Reports on the chemical analysis of samples of water drawn from cisterns in different parts of the City of Glasgow / by Professor Anderson and Dr. Wallace, and note thereon by Dr. Gairdner (Medical Officer of the City).

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REPORTS

ON THE

CHEMICAL ANALYSIS

OF

SAMPLES OF WATER

DRAWN FROM CISTERNS IN DIFFERENT PARTS OF THE CITY OF GLASGOW.

BY

PROFESSOR ANDERSON

AND

DR. WALLACE,

AND NOTE THEREON BY DR. GAIRDNER,

MEDICAL OFFICER OF THE CITY.

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REPORT

ON THE EXAMINATION OF SPECIMENS OF WATER DRAWN FROM CISTERNS IN DIFFERENT PARTS OF THE CITY OF GLASGOW.

ACCORDING to the instructions of Dr. M'Gill, I have examined ten specimens of water, taken under his direction, for the purpose of ascertaining whether they have become contaminated with sewage gases or other impurities while lying in the cisterns.

These waters were taken from the following localities:—

No. 1. From cistern at top of the tenement, 35 Nicholas Street. The cistern, which is in the roof, immediately under the slates, supplies several houses and water-closets. The house from which the water was drawn was dirty and ill-kept.

No. 2. From cistern at 26 Taylor Street. The cistern, which supplies the whole house, is in the water-closet.

No. 3. From cistern at 42 St. Mungo Street. The cistern is in the roof.

No. 4. From cistern at 183 George Street. It supplies the house and bath.

No. 5. From cistern at 18 North Albion Street. The cistern is in the water-closet, and supplies the whole house.

No. 6. From cistern at 266 Dumbarton Road, supplying house and water-closet. The house has been unoccupied since March last.

No. 7. From another cistern in the same tenement, also unoccupied since March.

No. 8. Cistern at 276 Dumbarton Road, supplying house and water-closet. House unoccupied since May last.

No. 9. Cistern at 296 Dumbarton Road, which supplies

both house and water-closet. House has not been occupied since March.

No. 10. Cistern at 492 St. Vincent Street, supplying both house and water-closet. The house has been unoccupied since May last.

For comparison with these I have also examined water drawn direct from a pipe in the Laboratory, which does not communicate with a cistern, and must therefore represent the water exactly as supplied to the public. This I have marked No. 11.

The whole of these waters were perfectly clear, colourless, and tasteless, and were quite free from sediment or any solid impurities, which might by possibility have got into the cisterns. Not the slightest trace of smell could be detected, even by the most minute examination. So far, therefore, as *external characters* are concerned, all these waters would be described as pure. On examining into the gases held in solution, it was found that none of them contained sulphuretted hydrogen. The proportions of the other gases found are contained in the following Table, in which the quantities of carbonic acid, oxygen, and nitrogen are expressed in cubic inches per gallon, and that of ammonia in fractions of a grain. In four cases traces of lead were also detected. These I have also given, the numbers giving the number of parts of water containing one part of lead.

	Carbonic Acid.	Oxygen.	Nitrogen.	Ammonia.	Lead.
1	0·63	2·12	3·63	0·024	...
2	0·21	2·03	3·98	0·005	...
3	trace	2·12	3·83	0·004	...
4	0·63	1·93	3·67	0·004	865,800
5	0·42	5·75*		0·008	932,400
6	0·43	1·93	3·66	0·012	...
7	0·21	1·93	3·66	0·012	...
8	0·63	2·15	3·63	0·029	560,000
9	0·64	1·93	3·45	0·008	932,000
10	0·43	1·93	3·65	0·004	...
11	0·42	2·34	4·04	0·008	...

* Owing to an accident in the Laboratory, the exact proportions of oxygen and nitrogen could not be determined. The oxygen, however, was abundant.

The conclusion to be drawn from these analyses is, that all the samples examined were entirely free from sewage matter. It will be noticed that in every instance the gases held in solution were identical with those found in the pure Loch Katrine water. The total quantity of gases in the cistern waters is somewhat smaller than in that drawn from the Laboratory pipe, but the difference is small, and is clearly attributable to the escape of a small quantity from the agitation the water undergoes as it flows into the cisterns. Had sewage waters been absorbed by the water, it would have been at once oxidized by the oxygen existing in the water with the production of carbonic acid, so that the proportion of the latter gas would have been increased, and that of the former diminished; and the fact that the relative proportions of oxygen and nitrogen remain unchanged is the most conclusive proof of the absence of sewage gases.

