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Metropolitan Board of Works.

REPORT

ON

DEODORISATION OF METROPOLITAN SEWAGE

AT THE

OUTFALLS.

WITH APPENDIX AND DIAGRAMS.

JULY—OCTOBER, 1887.

BY

SIR HENRY E. ROSCOE, F.R.S., D.C.L., LL.D., M.P.

Ordered by the Board (20*th January*, 1888, *No.* 8) *to be printed for circulation among the Members of the Board only.*

JUDD AND CO., LIMITED, DOCTORS' COMMONS, LONDON, E.C.,
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REPORT ON SEWAGE DEODORISATION.

LONDON, *December 9th*, 1887.

TO LORD MAGHERAMORNE,

Chairman of the Metropolitan Board of Works.

MY LORD,

I beg to hand you my Report on the Deodorisation of the Metropolitan Sewage at the Outfalls, being the results of Experiments undertaken last Summer at the request of your Board.

The Report on the Deodorisation of the Sewer Emanations, stating what has been done since the date of my last Report on this subject, will be sent in shortly.

I am,

Yours faithfully,

HENRY E. ROSCOE.

DEODORISATION OF SEWAGE AT THE OUTFALLS.

My Lord,

Outfall Deodorisation.

On August 7th last, I reported to the Board the results obtained up to that date, with reference to the deodorisation of the Metropolitan Sewage at the outfalls. I then advised that the experiments with bleaching powder should be followed by similar ones with manganate of soda, and I stated that other experiments were being conducted by me for the purpose of arriving at a conclusion respecting the relative action of these two deodorants. The experiments on a large scale, first with bleaching powder and afterwards with manganate of soda and sulphuric acid, were duly carried out, and the further ones are now sufficiently complete to enable me to report on the results as a whole.

Continuation of former Report.

Difficulties of the problem.

I desire, however, to state that, looking to the great importance and complexity of the subject, and bearing in mind that no standard investigations exist to which reference can be made, I do not consider that this report is final, many questions of importance having arisen during the investigation which require further careful examination.

Use of Chemicals a temporary expedient.

Before entering into the details of the main question submitted to me by the Board—viz., the relative value of the two deodorants employed during the last summer at the Outfalls—I beg to express my strong conviction that the use of Chemicals of any kind must be considered as a temporary measure, sanctioned solely by conditions of time and of place. That is to say, that considering the present position of the outfalls, the arrangements now existing there, and the conditions arising from drought and high temperature during the summer months, I am of opinion that the addition of some deodorant to the effluent Sewage may be advisable. I conceive, however, that the question would assume a different aspect should these conditions be altered, and that then the necessity for such addition might decrease or even disappear.

Principles of Sewage purification.

In considering the question of deodorants, it appears advisable first to form a clear idea of the principles upon which such deodorants act, as well as to understand the subsequent changes which the Sewage undergoes, after such treatment, in its passage into, and in its admixture with the water of the River.

It may, to begin with, be assumed that no amount of Chemicals which can, with any show of reason, be added, is sufficient, or nearly sufficient, to convert the whole of the fœcal matter into harmless forms. Hence the use of Chemicals can only be recommended for the purpose either of starting a process of purification, or of simply getting rid of the evil odour.

Natural processes of change.

The purification of the River, in which the Sewage may remain for some length of time, must therefore be effected by natural processes. Of these by far the most important is the change produced by living organisms. The change thus carried on may be of a twofold character; the one, due to the action of organisms requiring free oxygen for their growth, has the result of rendering the organic matter inoffensive; the other, due to organisms which flourish in absence of free oxygen, gives rise to products which are offensive.

Organisms healthy and unhealthy

It is therefore clear that efforts should be made to preserve and assist the life of such organisms as are capable of effecting this innocuous change and to prevent the growth of such as yield offensive products.

Dissolved Oxygen necessary.

The oxygen, necessary for the growth of what may be termed the "healthy" organisms, is usually derived from the air dissolved in all unpolluted running water. Sewage, however, is either entirely free from, or at any rate contains less dissolved oxygen than is necessary for the active growth of these healthy organisms.

In consequence of the absence of dissolved oxygen in the Sewage, this has, during its passage to the outfall, already begun to undergo change of a putrescent character, owing to the growth of the putrefactive or "unhealthy" organisms.

The products of this putrefactive change readily absorb free oxygen, passing into more stable forms, and therefore, when the Sewage is poured into the River, it rapidly robs the water of its dissolved oxygen. If now the quantity of Sewage thus poured in exceeds a certain proportion as compared with the river or fresh water, the whole of the River is deprived of its dissolved oxygen, and the "healthy" growths are thus practically killed.

Action of deodorants.

Hence the addition of deodorants has for its object the destruction by chemical oxidation of the putrescent material which not only causes the foul smell, but effects the removal of the free oxygen from the water of the river. This deodorisation is, however, only the first step in the process of purification; and, in order that growths necessary for the production of healthy change may flourish, the deodorised Sewage must be brought into contact with the free dissolved oxygen needed for the respiration of the organisms.

Deodorisation, first step in process.

This, under proper conditions, is obtained from the large volume of unpolluted water with which the Sewage is mixed. But should the river water either be insufficient in quantity, or have lost its oxygen by previous pollution, then the whole volume of water, after mixing with the Sewage, becomes incapable of supporting the life of the "healthy" organisms, and no further addition of an oxidising chemical can ever restore the River to its normal condition. The only natural remedy then remaining is the slow absorption of atmospheric oxygen at the surface of the water.

Deodorisation a means to an end.

It is thus seen that the chemical oxidation or deodorisation of the Sewage is only a means to an end, that end being the presence of a sufficient quantity of free dissolved oxygen.

Hence it remains to consider whether this same end cannot be brought about by different means. Such, for example, might be the aeration of the Sewage before entering the river.

Bleaching powder and manganate.

Reserving the consideration of this point, I now proceed to discuss the action of each of the two deodorants used, viz., the bleaching powder and manganate of soda acidified with sulphuric acid.

Relative oxidising power of deodorants.

In my former report of August 7th I stated that the relative oxidising power of these two chemicals was that three grains of bleaching powder was equal to five grains of manganate. To this I still adhere with the reservation that the chemical value of the manganate is somewhat over-stated.

For the purpose of ascertaining which of the two chemicals is the more efficacious and safer to employ, irrespective of cost, experiments on a large scale had to be carried out.

The following is a short description of what was done—

EXPERIMENT WITH BLEACHING POWDER.

Experiment with bleaching powder.

