Rivers Pollution Prevention Act, 1876. Second report to the Local Government Board by Dr. R. Angus Smith, one of the inspectors under the act, on the examination of waters.

RIVERS POLLUTION PREVENTION ACT, 1876.

SECOND REPORT

TO

THE LOCAL GOVERNMENT BOARD

BY

DR. R. ANGUS SMITH,

ONE OF THE INSPECTORS UNDER THE ACT,

ON THE EXAMINATION OF WATERS.

Presented to both Houses of Parliament by Command of Her Majesty.

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TO THE LOCAL GOVERNMENT BOARD.

My Lords and Gentlemen,

I beg to forward the Second Report under the Rivers Pollution Prevention Act. It consists of an inquiry into certain characteristics of water, and specially of new methods of examining the organic substances which may be found in them, and which are of such a character as may be supposed to affect health. It is divided into three parts. The first, which promises at present to be the most important, indicates a method of measuring the amount of organic activity amongst the microbes (at least of a certain class) which exist in the waters.

This is done by a chemical method and admits apparently of the greatest exactness. I find that in nearly all natural waters sugar is made to ferment and give out hydrogen gas. The amount of this gas produced is in some very small, but it increases in proportion to the impurity of the drainage. It is not found when distilled water is used, and it is not found with boiled waters.

The question may arise what kind of microbes are those which produce this decomposition. The answer so far is clear; they are such as, if in large numbers, render water impure to the senses.

The escape of hydrogen from decomposing organic substances is not a novelty, but the escape from waters with sugar added, so far as I know, was perfectly new when I first alluded to it a few months ago; the amount of hydrogen obtained being measurable with the greatest exactness, gives us, I consider, a clue to a mode of estimation of the value of waters which seems to me at the moment to be absolutely certain, in relation to some of the most important characteristics.

I have given a number of results which I think are satisfactory. They agree with all our common ideas of purity. In no case whatever has any hydrogen been obtained when distilled water or boiled water has been experimented upon. It is now about 10 years since, in my Tenth Report under the Alkali Act, I explained my endeavours to obtain results from air washings by using sugar, thinking by that means to obtain an indication of pure and impure substances, and especially of organised bodies existing in the air. I there mention that I got some hopeful results, but not sufficiently decisive. Having made another experiment lately in the same way, I have come to the conclusion that it was want of patience which prevented success, and this subject I hope to pursue. If so be that the results are similar to those found in water, we shall be able to measure exactly the force or the quantity of the decomposing matter in the air, so far as certain microbes are concerned. This is an expectation; the first is a result.

Having obtained a certain fixed foundation with substantial experiments regarding water, and promising ones regarding the air, I am naturally led to go further, and to consider how far the measurement of zymotic action by hydrogen may be viewed as a measure of the germs of disease.

When we use the word zymotic, it is quite clear that we refer to bodies quite other than those which gave the original name to yeast, and the question may than be asked when measuring the hydrogen: Are we not measuring also the zymotic action of innocent microbes? I think the facts stated here are at least a partial reply to this, unless we imagine that many classes of microbes are mixed up together in the different waters in such a manner as to be always in equal proportion, an idea which may be put aside.

To illustrate the belief that the method of measuring deals with bodies of an offensive character, we have the fact of their increase from the purest water of the mountains to the worst sewage, and this is practically a reply.

The bacteria found on the surface of gelatine which has been dissolved in sewage water may be called artificial, but they produce hydrogen in the same manner as the natural microbes found in the water and the sewage.

It would appear, then, that so far as hydrogen is concerned there is, as has been stated, a regular gradation. The question may now be asked, Is there a similar gradation of noxious material in all decomposing organic matters? The most noxious gases, the most destructive to human life, have been obtained from substances which pass into the sewer. The waters containing them gradually diminish in danger and offensiveness until they become the waters of some of our sewage streams which in certain stages of oxidation and dilution have lost, to the naked eye, the proof of their noxious ingredients. It would seem, then, as if the infectious or noxious matter of sewers could exist in almost any degree of intensity, as we see it mixed in every possible degree of innocence.

This is quite in agreement with what I have some years ago said with regard to the gases from closely confined sewers and from open sewers.

From these facts, which form the foundation of the inquiry, it is only natural that we should look forward and speculate on future work. If these microbes which may be found in sewage are analogous to those found in any zymotic diseases, we may expect that these latter will also produce hydrogen. Of course the question arises, how shall we know which class is the producer? This question it is not the part of the process to answer, but if the production of hydrogen is in proportion to the intensity of microzoic life in deceased matter as it is in the disease-bearing liquid called sewage, then we have a measure of the intensity of the disease or zymotic germ.

Of course this part must be treated as a speculation; still it is a speculation which gives us great hope of advance in this department of knowledge. It is probable that in sewage we have, at some stage or other, the germs of every disease existing in the community, and perhaps if intensified enough, the germs of every possible disease. But this also is a speculation. I hope to be able to examine the zymotic life, so to speak, pertaining to various unwholesome materials.

Of course it may turn out that I am looking too far; still I have given the foundation of my reasoning and the work done so far is not speculative, but fundamental.

A curious result of this power of calculating the force developed by microbes is, that we shall be able to calculate the electrolytic power of the movements involved in the life of a single microbe, and from this follows its mechanical equivalent.

A microbe comes out of the dark and invisible into light. The unseen movements are the modes of using its power. I refer to the whole of the movements preceding and producing the visible as indicating one life.

And indeed we have a point of divergence or of meeting where the mechanical power of a disease of a zymotic kind may find an expression.

This first part along with the second breaks entirely new ground.

The second part continues the proof of the natural purification of rivers now beyond dispute as it can be shown in the laboratory.

The third part is an examination of waters, using, so far as I was acquainted with it, Dr. Koch's gelatine process. There is a great deal more to be done to it, to make it of full service to chemists; but I think its general character will be seen in this paper, and the novelty of photographic proofs is, I consider, a valuable addition to the mere chemical analysis.

I am, &c.

R. Angus Smith.

Manchester, 1883.

Note.—I look also to examining the zymotic condition of a soil as well as other natural or artificial products and conditions of surfaces; this work is in progress and promises well: a few results are given in Tables 20 and 21. Surfaces in houses are also to be included.

ON THE EXAMINATION OF WATERS.

No. 1.

THE HYDROGEN PROCESS—A NEW METHOD.

HAVING shown some of my earlier opinions on the analysis of water and the necessity of searching for organisms found therein, it is clear that I have long been conscious of the imperfect nature of chemical analysis as applied to the question; Is this water well fitted for drinking or the preparation of food? I attempted but failed to develop the organisms as at one time I expected to do, and I was very desirous of obtaining a plan which might be able by means purely chemical to give us some idea of the amount of vitality, vegetable or animal, existing in water when the microscope failed to guide. Heisch's test, viz., the use of sugar as developing fermentation, seemed to promise very much, but even in the able hands of Mr. Heisch, Dr. Frankland, and Dr. Sanderson, did not produce the results which might have been expected. Some years ago I made experiments with air washings and sugar with unsatisfactory but not unpromising results. Lately it occurred to me to return to the use of sugar in the analysis of water. Tubes 7¼ inches long and ¾ inch diameter were filled with the water to be examined to which 1 per cent. grape sugar was added. These were inverted, sealed at the bottom by mercury, and allowed to stand. In every case there was a control experiment made by using the purest distilled water to which the same amount of sugar was added. The action was very slow, and for some time I was inclined to believe that nothing would take place, but, as a rule, after five days gases commenced to collect, and in most specimens of water tried, gas was eliminated. In ordinary cases I would have presumed that this was carbonic acid and would have left the matter, but it was considered better to make an examination. The gas was therefore collected, caustic potash was added to it, and the carbonic acid absorbed, which was in some cases very small. Care was not taken to remove the gas that might be absorbed by the water. Pyrogallic acid was added, and oxygen was found wanting. The remaining gas was removed into a eudiometer with mercury only; to this oxygen was added, and the mixture fired. Contraction took place instantly. It was expected that a good deal of carbonic acid would be formed, but this was not the case; a large portion of this gas was pure hydrogen, the rest nitrogen. That hydrogen should come from organic matter was not a novelty. I had myself found it as a peculiarity of some decompositions, but in very small quantities, and the fact will be found in books on chemistry. I am not aware, however, that hydrogen has been obtained in this way before, nor do I know that Heisch, who first used sugar as a test for water, came to make

this observation. However, it is difficult to read up everything, and I can only say that if anyone else has observed it, chemists seem to have forgotten it. I shall give in a tabular form some of the results which have been obtained by the examination of various waters. It has been observed that the decomposition of sugar by vibrios produced hydrogen. I am not at this moment able to give the name of the observer, but in any case I find it convenient to take up the subject at this point and to bring forward the action of sugar upon water, or rather the organic contents, as a method of testing the purity of water, and so far as I know, the only method of measuring the amount of organic life existing in the water by means which may be called purely chemical. It may, however, be asked, Is it a real measurement of organic life, or is it only a measurement of the vitality of certain organisms? On this point I do not intend at present to make any observations, further than to say that organisms, which I call bacteria, were present, and I shall not endeavour here to distinguish the forms of these. The subject, when it has arrived at this point, is difficult, and professed microscopists have not come to conclusions as to forms. It would appear, however, from the works of Pasteur, that microzymes may be various in activity without changing their appearance, that they may be *attenuated* to any extent, and that their power may be *virulent* to any extent. To say, therefore, that a certain class of microbe is present is not to have a very definite idea, the importance lies in the activity. Now, what is the measure of the activity? When these microbes are very active do they decompose sugar or produce hydrogen in greater abundance than when they are inactive? If so, the hydrogen becomes the measure of power.

These bacteria found in the waters which have been examined are not germs of disease necessarily; we are drinking them constantly. There may be conditions in which they cannot be called innocent. The question might now be whether the production of hydrogen may be a measure of other microbes, such as, for example, those really known as being productive of disease. These questions all require answering, and we have still to answer; Is any germ of disease dangerous or otherwise according to the conditions to which it is exposed? If it is attenuated by a little air or oxygen, it becomes innocent without changing its species, and the chemical nature of its surroundings may make the whole difference between dangerous diseases and innocent conditions. We arrive, therefore, at a point elsewhere expressed, where chemical laws and the action of organisms meet, and the results are modified by both.

This question has to be answered, Is the activity of these microzymes which we find in water diminished by aëration? Are these microzymes which are found in ordinary drinking waters to be objected to, or in other words are they hurtful? Are these microzymes of value in water, and, as they assist in the production of hydrogen when sugar is present, do they assist in digestion, or are they obstacles to digestion?

Again, do these microzymes constitute some of the secret qualities of water which have been found good or evil in the opinion of so many of mankind? If the hydrogen is a measure of the vitality of these bodies found in water, can it be used also as a measure of the vitality of similar bodies in diseased liquids, or in substances which are the products of disease?

This subject is a very interesting one, but requires a great deal of attention. Results of the experiments made on waters examined seem to point in the direction of those suggested questions, but it cannot be supposed that I should be able, at least at present, to give a sound answer to any of them. A great deal of work must first be done

I am inclined to think that the present aspects of the question point rather in the direction which has been imagined by some, that many diseases may grow out of the same so-called germ, and I cannot help looking back to an expression of my own made in 1848: "On the history of pestilence it has been remarked, "that new ones arise; we see here its analogy. New fer- "mentations do arise; when one is doing its work it pro- "duces entirely new conditions where it works; these new con- "ditions cause new actions, and it seems in the complexity of "organic nature as if the power of producing novelties were "increased by the number produced. Man, capable of one "disease to-day, is capable of another to-morrow."

For the present, then, I bring forward the production of hydrogen as a measure of the organisms which are active in water. Whether it measures their activity, quantity, or other characteristics is a matter to be decided.

The time allowed for the collection of gases was in all cases several weeks. It will be seen that the amount varies from 0 up to 14 c.c. from 50 c.c. of water. The gas consists of hydrogen, carbonic acid, and nitrogen. Carbonic acid we must expect in any of these decompositions. Nitrogen has, I suppose, come from the nitrogenous compounds, but it is also part of the nitrogen in solution; this opens up another investigation, viz., How are the nitrogenous compounds decomposed? The point at present under attention is the production of hydrogen, and as neither the carbonic acid nor nitrogen has ever appeared in such cases without hydrogen, I consider that gas to be the characteristic of the decomposition.

As a rule one may say that the suspended matter always gave the greatest amount of hydrogen and other gases, and that the relation of the nitrogen to hydrogen was often greater in such cases. Solid matter, however, taken from the water was always more active than anything in solution, thus leading us to the knowledge of the nitrogen in the organic matter and especially of undissolved matter.

I know that it is rather dangerous to publish these results. People will inquire how far they are hurt by drinking waters capable of producing this decomposition, but the work must be done, the inquiry must go on, and we cannot defer the publication

until it comes to an end, as we have no idea when that end may arrive. I look upon it in this light:—The time has now come when waters must be examined from a point of view of the organisms more than from any other point, but chemists must be very careful of the conclusions to be drawn, very careful also not themselves to be afraid of the existence of organisms, because, as I have often said, it is exceedingly probable that there are organisms of a wholesome as well as of an unwholesome character.

