Chemical and medical reports and evidence of the quality of the Loch Katrine water / Glasgow Corporation Water-works.

GLASGOW
CORPORATION WATER-WORKS.

CHEMICAL AND MEDICAL REPORTS

AND

EVIDENCE ON THE QUALITY

OF THE

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LOCH KATRINE WATER.

May, 1854.

In the course of the Parliamentary Investigation as to the propriety of supplying the City of Glasgow with water from Loch Katrine, a doubt was raised as to the safety to the health of the inhabitants which would attend such supply, by the assertion that the water from its excessive purity acted very violently upon lead. The Committee of the House of Commons, therefore, to whom the Bill had been referred, and who had expressed a very favourable opinion as to the merits of the scheme, adjourned on the 28th of March for some weeks to allow time and opportunity for full and proper investigation.

The doubt alluded to was raised by the evidence of Dr. Penny, Professor of Chemistry in the Andersonian University at Glasgow, who, while admitting the extraordinary purity of

the water of the Lake in its natural state, and expressing his great desire that it should be delivered in that condition to the inhabitants of Glasgow, exhibited specimens of the water upon which he had experimented, a few days previously, by immersing a piece of brightly polished lead in an open vessel, the effect of which, after forty-eight hours contact, was such as to produce a thick opalescent appearance in the water from the rapid decomposition of the lead. The water in this state, he declared poisonous; and though he would not say that such would be the effect in Glasgow in the ordinary course of distribution, he considered it desirable that further investigation should be made.

In this desire the promoters of the Bill entirely concurred; for they were naturally more anxious than any other party to obtain a pure and wholesome supply of water to the city, of which they were the representatives and governing body, charged with the administration of all public measures which could affect the health and comfort of their fellow-citizens.

Immediately, therefore, after the adjournment of the Committee, the Lord Provost and the gentlemen forming the deputation in charge of the Bill, met for the purpose of devising measures for ascertaining, in the best and most conclusive manner, whether the water would have the injurious effect which the evidence of Dr. Penny had suggested.

In conformity with the wish of the Committee, they determined upon calling in the advice of the most eminent Chemists, whose avocations would enable them to attend to the question. Amongst those who were suggested or applied to, they ultimately succeeded in obtaining the co-operation of Mr. Dugald Campbell, Analytic Chemist of London; Dr. Anderson, Professor of Chemistry in the University of Glasgow; Dr. A. S. Taylor, Professor of Chemistry, Guy's Hospital, London; Dr. R. D. Thomson of St. Thomas' Hospital, London; Dr. Hofmann of the Royal College of Chemistry, and Professor Graham of University College, London. Dr.

Lyon Playfair and other gentlemen applied to, were unable to give their assistance.

These gentlemen were all requested to examine the Loch Katrine Water, to analyze its quality, and to ascertain its effect upon lead; and that they would each follow out their examination in the way best calculated for enabling them to advise the Corporation upon the propriety of proceeding in, or abandoning their attempt to introduce Loch Katrine Water.

Mr. Campbell, Dr. Anderson and Dr. Thomson, have each visited Loch Katrine, and to all the gentlemen employed, samples of that water, as well as of many others, have been delivered.

As it appeared to the Deputation that the more important part of the inquiry would be as to the action of the water upon the lead cisterns and lead pipes already laid down in the city, and thinking it probable that the passage of the water through iron pipes might have some effect in diminishing its action upon the lead with which it would subsequently come in contact, they thought it desirable to try this experiment upon a tolerably large scale, as nearly similar as possible to the mode in which the water is actually delivered to the inhabitants. For this purpose, they gave instructions that a quantity of old and new iron pipes, and of old and new lead cisterns, and old and new lead pipes, (the old pipes and cisterns being those which were then in use in Glasgow) should be taken to the outlet of Loch Katrine, and there laid down in the manner of a small water-work for purposes of experiment. This work was placed under the charge of Mr. Mackain, the Engineer of the Glasgow Water-works, with instructions to do everything exactly in the same manner as if he were supplying water in Glasgow in the ordinary way. When the pipes and cisterns were laid and fixed, the experiments were placed under the charge of Mr. Campbell, with whom was subsequently associated Dr. Anderson, as Chemists, and of Mr. G. H. Hill, Mr. Bateman's Assistant, as Engineer.

The results of these experiments, which are of the most satisfactory character as proving conclusively the safety with which the water would be delivered to the inhabitants, will appear in the Reports of the several gentlemen.

It was also considered requisite to discover what effect might be produced by the geological character of the district through which the water must necessarily be conveyed to Glasgow. Specimens of the rocks and clays were, therefore, procured from the line of aqueduct, and carted to the experimental works at Loch Katrine, and experiments were made to ascertain the action of the water upon lead, after having been in contact with these materials for a similar time and extent to that which would be the case in practice.

The line of aqueduct, after passing for about nine miles through mica slate and clay slate, which appear to produce no change in the character of the water, crosses a thin bed of lime stone and then enters the old red sandstone formation. Through this formation it extends for about eleven miles, and through the succeeding strata of the coal measures, for a mile and three quarters more, making the total length of the sandstones of the old red and coal measure formations, with which the water will come in contact, nearly thirteen miles, and the time, eleven or twelve hours. The experiments shew that the contact of the water with these materials, for a fewer number of hours than will be the case in reality, deprives it of all sensible action upon lead; proving most conclusively that no possible danger could attend the use of the water when delivered in Glasgow.

Another important point to which the Deputation directed attention, was the effect which had been produced in towns or places supplied with water of similar quality. Towns situated in similar geological districts, or supplied with water of very pure quality, were accordingly selected for examination, and gentlemen were sent to various parts of England, Scotland, and Wales, to make inquiries. For this purpose,

the places visited in Scotland have been Dumfries, Edinburgh, the present and projected sources of the Gorbals Company, the Gare Loch, Loch Goilhead, Inverary, Tarbet, Inversnaid, Loch Lomond and the River Leven, Perth, Aberdeen, Inverness, Dunkeld, Taymouth, Loch Tay, Loch Rannoch, Loch Ness, Loch Lubnaig, and other places in that district. In England, the Lake district of Cumberland and Westmorland, including Ulleswater, Penrith, Windermere, Ambleside, Grassmere, Derwentwater, Keswick, Cockermouth, Ennerdale Lake, and Whitehaven; and in Wales, Bala, and Bala Lake, the River Dee, Bangor, Beaumaris, and other places. Besides these places, inquiries have been instituted at Manchester, Sheffield, Macclesfield, Bolton, Rochdale, Chorley, Heywood, Blackburn, Accrington, Darwen, and Bury, and water has been procured from Londonderry in Ireland, and from New York in America. The water of some of these places had no effect upon lead—of upwards of two thirds there is a very sensible action—in most equal, and in some cases greater than that of Loch Katrine. In all cases, the towns or places supplied are served through lead pipes and cisterns, and in no single instance has a trace of lead been discovered in the water which has passed through the pipes.

Of the places visited, those selected for particular examination have been Whitehaven, supplied from Ennerdale Lake; the works on the River Leven from Loch Lomond; Inverness, supplied from Loch Ness; Bolton and Blackburn in Lancashire, and Sheffield in Yorkshire; the three last, in common with most other places in hill districts, being supplied by means of reservoirs constructed for the storage of flood waters. Mr. Campbell and Mr. T. T. Mitchell have visited Inverness; Dr. Anderson has examined Whitehaven; and the officers of the Water-works and medical gentlemen from these and some of the other places, have tendered evidence proving the fact of no injury having been sustained by the supply of water which acts powerfully on brightly polished lead; but that, on the contrary,

much comfort and advantage have resulted, and the mortality of the several places has been diminished.

Many of the rivers, after flowing out of lakes, the water of which has violent action on lead, and which pass over sandstone or other neutralizing geological formations, have been traced down, to ascertain how soon and from what apparent cause the water is deprived of its power to act on lead. Among these are the Eamont, flowing out of Ulleswater; the Derwent, out of Bassenthwaite Water; the Dee in Wales, out of Bala Lake; the Tay, out of Loch Tay; and the Teith, from Loch Katrine. The Eamont loses its action very soon after leaving the lake, upon entering a limestone district. The Derwent, which flows over the slate rocks of the Cumbrian formation, retains its action to near Cockermouth, where it enters limestone. The Dee, from Bala Lake, retains its action to a considerable extent till mixed with water from the Caradoc sandstone; and the Tay, till after running for some distance over old red sandstone. The Teith, which passes over this formation when it leaves Loch Vennechar, loses much of its power before it joins the Forth, though, in consequence, probably, of the large body of water, and the gravel which prevents any close contact with the softer beds of sandstone, the action is not as much diminished as in other cases.

Several towns and waters which are mentioned in the preceding list, but which are not specially reported upon in the following pages, have nevertheless been carefully examined.

At Bolton-le-Moors, in Lancashire, a town having a population of 80,000 persons, the water which has supplied the town for nearly thirty years is extremely soft, and acts very powerfully upon bright lead. It is distributed to the inhabitants through lead cisterns and lead pipes in the ordinary manner. Dr. Black, a physician who has resided there for upwards of twenty years, and has during that period been uniformly supplied with the Water-works water, through lead pipes, and has himself ascertained its power of rapidly corroding bright lead, declares that

he has never known a case of injury arising from the supply of the water.

At Blackburn, where the action of the water is less powerful though still considerable, Mr. Dugdale, an eminent surgeon in the town, now Mayor of the Borough, and who has been Chairman of the Water Company since its formation in 1844, expresses the strongest opinion of the perfect safety with which the water has been supplied to the inhabitants through lead pipes, and of the great advantage which has resulted from its use.

At Sheffield, the water, which has been supplied to the inhabitants for nearly thirty years, acts upon lead nearly as energetically as that of Loch Katrine. It is almost uniformly delivered into leaden cisterns, being conveyed to the cistern, and from thence to the taps for domestic use, in leaden pipes. Mr. Gunson, the manager of the works, and who has held that situation since their establishment, receives the water he uses in the way above described, and states it to be the universal system of the town. He was perfectly astonished when he saw the effect upon the water by a similar experiment to that of Dr. Penny, never having heard of the slightest injury or inconvenience arising from its use. Mr. Wright, the medical gentleman who has attended his family, receives his own supply of water in the same way, and is a surgeon in extensive practice, connected with all the medical institutions of the town. He has never heard of a case of lead-poisoning connected with the supply of the water through lead, nor of any injurious effect whatever.

The information from many other places is to the same effect. Amongst the more important, is that contained in the "Report of the Water Commissioners of Boston, U.S., on the Material best adapted for Distribution Water-Pipes; and on the most economical mode of introducing Water into Private Houses," published in Boston in 1848. The substance of this Report will appear in an Appendix.

Samples of the waters to be experimented upon were delivered to the chemical gentlemen who did not obtain their own specimens, after having been carefully obtained and sealed up in glass or earthenware bottles, in such a way as to allow of their being clearly identified and proved.

The Loch Katrine and Inverness waters were accompanied by the following explanation of the samples, and instructions as to the character of the examination required. It will serve as a key to several of the Reports.

GLASGOW CORPORATION WATER-WORKS, APRIL 24, 1854.

LIST OF SPECIMENS OF WATER.

