On Water Supply. By STEVENSON MACADAM, Ph.D., F.R.S.E., F.C.S., Lecturer on Chemistry. Read before the Royal Scottish Society of Arts, on 8th January 1872.

The subject which I have now to introduce to the notice of the Fellows is probably the most important of any which has occupied our attention for many years; and the Royal Scottish Society of Arts is peculiarly fitted as the learned body before which the subject ought to be discussed. We profess to deal with the applications of science to everyday life; to its bearings upon the progress of the arts and manufactures, as well as its influence on sanitary matters. Moreover, the subject is one which specially concerns Edinburgh at the present time; and if as a Society, or as individuals, we can do anything to settle public opinion on this all-important matter, we are bound to do so—especially considering that, at this moment, the subject is an open one for discussion, and we may all feel at liberty to state freely and candidly what we do know about it.

In introducing the subject, I will endeavour to speak on all points from personal knowledge, and without bias, in the full hope and expectation that those Fellows of the Society, who either agree or disagree with me, may as freely and candidly express their views. The more the matter is discussed, I believe the sooner will we arrive at the truth, and at a common understanding with each other as to all the standards or essentials in water supply. The subject may be discussed under several divisions—

I. Quantity of Water.
II. Quality of Water.
III. Vegetable and Animal Life in Water.
IV. Action of Water upon Lead.
V. Nature of Gathering Ground.
VI. Effects of Filtration.

I. *Quantity of Water.*

The primary uses of water are for drinking, cooking and washing. So far as drinking and cooking—dietetic—purposes are concerned, the quantity of water absolutely required is comparatively small—probably a gallon a-head might suffice ; and the amount necessary for personal ablutions might be reduced to another gallon, being for primary purposes, *in primitive fashion*, two gallons a-head per day. But the cleansing of clothes, and of furniture, as well as the floors, walls and stairs of houses, necessitates a much larger supply. Even the smallest house, with its modicum of furniture, and the scantiest of clothing, make large demands upon water. Still more so, when the tendency of the present age is for all classes to live better than their forefathers; to have more roomy and airy houses; and to use more underclothing, and have more change of such—each necessitating more consumpt of water for their thorough and efficient cleansing. Even personal ablutions, as they ought to be carried out, by the periodic cleansing of the whole body—in baths where such are available, and in tubs where baths are too great luxuries—demand an increasing supply of water. And then our plan of drainage and sewerage, coupled with the water-closet system, has formidable and earnest claims upon quantity of water for the removal of impurities, not only from our houses into the sewers, but even more so from the sewers themselves. It may be a question whether the water system, for the removal of night soil and other impurities, is a correct one, as now carried out. I have grave doubts about it, unless quantity of water can be ensured at all times. The condition of the sewers in towns—built piecemeal as they are—is certainly not the best. Accumulations of fœtid matter are common in these underground tunnels, evolving pernicious gases, which permeate our house drains, and contaminate the air of our rooms. Means ought to be at hand for the weekly flushing of sewers, so as to remove deposited putrefying matter, and thus ensure mechanical cleansing. But equally important, as a sister aid, is the constant small run of water through sewers, which leads to chemical cleansing, for the water contains gases in solution, of which oxygen is one, and while flowing over deposited matter, or even over the foul bottom of the sewer, the dissolved oxygen burns up or oxydises the noxious gases evolved, and thus removes these from our drains and sewers.

I have little faith in the separate system of drains. At present there is a chance of flushing by rainfall, and the consequent removal of foul matters; but by the separate system of conduits, such periodic flushing will be practically lost. Still less have I faith in the water-closet system introduced into small houses. It is an element of danger at any time, and where little care is taken, becomes highly dangerous. Much better to retain and amplify the present can system, or adopt the Liverpool method of tank closets in the yards attached to each tenement, or the more troublesome, but certainly less dangerous system of the earth closet for each land of houses.

II. *Quality of Water.*

All natural waters contain more or less saline ingredients, and all possess a greater or less amount of organic matter, besides gases, in solution. Neither the saline nor the organic matters are necessarily *impurities.* They may be the natural constituents of wholesome waters. The saline matters are principally carbonate of lime (chalk), sulphate of lime (stucco), and chloride of sodium (common salt), with a small proportion of magnesium compounds. The organic matter is of vegetable origin, and is not putrescent.

