

XXIII.—*The Water Supply of the Metropolis during the Year*
1865–66.

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[Abstracted from the Annual Report to the Registrar-General.]

THE following are the results obtained in the monthly analyses of the metropolitan waters, during the year commencing February, 1865, and ending January, 1866* :—

The analytical determinations are conducted as follows:—1000 cubic centimetres of the water are evaporated in a weighed platinum dish on the water-bath, an accurately measured quantity of a solution of sodic carbonate of known strength having been previously added. The solution used contains 10 grammes of pure

* The analyses in the early part of the year were made by Dr. A. W. Hofmann.

dry sodic carbonate in one litre of water, and the quantity employed for one litre of the water under examination is 10 c.c., or .1 gramme of sodic carbonate.

The evaporation having been completed, the dish is transferred to an oil-bath, where it is exposed to a temperature of 120° — 130° C. (248° — 266° F.); it is then allowed to cool under a desiccator and weighed as quickly as possible, again exposed to the same temperature as before for about half an hour, and these operations are continued until the weight is constant. The weight of the dish and of the sodic carbonate added, being subtracted from that thus ascertained, the amount of solid residue in the quantity of water employed is obtained.

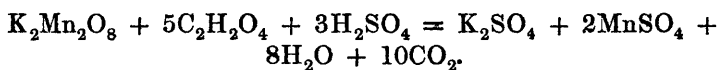
The dish containing the residue is now carefully ignited, and maintained at a dull red heat, until the organic matter has been burnt off. It is then allowed to cool, and a saturated aqueous solution of carbonic acid added, in quantity varying, of course, according to the amount of calcic and magnesian carbonates present, which is previously determined with sufficient accuracy by means of the soap test; every decigramme of calcic carbonate is supposed to require 20 c.c. of carbonic acid water.

When sufficient carbonic acid has been added, the dish is dried at the same temperature as before until its weight is constant. The difference between this last weight and that before ignition represents the amount of organic and other volatile matter in the quantity of water employed. The next step has for its object the determination of the amount of oxygen necessary to oxidise the organic matter, and for this purpose a standard solution of potassic permanganate is used. This is prepared and applied in the following manner:—

$\frac{1}{200}$ th of the molecular weight of oxalic acid in grammes, viz., .6300 gramme of crystallised oxalic acid ($C_2H_2O_4 \cdot 2aq.$) is accurately weighed out (after pressing between filter-paper), and dissolved in one litre of distilled water, which has been purified by re-distillation from potassic permanganate and sulphuric acid. About .4 gramme of potassic permanganate is now dissolved in another litre of water that has been similarly purified. A quantity of the oxalic acid solution (10 or 20 c.c.) is then accurately measured out into a large flask; the quantity of purified distilled water necessary to make it up to half a litre is added; and 15 c.c. of dilute sulphuric acid (1 vol. of acid to 5 of water) mixed with the whole. The permanganate is now added,

in small quantities at a time, from a burette furnished with a glass stop-cock, to the oxalic acid solution, care being taken to mix the liquids well after each addition. A portion of the mixed liquids is then poured into a glass cylinder 12 inches in height, and $1\frac{1}{2}$ inch in diameter, which is placed on a white surface. If, on looking down this column of liquid, a distinct pink coloration is visible at the expiration of ten minutes, the reaction is complete, and the number of c. c. of permanganate used is compared with the quantity of oxalic acid employed. The ratio of the two quantities having been observed, the strength of the permanganate solution is altered in such a manner that (as nearly as possible) n vols. of oxalic acid solution will require n vols. of permanganate solution to produce the above mentioned result. This experiment must now be repeated, and the strength of the permanganate altered, if necessary, until the desired result is obtained.

The following is the reaction which takes place in this experiment :—



One molecule of permanganate oxidises 5 molecules of acid, and, therefore, if the oxalic acid solution be of the strength of .63 grm. per litre (or .00063 grm. per c. c.), each c. c. of permanganate solution will contain .000316 grm. of pure potassic permanganate, as appears by the following calculation :—

Molecular weight of oxalic acid $\times 5$.	Molecular weight of potassic permanganate.	Amount of oxalic acid in 1 c. c.
630	316	: : .000630 grm. : x .

x = amount of pure permanganate in 1 c. c. = .000316 grm.

This amount of permanganate represents .00008 gramme of available oxygen, as the following calculation shows :—

Molecular weight of potassic permanganate.	Atomic weight of oxygen $\times 5$.	Amount of permanganate in 1 c. c.
316	80	.000316 grm. : x .

x = .00008 grm. = amount of oxygen in 1 c. c.

A measured quantity of the water to be analysed is now taken (half a litre is a convenient quantity), and 15 c. c. of dilute sulphuric acid (of the same strength as that used in standardizing

the potassic permanganate solution) having been mixed with it, the solution of permanganate is slowly added (exactly as in the experiment described above), until a pink coloration remains after the lapse of ten minutes. If the turbidity of the water, or the products of the oxidation of the organic matter contained in it, render the pink coloration undecided, a fresh experiment is made with 250 c. c. of the water, diluted with an equal quantity of purified distilled water. Should the amount of organic matter be small (requiring less than 1 c. c. of the permanganate), a litre of the water is used.