No. 1. *From Loch Katrine.* 4 gallon jar—Testing its action upon lead—Also effect of old red sandstone for 10 hours, with agitation, and of limestone upon water—Solid contents, per gallon, organic and inorganic—Gases in water—Quantitative and qualitative.

No. 2. *From River—at point at which water is diverted for experiment*—Action upon lead comparative with the above.

No. 3. After passing through *old iron pipes.* Action upon lead comparative with the above—Presence of iron.

No. 4. After passing through *new iron pipes.* Similarly examined.

The following to be tested for the presence of lead:

No. 5. After passing through *old iron pipes,* and lying in *old lead pipes* for 1 day.

No. 6. Ditto, after lying for 3 days.

No. 7. Ditto, after lying for 6 days.

No. 8. After passing through *old iron pipes*, and lying in *new lead pipes* for 1 day.

No. 9. Ditto, after lying for 3 days.

No. 10. Ditto, after lying for 6 days.

No. 11. After passing through *old iron pipes*, and lying in *old lead cistern* for 1 day.

No. 12. After passing through *old iron pipes*, and lying in *old lead cistern*, covered, for 3 days.

No. 13. Ditto, after lying for 6 days.

No. 14. After passing through *old iron pipes*, and lying in *old lead cistern*, with water constantly flowing through.

No. 15. After passing through *old iron pipes*, and lying in *new lead cistern* for 1 day.

No. 16. After passing through *old iron pipes*, and lying in *new lead cistern*, covered, for 3 days.

No. 17. Ditto, after lying for 6 days.

No. 18. After passing through *old iron pipes*, and lying in *new lead cistern*, with water constantly flowing through.

No. 19. After passing through *new iron pipes*, old lead pipes, and lying in *old lead cistern*, for 1 day.

No. 20. After passing through *new iron pipes*, old lead pipes, and lying in *old lead cistern*, covered, for 3 days.

No. 21. Ditto, after lying for 6 days.

No. 22. After passing through *new iron pipes*, old lead pipes, and lying in *old lead cistern*, with water constantly flowing through.

No. 23. After passing through *new iron pipes*, new lead pipes, and lying in *new lead cistern*, for 1 day.

No. 24. After passing through *new iron pipes*, new lead pipes, and lying in *new lead cistern*, covered, for 3 days.

No. 25. Ditto, after lying for 6 days.

No. 26. After passing through *new iron pipes*, new lead pipes, and lying in *new lead cistern*, with water constantly flowing through.

No. 27. After passing through *new iron pipes*, and lying in *old lead pipes*, taken from pipes, for 1 day.

No. 28. Ditto, after lying for 3 days.

No. 29. Ditto, after lying for 6 days.

No. 30. After passing through *new iron pipes*, and lying in *new lead pipes*, taken from pipes, for 1 day.

No. 31. Ditto, after lying for 3 days.

No. 32. Ditto, after lying for 6 days.

No. 33. From *stand pipe* to *new iron pipe* for 8 hours.

No. 34. From *stand pipe* to *old iron pipe* for 8 hours.

Parcel of red sandstone (hardness before and after use of sandstone).

Parcel of limestone (hardness before and after use of limestone).

INVERNESS WATER.

A. Water from Loch Ness, April 17, 1854. To test its action upon lead.

B. Water from River Ness, April 17, 1854. To test its action upon lead.

C. Water from tap in kitchen at the Caledonian Hotel, Inverness, after passing through lead pipe, April 18, 1854. To be tested for presence of lead, and also action upon bright lead.

Memorandum of MR. MACKAIN, *Engineer to the Glasgow Water Company, as to arrangements made to test the effect of the Water of Loch Katrine on Leaden Pipes and Cisterns.*

A point the nearest to Loch Katrine, in the course of the stream issuing from it, from whence a sufficient extent of level ground could be had for laying the iron pipes, and where there was a sufficient fall in the course of the river, was selected for the experiment.

The length of iron pipes which it was proposed to use in the experiments was 300 yards.

The fall in the river was required—

1st. To give motion to water in the iron pipes.

2nd. To give motion to water in the lead pipes.

3rd. To admit of cisterns being so placed as to be filled from the leaden pipes.

4th. To permit water to be drawn off from the lower part of the cisterns.

The total fall obtained, between the extreme points of the line of pipes, from river surface to river surface, was about 9 feet.

Where the pipes were laid into the river, there exists the remains of an old dam, which keeps up the surface of the river above it.

The iron pipes used, consisted of one line formed by about 130 yards of pipes of 6 inches inside diameter, connected to about 160 yards of pipes of 5 inches in diameter, which made about 290 yards in one curved line.

These had been formerly used in distributing water by the Glasgow Water Company.

A second line of pipes, of 3 inches inside diameter, about 306 or 309 yards long, was laid alongside the other line.

These were new pipes just procured from an iron foundry.

To the first-mentioned line of pipes, which may be called the 5-inch line, there were attached two lines of leaden pipes of three quarters of an inch in diameter, which had been used for conveying water to the houses of people in Glasgow.

Two lines of new leaden pipes of the same diameter, and

One line of new leaden pipe tinned inside.

Below the old leaden pipes were placed two leaden cisterns which had been used in Glasgow.

Below the new leaden pipes were placed two new leaden cisterns.

Below the tinned pipe was placed a new cistern, lined with tin.

To the second line of pipes, which may be called the 3-inch line, there were attached two lines of used leaden pipes, beneath which were cisterns which had been used, and two lines of new lead pipes with new cisterns.

To all the cisterns, stop-cocks were attached at about 2 inches from the bottom.

A street-well, or fountain, was attached to each line of iron pipes, by means of lead and iron pipes which had been used for that purpose in Glasgow. By means of these fountains the poorer classes in Glasgow are supplied with water.

Report by Dr. Thomas Anderson, *Professor of Chemistry in the University of Glasgow, and* Dugald Campbell, Esq. *Analytical Chemist to the Brompton Hospital in London, on the Examination of the "Water of Loch Katrine," in connection with the Glasgow Corporation Water-works Bill.*.

We have minutely examined the water of Loch Katrine, and have personally superintended an extensive series of experiments made at the Trossachs, the results of which are embodied in the following Report:

Our object being to examine the action of the water on lead, and the extent to which its value, as a source, for the supply of the City of Glasgow may be thereby affected, we have confined our attention mainly to that point. As regards its general physical and chemical characters, we shall content ourselves with stating that it is a very clear and colourless water, and of unusual purity, the total quantity of solid matters contained in a gallon amounting to only 2·20 grains, of which 1·35 is mineral, and 0·85 organic matter. The mineral matter is composed chiefly of salts of soda and lime, the exact proportions of which we think it unnecessary to detail. It contains, in solution, 7·25 cubic inches of air per gallon, 4·75 of which were nitrogen, and 2·50 oxygen, along with a trace of carbonic acid. Its hardness was 0·9.

When exposed in open vessels, along with bright lead, that is to say, lead which has been recently scraped, so as to expose a fresh metallic surface, a strong action manifested itself in the course of a very few hours, the lead being covered with a white film, and a deposit of oxide falling to the bottom of the glass.

The conditions under which this experiment was made are, however, materially different from those under which the water

would be supplied to the town, and a few further trials convinced us that very trifling modifications were sufficient to affect to a very great extent the nature of the results.

We particularly found that free exposure to the air, and likewise to the sun's rays increased both the rapidity and intensity of the action, while on the other hand exclusion from light and air had a precisely opposite effect. Experiments were made by enclosing the water in leaden pipes perfectly full, and carefully corked, and though allowed to stand for many days, the action was so small as to be barely appreciable. A similar result was also observed even in open vessels, with lead in the state in which it is usually obtained from the plumber's shop, and though in some instances a slight action was apparent at first, the metal became covered in the course of a few days with a thin coating which prevented all further corrosion.

From these facts, it became manifest that the first experiments, showing a strong action on lead, could not be taken as fairly representing the nature or amount of the action likely to be exerted on the pipes or cisterns of a large town, and that absolute conclusions could only be drawn from experiments in which the actual conditions of the water supply were more closely imitated. It was, therefore, with much satisfaction that we availed ourselves of the apparatus which Mr. Bateman had caused to be laid down at the Trossachs, and which was as close an imitation as circumstances would permit of the mode in which the water will be ultimately supplied to the city.

The apparatus consisted of two lines of iron pipes, one new, the other old, each of which was connected with new and old lead pipes and cisterns, so as to vary the conditions of the experiment as much as possible. As soon as the work was completed, water was passed through the iron pipes in order to wash out the dirt which had got into them during the operation of laying, and when the water began to flow perfectly clear, it was allowed to run through the lead pipes and cisterns until they were clean, which occupied only a few minutes. The

experiments were then commenced by filling the pipes and cisterns. After 24 hours, specimens were drawn from all the pipes and cisterns, and others were taken after the water had remained for 3 and for 6 days in contact with the lead. All these specimens were examined for lead with the utmost care, and the results were as follows:

No. 5. Water after passing through old iron pipes, and lying in old lead pipes for 1 day: no action upon the lead could be observed.

No. 6. After passing through old iron pipes, and lying in old lead pipes for 3 days: action not appreciable.

No. 7. After passing through old iron pipes, and lying in old lead pipes for 6 days: action less than one tenth of a grain of lead in a gallon of water.

No. 8. After passing through old iron pipes, and lying in new lead pipes for 1 day: a very slight trace of action.

No. 9. After passing through old iron pipes, and lying in new lead pipes for 3 days: action less than one tenth of a grain of lead in a gallon.

No. 10. After passing through old iron pipes, and lying in new lead pipes for 6 days: action less than one tenth of a grain of lead in a gallon.

No. 11. After passing through old iron pipes, and lying in old lead cistern for 1 day: no action.

No. 12. After passing through old iron pipes, and lying in old lead cistern for 3 days: no action.

No. 13. After passing through old iron pipes, and lying in old lead cistern for 6 days: action barely appreciable.

No. 14. After passing through old iron pipes, and passing very slowly through old lead cisterns: no action.

No. 15. After passing through old iron pipes, and lying in new lead cistern for one day: no action.

No. 16. After passing through old iron pipes, and lying in new lead cistern for 3 days: action barely appreciable.

No. 17. After passing through old iron pipes, and lying in new lead cistern for 6 days: action barely appreciable.

No. 18. After passing through old iron pipes, and flowing very gently through new lead cistern: no action.

No. 19. After passing through new iron pipes, old lead pipes, and lying in old lead cistern for 1 day: no action upon the lead.

No. 20. After passing through new iron pipes, old lead pipes, and lying in old lead cisterns 3 days: no action.

No. 21. After passing through new iron pipes, old lead pipes, and lying in old lead cisterns for 6 days: action scarcely appreciable.

No. 22. After passing through new iron pipes, old lead pipes, and flowing gently through old lead cistern: no action.

No. 23. After passing through new iron pipes, new lead pipes, and lying in new lead cisterns for 1 day: action barely appreciable.

No. 24. After passing through new iron pipes, new lead pipes, and lying in new lead cisterns for 3 days: no action.

No. 25. After passing through new iron pipes, new lead pipes, and lying in new lead cisterns for 6 days: action barely appreciable.

No. 26. After passing through new iron pipes, new lead pipes, and flowing gently through new lead cistern: no action.

No. 27. After passing through new iron pipes, and lying in old lead pipes for 1 day: no action.

No. 28. After passing through new iron pipes, and lying in old lead pipes for 3 days: no action.