Certain saline matters may, however, render water unsuitable for primary uses, as hydrosulphuric acid (sulphuretted hydrogen), which is present in sulphureous waters, and the carbonate and sulphate of iron, which are found in chalybeate waters. Even excessive proportions of the ordinary constituents communicate undesirable properties upon water, as much carbonate and sulphate of lime constitute unduly hard or calcareous waters, and much chloride of calcium and chloride of sodium yield saline purging springs.

As a general rule, the larger the proportion of saline matter the greater the degree of hardness. Thus the average of many analyses gave as follows:—

	Saline Matter in gallon.	Hardness.
Spring water from Pentlands, . .	12 grains.	7°
Reservoirs on north side of Pentlands,	8 "	$4\frac{1}{2}$°
Do. on central do.,	5 "	3°
South Esk water, ...	$4\frac{1}{2}$ "	$2\frac{1}{2}$°
Heriot water, ...	$5\frac{1}{2}$ "	4°
Talla water, ...	3 "	2°
St Mary's Loch water, . . .	3 "	2°

For cleansing purposes there is a decided disadvantage in hard water. It necessitates more or less waste of soda and soap. Independently of that, for personal ablutions, soft water is much more agreeable and effective. For cooking purposes a comparatively soft water is advantageous. It is more effective in extracting the nutrient value in infusions and extracts, such as tea and coffee, soups, &c. Hard waters are positively a hindrance in cooking many articles, as insoluble compounds are formed with the lime. Besides, hard waters lead to the incrustation of vessels, which necessitates extra firing and a certain risk in the filling up of pipes, and the consequent explosion of boilers, &c. For drinking purposes it is of little moment whether the water is hard or soft, provided it is palatable, which more depends on the gases dissolved in the water than on the saline matters in solution. For instance, even hard water, when boiled or heated, and then allowed to cool, is very mawkish to taste; whilst even distilled water, when the distil-aerator is employed, is in all respects decidedly palatable.

The large proportion of lime in the ordinary articles of food renders it unnecessary that lime should be present in the water supply, and, moreover, the lime in water is in the form either of carbonate or sulphate of lime, which is not the principal state in which it is required for the wants of the animal frame, which makes great demands on the phosphate of lime for the building up and sustenance of the bony skeleton. For town supply a water containing not more than 5° of hardness is of first-class quality for all domestic purposes. When the degree of hardness ranges between 5° and 10° the water is of second-class quality, and when from 10° to 20° of hardness the water is of third-class quality.

The organic matter present in waters may be of various kinds. In ordinary natural healthy or wholesome water the organic matter is of vegetable extraction. It may be of a peaty nature, when a yellow shade of colour is observable, or of a non-peaty character, when the colour is not affected. The average quantity of organic matter in water is about two-thirds of a grain in the imperial gallon. The colour is very deceptive in this case, for the organic constituents are often present in as large quantity in colourless as in coloured waters. The presence of lime hinders the observance of the colour—due apparently to the formation of a colourless compound. A water containing much peaty matter, when treated with a very small amount of lime, and then filtered, becomes quite colourless. The same result takes place more slowly when carbonate of lime, in the form of shells or pieces of lime rock, are present in the filtering bed. A mixture of the peaty water with a hard water gives rise to a similar decoloration of the mixed liquids.

We must distinctly draw the line between the above or non-putrescent organic matter and putrescent organic matter, either of vegetable or animal origin. Marshy waters become impregnated with vegetable matter, which is liable to putrefaction, and hence marshy waters do not belong to the same class as those tinged with peat. There is a decided difference in the nature and proportion of the gases. Animal impregnations derived either from sewage or from highly manured fields give rise to the most dreaded contamination, which may, when the entrance of the impurity is direct, be visible to the naked eye; but when the organic matter has percolated through the soil, it may be in part oxidised into nitrates, and the water be obtained perfectly clear and sparkling, as well as cool and refreshing, and yet be positively unwholesome and deadly when partaken of for dietetic purposes.

