No. VII.

Report on the Chemical Composition of Metropolitan Waters during the year 1854. By Dr R. D. Thomson.

WHEN an outbreak of cholera occurred in the autumn of 1854, spreading devastation into the heart of the metropolis, it was considered by the Board of Health advisable to institute an inquiry into the chemical condition of the water employed for domestic purposes in those houses where death had made the greatest havoc, and likewise into the state of the atmosphere surrounding the unfortunate victims. The object of this report is to present an account of the investigation which has been prosecuted in pursuance of the first of these intentions. It is not necessarily a part of the purport of this report to contrast the present water supply of London with other possibly superior sources. But the remarkable fact that the metropolis derives this necessary of life in great part from rivers and open canals, exposed to various contaminating influences—a species of supply which was rejected as unwholesome upwards of 2,000 years ago by the Samians and the Romans, and led those enterprising people to conduct spring water into their dwellings by means of the most stupendous engineering works—is well calculated to excite inquiry as to the cause of this retrograde movement in hygienic arrangements. The present experiments having insensibly extended so as to embrace the composition of a large variety of waters in the metropolis and in the provinces, many data will be here presented which may assist in forming a judgment as to the best sources of water supply.

In the year 1851 a commission was issued by Government for the purpose of obtaining an opinion respecting the chemical character of metropolitan waters. The gentlemen, however, to whom this duty was entrusted were not required to make any new investigations, but were merely desired to form a conclusion from certain documents which were submitted to their consideration. The printed data with which they were supplied seem, however, to have been so incomplete that new experiments were considered requisite to enable a conclusion to be drawn. But as this proceeding exceeded, apparently, the object of the commission, the waters of London were examined only on three consecutive days in January, after a fall of rain, the samples being taken from near the various companies' works, and with the cognizance, probably, of their respective engineers. The result of the analyses was to represent the river from Thames Ditton to Vauxhall as having the same chemical composition, or rather as increasing in purity in its descent towards the tide, since the water taken from the point of the river nearest to London was least contaminated with

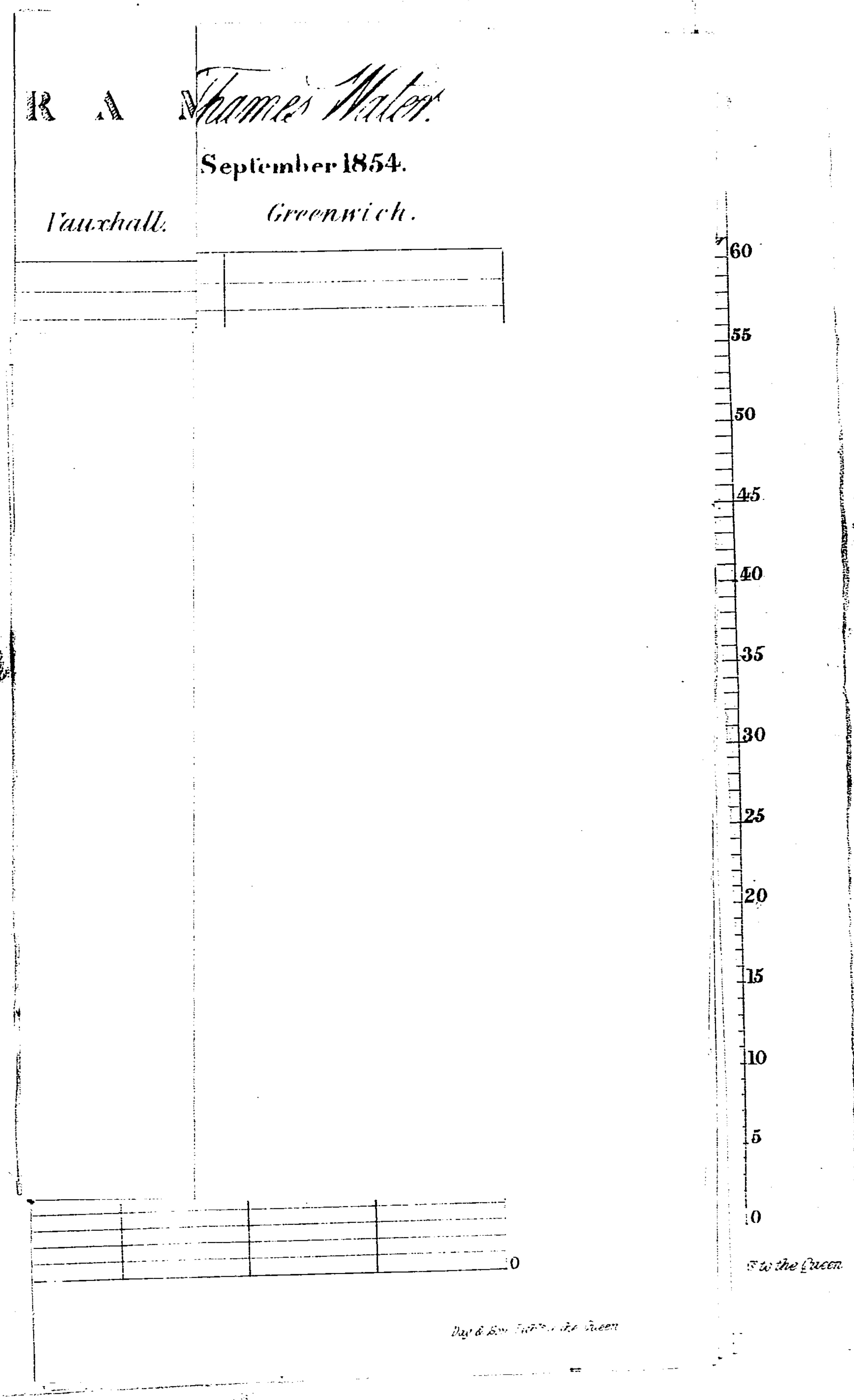

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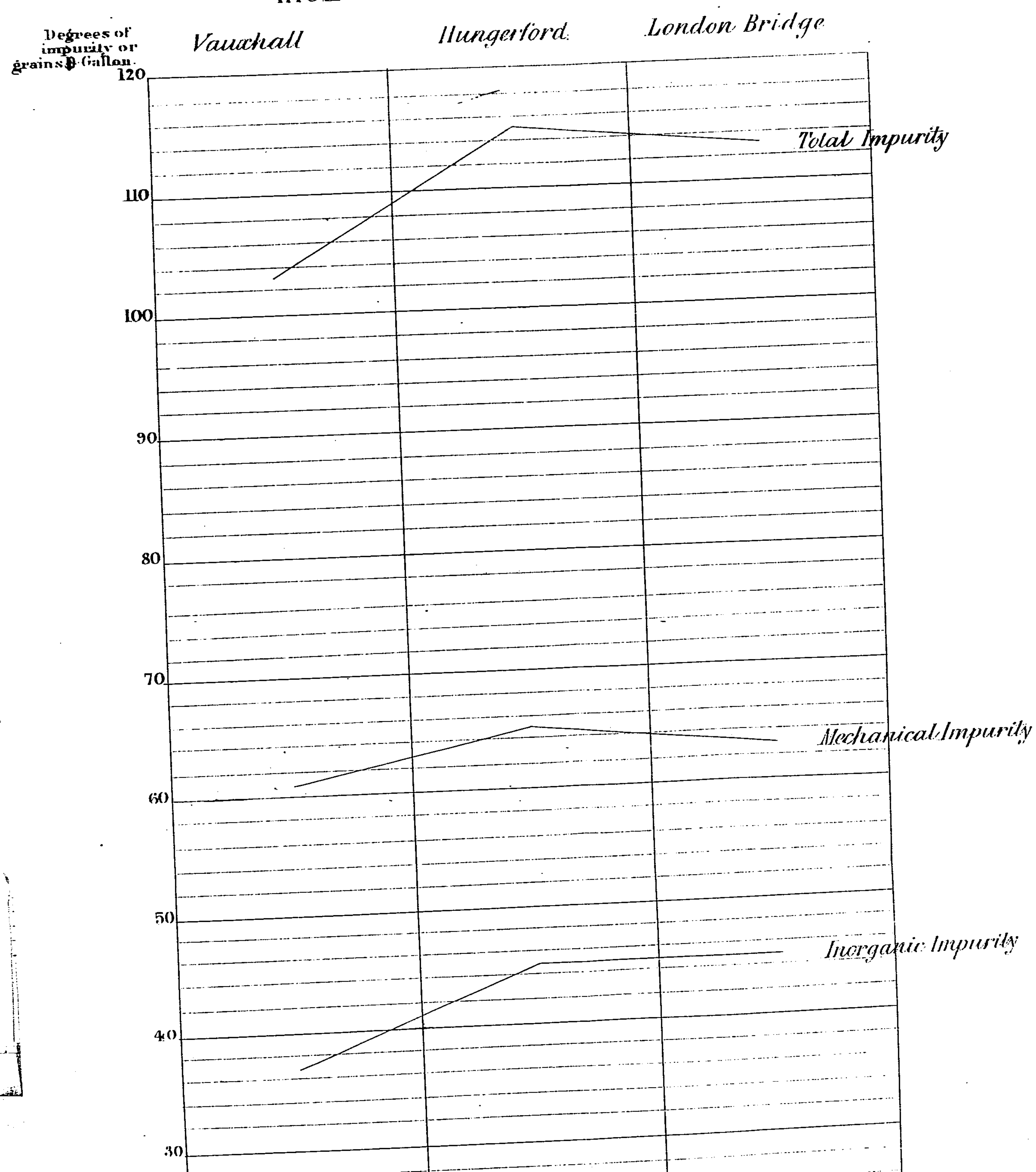
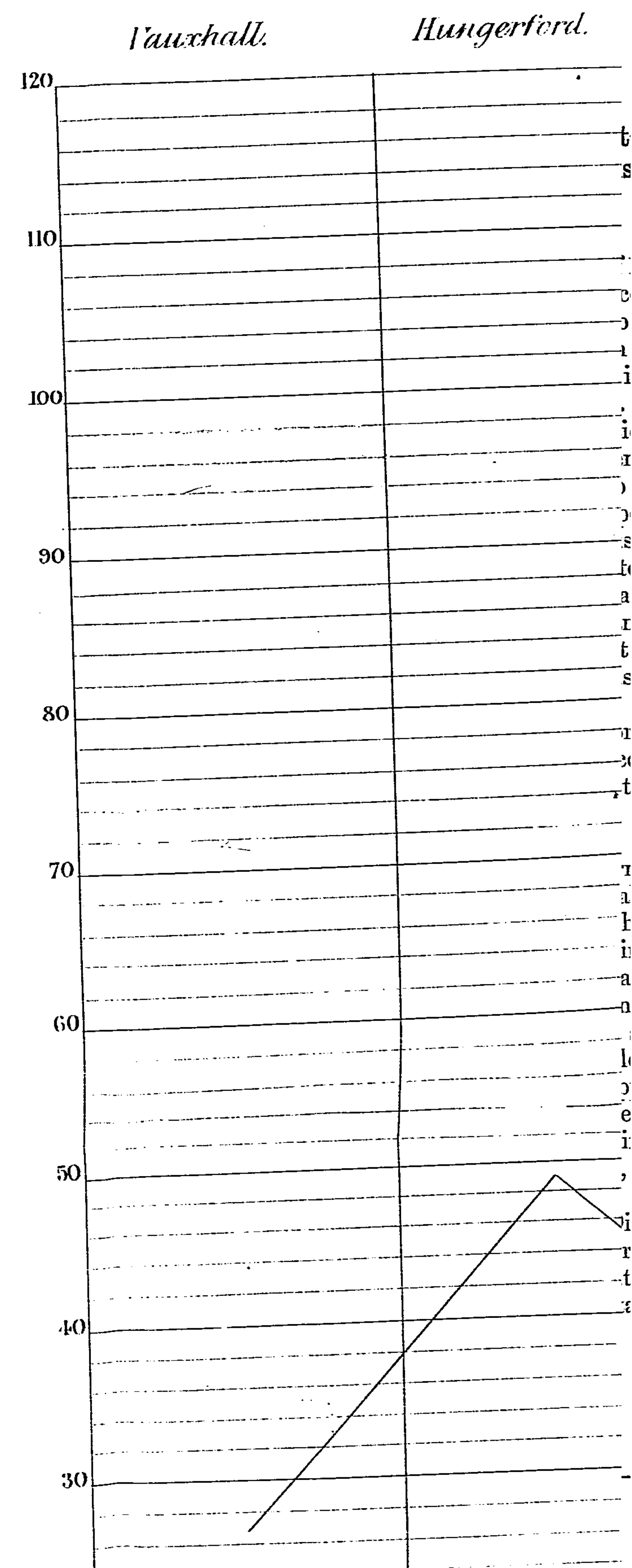
DIAGRAM (A.)

Impurities in Thames Water.

HIGH WATER, 8th December 1854.





...hames Water.

December. 1854.