I am at present engaged in the examination of some other samples of water, also taken from cisterns in different parts of the City, and I shall defer any remarks I have to make on the general question until I report on those, which I shall shortly do. Meanwhile, the present analyses may in some degree reassure the public mind, for they show that, if sewage gases do ever reach our cisterns, it must be in exceptional cases.

In the whole of the samples now analysed the waters were perfectly pure and quite unexceptionable.

THOMAS ANDERSON.

8th September, 1869.

SECOND REPORT

ON THE EXAMINATION OF SPECIMENS OF WATER DRAWN FROM CISTERNS IN DIFFERENT PARTS OF THE CITY OF GLASGOW.

In my former Report on cistern waters from different houses in Glasgow, I stated that I was at the time engaged with the analysis of another set of specimens, also received from Dr. M'Gill, the results of which I have now to submit.

The samples were taken from the following places:—

No. 1. Water from a cistern in the South Prison. It is on the top of the house, open to the air, and supplies the North-west Section of the Prison. Temperature of the water, 59°.

No. 2. From an occupied house, 48 Shamrock Street. The cistern supplies both house and water-closet. Temperature, 59°.

No. 3. From occupied house, 4 Derby Street. Cistern supplies both house and water-closet. Temperature, 59°.

No. 4. From occupied house, 23 Oswald Street. Cistern supplies both house and water-closet. Temperature, 59°.

No. 5. From occupied house, 13 Bellgrove Street. Cistern supplies both house and water-closet. Temperature, 59°.

No. 6. From 247 Dumbarton Road, unoccupied since May last. Cistern supplies both house and water-closet. Temperature, 60°.

No. 7. From 55 Kelvinhaugh Street, unoccupied since May last. Cistern supplies both house and water-closet. Temperature, 58°.5.

No. 8. From 36 Elderslie Street, unoccupied since May last. Cistern supplies both house and water-closet. Temperature, 55°.5.

No. 9. From 473 St. Vincent Street, unoccupied for five weeks. The last occupant died of fever. Cistern supplies both house and water-closet. Temperature, 58°.

No. 10. From 40 Elmbank Crescent, unoccupied since May. Cistern supplies both house and water-closet. Temperature, 61°.

To these I have added a sample drawn from the pipe in the Laboratory. Its temperature was 61°. I have marked it No. 11.

The analysis of all these samples was conducted in exactly the same manner as those in my previous Report; but in addition to the gases I have determined also the quantity of organic matter, fixed salts, and total solids.

The results of the analyses are contained in the two following Tables, the first of which gives the organic matter, fixed salts, and total solids in grains per imperial gallon, and the number of parts of water which contain one part of lead. Thus, in the water from the South Prison, a grain of lead is contained in two millions grains of water, which is about $\frac{1}{2\,8}$ of a grain per gallon. The second Table gives the quantities of gases in an imperial gallon; the carbonic acid, oxygen, and nitrogen in cubic inches; the ammonia in fractions of a grain.

TABLE I.

No.	Organic Matter.	Fixed Salts.	Total Solids.	Lead.
1	0·20	1·56	1·76	2,000,000
2	0·76	2·20	2·96	...
3	1·03	2·60	3·63	...
4	0·44	1·32	1·76	...
5	0·72	1·72	2·44	...
6	0·36	1·80	2·16	2,240,000
7	1·20	2·84	4·04	140,000
8	1·00	3·13	4·13	500,000
9	0·44	1·92	2·36	630,000
10	0·56	3·48	4·04	932,400
11	0·37	1·59.	1·96	...

TABLE II.

No.	Carbonic Acid.	Oxygen.	Nitrogen.	Ammonia.
1	0·43	1·93	4·09	0·0096
2	0·64	1·93	4·09	0·004
3	0·43	2·15	3·87	0·004
4	0·43	2·04	3·98	0·008
5	0·43	1·93	4·09	0·004
6	0·43	1·94	4·08	0·004
7	0·43	2·15	4·08	0·016
8	0·53	2·04	4·09	0·012
9	0·43	1·92	4·10	0·0064
10	0·66	1·93	3·86	0·0016
11	0·43	1·93	4·30	0·003

The whole of these waters were colourless, tasteless, and inodorous. They were also perfectly clear, with the exception of Nos. 2, 3, 8, and 10, which contained a slight trace of solid matters in suspension, but the quantity was so small that it could not be weighed. None of them contained sulphuretted hydrogen, nor could the slightest trace of that substance be detected in the neighbourhood of the cisterns from which the samples were taken. As regards the gases contained in the water, the results agree fully with those of the previous analyses. They consist of carbonic acid, oxygen, and nitrogen in the proportions in which these gases are found in natural waters of good quality, and there is no sewage contamination. Had there been any trace of this the quantity of oxygen would have been diminished, and that of carbonic acid and ammonia increased. So far from this being the case, the carbonic acid shows a very remarkable degree of uniformity, and the ammonia is so small as to be scarcely worthy of notice, for in No. 7, in which it is most abundant, it amounts to only one part in three and a half millions, and on the average does not exceed one in twelve millions. As an additional evidence of the absence of sewage matters, I may add that not a trace of nitric acid could be found in any of the samples.