The quantity of organic matter dissolved in the waters of the present Edinburgh supply, the South Esk, the Heriot, and the St Mary Loch districts, is close upon two-thirds of a grain in the imperial gallon, and there is practically no difference in the amount furnished by each water. This organic matter is entirely non-putrescent. Where the peaty matter is much greater in quantity, as in some of the compensation reservoirs on the Pentlands, the organic matter may be as much as 1½ grains to 2¼ grains in the imperial gallon. Even the water of Loganlea reservoir has one grain of organic matter in the gallon; whilst the highest proportion present in any feeder of St Mary's, or any portion of the loch, is ·79, or four-fifths of a grain, which is the quantity found in the Little Yarrow.

In waters which are contaminated by the products of animal matters derivable from sewage or from highly manured fields, the amount of organic matter ranges from 1 to 10 or more grains in the imperial gallon.

The gases dissolved in waters form one of the best guides as to the quality of the waters. These gases are mainly carbonic acid, oxygen and nitrogen. The proportion of carbonic acid varies according to hardness, when such is derivable from carbonates; whilst the relative amounts of oxygen and nitrogen should be very nearly as 1 of oxygen to 2 of nitrogen. When the water is of a wholesome nature, and the organic matter is not putrescent, then such is the ratio of these gases; but where there is putrescence, the oxygen decreases to 1 to 3, or less, which is indicative of positively unwholesome properties being present in the water. For instance, in the course of the inquiry into the condition of the Water of Leith, I had occasion to make many testings which led to these results, and the subsequent analyses of many hundreds of waters received from all quarters has confirmed these conclusions. The gases dissolved in the waters of the Edinburgh or Pentland, South Esk, and St Mary's Loch districts are as follows, taking the average results of many experiments made on each set of waters:—

	Edinburgh Spring Water.	South Esk River Water.	St Mary's Loch and Feeders.
Carbonic acid, .	10	5	4½
Oxygen, . .	29	30	30¼
Nitrogen, . .	61	65	65¼

In neither water, when kept for months in closed bottles, was there any practical difference in the quality of the gases or in any other property. The organic matter was, therefore, in all these waters of a non-putrescent and wholesome nature. At the same time, contact with the air and sun light has a material influence on the organic matter, which is thereby oxidised, and tends to lessen in quantity, so that the water becomes more and more colourless in course of time.

III. *Vegetable and Animal Life in Water.*

All waters when exposed to the air become impregnated more or less with organisms. Even spring water, which has never seen the light of day till it is run into our house cisterns, very soon acquires organisms, especially in the warmer months of the year, and in the warmer situations in households. In wholesome natural waters, impounded in natural or artificial reservoirs or ponds, the vegetable growth consists mainly of fresh water algæ, which adhere to and grow on stones in the quiescent parts where there is little current, and where the stones do not roll over each other, but are stationary. Every Highland and Lowland loch is an illustration of this. Take the ponds on the Pentland Hills, for example. At Loganlee the embankment is incrusted with such algæ. In the running stream which flows from Loganlee to Glencorse reservoir, little of the algæ is to be seen; but as the water enters the Glencorse reservoir, especially at the north-west corner and side, there is abundance of vegetable growth, including the algæ. At Clubbiedean, which is a spring water reservoir, the embankment is thickly incrusted with vegetable growth, and at the upper part of the waste weir, which communicates with Torduff, the same algæ are growing most luxuriantly, whilst at the embankment at Torduff the same vegetation may be seen. Then go to Loch Katrine, Loch Lomond, Loch Lubnaig, or Loch Earn, Loch Venacher or Achray, Lochs Menteith, Chon, or Ard, or any other loch or impounded water, and at all the quiescent parts you have the same vegetable growth—the same fresh water algæ. Wherever there is a sheltered spot, and where the wind and the waves do not roll stones over each other, there you have vegetable growth or algæ. Similarly at St Mary's Loch, at parts of the north side where the stones are not disturbed, the vegetable growth is to be observed; but where rolled stones are abundant, as at the east end and north-east side, there is practically no growth whatever. In the Yarrow, which is the natural outlet of St Mary's Loch, wherever water is flowing along leisurely, algæ are to be found; but where there is a rapid current, little or no vegetable growth is to be seen. The same is observable in the Megget, and the other main feeders of St Mary's Loch. The vegetable growth is common to all the stones on the shores of all natural and artificial lochs and reservoirs, and to the more quiet running parts of streams, and is more evidence of purity in the water than of impurity.