No. 29. After passing through new iron pipes, and lying in old lead pipes for 6 days: no action.

No. 30. After passing through new iron pipes, and lying in new lead pipes for 1 day: action appreciable less than one-tenth of a grain of lead per gallon.

No. 31. After passing through new iron pipes, and lying in

new lead pipes 3 days: action appreciable, but less than one-tenth of a grain of lead per gallon.

No. 32. After passing through new iron pipes, and lying in new lead pipes for 6 days: action appreciable, but less than one-tenth of a grain of lead per gallon.

No. 33. Water from stand-pipe, attached to new iron pipe, after 8 hours: no action of lead.

No. 34. Water from stand-pipe, attached to old iron pipe, after 8 hours: no action of lead.

The conclusions to be drawn from these experiments are: 1st, that the water, after lying for a considerable time in old lead pipes and cisterns, exerts no action upon lead, and that it is only after they have been 6 days in contact, that a barely appreciable action becomes apparent, and that only in some instances; 2nd, with new lead pipes and cisterns, an exceedingly minute trace of action was generally, though not always apparent, within the first 24 hours; but even after 6 days, the lead present in the water amounted to less than 1-10th of a grain per gallon, a quantity too small to produce any injurious effects; 3rd, when the water was allowed to flow slowly through the cisterns so as to imitate the frequent renewal of their contents which takes place when a cistern is in actual use, not the slightest trace of action on the lead could, in any case, be detected by the most delicate tests.

It is worthy of observation that *the old lead* cisterns employed were patched with *new lead*, and hence may in some degree be said to represent *new* rather than *old lead cisterns* as they are stated to be in the above experiments.

Had they been entirely old, we have no doubt that not the slightest trace of action would have been observed; and even with the new cisterns we believe that, had the experiments been continued for a sufficient length of time to produce a proper coating on the surface of the metal, no further action would have been apparent, and water might have been preserved in them for

any length of time without acquiring the least trace of lead. The necessity for being prepared to give evidence before the Committee of the House of Commons by a given time, prevented our continuing the experiments of the Trossachs sufficiently long to establish this point on the cisterns themselves; but we have kept pieces of lead which had been previously immersed in other waters in the Loch Katrine water, for several weeks, without the slightest trace of action being apparent, and even common plumbers' lead, when kept in the water for a sufficient time, ceased to act upon a new quantity.

But the experiments at the Trossachs do not completely fulfill the conditions under which the Loch Katrine water will be carried to Glasgow. In addition to iron and leaden pipes, it will be conveyed through many miles of a conduit built principally of the old red sandstone of the district, and in one place crosses a thin bed of limestone. Being aware that it frequently happens that though the water of a lake may act strongly on bright lead, the stream which flows from it, if examined some miles below its point of exit, is without action—a change manifestly due to the rocks and pebbles of which its bed is composed—we have examined the action of the old red sandstone and limestone on Loch Katrine Water. By repeated experiments we have ascertained that when the Loch Katrine water is allowed to stand for 10 or 12 hours over fragments of the old red sandstone, of which the conduit will be made, that the action upon bright lead is so greatly diminished, as to be barely appreciable, and upon lead in its ordinary state, no action whatever could be detected, on applying the most delicate tests.

The limestone produces a similar effect, but its influence is of much less importance as it forms only a thin bed with which the water is in contact for a very short time. With the sandstone, however, the water will be in contact for a considerable period, as we are given to understand that it is the material of which the greater part of the conduit will be built, and the time of flow through it will be about 10 or 12 hours.

It cannot, therefore, be doubted that during its passage through it, the water will necessarily be deprived of all power of acting upon lead as exemplified in our experiments. In other respects it will be little changed, and will still be a water of remarkable purity for all purposes. We find the solid contents, per gallon, after standing for 12 hours in contact with the sandstone, to be 3·02 grains, and the hardness 1·9 degrees.

So far we confined ourselves entirely to the water of Loch Katrine, but conceiving that information of an important character might be obtained by the examination of the water of other lakes, we have collected as many as possible for that purpose. The following table contains the result of our experiments;

	Degree of hardness.
Loch Ness, very powerful action . . .	0·95
Ennerdale Lake, ditto . . .	0·85
Ulleswater Lake, ditto . . .	1·72
Loch Lomond, ditto . . .	0·90
Streams flowing into Loch Lomond, very powerful action	0·90
River Leven, very powerful action . .	0·90
Loch Lubnaig, ditto . . .	0·94
Loch Doine, ditto . . .	0·93
Loch Voil, ditto . . .	0·97
Loch Tay, ditto . . .	0·90
Loch Rannoch, ditto . . .	0·88
Loch Achray, ditto . . .	0·92
Streams flowing into Loch Achray, very powerful action	0·92
Loch Vennacher, very powerful action . .	0·93
Brothers' Loch (Gorbals proposed Extension Water-works), very powerful action . .	1·08
Binnend Loch (Gorbals proposed Extension Water-works), very powerful action . .	1·36
Black Loch, (Gorbals proposed Extension Water-works), less powerful action . .	1·24

Among these waters, the three first are, at the present

moment, employed for the supply of towns; Loch Ness affording the entire supply of Inverness, Ennerdale Lake of Whitehaven, and Ulleswater of Penrith; and as they are in all respects similar to that of Loch Katrine, and act quite as powerfully upon lead, we have personally examined the whole conditions of the water-supply of these towns.

The water supply of Inverness is pumped from the River Ness at a short distance from the town. The water of Loch Ness, of the River Ness, at the point where it enters the pumps, and that drawn from the taps in the town, all act very powerfully on lead. But though leaden service pipes and cisterns are universally employed, no appearances of corrosion could be observed on a minute examination of a great number, both of pipes and cisterns, which had been in use for periods varying from 3 months to 20 years, nor could the slightest trace of lead be detected in the water drawn from them, although, when exposed in contact with bright lead, it acts with surprising intensity.

No injurious effects on the health of the inhabitants have ever been observed, nor are the cisterns or pipes found to require more frequent renewal than in other places. Indeed, the fact that the water acts on lead was entirely unknown to the inhabitants until it was pointed out to them.

The composition of the Inverness water is remarkably similar to that of Loch Katrine. It contains 2·5 grains of solid matter per gallon, of which 1·55 is mineral matter, and 0·95 organic matter. Its degree of hardness was 0·95.

The Ennerdale water is taken for the supply of Whitehaven from the stream about one and a half miles below the Lake, conveyed in iron pipes a distance of about six miles, and after passing through a gravel filter, is collected in a service reservoir from which it is carried through the streets of Whitehaven in iron, and into the houses in leaden service pipes.

The water of the reservoir as well as that drawn from the

service pipes act strongly upon bright lead when the experiment is made in open vessels; but it does not corrode the lead pipes, and the water drawn from them did not contain the slightest trace of lead. As a striking illustration of this, we may mention that a specimen of water was given us for examination which we were told had been lying in a lead pipe for six months in an empty house in the town. Not a trace of lead could be detected in it, although when exposed to bright lead in open vessels it acted with great vigour.

Notwithstanding the powerful action of the Whitehaven water on bright lead, we have ascertained by inquiries instituted among the medical practitioners of the town, that no cases of lead poisoning have occurred, and so far from any injurious effects on the health of the inhabitants having been observed, the very reverse is the case, a marked diminution in the mortality having taken place since the water-works were completed.

The water supply of Whitehaven has been particularly reported upon by the Government Commission, consisting of Professors Graham, Miller, and Hofmann, appointed in 1851 to report upon the chemical quality of the supply of water to the metropolis. They say in their Report (page 35), "From Whitehaven also, where water of the same extreme softness has been in use for the last six months, we learn that no case of lead poisoning had been seen or heard of by the medical practitioners of the town which could be attributed to the use of the water." Three years have since elapsed, and the statements made in the Report have been fully confirmed by our own inquiries.

The chemical composition of the Ennerdale Lake water corresponds closely with that of the Loch Katrine. Its degree of hardness is rather lower, being 0·85°.

The Penrith Water-works are scarcely yet in operation, and galvanised iron service pipes have been employed with the intention of avoiding any injurious effects, although our experiments lead us to the conclusion that this precaution is un-

necessary, and have afforded us an interesting illustration of the change produced on water by flowing over the bed of a river. The works are situated in the River Eamont, about $4\frac{1}{2}$ miles below the outlet of Ulleswater, at which point it has flowed for about 2 miles through a limestone district. The water taken from the bed of the river, immediately above the Water-works, has lost to a great extent the power of acting on lead, and that taken from the pumping reservoir, after passing through the filter beds, and about $\frac{1}{2}$ a mile of pipes, exerts only a barely appreciable action.

The hardness of Ulleswater Lake is 1·72°, that of the River Eamont before entering Water-works 4·10°.

In addition to these cases, which have been especially inquired into by ourselves, we have also examined the water supplied to the following towns, all of which we find to act upon lead, although to very different extents:

	Degree of hardness.
Sheffield, acts very strongly on lead	1·52
Heywood ditto	1·24
Bury, acts very sensibly on lead	3·68
Blackburn ditto	2·73
Accrington, acts slightly on lead	3·63
Rochdale, acts strongly on lead	1·76
Chorley acts very strongly on lead	1·20
Bolton ditto	1·14

In all these towns, leaden service pipes are employed, and no bad effects have been observed. In every case, we have tested the water drawn from the leaden service pipes, and have not found the slightest trace of lead.

Although the waters mentioned in the previous part of this Report, with the exception of those specially noticed, do not supply any towns, that of the River Leven which flows out of Loch Lomond is made use of at several manufactories and houses upon its banks into which it is carried by leaden pipes of considerable length. We have collected specimens of the water after passing through the leaden pipes, selecting those

which we were told were least in use, so as to have water which had lain a considerable time in them, and have invariably found that they contained no lead, although when exposed with bright lead in open vessels, they acted with great rapidity upon it. We specially examined in this way water from lead pipes at Messrs. Ewing's, and at Messrs. Alexander and Clarke's works. We have likewise examined the water used in the Inversnaid Inn, which is obtained from a stream flowing out of Loch Arklet; as also that of Tarbet Hotel, and the Trossachs Hotel; the first from a stream flowing into Loch Lomond; the last from a very small stream at the back of the hotel. In each case, the water passes through from 150 to 200 yards of lead pipe. But in none of them was a trace of lead found, although they all acted with great rapidity when placed in open vessels with bright lead.

We have made numerous experiments with these waters, the results of which it is unnecessary to detail. But we have particularly tried the action of Loch Katrine, Loch Ness, and Ennerdale Lake waters upon lead and leaden pipes which had been previously in contact with other water, and which may be conveniently termed *old*. The experiments were conducted in open vessels which have been fully exposed to air and light, and in some instances, with the leads partially, and in others entirely immersed in the water, in order to try them in every way. Already the leads have been in the water for weeks, yet they are not in the slightest degree acted upon, nor do the waters contain the faintest traces of lead, but they have not lost their action upon bright lead, for if a well scraped piece be dropped into any of the jars, the action becomes apparent in a very short time.

Our attention has also been directed to ascertaining whether any mode could be devised of protecting new and bright lead from the action of the water. We have experimented with alloys of lead, and small quantities of zinc and tin, and have found that a small addition of either of these metals, but

especially the latter, caused the lead to resist the action of Loch Katrine, Loch Ness, and Ennerdale waters in a very remarkable degree. An alloy containing 5 per cent of tin is scarcely acted on when bright, and not at all in the state in which it comes from the manufacturer.