From about July 2nd up to August 26th bleaching powder was mixed with the effluent Sewage at both the Outfalls. Owing to dearth of material at Barking, the Sewage at the Northern Outfall was not deodorised until July 20th, and for the same reason some few days occurred at both stations when no chemicals could be applied. The quantity used varied, at first from 2·5 to 5 grains per gallon of Sewage; this continued for about a week. Then the rate was altered to three grains per gallon, lasting for about a fortnight, and then for about five weeks a rate of about five grains per gallon was employed. The quantity being varied somewhat according to the condition of the Sewage.

The actual weights of bleaching powder added daily during the eight weeks' trial are appended. (See Table I., on page 16.)

Previous foul state of the River.

At the beginning of this experiment the River was in an extremely foul state. No attempts had been made during the spring or early summer to improve its condition by artificial means, the rainfall from January up to the beginning of July amounted only to 7·5 inches, whilst during the subséquent eight weeks the rainfall only reached 2·6 inches.

Hence the experiment was commenced under very unfavourable circumstances.

Efficacy of the deodorisation.

The daily routine for testing the efficacy of the process of deodorisation was as follows:—Samples of the effluent to which the specified quantity of bleaching powder had been added were tested by the smell every hour, or sometimes more frequently, during one of the two daily discharges. If the sample appeared not to be completely deodorised the quantity of bleaching powder needed for perfect deodorisation was ascertained. Evidence was thus obtained as to the actual daily condition of the deodorisation, and although owing to varying condition of the Sewage,

an occasional sample was observed to be over or under deodorised, it was found that, on the whole, the putrescent odour of the Sewage was effectually destroyed by the bleaching powder throughout the whole period. For details of observations at Crossness from July 19th to August 27th, see Appendix A, on page 14.

Average quantity of bleaching powder used.

The average daily quantity, used at the rate of 3 grains per gallon, reckoned on the average volume of dry-weather Sewage, at 156,800,000 gallons would be at Barking about 17 tons, and at Crossness about 13 tons of bleaching powder.

Bleaching powder a good deodorant.

Although from the foregoing there can be no doubt that bleaching powder does act as a good deodorant, it is difficult to come to a satisfactory conclusion as regards its effect on the general character of the River, because beyond occasional inspection, and the daily tests as to the composition of the river water carried out at Crossness, there are no definite means available for measuring this effect. Inspection is at best an uncertain and indefinite criterion, and it, like the results of river analyses, is subject to the influence of changes brought about by undetermined, and perhaps undeterminable causes, such as variation in the tides, wind, rain, &c.; moreover, the constantly diminishing volume of fresh water in the River during last July and August, and the constantly varying temperature, bring in factors whose influence it is impossible to determine.

Action on the river generally.

General result.

The general impression which I have, however, formed, taking those circumstances as well as I could into consideration is, that although no adverse decision can be given, it is certainly not possible to express any favourable opinion as to the action of the bleaching powder added, upon the general condition of the River.

Necessity for laboratory experiments.

Such being the position, it only remained to exclude these complicated and uncertain conditions by carrying out a careful series of laboratory experiments on the action of bleaching powder on Sewage. I propose to describe these experiments and discuss their results, together with similar experiments on manganate in a subsequent portion of this report.

EXPERIMENT WITH MANGANATE.

Experiment with manganate at Outfalls.

Having completed the investigation of the action of bleaching powder on the large scale, I resolved to commence a similar experiment with manganate of soda and sulphuric acid. The daily routine of ascertaining whether the deodorisation was satisfactory was similar to that already described. The experiment lasted from the evening tide on August 27th to the 5th of October. The proportions of manganate added were 15 grains per gallon of Sewage for 3 days; 10 grains per gallon for 3 days; and 5 grains for a period of 23 days, and lastly 3 grains for about 10 days.

Daily routine.

Comparative oxidising power.

Ten grains of manganate corresponds in oxidising power to the 5 grains of bleaching powder used during the greater part of the former experiments, and this quantity of manganate would therefore be required to effect perfect deodorisation on the supposition that the composition of

the Sewage remained the same as it was during the experiment with bleaching powder. This supposition, however, turned out not to be correct, as during the last few days of August and the first week in September 2 inches of rain fell, whilst at the same time the temperature of the River decreased, so that 5 grains of manganate per gallon was found to be sufficient to deodorise the Sewage flowing out during September and the first week in October. This difference is also partly due to the fact that the action of bleaching powder is much slower than that of manganate and that, therefore, more bleach must be added to effect immediate deodorisation than is equivalent to the manganate needed to produce the same effect. For detail of experiments on this point, see Appendix B, on page 15.

Change of condition of River.

These changes of condition occurred immediately after the commencement of this experiment; and from this time forward, the state of the River was markedly improved.

The daily quantities of manganate used during this experiment are appended. (Table II., on page 17.)

In this case, as in the former one, I am not able to estimate definitely the effect of the deodorants on the general state of the River, though the general impression which I have formed is that the manganate does not act prejudicially.

Action of manganate on River.

Referring once more to the means of ascertaining the state of the River, I desire again to emphasise my opinion that the quantity of dissolved oxygen may be taken as indicating the "healthy" condition of the water The amount of this oxygen, as taken from the Crossness analyses made by Mr. Dibdin, varies from 90 per cent of the possible maximum down to none. From the curves (A) appended to this report for the years 1885-6-7 it will be seen (the black line denoting oxygen) that during the early and the late months of the year the amount of dissolved oxygen is at its height, whilst a rapid fall occurs at the beginning of July lasting till October, when a slow rise occurs this becoming rapid in December. Concurrently with these changes corresponding changes are noticed in the volume of fresh water coming into the River as indicated by the quantity of sea salt (red curve) present in the River at low tide. The other curves give temperature (blue) and the vertical dotted lines the rainfall. The most valuable data of the quantities of fresh water passing over Teddington Locks do not seem to be obtainable. Daily Rainfall Register for 1885-6-7, are also appended on pages 20-1-2, and the amount of rainfall is indicated on the curves (A) by a dotted red line.

Measure of healthy cond tion of River.

Comparing the general aspect of the curves for the three years plainly shown in the second series of curves (B), it does not appear that those for 1887 show any material indications of a worse state of things than those for the two previous years. And it may well be doubted, from any evidence obtainable from the above sources, whether the state of the River in 1886, when upwards of £80,000 was spent in Chemicals, was perceptibly better than that in 1887 when £42,000 was spent, or even better than that in 1885, when only £29,000 was spent in deodorants. See returns of quantities

Yearly curves showing state of River.

appended, Nos. 1 and 2 on pages 18 and 19. Indeed, the idea forces itself on one's mind, that either the effects of the Chemicals are imperceptible, or that the methods of measuring those effects are imperfect.