A very important question may be asked here. Are these results uniform? In other words, do the same waters always give the same results? The reply is that they are uniform, but there are cases where the result was not expected; for example, in Derbyshire the results are very different (B. of Table 1 and B. of Table 2, one water). One gives no gas and the other a great deal. The reason of this is not clear, but in such delicate experiments we can easily imagine one; for example, the water taken near the bottom of the bottle, where there was more solid matter, was always inferior, and water that had been shaken or roughly handled was found inferior, throughout its whole mass, to that which was taken from its surface after standing for a while. In some of the other waters similar differences will be observed, but absolute uniformity in these first experiments could not be expected. The gases remaining in the waters after the evolution in the cold were not examined, but this may be done some day. The result will not affect the conclusions so far as they have been drawn.

The Thames waters show distinct inferiority to the hill waters, both as to hydrogen and transformation of gelatine, in Part III. As I feel deeply the responsibility of publishing these results, I was at first not inclined to give the names of the different water companies from which the specimens were taken.

The results of examination of sewage, sewage rivers, the decomposition of nitrates, and the escape of free nitrogen, the wonderful effects of putrefaction in destroying living organisms, the wonderful power of oxidation in finishing the process, and the complete disappearance of diseases or what we may call germs of disease after the fountain head is left, abundantly prove that nature has taken care that curative and purifying influences will be rapid and exist almost everywhere. With this belief, which may be called an undeniable fact, it is still true that there are many conditions in which it is found that impurity escapes somewhat in excess of the purifying influence. This may be said to be the condition of the rivers near the most of our large towns, and that some should escape from the great valley of the Thames is not a thing to be wondered at, or to be doubted. The question simply is, how far this impurity has gone, and to what extent it is to be objected to? I conclude from those experiments that the water of the Thames, even after being filtered, is less pure than the waters of the uplands of England; that truth can scarcely be called new, but I add also that the difference can be subjected to measurement and put into the form of figures so far as certain

qualities are concerned. This, however, I cannot add that we can measure in the same way the effect upon health, that question I must leave for the present.

Summary.

So far as the higher waters of Derbyshire are concerned, it is evident that the hydrogen given out is less than in the lower waters where sewage entered the brooks.

These waters gave out less gas than the lower waters of the drainage of any place tried, the Thames Valley included.

Waters from Flintshire gave out less hydrogen gas than the lower waters of Lancashire and the Thames Valley.

The same freedom from hydrogen was observed in experiments in some of the upper streams of Longdendale and neighbourhood where the Manchester water is obtained. Sometimes none whatever is obtained from the water-supply in Manchester, showing the great purity of the water at times so far as this test is capable of illustrating it.

The amount of hydrogen escaping when sugar is used is the main point of this inquiry. I may repeat that this gas is never evolved when pure distilled water is taken or when the water is boiled.

The hydrogen is evolved abundantly when the sugar solution is supplied with bacteria or microbes. The class of microbes used was obtained from the surface of the gelatine which had been dissolved in water containing more or less sewage and allowed to stand for a time.

This series of experiments was made for the purpose of finding whether the microbes were the actual cause of the evolution of hydrogen.

Nitrogen and carbonic acid are also given. It is found on inquiry that the nitrogen did not wholly appear to come from any of the substances, organic or saline, in the water, but part was driven out from solution by the nascent hydrogen and carbonic acid. To ascertain this an experiment was made on water which had given out a great deal of hydrogen; more sugar and bacteria were added without removal of the water from the tube sealed at the bottom with mercury. The gas that escaped after this contained only hydrogen and carbonic acid with a mere trace of nitrogen.

Notwithstanding this the amounts of nitrogen and carbonic acid have been retained in the tables, although the leading columns are the total gas; and pre-eminently the hydrogen, which has been put therefore in larger type.

From waters A. and B. of Table 18 it was found that Medlock water, which contains sewage and chemicals, gave out its hydrogen much more rapidly when bacteria were added.

From C., when a large amount of sugar was added, the action was not so rapid, although the total amount did not differ much. It may here be suggested that bodies analogous to sugar

may be decomposed in these waters and the action thus begun may be one of the means of purification.

From D. and E. of the same table, was learnt that sulphate of ammonia caused the hydrogen to be given out much more rapidly although the total amount is not much greater, and the percentage amount of hydrogen is rather different.

In a subsequent experiment the increase of sulphate of ammonia to one gramme diminished the speed.

From F. we learn that the addition of bacteria to distilled water produced results such as were found in less pure waters.

The same is learnt from G.

From H., I., and J. we learn that Manchester water when boiled and rendered incapable of producing gas from sugar gave out hydrogen like the others when bacteria were added.

TABLE 1.—DERBYSHIRE WATERS; collected April 19th, 1883. Sugar alone added to the Waters.

—	c. c. of Gas evolved from 50 c.c. Water.	c. c. of Hydrogen evolved from 50 c. c. Water.	c. c. of Nitrogen evolved from 50 c. c. Water.	c. c. of Carbonic Acid evolved from 50 c.c. Water.	Percentage Composition of Gases.			Remarks.
					Hydrogen.	Nitrogen.	Carbonic Acid.	
A	0·00	0·00	0·00	0·00	0·00	0·00	0·00	Clear spring, mountain side.
B	0·00	0·00	0·00	0·00	0·00	0·00	0·00	Clear well water, chlorine very high.
C	0·00	0·00	0·00	0·00	0·00	0·00	0·00	Clear, soft water.
D	4·93	2·62	0·12	2·19	53·12	2·46	44·42	Clear: reason of this result not explained.
E	3·02	1·88	0·80	0·34	62·31	26·39	11·30	Clear, receives sewage.
F	0·00	0·00	0·00	0·00	0·00	0·00	0·00	Clear.
G	0·00	0·00	0·00	0·00	0·00	0·00	0·00	Clear fountain.
H	2·85	1·98	0·75	0·12	69·50	26·34	4·16	Turbid fountain.
I	5·13	3·33	1·04	0·76	64·87	20·26	14·87	Muddy stream.
J	8·12	4·49	1·95	1·68	55·34	23·89	20·77	Mud from a stream.

TABLE 2.—DERBYSHIRE WATERS; collected April 19th, 1883. Sugar and Sodium Phosphate added to the Waters.

A	0·00	0·00	0·00	0·00	0·00	0·00	0·00	
B	8·22	4·50	2·00	1·72	54·74	24·32	20·94	
C	0 00	0·00	0·00	0·00	0·00	0·00	0·00	
D	0·50	0·00	0·00	0·00	0·00	0·00	0·00	
E	6·50	4·11	1·52	0·87	63·20	23·34	13·46	
F	0·00	0·00	0·00	0·00	0·00	0·00	0·00	
G	0·10	0·00	0·00	0·00	0·00	0·00	0·00	
H	0·75	0·48	0·20	0·07	64·11	26·56	9·33	
I	7·43	4·98	1·85	0·60	67·08	24·82	8·10	
J	9·17	5·53	2·06	1·58	60·25	22·48	17·27	

TABLE 3.—WATERS FROM FLINTSHIRE, NORTH WALES; collected June 4th, 1883. Sugar alone added to the Waters.

—	c. c. of Gas evolved from 50 c. c. Water.	c. c. of Hydrogen evolved from 50 c. c. Water.	c. c. of Nitrogen evolved from 50 c. c. Water.	c. c. of Carbonic Acid evolved from 50 c.c. Water.	Percentage Composition of Gases.			REMARKS.
					Hydrogen.	Nitrogen.	Carbonic Acid.	
A	3·00	2 00	0·70	0·30	66·75	23·25	10·00	Clear.
B	2·75	1·54	0·76	0·45	55·92	27·72	16·36	Not very clear.
C	1·80	1·12	0·44	0·24	62·37	24·63	13·00	Clear.
D	0·00	0·00	0·00	0·00	0·00	0·00	0·00	Clear.
E	5·65	3·18	1·49	0·98	56·24	26·33	17·43	Very clear, explanation wanted; it was from a sandy well.
F	6·00	3·06	1·53	1·41	51·08	25·55	24·37	Turbid.
G	4·21	2·78	1·10	0·33	65·98	26·12	7·90	Turbid.

TABLE 4.—WATERS FROM FLINTSHIRE, NORTH WALES; collected June 4th, 1883. Sugar and Sodium Phosphate added to the Waters.

A	4·33	2·19	1·10	1·04	50·53	25·35	24·12	
B	1·50	0·95	0·31	0·24	63·03	20·63	16·34	
C	2·90	1·87	0·46	0·57	64·62	24·65	10·73	
D	0·00	0·00	0·00	0·00	0·00	0·00	0·00	
E	5·01	2·68	0·73	1·60	53·50	27·17	19·33	
F	3·12	1·96	0·82	0·34	63·02	26·34	10·64	
G	6·84	4·40	1·75	0·69	64·40	25·67	9·93	

TABLE 5.—LONDON WATERS; received February 13th, 1883. Sugar alone added to the Waters.

A	Lost	—	—	—	—	—	—	
B	2·55	1·62	0·73	0·20	63·69	28·31	8·00	
C	3·33	2·08	0·87	0·38	62·26	26·28	11·46	
D	8·09	5·09	1·11	1·87	63·01	13·76	23·23	
E	4·16	2·17	0·98	1·01	51·65	23·67	24·68	
F	4·27	2·52	1·14	0·61	58·92	26·80	14·28	

TABLE 6.—LONDON WATERS; received February 13th, 1883. Sugar and Sodium Phosphate added to the Waters.

A	4·47	2·69	1·25	0·46	60·31	27·93	10·29	1·47 per cent. oxygen.*
B	8·71	5·40	2·31	0·93	61·97	26·56	12·65	0·82 per cent. oxygen.*
C	1·67	1·07	0·43	0·16	64·12	25·88	10·00	
D	1·42	0·92	0·36	0·14	64·80	25·20	10·00	
E	6·14	3·56	1·65	0·93	57·99	26·90	15·11	
F	3·01	1·90	0·86	0·25	63·05	28·44	8·51	

* A small amount of air entered the gases during the experiment.

TABLE 7.—LONDON WATERS; April 26th, 1883. Gases evolved from Sugar alone added to the Waters.

—	c. c. of Gas evolved from 50 c. c. Water.	c. c. of Hydrogen evolved from 50 c. c. Water.	c. c. of Nitrogen evolved from 50 c. c. Water.	c. c. of Carbonic Acid evolved from 50 c. c. Water.	Percentage Composition of Gases.		
					Hydrogen.	Nitrogen.	Carbonic Acid.
A	4·56	2·92	1·19	0·45	64·12	25·88	10·00
B	2·55	1·78	0·52	0·25	69·85	20·35	9·80
C	3·20	2·05	0·46	0·69	64·05	14·38	21·57
D	5·00	3·09	0·92	0·99	61·97	18·40	19·63
E	7·00	4·42	1·45	1·13	63·24	20·53	16·23

TABLE 8.—LONDON WATERS; received April 26th, 1883. Gases evolved from Sugar and Sodium Phosphate added to the Waters.

A	7·00	4·84	1·16	1·00	69·12	16·60	14·28
B	6·33	4·70	0·69	0·94	74·20	10·89	14·91
C	2·50	1·59	0·66	0·25	63·54	26·46	10·00
D	3·20	2·05	0·73	0·42	64·10	22·66	13·24
E	4·13	2·84	0·48	0·81	68·87	11·40	19·73

TABLE 9.—LONDON WATERS; received April 26th, 1883. The Waters were allowed to stand for 48 hours, then the clear Water syphoned off and Sugar alone added to the clear Water.

A	5·00	3·16	1·15	0·69	63·21	23·00	13·79
B	4·30	2·47	1·17	0·66	57·43	27·15	15·42
C	5·00	3·24	1·20	0·56	64·93	24·07	11·00
D	2·00	1·30	0·43	0·27	65·00	21·84	13·16
E	3·54	Lost	Lost	0·49	Lost	Lost	14·00

TABLE 10.—LONDON WATERS; received April 26th, 1883. The Waters were allowed to stand for 48 hours, then the clear Water syphoned off, and to the deposit Sugar alone was added.

A	3·00	1·96	0·74	0·30	65·21	24·66	10·13
B	7·00	4·48	1·59	0·93	64·03	22·74	13·23
C	6·54	4·18	1·33	1·03	63·98	20·26	15·76
D	3·33	1·78	0·87	0·68	53·47	26·21	20·32
E	8·42	5·48	0·92	2·02	65·12	10·93	23·95

TABLE 11.—LONDON WATERS; received May 8th, 1883. Sugar alone added to the Waters.

—	c. c. of Gas evolved from 50 c. c. Water.	c. c. of Hydrogen evolved from 50 c. c. Water.	c. c. of Nitrogen evolved from 50 c. c. Water.	c. c. of Carbonic Acid evolved from 50 c. c. Water.	Percentage Composition of Gases.		
					Hydrogen.	Nitrogen.	Carbonic Acid.
A	7·09	4·40	0·93	1·76	62·04	13·16	24·80
B	5·75	3·74	1·40	0·61	65·00	24·44	10·56
C	8·31	5·47	2·07	0·77	63·21	24·90	9·24

TABLE 12.—LONDON WATERS; received May 8th, 1883. Sugar and Sodium Phosphate added to the Waters.

A	6·31	3·82	0·93	1·56	60·34	14·85	24·81
B	4·20	2·72	0·63	0·85	64·80	14·89	20·31
C	9·00	5·19	1·63	2·18	57·65	18·14	24·21

TABLE 13.—LONDON WATERS; received May 8th, 1883. The Waters were previously softened by Clark's Process, then Sugar and Sodium Phosphate were added.