As the result of the inquiries and experiments detailed on the preceding pages, we have arrived at the following conclusions:

1st. The Loch Katrine water acts strongly upon bright lead, freely exposed to light and air.

2nd. The Loch Katrine water does not act upon old leaden pipes and cisterns arranged so as to imitate as closely as possible the actual conditions of the water supply of a town.

3rd. When the Loch Katrine water is allowed to stand for some time in *new* leaden pipes and cisterns, a slight action takes place, but even after 6 days the quantity of lead is too small to exert any injurious effects.

4th. When the water is allowed to flow slowly through *new and old* cisterns, so as to imitate the frequent renewal of the water, which actually occurs when they are in use, not the slightest trace of action could be observed, even by the most delicate tests.

5th. By standing in contact with the old red sandstone, of which the conduit will be made, the Loch Katrine water almost entirely loses its action on bright lead.

6th. The Loch Katrine water scarcely acts on lead alloyed with 5 per cent of tin.

7th. The waters of Inverness, Whitehaven, Sheffield, Bolton, Chorley, Heywood, &c., all act powerfully on bright lead, but in practice they do not corrode the pipes and cisterns, and no injurious effects have been observed from their use.

As the general conclusion, we are decidedly of opinion that *as it will be delivered in Glasgow*, the Loch Katrine water may, with the utmost safety, be preserved in the pipes and cisterns now in use. Even on new cisterns, we do not believe it would

have the slightest effect, but should any apprehensions be entertained on this point, the most absolute protection would be obtained by the use of an alloy of lead with 5 per cent of tin, although we are of opinion that this would be a very unnecessary precaution.

THOMAS ANDERSON.
DUGALD CAMPBELL.

Report by Dr. Alfred S. Taylor, M.D. F.R.S. *Professor of Chemistry in Guy's Hospital, London, on "Water from Loch Katrine."*

The sample for analysis was received at the Chemical Laboratory of Guy's Hospital, on the 27th of April, 1854.

The quantity received amounted to four gallons.

PHYSICAL PROPERTIES.

The water was clear, bright, and colourless. It had a fresh taste and was without odour. It contained a full proportion of air. Oxygen was abundant in it. Carbonic acid was rather deficient. The only gases in it were oxygen, nitrogen, and carbonic acid. It was much more aerated than ordinary river or superficial spring water. There was a small proportion of mechanical impurity in it, *i. e.*, undissolved matter which was rapidly deposited by subsidence, too small in a gallon to render it necessary to determine the quantity by weight.

SOLID CONTENTS.

A qualitative analysis showed a remarkable absence of the usual saline constituents of water. In the entire water only a trace of chlorine (indicative of common salt) was detected. There was no bicarbonate of lime, hence when boiled or cooled there was no deposit or incrustation of any kind. When the water was concentrated to one half of its volume, sulphuric acid and lime were detected in it in small proportions, but there was no magnesia.

An imperial gallon unfiltered (70,000 grains), left by slow

evaporation a brownish-coloured residue, weighing only two grains, being in the fractional proportion of one 35,000th part of the water by weight.

This residue, when heated to redness, became darkened, evolving a slight odour of burnt *vegetable* matter. The incinerated residue submitted to chemical examination was found to be thus constituted:

Chloride of sodium (common salt) . . .	0·7
Organic matter (combustible, vegetable) . .	0·3
Sulphate of lime, silica, and oxide of iron, including mechanical impurity	1·0
Total contents in an imperial gallon . . .	2·0

HARDNESS.

There was no difference in the water whether unboiled, or boiled and cooled. The hardness was the same. It was remarked that during boiling no unpleasant effluvia were evolved: the water did not become cloudy or turbid, and its physical properties were not in any way affected or altered. The gases evolved were common air and carbonic acid. The latter was collected.

The hardness of the water on Dr. Clark's scale, and determined by his own Soap test was $1\frac{1}{4}°$.

The hardness calculated on distilled or absolutely pure water being taken as the standard of comparison, and by a stronger solution of soap than that used by Dr. Clark was 1°.

So far as the use of soap is concerned, this water possesses all the qualities of distilled,—of the purest rain, or the purest ice water. There need be no waste of soap. The water immediately acquires detergent properties without any perceptible loss.

For all domestic purposes such as baking, brewing, and washing it is quite equal to distilled water.

CONCLUSION.

This is in my judgment a water of first-rate quality, and is well adapted for the supply of a town-population.

For dietetic use it is perfectly wholesome, and in reference to domestic use, it is well adapted for all the common purposes to which soft water is applied. It does not fur boilers; hence for manufactures in which steam-engines are employed, it will have a remarkable advantage over river or spring water. It will never damage the boilers, or to any injurious extent produce an incrustation within them.

ACTION OF LOCH KATRINE WATER ON LEAD.

Like all waters, chemically pure or comparatively free from saline matter, the water of Loch Katrine, as collected at the Lake, acts very powerfully upon lead when brought into contact with that metal under *certain circumstances.* (No. 1. Sample illustrating this.) The circumstances are these: 1st, if the lead be *bright* and *highly polished*, and 2nd if the lead and water be freely exposed to the access of air.

If the surface of the lead be dull, *i. e.* covered with its usual blueish grey coat of sub-oxide, which is seen on the manufactured sheet or pipe-metal, there is no perceptible action on lead.

No. 2. Sample illustrating this (old lead immersed for sixteen days).—Common sheet lead as supplied by the plumber for cisterns, the surface being only partly scraped or cleaned, and not polished, has a smaller amount of action than that which is bright and polished.

If the lead has been already in contact with water which has acted upon it, then the Loch Katrine water produces no noxious

compound of lead with it, even when exposed to a large surface of lead, and under a free access of air.

Two plates with discs of lead to illustrate this.

No. 3. A.—Loch Katrine water and polished lead from May 2 to May 18, the maximum effect had taken place in 48 hours.

No. 4. B.—The disc of lead in this sample had been exposed 48 hours to the Trafalgar Square (Artesian) water of London, which had given to it a slight coating (this water acts upon lead). The disc was then transferred on the 4th of May to a plate containing the Loch Katrine water. When examined on the 18th of May, it was found that the thin coating previously formed had prevented the lead from exerting any noxious action on the Loch Katrine water.

Two samples illustrating this:

If the lead be alloyed with 5 per cent of tin in its ordinary state as supplied by the plumber, there is no action. If scraped so as to be rendered quite bright, then a slight white coating forms on the lead, but there is no production of carbonate to render the water noxious to health. In an experiment subsequently performed, the above alloy was exposed to Loch Katrine water and air from the 11th to the 18th of May, and there was no change whatever.

If the Loch Katrine water be concentrated by boiling, there is no chemical action on lead in any state. This shews that the conditions for allowing and preventing the action of the water on pure and bright lead, are of a very slight kind. (No. 6. Sample illustrating this:) The action of the water on lead is suspended to a great extent when the access of air is cut off, even supposing all the circumstances to be otherwise favourable. This illustrates the condition of the water in closed leaden pipes or tubes on constant service. (Sample No. 7. Vessel tied over with caoutchouc and tin-foil.) When the water has been placed in contact with the old red sandstone, and with the limestone of the district through which

the aqueduct will pass, it loses its property of acting on lead. Samples illustrating this: Nos. 8 and 9.—The water after contact with these minerals was found not to have acquired, by the immersion of bright lead, any injurious impregnation whatever.

The influence of the free access of air is seen in the different action of this water on lead in samples No. 1 and No. 7. This may have an important bearing on the constant service and the intermittent system. In cisterns with an intermittent supply, there is great exposure to air. The water is not always at one level, hydro-carbonate of lead may be formed in the cistern above the margin of the water, which is liable to be washed off, and to expose a fresh surface. Owing to the evaporation continually going on in cisterns, some white incrustation is formed in nearly all cisterns above the water-level whether supplied *with hard or soft water*; the water evaporated being always of the nature of pure or distilled water. Hence before any water, whether hard or soft, can be safely used from a leaden cistern or pipe, it should be specially tested in order to determine whether there has been any action on lead, and if so whether this has gone on to an injurious extent.

The rapidity and the degree to which any protective coating is formed on lead, whether in pipes or cisterns, can be determined only by a number of experiments on the particular water,—selected and varied according to the circumstances under which it is intended that the water should be supplied. The results of the experiments on the Loch Katrine water after having been placed in pipes and cisterns for different periods, showed an entire absence of lead in twenty-three samples out of twenty-nine; and in the six in which lead was detected, the quantity was less than that which is often found in the Thames water supplied to London, taken from leaden cisterns. The quantity was insufficient to produce any injurious effect by the use of such water.

Waters which have a powerful action on bright or polished

lead, have been for some years supplied to towns in England and the United States without producing any effects injurious to health.

CONCLUSIONS.

1. The result of this inquiry is that the Loch Katrine water acts strongly on lead when the metal is bright and highly polished, and there is free access of air to the water and lead.

2. That this water does not exert any noxious action on lead when the metal is in its ordinarily dull state.

3. That the Loch Katrine water, which has been placed in contact with old red sandstone and limestone, obtained from the district which it was proposed that the water should traverse, has no action on lead. The water dissolves a small quantity of salt and carbonate of lime;—these substances protect the surface of the metal from further chemical action.

4. The Loch Katrine water has no action on an alloy of lead and tin, in the proportion of five parts of tin to ninety-five parts of lead.

REPORT ON SAMPLES OF WATER, MARKED IN MR. BATEMAN'S PAPER NOS. 5 TO 34.

INQUIRY *as to presence of Lead in certain Waters numbered respectively from No.* 5 *to No.* 34 *on Mr. Bateman's Paper.*

IT was first ascertained by experiment that 1-17th part of a grain of carbonate of lead in a gallon of water, or a quantity equal to only the 1-1,225,000th part of the weight of the water, admitted of very easy detection by chemical analysis. This is equal to a grain of carbonate in 17 gallons of water.

The smallest proportion of carbonate of lead in water, which has been known to produce injury to health, was in the Claremont case (the ex-royal family of France) in 1849. It amounted to about one grain and a third in an imperial gallon of water.

The samples as above numbered were for the most part clear, bright, and colourless. They presented very little mechanical impurity. There was not in any one, a crystalline opacity or an *insoluble white sediment of lead.* When exposed to air, they acquired no film of carbonate of lead, such as waters containing oxide of lead dissolved, are known to acquire.

Numbers 33 and 34 had a brownish colour. This obviously arose from the presence of some impurity. In No. 34 this was found to be oxide of iron.

The waters marked Nos. 8, 9, 10, 30, 31, 32, were the only waters of the series which were found to contain lead. The quantity in all these cases was minute.

No. 30 contained the largest proportion, but here the lead did not amount to more than 1-500,000th part of the weight of the water, *i.e.*, strictly to 1-490,000th part; this is equivalent to 1-7th of a grain in the gallon, or 1 grain in 7 gallons. This proportion of lead in water is, in my opinion, too small to affect the public health. I have found a quantity equal to, and greater, than this in the Thames water supplied to the inhabitants of London.

Nos. 9, 30, and 32 were as nearly as possible equal in the proportion of lead contained in them; it was rather less than in 31, and was estimated at 1-700,000th part of the weight of the water, or 1-10th of a grain in a gallon, or 1 grain in 10 gallons.