Careful oxygen determination necessary.

I am, however, strongly of opinion that accurate oxygen determinations do give a reliable measure of the "healthy" condition of the River; but I am not convinced that the present methods of analysis are satisfactory, and I think that this question needs re-investigation.

LABORATORY EXPERIMENTS.

Laboratory experiments.

Experiments made in the Laboratory appeared to be the only means left for obtaining more definite information as to the important question whether, and if so how far, each of the two deodorants used affect the life of the "healthy" organisms upon which the natural processes of Sewage purification mainly depend.

Difficult inquiry.

The intricate and difficult character of an investigation of this kind scarcely requires comment. Before commencing the inquiry I therefore thought it desirable to obtain the opinion of a well-known microscopist as to the nature and functions of the organisms occurring in Sewage. Professor H. Marshall Ward, of the Royal Indian College, has been good enough to report to me on this subject, and to examime some of the samples of treated Sewage microscopically.

Absence of knowledge of organisms.

Prof. Marshall Ward's opinion.

It appears that at present our knowledge of the character and properties of the active organisms contained in Sewage is very incomplete, and that a thorough investigation of the subject would entail the expenditure of much time and labour. So far as observations on the material placed before him enabled him to judge, Professor Ward concluded that the Sewage which had been treated with bleaching powder contained in common with that treated with manganate (both liquids being allowed to stand for some length of time in partially closed vessels) lower forms of life in quantity, but that the higher forms, such as algæ, were conspicuous by their absence in the first, and by their presence in the second case.

This conclusion, I may remark, was borne out by subsequent microscopic experiments next to be described, made under my own superintendence, with carefully sterilised vessels, as well as by the simple inspection of the liquids, which were allowed to stand for some weeks exposed to the action of light and air.

Although the functions of the numerous kinds of growths present in Sewage cannot as yet be satisfactorily distinguished, I am of opinion that the results of experiments already obtained are sufficiently conclusive to enable me to answer the question addressed to me in a fairly satisfactory manner.

Descripti of method of experiment.

The first series of experiments on the effects of the two Chemicals on the living organisms contained in the Sewage was carried out at Crossness, the remainder in Manchester.

They consisted in the observation, extending over a considerable number of days, of samples of Sewage to which known quantities of the two deodorants had been added.

The microscopic examination had for its aim, the determination of the quantity and quality of the growths, as existing in the liquid from time to time.

Results of experiments with bleaching powder.

The result of these experiments, most of which were made with carefully sterilised vessels, is (1) that a quantity of bleaching powder, equal to 9 grains per gallon of Sewage, completely and permanently stops the growth of all organisms visible under a high power; (2) that smaller doses, amounting to, say, 3 grains per gallon, appear for a considerable time to exert an equally powerful effect; (3) that the addition of one grain, though interfering with the growth of certain organisms, seems scarcely to affect the growth of others. Further experiments were made, with the view of ascertaining the action of bleaching powder on the life of higher organisms, such as minnows. It was found that water containing 1 grain per gallon killed such fish in two hours, that containing 3 grains in 1 hour, and 4 grains in half an hour. Smaller quantities, down to $\frac{1}{3}$ grain per gallon, also exerted a similar effect, but in a longer time. I am not able to report on the action of still smaller quantities than the above.

Peculiar action of bleaching powder.

It is important here to notice that the action of bleaching powder on Sewage differs from that of manganate, inasmuch as whilst the latter is immediately destroyed, the former disappears but slowly, it being possible to detect it some days after its addition, even when originally present in small quantities only. For detail of experiments on this point, see Appendix B, on page 15.

Hence the action of the bleaching powder on the organisms is one lasting over a considerable period of time, and its effect upon the River is greater than it would have been if its action had been instantaneous.

Action of manganate upon life.

With regard to the effect produced upon life by the addition of manganate of soda to the Sewage, experiment showed—(1) That neutral permangate of soda added to Sewage in quantities amounting to 9 grains per gallon, whilst it does not prevent, appears to retard the growth of organisms; (2) That smaller doses from 1 to 3 grains produce no visible effect, and therefore do not act as poisons. In corroboration of this, it was found that minnows will live for some days in fresh water to which 1 grain of permanganate has been added, and smaller doses do not seem to affect the fish in any way, whilst a dose of 2 grains per gallon does not prove fatal until after the lapse of twelve hours. It is to be remembered that 1 grain of permanganate per gallon in fresh water gives a pink solution, showing the presence of the undecomposed salt, whereas if Sewage had been used, the permanganate would have been instantly destroyed, even if added in very much larger quantity.

Conclusion as to use of manganate.

Hence the conclusion is to be drawn, that apart from the consideration of cost, manganate is to be preferred as a deodorant to bleaching powder.

The important question to what extent, if any, the use of deodorants effects a radical improvement in the River is one to which, as has been stated, it is not possible with the present evidence to give any decisive answer. In absence of further evidence, and of any more satisfactory means of dealing with the evil than the chemical one, I should advise the addition of manganate in moderate quantity, say about 3 grains per gallon, during such periods of the year as the dissolved oxygen falls below, say, 20 per cent. of the possible maximum, or the chlorine exceeds 200 grains per gallon, both analyses being made on low-water samples.

Recommendation as to use of manganate.

On this estimate—the data as regards the probable necessary duration of the addition of Chemicals being taken from the curves appended—the average annual cost of maganate I estimate to be about £40,000. I may add that the cost of sulphuric acid has not been taken into account, the advantages of its use being in my opinion more than doubtful. This point requires further working out, and it is to borne in mind that even this outlay will not prevent a foul condition of the River occurring during the summer months, in droughts or during hot weather.

Probable Cost.

It next has to be considered whether any more satisfactory or less costly means can be devised for effecting the end in view, viz., the prevention of Sewage nuisance.

Question of äeration.

In my opinion the only other feasible plan is that of äeration. Free oxygen is to be had for nothing, and the cost of pumping air need not be considerable. The adoption of such a plan raises questions with which I am not now in a position to deal, although I believe that this may turn out to be a solution of the problem. At any rate, I feel sure that this is a matter well deserving of further inquiry. The rapid purifying effects of äeration on the Sewage have been repeatedly observed in my laboratory experiments.