The animal life visible in fresh waters consists mainly of minute organisms about the size of a pin head, and which are minute crustaceans, principally *Daphnia pulex* and *Cyclops quadicornis.* Of course, at the sides of all lochs and reservoirs, you can pick up the larvæ of insects, water scorpions, and other animal forms which live in shore, and which are equally found in every impounded water, and in every running stream. The so-called water fleas, however, the *Daphnia pulex* and the *Cyclops quadicornis*, are the denizens of the water, and are distributed throughout the lochs, and are also found in house cisterns. The Cyclops is the more common, and seems to appear earlier in the season. In June they are abundant in every pond on the Pentlands, especially at Clubbiedean, Torduff, and Bonally. There are apparently fewer in Loganlee and Glencorse, which is probably to be explained from there being a constant current of water running through the latter. As the month progresses, the Daphnia becomes abundant, and they are especially numerous in the reservoir of Clubbiedean. On the face of the embankment the algæ are growing rather luxuriantly, so that there is much living vegetable matter, and such organic matter apparently forms excellent feeding ground for the fleas. In other lochs you find the same forms of animal life. In June, in Loch Lomond, you will everywhere find the Cyclops, not only at the side, but all up the middle of the loch, wherever a bottle is put down, the water which is drawn up always brings up some fleas. At Loch Katrine, all along the shores, including the region immediately surrounding the mouth of the tunnel leading to Glasgow, the fleas are present in the water, as well as at the piers, and throughout the whole length of the loch. You cannot lift a bottle of the water without finding the water flea. In St Mary's Loch the water contains few fleas as compared with the water of the Pentland ponds, which I believe is due to the current of water which is constantly flowing through the loch. In the warmer months, however, the Cyclops is seen distributed through the water, but I have seldom seen the Daphnia in any part of the loch. At the north-east end, where the Yarrow flows out, and where the proposed pipe for town supply was intended to be introduced, there is comparative freedom from fleas in the water, and even from the fresh water algæ which form the feeding ground of such. In August, more vegetable and animal life are to be found everywhere in all the lochs and reservoirs, but I may safely say that the number of fleas in the water of St Mary's Loch even at that time is certainly much less than the number to be found in any reservoir in the Pentlands, whether used for compensation or otherwise.

The water fleas are extremely delicate organisms. A very little alcohol added to the water kills them, and when the water is heated to a temperature of 100° F. they die at once. Any decrease in the amount of the oxygen dissolved in the water below the wholesome quantity quickly causes their death. Thus, when water containing the fleas is bottled up for a night, the majority, if not all of the fleas will be found dead in the morning. Care must be taken to leave the bottles open, so as to ensure the continued aeration of the water, and thus enable the fleas to have the most wholesome of air in solution in the water. Fleas, therefore, are evidence of the purity of waters. They are never found in contaminated waters. Not a single flea was observed in the whole course of the experimental observations on the Water of Leith, from Coltbridge downwards. Any putrescent material introduced into the water will influence the quality of the gases in solution, and the fleas die by the foul air. These remarks apply equally to hard and soft waters. In running streams the fleas are found in all the quiet corners where the current is reduced to a minimum. Filtration through sand and gravel removes the greater number of the fleas, but not all. When examining the Torduff filtering beds in June of last year, I found the Cyclops in the newly filtered water, and during the summer the fleas were in the water transmitted to the city, as evidenced by their daily presence in the water supplied to my laboratory and house.

IV. *Action of Water upon Lead.*

The common notion that soft waters act more upon lead than hard waters is erroneous. During a very lengthened experience as an analyst, I have found many more hard waters which acted upon lead than soft waters which did so. A natural water taken from a stream, lake, or spring, and containing the proper kind of ingredients—however soft—has no deleterious action upon lead, but when impurities are present in either hard or soft waters, they have a more or less powerful action upon lead. Thus, the impregnation of either soft or hard water with sewage products, or the drainings of highly manured land, confers upon the water the property of dissolving lead, which is mainly due to the action of the calcic nitrate in solution in the water. A similar result is traceable to marshy water which contains putrescent material. But no such action upon lead occurs with waters which have a peaty tinge. The late Prof. Miller, of King's College, London, even said that the peaty matter was a preservative against the water acting upon the lead, but I scarcely think it necessary to consider that such is the case.