Nos. 8 and 10 contained the smallest proportion of lead—the proportion was equal to 1-1,225,000th part of the weight of the water, or to 1-17th part of a grain in a gallon.

CONCLUSION.

Before stating the conclusion derivable from this branch of

the analysis, I may observe, that until after it was made, and the results reported, I was not aware that the various samples from No. 5 to No. 34 were samples of Loch Katrine water which had been exposed for various periods, from one day to six days, in contact with leaden pipes and cisterns.

From the statements furnished to me, it appears that new and old lead pipes and cisterns were used in these experiments. In twenty-three out of twenty-nine samples, there was no trace of lead, either in a dissolved or in an undissolved state, although less than a millionth part of lead may be easily discovered by chemical tests. In the six samples in which lead was found, the quantity present, as I have already stated, was such as to be quite uninjurious to health. These samples had been in contact with new lead pipes and cisterns.

I therefore conclude, from these experiments, that the Loch Katrine water is not liable to acquire a noxious impregnation from its distribution through leaden pipes and cisterns.

ADDITIONAL EXPERIMENTS.

Four ounces of the Loch Katrine water were placed in about two feet of leaden pipe which had been used during two years for the supply of river water to my house. After *five days*, in one experiment, and *sixteen days* in another, the water was tested, and no lead was found in it. There was a slight incrustation or deposit on the interior of the pipe, which had protected the metal from the action of the water.*

* It should be observed that the noxious action of water on lead, if manifested at all, is generally manifested within forty-eight hours.

REPORT ON SAMPLES OF INVERNESS WATER, MARKED A, B, C, ON MR. BATEMAN'S PAPER.

a. Water from Loch Ness.

There was no immediate action on lead, but a chemical action began in about a quarter of an hour after contact. After forty-eight hours, there was a full impregnation, but the action was less than in Loch Katrine water.

b. Water from the River Ness.

The chemical action of this water upon lead was instantaneous. It was so rapid and violent, that in five minutes the water was quite milky from the production of carbonate of lead. In one hour the deposit of carbonate was very considerable. After forty-eight hours, the deposit was greater than in the Loch Katrine water. Such water would be pronounced eminently unfit for domestic use, if distributed through leaden pipes or cisterns.

c. Water from a Tap of the Caledonian Hotel, Inverness.

This water produced no immediate effect on lead. In this respect it somewhat resembled sample *a*. In a quarter of an hour the action began, and went on pretty rapidly for forty-eight hours, when it ceased. The deposit of carbonate of lead was less than in *b*, and about as great as in *a*. The action was such as to render the water unsafe for use in highly polished leaden pipes or utensils,—its action on lead being equal to that of the Loch Katrine water.

EXAMINATION OF *c* FOR LEAD.

In two separate experiments on twelve ounces and eight ounces of this water respectively, trials were made to determine whether there was any lead contained in it. There was no

carbonate or undissolved salt, since the water was quite clear, and did not acquire a film on exposure. There was no sediment or deposit of an insoluble salt of lead in the bottle.

On applying the test to the two quantities of water above-mentioned, there was not the slightest trace of any salt of lead present. Had the 140th part of a grain of lead been present in the twenty ounces of water, it would have been detected; but there was not even so small a quantity as the one millionth part present. This water was tested side by side with an equal quantity drawn from the tap of a leaden pipe at Guy's Hospital (Thames water), the water coming out of a leaden cistern holding 75,000 gallons. The results were the same. There was no lead present in either water. The Guy's water does not act upon lead. The water *c* does not contain any lead, but it acts upon polished lead so as to produce speedily a noxious impregnation.

The results of this analysis are very important in reference to the water-supply of towns. I am informed that the town of Inverness is supplied with the water marked *b*, and that it has been supplied with it for some time. This water, placed under precisely similar circumstances, acts much more rapidly and more powerfully on lead than that of Loch Katrine. It is quite certain that a chemist, judging only by the action on *bright* and *polished* lead, would condemn this water as unfit for use. But the remarkable fact is, that the water *c*, which is nothing more than *b*, drawn from a tap in the Caledonian Hotel, after distribution by intermittent service through *leaden cisterns and pipes*, does not contain a trace of lead, either in a dissolved or in an undissolved form. Here then is a water *acting powerfully on lead*, and *distributed through lead*, yet it *contains no lead;* and it is and has been for a long period used by the population of Inverness in leaden pipes and cisterns without any injury to health. The exemption of the inhabitants from injurious consequences is explained by the water having ceased to act on lead, and by its being found to contain no lead. The interior of the pipes and cisterns has no doubt been speedily

coated with a deposit which has wholly prevented any injurious chemical action.

But the remarkable fact is that this water *c*, thus supplied to the inhabitants of Inverness has not lost the property of acting on lead. If the metal be scraped or polished, and placed in it, there is a chemical action in a quarter of an hour, and this after forty-eight hours had reached such a degree that a chemist, unacquainted with the facts, might have been induced to pronounce the water as likely to be dangerous to health if distributed through leaden pipes or cisterns.

The waters supplied to Aberdeen and Merthyr Tydvil act upon lead, but for the reasons above stated they cause no injury to public health.

The Loch Katrine water may then, in my opinion, be just as safely used for the supply of a town as the water of the River Ness, quite irrespective of all consideration of the neutralizing effect of the geological character of the district through which the water must pass.

ALFRED S. TAYLOR, M.D.

Report of ROBERT DUNDAS THOMSON, M.D. F.R.S. L. & E. *Professor of Chemistry in Saint Thomas's Hospital, College, London, on the "Loch Katrine Water."*

Having been consulted on the subject of the supply of water to Glasgow, Dumfries, Kilmarnock, Stirling, London, Newcastle, Swindon, Liverpool, &c., &c., and very extensively on the sanitary condition of waters; the subject of the action of water on lead has for many years been familiar to me, and I have had considerable opportunities of meeting with cases where paralysis had been produced by the action of lead on the human system. As far as I can ascertain from the experience of hospitals, the occurrence of disease from the corrosion of lead pipes is an exceptional circumstance, if it has ever occurred in these institutions, the general cause of affections from lead being occupation in white lead manufactories.

Waters, from whatever source, appear to act on a freshly polished surface of lead. Thus I have found the water taken from the Thames, Clyde, Gorbals Water-works, Kypes River, Givel River, Paisley Water-works, sources in the neighbourhood of Glasgow, to act on lead; the greatest amount of saline matter in these specimens being in that of the Thames, which contains about twenty-two grains of solid residue in the imperial gallon, while the Givel contains only about seven grains. Again, I find the water in a well at St. Thomas's Hospital, London, to act very sensibly on a fresh surface of lead, although the solid constituents in the gallon amount to about one hundred grains. This experiment is further corroborated by a circumstance in reference to a well, respecting which I was consulted several years ago in Glasgow. The wells of Glasgow, like all those of large cities, are known to be impure. They contain from 15 to 100 grains of salts in the imperial gallon, and yet on one

occasion water was brought to me which had been pumped through a new lead pipe from a well in a garden which contained a considerable quantity of oxide of lead diffused through it. I inferred that the oxide of lead was only in suspension from the fact that when the water was filtered through a single paper filter, no lead could be detected in the water when it had passed the paper. And it is a well ascertained fact, that water contaminated with oxide of lead is entirely freed from it by permeating a filter of sand. All these facts relate to lead possessing a bright surface; for lead, when allowed to remain in these waters for a few days, ceases to suffer appreciable corrosion, or if the lead be removed from the water, exposed to the air, and afterwards immersed, but an insignificant action, if any, can be detected.

Loch Katrine water I examined several years ago, when it was proposed to be introduced for the supply of Glasgow. I considered it then, as I do now, a water admirably adapted for domestic use, and have not had my opinion in the slightest degree affected by the laboratory experiment exhibited on the Committee's table, as I am convinced from my acquaintance with the subject that, if the Loch Katrine supply had been introduced to Glasgow, nothing would have been heard of its influence on lead. I found it to contain about two grains of solid matter in the gallon, its constituents being organic matter, common salt, sulphate and carbonate of lime.

When lead with a clean bright surface is introduced into it, the lead is rapidly acted on, and white scales of oxide fall to the bottom of the vessel in which the experiment is made. When such water, with the suspended oxide of lead is passed through a double filter of paper, the oxide is detained on the filter, and little or none seems dissolved in the water, which passes through the paper. Hence it would happen, that should any corrosion occur on the first use of new lead cisterns, the insoluble oxide will be deposited at the bottom of the cistern, and will not intermingle, or but in a trifling degree, with the

contents of the cistern, while in old cisterns, or after the new cisterns have become tarnished, little or no action will occur. But to prevent any corrosion on first using the cisterns or pipes, the plan sometimes adopted at Tunbridge Wells might be had recourse to, of brushing over the interior fresh surfaces with a coating of lime. No description of water could be purer, or better fitted for a beverage, or for culinary purposes than the water supplied by lead pipes to the Trossachs Hotel, at Loch Katrine, where I lately examined it when inspecting the experiments made under the charge of the engineer, at the outfall of Loch Katrine.

To set the objections at rest which have been urged against the use of Loch Katrine water, I may detail an experiment on a sufficiently large scale of a parallel nature which has been in action for forty years. About 1814, a plumber of Tunbridge Wells introduced at his own risk a spring of water by means of lead pipes and lead cisterns into the houses of that place. A similar objection was taken to its use as on the present occasion, traces of lead were even detected in that portion of the water in immediate contact with the new lead cisterns, but none in the body of the water or in the water discharged from the cisterns. Specimens of this water were sent to London in 1815, and tested by Dr. Thomas Thomson without his being able to detect a trace of lead. I have a letter in the handwriting of the late Dr. Wollaston, dated December 27, 1815, in which he states that he could detect no lead in water sent to London from Tunbridge Wells. Traces were occasionally detected in the new cisterns, as I was assured by the late Dr. Thomson, only on the margins in contact with the lead, the largest quantity obtained being 1 grain in 20 gallons. Yet from these incidental results, the water supplied to the village was condemned by the opponents of the scheme as *poisonous*. But the water still continues in use; the village has increased to a large town of 10,000 inhabitants; it is a popular place of resort for invalids; and after careful inquiry, I have not been able to discover among its residents,

even a suspicion of its contamination by lead. I examined the engineer in charge of the company who worked at the original works, and laid down many of the lead pipes and cisterns in his capacity at that time of plumber, and several persons, residents of twenty years, who assured me that they had never heard the subject of danger to water from lead pipes mooted.