The results of the determination of the solid constituents of these waters are, however, not without importance. It is

to be observed that in some of them the quantity of total solids is very materially in excess of that found in the pure Loch Katrine water. This occurs to the most marked extent in the water from the uninhabited houses, and I am induced to attribute it partly to evaporation, owing to the water having lain so long in the cisterns, and partly to the access of dust. The substances found in the water were only those which exist in the natural Loch Katrine water, and even with this addition the waters are still very pure, and far superior to those generally used for domestic purposes.

An exception, however, must be made to the presence of lead, which appears in the water from unoccupied houses to an appreciable, and, in some cases, to an injurious extent. This is especially the case in No. 7, where it amounts to half a grain in the gallon. There can be no doubt that the continued use of such water would be followed by symptoms of lead poisoning. It must be borne in mind, however, that the water here was from an uninhabited house, where it had been exposed for more than four months to contact with the leaden cistern. Had the house been occupied, and the water pipes in daily use, so that fresh water was constantly passing through the cistern, there can be no doubt that no such contamination would have been found. In the cases in which lead was found in the water of inhabited houses, it did not exceed $\frac{1}{12}$ of a grain to the gallon, a quantity incapable of producing injury, and less than that invariably found in the water supplying the city of Aberdeen.

The facts here observed should indicate the necessity for carefully emptying cisterns in houses which have been unoccupied for some time before they are again used.

As far as the primary object of these analyses is concerned, namely, that of ascertaining whether the water in cisterns is or is not contaminated by sewage gases, these results are perfectly conclusive, for they show most incontestably that not the slightest trace of such gases could be detected; nor, as it appears to me, could any other result have been expected. A very exaggerated opinion seems to prevail in the mind of the

public as to the quantity of gases evolved from sewage matter. The fact is, the quantity is far from considerable, and they are only produced after the decomposition of sewage has become somewhat advanced. Before this occurs the sewage has generally been more or less completely carried out of the house drains, and the return of gaseous matters is there prevented by the traps which always intervene between the house and street drains.

THOMAS ANDERSON.

GLASGOW, *4th October, 1869.*

REPORT

ON THE CHEMICAL ANALYSIS OF SAMPLES OF CISTERN WATER.

By Dr. Wallace, F.R.S.E., F.C.S.

The samples, which were received on the 2nd, 3rd, and 4th inst., were ten in number, and were stated to be taken from cisterns situated in the tenements undermentioned. Another sample (No. 11) was taken, for purposes of comparison, from the tap of my Laboratory, which is supplied direct from the street main.

No. 1, South Prison.
„ 2, 48 Shamrock Street.
„ 3, 4 Derby Street.
„ 4, 23 Oswald Street.
„ 5, 13 Belgrove Street.
„ 6, 247 Dumbarton Road (empty house).
„ 7, 55 Kelvinhaugh Street (empty house).
„ 8, 36 Elderslie Street (empty house).
„ 9, 473 St. Vincent Street (empty house).
„ 10, 40 Elmbank Crescent (empty house).

The following Table represents the amount of solid ingredients obtained on evaporation, the organic matter, the oxygen required to oxidize the organic matter, and the lime in each sample, represented in grains in an imperial gallon of water :—

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.
Total Solids,.....	1·88	2·36	1·94	2·99	2·83	2·58	3·34	3·44	1·79	3·95	1·89
Organic Matter,.....	0·60	0·64	0·86	0·64	0·88	0·76	1·13	1·15	0·51	1·30	0·54
Oxygen required to oxidize O.M.,	0·07	0·11	0·09	0·10	0·11	0·08	0·14	0·14	0·11	0·08	0·08
Lime,.....	0·18	0·18	0·15	0·21	0·22	0·29	0·32	0·29	0·23	0·46	0·20

The gases existing in solution are as follows, in cubic inches in a gallon, and also in percentage quantities:—

PERCENTAGE QUANTITIES.