Hard waters are more likely to be contaminated with impurities, because they generally rise in lowland districts where there is a considerable population, which directly or indirectly send sewage into the streams, and where the arable land is heavily manured. Soft waters, on the other hand, can scarcely be polluted at all, for they generally rise in hilly districts, where there is a scattered population and scanty cultivation, so that neither sewage nor the drainings of highly manured fields can contaminate them.

The proper mode of testing the action of water upon lead is to proceed to bring the lead and water in contact with each other as they would be in ordinary use. The placing of pieces of sheet-lead with fresh cut edges, and often with scraped surfaces, in the water contained in a bottle, is not to be commended, as the results give an exaggerated notion of the power of the water to act upon lead. Indeed, there is no natural water which may not in this way be shown to act so powerfully on lead as to be hurtful and poisonous. The proper method of testing the action is to bring the water in contact with the lead having its natural skin or surface, which is probably a thin film of an oxycarbonate of lead. A short length of lead pipe, an inch in diameter, with the one end beaten close, or a lead cistern soldered in the ordinary way, may be employed in the experiments. The pipe or cistern is rinsed out with the water to be examined, and the tube or cistern is then filled up, and the water allowed to stand in it for at least twenty-four hours. In my later experiments I have supplemented those smaller trials with a cistern to which there is attached twenty feet of lead pipe and a brass cock, the whole being soldered and fitted together in the same manner as an ordinary house cistern with pipe and cock is constructed. Working, therefore, with the short length of pipe, the small cistern, and the house cistern and pipe, I find that the present Edinburgh spring or pond water, the South Esk water, the Heriot water, and St Mary's Loch water, act practically the same upon the lead. Thus, when the lead is fresh and new, the action during the first twenty-four hours is to the extent of $\frac{1}{100}$th of a grain of lead in the gallon of water, which decreases in a week to $\frac{1}{400}$th of a grain, even when allowed to stand for three days, and thereafter the action does not exceed the $\frac{1}{600}$th of a grain even when the water remains in the cistern. Where the water is run in and out, as takes place in daily use in households, the proportion of lead in solution becomes infinitesimal, and cannot be recognised even by chemical tests. Even at the first the action is far within the limits of safety, and, certainly, when a few days are past, the water ceases practically to have any solvent power over the lead. A word of caution requires, however, to be given in regard to dirty cisterns, especially when lime falls into them, as a sediment is often found in cisterns which contains much sand and clay, accompanied by lime and much carbonate of lead in fine division. Where such is the case, the rapid influx of the water may stir up this sediment, and cause part of the carbonate of lead to be mechanically diffused through the water, which may thus exert deleterious properties. All cisterns should be cleaned out once a month with a soft brush, so as to avoid the contamination alluded to here. My experiments on the action of water and saline matter upon lead are very numerous, and must be reserved for another paper.

V. *Nature of Gathering Ground.*

That water for town supply should not be collected in the neighbourhood of populous places, either from the surface or from wells, will be admitted by all. Professional acquaintance with the water supply of many towns and villages has led me to the conclusion, that at least three-fourths of all the well waters in populous places are contaminated with sewage, and are unwholesome. That water should be collected from cultivated districts is scarcely less to be deprecated. The fields are often highly manured, sometimes with police manure, and the drainings from such are more or less polluted with noxious ingredients. Even districts which are likely to be chosen for breaking up by farmers—comparatively flat land or agricultural areas—should not be fixed upon for the water supply of large towns. Numerous instances can be adduced of water of good quality at one time becoming thus contaminated by the breaking in and manuring of land, leading to unwholesomeness in the water, as well as the power to act more or less energetically upon lead.