When bright lead is introduced into this water, it is acted on immediately. It contains between three and four grains of salts in the imperial gallon, and is upon the whole, one of the purest waters which I have examined in reference to the supply to towns. In examining the reservoir in which the water is retained for the supply of the town, I observed a perforated plate of lead through which the water passed to the iron conduit pipe, which was covered with a coating of oxide of lead precisely similar to the coating lining the lead pipes which I have seen brought from Inverness, a town with whose water supply I am well acquainted. The plate, I was told, had been in this position for six years. The deposit was therefore insoluble, or nearly so in the water, and acted as a protecting covering against any further action on the lead. Hence it would appear that this water, by its rapidly oxidating power on lead, furnishes with so much the greater efficiency, security against further corrosion. Perhaps no stronger fact could be adduced in proof of the perfect confidence of the inhabitants of Tunbridge Wells in the sanitary quality of the water, than that of which I was assured by the engineer, that the company is now paying an annual dividend of ten per cent. The original spring, introduced for supplying the village, is situated at the distance of about a quarter of a mile to the south, and is emitted from the northern aspect of a declivity. Many years after it was in use, from the increase in the population, the supply was found to be inadequate to the demand, and another spring at about a mile's distance in the same direction, but issuing on the southern declivity of the same ridge, was collected in a similar reservoir

of brick, and pumped into the village reservoir to mix with the waters of the first spring, which is conveyed to its destination by gravitation. The second spring I found to be more rapid and more extensive in its action on lead than the water of the first spring, which alone, as far as I could learn, had attracted any attention; and even the circumstances to which I have already referred, were quite unknown to any persons with whom I came in contact. Still more recently, a third spring, under different management, but of very soft water, and therefore with the corrosive qualities upon lead, of the waters affording the previous supply, has been introduced into the town with the universal approbation of the inhabitants as far as regards its wholesomeness, purity and softness.

Although in the preceding Report, I have given it as my decided opinion that no more permanent danger is to be apprehended in reference to health from the transmission of Loch Katrine water through lead pipes, and detention in lead cisterns, than there is in the case of other waters supplied to towns, I have always recommended the substitution of iron and other materials for water pipes, as much as possible for lead, and also where lead is employed, that it should be alloyed with tin.

ROBERT DUNDAS THOMSON, M.D.

Report by PROFESSOR GRAHAM, *of University College, London, and* PROFESSOR HOFMANN *of the Royal College of Chemistry, London.*

Specimens of water taken from Loch Katrine, and properly authenticated, were received by us from Mr. T. T. Mitchell, Mr. Bateman, and Mr. George H. Hill, and made the subject of the experiments and observations to be reported by us.

The water of Loch Katrine was submitted to a careful and minute chemical analysis, of which the detailed results will be subjoined. This water is of the first class in point of softness and purity—its hardness being under one degree, and the whole amount of solid matter not more than 2·21 grains in the gallon of which 1·24 are mineral matter.

Like distilled water, and most soft and pure waters, the Katrine water, when taken directly from the Lake, has a considerable action upon lead. This property of the water appears, however, to be of a temporary and fugitive character, being diminished or disappearing entirely under a variety of influences to which it will be unavoidably exposed during its conveyance in conduits and pipes from the Lake to Glasgow. Such is the conclusion which must be drawn from the following facts:

I. The solvent action of Katrine water upon lead was observed by us to be already considerably diminished in a specimen taken from the river, at the point at which the water is diverted for experiments.

II. Thirty specimens of Katrine water numbered from 5 to 34 were received and examined by us, which had previously been exposed to contact with lead, in experiments made near the Lake, as described below; the result of our analysis of the

specimen of water, made to ascertain whether lead has been taken up by the water and remains in it, is added in each case.

No. 5. Katrine water after passing through *old iron pipes*, and lying in *old lead pipes* for 1 day: no lead found in the water.

No. 6. Ditto, after lying for 3 days: no lead found in the water.

No. 7. Ditto, after lying for 6 days: the lead found in the water amounted to, or slightly exceeded one millionth part of the weight of the water.

No. 8. After passing through *old iron pipes*, and lying in *new lead pipes* for 1 day: the lead found in the water did not amount to one millionth part of the weight of the water.

No. 9. Ditto, after lying for 3 days: the lead found in the water did not amount to one millionth part of the weight of the water.

No. 10. Ditto, after lying for 6 days: the lead found in the water did not amount to one millionth part of the weight of the water.

No. 11. After passing through *old iron pipes*, and lying in *old lead cisterns* for 1 day: no lead found in the water.

No. 12. After lying, as in No. 11, covered for 3 days: no lead found in the water.

No. 13. Ditto, after lying covered for 6 days: no lead found in the water.

No. 14. Ditto, after lying covered for 6 days, with water constantly flowing through: no lead found in the water.

No. 15. After passing through *old iron pipes*, and lying in *new lead cistern* for 1 day: no lead found in the water.

No. 16. Ditto, after lying for 3 days: no lead found in the water.

No. 17. Ditto, after lying for 6 days: no lead found in the water.

No. 18. Ditto, after lying for 6 days, with water constantly flowing through: no lead found in the water.

No. 19. After passing through *new iron pipes, old lead pipes,* and lying in *old lead cisterns* for 1 day: no lead found in the water.

No. 20. Ditto, after lying for 3 days, (cistern covered): no lead found in the water.

No. 21. Ditto, after lying for 6 days: the lead found in the water did not amount to one millionth part of the weight of the water.

No. 22. Ditto, after lying for 6 days, with water constantly running through: no lead found in the water.

No. 23. After passing through *new iron pipes, new lead pipes,* and lying in *new lead cisterns,* for 1 day: no lead found in the water.

No. 24. Ditto, after lying for 3 days: no lead found in the water.

No. 25. Ditto, after lying for 6 days: no lead found in the water.

No. 26. Ditto, after lying for 6 days, with water constantly flowing through: no lead found in the water.

No. 27. After passing through *new iron pipes,* and lying in *old lead pipes,* taken from the pipes, for 1 day: no lead found in the water.

No. 28. Ditto, after lying for 3 days, (cistern covered): no lead found in the water.

No. 29. Ditto, after lying for 6 days: the lead found in the water did not amount to one millionth part of the weight of the water.

No. 30. After passing through *new iron pipes,* and lying in *new lead pipes,* taken from the pipes, for 1 day: the lead found in the water amounted to, or slightly exceeded one millionth part of its weight.

No. 31. Ditto, after lying for 3 days: the lead found in the water amounted to, or slightly exceeded one millionth part of its weight.

No. 32. Ditto, after lying for 6 days: the lead found in the

water amounted to, or slightly exceeded one millionth part of its weight.

No. 33. From *stand pipe* to *new iron pipe*, for 8 hours: the lead found in the water amounted to, or slightly exceeded one millionth part of its weight.

No. 34. From *stand pipe* to *old iron pipe*, for 8 hours: the lead found in the water amounted to, or slightly exceeded one millionth part of its weight.

It will be observed that a considerable majority of these specimens of Katrine water were found not to contain the minutest trace of lead, although such specimens of water, after passing through an iron pipe, had been left in contact with leaden pipes or cisterns, both old and new, for an entire day, or even for three days, in several of the experiments made on the spot. No lead, therefore, appears to have been taken up, and the water has not suffered from its contact with the metal. These specimens are Nos. 5, 6, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 22, 23, 24, 25, 26, 27, 28, 33 and 34.

In the next specimens, the presence of lead could only be discovered by the most delicate tests, and did not amount to so much as one millionth. These are Nos. 8, 9, 10, 21 and 29.

In the remaining specimens, the lead present amounted to one millionth, or slightly exceeded that proportion. These are Nos. 7, 30, 31 and 32.

Such minute traces of lead in water are, in our opinion, quite innocuous, and may safely be disregarded. They appear only to occur also where either the iron pipes, or the lead pipes were new, and generally where the water had been allowed to stagnate in contact with lead for several days.

The experiments above referred to are of the greatest practical importance, as they show that Loch Katrine water does not act upon lead under the circumstances in which it would be placed when used for the supply of a town.

III. The experiment was made by us of agitating Katrine water in contact with the old red sandstone in a broken state, and afterwards exposing this water to lead. The water retained its great original softness, but lost entirely its action upon lead. We infer, therefore, that the Katrine water would speedily lose its power of acting upon lead, by passing through channels composed of the old red sandstone rock, such as it is proposed to construct for the conveyance of the water to Glasgow.

IV. A similar experiment was made by substituting for the red sandstone the mountain limestone of the Loch Katrine district. The hardness of the water was increased from one degree to three degrees, while the power of the water, to act upon lead disappeared entirely as in the previous experiment with the old red sandstone. Hence the employment of this rock in the construction of the conduits, or its presence merely in broken pieces in the bed of the stream, would ensure an entire immunity to the water from subsequent contamination with lead.

V. The facility with which the Katrine and other similar soft waters lose the power they originally possessed of acting upon lead appears to have some light thrown upon it by the following experiments.

The power of acting upon lead of both distilled water and of Katrine water for 24 hours was destroyed by the addition of 1-50,000th part of carbonate of lime (chalk).

The water was equally prevented from acting upon lead by the addition of 1-20,000th of the following substances:

Bicarbonate of ammonia
Carbonate of soda
Bicarbonate of soda
Phosphate of soda.

With the same small proportion of sulphate and of soda, ammonia, and lime, the metal was considerably corroded

by the water, but the proportion of lead actually dissolved within a short period, such as 24 hours, was much less than is dissolved in pure water.

The substances which give the greatest amount of protection to water from the action of lead are of an alkaline character, such as soluble carbonates and phosphates; but free carbonic acid also in a proportion not exceeding 1 per cent. gives a temporary protection, extending to 12 or 24 hours, probably due to the extreme insolubility of the carbonate of lead.

It is to be observed that several of these protecting substances may often be obtained by water from the atmosphere, such as carbonic acid and carbonate of ammonia, or from the soil and rocks over which the water passes, such as carbonate of lime, and occasionally, carbonate of soda.

It is also evident that no soft water intended for a town supply need be allowed to remain with the power to act upon lead, seeing that the utmost degree of safety may be obtained by allowing the water to come in contact with carbonate of lime.

In conclusion, we would press strongly the facts that the water of Loch Katrine is in no respect peculiar or exceptional in its composition and properties, and that the safety for town use of the class of waters to which it belongs has already been decided by the most ample experience. It is stated by the Commissioners who reported to Government in 1851 upon the Metropolitan Water Supply, "that no recent and authenticated case can be cited of the health of any of the numerous towns lately supplied with soft water being affected by the use of leaden distributory tubes, although apprehensions were often entertained from the introduction of soft water, as at Boston, in the United States, where the subject has excited much attention; and at New York, since the introduction of the Croton River." New York, with a population of 400,000, and Philadelphia, with 300,000, have been supplied, the former for nearly ten, and the latter for upwards of twenty-five years, with a water as soft as

that of Loch Katrine, and the water frequently examined for lead, after passing through the usual service pipes of that metal, without any contamination of the water being discovered. The physicians of both places also testify that no case of lead-disease from this cause has been ever heard of. We have also had occasion to examine the water with which the towns of Inverness and Whitehaven are supplied, both before and after passing through lead pipes and cisterns, and find these waters to have the same high degree of softness as the water of Loch Katrine, and also the same decided action upon lead. Yet the injurious action of the metal upon the water in use in these towns has never been observed nor even suspected, nor can a trace of metal be found in the water which has passed through lead. In fine, the apprehension of danger from the use of Loch Katrine water with leaden service pipes is entirely speculative, and cannot fail to be dissipated the moment that reference is made to the experience of other towns supplied with water of equal softness and purity.

(Signed) THOMAS GRAHAM,
A. W. HOFMANN.

CHEMICAL ANALYSIS OF WATER FROM LOCH KATRINE.