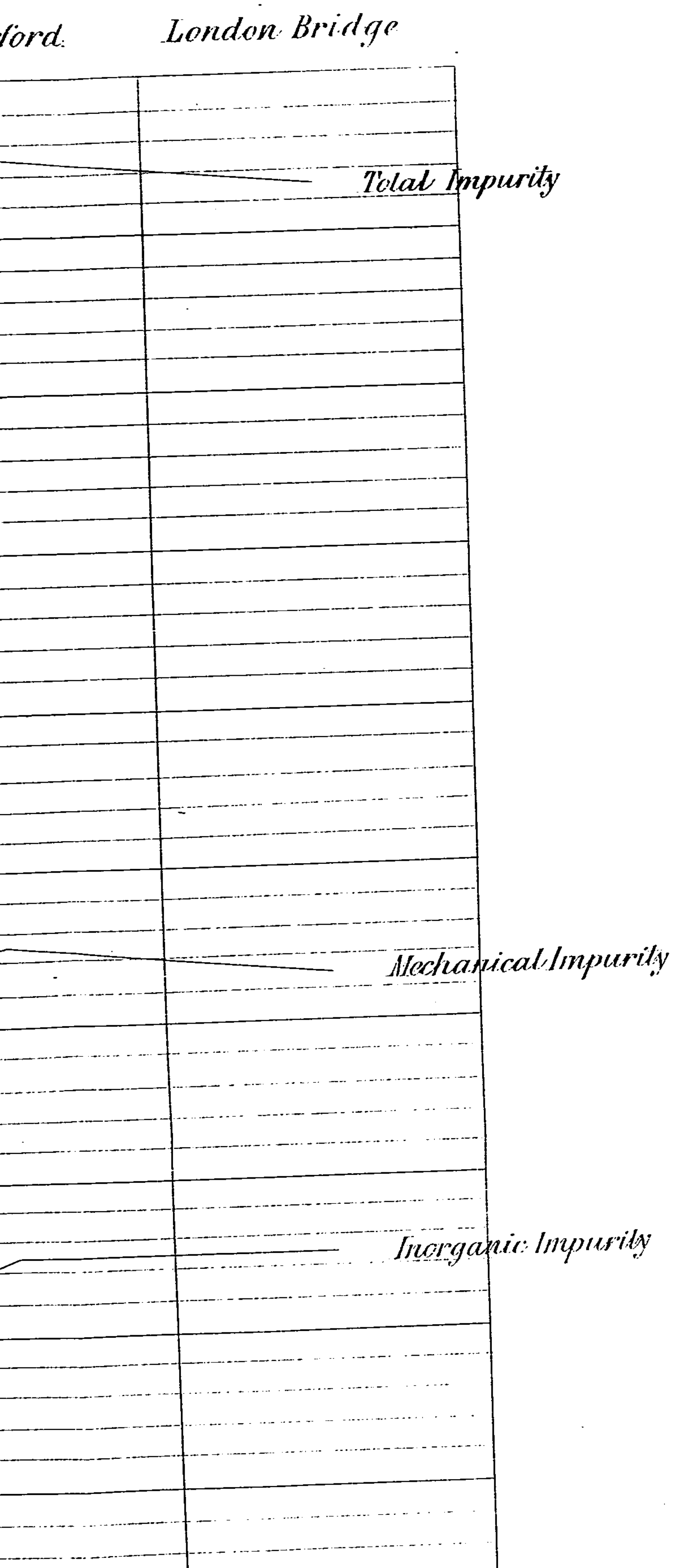
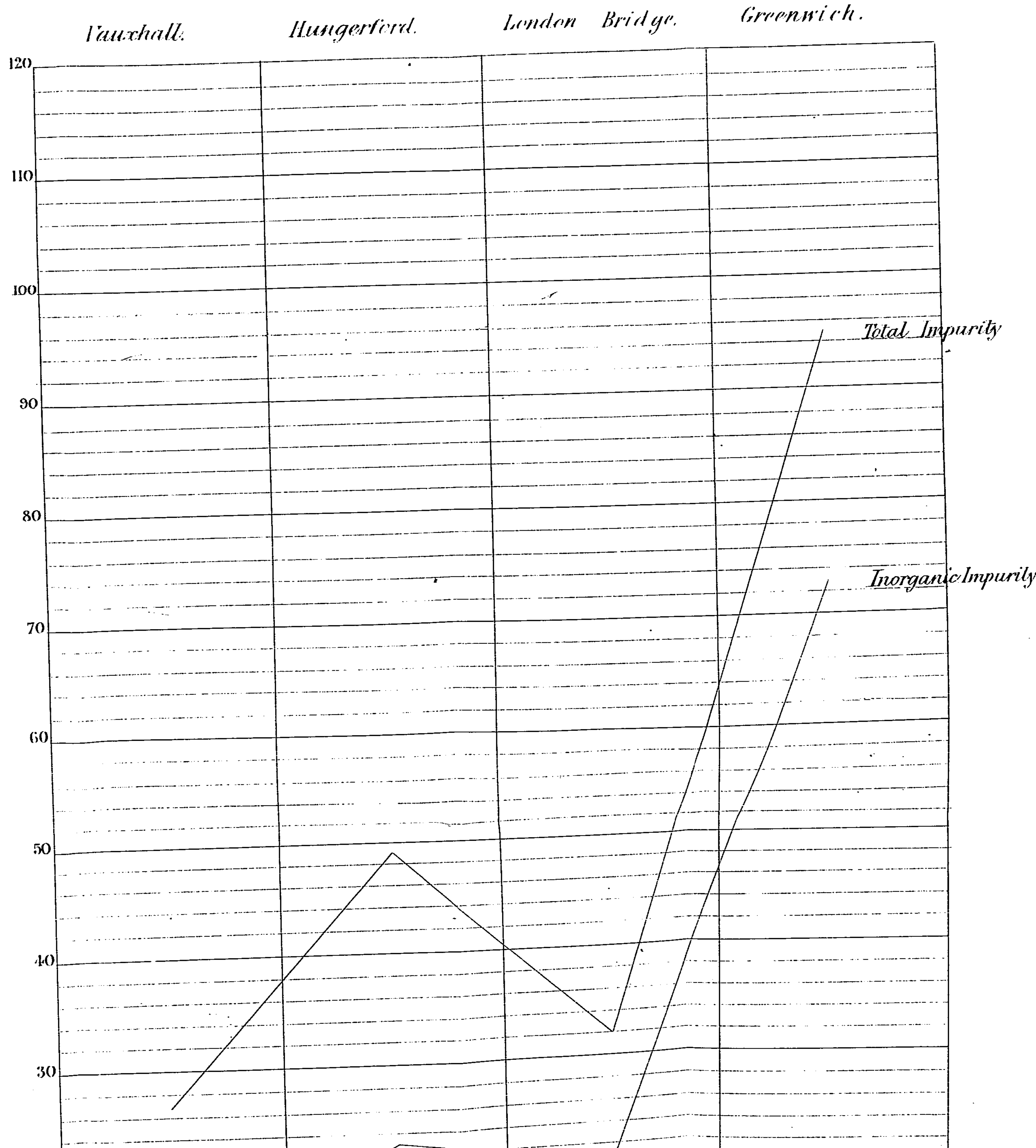
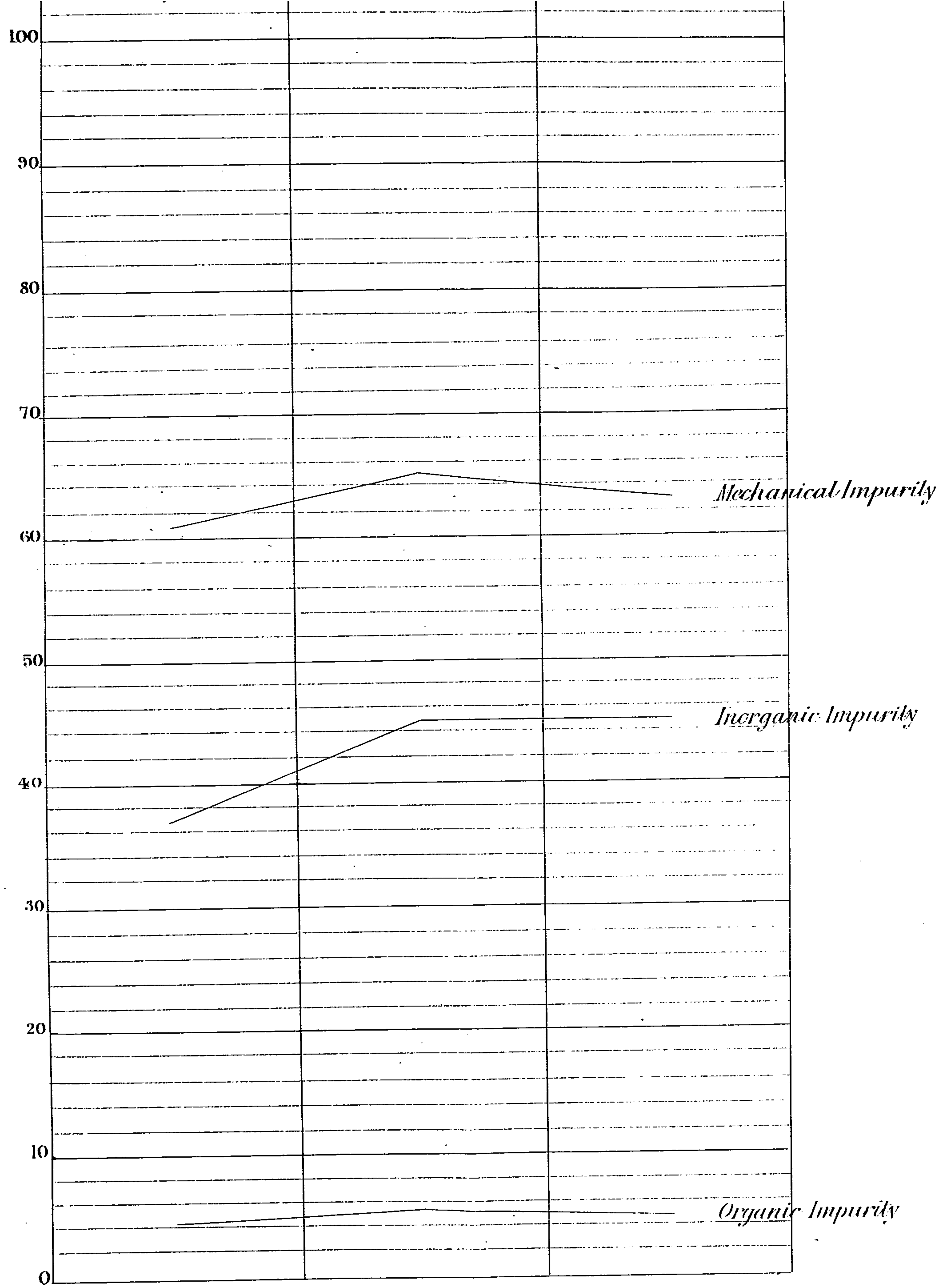
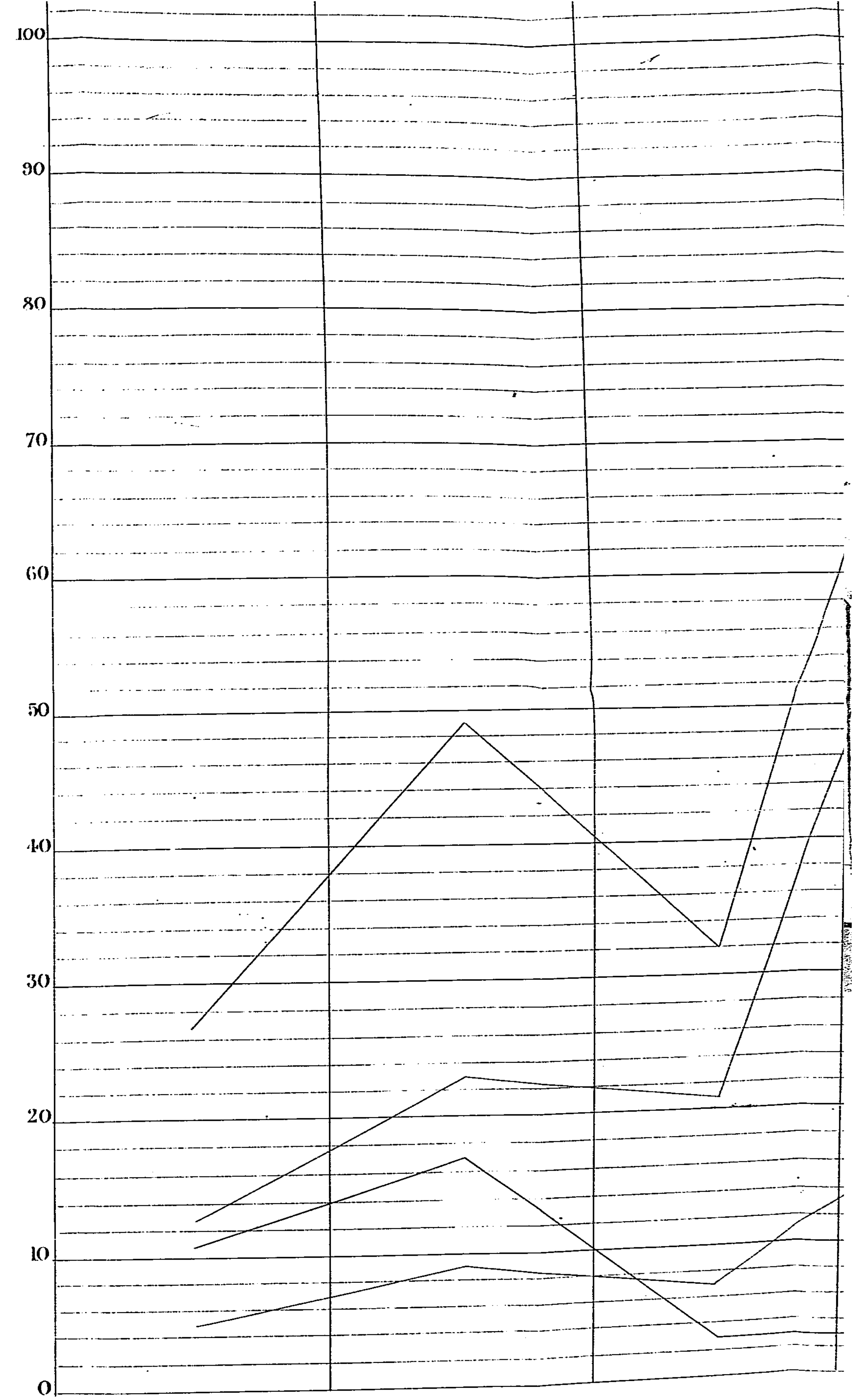


DIAGRAM (A.) Impurities in Thames Water.

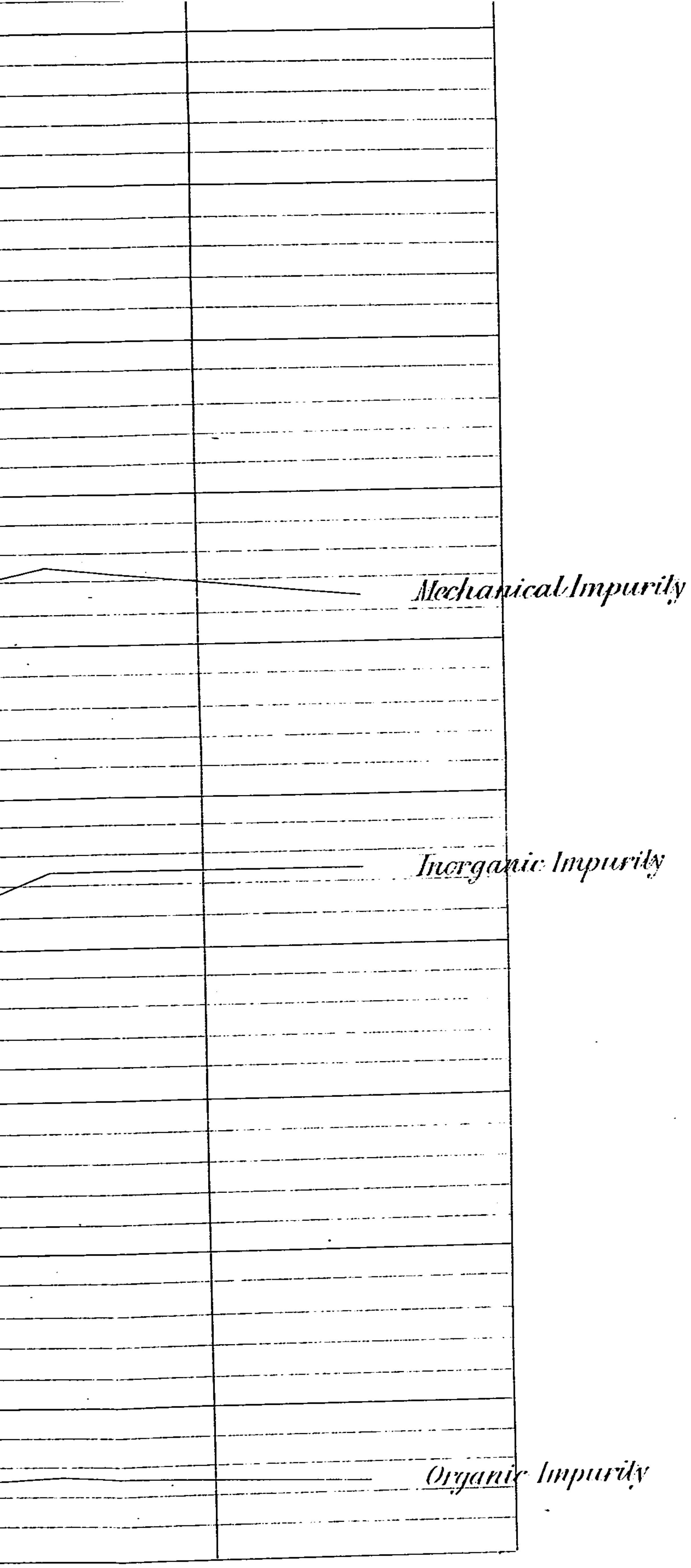
LOW WATER 2nd September 1854.



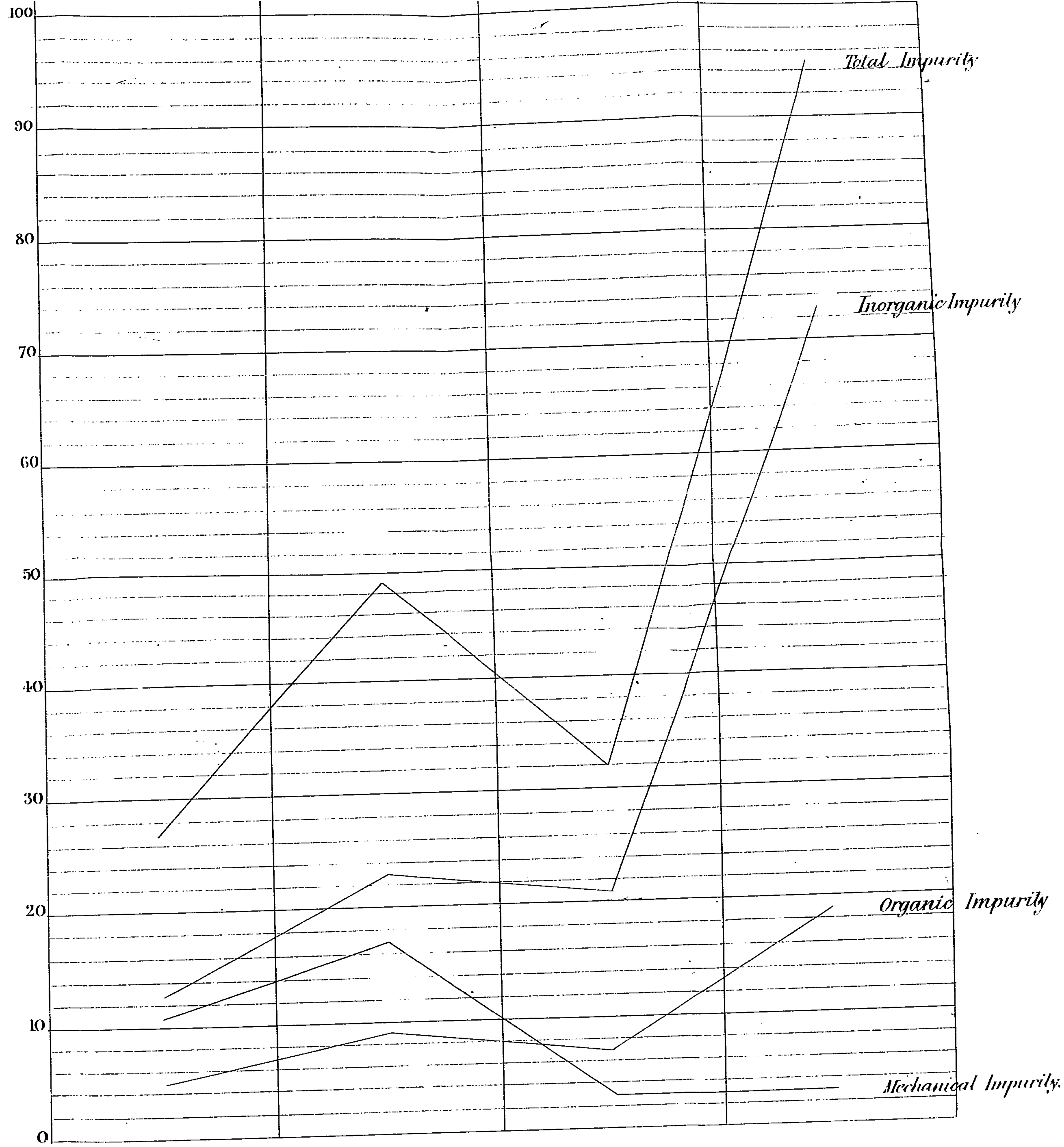




Day & Son, Lith^rs to the Queen



Mechanical Impurity
Inorganic Impurity
Organic Impurity



100
90
80
70
60
50
40
30
20
10
0
Total Impurity
Inorganic Impurity
Organic Impurity
Mechanical Impurity.

