitution of the water at all times and seasons. The condition of a water, for instance, in a well is not always the same ; it may be fairly good in seasons of drought, but in times of flood subject to serious contamination—in other words, subject to that most serious of all pollutions, viz., intermittent pollution ; but an analysis of sample of water taken in a dry season would in no wise reflect the constitution of the water when polluted, nor even show that it was subject to any pollution at all.

If in the estimation of total solid matter an undue proportion is found to consist of organic matter, the water is certainly not a good one, especially if the amount of total solids be large. A large amount of solid matter up to about forty or fifty grains per gallon does not necessarily condemn the water if the proportion of organic constituents is low. A large quantity of organic matter, as determined by any process, in addition to an excess of chlorine, shows pollution by animal excretions, and at once condemns the water as unfit for use. The same may be said of nitrates with excess of chlorine. But these are only a few of the conditions you are likely to meet with, and in the great majority of cases the chemical analysis will be such that no definite conclusion can be drawn from it. And I would here warn you against placing too much reliance on an opinion drawn from the consideration of chemical analysis alone. Some of the constituents of a water to which great objection is taken can often be shown to have a harmless origin, whilst others to which water analysts often attach very little importance may indicate grave danger of pollution. It is quite a mistake to suppose, as many appear to do, that a chemist working in a laboratory in London or Edinburgh is competent to express an opinion on the quality of a sample of water sent to him he knows not whence. In order to come to a correct conclusion on the merits of any water, it is essential, in addition to the chemical analysis, to know the origin and history of the water, so that all its constituents may be accounted for and allotted their due share of importance.

Let me say a word or two on the diseases caused by impure water. Decomposing vegetable matter either in suspension or solution may cause such gastro-intestinal troubles as dyspepsia and diarrhœa, but the small amount of peaty matters existing in moorland water seems to be harmless, although imparting a brownish tint. It is different, however, with *animal* matter, such as the soakage from defective drains and cesspools. This produces all kinds of indefinable ailments and gradually impairs the health, although no definite disease may apparently be produced. Nevertheless, many epidemics of diarrhœa have been proved to be due to the contamination of water with animal impurities. But water liable to such pollution may at any time become infected with the germs of a specific disease, the spread of typhoid fever often being caused by specifically infected water.

Other diseases, *e.g.*, urinary calculi, in the eastern counties of England and Goitre in Derbyshire have been attributed to the peculiarities of the water supply, but not in my opinion, with sufficient reason.

PURIFICATION.

The purification of water may be carried out by several methods, one of which is Distillation. This process gives a very pure water, and is now extensively used at sea. In the last Egyptian campaign water was distilled on board ship and conveyed to the army ashore. The only matters left in solution after distillation are traces of various salts and a little ammonia, and these can be much reduced by the addition of a little free manganate of potash and re-distillation. Distilled water is not palatable, but insipid, and before being used for drinking should be ærated by passage through the air in finely-divided streams.

Boiling destroys all microbes, so that if the water be suspected to contain germs of any specific disease this process should always be applied before drinking. Temporary hardness is also removed by boiling, and organic matter in suspension is carried away by the precipitate of calcic carbonate as it forms. Boiled water tastes very like distilled water, and requires æration.

Another method is Precipitation, which is intended chiefly to remove temporary hardness, although it does remove organic impurity as well. It is partly chemical and partly mechanical in its action. In Clark's process a sufficient quantity of lime water is added to the water to combine with all the carbonic acid present and so precipitate both the carbonate of lime in solution and that formed by the action of the carbonic acid on the lime added. The precipitate in settling carries down organic matter if the water happens to contain it. A modification of the process is the Porter-Clark process, in which after precipitation the water is forced through cloth, under pressure, in order to remove the calcic carbonate quickly instead of waiting for subsidence, as is done in the Clark process. Another method of precipitation is the addition of a small quantity of alum; calcic sulphate and a flocculent precipitate of hydrate of alumina are formed, and the latter, on subsiding, carries down the organic impurity with it. However, the most extensively used method of purification is Filtration, carried out both on the large scale by means of filter beds at waterworks, and in a much smaller scale at home by domestic filters, the object of the process being the removal of suspended material as well as organic matter in solution. Some dissolved mineral salts, such as chlorides and sulphates, are unaffected, or only slightly so, but temporary hardness is reduced and nitrates and ammonia are oxidised into nitrates. The slide I now show you represents a section of the Thornton Moor filter beds, near Bradford, taken from a plan kindly lent to me by our Waterworks Engineer, Mr. Watson. The beds are composed of sand and gravel, the top layer consisting of fine sand and the bottom one of gravel, the particles of which gradually increase in size from that of a pea to a potato. Through the side walls pass channels to carry off the water and permit the escape of air. The depth of water in the beds is about three feet, the admission valve being so regulated that water enters at one point as fast as it escapes through the filtering material. Altogether there are four of these filter beds at Thornton Moor, three of which are in constant use while the fourth is being cleansed. The effect of sand in filtering off suspended matters, whether mineral or organic, is particularly good, its various particles powerfully attracting suspended impurities until they become completely covered; but on organic matter in solution the effect is not so marked; it is certainly active for a time but afterwards ceases and requires washing.