Statement of saline constituents :

	In 1000 grains of the water.	In the gallon.
Sulphate of lime	0·0054	0·378
Sulphate of potash	trace	trace
Chloride of sodium	0·0064	0·448
Sulphate of soda	0·0040	0·280
Carbonate of soda	0·0021	0·147
Carbonate of magnesia	0·0022	0·154
Sesquioxide of iron	trace	trace
Silica	trace	trace
Organic matter	0·0117	0·819
	0·0318 grains.	2·226 grains.

dissolved by the water, and expelled by ebullition in vacuo.

Total volume calculated to 30 inches barometric pressure, and 60° Fahr. (15·5° Centigrade) temperature:

Cubic inches in 1000 grains of water .	= 0·1019
„ in the gallon of water . .	= 7·133

Composition of the gases:

In 100 volumes.	
Carbonic acid . . .	1·30
Oxygen	33·28
Nitrogen	65·42
	100·00

Cubic inches of the several gases in the gallon of water:

Carbonic acid . . .	0·09
Oxygen	2·38
Nitrogen	4·66
	7·13

ANALYSIS OF WHITEHAVEN WATERS.

Specimens of the water with which the town of Whitehaven is supplied were forwarded to us by Dr. Anderson. No. 1, which was taken from Ennerdale Lake, proved to be as soft as the Loch Katrine water, its hardness being 0·85 degrees, and the whole amount of solid matter being 3·097 grains in the gallon, of which 2·186 grains were mineral matter. This Ennerdale water acted powerfully on lead.

No. 2 was drawn from the reservoirs of the town of Whitehaven, after having run from Ennerdale about a mile and a half in the bed of a stream, and about six miles in iron pipes. Its hardness was 1·83, and it contained 3·919 grains of solid matter in the gallon, of which 2·795 grains were mineral matter. This last specimen, placed in contact with lead for 24 hours, still dissolved a minute quantity of metal. The original solvent powers of the Ennerdale Lake is thus proved not to be destroyed, although somewhat reduced by the contact of the water with the substances it meets in its channel.

1. ENNERDALE LAKE.

Specific gravity .	1·00014	Hardness .	0·85
Solid constituents:			
Mineral matter . .	2·186	grains in the gallon.	
Organic matter . .	0·911	„ „	
Total solid residue .	3·097	„ „	

2. SERVICE RESERVOIRS OF WHITEHAVEN WATERWORKS.

Specific gravity .	1·00004	Hardness .	1·83
Solid constituents:			
Mineral matter . .	2·795	grains in the gallon.	
Organic matter . .	1·124	„ „	
Total solid residue .	3·919	„ „	

3. TAP AT GLOBE HOTEL, WHITEHAVEN.

Specific gravity .	1·00005	Hardness .	1·37
Solid constituents:			
Mineral matter . .	2·502	grains in the gallon.	
Organic matter . .	0·839	„ „	
Total solid residue .	3·341	„ „	

Evidence with reference to the Supply of Water to the Town of Inverness.

JOSEPH MITCHELL, Civil Engineer, states:

I am engineer of the government roads, bridges and harbours in the Highlands and Islands of Scotland; and have been so for thirty years, having succeeded my father in 1824. I am a native of Inverness, and with the exception of a few years while with the late Mr. Telford in London, have resided there all my life.

There is a gas and water company in Inverness, and I advise them upon engineering matters. The town of Inverness contains a population of about 14,000. The town is built on the banks of the River Ness, where that river enters the sea. The River Ness flows from Loch Ness, a large Highland lake; the distance between the Loch and the town being about five miles. The town has been supplied with water from the River Ness since 1830. There is a pumping engine about a mile above the town, which forces the water into iron mains laid along the streets. The water is distributed from the iron mains into the interior of the houses by lead pipes. The houses have also cisterns to contain a supply of water during the time the engine is not at work. These cisterns are lined with lead; my own house is fitted up in this way. I have two cisterns placed in the attics, one has been there for eighteen years, when I built the house. I made an addition to my house about eight years ago, and placed the other cistern alongside the former one. The water is beautifully clear, and the inhabitants are highly pleased with it.

In using the water as we do through lead pipes and cisterns, we have never found the slightest appearance of any deposit, nor

any bad effect, nor any symptom of the water being affected in the slightest degree by passing through lead; it is as beautifully pure when placed on the table for use, as if taken out of the river or the lake. I never heard a whisper about any danger in using the water through lead, until some parties connected with the Glasgow Water Bill made inquiries about it a few days ago. That was the first time my attention was called to the subject, they showed me the strong action our water had upon lead, by placing a piece of lead in a tumbler. It created a considerable deposit in a few hours. I was making some alteration in the interior of my house at that time, and had just got a new lead pipe laid into a room which had not yet been in use, and I observed particularly if there was any symptom of the peculiarity referred to, by shutting up the water for twenty-four hours, and could not observe the slightest difference upon the water, than if taken out of the river. The Ness water taken from the Loch, the river, or a house pipe, has the same effect upon lead when tried experimentally, as that of Loch Katrine. In practice, however, and from my experience of the water, I am quite satisfied that it can be used through lead pipes for domestic purposes with the greatest impunity, and notwithstanding what I have seen since this subject was brought under my notice, I will continue to use it through lead pipes for the use of myself and family with the greatest confidence.

William Welsh Forbes, Member of the Royal College of Surgeons, Edinburgh, states:

I am a native of Inverness, and (with the exception of some years passed in the country, and afterwards at the University in Edinburgh) have resided there all my life.

I have been in pretty extensive medical practice in Inverness for the last twenty-six years, and have attended all classes of its inhabitants.

Inverness is supplied with water from Loch Ness, which flows towards the town by the River Ness. It is pumped up by an engine, situated about half a mile above the town, into iron mains laid under the streets, and is conveyed from the mains to the interior of the houses by leaden pipes. The houses generally have also cisterns lined with lead for storing the water.

The water so supplied from the Ness is very pure and wholesome, and the inhabitants are much pleased with it.

During the whole course of my practice, I never had occasion to attend any one whose illness I could attribute in the most remote degree to the contamination of the water by lead. I never heard of the water, as used by us, being altered in any way by the use of lead cisterns and pipes, nor was the subject ever brought under the notice of myself or any of the other medical gentlemen of the town, as far as I ever heard, until within the last few days, when some parties connected with the Glasgow Water Bill came down to make inquiries about it.

I have tried an experiment upon the Ness water from the Loch, the River, and the lead pipe in my own house, and also upon the Loch Katrine water (all taken by myself), by placing a piece of polished lead in a tumbler full of the several waters. The action of the Ness water is the same upon the lead as that of Loch Katrine.

From the experience I have had of the Inverness water, and from what I have seen of the Loch Katrine water, I am satisfied that the latter can be used in Glasgow, even supposing it undergoes no change before reaching that city, if distributed through lead pipes, with perfect safety to the health of the inhabitants.

Evidence with reference to the Supply of Water to the Town of Whitehaven.

Mr. William Barwick Clarke, of Whitehaven, in the County of Cumberland, surgeon, and a trustee of the town and harbour of Whitehaven, states:

I have been nearly seventeen years in practice in Whitehaven as a surgeon—for the last thirteen years extensively—and during this time have had ample opportunities both from my private practice and as one of the surgeons to the Whitehaven and West Cumberland Infirmary, of forming an opinion of the prevailing diseases of the town. Since the introduction of the Ennerdale water I have never seen or heard of any instances of the inhabitants being affected injuriously by it. I have never seen or heard any cases of poisoning by lead in any of its various forms as a consequence of the introduction of the water, nor, upon inquiry amongst the other medical men, have I been able to learn that any of them have.

I am familiar with the symptoms of poisoning by lead, but have only seen one instance of it in the town of Whitehaven during the time I have been in practice there, and that one was the case of a painter, who in the summer season was periodically affected by the complaint, during the time that he was engaged in his business of working among white lead. He was equally affected by his trade, both before and since the introduction of the water.

The water was introduced into the town in May, 1850, and by the end of August of that year, the service pipes which are of lead were laid into all the houses. From this time, the supply from the water-works may be said to have been general. The old supply of water, which was from springs in the neighbourhood, and from pumps in the town, was at once

discontinued, and from that time up to the present the inhabitants have been entirely supplied by the Ennerdale water.

Having, as stated, never seen any bad effects upon the inhabitants from the use of this water, I may state on the other hand that in my own practice, I have seen the most beneficial results. There has been a marked diminution in the number of fatal cases from the zymotic class of diseases, particularly from typhus fever, scarlet fever, measles, influenza, remittent fever, diarrhœa, and dysentery. The registry of deaths in my own practice in these diseases, gives the following results.

For the four years previous to the introduction of the Ennerdale water, the deaths from diarrhœa and dysentery were . . . . . 37, and for
the four years subsequently . . 12
From typhus and remittent fever . . 19 previously,
and for the same complaints . . 10 subsequently.
From scarlet fever, measles, and influenza . 53 previously,
and for the same complaints . . 7 subsequently.

And this is the result although my practice has been increasing.

On analyzing the statistics of fever, as recorded at the Whitehaven and West Cumberland Infirmary, I find a most remarkable diminution on the number of fatal cases.

The average number of fatal cases for the 4 years previous to the introduction of the water were $89\frac{1}{4}$, and for the 4 years subsequently only $17\frac{1}{4}$. If the average of years is taken for 8 years previously, the number of cases was $59\frac{7}{8}$, if for 12 years $45\frac{7}{12}$, and if for 16 years $37\frac{13}{16}$, so that it is quite obvious that however long the average is extended, the reduction in the number of fatal cases, since the introduction of the water, has been astonishingly great.

The same beneficial results are evident from an examination of the Superintendent Registrar's returns of the mortality of the town, previous and subsequent to the introduction of the water.

The following are the returns for the town of Whitehaven, which comprises the townships Whitehaven proper, and Preston quarter.

Year.	Deaths in Whitehaven and Preston.		
1839	395		
1840	375		
1841	421		Population 16·635
1842	402		
1843	450		
1844	425		
1845	401		
1846	692	35·8 per 1000	
1847	736	38·1 per 1000	
1848	654	33·9 per 1000	Population 18·791
1849	606	32·2 per 1000	
	Water introduced in summer of 1850.		
1850	482	24·9 per 1000	
1851	452	23·4 per 1000	Population 19·281
1852	445	23· per 1000	
1853	437	22·6 per 1000	

This return shows that, for the 4 years previous to the introduction of the Ennerdale water into the town, the average deaths were 34·8 per 1000. And for the 4 years subsequently, the average deaths were 23·5 per 1000, thus demonstrating beyond the slightest doubt the beneficial results which have followed from the use of the water.

APPENDIX.

Extracts from Report of the Water Commissioners of Boston, U. S., on the Material best adapted for Distribution Water-Pipes; and on the most economical mode of introducing Water into Private Houses.

This Report is mainly as to the propriety of employing leaden service pipes in the introduction of the water of the Cochituate Lake into Boston. Much excitement, it appears, had prevailed in Boston on the question, arising from the fact, that the water of certain wells acted rapidly on lead exposed to it; and hence it became important to see what would be the effect of the water of the lake on that metal. This was shown to be analogous to that observed in the case of the waters of the Thames, Schuylkill, Croton,* &c., being in no case to such a degree as to act injuriously on the system. The Board of Consulting Physicians of the City not having, in their Report to the City Council, specified or expressed an opinion as to the material most entitled to preference for water pipes, the Water Commissioners, in coming to a decision, paid "careful attention to the information and opinions of the scientific gentlemen who have given replies to the inquiries addressed to them by the Board of Consulting Physicians, and particularly the results of the very thorough investigation and experiments of Professor Horsford, of Harvard University." "These results," they pro-

* The Thames in England; the Schuylkill supplying Philadelphia; and the Croton, New York in America.

perly remark, "appear to us to be of great value, and in corroboration of the great mass of evidence derived from a very extensive observation of the use of leaden pipes, for the supply of cities and towns, for a long series of years, entirely satisfactory and conclusive."