Districts having hard water are more likely to be influenced by the progress of agriculture, because they are generally more flat, whilst soft water districts, being more hilly as a rule, are less capable of being turned to arable purposes, and hence remain strictly pastoral. The drawback to soft water districts is the presence of more or less peat, which communicates a greater or less tinge of colour to the water; but surely the mere appearance of a water is not to be sacrificed to unwholesomeness. The majority of Highland and Lowland lochs, and the districts draining into such, as also the available collecting grounds for artificial reservoirs, must necessarily be in localities where there is some peat, and such is certainly as abundant in the Highlands as in the Lowlands. It is equally sure that Highland lochs as well as Lowland lochs contain water which is tinged with peat. A slight impregnation of the water with peat should not be considered objectionable, as it is not unwholesome. No pernicious effects have ever been traced to such. Difficulties have arisen from mixing up *marshy water, peaty water, and sewage impregnated water* all together. Many towns are supplied with the so-called peaty water, including Glasgow, Aberdeen and Inverness, and there is absolutely no proof whatever of any noxious quality being derived therefrom. Even in Edinburgh we drink in part the water from Loganlee reservoir, which is markedly peaty.

The South Esk, Heriot, Talla, and St Mary's Loch districts contain some peat on the tops of the hills, but practically the effect of such upon the waters of the districts is little. As the South Esk, Talla, and Heriot waters are not naturally impounded, there is a difficulty in knowing exactly the average composition of such waters over the year; but we may judge from analogy in the case of the St Mary's Loch water, where the loch is certainly large enough for the mingling of the waters, being three miles in length by about half a mile in breadth, and being connected by a short narrow streamlet to the Loch of the Lowes, which is a mile in length, and may be regarded as an extension of the larger loch. At the east end, or lower part of St Mary's Loch, near where the water flows into the Yarrow, and where it was proposed to draw off the supply for the city, the average of the whole waters may be obtained. This water has been collected at all seasons of the year, and the composition, as determined by chemical analysis, has been practically the same at all times. The Megget stream, which is the principal feeder of the loch, flows in on the north side with a deep channel, which, at a distance of 150 yards from the mouth of the stream is 90 feet deep, with a stony or pebbly bottom, as evidenced by the plumb striking hard upon it. Towards the east of the Megget the ground generally shallows near the side, which is caused by a delta being formed there, consisting of fine silt composed of the comminuted graywacke rock of the district, with some broken stalks of brackens, a little grass, and a few minute fragments of peat. These were the results of dredging, and also of the hollowed out lead plunger or plummet. On chemical examination of the silt when dried, not one per cent. consisted of organic matter. I have never seen cleaner silt dredged or taken from the bottom of any loch. In all the ponds and reservoirs in the Pentlands you have similar finely divided earthy matter, accompanied by a minute proportion of organic matter thrown down, the only differences being that in the Pentland ponds the silt is more ferruginous and ochrey in its nature, and when agitated causes more discoloration of the water. At certain parts, as at the north-west side of Glencorse reservoir, where the burn from Loganlee enters, the silt contains a much larger proportion of organic matter, there being in some samples examined from 5 to 10 per cent.

In lifting samples of water for chemical analysis, care should be taken that the water is collected as it naturally flows in the stream or loch, and that the banks or bottom be not disturbed. Where the water is to be taken from the side, it is better to lift it in a large spoon lined with porcelain and attached to a wooden pole, so that the operator may stand firmly on the bank without disturbing the stones or earth on the immediate brink, and be able to stretch out the instrument some feet into the stream or loch. Where no such lifter is used, and the collector stands on earth or stones immediately alongside, or in the water course, and dips down the bottle, there is almost certain to be disturbance of the bottom, and more or less sedimentary matter passing into the bottle. Where the water is to be collected at depths not exceeding 6 feet, I employ a galvanised iron cylinder fitted up with tubes and stopcocks, which can be opened and closed when the cylinder is lowered to the required depth. Where it is desirable to take the water from greater depths, say 20, 50, or 100 feet, I use a galvanised cylinder fitted up with a valvular arrangement, which remains open when the apparatus is being lowered in the water, and closes at once on the descent being arrested at any point. In order to admit of the apparatus being lowered perpendicularly with sufficient rapidity to ensure the constant current of water through the cylinder, a hollowed out lead plunger is attached to the lower part, which not only performs the duties of sinking the apparatus rapidly, but also serves to bring up a portion of any sediment or silt which may be at the bottom. The line attached to the cylinder is marked off in fathom lengths, so that the depth may be at once known. The instruments described were employed in the collection of all the waters from the Pentland reservoirs and St Mary's Loch; and in every case the waters collected at great depths agreed in chemical composition and properties with those lifted from the surface of the respective reservoirs or lochs.