DIAGRAM (B)

Shewing the degrees of Impurity in London Waters.

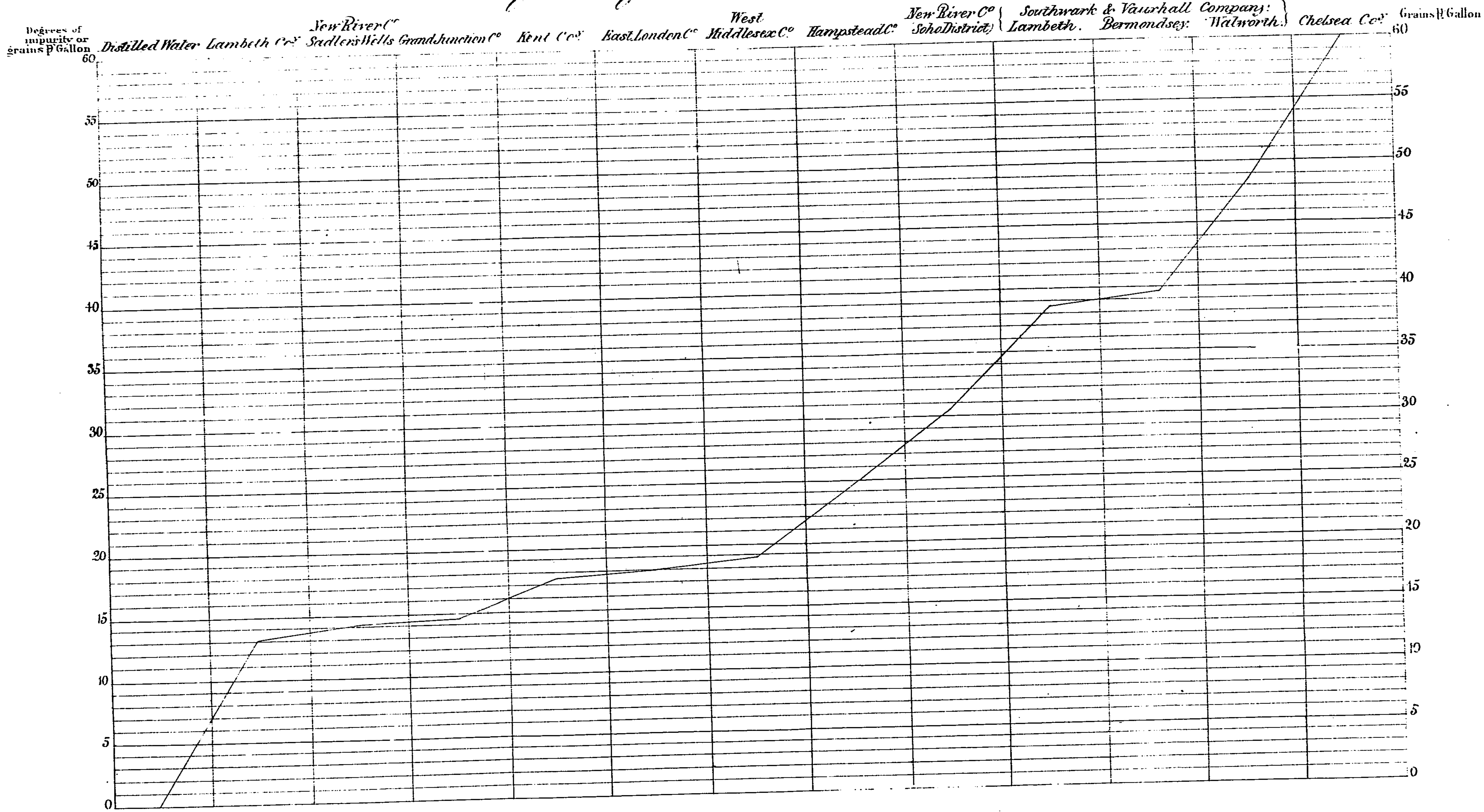


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DIAGRAM (C)

Of degrees of Organic Matter in London Waters.

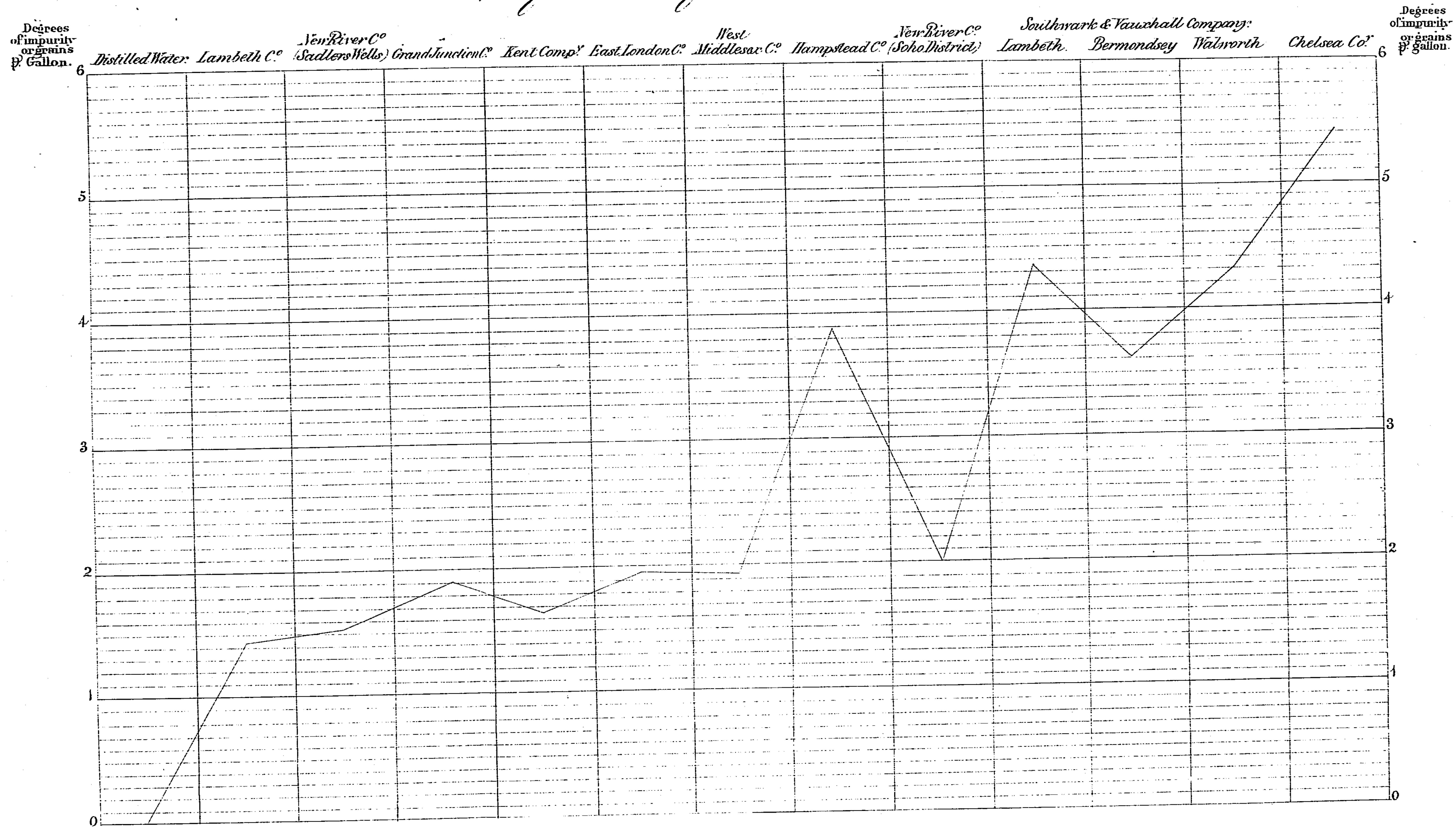

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DIAGRAM (D)

Of degrees of Hardness of London Waters.

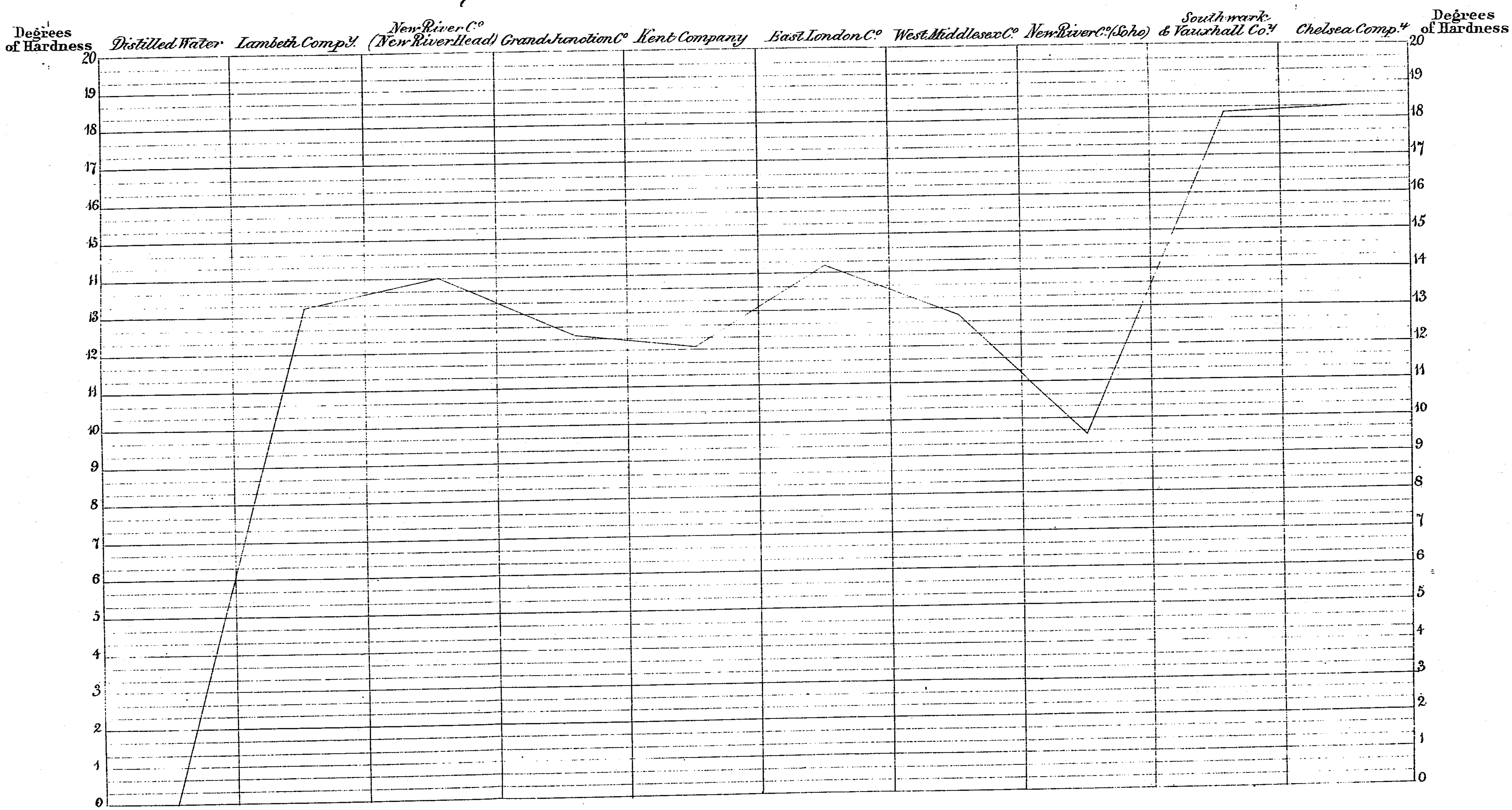

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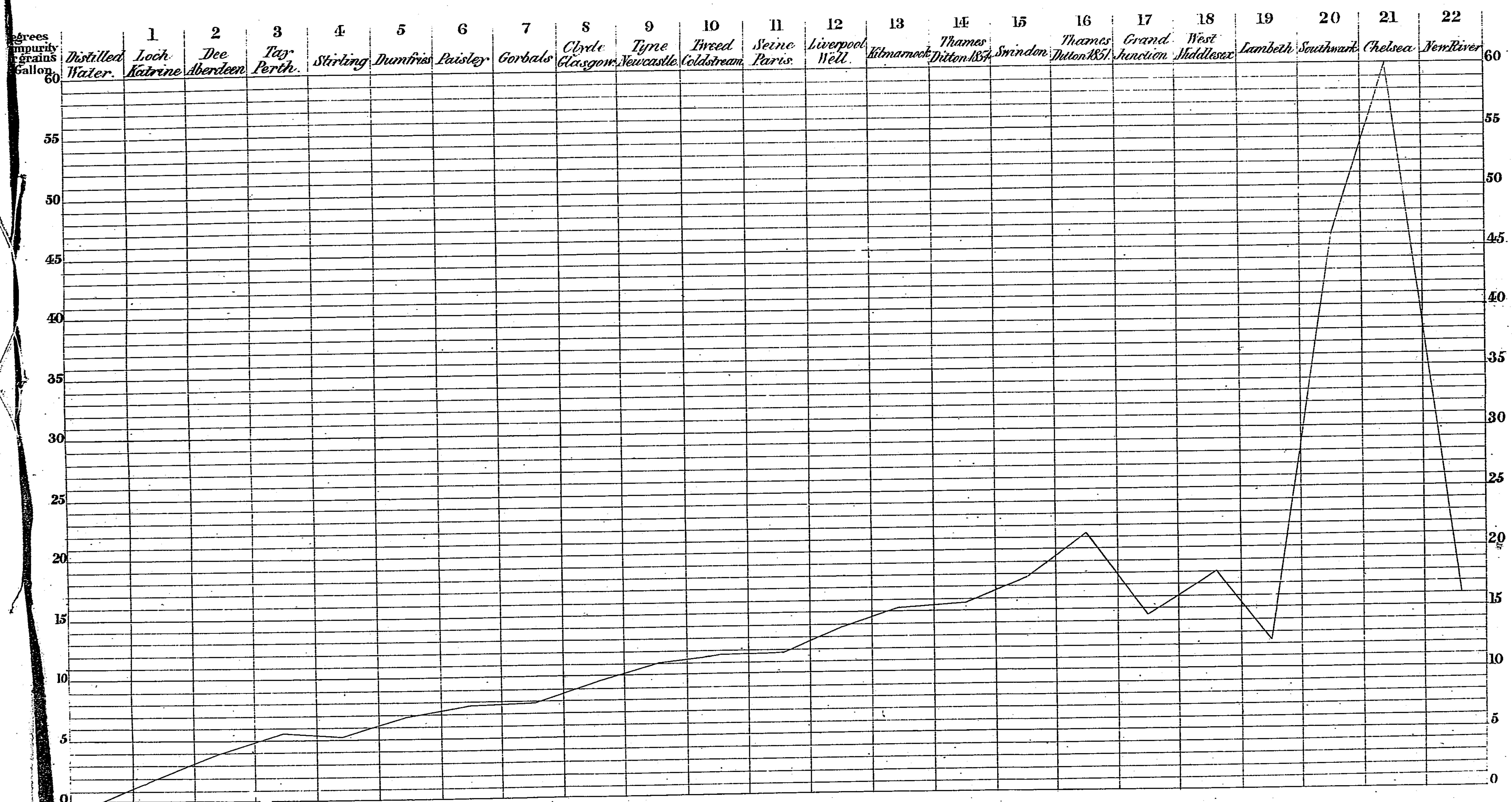
DIAGRAM (Æ)

Exhibiting the degrees of impurity in Waters supplied to Towns.