A	3·00	1·86	0·84	0·30	65·21	24·84	9·95
B	4·50	2·91	1·14	0·45	64·72	25·28	10·00
C	7·50	4·22	1·78	1·50	56·24	23·74	20·02

TABLE 14.—LONDON WATERS; received May 8th, 1883. The Waters were allowed to stand for 48 hours, and to the deposit Sugar and Sodium Phosphate were added.

A	10·37	6·66	2·32	1·39	64·21	22·34	13·45
B	8·24	3·46	3·62	1·16	60·20	25·68	14·12
C	6·78	4·40	1·62	0·76	64·93	23·86	11·21

TABLE 15.—WATERS FROM LANCASHIRE AND ITS BORDERS; collected October 5th, 1883. Sugar alone added to the Waters.

A	4·50	3·04	0·42	1·04	67·55	9·33	23·12
B	4·13	3·11	0·45	0·57	75 30	10·89	13·81
C	10·00	7·57	0·75	1·68	75·70	7·50	16·80
D	12·13	9·46	1·10	1·57	78·00	9·06	12·94
E	21·00	16·80	1·24	2·96	80·00	5·90	14·09
F	0·00	0·00	0·00	0·00	0·00	0·00	0·00
G	0 00	0·00	0·00	0·00	0·00	0·00	0·00
H	0·00	0·00	0·00	0·00	0·00	0·00	0·00
I	8·63	6·50	0·87	1·26	75·31	10·08	14·61
J	0·00	0·00	0·00	0·00	0·00	0·00	0·00
K	0·00	0·00	0·00	0·00	0·00	0·00	0·00
L	14·00	11·11	1·21	1·68	79·37	8·64	12·00

Table 16.—River Waters; with Sugar added.

—	c. c. of Gas evolved from 50 c. c. Water.	c. c. of Hydrogen evolved from 50 c. c. Water.	c. c. of Nitrogen evolved from 50 c. c. Water.	c. c. of Carbonic Acid evolved from 50 c. c. Water.	Percentage Composition of Gases.		
					Hydrogen.	Nitrogen.	Carbonic Acid.
A	10·2	6·63	0·73	2·83	65·05	7·21	27·74
B	12·0	7·60	0·77	3·63	63·32	6·47	30·21
C	11·4	8·31	0·94	2·13	72·92	8·42	18·66
D	13·4	10·48	1·14	1·78	78·24	8·53	13·23
E	15·7	10·80	1·25	3 65	68·81	7·95	23·24
F	13·7	9·20	0·97	3·52	67·29	7·12	25·68
G	11·3	7·01	0·86	3·43	62·06	7·62	30·32
H	14·0	10·45	0·88	2·67	74·67	6·33	19·00
I	12·7	9·39	0·89	2·42	73·92	7·60	19·08
J	11·9	8·96	0·74	2·20	75·34	6 23	18·43

Table 17.—Sewage Waters; with Sugar added.

A	7·5	4·66	0·56	2·27	62·15	7·51	30·34
B	7·0	4·24	0·55	2·20	60·64	7·93	31·43
C	9·0	5·67	0·57	2·75	62·98	6·38	30·64
D	9·5	5·60	0·76	3·13	58·98	8·00	33·02

Table 18.—Sugar and Bacteria; with various Liquids.

A	3·320	2·421	0·313	0·586	72·92	9·43	17·65
B	4·100	2·988	0·400	0·712	72·88	9·75	17·37
C	3·900	2·934	0·365	0·601	75·23	9·36	15·41
D	3·967	2·676	0·348	0·943	67·45	8·77	23·78
E	4·503	3·039	0·388	1·076	67·50	8·62	23·88
F	5·032	3·522	0·484	1·026	70·00	9·62	20·38
G	5·660	3·763	0·512	1·325	67·19	9·14	23·67
H	3·211	2·863	0·221	0·127	89·16	6·88	3·96
I	2·924	2·273	0·208	0·443	77 73	7·12	15·15
J	—	—	—	—	—	—	—
K	—	—	—	—	—	—	—
L	4·00	3·52	0·20	0·28	88·00	5·00	7·00
M	3·876	3·121	0·022	0·733	80·52	0·57	18·91

Table 19.

The average of Hydrogen from Waters examined.	Average amount of Hydrogen evolved in c.c.
Derbyshire Waters; collected April 19th, 1883:	
Sugar alone added to the waters	1·09
Sugar and sodium phosphate added to the waters	1·56
Flintshire Waters; collected June 4th, 1883:	
Sugar alone added to the waters	1·95
Sugar and sodium phosphate added to the waters	2·01
London Waters; received February 13th, 1883:	
Sugar alone added to the waters	2·69
Sugar and sodium phosphate added to the waters	2·59
London Waters; received April 26th, 1883:	
Sugar alone added to the waters	2·85
Sugar and sodium phosphate added to the waters	3·20
The waters were allowed to stand for 48 hours; then the clear water syphoned off and sugar alone was added to the clear water	2·54
The waters were allowed to stand for 48 hours; then the clear water syphoned off, and to the deposit sugar alone was added	3·57
London Waters; received May 8th, 1883:	
Sugar alone added to the waters	4·54
Sugar and sodium phosphate added to the waters	3·91
Waters previously softened by Clark's process, then sugar and sodium phosphate were added	3·00
The waters were allowed to stand for 48 hours, and to the deposit sugar and sodium phosphate added	4·84
Waters from Lancashire; collected October 5th, 1883:	
Sugar alone added to the waters	3·71
Sewage Rivers, Irk, Irwell and Medlock, and Canal Water:	
With sugar added	8·88
Salford Sewage Waters:	
With sugar added	5·04
Scum from a Reservoir at Woodhead	16·80
Mud from a Stream at Buxton:	
Sugar alone added	4·49
Sugar and sodium phosphate added	5·53

DERBYSHIRE WATERS; collected April 19th, 1883.
(Tables 1 and 2.)

A.—Spring, mountain side, 4 miles from Buxton on the Bakewell Road.
B.—St. Anne's Well, Buxton.
C.—Town supply, Buxton.
D.—Spring, 3 miles from Buxton on the Bakewell Road.
E.—Stream, which receives sewage matters, &c.
F.—Well, Burbage village, 1 mile from Buxton.
G.—Drinking fountain, near Buxton Station.
H.—Drinking fountain, West Street, Buxton.
I.—Stream in Public Park, Buxton.
J.—Mud from the stream in Public Park.

FLINTSHIRE WATERS, NORTH WALES; June 4th, 1883.
(Tables 3 and 4.)

A.—St. Asaph.
B.—Pump, village of Llanasa, near Holywell.
C.—St. Winifred's Well, Holywell.
D.—Pump, village of Gwespr, near Mostyn.
E.—Ffynnon-y-coed Well, near Mostyn.
F.—Well, Newmarket.
G.—Water tap, Mostyn Quay, Mostyn.

LANCASHIRE WATERS. (Table 15.)

A.—Fountain below Hadfield, Woodhead.
B.—Paradise Well, village of Tintwistle.
C.—1st Reservoir, Tintwistle.
D.—2nd Reservoir.
E.—Scum from 2nd Reservoir.
F.—Stream, mountain side, between Tintwistle and Woodhead.
G.—Mountain stream.
H.—Mountain stream near Crowden Station.
I.—No. 3 Reservoir.
J.—Mountain Stream near Woodhead.
K.—Mountain stream, 1 mile from Woodhead Station.
L.—No. 5 Reservoir.

RIVER WATERS. (Table 16.)

A.—Irk water.
B.—Ditto.
C.—Irwell water.
D.—Ditto.
E.—Medlock water.
F.—Ditto.
G.—Ditto.
H.—Canal water.
I.—Ditto.
J.—Ditto.

SEWAGE WATERS. (Table 17.)

A.—Salford sewage.
B.—Ditto.
C.—Ditto.
D.—Ditto.

SUGAR and BACTERIA with various LIQUIDS. (Table 18.)

A.—50 c. c. Medlock water + Bacteria + 0·5 grm. sugar. November 3, 1883.
B.—50 c. c. Medlock water + Bacteria + 0·5 grm. sugar. November 5, 1883.
C.—50 c. c. Medlock water + Bacteria + 1·0 grm. sugar. November 5, 1883.
D.—50 c. c. Medlock water + Bacteria + 0·5 grm. sugar + 0·5 grm. sulphate of ammonia. November 3, 1883.
E.—50 c. c. Medlock water + Bacteria + 0·5 grm. sugar + 0·5 grm. sulphate of ammonia. November 5, 1883.
F.—50 c. c. distilled water + 0·5 grm. sugar + Bacteria. November 3, 1883.
G.—50 c. c. distilled water + 0·5 grm. sugar + Bacteria. November 5, 1883.
H.—50 c. c. Manchester water + 0·5 grm. sugar boiled. When cooled 0·5 grm. sugar added and Bacteria.
I.—50 c. c. Manchester water + 0·5 grm. sugar boiled. When cooled shaken up with excess of air and 0·5 grm. sugar and Bacteria added.
J.—50c. c. Manchester water + 0·5 grm. sugar boiled. No gas evolved.
K.—50 c. c. Manchester water + 0·5 grm. sugar boiled. When cooled 0·5 grm. sugar added. No gas evolved.
L.—50 c. c. Manchester water + 0·5 grm. sugar boiled. When cooled 0·5 sugar and Bacteia added. November 7, 1883.
M.—50 c. c. pond water + 0·5 grm. sugar. After the gas had been evolved 0·5 grm. sugar and Bacteria were added.

The new light which this hydrogen process promises to throw on the internal condition of liquids and the surfaces of solids in which there is an action of microbes suggests of course the examination of so many substances that the end of the inquiry seems far away. As a specimen I shall give the results obtained from soil and from drainage in a few cases; also from perspiration and a few surfaces. I cannot of course tell the conclusions to be drawn from these results, but in one case it is quite clear that the organic activity of the soil in producing hydrogen was a measure of the organic growth; the amount of phosphate has a very powerful influence, and as the examination of a soil for phosphate

is rather a tedious process and the condition of the phosphate a point difficult to estimate, this may be one of the modes of the examination. We must, however, always have the other side in view, and I cannot tell how far these gases may be influenced by a state of soil which may be offensive to plants. I think it clear, however, that the experiments show where there is poverty of soil. The results will form Tables 20 and 21.

TABLE 20.—SOILS.

A.—Ordinary sand from Kersall Moor near Manchester.
B.—Poor peat.
C.—Rich dark peat.
D.—Ordinary garden soil.
E.—Loam soil.
F.—Decayed leaves.
G.—Rotten manure.

TABLE 20.—SOILS ; with Sugar added.

—	c.c. of Gas evolved from 3 grammes.	c.c. of Hydrogen evolved.	c.c. of Nitrogen evolved.	c.c. of Carbonic Acid evolved.	Percentage Composition of Gases.		
					Hydrogen.	Nitrogen.	Carbonic Acid.
A	0·00	0·00	0·00	0·00	0·00	0·00	0·00
B	3·40	2·48	0·30	0·62	72·94	8·82	18·24
C	7·46	4·73	0·42	2·31	63·40	5·63	30·97
D	12·00	7·55	0·67	3·78	62·91	5·58	31·51
E	17·12	10·27	1·20	5·65	60·00	7·00	33·00
F	22·00	13·68	1·16	7·16	62·21	5·29	32·50
G	27·89	18·50	1·80	7·59	66·35	6·47	27·18

TABLE 21.—DRAINAGE WATERS.

A.—Drainage from a potato field.
B.—Drainage from boggy ground.
C.—Drainage from a grass field.
D.—Drainage from a potato field.
E.—Drainage from a clay soil.
F.—From an open ditch at the side of a meadow, water slowly flowing.
G.—Water flowing over a sandy soil.
H.—Water flowing over a sand and peat district (Lindow).
I.—Peat water from a deep cutting, No. 1.
J.—Peat water from a deep cutting, No. 2.
K.—Water flowing over peat.

TABLE 21.—DRAINAGE WATERS.

—	c. c. of Gas evolved from 50 c. c. Water.	c. c. of Hydrogen evolved.	c. c. of Nitrogen evolved.	c. c. of Carbonic Acid evolved.	Percentage Composition of Gases.		
					Hydrogen.	Nitrogen.	Carbonic Acid.
A	10·00	6·53	0·65	2·82	65·30	6·47	28·23
B	11·42	8·24	0·82	2·36	72·20	7·20	20·60
C	14·00	9·80	0·97	3·23	70·00	6·94	23·06
D	11·93	8·88	0·67	2·38	74·50	5·63	19·87
E	2·20	—	—	—	—	—	—
F	9·70	6·66	0·67	2·37	68·71	6·97	24·32
G	0·30	—	—	—	—	—	—
H	3·95	2·45	0·16	1·34	62·00	4·21	33·79
I	12·70	9·79	0·89	2·02	77·12	7·00	15·88
J	7·33	5·40	0·54	1·39	73·68	7·43	18·89
K	7·83	5·87	0·50	1·46	75·00	6·42	18·58

PART II.

THE ELIMINATION OF NITROGEN DURING PUTREFACTION IN WATER.