In conclusion, I wish to remark that I offer no opinion as to the processes of precipitation by chemical treatment, as this question was not submitted to me by the Board. Looking, however, at the broad question of the permanent disposal of the Metropolitan Sewage, and believing that the use of deodorants ought to be regarded only as a temporary expedient, I feel convinced that sooner or later the recommendations of Lord Bramwell's Commission (see Conclusions, &c., 10 and 13 in the Report of the Royal Commission) will have to be adopted and that the Sewage, whether previously clarified or not, must either be filtered through land, or discharged into the estuary at a point not higher than the Sea Reach. The growth of the Metropolis during the quarter of a century which has elapsed since the adoption of the present main drainage and outfall system has been so enormous, that arrangements which worked satisfactorily up to some few years ago are now found to be inadequate, and will of course become more so as time goes on.

General conclusions.

The gravity of this question can hardly be over-estimated, and its character and scope was brought prominently before me as a member of Sir Charles Russell's Select Committee on the pollution of the River Lee, in April, 1886.

I desire to express my thanks to my assistant, Mr. Harry Baker, F.C.S., who has ably carried out both the experiments at the Outfalls and those made in the Laboratory; to Messrs. Carey and Brock, of Widnes, who kindly lent skilled men to superintend the work of deodorisation; and lastly to the several officials of the Board, without whose co-operation and goodwill the above inquiry could not have been carried out.

I have the honor to remain, my Lord,

Yours faithfully,

HENRY E. ROSCOE.

December 9th, 1887.

To Lord Magheramorne, &c., &c.,

Chairman of the Metropolitan Board of Works.

APPENDIX,

CONTAINING DETAIL OF EXPERIMENTS, QUANTITIES OF DEODORANTS USED, RAINFALL RETURNS, CURVES, &c.

Appendix A.

Bleach as Deodorant.

Examination by smell of Sewage discharged after Treatment at Crossness.

July 19.—1, only slight smell; 2, improved by 3 grains bleach; 3, much improved by 3 grains bleach; 4, smell quite sewagy, nearly deodorised by 3 grains bleach.

,, 20.—(Tested 21st.) 1, almost odourless; 2, bad smell; 3, bad smell; 4, smelt badly, deodorised by 3 grains bleach.

,, 21.—(Tested 22nd.) 1, smelt of bleach; 2, deodorised; 3, smelt bad, deodorised by 3 grains bleach; 4, not very strong smell.

,, 22.—(Tested 23rd.) 1, does not smell badly; 2, bad; 3, stinks; 4, smells badly.

,, 25.—1, deodorised; 2, deodorised; 3, deodorised. (Ditto, tested 26th); 1, not bad; 2, bad; 3, smelt; 4, smelt.

,, 26.—(Tested 27th.) *a*, rather badly; 1, deodorised; 2, sewage; 3, sweet; 4, deodorised.

,, 27.—1, slight fatty, sweet, smell of bleach; 2, very faint sewage; 3 very faint sewage.

,, 28.—(Tested 29th.) 1, stinking; 2, like boiled urine; 3, ditto; 4, sweet fatty smell.

,, 29.—1, bleach; 2, very slight bleach; 3, foul; 4, mixed bleach and sewage.

August 2.—(Tested 3rd.) 1, bleach; 2, very faintly of bleach; 3, odourless; 4, bleach.

,, 3.—1, bleach; 2, a little of sewage; 3, very faintest of sewage.

,, 4.—1, good; 2, slightly of bleach.

8.—(Tested 9th.) 1, sweet; 2, sweet; 3, bad; 4, bad but better than 3.

,, 9.—2, little sewage; 3, little sewage and nasty; 4, bleach.

,, 10.—1, sewage moderate; 2, sewage moderate; 3, bad; 4, bad.

,, 11.—1, trace of bleach; 2, sweet; 3, little of sewage; 4, fatty and small sewage.

,, 12.—1, bleach; 2, no sewage, but nasty; 3, smell badly; 4, fatty, no sewage.

,, 13.—1, sweet; 2, bleach faintly; 3, sewage slightly; 4, fatty.

,, 15.—1, bleach; 2, least trace sewage; 3, very faintly of sewage and bleach 4, bleach.

,, 16.—1, quite odourless; 2, trace bleach; 3, trace bleach; 4, perhaps trace of bleach.

,, 17.—*a*, almost odourless; 1, peculiar, perhaps bleach; 2, no distinct sewage; 3, faintest bleach; 4, trace bleach.

,, 18.—1, sweet; 2, bleach; 3, trace bleach; 4,

,, 19.—1, fatty and sweet, bleach; 2, peculiar, no sewage; 3, sweet; 4, bitter and sweet, no sewage.

„ 20.—1, bleach; 2, faint bleach; 3, bleach; 4, bleach.
(P.M. tide, tested 22nd.) 1, slightly bleach; 2, stinks; 3, ; 4, stinks.

„ 21.—(Tested 22nd.)—1, very fatty; 2, fatty; 3, fatty; 4, bleach.

„ 22.—1, fatty and of bleach; 2, fatty and nasty; 3, fatty; 4, fatty.
(P.M. tide.) 1, odourless; 2, sweetish; 3, trace bleach; 4, of burnt wood.

„ 23.—*a*, trace bleach; 1, odourless; 2, slight bleach; 3, fatty; 4, sweet.

„ 24.—3, sweet; 4, fatty.

„ 25.—2, odourless; 3, sweet; 4, faint bleach.

„ 26.—1, sewage faintly; 2, bleach faintly; 3, sweet; 4, fatty slightly.

„ 27.—1, acid, urinous smell; 2, ditto; 3, sharp, urinous, trace of bleach; 4, fatty and sweetish.

End of Treatment with bleach.

Quantities used per gallon, July 2— 5.....2½ grains.
„ „ „ 6— 7..... ..6 „
„ „ „ 8—10.....None.
„ „ „ 11—12.....6 grains.
„ „ „ 12—26.....3 „
„ „ „ 26—20 August (1), 3; (2), 5; (3), 6; (4), 6 grains; *i.e.*, average about 5 grains.
„ „ August 20—27.....double the above, *i.e.*, average about 10 grains.

Appendix B.

Experiments showing:—(1) That Bleaching Powder is destroyed by Sewage slowly. (2) That the amount destroyed depends upon the amount added.