Each Degree equal to One Grain per Gallon.



Day & Son Lith^rs to the Queen

foreign matter. The present inquiry, carried on during the greater part of four months, has led to a very different conclusion, and has shown that there is a very great disparity in the purity of the waters as supplied by companies from the Thames. The analyses contained in the report of the commission of 1851, must only be viewed as giving the composition of the waters after rain, and in certain cases afford a much more favourable view of the water than is borne out by the present report. The report of that commission does not profess to give any information respecting the condition of the waters in the houses of the consumers, but is confined to the analyses of the waters as delivered by the engineers. These remarks it was necessary to premise, in order that the cause of the material difference in the impurity of certain waters as given in that report, and as obtained in the present inquiry, may be sufficiently understood.

Impurity of Water.

An absolutely pure water is one that when boiled until it is entirely evaporated leaves no residue behind. Scarce any water has ever been found in nature to which this discription will apply. Even rain water, which may be viewed as the condensed vapour primarily distilled from the aqueous deposits on the surface of the earth, contains in solution gases, ammonia, and organic matter which it encounters in its descent. In London and its neighbourhood, rain water has been found sometimes to have an acid reaction, and to yield evidence of the presence of sulphuric acid to the appropriate tests. The source of this acid is obviously to be traced to the sulphurous acid emitted as a product of combustion, and diffused through the atmosphere, since it has been observed at St. Thomas's Hospital that when large quantities of air, derived either from the wards of the hospital or from the external atmosphere, are passed through distilled water, a strong acid reaction is communicated to that fluid. The acid condition of rain water affords a striking contrast with the alkaline qualities which it is described as possessing when it is precipitated from the heavens at greater distances from the haunts of men, as in Switzerland and India (Stark, Saussure, Laidlaw, McLelland). When rain water falls on the earth, it gradually dissolves *organic* matter and *inorganic* salts as it percolates the soil, and when during floods it is hurried over the surface of the land to be discharged into streams and rivers, it carries in a mechanical state of suspension much earthy and vegetable matter which alone can be separated by filtration. Rain water in the neighbourhood of the sea during a strong gale may be contaminated with common salt when sea water raised from the ocean in the form of spray is forcibly conveyed landward. It is to this mechanical method of carriage that is to be attributed the circumstance of the existence of traces of common salt frequently, as I have ascertained, in the freshly deposited rain on the summits of the Highland mountains, and in all the springs and streams at their loftiest and earliest origin on purely granite formations. It is to the same mechanical dispersion of common salt that I am led to attribute the injury inflicted on vegetation generally and strikingly on thinly planted woods along our sea coasts. Residents on the Atlantic shores are familiar with incrustations of salt on their windows during westerly gales of wind, results which have even been recognized at Manchester. Hence it will be noticed that it is the foliage next the sea which is the greatest sufferer, and that when trees are thinly planted, those most distant from the shore or most elevated are least deteriorated. The popular idea of sea air being prejudicial to vegetation does not appear in this aspect destitute of foundation; while the same circumstances may perhaps throw some light on the opinion of Hippocrates, that the characters of waters are influenced by the direction of the wind.

In this report it is proposed to represent distilled water, the only pure water, as the standard of comparison or basis of the scale of waters, and to designate it by the symbol 0° or *no degrees* of *impurity;* there being no grains of foreign matter in the gallon while every grain of matter per gallon, present in water will constitute 1° (one degree) of impurity. *Total impurity* will comprehend mechanical as well as dissolved matter; while *mechanical, organic,* and *inorganic* impurity will refer respectively to the diffused materials, to the vegetable and animal substances actually dissolved, and to the earthy and alkaline salts in a state of solution. The gradation of each of these species of impurity will be expressed in degrees, 1° denoting one grain per gallon of foreign matter contaminating the purity of the water.

Chemical Condition of the River Thames in the Metropolis.

As the river Thames is employed to supply upwards of 28½ millions of gallons of water daily to the inhabitants of the metropolis, and especially to districts where the epidemic raged with great fury, some attention has been bestowed on the condition of the river, not only at the localities from which the water supply is subtracted, but beyond these limits, for the purpose of detecting the marine and sewage sources of contamination. Table I. gives the composition of the river water, at high and low states of the tide, at Vauxhall, Hungerford, and London Bridge; the total impurity at high water being respectively at these places 102·42, 115·68, and 113·24 degrees or grains per gallon, while during low water the numbers were 27·14, 48·84, 32·08, and at Greeewich 95·68. The relative conditions of impurity are made obvious to the eye in *Diagram A.* The water was taken on each occasion from the river near the Vauxhall waterworks, at Hungerford Pier, at the Surrey end of London Bridge, and off the pier at Greenwich. To detect the existence of sea water in the fluid at high water, a determination was made of the chlorine which was respectively found to be at the three stations, beginning at the most westerly as above, 22 grains, 24 grains, and 24 grains per gallon, equivalent to 36·23, 39·53, and 39·53 grains of common salt. The source of this large accumulation of chlorine, which at Thames Ditton did not exceed during the investigation 1·36 grains, equal to 2·24 grains common salt, must be sought for in the intermixture of the tidal waters. The results exhibit a marked distinction between the composition of the Thames at high and low water. The obstructing influence of the tidal wave appears not only to act as a barrier to the downward progress of the mechanical impurities so as to equalize the turbidness of the waters from Vauxhall to London Bridge; but it likewise causes the impure fluids from the sewers to accumulate, and imparts to the whole a retrograde movement, until rising to a tidal current, the sea and river waters are commingled. The greater impurity of the Hungerford waters in both conditions of the tide is sufficiently explained by the constant mechanical action at work at that point, and by the proximity of the locality where the water was taken to a common sewer which is there discharged into the river, and where a disgusting outflow continually occurs. The nature of the mechanical deposit falls to be described in the microscopical report. It is sufficient here to refer briefly to its chemical relations, premising that when magnified it presents the aspect of clouds of green organism, amid which lively animal motions can be discriminated. The February deposit at Greenwich, Table I., when dried in the open air, yielded above a fifth of its weight of organic matter, while in March the proportion was under a seventh; a large amount of the organic matter is in intimate union with the siliceous constituent of the diatomaceous beings which abound in the Thames waters. These bodies, when incinerated, undergo but a slight change in configuration, and leave siliceous shields, the framework of their organisms. The proportion of organic matter present in these beings is 12 per cent., the siliceous shields forming the remaining 88 per cent. according to my usual results. A certain quantity of mud, and often of feculent matter, is intermingled with the organisms, derived either from matter accompanying the water which has not yet subsided, or brought up from the bottom by the numerous mechanical agents unceasingly astir in the river; but the diatomaceæ, as found in the Thames, when carefully washed free from the mud and organic matter which usually accompanies them, yield on calcination a reddish siliceous ash, indicative of the presence of iron in their constitution. These general data being premised in relation to the chemical constitution of the river, as it flows through the metropolis, and as it exists in the neighbourhood of the localities where two of the companies (Southwark and Vauxhall company and the Chelsea company) abstract their supply for the use of large portions of the population in the western and southern districts of London, the conditions of the waters as occurring in houses will be more readily comprehended, and discrepancies between the present and former analyses sufficiently explained.

Metropolitan Water Companies.

The map published by the Board of Health exhibits the districts deriving their water from the respective water companies. The following table affords a view of the amount of water supplied by each company daily in 1853.

THAMES WATER.

	Gallons pumped daily.	Houses, &c. supplied.
Lambeth - - -	5,603,000	26,107
Grand Junction -	5,115,675	16,019
West Middlesex -	5,000,606	24,404
Chelsea - - -	5,632,000	24,729
Southwark & Vauxhall	7,287,289	40,046
Total Water from the Thames -	28,638,570	131,305

OTHER COMPANIES.

	Gallons pumped daily.	Houses, &c. supplied.
New River - -	17,537,396	90,924
East London - -	11,990,989	63,605
Kent - - -	1,840,097	14,594
Hampstead - -	607,368	5,454
Total - -	31,975,850	174,577
Total daily supply from all sources -	60,614,420	305,882

But the subsequent analyses show that these waters contain a considerable amount of solid inorganic and organic matter. Reckoning the mean solid matter in a gallon at 27·5 grains, the total solids pumped by the water companies daily amount to 238,128 pounds avoirdupois, or 1·9 ounces to each inhabitant of 2,000,000. The amount of organic matter in the daily water supply at 3·07 grains per gallon averages 26,458 pounds daily.

1. *Lambeth Company.*—The highest point at which water is taken from the river is at Thames Ditton, to the neighbourhood of which, after the lapse of a short period, all the waterworks of the Thames are to be transferred. In Tables II. and IX. Lambeth water is placed first, as being derived from a point nearer than any of the companies to the source of the river, and hence containing a less amount of total impurity than is characteristic of the water taken at a lower point in the river's course to the ocean. This company supplies Lambeth and Brixton, &c.

2. *Grand Junction Company.*—This company derives its water from the Thames at Brentford, and is distributed towards Paddington and Westminster.

3. *West Middlesex Company.*—Descending the river the works of this Company are reached at Barnes, from whence it is distributed to Hammersmith, Marylebone, and the Regent's Park, &c.

4. *Chelsea Company* draws its supply from the river on the north side opposite to Battersea, and is distributed to Chelsea, Westminster, and the neighbourhood of St. James's and Hyde Parks. The source of this water, as is obvious from the experiments detailed in this report in reference to the state of the river at high and low water, Table I., is thoroughly under the influence of the tidal wave.

5. *Southwark and Vauxhall Company.*—This waterwork, which is situated opposite to the Chelsea works, supplies Vauxhall, Clapham, Wandsworth, and Southwark.

6. *New River Company.*—The water of this Company is derived from the river Lea above Ware, and a variety of springs and wells partly discharged into the river.

7. *East London Company.*—The supply of this Company is derived from the river Lea at Lea-bridge and above Tottenham.

8. *Kent Company.*—This water is abstracted from the Ravensbourne below Lewisham, and is distributed to Deptford, Greenwich, and Woolwich.

9. *Hampstead Company.*—The supply is taken from springs at Hampstead and two artesian wells.

The object of the present chemical investigation being to determine with minuteness the composition of the waters used by the unfortunate individuals who had sunk under the influence of the epidemic, the specimens were generally taken from houses where the disease had numbered its victims. Many of the samples were taken in company with Dr. Hassall, whose microscopical examinations will, therefore, correspond in many instances with the specimens analysed in this report.*

Of all these waters it may be generally premised, in reference to the present investigation, that they were characterized by the formation of a deposit on standing, consisting principally of vegetable organisms mixed with abundance of animal life, when examined with microscopical assistance. Usually, however, in the Thames waters, on the scale of analysis which is commonly limited, the application of the balance was inadmissible for the quantitative discrimination of the mechanical residue. This remark does not apply so much to water extracted from cisterns, where the mechanical deposit can be often weighed, particularly during floods, but to water flowing in the distributing pipes. By the examination of the waters in both circumstances satisfactory evidence has been obtained that living growths exist in the waters supplied to the metropolis in the interval between the filter and the consumer, and, therefore beyond the influence of engineering talent to check or stay by the present arrangements. The conclusion seems inevitable that the waters of the Thames, even when purified as we may expect by the most delicate and refined adaptations of modern mechanism, still retain in their chemical constitution a condition which renders them fertile creative sources of vegetable and animal life.

* Other specimens were collected by my assistant, Mr. Walker, and others were forwarded by the Board of Health.—See Dr. Hassall's report. For unremitting aid in the prosecution of this inquiry, I am indebted to my assistants, Messrs. David Walker and James Napier.

Districts supplied by the Lambeth and the Southwark and Vauxhall Companies.

The first district investigated was that of Lambeth, under the guidance of Mr. Mears, the district registrar, on the 5th of September, where the disease broke out and spread with great virulence. The groups of spectators encountered in the streets, conjoined with the mournful preparations that met the eye, spoke more powerfully than language, of the fell work of the destroyer. But the hospitable nature of the reception experienced by the deputation, and the hopeful anxiety depicted on the countenances of the parties visited, indicated expressively the gratitude of the people for the desire exhibited by Government to mitigate the bitterness of their sufferings.

This district is supplied with water from two sources, the Lambeth Company deriving their supply from Thames Ditton, above the influence of the London sewage and tide flow, and the Southwark and Vauxhall Company, abstracting their water from a part of the river where both of the causes of contamination mentioned are in full operation, as is demonstrated by Table I. and Diagram A. In several instances the names of the companies supplying houses were erroneously communicated on the spot, but no difficulty was experienced in correcting the inaccurate information by the chemical analysis of the waters, as will be obvious by an inspection of the data, Tables II., IV., IX., Diagrams B., C., D., expressive of the relative impurity and of their peculiar composition.

In considering the relative impurities of the water supplied to the Surrey side of the metropolis by these two companies, it is to be borne in mind that much of the district at present referred to is under the level of the river, rendering it thus liable to the gravitation of some sedimentary matter in the pipes, which would be less likely to occur under an ascending tendency of the current of distribution. As this influence operates on the organization of both companies, it may be viewed as a constant quantity to be added or subtracted from each supply, but increasing in a direct ratio with the mechanical impurity of each particular water at its source. It is certain, that during the period of the present investigation, water, whether drawn from cisterns or pipes of the Lambeth or Southwark Companies, always yielded a deposit on standing, but of largest amount in the water of the latter company. From Diagrams B. and C., the relative mean total and organic impurities of the two waters are rendered visible to the eye, while in tables II., IV., and IX., the details of these results as derived from various houses where the epidemic occurred, together with the number of deaths in each, are represented in parallel columns. From these data it appears that in nine houses in Lambeth and Walworth, where 14 deaths were occasioned by the epidemic, the mean total impurity (distilled water being 0°) in the Lambeth Company's water was 13·37 degrees (each degree being equal to one grain per gallon), the organic impurity being 1·43 degrees; while in an equal number of houses supplied by the Southwark and Vauxhall Companies, where 16 deaths and seven cases (still living when the water was taken) occurred, the mean number of degrees of total impurity of the water was 46·09, and the mean organic impurity was 4·11 degrees. These data are not to be understood as affording a type of the relative mortality in the house supplied by the two companies; the houses having been indiscriminately entered during the prevalence of the cholera, rather with the object of convenience at the time than with any idea of selection. They, however, demonstrate, both as respects total and organic impurity, that the Southwark and Vauxhall Company afforded a necessary of life to the houses visited, which was three times more impure than that which was derived from the Lambeth Company's waterworks. These observations apply to the relative amount of foreign matters present in the several waters; but when we investigate the details of these total impurities, we shall also be enabled to detect characteristic distinctions (Table IX.*); for while ten substances are common to the constituents of the two waters, there is one ingredient, chloride of calcium, which is absent from the Lambeth water, while two, nitrate of lime and carbonate of ammonia, largely predominate in the Southwark over the amount of the same bodies detectable in the Lambeth water. In the Lambeth water the total amount of residue insoluble in water is 12·245 grains per gallon, and that of the salts soluble in water 3·585, the soluble matter existing in the ratio to the insoluble matter of 1 to 3·41. But in the Southwark water the ratio is reversed, for while the proportion of total Lambeth to total Southwark salts is as 1 to 2·4, or nearly twice and a half greater, the proportion in the Southwark of the insoluble to the soluble ingredients is 1 to 2·19. The usual characteristic of European rivers is the predominance in their composition of earthy salts, which are insoluble in water under ordinary circumstances. In the Rhine the insoluble salts are about 6⅓ times greater than the soluble ingredients; while in the Rhone, the insoluble are double the soluble salts. In the Clyde, likewise, the ratio is as one soluble to nearly two insoluble matter. We have thus supplied to us a characteristic feature which enables us to distinguish a river water from one which is contaminated by matter from foreign sources. The existence of such a large quantity of common salt in the Thames water between bridges is sufficient to demonstrate, as has been previously pointed out, the commixture of sea water with the river current, as one extensive cause of the impurity of the Thames in this part of its course.

A peculiarity which pertains to Thames water as high at least as Chelsea, during the tidal flow, in common with sea water and the water of some wells, is the property which the saline residue obtained by boiling away the water possesses of fusing in the flame of a lamp or candle. It is sufficient to dip a moistened loop of platinum wire in the residue of Thames water derived below the western limit noticed, when it will be found to fuse with facility into a mass, and thus to afford a discriminating test from all genuine river waters with which we are acquainted, and certainly from all the metropolitan waters supplied by running streams.