The elimination of free nitrogen gas during the process of decay or putrefaction has been a subject of inquiry on many occasions. In my first report under the Rivers Pollution Prevention Act, page 9, I mention a conclusion to which I came, that a peculiar putrefactive condition produces a deoxidation of nitrates. In some conditions nitrogen is eliminated as gas, the oxygen going to the carbon in the whole or in part. In weak solutions containing water enough to absorb the carbonic acid, nearly pure nitrogen may be obtained with considerable rapidity.

As an example, 1,100 c.c. of water containing excreta with two grammes of nitre added, commenced to give off gas after 12 hours. This amounted to nitrogen 98·4 per cent. and carbonic acid 1·6 per cent., that is over the watery solution. Many experiments were made with similar results.

This subject was fully discussed in the report alluded to. When I found it, I sent a notice to the Chemical News, March 25th, 1881. I may be allowed to state that about a year and a half after my first notice, a similar account was given to the Paris Academy by MM. Gayon and Dupetit. *See* Comptes Rendus, Tome XCV., No. 15, 9th Octobre 1882, pages 644 *et seq.*

It will be seen in this view of the question, that nitrogenous bodies have a peculiar power of taking up oxygen and giving out nitrogen; they seem to be used for the purpose of purifying substances as transferers of oxygen. So far as I know in relation to cases of great impurity, it is not proved that nitrates are formed and nitrogen given out afterwards, yet we can prove that when impurity is moderate, nitrates are formed, and in any case they give out their nitrogen in this way.

I mentioned in that report many cases where the nitrate of potash was decomposed and ceased to be found in the liquid. Sulphuretted hydrogen did not exist or it was found in minute quantities only. At the same time the action seemed to be caused by organisms, that is, it took place in liquids which had a great amount of organic matter ready to assert itself. In many putrid liquids the whole of the nitrogen of a given weight of nitrate of potash was collected. I believe that in this way, I sufficiently proved that putrefying bodies were continually destroying themselves, and that putrefaction in rivers was of necessity, a mode of purification.

The following extract from the report spoken of will explain more fully. *See* page 26.

"We may then come to the following conclusions:—Bodies containing protein compounds, when in abundance of water and in common air, may oxidise and form nitric acid.

"The same organic bodies in a state of decomposition, and in water, may oxidise at the expense of nitrates, and give out nitrogen.

"The first condition is that in which a certain amount of sewage is in the water, but is overpowered by the amount of air.

"The second is when the sewage is in excess, and overpowers the nitrates.

"Nitrates may be formed by the oxidation of inorganic nitrogen, but not, so far as we know, by contact with common air under ordinary conditions. The oxygen must be presented in a more concentrated or more active condition.

"Putrefaction destroys organic matter without the influence of oxygen; it breaks up organic compounds and destroys organisms. The evidence seems to indicate that it destroys even those bodies that produce disease, but that in certain conditions it produces others. This is a point not to be enlarged upon without more knowledge, but it is evident that by putrefaction we get rid of an enormous amount of offensive matter. Oxygen cannot enter under the surfaces of actively putrefying bodies, but whenever it is allowed to enter by the putrefaction being less active, an action begins which in time completes the destruction of the body. We are not, therefore, to suppose that the germs of disease can resist all these efforts of nature to destroy noxious things, nor are we to suppose that an invisible germ of disease can pass on from stage to stage unaffected by the putrefaction of sewage and the action of air. We must believe for the present that it is not so. In water we see perfect purification, nitrogen itself being lost.

"In ordinary putrefaction sulphuretted hydrogen comes off in abundance with much carbonic acid and some nitrogen. Oxygen resists this action and if the oxygen is supplied in a concentrated condition a change takes place, nitrogen is evolved as the principal gas and a decomposition of nitrogen compounds takes place. Nitrogenous bodies are thus destroyed, in one manner by their voluntary putrefactions, in another by oxidation. Up to a certain point not determined the greater the amount of nitrogenous bodies the more rapid is their decomposition.

"The oxygen of the nitrates passes in part to the carbon; some will be retained forming a carbonate. I have not estimated how much or if all is taken by the carbon. If the solution is weak the nitrogen takes up the oxygen and does not allow it to pass away, thus forming nitrates.

"Putrefaction and oxidation are two well known modes of destroying organic bodies at ordinary temperatures. The second is not proved to be connected with organisms.

"How far then can oxidation or a great supply of air be employed to destroy putrefaction or to purify?

"The bearing it has on the analysis of water will be clearly seen by chemists. The bearing on the sewage question is also interesting. Substances and living things may be carried by the rapid sewage system into the range of a new activity before

undergoing that putrefaction which breaks them up in proximity to us or in the sewers themselves. It seems to point to a plan of causing the destruction of organisms by putrefaction and subsequent oxidation or by chemical action. At least it seems to me that we require to learn if it be true that any of the germs of disease, or which germs of disease, will live in an abundance of good air. We know that abundant dilution will render them all ineffective. It is probable that there will be a difference amongst them in this respect, whilst all will yield to the double action of first putrefaction and then oxidation."

In my presidential address to the Sanitary Congress at Glasgow 1883, I stated that: "If nature had contrived no method "of destroying such seeds of death populations such as this would "never have grown up. And what is the method? That "method is, first, putrefaction, at least, I know of none other, "except the concluding portion of the work, viz., thorough oxida- "tion. When, therefore, you see the Clyde seething with gases "of putrefaction, and when you smell it to such an extent that a "feeling of loathing is produced, you may remember this, that "the work of destruction is going on with a wonderful rapidity, "and that the enemies of life are being slaughtered there millions "upon millions, never to appear again in a similar form, though "other generations of them may rise up."

Speaking of oxidation in my first report, I mention that animal or vegetable matter containing nitrogen produces nitrates by oxidation with and without organisms. This may be shown by the action of permanganate of potash when strong on ammoniacal salts. This action is one which has not been attended to; but it is important to illustrate the influence of inorganic substances in oxidation. It is an action of the oxygen without the intervention of organisms, and it is probably carried out to a great extent in nature.

On this subject I must refer also to my experiments in the first report, wherein I show that under certain conditions permanganate oxidizes the nitrogen of ammonia. Persalts of iron, I believe, do the same according to some old experiments which I cannot at present recall. I was inclined to think that this would have a great effect in diminishing Wanklyn's mode of testing waters, but in practice in reality I have not found it so.

Some Additional Results illustrating the Escape of Free Nitrogen from Sewer River Water, when Nitre is added

1. Medlock water; collected April 30th, 1883. 1,150 c.c. + 1 grm. KNO_3; experiment commenced April 30, 1883. Gas evolved on June 8, 1883, 103·3 c.c. nitrogen. 1 grm. potassium nitrate contains 110·2 c.c. nitrogen.

2. Medlock water 50 c.c. + 50 mgms. KNO_3; commenced April 30, 1883. Gas evolved on June 8, 1883, 4·80 c.c. nitrogen; 50 mgms. KNO_3 contain 5·51 c.c. nitrogen.

3. Bridgewater Canal water 50 c.c. + 50 mgms. KNO_3. Experiment commenced April 30, 1883. No gas evolved during 46 days observation.

Manchester water containing nitrate of potash did not evolve any gas during 46 days observation.

ESCAPE of FREE NITROGEN from SOLUTIONS of ORGANIC MATTER containing NITRATE of POTASH.

1. Salford sewage 50 c.c. + 50 mgms. KNO_3. Experiment commenced April 31st. Gas evolved collected over mercury and analysed, May 22nd. Gas evolved 5·53 c.c. nitrogen. 0·050 grm. KNO_3 contain 5·51 c.c. nitrogen.

2. Salford sewage 50 c.c. + 25 mgms. KNO_3. Experiment commenced April 31st. Gas evolved collected over mercury and analysed, May 22nd. Gas evolved 2·75 c.c. nitrogen and a trace of CO_2. 0·020 grm. KNO_3 contain 2·75 c.c. nitrogen.

3. Salford sewage 350 c.c. + 0·35 grm. KNO_3. Experiment commenced April 30th. Examined May 28th, 1883. Gas evolved 37·80 c.c. nitrogen. 0·35 grm. KNO_3 contain 38·60 c.c. nitrogen.

4. Sewage mud + 0·09 grm. KNO_3. Experiment commenced May 4, 1883. Gas evolved examined May 28, 1883. Gas evolved 10 c.c. nitrogen. 0·09 grm. KNO_3 contain 9·93 c.c. nitrogen.

In each of the above experiments the gases were exploded with hydrogen and oxygen separately, but only nitrogen was found. They were also tested with caustic potash and pyrogallate of potash.

In experiments 1, 2, and 3 the gas evolution commenced on the sixth day, but experiment 4 commenced on the third day.

APPENDIX

It is only fair to give here the results obtained by Mr. Lauth, when examining the sewage of Paris. He tried aëration before I made my fullest experiments, given in the First Report under the Rivers Pollution Prevention Act, 1882, both with and without lime, and took out the ammonia to a greater extent than I have been able to do. The cause must lie in the different qualities of the sewage and the temperature.

ON THE SEWAGE WATERS OF PARIS (Note from Mr. Ch. Lauth, presented by Mr. Wurtz).—Comptes Rendus, 1877, Vol. 84, page 617.

Origin.—The sewage waters upon which I have operated have been drawn from a syphon of the Alma Bridge and in the gathering ground of the Pépinière; they have been mixed in a manner to represent the mean of the large gathering ground. I obtained them through the kindness of Mr. Belgrand.

Composition.—The sewage waters vary sensibly in composition according to the hour and the time at which they are collected. Mr. Durand Claye has verified this fact before in 1869.

The following is the mean composition of the waters of February 1877:

MATTER contained in 1 CUBIC METRE of SEWAGE WATER.

	Gr.
Matter in suspension - - - -	1242
,, solution - - - -	682
Ammoniacal nitrogen - - - -	6·880
Nitric acid - - - - -	1·900
Organic nitrogen in the insoluble parts (by soda lime) - - - - -	14
Organic nitrogen in the soluble parts (by soda lime) - - - - -	18·64
Total nitrogen (by volume) - - -	35·00
Organic matter including the nitrogen - -	660

Alteration.—As soon as the waters have entered the sewage, they become muddy, but have little colour and are *inodorous.* When they are kept in stoppered flasks without filtering, they commence to alter after some days. At the end of 10 or 20 days, they are entirely putrid; they have become black and absolutely infected. These phenomena have probably been due to matter in suspension, for I have been able to preserve for two months a sample of water previously filtered, without perceiving any odour. The alteration which we notice in stoppered flasks is evidently of the same nature as that which has taken place at the bottom of the Seine.

Purification by Air.—Authorities have stated that employing sewage waters in agriculture, putrescent substances are oxidised at the surface or in the depths of the soil; I have thought that it would be interesting to observe if this oxidation would be produced by the simple passage of air without the intervention of the soil, and to study at the same time the nature of this oxidation.

When air is blown into sewage water its properties and its composition are rapidly modified; *the water saturated with air is no longer liable to putrefaction.* In order to prove this it is sufficient to observe that if two vessels are taken, viz., a stoppered bottle filled with ordinary sewage water and a beaker filled with the same water, previously aerated, that at the end of 10 to 20 days, in winter, the first has become black and infected, the second is still clear and inodorous after two months.

CHEMICAL TRANSFORMATIONS OPERATED BY AERATION.

——	Insoluble Nitrogen.	Soluble Nitrogen.	Nitric Acid.	Ammoniacal Nitrogen.	Total Nitrogen by Volume.
	Gr.	Gr.	Gr.	Gr.	Gr.
Before aëration -	14·70	20·65	1·175	8·4	38
After aëration -	8·05	26·95	1·122	14·0	—

In another series of observations, which lasted three days (with analysis and aeration each day), we have had the following results, before aeration 5 · 282 grs., after 13 grammes.

Thus, by aëration, the nitrogen of the insoluable parts diminishes; the nitrogen of the soluble parts increases the same quantity, nitrates do not form, and the quantity of ammonia increases to a high proportion.

Purification by Lime.—Several chemical agents facilitate the purification of sewage waters; lime has been recommended for a long time and I have obtained with it the following results:—

——	Insoluble Nitrogen.	Soluble Nitrogen.	Nitric Acid.	Ammonia.
	Gr.	Gr.	Gr.	Gr.
Water without treatment -	14·70	20·65	1·17	8·4
Water treated by lime - -	10·15	25·55	2·60	18·20
Water treated by lime and air -	6·65	28·87	2·12	21·35

The maximum effect has been obtained with a water which of 5·282 grammes ammonia has increased to 18·550. Water treated by lime is inodorous and colourless after two months observation.

These observations may perhaps attract the attention of agriculturists and authorities who have studied the question of the assimilation of the nitrogen and who doubtless may consider that the reactions which take place in the laboratory also take place at the surface of the soil, and that considerable quantities of nitrogen disappear in the atmosphere in the state of ammonia.

Microscopical Examination. A. *Water preserved by the Action of Air.*—Water containing sewage shows at first upon its surface moving and stationary bacteria, some vibrionia, some monads; at the bottom of the beaker debris of all sorts without animal life. After two days the surface presents a pellicle of bacteria, germinating growths on its lower surface; monads abundant, kolpoda commence to show themselves. On the fourth day vorticella and large infusoria (englena, parmecia) appear; at the same time algæ show themselves, some extremely fine, long points larger than $\frac{1}{1000}$ of a millimetre and twisted round themselves, others large and short and between these two extreme forms, others intermediate, all of which perhaps it is not correct to connect with a single polymorphe.* A recent work presented to the Academy on the sulphuration of waters by the "sulfuraires" has naturally attracted my attention on these points. Towards the seventh day, the water which had no odour became nauseous, commenced to blacken, a thick globule seemed to collect appearing to contain some infusorial enkystes; numerous remains of dead and black points. After four to five weeks the

* Once I have found one of these aërial germinating algæ presenting the character of Penicillium.

odour of the liquid is infected and fetid; all trace of life had for the present disappeared.