And the Commissioners say that "Upon a careful examination of this mass of testimony, we regard it as satisfactorily proved that the water of Cochituate Lake, which is about to be introduced into the City (Boston), may be safely distributed to private dwellings by means of leaden pipes, without danger to the health of those who may freely use it with their food."

Cochituate water is a very soft and pure water, acts powerfully on lead, and contains only 1-18600th part of solid residue.

The opinion of the Commissioners on the subject of the best material for water pipes, and on the interesting results arrived at by Professor Horsford, is stated in the Report as follows:

"While this subject was undergoing the investigation of the Consulting Physicians, and of the eminent chemists who had been invited to aid them in the inquiry, the Water Commissioners were under the necessity of beginning the work of laying down the distribution pipes. They deemed it improper to make use of a material which might in the result be proscribed as dangerous to the health of the citizens. They accordingly procured iron pipes of one and a half and two inches in diameter, to be cast, which have been laid down for carrying the water from the street mains to the side walks, and in part to the dwelling-houses, so far as this branch of the work has been yet accomplished.

"The cost of pipes of this description, including the laying down, is considerably higher than that of pipes of lead, independently of the cost of making additional joints, where they are required. There is also a further objection to the use of these pipes, that with the greatest caution which can be used in laying them, they are more liable to be broken than pipes of lead, or other flexible metal.

" In the meantime, we have given attention to experiments which have been made of pipes constructed of various other materials. Tin has been used for coating the internal surface of pipes of iron, lead and copper, for the purpose of preserving them against the action of the water upon those metals. Pipes of each of these descriptions have been strongly recommended on some limited experience; but we are of opinion that there is not sufficient evidence of the durability of the coating, in either form, to justify its adoption for general use. Pipes of block tin appear to be, in some respects, preferable to either description of those formed of other metals, and merely coated with tin. The cost of tin per pound is about four times that of lead; but as it is of greater tenacity than lead, a smaller quantity of metal serves to give the pipes a sufficient degree of strength, so that pipes composed of block tin, of a suitable thickness, can be procured at about double the cost of pipes of equal strength composed of lead. But the experiments detailed in the 'Reports' of Professor Horsford, as well as information derived from other sources, show that tin is gradually dissolved by the Cochituate, and other similar waters; and that the decomposition does not in a short time cease, like the lead in the same water, but continues, as far as any experiment has been made, indefinitely. It is also liable to rapid decomposition, by being brought in contact externally with certain acids and gases, to which in various positions it will be exposed. Whether any sensible deleterious effect upon the water is produced by the gradual decomposition of the tin pipe, is a question which has not been satisfactorily determined. But for the reasons briefly stated, we are of opinion that, independently of the question of comparative cost, tin is no better adapted for the distribution of the water of Cochituate Lake than lead, and that probably it would prove less durable.

" Pipes manufactured of malleable iron are used to some extent in various places for the distribution of water for

domestic uses. They are in every respect well adapted to the purpose, with the exception of their liability to corrode by the action of the water within, as well as the effects of moisture on the external surface. They are stronger than lead, and not more expensive. They can be made of any desirable dimensions, and are not liable, like cast iron, to be broken by an unequal pressure on the different parts. The experience of their use, however, so far as it has come to our knowledge, is too limited to enable us to form a positive judgment of the force of the objection above mentioned. It has been apprehended, that the effect of rust would be such as to render the water unfit for use in the washing of clothes and linen, and in process of time to close the aperture of the pipe.

" Pipes formed of sheet iron, coated internally with hydraulic cement, have been recently introduced, and they promise to be highly useful under certain circumstances. When laid in the earth, and in situations exposing them externally to moisture, they are protected by a covering of hydraulic cement, which, besides preserving the iron against rust, gives an additional strength to the pipe. Whether they can be economically used for the distribution of water from the mains, has not been fully determined by any experiment within our knowledge.

" The Consulting Physicians, in their Report above referred to, although they did not recommend the use of distribution pipes composed of lead, strongly intimated the expectation that the doubts which they entertained might be removed by further experiments. It was important to reconcile the fact, that on immersing lead in water taken from the Fairmount, Croton and Jamaica Pond Water-works, it undergoes a perceptible partial dissolution, with the well-attested evidence, that a large portion of the population of the cities of Philadelphia, New York and Boston are in the constant use of water from those works, drawn through leaden pipes, without experiencing from it any injurious effects. The experiments which had been at that date

begun by Professor Horsford, and have been since more thoroughly prosecuted by him, afford in our opinion a satisfactory solution of this apparent contradiction. These experiments demonstrate that the action of the comparatively pure water of lakes and rivers, upon bright bars of lead, which on their immersion in it is distinctly perceptible, ceases after a period of a few days; and that this immediate action of the water upon the surface of lead, forms a coating, which, for all practical purposes is impervious to water, and entirely insoluble in it. This coating remains unchanged during any period in which it has thus far been immersed; its appearance after some months or years of immersion, in the case of the Croton, is quite the same as within three or four days from the first immersion. The water on the first and second days in which the lead is so immersed, and during the continuance of any perceptible action on the surface of the leaden bars, shows traces of a mixture of lead, on trial by the ordinary tests; but on the repeated removal of this water, and substitution of other water from the same source, after the coating is formed, no trace of lead is discoverable by the most effective tests after any length of exposure of the water in contact with the lead, which will ordinarily occur.

"It has, however, never been doubted by those who have investigated this subject, that the water of wells and springs of certain descriptions, and in certain situations, exerts a much more powerful and a continued effect upon lead with which it comes in contact; and that cases of paralysis, colic, and even death, have been traced to the drinking of water contaminated by this poisonous mixture. The negative evidence that no well authenticated cases of these diseases have occurred, in consequence of drinking the waters furnished by the public Waterworks of the cities of London, Philadelphia, New York, and many other places, when distributed through leaden pipes, authorizes the belief, that the scattered cases of disease of these descriptions, which have been usually traced to the use of water

from wells and springs, have arisen from some property peculiar to the water from those sources, and not common to water derived from lakes and rivers. Attempts have accordingly been made to discover the nature and sources of the mixtures, which impart to water the power of acting more energetically upon lead. It is observed that nitrates possess this power, and that they are frequently found in well-water. The observations of Professor Horsford have led him to the conclusion that the unequal proportion of these salts constitutes the chief distinction between different waters, in their relation to lead. These salts are often, if not uniformly found, in the water of wells and springs, so situated as to be replenished by the filtration of water through a soil enriched from the stable, or by the wash from collections of animal substances of any description. A small solution of saltpetre, or of a nitrate of any description, in water, is found to impart to it the property of dissolving lead, and thereby forming the nitrate of lead. This substance renders the water undoubtedly deleterious and dangerous to the health of those who drink it, or use it in the preparation of their food. This explanation, which seems to be fully confirmed by ample experiments, accounts sufficiently for the fact that the water of wells situated, as are a large portion of those in towns and cities, and of springs situated in the midst of richly cultivated fields, or in the vicinity of animal deposits of any description, may produce the chemical effect here described, upon the leaden pipes used to conduct it, while the waters of rivers and lakes, not particularly exposed to contact with substances of that nature will be destitute of any such power.

"So long as it remained unknown what ingredients imparted to water the property of acting upon the surface of a leaden pipe, in such manner as to convert it into an active poison, the fact that the water flowing from a particular source was harmless at one time, did not afford a satisfactory assurance against its becoming dangerous at another; especially when it was fully ascertained that it possessed the property of dissolving lead in a

sensible degree, on its first immersion in it. But since it has been discovered, as the result of repeated trials, that the effect of the waters of the Schuylkill and Croton rivers, and of Cochituate and Jamaica lakes, upon lead, is limited to a short period from its first immersion, and that by this temporary effect, there is invariably produced an indissoluable coating on the surface of the lead, which permanently protects it against any further action of the water upon it, and consequently preserves the water against imbibing any poisonous property; and since it is further ascertained that the more efficient power of dissolving lead, which is found to reside in certain waters apparently pure, is imparted by a substance rarely if ever found, except in a very minute degree, in the water of lakes and rivers, but which is often found in the water of wells and springs, there appears to be no longer any good ground to apprehend injurious effects upon water, of the former description, from its being transmitted through leaden pipes. A perceptible line of distinction is thus drawn between a class of waters which are liable to acquire the property of imbibing a poisonous substance by contact with lead, and another class, which, in a very wide experience of their use for domestic purposes, have been found not to possess that property.

"For the evidence of these facts, we refer to the several Reports of Professor Horsford, appended to the Report of the Board of Consulting Physicians, and (until the publication of a more detailed report of his further experiments) to his letters subjoined to this Report, and to the corroborative documents annexed.

"Professor Horsford, in the letter dated July the 25th expresses the following opinion: 'Without an attempt at further enumeration of the conclusions at which I have arrived, I may state, with whatever of emphasis uninterrupted investigation from the first of last February until now may justly give to the opinion, that *Cochituate water may be served from leaden pipes connected with iron mains, without detriment to*

health.' The opinion here expressed would command a high degree of confidence if it stood alone. Confirmed as it is by our evidence of collateral testimony, derived from long continued experience, we consider it entitled to entire confidence. The experiments detailed in Professor Horsford's first Report exhibiting the chemical action of the water of the Fairmount, Croton and Jamaica Pond Water-works, and of the Cochituate lake, prove that there is a strong similarity in the effects of the waters from those several sources, upon lead.

"The ample testimony, founded on the continued use of the waters from the three first-named sources, for a series of years, by thousands of families, without a single distinctly proved case of lead-poisoning, although the water is served from the mains to the dwelling-houses almost universally through leaden pipes, affords as satisfactory demonstration as the nature of the case admits of, that the Cochituate water may be safely distributed in the same way."

Evidence, in regard to the absence of noxious lead impregnation from the New York, Philadelphia, and other waters, in which leaden service pipes have been and are employed, is given by numerous chemists and physicians; and the Report concludes as follows:

"The grounds on which lead is preferred for the composition of small distribution pipes are, that the metal is cheap; it is easily formed into pipes, of any convenient size or length; it is flexible, and easily adapted to all situations in which it is desirable to place it; it is of sufficient strength to bear the pressure of any ordinary head of water, and if made of a suitable thickness, and provided with proper guards against the effects of a sudden check of the current, it is capable of resisting the extraordinary shock thus produced. It moreover preserves the water in a state of purity, and is itself durable, unless dissolved by the action of substances foreign to the source from which the city

is to be supplied. Pipes of this material may be laid in a much shorter space of time, and at less cost, than those of cast iron.

" We have, therefore, on these considerations, resolved to use leaden pipes for conducting the water to houses, except in cases in which the owners or occupants shall make known their preference of iron pipes, and announce their determination to make use of pipes of iron, or of some other material than lead, for the conveyance of the water through their respective houses, to the place of delivery for use, for culinary purposes. Persons making such requests will be furnished with the water by means of pipes of cast iron."

END.

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