By this test it was easy to distinguish Lambeth and Southwark waters. This character has been found to hold during the four months of the continuance of this investigation. But at certain periods of low water, the characteristics of river water may be recovered; the large amount of nitric acid and ammonia detected in the present series of analyses, has hitherto been greatly under-estimated in the Southwark water; particularly the ammonia, which has been obtained on such a scale and in such abundance as to warrant the conclusion that the influence of the sewerage upon the chemical character of the river Thames is much more extensive and unwholesome than was anticipated, although it points out this water as being admirably adapted for purposes of irrigation, since the numbers given in the table, which exhibit upwards of a $\frac{1}{4}$ grain per gallon of ammonia, and $\frac{5}{100}$ths of a grain of nitric acid per gallon, were obtained as an average of many trials, made after a fall of rain, and do not probably by any means represent the maximum amount of these substances present in the Southwark water during the driest season of the year. Experiments conducted on such a scale that the ammonia condensed and combined with sulphuric acid yielded, as the product of one operation, upwards of 50 grains of sulphate of ammonia, admitted of the easy demonstration of the abundance of ammonia in this company's water. The materials mixed with the water from which the ammonia and nitric acid are derived, are usually considered to be, in general language, organic matter, which is characterised by its containing the nitrogenous element for the production of ammonia. But when we investigate the nature of that form of animal matter which is discharged in great abundance into the river from which ammonia can with the greatest facility be elicited, we are led to the conclusion that it is the urea of urine which constitutes the most ready and the predominating source of this volatile compound; and that while ammonia is the first stage of the change of urea into simpler forms, nitric acid constitutes the second change, being produced under the influence of atmospheric air, which oxidizes the ammonia. Hence we find in almost every sample of Thames water the amount of nitric and ammonia to vary considerably, the difference in proportion being probably dependent, in a great degree, on the changeable nature of the tidal obstructions to the outflow of the sewage ingredients of the river water. It is thus necessary to be able to distinguish the source of the ammonia and nitric acid, since these substances, when mixed artificially in small doses in drinking water, could scarcely be designated as injurious to health, however objectionable they might be considered as foreign bodies impairing the purity of water. But their presence in Thames water is indicative of the constant mixture with the river of the most objectionable of all impurities, that of animal débris in various stages of decomposition. That the animal matter brought down by the sewers has not been wholly converted into the simpler and less noxious forms of ammonia and nitric acid, is obvious from the fact that in several trials made with Southwark water, nitrogen, the usual characteristic of animal and its identical vegetable prototype, was invariably found to be present in some solid form which was capable of solubility in water. This is an inference irrespective of the evidence, sufficiently palpable to microscopical observation, of

the presence of muscular fibre in the mechanical deposit from the same waters, as first observed by Dr. Hassall, which had certainly formed a part of the feculent matter derived from the teeming population of this great metropolis. The ammonia and nitric acid being viewed as the stages of transmutation of animal matter into less noxious forms, it appears probable that in the presence of much organic matter in waters, and of only minute quantities of ammonia and nitric acid, the objectionable character of water may be augmented.

When we take into consideration the facts that the Lambeth and Southwark Companies supply contiguous houses throughout the same district, that the elevation of their sites in relation to the river is identical, that the inhabitants supplied by both Companies are exactly similar with regard to means, and yet that the mortality in the houses supplied by the Southwark Company exceeded by nearly 2,000 the deaths that would have occurred, if cholera had only been as fatal as it was in the houses that derived their water supply from the Lambeth Company (Regis.-Gen. Weekly Report, 6th Dec. 1854), without viewing the subject in an extreme aspect, it is impossible to avoid drawing the conclusion, that the Southwark water must at least have had a more predisposing influence in the production of the disease than that of the Lambeth Company. It does not appear that sufficient data exist to enable us to decide as to the peculiar nature of the influence in the production of the disease communicated by impure water to the human system. Whether it be the seeds of the disease existing in the water, according to an old and very prevalent oriental theory, or whether by the access of other local and general influences a predisposition to the lodgment of the epidemic is engendered in the animal frame by the use of water tainted with organic matter, are uncertain, although it is just possible that the conditions under both hypotheses, when certain circumstances prevail, may influence the production and communication of the epidemic.*

The latter view seems most reconcilable with a general survey of the cholera as it occurs in different localities and climates. The facts connected with the occurrence of cholera on river margins have been elaborately urged by Dr. Snow in favour of the Indian theory, while the same circumstances have been most ingeniously applied by another theorist to the use of autumnal stores of unsound flour. The law of elevation, however, established by Dr. Farr, takes cognizance of such facts and affords a general view of the subject. Exclusive theories are objectionable on the ground of their overlooking circumstances of moment, not only in regard to theory but even in respect to the practical management of the disease. The oriental and farinaceous theories will receive the acquiescence of all, in so far as they condemn impure waters and decomposing flour. There are some instances, however, on which, so far as the evidence before us leads, the disease appears to be propagated entirely by atmospheric media. The appearance of cholera in St. Kilda without any known communication with the main land, has been cited by Dr. Robert Macgregor, of

* Analogy leads to the inference that a morbid organized poison cannot both act by intestinal and by pulmonary absorption.

Glasgow, as one of those otherwise inexplicable phenomena. In reference to the connexion of tainted atmospheres with the propagation of disease, the insufficiency of the drainage in the district now under consideration could not fail to be forcibly impressed on the senses of the inquirer. In many instances it was found that no communication existed between the houses and the sewers; and frequently when a house drain did terminate in the sewer, the original cesspool remained, so that a well of garbage and excrementitious filth, extending its domains in every direction by infiltration, constituted a never-failing source of pollution to air and soil—the overflow alone escaping to the sewer. That the contents of cesspools permeate the surrounding media like a sponge, has been abundantly illustrated even in the comparatively more healthy portions of the metropolis, where wells reeking with organic odours have been chemically examined and condemned as noxious to health. The water from a well on the hill at Camberwell, used by a family where much delicacy had occurred among the inmates, when it reached the laboratory of St. Thomas's hospital emitted a disgusting smell resembling that of putrid cabbage (Table of Wells) and contained no less than 16·63 grains of organic matter, nitric acid, and ammonia in the gallon. On filling up a cesspool with which the well had previously been in communication, after six months interval it still contained 7·26 grains of similar matter per gallon, although no smell was perceptible.

It might appear on a cursory examination that the circumstance of cases of cholera occurring in houses supplied by the Lambeth Company militates against the possible influence of impure water in the promotion of disease. But when it is borne in mind that the Lambeth water is by no means a pure form of that fluid, as is obvious to the eye in diagrams B. and C., representing the impurity of various waters supplied in many towns in England and Scotland, being from a third to a half more impure than the river Clyde, which has been discarded by the inhabitants of Glasgow as a proper source of supply, and equally more impure than the water used in Paris from the Seine. The water of the Lambeth Company, as has been previously stated, is abstracted from the river at Thames Ditton, after it has served as a sewer for an extensive country, well manured and studded with towns, which are occupied by a numerous population, continually on the increase. This water was found to contain ·023 grains of ammonia per gallon, which is equivalent to ·064 grains of carbonate of ammonia; a strongly presumptive evidence of the contamination of the river, even at this part of its course, with organic matter, independent of the solid organic matter actually detected in a state of solution in the water. It is, consequently, a subject of much regret that the water companies should have embarked a large additional amount of capital in improving their mode of supply exclusively from a source of objectionable character, and subject to continually augmenting means of deterioration.

District supplied by Grand Junction and New River Companies.

On the 31st August and 1st September the epidemic broke out with great virulence in the neighbourhood of Golden Square, Soho,

and spread with a fatality scarcely exceeded by the mortality of the plague, as described by the romantic pen of Defoe. The number of deaths from cholera in this limited district in six weeks exceeded 600. The fatal character of the disease on the 9th of September, when the samples of water were taken, had become extensively known, and had produced such alarm among the residents that the greatest gloom pervaded the locality from the suddenness and almost explosive nature of the attacks. Specimens of water were taken from five houses supplied by the Grand Junction Company, in which 15 cases of cholera had occurred, and from seven houses supplied by the New River Company where 40 cases of cholera and diarrhœa had prevailed. The pump water in Broad Street was also preserved for examination. On analysis it was soon evident that the water supplied by the New River Company presented a remarkable anomaly, for when subjected to examination in 1838, I did not find the New River water to contain more than one half the impurity which the present specimen exhibited. It was therefore considered of importance to compare it with samples derived from the New River Head. The results of the determination of the relative degrees of impurity in these two examples are illustrated in Tables VI. and X., where the water from the reservoir was found to possess a mean of 16· degrees of total impurity and of 1·51 degrees of organic impurity, while the water from the Soho district, supplied by the same company, had a mean total impurity of 28·64 degrees, and of organic impurity of 1·98. That no doubt might exist as to the true source of supply, I was empowered by the Board of Health to obtain the assistance of the registrar of the district, to visit the houses and see the water-rate receipts. This was done in all the houses said to be supplied by the New River Company. The table has, therefore, been constructed from this information. From the table it will be found that this greater degree of impurity was not confined to the period of the prevalence of the epidemic, but continued up to the subsequent November, when it was again subjected to examination, and compared with water taken from the reservoir at Sadler's Wells on the same day. It is, therefore, demonstrated that the water professed to be supplied by the New River Company to a portion of the district examined, was totally different in its chemical character from that contained in the Company's reservoir at Sadler's Wells. Another peculiarity, in addition to the much greater amount of saline residue, is detected in the character of the matter in solution, which renders it comparable with Thames water. The salts were found to be easily fusible when their quantity greatly exceeded that of the reservoir samples, and infusible when they approximated the weight and normal condition of the usual water supplied by the Company. In the Diagram B. it becomes apparent to the eye, that the New River water supplied to the Soho district approaches the same category of impure waters, as the most impure of the Thames waters.

The proportion of organic matter present in it, likewise, is in comparative excess in the relation of 100 in the reservoir water to 131 in the water of the Soho district. It was at first suspected that the water was derived from the Thames, from which it is understood that at one time this company obtained a partial supply, but the chemical analysis rendered this improbable (Table X.), from the difference in the constitution of the saline ingredients. These and other circumstances have led to the inference that the supply may be derived from one of the numerous sources possessed by the New River, before being diluted with other purer specimens of their waters. It deserves remark, too, that this anomaly in the water could only have been detected by a minute chemical investigation of the details connected with the local occurrence of the epidemic, and supports the propriety of the specific inquiry set on foot by the Board of Health, instead of trusting to a general superficial survey.*

The remaining houses examined derived their water from the Grand Junction Company. It left comparatively a smaller amount of residue, but contained rather an excess of organic matter (3·78 degrees), particularly when compared with the amount present, 1·92 degrees, in November, as detailed in Table III. The only other source of water in the district is that of wells, one of which, in Broad Street, when examined, was found to contain 92·06 degrees of impurity or grains per gallon, of which 7·8 were due to organic matter, nitric acid, and ammonia; but the organic matter seemed to have but recently reached its destination, since from the absence of much nitric acid oxidation had but slightly commenced to change its form. It is scarcely possible to condemn in too strong terms such a source of supply of water as a shallow well in a great city, which chemical and physical examination universally proves to be a pool of water deriving its contents from the oozings of fluids from cesspools and sewers, mixed with rain water, and holding in solution more or less of all noxious soluble filth contained in the soil. That cesspools predominate to a great extent in this district was ascertained by inquiry. For notwithstanding the large amount of new sewerage lately completed in this locality, and executed with great skill, it does not appear that the house proprietors have availed themselves of the advantage thus presented to them of improving the sanitary condition of their properties by carrying off the house refuse into the sewers; since, if I am correctly informed, only a small per-centage of the houses has any communication with the sewers. When, too, drains have been executed, it appears that in many instances the original cesspools still remain, and it is only the overflow which passes to the sewers. This is an evil which seems to demand searching inquiry, and to be provided against by stringent means, otherwise an immense expenditure may be incurred and talent wasted in the construction of sewers, without any adequate advantage to the health of the community. The sewage water in Silver Street, Golden Square, when examined, was found to hold in suspension much organic matter, and to leave a residue by evaporation of 88·68 degrees or grains per gallon, of which 26·88 consisted of organic matter. The fluid contents of the sewer in Peter Street gave 48·98 grains of residue per gallon and 4·8 grains of organic matter,

* I have since been informed by Mr. Mylne, engineer of the New River Company, that this district is supplied from two sources, the New River head, and a well in the northern part of the metropolis. Their intermixture by lateral communication explains the variable conditions of the Soho district water in the table.

while in Husband Street it was found to yield 58·6 grains of residue, including 6·04 grains of organic matter. The fluids possessed a most abominable odour, and decomposed or fermented most extensively when preserved in close vessels, sulphuretted hydrogen constituting a part of the gaseous exhalations. It is a circumstance of some moment that during several years connexion with the Blenheim Street Dispensary, to which charity I acted as physician, (and of which I was one of the founders in 1836,) a large number of patients came from this locality affected with epidemics and diseases indicative of a low state of cleanliness and civilization.

Water supplied by the Chelsea Company.

In the district of Chelsea, particularly in the southern part, cholera prevailed to some extent. The mortality being 60 per 10,000 inhabitants, a fatality very considerably in excess of the mean (45 per 10,000) of the western metropolitan districts. Water was collected from four houses, in which 12 deaths and seven additional cases of cholera had occurred. These waters, which were all supplied by the Chelsea Water Company, were proved by analysis to have a very high standard of impurity, the mean degrees of impurity being 60·17, (Tables V. and IX.), the maximum impurity being 65·66, and the minimum 50·4 degrees. The average thus obtained is much above the mean of the Southwark and Vauxhall Company's water; but the circumstance that it is derived from a more limited series of data must be taken into consideration; although the fact remains intact that the average impurity of Chelsea Water in cholera houses greatly exceeded that on the Surrey side of the River under similar circumstances. The mean of organic impurity is also decidedly greater in the Chelsea water, 5·41 degrees, than in the Southwark water, 4·38 degrees. To determine if the impurity of the Chelsea Water remained permanent, a specimen of water was examined from one of the same cholera houses, long after the cholera had disappeared from the neighbourhood (8th December), when it was ascertained to be 36·96 degrees, approximating to that of the Southwark Company, 38·72 degrees in September, during the prevalence of the epidemic in the Lambeth district. But the data supplied by Table I., diagram A., of the variable composition of the Thames water at the sources from which the Southwark and the Chelsea Companies are derived, sufficiently attest the dependence of the chemical results upon the condition of the tide at the time during which the water is abstracted from the river, and likewise demonstrate that neither of these waters is always drawn when the river is in its most favourable sanitary condition. The great discrepancy between the mortality in the Southwark and Chelsea districts, notwithstanding the greater impurity of the Chelsea water, shows that the condition of the population in regard to drainage and physical conformation, must be regarded as well as the water in connexion with the epidemic.

Districts supplied by East London, Kent, and Hampstead Companies.

The water supplied by these companies possessed respectively the following degrees of impurity, viz.,—East London, 18·3 total degrees of impurity; organic impurity, 1·97; Kent water, 17·76 total impurity; 1·66 organic impurity; Hampstead, 24·22 total impurity; 3·88 organic impurity. The East London alone was taken from houses in which cholera had occurred. The greater tendency to the production of animalcules in the water of open exposed streams or canals, places certain springs which are not liable to lateral infiltration of impurities in a more favourable position, as far as the peculiarity of the ingredients is concerned, although they possess the disadvantage of exceeding in total impurity. So far as the water could have any influence in the production or propagation of cholera, the Hampstead water contrasts favourably with the East London and Kent districts, for while in the Hampstead district the mortality was only 12 per 10,000 in 15 weeks, that of the East London in Bow and Poplar was 42 per 10,000, and that of the Kent a mean of 48 per 10,000. The greater mortality in the Deptford and Rotherhithe districts is probably referable to the low position in reference to the river (+ 4 feet, and below the river level), and to the contamination of the air by the noxious exhalations emanating from an imperfect drainage. The marshy condition of the river side downwards is undoubted while the stagnating débris of a large population cannot fail to act prejudicially to human life. The influence of want of drainage, and the accumulation of organic fluids, is well illustrated in the Plumstead marshes, where stagnating waters, disgusting from their noxious odours contain above 102 degrees of impurity, and 20 degrees of organic impurity, which is accompanied with nitric acid and ammonia, all symptoms of the presence of putrefying animal matter. To form a faint notion of the unhealthy position of those parts of London placed beside the river, and beneath its level, we have only to imagine a town built on the Plumstead marshes, its subsoil thoroughly impregnated with decomposing organic matter, and deriving a plentiful accession of additional filth from the continually increasing deposition of débris from animal life.

ROBERT DUNDAS THOMSON, M.D.

London, St. Thomas's Hospital,
15th Jan. 1855.

Report on the Chemical Composition of some London and Provincial Wells.