In addition to sand and gravel, other materials are used for filtration on a large scale; beds of magnetic carbide of iron, covered with a layer of fine sand, have been found very efficient. Polarite, a patent, is also a good filtering and purifying material, and of late years, I believe, has been extensively used. For domestic filters, a great variety of materials have been introduced, the best known of which is perhaps *Animal Charcoal*, used either by itself or in combination with manganese or silica. There is no doubt that animal charcoal is a most effective filtering medium, removing not only suspended matters, but those in solution. But it requires great attention, and if neglected is sure become a source of impurity. Its action on lead is no doubt due to the phosphates it contains, a chemical reaction taking place resulting in the formation of insoluble phosphate of lead, which is deposited in the charcoal. But this action is only temporary, so that if used as a protection against lead-poisoning it must be frequently renewed. After being in use for a few months charcoal becomes saturated with organic matter, and affords an excellent breeding ground for microbes that find their way into it. Whenever and in whatever form used it requires frequent renewal once in four months at the least. Block charcoal should be frequently removed and cleaned by scrubbing and treating with per-manganate of potash and hydrochloric acid.

Another good filtering medium is spongy iron, the action of which on water is both chemical and mechanical, organic matter in solution being oxidised in addition to the removal of suspended matters. It is also said to have the power of decomposing water and setting free oxygen to act upon dissolved organic matters. It retains its filtering power for a long time and yields nothing to water.

Other effective materials are carbalite, carferal, and porcelain. But whatever kind of filter be used the following qualities are essential (Parkes):—

1. That every part of the filter shall be easily got at for the purposes of cleansing or renewing the medium.
2. That the medium shall act chemically on organic matter in solution and arrest organisms or their spaces in suspension and be present in sufficient quantity.
3. That the medium yield nothing to water that may favour the growth of low forms of life.
4. That the purifying power shall be reasonably lasting.
5. That nothing in the construction of the filter be capable of undergoing putrefaction or yielding metallic impurities to the water.
6. That the filtering materials shall not be liable to clog, and the delivery of water be sufficiently rapid.

If these points are all observed there should be no difficulty in getting a good filter. I will conclude with merely asking you not to use filters unless they are necessary, and when used to pay great attentiou to their regular cleansing.

Colonel Mackie moved a vote of thanks to Dr. Evans for the admirable manner in which he had treated the subject. He was quite sure no one, whether of a scientific turn of mind or an ordinary observer of the facts of the day, could fail to have been not only very much interested, but also to have derived considerable instruction.—Mr. D. B. Kendell seconded the motion, which was heartily carried.—Dr. Evans suitably acknowledged the compliment.

Mr. T. Gledhill, of Heckmondwike, in proposing a vote of thanks to the Chairman, hoped that the County Council would introduce another series of lectures for Local Board members, as it was no use instructing the officers if *they* were not "posted up" at the same time (hear, hear). He was not referring to Heckmondwike (laughter), but to various parts of the country. He had had 26 years' experience, and was of opinion that the officers could not do their duty because the members were not prepared to put the law into operation.—Mr. CHAMBERS, of Goole, seconded.—Colonel MACKIE thought it very desirable that the members of Local Boards should be further educated on Sanitary matters.—The motion was carried.

QUESTIONS AND ANSWERS.

The following are the questions and answers :—

Would the Lecturer consider the water from wells in the cellar of dwelling-houses suitable for domestic consumption? (W. M DRAKE).—I should hardly consider a cellar a suitable place for a well. If you can get a cellar without a well I should recommend you to do so. Of course, in a country district where there is no other supply available, whatever supply can be got has to be used.

The Doctor recommended slate for storing water for drinking porposes—is not porcelain also good, being without joints? (S. WHITELEY)—Yes, very good indeed; I mentioned slate, but porcelain is an equally suitable material.

How do you account for the average consumption being so much greater in some towns than others? (S. WHITELEY)—This is a very difficult question to answer. As I told you in the lecture, the high consumption of water is sometimes accounted for by leakages from the mains before it actually reaches the consumers. In other towns it depends upon the trades and manufactories. There are various reasons to account for it.

What would the Lecturer suggest when the reservoir is surrounded by cultivated land and the drainage therefrom flows into such reservoir? (W. H. HARRISON, Sheffield)—That is a very unsatisfactory state of affairs, and it is a matter really for the Waterworks Committee or the Town Council to see that in some way or other the drainage is prevented from getting into the water. If it cannot be done, purification by filtration must be effected afterwards.

Will the Lecturer tell us how to examine a sample of water microscopically? (W. H. HARRISON, Sheffield)—If you think that your sample of water contains turbidity, you should put a quantity aside in a conical vessel. Allow the sediment to deposit itself at the bottom, put it on a slide, and then examine it by means of a microscope.

What standard of hardness would the Lecturer suggest as a good all-round water for domestic purposes? (W. H. HARRISON)—The softer you can get it the better. I do not like hard water for any purpose—drinking, cooking, or any domestic purpose. Anything above ten degrees I should call a hard water, and not desirable for a domestic supply, although I must admit, at the same time, that some towns, such as London, Cambridge, and others on the chalk, though supplied with hard water, are very healthy places.

Do you consider the water from any large gathering grounds fit for drinking purposes without filtration? (THOS. BOTTOMLEY, Bingley)—It depends altogether upon the gathering ground. The water obtained from some gathering grounds is pure and does not need filtration, but water from peat is better filtered.

The Lecturer having quoted from Dr. Whitelegge's "Hygiene," will he please say where it may be purchased and at what price?—It is published by Cassells & Co., 7/6 being the published price.