I.—*Experiments by Dr. Hurter, Widnes.*

Bleach per gal. added, *i.e.*, No. of grains.	Grains of bleach destroyed in— 1	10	15 minutes.
10 ...	3·52 ...	5· 9 ...	5· 9
12·8 ...	3·82 ...	4·18* ...	4·44 *in 6 minutes
25·6 ...	8· 8 ...	9· 0† ...	10·2 †in 8 „

II.—*Experiments at Crossness.*

Grains of bleach added, per gallon	Grains of bleach destroyed, after standing hours— ½	1	2	4	6	15 days.
2½ ...	1·37 ...	1·50 ...	1·61 ...	1·72 ...	1·94 ...	all but a trace.
5 ...	1·47 ...	1·85 ...	2·07 ...	2·18 ...	2·46 ...	4·66
10 ...	2·28 ...	2·39 ...	2·62 ...	2·90 ...	3·24 ...	7·75

III.—*Experiments at Manchester.*

Grains of bleach added, per gallon.	Grains of bleach destroyed, after standing hours— ¼	24	72	144
2 ...	1·46 ...	1·75 ...	1·91 ...	2·00
4 ...	1·50 ...	3·16 ...	3·62 ...	3·68
8 ...	2·48 ...	4·87 ...	6·71 ...	6·03
12 ...	2·98 ...	6·49 ...	9·53 ...	10·76
20 ...	5·94 ...	11·55 ...	16·15 ...	18·42

TABLE I.

Showing Quantities of Bleaching Powder used as a deodorant at Barking and Crossness, from July 2nd to August 26th, 1887.

Date.	Barking.				Crossness.				Remarks.	
1887.	Tons	Cwts.	Qrs.	Lbs.	Tons	Cwts.	Qrs.	Lbs.		
July 2	..	..	..	..	7	8	2	14	Owing to non-delivery of Bleaching Powder at Barking, the deodorisation did not commence until July 6th.	
,, 3	..	..	..	..	3	14	1	23		
,, 4	..	..	..	..	7	15	1	4		
,, 5	..	..	..	..	9	10	2	11		
,, 6	20	5	2	23	17	19	1	19	The stock of Bleaching Powder was exhausted at Crossness on July 7th, and a fresh supply obtained on July 11th. The same happened at Barking on the 9th and 12th. Between these dates no deodorant was added.	
,, 7	32	7	1	23	23	15	1	5		
,, 8	33	15	0	4	..	..	..	..		
,, 9	2	0	3	12	..	..	..	..		
,, 10	..	..	..	..	..	..	..	..		
,, 11	..	..	..	..	12	19	3	8		
,, 12	8	11	1	8	19	8	0	22		
,, 13	17	1	2	3	13	3	0	24		Three grains per gallon.
,, 14	16	17	3	20	12	19	1	13		
,, 15	16	12	0	22	16	2	3	19		
,, 16	17	1	3	16	13	13	1	12		
,, 17	17	3	0	0	13	5	1	15		
,, 18	16	18	1	24	5	11	2	24	Three tides only.	
,, 19	8	10	3	16	11	9	3	27		
,, 20	17	3	1	17	12	8	3	16		
,, 21	17	3	1	1	12	2	0	12		
,, 22	16	17	3	1	12	0	3	11		
,, 23	22	10	0	11	12	9	0	5		
,, 24	27	6	3	5	12	6	1	14		
,, 25	28	7	1	5	18	11	0	15		Five grains per gallon.
,, 26	28	5	1	12	16	4	2	24		
,, 27	28	14	3	0	21	13	3	8		
,, 28	28	4	0	13	18	7	3	26		
,, 29	28	6	2	27	19	11	0	22		
,, 30	28	0	1	18	17	15	0	9		
,, 31	28	1	1	26	16	17	2	0		
August 1	14	2	0	14	6	5	1	20	One tide only.	
,, 2	28	6	3	11	15	14	2	26		
,, 3	28	3	2	16	17	13	2	22		
,, 4	28	9	2	3	17	18	3	6		
,, 5	28	6	0	26	16	11	0	24		
,, 6	28	11	0	6	13	12	0	23		
,, 7	28	10	1	13	13	13	1	11		
,, 8	28	2	3	26	15	3	0	26		
,, 9	28	12	2	8	17	16	0	2		
,, 10	28	7	3	23	19	4	2	6		
,, 11	28	10	2	24	17	19	3	4		
,, 12	28	5	0	2	17	17	2	9		
,, 13	28	5	0	24	17	18	2	0		
,, 14	28	2	3	2	17	11	3	8		
,, 15	28	11	0	20	15	3	0	11		
,, 16	28	6	0	17	15	14	2	24		
,, 17	14	4	0	18	17	10	0	0	One tide only.	
,, 18	28	3	2	8	32	14	1	26	Overflow at Crossness.	
,, 19	28	11	1	24	22	12	3	17		
,, 20	28	6	1	19	37	9	2	0	Do.	
,, 21	28	16	0	18	33	5	1	17	Do.	
,, 22	28	4	3	15	35	6	3	24	Do.	
,, 23	28	12	0	14	34	5	0	27	Do.	
,, 24	28	6	1	9	38	5	3	26	Do.	
,, 25	28	12	2	23	35	7	1	5	Do.	
,, 26	29	7	2	6	34	1	0	15	Do.	

Metropolitan Board of Works.

Chemical and Gas Department,
Spring Gardens, S.W.,
2nd December, 1887.

TABLE II.

Showing Quantities of Manganate of Soda and Sulphuric Acid used at the Outfalls, 1887.