HAVING taken no inconsiderable share in pointing out the objectionable nature of well waters in towns for domestic use, it may be premised that my attention was especially drawn in 1845 to the detection of nitric acid in them and in other waters by Baron Liebig, who had many years previously directed much attention to the subject. In 1751 Margraf, of Berlin, had obtained nitric acid in the wells of that city, but was unable to detect it in country wells. In 1825 Liebig confirmed the experiments of the Prussian chemist, and traced the origin of the nitric acid to the organic matter of towns. Saussure in the beginning of the century detected ammonia in the atmosphere, while Dabit obtained it in the distillation of river water in 1805. In 1845 I happened to be engaged in examining many of the tributaries of the river Clyde, for the purpose of fixing on a proper source of supply for the city of Glasgow. Professor Liebig, who visited me during the period, suggested the propriety of testing the waters for nitric acid, but having failed in discovering it in running streams near their source, on the scale of analysis to which I was necessarily confined, I tried for it in the Glasgow well waters with completely successful results, and ascertained that nitric acid occupied a much more prominent position in the constitution of these waters than could have been anticipated from any researches previously made public on the subject. In 1847 it was proposed by some parties in Glasgow, from benevolent motives, to sink new wells in that city, in order that the working classes might have a plentiful supply of water gratuitously, and a considerable sum of money was upon the point of being expended by the Town Council on this object. But on the facts being laid before them as to the impurity of well waters, the project was speedily abandoned. The report made to the Council on the constitution of the wells was published by them, and drew the attention of other towns to the presence of human excretions in well waters. Table XV. contains the results of the examination of the total degrees of impurity of 18 Glasgow wells. In some of these the nitric acid amounted to not less than 3·64° and 3·48° grs. per gallon, while the total impurity ranges from 99·5° to 14·9°. In the beginning of 1850 the corporation of Liverpool requested me to examine the wells of that city, from which the whole water supply of the inhabitants was derived. In the waters of all the 21 wells examined nitric acid was readily detected. Table XV. likewise affords a view of the total degrees of impurity in these wells. In the case of the most impure of the Liverpool wells, which is situated at a distance of 1,050 yards from the River Mersey, the water when I visited it tasted quite brackish and was unfit for drinking, but

I was assured by the workmen on the premises in which the well is sunk that they used it as a beverage a few years anterior to my visit. This and other facts have shown that in a pervious soil the removal of surface water from it by pumping leads to lateral permeation by the tide to replace the water thus withdrawn from between the particles of the soil in which it was contained: and that in proportion to the rapidity with which the well water is abstracted, so is the influence of the tidal current detected in the well waters. It is almost unnecessary to remark, that when water can be thus proved to permeate a soil laterally for the distance of 1,000 yards, still less difficulty will be experienced in the filtration of noxious fluids from more approximate sources of impurity, such as cesspools, &c.; and it will then be understood that city wells are, practically, reservoirs into which all soluble surface nuisances drain. The variable nature of the chemical composition (Table XII.) of London wells, proves that the ingredients of the same wells at different periods vary to a very considerable extent. Thus, Aldgate pump, in January, was characterized by 49·12° of total impurity, and 13·94° of organic impurity, while in February these numbers were respectively 44·64° and 6·3°. The remarkable impurity of the Putney wells, 180·4° and 101·3° of total impurity, and respectively 16° and 14° of organic impurity, is sufficient to indicate the proximity of some noxious sources of contamination which render the waters unfit for animal consumption. That the use of such infusions of filth by the population is not instantly followed by death, is undoubtedly the cause of perseverance in much inattention to hygienic foresight. But experience must point out to us that, even reasoning on the theory of probabilities, a pure beverage is less likely to prove unhealthy than one which contains in solution the most naturally disgusting and unwholesome of all matter to human beings, viz., the excretions from their own bodies. To the chemical physiologist, it is impossible to view the employment of such beverages otherwise than as an infringement of sanitary laws, and therefore as liable to natural punishment. It has been correctly observed, "that such and such miseries naturally follow such and "such actions of imprudence and wilfulness, as well as actions more "commonly and more distinctly considered as vicious;" and, "that "though we may imagine a constitution of nature in which these natural "punishments, which are in fact to follow, would follow immediately "upon such actions being done, or very soon after, we find, on the "contrary, in our world, that they are often delayed a great while, "sometimes even till long after the actions occasioning them are "forgot." (Butler's Analogy, chap. ii.) The terms *springs* and *spring waters*, by which these filthy infusions are often designated, seem to modify in some measure their impurity, by throwing a rustic halo around them, and assimilating them in language, though in words alone, to their purer prototypes, which are situated at a distance from liability to noxious impregnation. This would be found to be the great obstacle to the success of the attempt to supersede the use of impure well waters by the more healthy supplies. Voluntary recommendation seems to have failed in causing these sources to be abandoned, and therefore we must look to the more stringent means of shutting up waters of such an impure nature, and all other similar objectionable articles of food, on the score of regard to the health of the least protected portion of the community. It must be viewed at least as a striking coincidence, that the cities of Liverpool and Glasgow, in which well waters are very extensively employed by the population, are precisely the localities where cholera has assumed its most fatal phase; and it is not probable, when experience points out the unacquaintance among the more educated classes with the impurities of human food, that the more illiterate class should cease to employ tainted waters so long as wells are open gratuitously for their use. The legislature would confer great benefits on health by causing the poor to be freely supplied with water from the purest sources by means of a house rate or some similar provision.

When Newcastle was visited in 1853 by a remarkably fatal invasion of cholera, the coincidence of the occurrence of the disease with the use of impure water from the River Tyne, formed a striking fact in the history of the epidemic. The local statement which was made at the time, that the troops in the barracks, who were said to be supplied with *pure spring water*, and were severely attacked by cholera, seemed deserving of investigation in its chemical relations. On the outbreak of the disease I examined the water of the river for the Board of Health, taken from the point at which it was pumped by the Water Company from the Tyne at Elswick two or three hours after low water, and found it to be characterised by 15·662 degrees of total impurity, of which 4·5° were due to mechanical impurity, 2·68° to organic impurity in solution, the remaining 8·48° consisting of inorganic impurity. The data which have been supplied in reference to the condition of the River Thames (Table I. Diagram A.) are sufficient to indicate the relative impurity of river water influenced by town sewage at high and low states of the tide. The constitution of the Tyne is not therefore here represented in its most exceptional condition. On the contrary, reasoning from analogy, we should infer that it was nearly in its purest form. To ascertain whether the statement made was correct, that the *spring water* used by the military was *pure*, a quantity was sent to me for analysis; upon examination it was found to possess 100·56 degrees of impurity (or grains of foreign matter per gallon), of which 15·052° were due to organic impurity, including abundance of nitric acid, and 85·5° of inorganic impurity. It was therefore evident that the statement of the water being *pure* and being *spring water* was a fallacy, and that the so-called spring was merely one of those familiar wells, or pits as they should be termed, which in towns serve as reservoirs for the drainage of soluble surface filth. After the termination of the epidemic at Newcastle, it was observed from the returns that diarrhœa, and not cholera, was the prevailing disorder among the troops; and this was used as an argument in favour of the advantage of *pure spring water* over impure river water, in checking the progress of the preliminary symptoms into the more advanced stages of Asiatic cholera. Although these remarks apply peculiarly to shallow wells, much organic matter often accompanies in solution waters arising from great depths in the form of Artesian wells. A spring of this description in the neighbourhood of Glasgow, which contained 40·5 degrees of impurity or grains of residue in the gallon, possessed nearly 2 per cent. of organic matter, which was deposited in such quantities in pipes through which it was conducted, on rising from a sandstone stratum at a depth of above 1,000 feet, that they speedily became choked up and unfit for use. But the amount of the organic matter varies very considerably in shallow wells at different times. The same observation applies to the amount of impurity both organic, and inorganic, as is observable in Table XV., where the impurity of Glasgow wells is exhibited. Nos. 6 and 7 indicate for the same well in two consecutive months 58·84° and 66·2°, and Nos. 13 and 14 likewise another well in succeeding months 50·64° and 43·24°. In the Liverpool wells, too, where the water has less time to accumulate and concentrate saline matter, in consequence of the town supply being derived entirely from them, we observe Nos. 9 and 10, Table XV., that Bevington Bush in January contained 48·63° of impurity, and in February 45·90°. These results, therefore, agree with the previous remarks which have been made in this report as to the variable character of the constitution of the London shallow wells. But these conditions of the shallow wells seem to afford a striking contrast with the waters of Plumstead and Watford, Nos. 14 and 16, Table XIV., derived from fissures in the chalk, which appear to retain a steady composition, thus showing that they are not subject to sudden mixture with impurities, but that their source is rain-water, which permeates slowly and regularly to a great depth, strata which yield up to each successive portion of water, as it descends, the same soluble ingredients. Thus, I found the Watford water to contain 22·4° of impurity, a number identical with that obtained by the Commissioners in 1851. This character of stability is one of the most important in reference to an article of human consumption, since an alteration in the amount or variety of the materials dissolved in water must always indicate its connexion with some uncertain source of supply, and therefore a liability to contamination by unknown impurities. Well water derived from a considerable depth is usually cool and clear in summer, and it is from these characters that in London it is chiefly valued. It is obvious that coolness might be equally communicated to a pure water by immersing closed bottles filled with it in wells, or by the application, as customary, of ice or cooling refrigerating mixtures. The most impure of all the wells which I have examined was No. 1 (Table XII. 20), from Newton, Wisbeach, possessed of 48·176° of total, and 49·6° of organic impurity, with 3·2° of mechanical impurity. No. 2 (Table XII. 21), from the same locality, had an impurity of 348·8°, and 21·6° of organic impurity, with 9·33° of mechanical impurity. It will be observed in these instances that no idea of the total matter in solution could have been anticipated from the amount of sediment. And the same observation applies to a well water from Mill Corner, Hadley, (Table XII. 19,) whose mechanical impurity was 37·81, and the total impurity in solution 83·2°, the organic impurity being 27·6°.

Hardness of London Waters.

The hardness of water, so readily distinguishable when water possessed of that property is subjected to friction between the fingers, is a character of importance in reference to domestic purposes. The property of hardness is most readily apprehended when we compare sea or well water with rain water; and when hard water, detected by the sensation communicated to the fingers, is mixed with a solution of soap in distilled water added drop by drop, a precipitate is observed to fall or curdle, which increases, in proportion to the amount or degree of hardness. When we examine the precipitate, which is insoluble in water, it is found to consist of the acid of the soap united with lime and magnesia, previously existing in solution in the water. After the cessation of precipitation, if we filter the water we shall find that it no longer produces the harsh sensation when rubbed between the fingers, but that the removal of the lime and magnesia has deprived it of its hardness. One of the results then, it is obvious, of the hardness of water, in other words, of the presence of earths in solution in water, is to waste the first portions of soap which are added to it when hard water is used for the purposes of washing; and it is likewise evident that, by taking a solution of soap of a given strength, and adding it cautiously to a given quantity of water, we are in a condition to estimate the hardness of the water by the amount of soap solution required to be added before the new precipitation or curdling ceases. The relative hardness of water might therefore be expressed in numbers by the amount of soap consumed by each. But as this quantity might be liable to some variation, it has been agreed, at the suggestion of Dr. Clark, to denote the hardness by the amount of lime and magnesia which causes the curdling of the soap, and to speak of degrees of hardness, each degree of hardness being equivalent to one grain of carbonate of lime per gallon present in the water, distilled water being 0°. Table XI. and Diagram D. give the relative hardness of the waters supplied by the Metropolitan Companies during the period when the analyses detailed in this report were made. From these it appears, that the Chelsea water was the hardest, or 18·4°, and the anomalous water supplied by the New River Company to Soho was the softest, or 9·6°. The mean hardness of the Metropolitan Companies' waters, omitting the Chelsea Company and the Southwark and Hampstead Company, is 13·1°; including the Chelsea and Southwark Companies, it is 14·4°. Judging from preceding investigations in reference to the hardness of the London waters, it appears that they are rather softer in dry weather than after rain, which appears to carry down the calcareous salts into the river in those districts where these substances predominate. One great objection to the use of hard water by a community, is the expense incurred in using it for washing by the waste of soap sustained in the manner already detailed. That this is an important consideration will be readily understood if we take the estimate as correct which makes the amount of soap consumed in the metropolis annually exceed in value half a million sterling, and the washing bills alone upwards of five millions sterling. The facts which have been mentioned in respect to hardness show that a considerable amount of this soap expenditure is due to the earthy salts in the water; and that the softening of the water, or the removal of the earthy salts before coming in contact with the soap, would occasion a material saving in the quantity of soap used in washing. The difference in the composition of water in its natural state and when softened by the process of Dr. Clark, is shown in Table XIV., Nos. 14, 15, 16, and 17. Plumstead water, derived from the fissures in the chalk formations on the Thames, contains 30·9 grains or degrees of salts or impurity per gallon; by softening, this impurity is reduced to 18·06, or by 12·84°, which consist of earthy salts, to which the water owes much of its hardness. Water from similar strata at Watford, as derived from its natural position, contains 22·4° of impurity, and when softened by Dr. Clark's process, suffers a diminution in impurity and hardness to 8·03°, or by 14·37°, the matter removed being, as in the former case, earthy salts, communicating the quality of hardness to the water. Table XIV. shows the relative composition of Watford and Plumstead waters in their natural and softened states.

But there is another perhaps even more serious objection to hard waters (when this property depends on calcareous matter) which has been urged by the best authorities, that they are prejudicial to the health of persons not in the most robust health, or who have a tendency to the formation of urinary deposits. It has been well ascertained that many persons with a predisposition to certain diseases are only attacked by such complaints when their diet has been of an improper description. "Of hundreds of individuals," says Dr. Prout, "in whom the oxalic acid diathesis prevails, a few "only suffer from calculus;" but well marked instances have occured in which an oxalate of lime nephritic attack has followed the free use of rhubarb, "particularly when the patient has been in the habit at the "same time of drinking *hard* water." Again he says:—"The quality "of the water employed is of the utmost importance. Those whose "assimilating organs form oxalic acid, and who at the same time "drink water containing lime, are exceedingly liable to get an "oxalate of lime calculus. The purest water, therefore, that can be "obtained, even distilled water, should in all instances be preferred." The occurrence of oxalic acid in the system is by no means rare; on the contrary, it is so frequent that it has been viewed by some, although probably erroneously, as by no means of import in the category of disease. "Hard and impure waters," again says Dr. Prout, "possess great influence on urinary diseases and deposits; an old "opinion, of which I am constantly reminded by experience. They "operate in various ways, and produce very different effects on "different diseases and constitutions; but their general influence "in all forms of urinray deposition is, according to my observation, "very unfavourable." It is evident that these observations refer to the influence of hard waters generally, as well as to their special effect; and I believe the experience of all who have devoted attention to the chemical conditions of the system will be found consonant with that of Dr. Prout, who is pre-eminently the father of organic chemistry as applied to medicine.

WATERS supplied to PROVINCIAL PLACES affected with CHOLERA. (Table XVII.)

The waters supplied to provincial localities where cholera occurred, in addition to those places already mentioned, were found to be very impure. The waters of Sandgate are exceedingly hard, and vary in composition, being 40·96° or grains of impurity per gallon, and the least impure being possessed of 31·54° of impurity. The amount of organic matter varied from 5·2° to 3·74°. Three samples of water were examined from Newton Abbott, Bovey Tracey; one was from "the running brook from Narrowcombe under Woodhouse "before joining the mine water." It contained 102·1° of impurity and 12·2° of organic matter. A second specimen, "taken from the "mine, consisting of the engine-delivered water from the 40-fathom "shaft, and the washing water from the shutes and platforms" (mine produces lead, silver, zinc, arsenic, &c.), possessed 63·3° of impurity and 8·9° of organic matter. A third sample, "taken "from the stream at Levaton," had 153·24° of total and 7·84° of organic impurity. No traces of any of the metals enumerated could be detected in any of them. But in the first specimen numerous and large crystals of Glauber's salt were obtained by evaporation; a saline aperient by no means desirable as an ingredient in the food of persons either predisposed or actually under the influence of the premonitory stage of cholera.

COMPARISON of the METROPOLITAN WATER SUPPLY with the Water of some other TOWNS.