B. *Water treated by Lime.*—Absence of life and vegetation.

C. *Water treated by Air.*—In aërated sewage water life is more active; points, infusoria develop in great number, they disappear altogether little by little at the end of some weeks; but at the same time one does not observe any nauseous odour and the water remains clear.

For these microscopical observations, Mr. Pouchet has been so good as to aid me with his advice.

Conclusions.—The work stated shows that sulphydric putrefaction of the sewage waters perhaps may be stopped by the addition of lime with results much more important than by simple aëration. Putrefaction does not manifest itself when sewage water is exposed to the action of the air. As these last conditions probably refer to the basin of the Seine, one is allowed to suppose that the work which I have indicated may be ultimately applied to its purification.

PART III.

Dr. KOCH'S GELATINE PROCESS.

When Dr. Koch published his very interesting account of the action of gelatine in giving an opportunity for the expansion of living germs in water it was natural that I should be attracted to the subject as I had myself failed to produce good results by cultivation. I seized on the use of gelatine with great earnestness, and soon satisfied myself that there was much to be gained by its use. I do not know, even now, if I employ the method which Dr. Koch would consider the best, but the book on the subject promised by himself and his coadjutor not having appeared, I consider myself at liberty to proceed with my inquiries, especially as Dr. Koch has himself informed me that he is glad I have taken up the subject. It has been my wish to collect together a considerable variety of waters, to expose them to the conditions involved in the use of gelatine, and to endeavour to find how far the results will be found advantageous to the public. The method of working was this: a solution was made containing 5 per cent. of solid gelatine. This was prepared from the thin leaf, then, when dissolved, clarified by filtration or by fresh albumen. This solution melts at about 27° C. or about 80° F.; 25 c.c. of this have been usually mixed with 25 c.c. of the water to be examined, and kept for some minutes about the temperature indicated, but much smaller quantities are frequently sufficient.

The experiments were all made in test tubes with stoppers of cotton wool only. The tubes contain about 80 c.c., and are in length 8 inches (in diameter 1 inch), or they contain about 1,230 grains. The size of the tube is a matter of no importance, and it may be better to give up test tubes entirely.*

One of the chief advantages obtained by the gelatine method is found, as I believe, in the fact that the gelatine prevents the water from moving, that every point, therefore, which has vitality in it is able to assert itself, and one sees at a glance the number existing in the water. The advantage of this is great to the operator, but it is also important to the public, as the whole may be photographed and a picture given which cannot speak falsely. The result seems to be that in sewer waters and very impure waters the gelatine is rendered fluid at the surface, and this fluidity increases in depth until the whole is rendered fluid. If this fluid part be examined, it will be seen to be alive with bacteria. It seems as if, in a very impure water, this class of activity could not transmit itself to a great depth at once, because of the want of oxygen. These very impure waters, therefore, might at first sight by this test appear to some advantage. Perhaps the better way to treat them would be to take out a small portion and add it to pure water and then compare the results. As at times this interruption of the flow of oxygen is so great that the gelatine

* Equally good results have been obtained by using other vessels.

remains for a long time very solid. If the water contains any disinfectant, a mineral acid, for example, this is especially the case, and it is probable that the method may be employed as a measure of the power of the disinfectant, and photographs may be obtained to show to the eye the relative value.

In waters which are usually drunk, Manchester water, for example, there is one condition frequently observed—the whole tube becomes filled with perfectly formed and transparent spheres, forming very beautiful objects. At the bottom of these spheres is a little white line; sometimes this becomes rather marked, and if it is too heavy, it sinks below the circumference, and gives an appearance of a balloon with a parachute.

If a pipette is put into these spheres and suction applied it will be found that they are full of liquid whilst the gelatine around is solid. The deposit below contains a great mass of active and inactive bacteria. So far as I can observe at present a specimen of water that gives some of those clear spheres is not to be objected to on that account as a drinking water, although I suppose the fewer the better, and I shall suppose them for the present to stand as a measure of quality to a certain extent. There is another phenomenon appearing in some of them, viz., a number of very minute white dots which increase to a size of a pin head. These may be scattered in countless numbers through the water and seem to indicate the number of points of vitality in the water. These dots seem to be filled with a different kind of bacteria from those mentioned above, as they do not form spheres of liquid gelatine around them. There are also in other waters countless other specks more or less transparent until we come to a point where to the ordinary eye the gelatine appears perfectly clear; this was the case in water taken from the coast of Norway and tried about six weeks after collection, although upon careful examination there were minute transparent forms. The fluid gelatine has been examined and the solid matter found to contain 14·73 per cent. nitrogen. No gas escapes during the transformation of the gelatine, and the result of the process seems only a change from the solid to the liquid.

In other cases the number of spheres is so enormous and the number of bacteria alive consequently so prodigious that one can scarcely see any transparent gelatine.

In a few cases gases are evolved and form globules more or less compressed and misshapen in consequence of the difficulty which they have in passing out of the solid gelatine.

Of all these forms of change that which seems to be connected with the most offensive waters is the liquifying of the surface. The other changes are more or less objected to according to the number of points of activity, which one naturally considers a measure of impurity. As has been said the great value of the process at first sight is in enabling us to find an easily observed measure of this activity in showing it photographically and enabling us to have it printed permanently.

I confess it is to me a matter of serious consideration how far

these results ought to be published and explained before we are able to ascertain what is the exact physiological effect of an increase of that class of bacteria or microbe of whatever kind it is that is most frequently found in waters. Is any one of them a germ producing a disease? Is any one to be supposed productive of disease according to the multiplication of the individuals? Now none of these questions am I able to answer. I see no hope of answering them at an early period or without an amount of investigation which years and numbers of men are required to produce. Are we therefore to withhold this minimum of information until it is perfect, or are we to frighten the public at once by showing them clearly on paper the numerous living points which they are doomed to swallow? I see no difficulty in answering the question; the information cannot be withheld and I think the public will not be too much alarmed. It has already for many years been a custom to listen to wonderful stories about the enormous number of living things which we are supposed to be swallowing continually in every drop of water apparently pure, and these stories have been sent out by scientific men to the wonder of many who have known how false they have been. The origin probably has been this, microscopists have allowed the solid matter of water to fall to the bottom and having taken out a drop of the precipitate have forgotten to make allowance.

From the examination of the photographs here given we see that there is a great variety in the appearance, and we are obliged to confess that some waters are given out by nature very much purer than others although not strikingly so to the eye.

This gelatine process has the great value of bringing out the smallest points by causing them to exert their energies, and, as it were, to build their structures, the size and numbers of which we can to some extent measure and count. But the great fear I have is this, that in waters that are considered excellent people may see danger when certainly there is none. Take, for example, Loch Katrine water, which we have always held as a model; we still see forms there. Take the Manchester water, which we have at least been accustomed to consider as very fair; forms are always present, but then we can say in this case that at times they are more numerous, and in those cases where they are more numerous the water is not so good to the senses, so that here we have clearly a measure of excellence that does not depend on the opinion of any man, and which may be shown as a witness to speak for itself.

The gelatine test with water alone gives, I incline to think, clearer and simpler results than with phosphate of soda added. The use of sugar increases those results immensely, but experience must discover whether this is an advantage. The use of phosphate of soda is productive of a much greater number of spheres and frequently causes confusion, and renders the comparison of the waters more difficult.

The hydrogen method agreed well with the results obtained with the gelatine, but the gelatine sometimes shows spheres when

the hydrogen does not appear. The result of this seems to be that the gelatine process detects minute impurities consisting of active organisms of the kind which cause a transformation in gelatine, but the hydrogen gives exact results, and enables us when it does appear to estimate the activity of the organisms quantitatively, and to give correct figures for each water. I look on this as the most important result of the hydrogen process, as it may be called.

The question may be asked—Are they the same microbes that transform the gelatine and produce the hydrogen? I have no reply except this, which has already been said, that the results correspond very fairly, and the probability is in favour of an affirmative.

BUXTON WATERS, DERBYSHIRE; collected April 19th, 1883. Experiments commenced April 20th, 1883.

EXAMINATION of the WATERS by the GELATINE PROCESS compared with DISTILLED and MANCHESTER WATERS.*

(1.) Distilled water (Fig. 1).—No alteration after 15 days observation.

(2.) Manchester water (Fig. 2).—On the second day a number of minute spheres appeared, which had enlarged on the third day, surface of the gelatine not altered. On the fourth day the spheres had increased in size and number, and a deposit was forming at the bottom of the spheres.

Spring water, clear. One of the better natural waters (Fig.3).—On the second day a few minute spheres appeared. On the third day the spheres had enlarged. On the fourth day a deposit was forming at the bottom of the spheres; the surface of the gelatine had given way very slightly.

Well (Fig. 4).—On the second day a number of minute specks appeared, but no spheres. On the third day a few minute spheres appeared, especially near the surface; the surface of the gelatine not altered. On the fourth day, surface layer semi-liquid, and of a greenish colour, numberless amount of small spheres appeared dispersed throughout the tube.

Town's water (Fig. 5).—On the second day an innumerable quantity of minute dots appeared, which enlarged to spheres on the third day; the surface of the gelatine was still firm. On the fourth day the surface had a greenish appearance, was giving way very slightly, the spheres not enlarging much.

Spring, 3 miles from Buxton on the Bakewell Road (Fig. 6).—On the second day a distinct band of minute specks appeared, at the surface 1 mm. deep. On the third day these specks had enlarged to dots and the surface of the gelatine had a greenish

* Owing to the cost of their reproduction, the whole of the photographs taken in connexion with the experiments are not included in this Report. The six photographs selected by Dr. Angus Smith to accompany the Report contain figs. 1 to 21, 37 to 57, and 64 to 70.

appearance; also a few spheres, but very minute, dispersed throughout the gelatine. On the fourth day the surface layer was liquid to a depth of 2 mm. About five or six spheres appeared dispersed throughout the gelatine.

Below Buxton, receiving sewage although looking clear (Fig. 7). —On the second day a distinct band of minute specks appeared at the surface of the gelatine. On the third day the surface of the gelatine was quite liquid to a depth of 5 mm. and of a greenish colour. On the fourth day a few discs of gas appeared, the surface of the gelatine was liquid to a depth of 7 mm,

Well at Burbage, 2½ miles from Buxton (Fig. 8).—On the second day a few minute specks appeared near the surface forming a faint band. On the third day the specks had enlarged to spheres and a number of minute spheres appeared, dispersed throughout the gelatine. On the fourth day surface band 3 mm. deep, semi-liquid, and greenish.

Fountain near the railway station, Buxton (Fig. 9).—On the second day a few minute dots appeared. On the third day the dots had enlarged to spheres. The surface layer semi-liquid to a depth of 2 mm. No decided alteration was visible on the fourth day.

Fountain, West Street, Buxton, turbid (Fig. 10).—On the second day a number of minute specks appeared near the surface forming a distinct band. On the third day the surface of the gelatine was liquid to a depth of 4 mm., and of a greenish colour. On the fourth day a few minute spheres appeared, the surface of the gelatine was liquid to a depth of 6 mm.

Stream in the public park (Fig. 11).—On the second day a number of specks appeared near the surface forming a distinct band. On the third day the band was becoming liquid and of a greenish appearance about 5 mm. deep; also a number of small spheres dispersed throughout the gelatine. On the fourth day discs of gas appeared, surface of gelatine liquid to a depth of 6 mm.

Mud from stream in the park (Fig. 12).—On the second day a white band appeared at the surface which became liquid on the third day to a depth of 2 mm. On the third day an innumerable number of discs of gas appeared dispersed throughout the gelatine. On the fourth day the surface layer was quite liquid to a depth of 7 mm.

All the waters mentioned about Buxton were clear unless it is otherwise stated. We learn from this that a distinct advantage is obtained by the use of the gelatine process. The results are very different, and in some cases the presence of sewage was known to be the cause. The number of spheres or centres of microbes is one measure, the depth to which the surface becomes liquid is another important one, and the number of days mentioned is also a mode of comparison because about that time putridity set in.

But it must be distinctly observed that the effects differ very much with temperature and without comparison with known waters there is a danger in drawing conclusions.

Flintshire Waters.—Experiments commenced June 4th.

Distilled water.—No alteration after four days' observation Fig. 13.

Manchester water (Fig. 14).—After two days innumerable spheres and dots appeared. After three days a deposit had formed at the bottom of the spheres, the surface layer was becoming liquid. After four days the whole of the gelatine had completely given way, a few bubbles of gas had formed which gradually ascended to the surface.

A. Well, St. Asaph (Fig. 15).—After one day a faint band appeared at the surface, and a number of minute specks appeared dispersed throughout the gelatine. After two days the surface layer was quite liquid and turbid to a depth of 2 m.m., the specks had enlarged to distinct dots innumerable and two minute discs of gas appeared. After three days in a slightly advanced stage about 12 discs of gas had appeared. After four days the surface layer was liquid and turbid to a depth of about 5 m.m., the rest of the gelatine firm. The dots did not increase in size nor the quantity of gas in that time.