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.
Carbonic Acid,	5·0	5·5	4·3	5·0	3·3	3·9	3·2	5·	3·9	3·0	3·2
Oxygen, ...	29·1	28·6	30·4	29·1	29·7	29·4	30.0	29·	30·4	31·6	29·7
Nitrogen,.....	65·9	65·9	65·3	65·9	67·0	66·7	66·8	66·	65·7	65·4	67·1
	100·0	100·0	100·0	100·0	100·0	100·0	100·0	100·	100·0	100·0	100·0

CUBIC INCHES PER GALLON.

Carbonic Acid,	0·32	0·36	0·27	0·32	0·21	0·26	0·21	0·31	0·24	0·19	0·20
Oxygen,.....	1·88	1·84	1·91	1·85	1·87	1·95	1·92	1·80	1·90	2·01	1·89
Nitrogen,.....	4·26	4·24	4·11	4·18	4·22	4·42	4·27	4·10	4·11	4·17	4·28
Total Gases,	6·46	6·44	6·29	6·35	6·30	6·63	6·40	6·21	6·25	6·37	6·37

The waters did not afford the slightest indication of the presence of sulphuretted hydrogen, or other gases likely to be derived from sewage, and the quantity of ammonia in all was exceedingly minute. A microscopical examination showed no living organisms, either animal or vegetable, and only such particles as are commonly found in ordinary dust.

As regards the gases, there is but little difference in the total quantities, and the water in all cases was, considering the previous hot weather, well aerated. The amount of the total gases in the Loch Katrine water (as in other waters) varies with the season of the year, and, according to former experiments, is sometimes as high as 8·5 cubic inches per gallon. The average throughout the year is probably about $7\frac{1}{2}$ cubic inches. The proportion of carbonic acid in the water at the Loch does not exceed 1 per cent of the total gases, but when the water is kept for some time there is a gradual increase of carbonic acid, and a corresponding decrease of oxygen, arising from the oxidation of some of the organic matter.

The solid ingredients have in most cases increased, especially in the case of the samples taken from houses that have been shut up for some time. This I ascribe to evaporation, which will be greater in warm than in cold weather; while in houses that are occupied there will be a sensible amount

of evaporation where the cisterns are placed in a warm situation. In general, the amount of lime has not increased quite in the proportion of the total solids, which indicates a slight deposition of lime upon the surface of the lead.

It will be interesting to compare the composition of the Loch Katrine water, as delivered in Glasgow at the present time, with the pure water from the Loch, and that supplied to Glasgow soon after the water was introduced (*Vide* British Association Report for 1861; also *Glasgow Herald* of 16th September, 1861).

	Loch Katrine, 1854.	Glasgow, 1861.	Glasgow, 1869.
Lime,	·19	·47	·20
Magnesia,	·11	·12	·11
Sulphuric Acid,	·33	·36	·33
Chlorine,	·33	·30	·36
Alkalies and Carbonic Acid,	·12	·51	·15
Alumina and Phosphates,	·10	·16	·15
Oxide of Iron,	—	minute trace.	—
Silica,	·01	·06	·05
Organic Matter,	·80	·84	·54
Total Grains per Gallon,	1·98	2·82	1·89
Hardness by Dr. Clark's Scale,	·7°	1·3	·8°

A comparison of these results shows that the present water supply of Glasgow is practically identical in composition with the water of Loch Katrine itself, while the supply of 1861 was considerably harder, and contained more lime, chiefly in the form of carbonate. This was evidently derived from the exposed surfaces of sandstone and limestone of the conduit and other buildings connected with the works; but, as was to be expected, this increase of lime was of a temporary character. The proportion of lime has an important bearing on the question of the solution of lead by the Loch Katrine water—a subject which attracted much attention at the time this water was proposed to be introduced into Glasgow. In 1861 experiments were made to test the influence of the water on lead, and it was found that although

the water acted less rapidly than that of the Loch, still its action was by no means so insignificant as not to deserve attention. The results of the present inquiry show that the proportion of lead dissolved, although under ordinary circumstances very minute, may, if the water is retained for a lengthened period of time in cisterns or pipes, become so very considerable as to make it questionable whether the cistern system should be retained for the domestic supply of water to the people of Glasgow. The samples gave the following quantities of lead in parts of a grain per gallon:—

No. 1.	South Prison,	·033
2.	Shamrock Street,	·04
3.	Derby Street,	·05
4.	Oswald Street,	·02
5.	Belgrove Street,	·1
6.	Dumbarton Road,	·012
7.	Kelvinhaugh Street,	·333
8.	Elderslie Street,	·166
9.	St. Vincent Street,	·05
10.	Elmbank Crescent,	·055
11.	Direct from the Main,	·0
12.	Pipe, 42 Bath Street, after 18 hours,	·011
13.	Do. do. after 2 days,	·05