Date.	Barking.								Crossness.							
	Manganate of Soda.				Sulphuric Acid.				Manganate of Soda.				Sulphuric Acid.			
1887.	Tons.	Cwt.	Qrs.	Lbs.	Tons.	Cwt.	Qrs.	Lbs	Tons.	Cwt.	Qrs.	Lbs.	Tons.	Cwt.	Qrs.	lbs.
August 27	40	2	3	26	13	12	0	0	14	11	0	27	2	15	0	0
,, 28	80	3	0	0	27	5	2	0	34	8	1	8	6	1	0	0
,, 29	80	12	2	7	25	0	0	0	34	9	2	13	6	1	0	0
,, 30	67	18	3	4	23	10	0	25	18	4	3	25	2	15	0	0
,, 31	28	11	0	22	..	..	..	..	53	18	1	0	11	0	0	0
September 1	57	1	1	21	18	0	0	0	52	3	2	3	12	8	2	23
,, 2	56	12	1	21	17	12	0	0	38	3	0	1	12	16	0	6
,, 3	28	13	1	23	8	5	0	27	27	13	1	0	9	7	0	13
,, 4	28	18	2	12	9	0	0	0	37	17	0	8	12	16	0	6
,, 5	28	13	3	4	9	0	0	0	28	19	3	1	9	16	3	24
,, 6	28	14	0	15	9	0	0	0	23	7	3	27	11	6	2	1
,, 7	28	9	3	2	8	19	2	0	25	19	1	24	14	15	1	22
,, 8	28	13	0	4	4	10	0	0	19	3	3	27	11	16	1	12
,, 9	28	9	2	24	9	0	0	0	20	13	3	10	14	10	2	3
,, 10	28	9	0	6	9	0	0	0	20	2	0	13	12	6	0	6
,, 11	28	6	1	5	9	0	0	0	16	9	3	5	11	1	2	9
,, 12	28	3	3	1	8	19	2	14	19	19	2	8	10	18	3	24
,, 13	28	9	0	13	9	0	0	0	19	2	1	17	11	16	1	12
,, 14	28	14	2	18	9	0	0	0	19	13	1	11	12	6	0	23
,, 15	28	8	0	5	9	0	0	0	7	14	2	16	4	18	1	26
,, 16	14	1	1	24	4	10	0	0	19	15	2	27	12	16	0	6
,, 17	28	4	1	22	4	4	1	8	41	17	2	2	25	7	0	21
,, 18	28	6	1	24	9	0	0	0	16	0	2	22	9	16	3	24
,, 19	28	8	3	27	9	0	0	0	16	2	1	6	10	16	2	18
,, 20	28	1	0	19	9	0	0	0	18	8	2	27	..	..	..	..
,, 21	28	1	0	8	9	0	0	0	21	3	1	22	6	8	0	3
,, 22	28	6	0	21	8	19	2	7	19	9	3	16	13	5	3	17
,, 23	28	8	0	15	9	0	0	0	19	13	1	0	13	5	3	17
,, 24	28	3	2	15	9	0	0	0	18	12	1	20	7	7	2	25
,, 25	27	19	2	27	9	0	0	0	16	16	3	16	7	17	2	8
,, 26	28	2	3	20	8	19	2	7	17	15	0	22	12	16	0	6
,, 27	22	9	2	9	7	5	0	0	22	19	0	18	10	16	2	18
,, 28	16	16	0	0	5	10	0	0	11	13	2	2	6	17	3	14
,, 29	8	7	2	0	2	15	0	0	5	19	3	22	3	18	3	4
,, 30	16	16	3	10	5	10	0	0	13	1	0	6	7	7	2	25
October 1	16	17	3	21	5	10	0	0	13	0	2	25	8	7	1	19
,, 2	16	16	3	2	5	10	0	0	10	6	2	24	6	17	3	14
,, 3	16	14	1	4	5	10	0	0	9	3	0	14	6	8	0	3
,, 4	15	0	3	3	3	16	1	3	11	5	3	24	5	8	1	9
									14	1	1	2	9	16	3	24
	1,208	9	3	0	367	13	3	7	870	3	3	1	387	11	0	5

On August 4th and 5th, 1887, there were used at Deptford Pumping Station, in addition to the above, 109 tons 0 cwt. 0 qrs. 20 lbs. of Sulphuric Acid, and 95 tons 5 cwt. 0 qrs. 22 lbs. of Manganate of Soda.

W. J. DIBDIN.

Metropolitan Board of Works.

RETURN OF QUANTITIES. No. 1.

Engineer's Department,
Spring Gardens, S.W.,
22nd November, 1887.

Deodorisation.

DEAR SIR HENRY,

Hereunder I send you the information asked for in your letter to me of the 8th instant:—

QUESTIONS.	ANSWERS.	£ s. d.
1.—"Cost of deodorants applied to the "Sewers for removing emanations "this year?"	1.	49 18 1
2.—"Cost of chemicals used at outfalls "this year?"	2.	42,467 12 1
3.—"Ditto, for years 1885 & 6?"	3.—1885, Sewers ...	5,539 0 0
	,, Outfalls ...	26,153 9 3
	1886, Sewers ...	33,325 0 0
	,, Outfalls ...	47,747 0 0
4.—"Number of complaints of smell from "Sewers since June last?"	4.—Forty-three, particulars of which are enclosed.	

All the foregoing amounts are *exclusive* of the cost of labour.

I am, dear Sir Henry,
Yours faithfully,
J. W. BAZALGETTE.

Sir H. E. ROSCOE, M.P.,
10, Bramham Gardens,
Wetherby Road, S.W.

Metropolitan Board of Works.

RETURN OF QUANTITIES. No. 2.

Engineer's Department,
Spring Gardens, S.W.,
2nd December, 1887.

Deodorisation, 1887.

DEAR SIR HENRY,

The following are the details with which you wish to be furnished respecting the Chemicals used by the Board for deodorising purposes during the present year:—

Outfalls.	Chemicals.	Quantity used.				Cost of quantity used		
		Tons.	cwts.	qrs.	lbs.	£	s.	d
Barking	Manganate of Soda ...	1,208	9	3	0	12,828	1	11
	Sulphuric Acid ...	367	13	3	7	627	8	4
	Chloride of Lime ...	1,231	7	3	9	9,978	5	5
Crossness	Manganate of Soda ...	870	3	3	1	9,237	0	11
	Sulphuric Acid ...	387	11	0	5	661	6	2
	Chloride of Lime ...	979	12	3	9	7,938	5	7
		5,044	19	0	3	41,270	8	4
Deptford	Manganate of Soda ...	95	5	0	22	1,011	3	7
Pumping Station ...	Sulphuric Acid ..	109	0	0	20	186	0	2
		5,249	4	1	17	£42,467	12	1
Sewers	Sulphuric Acid ...	...	...	...	...	£49	18	1

I am, dear Sir Henry,
Yours faithfully,
J. W. BAZALGETTE.

Sir H. E. ROSCOE, M.P.,
10, Bramham Gardens,
Wetherby Road, S.W.

REGISTER OF RAINFALL IN 1885.

Kept at Office, Metropolitan Board of Works, in the County of Middlesex, by J. W. Bazalgette.

Latitude 51° 31′ N.

Longitude 0° 0′

RAIN GAUGE.

Diameter $7\frac{11}{16}$

Height of Receiver above Ground 6.0 feet.

Height of Receiver above Ordnance Level 34·98 Lip.