B. (Fig. 16.), Llanasa pump water.—After one day a faint band appeared at the surface and innumerable minute specks appeared dispersed throughout the gelatine. After two days the surface layer was semi-liquid and turbid and a number of discs of gas appeared. After three days in an advanced stage the tube one mass of discs of gas. After four days the surface layer was liquid to a depth of 10 mm. The rest of the gelatine had given way very slightly. The specks had become dots, a word that may be used for a more decided bulk.

C. Holywell (Fig. 17).—After one day a distinct band appeared at the surface. After two days the surface layer was liquid and turbid to a depth of 2 mm. An innumerable amount of spheres appeared. After three days the spheres had enlarged in size and a very faint deposit was forming at the bottom of the spheres, the surface layer was liquid to a depth of 4 mm. After four days the whole of the gelatine had given way slightly, a few bubbles of gas had formed which were struggling to rise to the surface, the surface layer was liquid and turbid to a depth of 20 mm.

D. Pump-water at Gwespyr near Mostyn (Fig. 18).—After one day a very distinct band appeared at the surface. After two days a number of dots appeared, the surface layer was liquid and turbid to a depth of 3 mm. After three days a number of small discs of gas appeared. After four days the discs of gas had enlarged, the surface of the gelatine was liquid to a depth of 12 mm.; the dots were very distinct in this water.

E. Well at Ffynnon y Coed near Mostyn, (Fig. 19).—After one day a distinct band appeared at the surface and an innumerable quantity of specks were dispersed throughout the gelatine.

After two days the surface band was semi-liquid and turbid, and a few minute spheres appeared along with the specks. After three days the same condition. After four days a faint deposit

had formed at the bottom of the spheres which had not enlarged. Minute dots and specks had appeared; the surface layer was liquid and turbid to a depth of 4 mm.

F. Pump at Newmarket near Rhyl (Fig. 20).—After one day a distinct band appeared at the surface, and innumerable specks appeared dispersed throughout the gelatine. After two days a number of discs of gas appeared, the surface of the jelly was liquid to a depth of 3 mm. After three days the gelatine was one mass of discs of gas; surface layer liquid to a depth of 4 mm. After four days the surface layer was liquid and turbid to a depth of 8 mm.

G. Water Tap, Mostyn (Fig. 21).—After one day a distinct band appeared at the surface, and innumerable dots appeared dispersed throughout the gelatine. After two days the surface layer was liquid to a depth of 3 mm., and a few spheres appeared dispersed throughout the tube after three days in a similar condition. After four days the dots had enlarged, were opaque and varied in size, the surface of the gelatine was liquid and turbid to a depth of 7 mm.

We may remark here a distinct inferiority to the Derbyshire waters which latter have the advantage, one long recognised, of being filtered through chalk. The Flintshire waters partake more of the character of surface waters and from them organisms are likely to be obtained. The results seem to agree with our ordinary observations, but the advantage of the experiment is that the ordinary eye can judge.

Waters from Lancashire and District.—October 5th, 1883.

Examination of the Waters by the Gelatine Process.—Experiments commenced October 6th, 1883.

Distilled water.—No alteration during eight days observation.

Manchester water (from tap in laboratory).—After three days innumerable small spheres appeared. After four days these spheres had increased in size, the surface of the gelatine remained firm. After five days a deposit had formed at the bottom of the spheres, and transformation of the gelatine was taking place very rapidly.

Samples of water taken from the reservoirs between Woodhead and Hatfield which supply Manchester with water gave similar results to the specimen taken from the tap in the laboratory.

Samples of water taken from the streams on the mountain sides developed a large number of points after three days. After four days discs of gas appeared, but spheres were absent. Dots were observed, but they did not increase in size.

Scum taken from one of the reservoirs showed after three days innumerable dots dispersed throughout the gelatine and a large number of discs of gas also appeared. The gelatine gradually softened and the development of the germs was far more advanced than in any of the other specimens of water under examination.

LONDON WATERS, received February 15th, 1883.—Experiments commenced 15th February 1883.*

EXAMINATION of the WATERS by the GELATINE PROCESS.—Sugar and Sodium Phosphate added.

Distilled water (ordinary), (Fig. 22).—After five days no alteration, with the exception of the appearance of a few minute spheres.

Manchester water (Fig. 23).—After three days a number of minute yellowish spheres appeared dispersed throughout the tube, and a very fine delicate growth of confervoid bodies also appeared. After four days the yellowish spheres had enlarged, the surface of the gelatine had become liquid to a depth of 2 mm.

Sample of water taken from the River Thames at the intakes of the West Middlesex Grand Junction and Southwark and Vauxhall Companies, at Hampton (unfiltered), (Fig. 24).—After two days a distinct band appeared at the surface, consisting of a number of delicate points. After three days innumerable minute spheres appeared, more than in any of the other waters in this series and the surface of the gelatine was beginning to liquify. After four days the spheres had slightly increased in size and the surface of the gelatine had become liquid to a depth of 4 mm.

Sample of Southwark and Vauxhall water taken at Hampton, and used for the supply of that Company's country district (filtered), (Fig. 25).—After two days a very faint band appeared at the surface. After three days yellowish-white spheres appeared and the surface of the gelatine was giving way. After four days the spheres (about 40 in number), had increased considerably in size, the surface of the gelatine had become semiliquid to a depth of 6 mm.

Sample of Southwark and Vauxhall water taken at Battersea, and used for the supply of that Company's town district (filtered), (Fig. 26).—After two days, a distinct band appeared near the surface. After three days a number of minute spheres appeared. After four days, the spheres had increased in size, the surface of the gelatine had become liquid to a depth of 6 mm.

Sample of Grand Junction water from works at Hampton, and used for the supply of that Company's country district (filtered) (Fig. 27).—After two days, a distinct band appeared near the surface. After three days a number of spheres appeared. After four days, the spheres had increased in size, the surface of the gelatine did not become liquid as rapidly as in any of the other waters in this series.

Sample of Grand Junction water from works at Kew, and used for supply of that Company's town district (filtered) (Fig. 28).—After two days a very faint band appeared near the surface. After three days a number of spheres appeared. After four days the spheres had increased in size, the surface of the gelatine had become liquid to a depth of 6 mm.

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* See foot note on page 31.

Sample of West Middlesex water from works at Hammersmith (filtered) (Fig. 29).—After two days a very faint band appeared near the surface. After three days, a few minute spheres appeared. After four days, the spheres had increased in size, the surface of the gelatine had become semi-liquid to a depth of 1 mm.

London waters of February 15th, 1883, containing 80 per cent. of distilled water gave similar results to those with London water alone.

London waters, February 15th, 1883, containing sugar, gave similar results to waters with sugar and sodium phosphate, except that the surface layer did not become liquid as soon as those with sodium phosphate.

London waters, February 15th, 1883, containing only sodium phosphate, gave similar results to those containing both sugar and sodium phosphate, the surface layer becoming rapidly liquid.

London waters, February 15th, 1883, containing gelatine alone, did not give so many spheres, and were not so distinctly different from each other as those with sugar and phosphate of soda, still there was a marked difference which coincided with the sugar and sodium phosphate experiments.

Figure 43 is a distilled water experiment.

Figures 30, 44, 51, 64, 71, 78 are Manchester waters taken from the tap in laboratory.

Figures 31, 32, 33, 34, 35 and 36 are London waters, February 15th, 1883, with sodium phosphate alone added to the waters.

Figures 37, 38, 39, 40, 41 and 42 are London waters, February 15th, 1883, with 80 per cent. distilled water added to the waters, besides sugar and sodium phosphate. Photographed after five days.

Figures 43, 44, 45, 46, 47, 48, 49, and 50 are London waters February 15th, 1883, with sugar and sodium phosphate added to the gelatine.

Figures 51, 52, 53, 54, 55, 56, and 57 are London waters, February 15th, 1883, with gelatine alone.

Figures 58, 59, 60, 61, 62, and 63 are London waters, February 15th, 1883, with 80 per cent. distilled water added to the waters, besides sugar and sodium phosphate. Photographed after seven days.

Figures 64, 65, 66, 67, 68, 69, and 70 are London waters, February 15th, 1883, with sodium phosphate alone added to the gelatine.

Figures 71, 72, 73, 74, 75, 76, and 77 are London waters, February 15th, 1883, with sugar alone added to the gelatine. Photographed after five days.

Figures 78, 79, 80, 81, 82, 83, and 84 are London waters, February 15th, 1883, with sugar alone added to the gelatine, Photographed after seven days.

London Waters.—April 26th, 1883.

Examination of the Waters by the Gelatine Process. Experiments commenced April 27th, 1883. Photographed after five days.*

Distilled water (Fig. 85).—No alteration during six days bservation.

Manchester water (Fig 86).—After three days innumerable minute spheres appeared dispersed throughout the gelatine, which did not increase considerably in size after four days. After six days some of the spheres increased in size, and a deposit was was forming at the bottom of them.

Loch Katrine (Fig. 87).—After three days innumerable minute dots appeared, which were in a somewhat similar condition after four days.

Lambeth Waterworks Company water as supplied to the town district (Fig. 88). — After three days innumerable spheres appeared, a little larger than those in Manchester water; surface of the gelatine quite firm. After four days in a similar condition.

Grand Junction Waterworks Co. Water as supplied to the town district (Fig 89).—After three days innumerable spheres appeared, a little larger than those in Manchester water, surface of gelatine firm. After four days in a similar condition except that two or three of the spheres had increased in size and a deposit was forming at the bottom of the spheres.

Chelsea Water-works Co. (Fig. 90). Water as supplied to the town district.—After three days innumerable spheres appeared, a little larger than those in Manchester water, surface of gelatine firm. After four days in a similar condition except that two or or three of the spheres had increased in size and a deposit was forming at the bottom of the spheres.

West Middlesex Waterworks Co. (Fig. 91). Water as supplied to the town district. After three days a number of very minute dots appeared which had not enlarged after four days. This water was one of the best of the series.

Southwark and Vauxhall Water Co. (Fig. 92). Water as supplied to the town district.—After three days innumerable spheres appeared, a little larger than those in Manchester water, surface of the gelatine quite firm. After four days in a somewhat similar condition, one or two of the spheres had increased in size.

Figures 93, 94, 95, 96, 97, 98, 99, and 100 are the same series of waters with gelatine alone. Photographed after five days.

Figures 101, 102, 103, 104, 105, 106, 107, 108 are the same series of waters with sugar and sodium phosphate added to the gelatine, but photographed after seven days.

Figures 109, 110, 111, 112, 113, 114, 115, 116 are the same series of water with gelatine alone, but photographed after seven days.

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* See foot note on page 31.

LONDON WATERS; received May 8th, 1883.

EXAMINATION of the WATERS by the GELATINE PROCESS. Experiments commenced May 9th, 1883. Sugar and sodium phosphate added to the gelatine. Photographed after six days.*

1. Distilled water (Fig. 117).—No alteration during six days' observation.

2. Manchester water (Fig. 118).—After four days innumerable spheres appeared. After five days the spheres had increased in size and the surface of the gelatine was still firm. After six days a deposit had formed at the bottom of the spheres. Surface of the gelatine liquid to a depth of 3 mm.

3. London water. Water from river above Hampton (Fig. 119).—After four days innumerable small spheres appeared. After five days these spheres had increased in size, and the surface of the gelatine had become liquid to a depth of 4 mm. After six days a deposit had formed at the bottom of the spheres; surface of the gelatine liquid to a depth of 7 mm.

4. Grand Junction Waterworks. Sample from their underground supply of Hampton (Fig. 120).—After four days in the same condition as 119. After five days the surface layer was liquid to a depth of 4 mm. After six days a deposit had formed at the bottom of the spheres, globules of gas had also appeared, and the surface of the gelatine was liquid to a depth of 4 mm.

5. Water from River at Hampton (Fig. 121)—After five days similar to London water No. 119, except that the surface layer was liquid to a depth of 6 mm.

Figures 122, 123, 124, 125 are the same series of waters with gelatine alone; photographed after six days.

The London waters of February 15th, 1883, with sodium phosphate and sugar, and the Derbyshire and Flintshire waters may be compared on the photographs.

They are inferior to the Derbyshire and Flintshire waters, also Lancashire and district. The same may be said of London waters received April 26th and May 8th, 1883, but these waters gave way more at the surface, and, as I have previously stated, the effect of temperature upon the experiments makes it very difficult to draw correct conclusions, especially as all the experiments were not made at the same time of the year; but this we can say, the Manchester water was always superior to any of the London waters when tested at the same time. It seems necessary, therefore, before drawing sweeping conclusions, that all these waters should be tested carefully at all times of the year.