Samples were also taken from a dwelling-house in Granby Terrace, Hillhead, after the house had been closed for 18 days. The pipes and cistern had been in use before the introduction of the Loch Katrine water. The cistern gave ·012 of a grain per gallon, and the pipe ·02, quantities altogether insignificant. The water from the hot-water apparatus of the same house was also tested, and found to contain the alarming quantity of ·143 of a grain per gallon. I have long suspected that such pure water as that of Loch Katrine, when passed in a heated state through lead pipes, must dissolve an appreciable quantity of the metal, and have directed that such water must not be used for cooking. The result now obtained shows that my suspicion was well founded, and I think that the public should be warned about this source of danger.

The present inquiry has shown that the alarm created in

the minds of the citizens of Glasgow by certain rumours which appeared in the newspapers during the past summer has been without foundation, so far as concerns the introduction of poisonous gases into the water retained in cisterns from the water-closets usually associated with such cisterns; but it has revealed a possible source of injury to the health of the inhabitants which demands the earnest attention of the medical officers of the Sanitary department. As a chemist, I am not prepared to give an opinion upon the matter, but merely state facts, from which the recognised medical authorities may arrive at a definite conclusion. It will rest with them to decide whether the system of supply by cisterns should be retained or discontinued. I have only to remark, in conclusion, that while, in that system, a very large quantity of water must be run to waste in order to fill the cistern with fresh water, a pipe can be completely emptied by running off at most a couple of gallons. A cistern of moderate dimensions will hold about 50 gallons, and, as fresh water runs in while that in the cistern is being discharged, it will probably require an expenditure of 150 or 200 gallons to fill the cistern entirely with fresh water. On the other hand, a gallon of water will fill a half-inch pipe to the length of 141 feet, a ¾-inch pipe about 52 feet, and an inch pipe nearly 30 feet; so that, in returning to a house that has been shut up for some time, the expenditure of a gallon or two of water will carry off any possible impurity, and obtain a supply direct from the street main.

WILLIAM WALLACE.

42 Bath Street,
Glasgow, *24th Sept., 1869.*

NOTE BY THE MEDICAL OFFICER.

The two Reports here submitted by order of the Board of Police may be considered as completely exhausting the chemical aspect of the question which excited so much attention, and gave rise to so much newspaper correspondence, a few months ago, viz.:—As to the safety of using water for drinking derived from a cistern instead of from the main. The almost entire coincidence of the two Reports as to their details, especially in the cases where the same water was twice analysed, gives a very satisfactory testimony to the exactness of the conclusions arrived at.

I agree with the reporters entirely in considering that the apparent panic which took possession of certain minds, and found expression in the newspaper articles referred to, was founded on exaggeration. Nevertheless, I am not disposed to admit that the use of cisterns, as they are habitually used in Glasgow, in flats, and in houses of limited accommodation, is perfectly safe, or in any respect worthy of commendation. The placing of the cistern for drinking water near, or even in the same apartment as, the water-closet is especially a filthy practice, which ought to require no authority to condemn it; and even where the cistern is less objectionably placed, the advantage of perfectly fresh water is so obvious that any one who fails to insist upon the privilege, so easily acquired in most cases, of a direct supply is not, in my opinion, well advised. It may even happen that serious disease may (though probably rarely) be the consequence of a supply taken from the cistern; for I have known at least one instance in which enteric or typhoid fever certainly appeared to have been propagated in Glasgow by a leakage from the water-closet of a flat into the cistern of the flat below. I advise, therefore, as a matter of reasonable sanitary precaution, that direct supply should be introduced as widely as possible, and that drinking out of cisterns should only be

practised where the requisite supply cannot be obtained otherwise.

The risk of lead poisoning, alluded to more pointedly in Dr. Wallace's than in Dr. Anderson's Report, does not appear to me to be very serious. Lead poisoning is not so easily produced by a few doses only of the poison as by a long-continued exposure to it. Such continuous exposure is not very likely to arise even where cisterns are used, if they are constantly being filled and emptied. As a question of fact, neither my own experience, nor that of other medical practitioners whom I have consulted, has disclosed a single case of lead poisoning in Glasgow due to the drinking water; and lead poisoning of any kind in Glasgow seems to be extremely rare. The same remark, however, applies here as in the case of sewage contamination, viz.:—That the risk, whatever it may be, is undoubtedly increased by the use of the cistern as above.

W. T. GAIRDNER.

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