Date.	Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Date.
	In.	In.	In.	In.	In	In.	In.	In.	In.	In.	In.	In.	
1	..	·30	..	..	·02	..	..	..	..	·05	..	..	1
2	..	·05	..	..	·06	..	..	..	·43	·06	·07	..	2
3	..	..	·41	..	..	..	..	..	·07	..	·20	·14	3
4	..	·30	..	..	·09	..	..	..	·20	·01	·27	·06	4
5	·02	.03	·02	·17	·12	·30	..	·06		·05	·04	·39	5
6	..	·07	·17	..	·23	..	..	·02	Sunday ·20	·59	..	..	6
7	..	..	..	..	·13	Sunday ·37	·02	..	·22	..	..	..	7
8	·10	·15	..	..	·06	·83	·01	..	·30	·10	..	..	8
9	·22	..	..	·02	·01	..	..	..	..	·39	·02	..	9
10	..	..	..	·08	..	..	..	..	1·85	·04	·04	..	10
11	Sunday ·30	..	..	..	..	..	..	..	·03	..	·01	..	11
12	..	..	..	..	..	..	Sunday ·39	·08	·01	..	..	..	12
13	..	..	..	..	..	..	·14	..	..	·09	..	..	13
14	·10	..	..	..	..	..	..	..	..	·10	·09	..	14
15	·03	Sunday ·54	..	·87	..	..	..	..	..	·24	..	..	15
16	·06	·62	..	·31	..	·13	..	..	·86	..	..	..	16
17	..	..	·06	..	Sunday ·22	..	..	..	..	..	..	·01	17
18	..	..	..	..	..	·07	..	..	·18	..	..	..	18
19	..	..	..	..	·14	·03	·17	..	·09	..	..	..	19
20	..	..	..	..	·19	..	..	·19	·04	..	..	..	20
21	..	..	..	..	·34	Sunday ·15	..	·04	..	·01	..	..	21
22	..	·09	Sunday ·87	..	·13	..	..	..	..	..	..	..	22
23	..	..	..	·21	..	..	..	..	·14	·87	·19	..	23
24	..	·04	..	·09	Sunday ·22	·13	..	..	..	..	·60	..	24
25	..	·12	..	·10	·02	..	..	..	..	·15	·28	..	25
26	..	·18	·10	..	..	..	..	·30	..	·07	·58	..	26
27	..	·05	..	..	..	..	..	·06	·05	..	·31	..	27
28	·04	·03	..	·47	·31	..	..	..	·35	..	..	·14	28
29	·11		..	..	..	..	..	..	..	..	Sunday ·32	·02	29
30	·09		..	..	..	..	..	..	·07	·55	·16	·26	30
31	·28		..		..		..	·01		·20		..	31
Totals	1·35	2·57	1·63	2·32	2·29	2·01	0·73	0·76	5·09	3·57	3·18	1.02	Totals

REGISTER OF RAINFALL IN 1886.

Kept at Office, Metropolitan Board of Works, in the County of Middlesex, by J. W. Bazalgette.

Latitude 51° 31′ N.

Time of Observation 9.0 a.m.

Longitude 0° 0′

RAIN GAUGE.

Diameter 7¾

Height of Receiver above Ground 6.0 feet.

Height of Receiver above Ordnance Level 34·98 feet Lip.

Date.	Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec	Date.
	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In	
1	·02	Rain	..	..	..	·30	..	·10	..	·01	·09	..	1
2	..	Snow	..	·18	..	·01	..	·01	·20	..	..	..	2
3	·16	Snow	..	..	..	..	..	..	·41	..	·26	·11	3
4	·18	..	..	..	..	..	..	..	Sunday	..	..	·32	4
5	Snow and Rain	..	..	..	..	..	..	..	·06	·22	·56	..	5
6	·44	..	..	..	..	..	..	..	·03	·09	·07	·03	6
7	..	..	..	·05	..	..	..	..	..	·14	..	·55	7
8	Snow and Rain	..	..	·31	..	..	..	·06	..	..	..	·10	8
9	..	..	..	..	..	..	·01	·19	..	·15	·26	·03	9
10	Snow and Rain	..	..	Sunday	..	·23	..	·02	·61	..	·55	·04	10
11	,,	Rain	..	·17	·15	·02	·18	..	..	·05	·42	·14	11
12	,,	Rain	..	..	1·52	Sunday	·33	·08	..	·40	·10	..	12
13	,,	..	..	..	·08	·10	·21	·05	..	..	..	..	13
14	..	Rain	..	·05	·03	..	..	..	..	·12	..	·71	14
15	Rain	Rain	..	..	Sunday	..	..	·15	..	·22	·15	·03	15
16	,,	..	..	..	·36	..	·03	..	..	·19	·36	..	16
17	,,	..	..	Sunday	·02	...	·27	..	..	..	·02	·22	17
18	..	..	..	·15	..	.09	..	·02	..	·04	..	..	18
19	..	..	·17	..	·02	..	·30	·14	..	..	..	..	19
20	Snow	..	·24	..	·14	..	..	..	..	·01	..	..	20
21	..	..	..	..	·47	..	..	..	..	..	..	..	21
22	Snow and Rain	..	·05	..	·57	·04	..	..	..	·03	..	·13	22
23	,,	..	..	..	..	..	·28	..	..	·03	..	..	23
24	,,	..	..	·05	1·39	..	..	..	..	..	..	·23	24
25		..	..	..	..	..	·68		Sunday	·02	..		25
26	..	..	·11	..	·33	..	·03	..	·10	..	..	1·00	26
27	..	..	Sunday	·02	·07	..	..	..	·39	·07	..	·41	27
28	..	..	·14	·40	·01	..	..	..	..	..	·01	..	28
29	Rain	..	·10	..	..	..	..	..	..	..	..	..	29
30	,,	..	·10	..	..	..	·04	..	..	..	..	..	30
31	,,	..	..		..	..	·04	..	..	·13	..	..	31
Totals	0·80		0·91	1·38	4·96	0·79	2·40	0·82	1·80	1·92	2·85	4·05	Totals

Rain gauge damaged by frost from January 8th to 31st. Rain gauge undergoing repairs from February 1st to 8th.

REGISTER OF RAINFALL IN 1887.

Kept at Office of Metropolitan Board of Works, in the County of Middlesex, by J. W. Bazalgette.

Latitude 51° 31′ N.

Time of Observation 9.0 a.m.

Longitude 0° 0′.

RAIN GAUGE. Diameter $7\frac{11}{16}$.

Height of Receiver above Ground 6·0 feet.

Height of Receiver above Ordnance Level 34·98 Lip.