In the course of this report several important facts have been detailed, which seem to show that the waters supplied for the consumption of the inhabitants are not such as the present condition of medical science warrants the use of. In order that a comparison may be instituted between the London waters and those of various towns and rivers, of which my own observations enable me to furnish data, Table XVI. and Diagram E. are appended. From the facts afforded by these documents, it will be observed that the Scottish towns are in advance of the metropolis in reference to the water supply. Glasgow has long derived its water from the river Clyde, which is possessed of an impurity of 9·57°. The portion of the inhabitants of the city south of the Clyde was, some years ago, not satisfied with using the water of a river which has served as a drain or sewer to an extensive district of country, and succeeded in bringing in a purer water from the adjacent hills. This Gorbals Company's water has an impurity of 7·80°. But even this water, although it is nearly three times purer than the Thames Ditton water after rains, was not sufficiently pure, it was considered, for a large population, and it has now been decided to bring in the water of the romantic Loch Katrine from the borders of the Highlands, with an impurity of only 2° above distilled water. In the diagram E., the inferiority of the London waters is at once caught by the eye, as they commence where the curve rapidly rises. Several of these waters are, no doubt, represented here in their most favourable condition, while others, such as the Chelsea water, appear in their worst aspect, yet all contrast most unfavourably with the earlier portion of the curve. The true theory of a pure water is to collect rain water as soon after it has fallen on the earth as possible, to store it, and expose it to the atmosphere, so that it may absorb air. This is effected most conveniently by having recourse to the origin of streams in their progress down the hill or mountain side, or, in short, by detaching the water from the most convenient and early source of rivers and streams. In a mountainous region, as in the Highlands of Scotland or in Wales, the drainage of a large elevated district is deposited in lakes or natural reservoirs, which ought to be studied by the engineer as the types of the most perfect possible source of a water supply. The data now given exhibit the advantages obtained by procuring water which has traversed the surface of a rock, or soil destitute of much soluble matter. The water of Loch Katrine, derived from a drainage of surface consisting of insoluble mica slate rocks, is a striking example in point. The river Dee likewise, traversing slaty and granitic soils, reaches Aberdeen after a course of upwards of 90 miles with only 4 degrees of impurity; while the river Tay, after draining an extensive district of slate rocks, approaches the sea at Perth with an impurity rarely exceeding 5·5°. The water brought into the town of Stirling with an impurity of 5·29° is derived from hills of considerable elevation, formed of an indurated greenstone trap. An occasional impurity, which might have been wholly prevented in this instance, has been the contamination by the soluble matter of peat turned up in the formation of an artificial reservoir. This source of taint is, of course, avoided when the drainage of a district is received in natural reservoirs in the form of lakes, as in the mountainous parts of the country, or when considerable expense is incurred by the formation of an artificial bed to the reservoir. The impurity in such cases is principally organic matter, which, when burned, evolves the odour of ignited peat, while the amount of saline matter in solution is comparatively insignificant, but, of course, varies with the geological formation on which the rain water falls. In Table XVI. it will be observed that the rivers Tyne, Tweed, and Seine are closely allied in composition, being nearly twice as pure as the river Thames at Thames Ditton in 1851, and about one-third less impure than the same water in 1854. Even the purest wells at Glasgow and Liverpool, which admittedly contain portions of sewage, are superior to the Thames water destined for the supply of a large portion of the metropolis. Yet these wells are about to be abandoned by the inhabitants of those cities as unfit for human consumption, while the inferior Thames water has been only lately fixed on as a proper source of supply. It is impossible to view this circumstance otherwise than as a very unfortunate one.

Superior Sources of Supply for London.

In consequence of the contamination of the river Thames by organic matter, and the resulting tendency to the production of animalcules which I have found in all weathers in the water, even when the temperature of the atmosphere had remained under the freezing point for some weeks, and the liability to the introduction of foreign matter into the other waters, the discovery of a pure source of supply seems to be one of the great questions of the day in relation to the health of the metropolis. To assist in forwarding this important object, it seemed most desirable, not only to be able to detect faults, but likewise to be able to afford some mode of obviating the difficulties pointed out by the chemical examination exhibited in this report. Through the attention of S. C. Homersham, Esq., engineer of the Plumstead Waterworks, I have been enabled to make some analyses of the waters derived from the chalk strata, and to examine upon a sufficiently large scale the method of purifying such water for domestic purposes. The water supplied at the present time to the three parishes of Plumstead, Woolwich, and Charlton, by the Plumstead Consumers' Pure Water Company, is derived from fissures in the chalk by means of a vertical shaft and horizontal adit. The water is pumped up from the adit, and is described by the engineer as being most abundant. The temperature in winter, as taken in my presence, was 49·3°, and as it is conveyed from such a distance under the surface, this is no doubt nearly the mean temperature of the water, as well as of the locality. The temperature of the water obtained from a bore terminating at 584 feet below the surface, or 500 feet below Trinity datum, is 53·25° F.; of that from the adit, at about 115 feet from the surface, 49·3°. (Mr. Homersham.) The water, as brought to the surface, is beautifully clear, and nearly destitute of sediment; and if the temperature remains constant at 49·3° throughout the year, or even within a degree or two of this point, it cannot fail to be a cooling and refreshing beverage. But what must be considered of the greatest importance is the fact of its not being subject to contamination by organic matters; and even if these should gain access to the rain water, which is the primary source of this deep aqueous deposit, the extent of percolation through the porous chalk will tend to oxidize the organic matters, and convert them into new inert forms. The total quantity of impurity in the Plumstead chalk water I found to be 30·9 degrees or grains per imperial gallon; of this 2·72° were organic matter. The hardness of this water I found to be 19·63°, which was due to 11·406° carbonate of lime, 1·45° carbonate of magnesia, and 8·864° sulphate of lime. The carbonate of lime can be removed by Dr. Clark's process, and when thus subjected to the purifying influence of lime the hardness becomes only 7·47°, or the water is made about twice as soft as the river Thames is in its natural state. The softening, however, might be carried a little farther, as I still found nearly half a degree of the residual hardness due to carbonate of lime. In Table XIV. the composition of the Plumstead water before and after softening is exhibited in Columns 3 and 4. The softening process of Dr. Clark is carried out at these works in a most practical and efficient manner, so as to do great credit to the proposer of the chemical plan, and to the engineer by whom the work has been contrived and is conducted. The result of the process seems simply to remove chalk from its state of solution and to precipitate it in the form of a crystalline powder, which, when dry, sparkles in the sun, and under the microscope presents the aspect of minute rhomboidal crystals. Although there seems no evidence, from the comparative analyses, that any organic matter is removed by the softening process from the natural water, at least it is certain that a considerable portion of organic matter remains in the softened water, as has been ascertained by repeated careful trials. Still some circumstances have been noticed, in conducting the process on the large scale, which seem to render it certain that the tendency to vegetation in the softened water is either checked or entirely destroyed. A reservoir, for example, situated at an elevation above the works, when formerly filled with the chalk water as pumped from the well, was covered in its bed with abundance of green aquatic vegetation; but since the introduction of the softened water into the same reservoir few or no symptoms of vegetation are apparent, so that the water is perfectly transparent, and permits the clear bottom to be distinctly visible. This preservative power may be explained by the supposition that the lime and vegetable matter have formed a chemical compound, or that sporules seem less liable to vegetate in an alkaline state derived from causticity than in an acid fluid—an observation which was frequently made, and is noticed under the report of the examination of the atmospheres during the prevalence of the epidemic. The Plumstead water seems well adapted for domestic use. The only drawback is, that the hardness still remains at 7½°, even after the application of the softening process; and this is incapable of further reduction, in consequence of the lime salt (the cause of the hardness) being in the state of a soluble sulphate of lime, which remains unaffected by the addition of milk of lime to the water. There seems ground of belief, however, that the waters, stored in the chalk formations, vary in their relative composition somewhat in different localities. Thus the Gravesend water appears to be capable of undergoing a greater amount of softening than that brought to the surface at Plumstead; and there can be little doubt that a selection might be made of softer descriptions of water, and better adapted for the application of the softening process, should proper attention be directed to the waters deposited in the chalk strata, which have hitherto received a less share of public interest than their importance and value seem to demand. The geological observations which have been made on the chalk strata appear to indicate that unlimited supplies of water may be obtained from these porous deposits, which at present pass into the sea or the river Thames, and require only to be intercepted, as they have been at Plumstead, to afford this important beverage, in a comparatively pure form, to any amount of population. I am indebted to Mr. Homersham, likewise, for the opportunity of being able to make an analysis of hard and softened water of a still purer description from the chalk of Watford, a source from which it has been proposed to convey the purified water to town in pipes. A company was formed for the purpose; but, as in many other attempts to improve the health of the metropolis, private influence seems to have failed. The Watford water (Table XIV. 1 & 2) was found to have a total impurity of 22°, and a hardness of 17·45°. The organic matter amounted to 1·4°. When softened by liming, the total impurity is found to be 8·030°, and the hardness is reduced to 2·75° or it is diminished by 14·7°. Hence we see, that by this purifying process we are able to obtain a water which, originally of the same degree of impurity as Thames water, becomes in some measure comparable with the water supplied to Glasgow, &c. (Table XVI., 9. Diagram E.)

These and other sources of supply in the environs of the metropolis are well deserving of attention, from the commercial companies to whom London is at present indebted for its water supply.

I have not succeeded in detecting lead in any of the specimens of water subjected to examination, although some of the waters possessed an action on lead when experiments were made on a small scale in the laboratory. This affords evidence that, so far as the metropolitan waters are concerned, the corrosion of lead is not a practical objection to the employment of pipes and cisterns of that metal, although no doubt it would be preferable to dispense with its use if possible. Although sulphuretted hydrogen has not been described in this report as entering into the composition of Thames water, I obtained abundant evidence of its presence in the river, during the construction of the Thames Tunnel, when water from the river saturated with that gas made its way into the tunnel, and proved injurious to the workmen by escaping from its solution and contaminating the atmosphere.

Summary.

The facts communicated in these reports seem to demonstrate:

1. That in the waters examined, which were taken from houses where deaths had occurred from cholera, with some exceptions impurity was their characteristic feature; and that it is difficult to disconnect this fact from the propagation of the epidemic.
2. That some of the metropolitan waters were particularly impure; and that even water derived from the river Thames at the point from which the water of that river is soon to be entirely taken for the supply of London, contains matters which show that it is subject to contamination by most objectionable impurities.
3. That the water distributed to the metropolis, when compared with that of many other towns, stands low in the scale of purity and wholesomeness.
4. That the shallow wells of London and of other localities in the immediate neighbourhood of human habitations, being surrounded by matter soaking in from cesspools and surface filth, are liable to be impregnated with surface impurities, and that their closure would be a benefit to the health of the community.
5. That the waters derivable from the environs of London which are not liable to be contaminated with human excretions deserve to be thoroughly investigated, not only in their chemical relations, but likewise as to the possibility of their existing in sufficient abundance to satisfy the demands of a large population.
6. That from the remarkably variable chemical character of the metropolitan water supply, the frequent periodical examination of the waters as distributed to the houses in London might have a beneficial influence in securing a more agreeable and wholesome form of fluid for consumption.

Robert Dundas Thomson, M.D.

St. Thomas's Hospital,
January 1855.

TABLES exhibiting the CHEMICAL COMPOSITION of METROPOLITAN WATERS, September to December 1854.

TABLE I.

TABLE exhibiting the DEGREES of IMPURITY of the RIVER THAMES between VAUXHALL and GREENWICH, each Degree being equal to One Grain per Gallon.

—	Vauxhall.	Hungerford.	London Bridge.	Greenwich.
I. *High Water, 8th December* 1854.				
Mechanical impurity	60·50	64·64	63·44	—
Organic „ -	5·28	5·80	4·72	—
Inorganic „ -	36·64	45·24	45·08	—
Total Impurity -	102·42	115·68	113·24	—
II. *Low Water, 2d September* 1854.				
Mechanical Impurity	10·26	16·80	3·52	3·70
Organic „ -	4·34	8·40	7·36	19·44
Inorganic „ -	12·54	23·64	21·20	72·54
Total Impurity -	27·14	48·84	32·08	95·68

THAMES DEPOSIT alongside the DREADNOUGHT.

	Dec. 1850.	March 1850.
Water - - - -	9·04	9·27
Organic Matter - - -	21·28	15·45
Silica and Clay - - -	69·68	75·28
	100·	100·

TABLE II.

TABLE exhibiting the DEGREES of IMPURITY of LAMBETH WATER COMPANY, or RESIDUE, per Gallon, in Grains.

—	Date when taken.	Cholera Cases.	HOUSE.	Degrees of Total Impurity, or Total Residue, per Gallon, in Grains.	Organic Matter.
	1854.		*Lambeth District.*		
*1	Sept. 5	1	66, Wootten Street - -	13·72	
2	„	1	111, Cornwall Road - -	13·03	
3	„	1	107, Cornwall Road - -	13·	
4	„	1	17, Commercial Road -	13·07	
5	„	0	126, Waterloo Road - -	14·16	
			Mean - -	13·39	
			St. Peter's, Walworth.		
6	Sept. 16	1	22, Carter Street - -	12·78	1·44
7	„	2	4, Little King Street, Kent Road - - - -	13·78	1·46
8	„	2	7, Monmouth Place - -	12·38	1·08
9	„	3	1, Bedford Court - -	12·12	1·74
10	„	2	21, Bolingbroke Row -	15·74	1·46
			Mean - -	13·36	1·43
11	Nov.10		126, Waterloo Road - -	17·49	1·36
12	„		Ditto ditto - -	17·40	1·40
13			Mean - -	17·44	1·38
	Sept. 3		Thames Ditton - -	15·76	

* Water in cisterns is found to deposit carbonate of lime.

TABLE III.

TABLE exhibiting the DEGREES of IMPURITY in GRAND JUNCTION WATER, each Degree equal to One Grain per Gallon.

—	Date when taken.	Cholera.	HOUSE.	Degree of Total Impurity.	Organic Matter.
	1854.			°	°
1	Sept. 9	3	3, South Row, Soho - -	13·04	3·56
2	„	3	5, South Row, Soho -	15·34	4·46
3	„	2	14, Cambridge Street, Soho	16·10	3·82
4	„	4	13, Marshall Street, Soho -	13·36	3·04
5	„	3	39, Broad Street, Soho -	14·46	4·00
			Mean - -	14·46	3·78
6	Nov. 10	- -	5, South Row, Soho - -	17·98	1·88
7	„	- -	Ditto ditto - -	17·92	1·92
			Mean - -	17·95	1·90

TABLE III*.

TABLE exhibiting the DEGREES of IMPURITY in WEST MIDDLESEX WATER.

—	Date when taken.	Cholera.	HOUSE.	Degrees of Total Impurity.	Organic Matter.
	1854.			°	°
1	Sept.	- -	77, Upper Berkeley Street	19·04	1·78
2	Nov. 16	- -	St. John's Wood - -	18·97	2·08
			Mean - -	19·00	1·93

TABLE IV.

TABLE exhibiting DEGREES of IMPURITY in SOUTHWARK AND VAUXHALL WATER, each Degree equal to One Grain per Gallon.

—	Date when taken.	Cholera.		HOUSE.	Degrees of Total Impurity.	Organic Matter.
		Cases.	Deaths.			
	1854.			*Lambeth District.*	°	°
1	Sept. 5	-	2	131, Waterloo Road - -	39·64	5·51
2	„	-	1	154, Waterloo Road - -	40·83	-
3	„	-	2	29, Wootton Street - -	39·25	3·65
4	„	-	1	15, Eaton Street - -	39·69	4·78
5	„	-	1	41, Brad Street - -	34·18	3·57
				Mean - -	38·72	4·38
				St. Peter's, Walworth.		
6	Sept. 16	-	2	10, Berkeley Terrace -	46·76	4·26
7	„	-	2	25, Bolingbroke Row -	50·62	4·38
				Mean - -	48·69	4·32
				St. James's, Bermondsey.		
8	„	7	2	Flora Cottage, Blue Anchor Road - - -	34·72	3·72
9	„	-	2	Cottage Row - - -	45·24	3·32
10	„	-	2	9, Prospect Row - -	72·66	4·80
				Mean - -	50·87	3·64
				St. Thomas's Hospital.		
11	Aug. 31	-	-	Laboratory - - -	56·04	4·50
12	Nov. 3	-	-	Cab Stand - - -	41·78	3·64
13	„ 16	-	-	Laboratory - - -	41·80	4·19
				Mean - -	41·79	3·91
	1855.*					
14	Mar. 15	-	-	Laboratory - - -	22·50	2·82
15	„	-	-	Cab Stand - - -	23·80	4·00
16	April 15	-	-	Ditto - - -	23·40	2·16
				Mean - -	23·23	2·99
17	May 7	-	-	Laboratory - - -	32·20	1·86
18	June 7	-	-	Cab Stand - - -	41.88	4.68
				Clapham.		
18	Sept.	-	-	Main Pipe - - -	54·44	6·26
19	„ 29	-	-	Wandsworth Road, 12, Neptune Street -	68·92	5·20

* These five cases have been added since the report was drawn up.

TABLE V.

Table exhibiting the Degrees of Impurity in Chelsea Water, each Degree equal to One Grain per Gallon.

—	Date when taken.	Cholera.		House.	Total Impurity or Total Residue, in Degrees or Grains.	Organic Matter.
		Additional Cases.	Deaths.			
	1854.				°	°
1	Sept. 27	2	2	53, Queen's Road West	60·34	4·96
2	„ „	6	2	27, Lawrence Street -	64·30	5·90
3	„ „	4	1	3, Heatley's Buildings, Manor Street -	50·40	5·30
4	„ „		2	5, Lawrence Street -	65·66	5·50
				Mean -	60·17	5·41
5	Dec. 8	-	-	3, Heatley's Buildings, Manor Street -	36·96	

TABLE VI.

Table exhibiting the Degrees of Impurity in New River Water Company, or Residue per Gallon in Grains.