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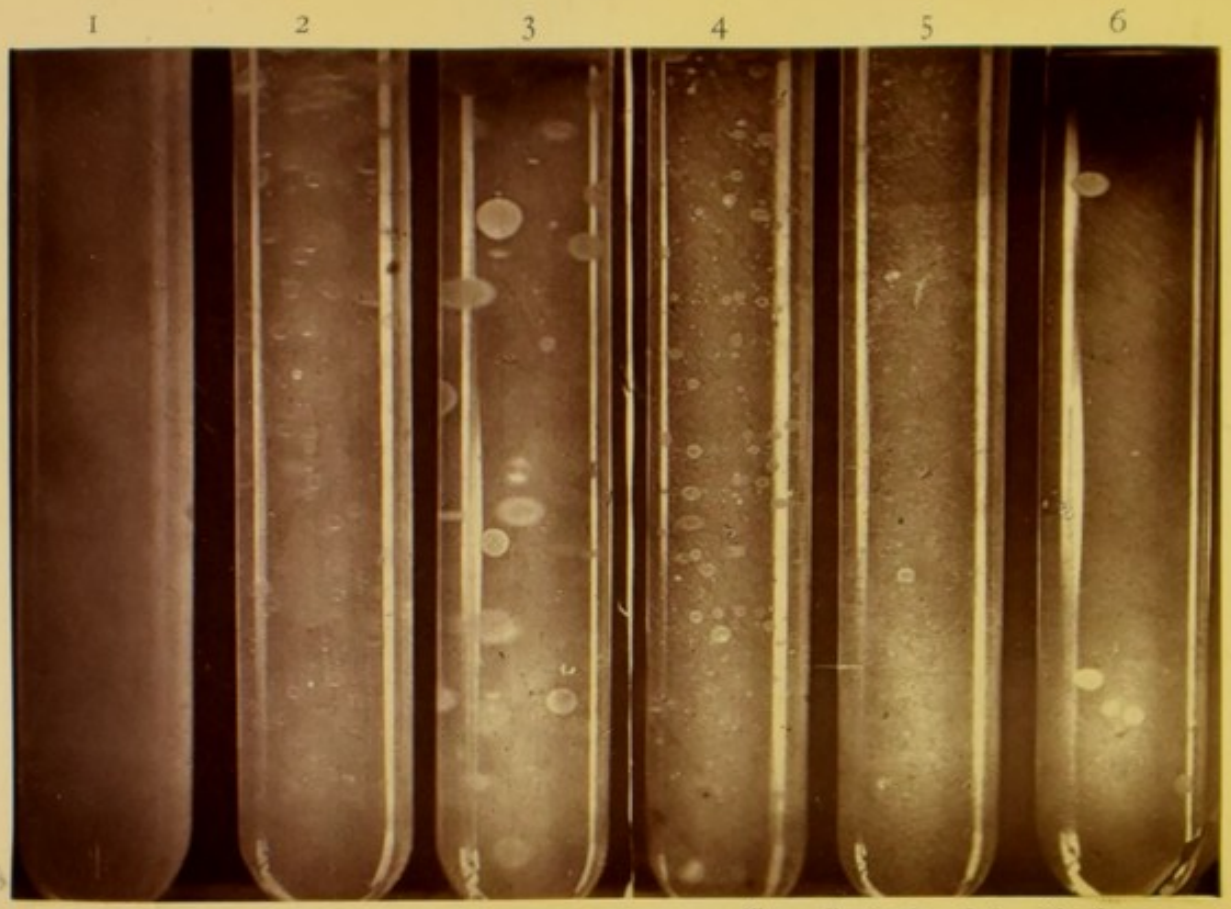
* See foot note on page 31.

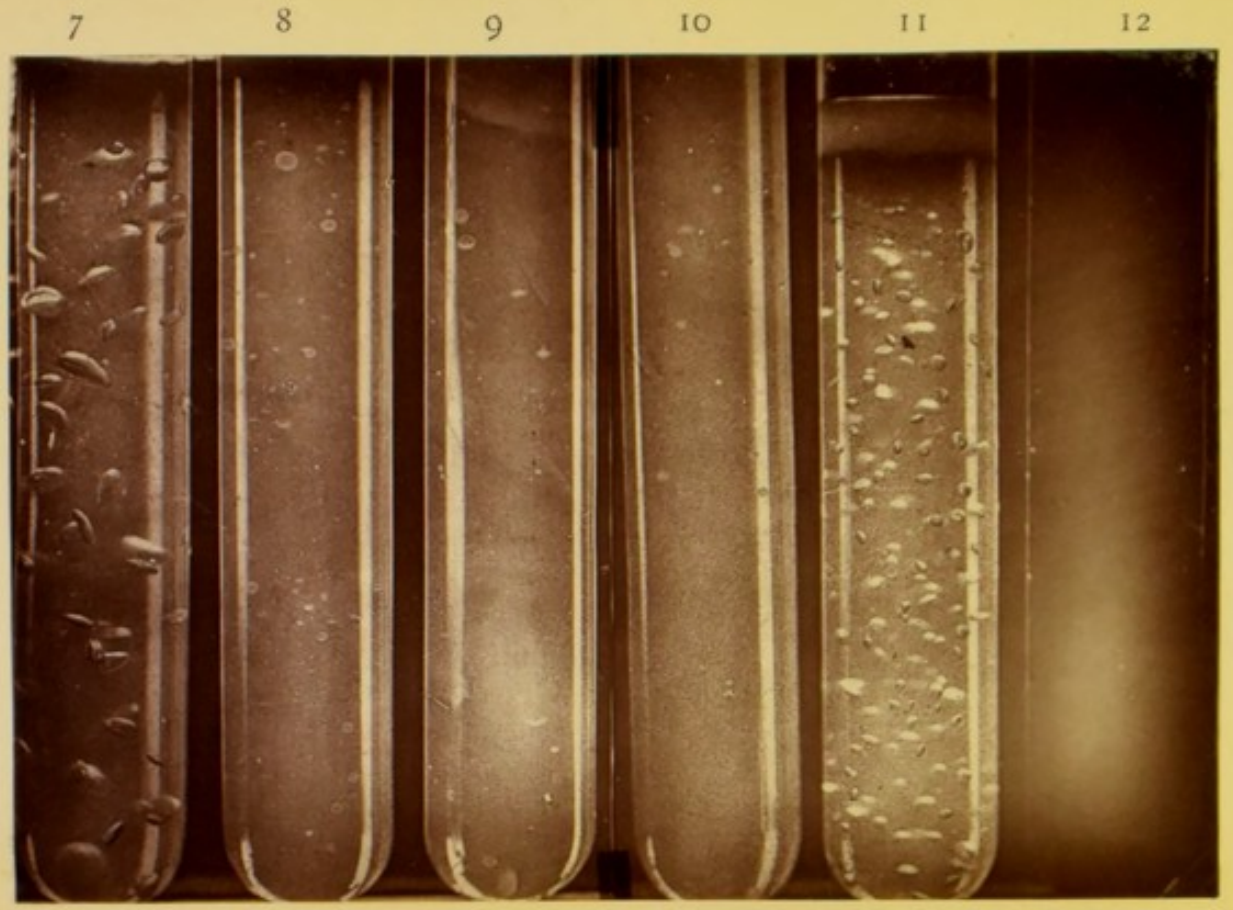
GELATINE ALONG WITH SUGAR AND SODIUM PHOSPHATE.

Photographed after Five Days.



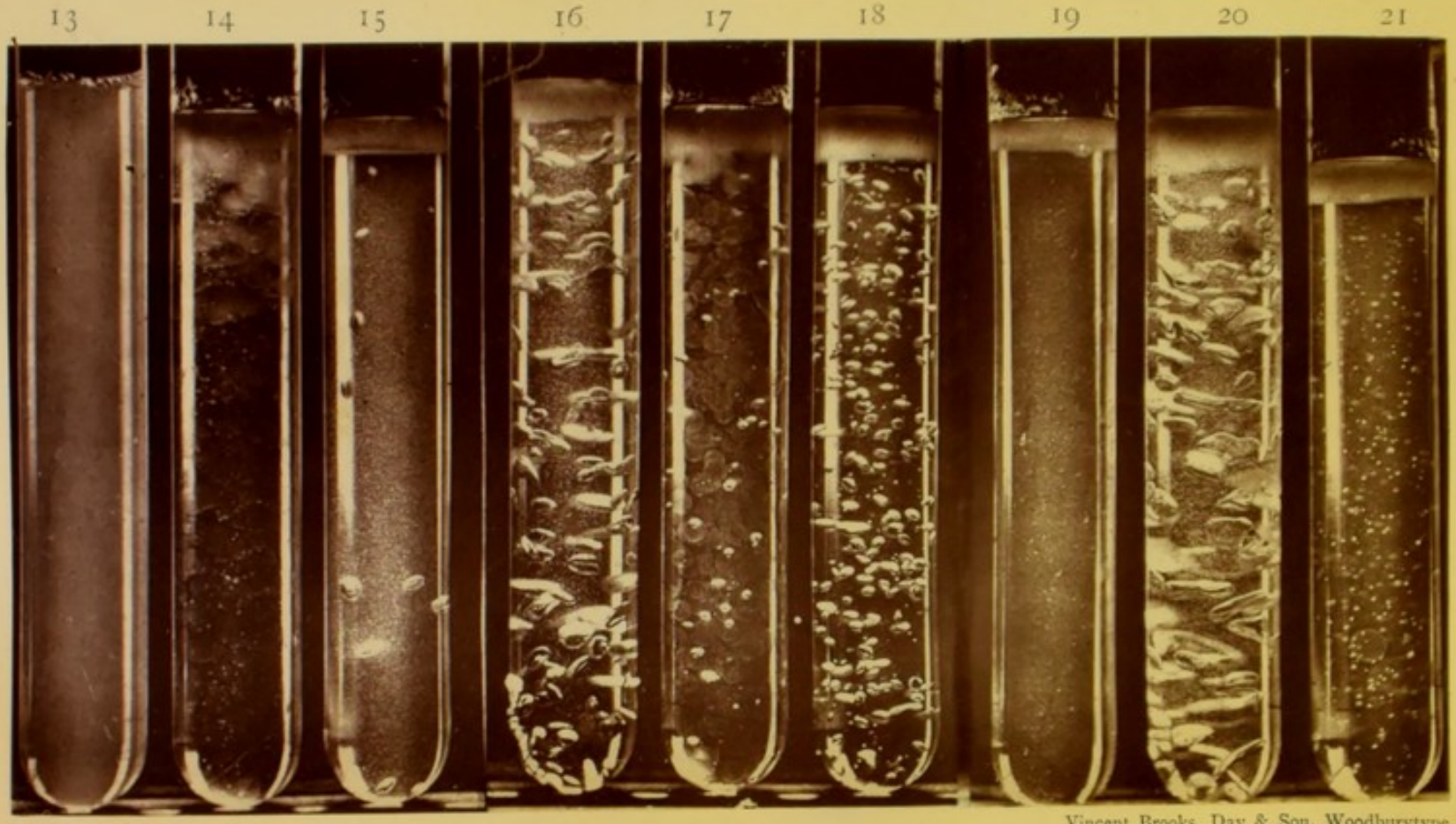
Vincent Brooks, Day & Son, Woodburytype

GELATINE ALONG WITH SUGAR AND SODIUM PHOSPHATE.
Photographed after Five Days.



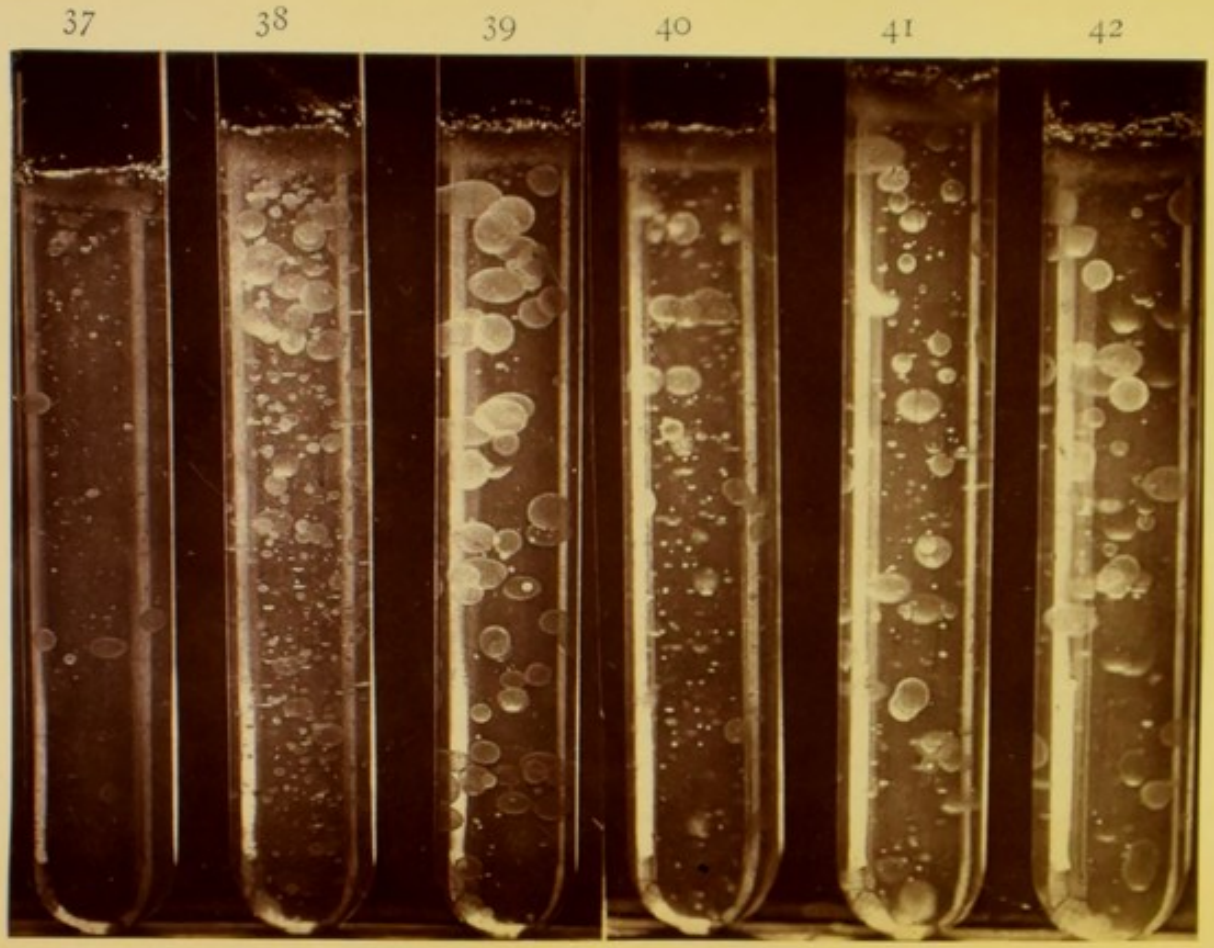
Vincent Brooks, Day & Son, Woodburytype

GELATINE ALONG WITH SUGAR AND SODIUM PHOSPHATE.
Photographed after Three Days.