The South Esk, Talla, and Heriot waters, not being impounded in bulk, excepting the comparatively small amount lodged in the Portmore Loch, which belongs to the South Esk district, no direct observations could be made in these waters exactly similar to those carried out at St Mary's Loch. But considering the composition of the waters referred to, especially those of the Heriot and South Esk, which in ordinary times are slightly harder, there is every reason to believe that were these waters impounded in artificial reservoirs capable of retaining the flood waters of the district, the average composition of the water would show less saline matter, and the degree of hardness be smaller, so that practically they would approach the average composition of the waters of the St Mary's Loch district—both in quantity of ingredients and degree of hardness.

In all large lochs and reservoirs, the waters become uniformly distributed during their retention in and passage through the loch or reservoir. You pick up at all depths water of the same colour and quality, and possessing the same saline, organic, and gaseous constituents. In the ponds on the Pentland Hills, water taken from the surface of the reservoir, and that collected near the bottom, were practically identical in chemical composition and all other properties. The same remark applies to the water of St Mary's Loch, which taken either from the surface or from 100 feet in depth, was essentially the same in colour as well as in chemical and other properties. The temperature of the water was slightly different. On the 27th May, I found the water at a foot from the surface to be 53° F., whilst at 60 feet in depth the temperature was 51° F., there being thus a difference of 2°. The slight film of water which floats immediately on the surface of all impounded waters varies much in temperature from day to day, according to the warmth of the air, but the daily influence of the sun does not extend in calm weather to more than two or three inches from the surface. The general influence of the season's temperature, however, must be exerted much further down. The difference in temperature between water taken at various depths affords no evidence whatever that the water has remained in the lower depths of the loch from winter to winter, or that the water should be called stagnant in any sense of the term. It is really fresh in every view of the question. The difference in temperature may be fairly ascribed to the effects of three causes, viz., (1) the action of the sun's heat on the surface; (2) the cooling influence of the ground; and (3) the introduction of spring water.

The first cause is very apparent. The direct sun's heat can only affect the water to a certain depth, but partly by conduction and partly by convection, and the consequent establishment of currents, the heat will, during the summer or warmer months, penetrate down some distance.

The second cause of the difference in temperature is the cooling influence of the ground. The sun's heat can only pass a comparatively short distance into the earth. Take a hill side, and, during the summer or warmer months, bore a hole in the ground. As the descent is made, the temperature of the ground decreases, being further removed from the influence of the external heat, and at a varying but certain depth you arrive at a point which neither the heat of summer nor the cold of winter can affect. This is the region of uniform temperature, and is much lower than that of the surface of the soil in summer weather. If a loch fills up a valley to some height, the ground which it covers being removed from the heating effect of the solar orb, must approach the degree of uniform temperature, and all water lying in such a valley must be cooled down from day to day by the lower temperature of the ground forming the sides and bottom of the loch or reservoir. The cooling effects of the ground in the region of uniform temperature is very well observed in the case of the spring water from the Pentlands. These springs owe their origin to rain water falling on the hills, which permeates the ground, and then issues as springs. During the summer, the rain water, when it falls upon the ground, has an average temperature ranging between 50° and 60° F., whilst, when it issues as spring water, the temperature ranges from 40° to 44°.

The third cause of the difference in temperature is the introduction of spring water. In valleys where the water is not impounded by natural or artificial means, numerous springs crop out from the hills in every direction. These springs are more numerous near the foot of the hills, where there is more drainage area, than near the top, where the collecting area is comparatively small. Trace a streamlet up such a valley in summer time, when the rainfall is at a minimum, and you will find that whilst the tops and the upper ridges of the hills are dry and parched, and scarcely a spring is to be seen, yet down near the valley you will see numberless little trickling rills flowing, which are formed from springs near the foot of the hills, and gradually adding their quantity of water to a common stock, ultimately form the streamlet. The temperature of the water in these springs as they issue forth from the hill side will range from 40° to 44°, whilst as the streamlet progresses the water becomes more heated by the summer warmth. Now, raise an embankment in such a valley. The mere damming up of the water to a height to cover these springs will not stop the issue of the cool water therefrom, and when the reservoir has been formed, the water contained therein will necessarily differ in temperature at various depths, as (1) the sun heats up the mere surface water; (2), the cool ground tends to keep down the temperature of that which is lying in the bottom; and (3), as the comparatively cold springs constantly make accessions to the common stock of water.