—	Date when taken.	Cholera.		House.	Degrees of Total Impurity, or Total Residue, in Grains per Gallon.	Organic Matter.
		Additional Cases.	Deaths.			
	1854.			*Soho District.*	°	°
1	Sept. 9	3		3, Broad Street - -	33·84	
2	„ „	3	2	10, Portland Mews, Portland Street -	27·04	
3	„ „	5	2	5, Berwick Street -	30·10	2·46
4	„ „	8	8	9, Hopkins Street -	33·26	2·
5	„ „	3	2	11, Hopkins Street -	34·94	2·02
6	„ „	6		23, Peter Street -	22·14	1·6
7	„ „	6		9, Broad Street - -	19·18	
				Mean -	28·64	2·02
8	Nov. 10			9, Hopkins Street -	35·05	1·98
				New River Head.		
1	Oct. 7			Sadler's Wells Theatre	16·32	1·27
	„ „			„ „ „	15·75	1·76
2	Nov. 10			„ „ „	20·78	2·33
				Mean -	17·62	1·78
3	Oct. 4			Bayley's Yard, Allen Street, Clerkenwell -	17·22	1·46

TABLE VII.

Table exhibiting the Degrees of Impurity in East London Water Company, Residue per Gallon in Grains.

—	Date when taken.	Cholera.	House.	Total Impurity or Total Residue, in Degrees or Grains.	Organic Matter.
	1854.			°	°
1	Oct. 7	-	Canal, Lea Bridge -	18·62	
2	„ „	-	„ „	19·00	1·62
3	„ „	-	4, Allen's Cottages, Park Place, Bow - -	17·74	1·60
4	„ „	-			
5	„ „	-	„ „ „	17·02	
6	„ „	-	25, Willis Street, Bow -	18·44	2·20
			„ „ „	18·98	2·48
			Mean - -	18·30	1·97
7	1855. Jan.	-	Brunswick St., Blackwall	19·60	1·60

TABLE VIII.

Table exhibiting the Degrees of Impurity in Kent Water.

—	Date when taken.	House.	Impurity; Total Residue in Degrees or Grains.	Organic Matter.
	1854.		°	°
1	Sept. 30	From Tap at Works - - -	21·10	2·80
2	„ „	From Filter at Works - -	17·16	1·72
3	„ „	97, New Street, Deptford - -	15·02	1·48
		Mean - -	17·76	2·00

TABLE VIII*.

Table exhibiting the Degrees of Impurity in Hampstead Water.

—	Date when taken.	House.	Impurity; Total Residue in Degrees or Grains.	Organic Matter.
	1854.		°	°
1	Sept.	—	24·22	3·88

TABLE IX.

TABLE exhibiting the COMPOSITION of THAMES WATERS in Grains per Gallon as found by Analysis.

—	I. Lambeth Company, supplied at Thames Ditton.	II. Grand Junction Company, supplied at Brentford.	III. West Middlesex Company, supplied at Barnes.	IV. Chelsea Company, supplied at Vauxhall.	V. Southwark and Vauxhall Company.
Organic Matter - -	1·390	1·920	2·080	5·410	3·560
Silica - - - -	·350	·090	·520	1·511	·240
Sesquioxide of Iron, Alumina, and Phosphates - - -	·215	·730	·460	·639	·460
Insoluble Lime - -	5·680	4·967	5·555	5·348	5·992
Soluble Lime - -	·944	·975	·868	2·649	2·374
Insoluble Magnesia -	·281	·343	·342	·209	·238
Soluble Magnesia - -	·260	·228	·157	1·283	·886
Sodium - - -	·379	·372	·643	11·708	5·967
Potassium - - -	·328	·249	·259	1·304	1·086
Chlorine - - -	1·020	·980	1·160	19·554	12·160
Sulphuric Acid - -	1·599	1·647	1·504	6·043	2·980
Carbonic Acid - -	9·550	8·560	9·106	8·862	9·941
Nitric Acid - - -	—	—	—	—	·050
Ammonia - - -	·023	—	—	—	·297

1. *Lambeth Company.* Sample taken from cistern, 126, Waterloo Road, 10th November 1854.
2. *Grand Junction Company.* Sample from cistern, 5, South Row, Golden Square, 10th November 1854.
3. *West Middlesex Company.* Cistern, 11, Marlborough Hill, St. John's Wood, 16th November 1854.
4. *Chelsea Company.* Mixed Salts from 53, Queen's Road, 27, and 5, Lawrence Street, 3, Heatley's Buildings, from cisterns.
5. *Southwark and Vauxhall.* From the Stand pipe opposite St. Thomas's Hospital, 3d November 1854.

The terms insoluble and soluble refer to the chemical characters of the residue by evaporation.

TABLE IX.*

TABLE exhibiting the COMPOSITION of THAMES WATERS, in Grains per Gallon, calculated from the preceding TABLE.

—	I. Lambeth Company.	II. Grand Junction Company.	III. West Middlesex Company	IV. Chelsea Company.	V. Southwark and Vauxhall Company.
Organic Matter - -	1·390	1·920	2·080	5·410	3·560
Silica - - -	·350	·090	·520	1·511	·240
Sesquioxide of Iron, Alumina, and Phosphates. - - -	·215	·730	·460	·639	·460
Carbonate of Lime -	10·144	8·870	9·919	9·550	10·700
Sulphate of Lime - -	2·149	2·368	2·109	6·432	3·179
Chloride of Calcium -	—	—	—	—	2·108
Nitrate of Lime - -	trace	trace	trace	trace	·076
Carbonate of Magnesia	0·592	0·720	·720	·438	0·500
Sulphate of Magnesia -	—	—	—	1·390	—
Chloride of Magnesium	·617	·542	·360	1·947	2·101
Sulphate of Potash -	·730	·553	·577	2·903	2·413
Chloride of Sodium -	·966	·947	1·637	29·797	16·001
Total - - -	17·153	16·740	18·443	60·017	40·564
Residue by Evaporation	17·440	16·920	18·970	60·170	41·780
Carbonate of Ammonia	·064	—	—	—	·840

TABLE X.

TABLE exhibiting the COMPOSITION of the NEW RIVER, EAST LONDON, and KENT COMPANIES' WATERS, as found by Analysis, in Grains per Gallon.

—	VI. New River, New River Head.	VII. New River Company, supplied to Soho.	VIII. East London.	IX. Kent Company.
Organic Matter - -	2·330	1·980	1·940	1·480
Silica - - - -	·180	·780	·320	·420
Sesquioxide of Iron, Alumina, and Phosphates - - -	·400	·210	·520	·130
Insoluble Lime - -	6·712	3·967	6·718	5·342
Soluble Lime - -	·918	·627	·449	1·254
Insoluble Magnesia -	·407	·565	·354	·100
Soluble Magnesia -	trace	trace	·100	·400
Sodium - -	0·925	9·951	·442	·343
Potassium - - -	·320	·569	·307	·518
Chlorine - - -	1·430	4·740	·860	1·240
Sulphuric Acid - -	1·393	6·015	·841	2·344
Carbonic Acid - -	11·442	11·554	11·336	8·616
Nitric Acid - - -	trace	trace	trace	trace
Ammonia - - -	trace	trace	trace	trace

6. The analysis here given is of a mixed salt from the open conduit at Sadler's Wells, and of water from the reservoir.

7. The water was taken from the cistern at 9, Hopkins Street.

8. The East London salts were obtained from waters mixed from cholera houses enumerated in Table VII., and from the New Canal at Lea Bridge.

9. Kent Company. This sample was a mixed one, as mentioned in Table VIII.

TABLE X.*

TABLE exhibiting the COMPOSITION of the NEW RIVER, EAST LONDON, and KENT COMPANIES' WATERS, as calculated from the preceding Tables, in Grains per Gallon.

—	VI. New River Company, New River Head.	VII. New River Company, supplied to Soho.	VIII. East London Company.	IX. Kent Company.
Organic Matter - -	2·330	1·980	1·940	1·480
Silica - - - -	·180	·780	·320	·420
Sesquioxide of Iron, Alumina, and Phosphates - - -	·400	·210	·520	·130
Carbonate of Lime -	11·985	7·085	11·997	9·540
Sulphate of Lime - -	1·812	1·523	·897	3·085
Chloride of Calcium -	—	—	—	—
Nitrate of Lime - -	trace	trace	trace	trace
Carbonate of Magnesia -	·855	1·185	·743	·210
Carbonate of Soda -	trace	4·909	—	—
Sulphate of Magnesia -	trace	trace	trace	trace
Chloride of Magnesium	trace	—	·237	·949
Sulphate of Potash -	·712	1·266	·682	1·153
Sulphate of Soda - -	—	8·051	—	—
Chloride of Sodium -	2·355	7·807	1·125	·874
Total - - -	20·629	34·796	18·461	17·841
Residue by Evaporation	20·780	35·050	18·300	17·760

TABLE XI.

TABLE exhibiting the DEGREES of HARDNESS of METROPOLITAN WATERS.

Each Degree equal to One Grain of Carbonate of Lime per Gallon.

Lambeth Company - - -	13°2
New River Company (New River Head) -	14·0
Grand Junction Company - - -	12·6
Kent Company - - - -	12·2
East London Company - - -	14·2
West Middlesex Company - -	12·8
New River Company (supplied to Soho) -	9·6
Southwark and Vauxhall Company - -	18·2
Chelsea Company - - - -	18·4

Table XII.

Table exhibiting the Degrees or Grains per Gallon of Impurity of London Wells.

Distilled water, 0°.

	Date.	Situation.	Total Impurity in Degrees or total Residue in Grains.	Organic Matter and Nitric Acid.	Degrees of Mechanical Impurity.
1.	Jan. 18, 1854	Aldgate pump -	49°12	13°94	°
2.	Feb. 1854 -	Ditto - - -	44·64	6·30	
3.	Mar. 1855 -	St. Thomas's pump	89·70	10·40	
4.	May 15, 1854	Camberwell -	62·67	10·69	
5.	Nov. 25, 1854	Ditto - - -	48·72	7·26	
6.	July 20, 1854	Blackheath - -	28·00		
7.	Sept. 1854 -	Broad-street, Soho -	92·06	7·80	
8.	„ „ -	Buckingham Palace well - - -	59·00	8·08	
9.	„ „ -	Charing-cross Artesian well, supplied at Buckingham Palace - -	56·04	2·12	
10.	- - -	Putney, Cock's-buildings - -	180·40	16·00	
11.	- - -	„ Price's-folly -	101·30	14·00	
12.	- - -	„ Stratford-grove	67·20	14·80	

Provincial Wells.

	Date.	Situation.	Total Impurity	Organic Matter and Nitric Acid.	Degrees of Mechanical Impurity.
12*	Jan. 1854 -	Newcastle Military well - - -	100·56	15·052	
13.	Sept. 1854 -	Brasted, Kent -	54·10	8·300	1·5
14.	Oct. 21, 1854	Plumstead, hard (in chalk) - -	30·90	2·720	
15.	„ „ -	„ softened -	18·06	2·800	
16.	Nov. 1854 -	Watford, hard (in chalk) - -	22·40	1·400	
17.	„ „ -	„ softened -	8·03	1·420	
18.	- - -	Nottingham - -	42·24	3·200	101·87
19.	- - -	Hadley, Mill-corner	83·20	27·600	37·81
20.	- - -	Newton, Wisbeach, „ No. 1 -	481·76	49·600	3·20
21.	- - -	„ No. 2 -	348·80	21·600	9·33

Table XIII.

—	Well at Camberwell. May 15, 1854.	Well at Camberwell. Nov. 25, 1854.	Well in Broad-street, Soho, Sep. 9. 1854.
Organic matter, nitric acid, ammonia - - -	12·900	7·260	7·800
Silica - - - - -	- - -	·320	·539
Sesqui-oxide of iron, alumina, and phosphate of lime -	·250	·180	·944
Carbonate of lime - -	3·710	7·080	13·926
Sulphate of lime - - -	25·899	12·758	11·874
Chloride of calcium - -	- - -	3·424	14·928
Carbonate of magnesia -	·097	1·380	1·618
Chloride of magnesium -	- - -	4·749	7·550
Sulphate of potash - -	6·104	4·202	14·883
Carbonate of soda - -	- - -	1·113	5·233
Chloride of sodium - -	13·850	6·134	12 070
Total - -	62·840	48·600	91·555
Residue by evaporation -	62·690	48·720	92·060

Table XIV.

Table exhibiting the Composition of the Watford and Plumstead Chalk Waters in their natural State, and when softened by Dr. Clark's Process.

—	1. Watford. *Hard Water.*	2. Watford. *Softened Water.*	3. Plumstead. *Hard Water.*	4. Plumstead. *Softened Water.*
Organic matter - -	1·400	1·420	2·720	2·800
Silica - - - - - -	·480	·680	·720	·720
Alumina, sesqui-oxide of iron, and phosphate of lime - -	·240	·120	·340	·280
Carbonate of lime - - -	15·280	·520	11·406	·400
Sulphate of lime - - -	·377	·590	8·864	8·976
Nitrate of lime - - -	1·599	1·580	—	—
Carbonate of magnesia - -	·870	·390	1·450	·400
Sulphate of potash - - -	·569	·569	·284	·284
Sulphate of soda - - -	- -	- -	1·235	1·445
Chloride of sodium - - -	1·153	1·548	3·558	3·064
Total per gallon - - -	21·968	7·327	30·577	18·369
Residue by evaporation - -	22·400	8·030	30·900	18·280
Hardness - - - -	17·45	2·74	19·63	7·47

TABLE XV.

TABLE exhibiting the IMPURITY of PROVINCIAL WELL WATERS expressed in Degrees or Grains per Gallon.

			Total Residue in Degrees or Grains.
		GLASGOW WELLS.	
1.	June 1847	Stirling-square	99°5
2.	Feb. 1848	St. David's	83·3
3.	" "	Bridge-gate	84·4
4.	Jan. 1848	Orr-street	79·8
5.	Feb. 1848	Cheapside	71·9
6.	" "	Cannon-street	58·84
7.	March 1848	Ditto	66·20
8.	Feb. 1848	Wilson-street West	64·20
9.	June 1847	George-street	57·90
10.	Feb. 1848	Cochrane-street	51·80
11.	June 1847	Union-street	52·90
12.	" "	St. Vincent-street	51·60
13.	Feb. 1848	Norfolk-street	50·64
14.	March 1848	Ditto	43·24
15.	June 1847	Glassford-street	40·00
16.	" "	Infirmary Well	25·60
17.	" "	Lady Well	17·73
18.	" "	Arn's Well (Green)	14·9
		LIVERPOOL WELLS.	
1.	Jan. 19, 1850	Vauxhall-road (1050 yds. from river)*	417·02
2.	" "	Batchelor-street (760 do)	299·45
3.	" "	Crone's Sugar Refinery	228·48
4.	" "	Barton's Tan-yard	237·90
5.	" "	Smithfield (800 yards from river)	226·25
6.	" "	Steele's Soapwork	113·68
7.	" "	Gregson's Sawmills	107·91
8.	Jan. 21, 1850	Holmes's, Benson-street	51·01
9.	" "	Bevington Bush	48·63
10.	Feb. 14, 1850	Ditto	55·90
11.	Jan. 21, 1850	Copperas-hill	31·60
12.	- - -	Hotham-street	29·60
13.	- - -	Windsor Station	25·50
14.	- - -	The Park	22·95
15.	- - -	Edgehill	22·29
16.	- - -	Soho	22·30
17.	- - -	Bootle	19·40
18.	- - -	Ditto	18·90
19.	- - -	Windsor Well	17·96
20.	- - -	Water-street	17·80
21.	- - -	Green-lane	13·80

* The distances supplied by James Newlands, Esq., C. E.

TABLE XVI.

TABLE exhibiting the DEGREES of IMPURITY in WATERS used for the Supply of Towns in England, Scotland, &c.; each Degree being equal to One Grain per Gallon.

	Distilled water	0°·
1.	Loch Katrine	2·
2.	Dee, Aberdeen	4·
3.	Tay, Perth	5·5
4.	Stirling	5·29
5.	Dumfries	6·96
6.	Paisley	7·59
7.	Gorbals	7·80
8.	Leven	8·60
9.	Clyde	9·57
10.	Tyne, Newcastle	11·16
11.	Tweed, Coldstream	11·66
12.	Seine, Paris	11·78
13.	Liverpool Well (purest)	13·80
14.	Glasgow Well (ditto)	15·00
15.	Kilmarnock	15·22
16.	Thames Ditton (1854)	15·52
17.	" " (1851)	21·33
18.	Swindon	17·51
19.	Glasgow Well (most impure)	96·00
20.	Liverpool Well (ditto)	417·02

TABLE XVII.

TABLE of the IMPURITIES in WATERS supplied to some Provincial Places in Grains or Degrees per Gallon.

		Total Degrees of Impurity, or Grains per Gallon.	Degrees of Organic Impurity.
1. Bovey Tracy, Newton Abbott	Brook	102·1	12·20
2. Ditto	Mine	63·3	8·90
3. Ditto	Stream	153·24	7·84
4. Sandgate—Bellevue House		40·96	5·20
5. Ditto Reservoir		31·54	4·00
6. Ditto Mr. George's house		31·64	3·74