Vincent Brooks, Day & Son, Woodburytype.

EIGHTY PER CENT. DISTILLED WATER ADDED TO THE WATERS, BESIDES SUGAR AND SODIUM PHOSPHATE. Photographed after Five Days.

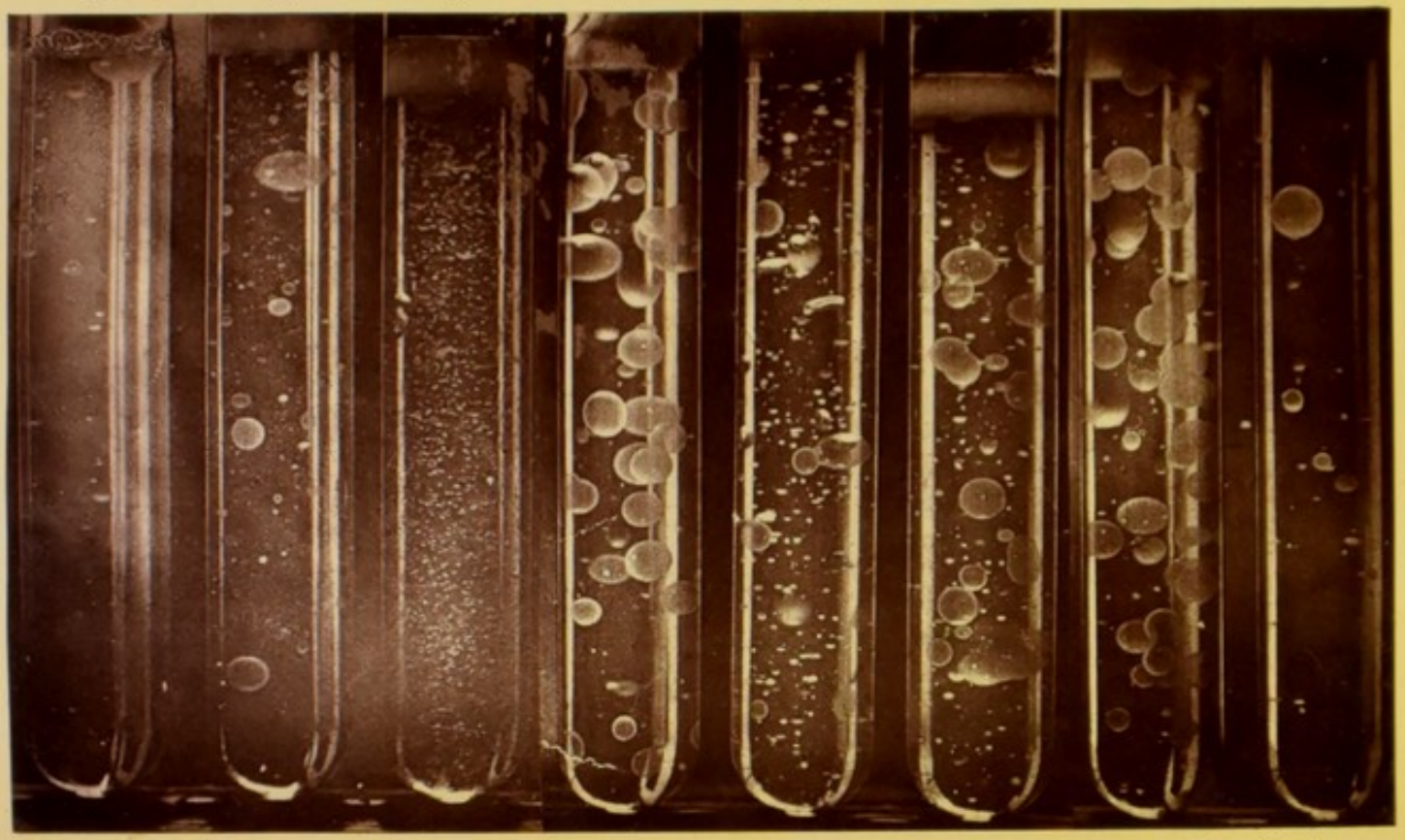


Vincent Brooks, Day & Son, Woodburytype.

SUGAR AND SODIUM PHOSPHATE ADDED TO THE GELATINE.

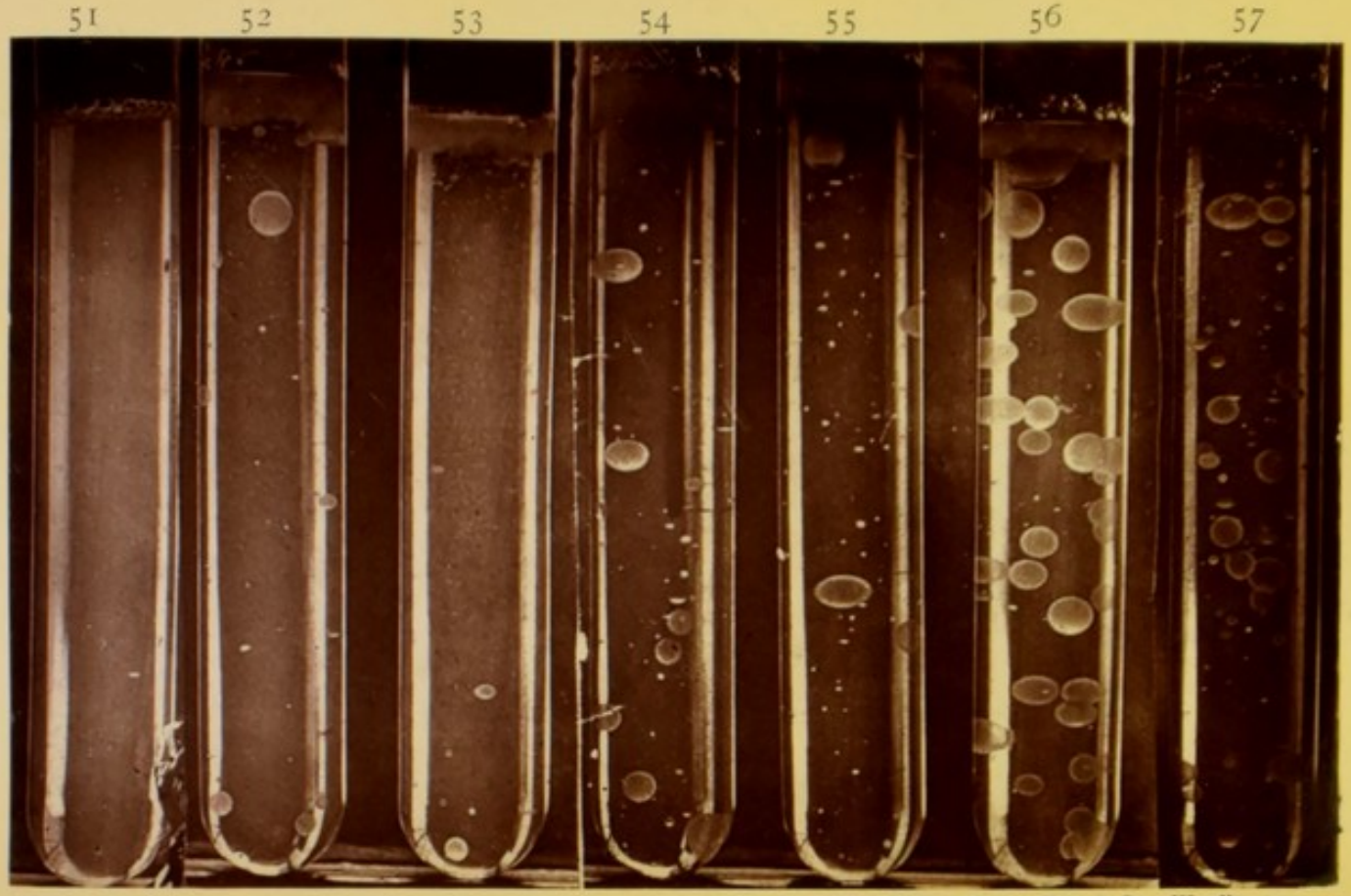
Photographed after Five Days.

43 44 45 46 47 48 49 50



Vincent Brooks, Day & Son, Woodburytype.

WATERS WITH GELATINE ALONE. Photographed after Five Days.

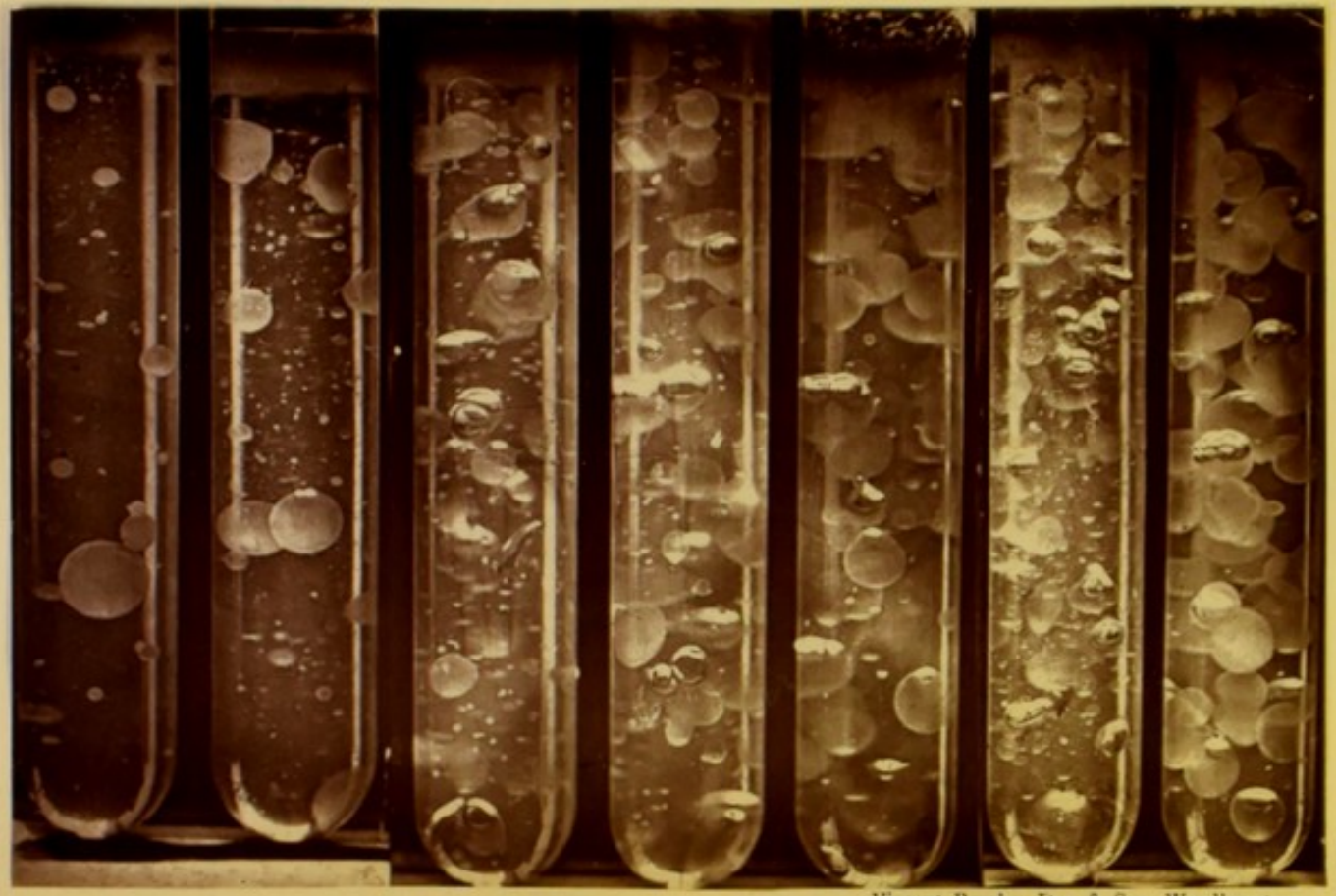


Vincent Brooks, Day & Son, Woodburytype.

SODIUM PHOSPHATE ALONE ADDED TO THE GELATINE.

Photographed after Seven Days.

64 65 66 67 68 69 70



Vincent Brooks, Day & Son, Woodburytype.