The South Esk district is full of such springs, which issue forth from the ground, and the raising of an embankment will not stop the escape of water, but will simply store such. The springs will still run and be feeders of the reservoir. So in the Talla district, where, on the very site of the proposed reservoir, some very fine springs are observable. Construct an embankment, and these springs, though then invisible—because covered with water—will still continue to flow, and be one source at least of supply to the reservoir. Then go to St Mary's Loch district, traverse the Megget valley in seasons of summer drought, when little or no rain has fallen for months, and all up the valley you meet little streams fed by springs issuing out of the hill side. There is no other source of the water during a dry season. Embank the Megget, and these springs would still be the main sources of water in the drier months, and contribute also enlarged quantities in winter and more rainy seasons when the springs are running full. Similarly, no doubt, in the connecting valley of St Mary's. Were the loch drained, all analogy proves that springs would be found issuing from the hill sides down to their very base, and there is no reason to consider, because the loch is naturally embanked, that the springs have ceased to run, or that the special district of St Mary's is exempt from such springs as we find in every other valley.

VI. *Effects of Filtration.*

All reservoir waters are improved by filtration. Mechanical impurities, such as finely divided clay from artificial banks, and organisms of all kinds, are arrested in great part. Chemical impurities, however, such as the drainings of highly manured fields, or the products of decomposing sewage, are not removed by a mechanical filter. Any slight tinge of colour is lessened, especially if the filtering bed contain shells. One of the best evidences of such is observed in the water of Loganlee, as it passes through the embankment, and flows on to Glencorse reservoir. The water of Loganlee is decidedly of a peaty tinge; whilst, when it filters through the bank, the shade of colour is reduced very much. There are two ways of determining the colour of water. The best method is to introduce the water into a testing tube about sixteen inches long and two inches wide, the one end of which is closed with a piece of plate glass. This apparatus has been in use for at least half a dozen years among all analytical chemists who have devoted attention to the subject of water analysis. The tube is filled with the water to be examined, and is held in the hand over a piece of white paper, while the operator looks down the whole length of the column of liquid. Different shades and degrees of colour can be very easily and correctly distinguished in this manner. Another plan which can be resorted to in all lochs and reservoirs, is to lower a white porcelain plate, about six inches in diameter, and observe the colour which the water imparts to the plate at certain depths, as also the exact depth at which the plate disappears from the eye. Now, using the latter method of determining the colour, the porcelain plate, when lowered in Loganlee reservoir, disappeared at four feet from the surface; whilst, when the same plate was lowered in Glencorse reservoir, it was still though barely visible at 10 feet from the surface, and only became invisible at 12 feet. In trying the same plate in other ponds and reservoirs, it disappeared as follows:—In the Pentland reservoirs, Torduff, at 9 feet 10 inches; and Clubbiedean, at 12 feet 2 inches. In Portmore

Loch, part of the South Esk collecting ground, at 15 feet; and in St Mary's Loch at 12 feet; whilst in the compensation reservoirs on the Pentland Hills, which are now used for motive power, the plate disappeared at much less depths, being at Harelaw, 4 feet; Thriepmuir, 3 feet 6 inches; Harperrig, 2 feet 11 inches; and at Crosswood, 1 foot 11 inches.

During the conveyance of all water to town in built conduits, tunnels, or pipes, the water becomes of a uniform temperature throughout the year, and is delivered about 44° F., so that neither the extreme heat of the surface water of a collecting loch or reservoir in summer, nor the extreme cold of winter, materially affects the temperature of the water as delivered from the mains.

I have thus endeavoured to mention a number of points which are of importance in water supply. I hope that the paper will serve the purpose of enabling us to know what lochs and reservoirs are, and what we may expect to find in them. My earnest wish is that in Edinburgh we may have an abundant supply of good water, and that we may be no more stinted in water than we are in air.