Date.	Jan.	Feb.	March	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Date.
	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	
1	..	·10	..	.09	·17	..	..	..	.15	..	·30	..	1
2	..	·11	..	..	..	·49	..	..	..	..	.29	..	2
3	·13	..	..	..	·24	·70	..	..	·29	..	·79	..	3
4	·54	..	..	..	..	..	·06	..	..	..	·14	..	4
5	..	..	..	·12	·19	..	..	..	..	..	·23	..	5
6	..	..	..	..	..	..	..	..	·34	..	..	..	6
7	·14	..	..	..	..	..	..	..	..	..	·42	..	7
8	..	..	..	..	..	·03	..	..	..	..	.15	..	8
9	·09	..	..	..	..	..	..	..	..	·14	·39	..	9
10	..	..	..	..	..	..	..	..	·07	·28	..	..	10
11	·09	..	·30	..	..	..	..	..	..	·03	..	..	11
12	..	..	..	..	..	..	..	..	..	..	..	..	12
13	..	..	..	..	..	..	..	..	·03	..	..	..	13
14	..	..	.45	..	..	..	·24	..	·05	..	..	..	14
15	..	..	..	..	..	..	·14	·65	·47	..	..	..	15
16	..	..	..	..	..	..	..	·92	·03	..	..	..	16
17	·12	·14	..	..	..	..	..	..	..	..	·32	..	17
18	..	·08	..	..	·09	..	..	..	..	..	..	..	18
19	·16	..	..	..	..	..	..	..	..	..	..	..	19
20	..	·07	..	..	·47	..	..	·07	..	..	..	..	20
21	..	..	..	·04	..	..	..	..	..	..	·17	..	21
22	..	..	·26	..	·15	..	..	..	..	..	·13	..	22
23	..	..	..	..	..	..	..	..	..	06	..	..	23
				Sunday									
24	..	..	·09	·44	..	..	·32	..	..	..	..	..	24
25	..	..	..	·12	..	..	..	..	..	..	..	..	25
26	..	..	·15	·18	·17	..	·08	·03	·15	..	..	..	26
27	..	..	..	·20	·08	..	·09	·89	..	·07	·03	..	27
28	..	..	..	·25	..	..	..	..	..	..	·07	..	28
29	..	..	..	..	..	..	..	·09	..	·70	..	..	29
30	..	..	..	..	..	..	..	·63	·13	..	..	..	30
31	..	..	·30	..	..	..	..	·10	..	..	..	..	31
Totals	1·27	·50	1·55	1,44	1·56	1·22	.93	2.88	1·71	1,28	3·43	..	Totals.

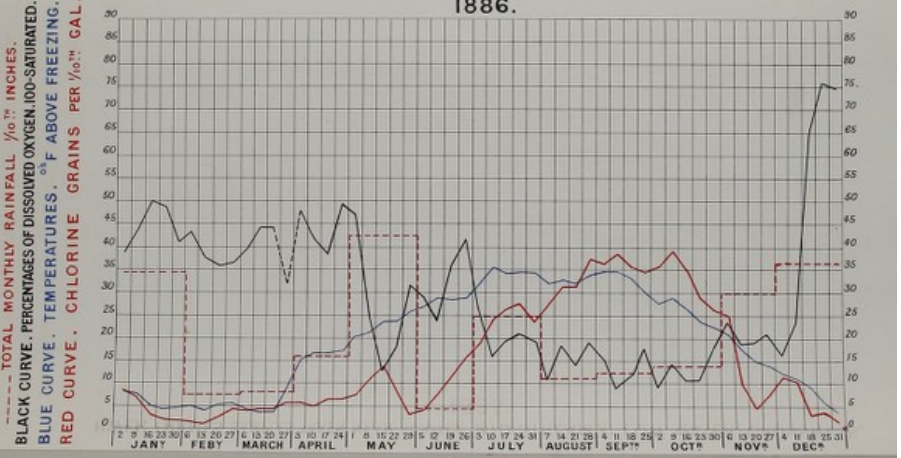
Curves A.

RIVER THAMES. SAMPLES TAKEN NEAR SURFACE MID-STREAM AT LOW WATER; CROSSNESS.

1885.

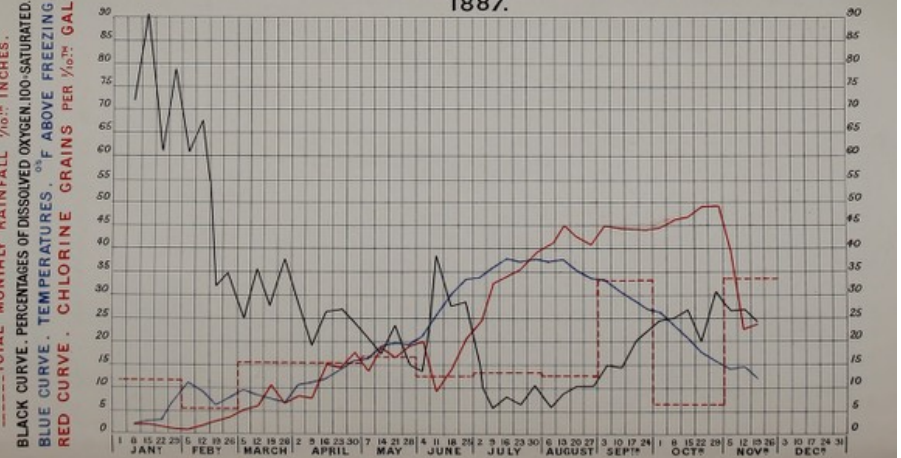
RIVER THAMES. SAMPLES TAKEN NEAR SURFACE MID-STREAM AT LOW WATER; CROSSNESS.

1886.



RIVER THAMES. SAMPLES TAKEN NEAR SURFACE MID-STREAM AT LOW WATER; CROSSNESS.

1887.



DEG

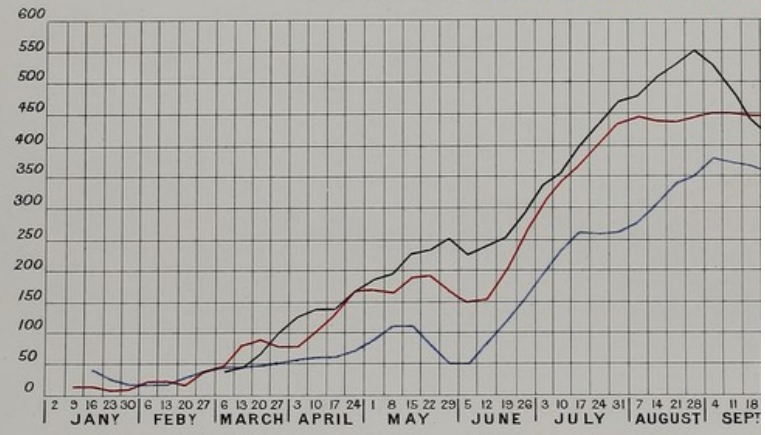
JAN? | FEBY | MARCH | APRIL | MAY | JUNE | JULY | AUGUST | SEP?

COMPARISON OF CHLORINE CURVES FOR 18

1885 BLACK. 1886 BLUE. 1887 RE

EACH POINT THE MEAN OF THREE WEEKLY AVERAGES.

GRAINS PER GALLON.



COMPARISON OF OXYGEN CURVES FOR 18

1885 BLACK. 1886 BLUE. 1887 RE

EACH POINT THE MEAN OF THREE WEEKLY AVERAGES.

100 = SATURATED.