The number of c. c. of permanganate used is read off, and multiplied by the number that expresses what aliquot part of a litre of the analysed water was employed. The number thus obtained is now multiplied by .00008 (amount of oxygen in 1 c. c.), and we then have the amount of oxygen necessary to oxidise the organic matter in a litre of the water.

The above experiments are best performed by daylight.

The last operation consists in the application of Clark's soap-test, which is performed in the ordinary manner. The *permanent* hardness is determined after boiling the water for half an hour.

The results contained in the tables marked A, B, C, D, will now be sufficiently intelligible. Table A contains the amount of solid matter left on evaporation, and desiccation at 120°—130° C. (248°—266° F.); Table B, the loss which this matter undergoes on incineration; Table C, the amount of oxygen required to oxidise the organic matter; and, lastly, Table D, the degrees of permanent, temporary, and total hardness. The results are recorded in 100,000 parts.

Thus:—In September, 1865, we find, on referring to table A, that 100,000 lbs. of Chelsea water contained 24.45 lbs. of solid matter, of which, we find, by Table B, that 1.20 lbs. was driven off by incineration; from Table C, we learn that .0368 lb. of oxygen was required to oxidise the organic matter, in the said quantity of Chelsea water; while from Table D, we find that 18.1 lbs. of the solid residue were calcic carbonate, or its equivalent of hardening salts, of which 12.4 lbs. were removed by boiling, and 5.7 lbs. remained.*

* The degree of hardness hitherto employed by chemists is that first proposed by Dr. T. Clark, viz., one grain of calcic carbonate, or its equivalent, in one imperial gallon of water. The degrees in the above table are readily converted into Clark's degrees by multiplying by 7.

The tables may also be read (a) in the French method, *i. e.*, milligrams per kilogram, or litre, and (b) in the English method, *i. e.*, grains per gallon. As to the first method:—by moving the decimal point one place to the right, the above figures express in milligrams the quantities contained in one kilogram of the several waters. As to the second method:—A gallon of water weighs 10 lbs., and the amount of each constituent in grains per gallon is at once found by multiplying the numbers in the tables by $\cdot 7$. Thus, in September, 1865, a gallon of Chelsea water contained 17·115 ($= 24\cdot45 \times \cdot 7$) grains of solid residue.

I have also drawn out four additional tables marked respectively E, $F_{(1)}$, $F_{(2)}$, and G.

In these tables, the horizontal lines, on the left of which figures are placed, represent the respective number of parts of the constituent mentioned at the head of each table contained in (or required for) 100,000 parts of the waters. The spaces between the perpendicular lines represent the respective months the names of which appear at the head of the table.

The various curves against which the names of the Water Companies appear, represent, in the waters delivered by those companies, the monthly variation in the amount of the constituent mentioned at the head of each table, and also the amount of such constituent at any given time of the year.

Thus, for example, we find, on referring to Table A, that the analysis of a sample of water supplied by the New River Company in February, 1865, showed that it contained 29·60 parts of solid matter in 100,000 parts of the water; a reference to the records of the analysis (not given in the monthly tables) shows that the water in question was collected on February, 24. Accordingly these three facts are represented by the line marked "New River," commencing rather above midway between 29 and 30 on Table E, at a position in the space representing February corresponding to the above date.

The points belonging to the other months are determined in a similar manner.*

An inspection of the curves drawn in these tables shows that river waters—viz. those supplied by the Thames, New River, and East London (River Lea) Companies—are subject to variations which occur but to a slight extent in the spring

* As the hardness of the waters was only estimated during the last five months of the year, the curves exhibiting its variation are omitted.

or artesian well waters delivered by the Kent and South Essex Companies.

The total solid matter contained in the former waters undergoes in all three cases a tolerably uniform diminution to the end of April; between which time and the end of May it suffers, in all cases, a sensible increase, after which it again diminishes to June and July. There is, then, a series of slight oscillations until November 1, when the curves make a sudden and enormous rise, which is tolerably well maintained until the end of the year.

It will also be found that the curves representing the variation in organic and other volatile matter, and in the oxygen required to oxidise the organic matter, take, in the case of the river waters, substantially the same form.

It is interesting to compare these curves with that representing the rain-fall during the same periods, given in Table H.

This comparison shows clearly (as might be anticipated) how closely the condition of river waters is connected with the amount of rain-fall; but, in opposition to the commonly received opinion, it proves that the waters in question are much purer in dry than in wet weather, even if the drought occurs during a very hot summer. Such, at all events, is the result of one year's observations; but it would obviously be premature to generalise upon the condition of the waters during a single year, which has been, moreover, in several respects, an exceptional one. For the same reason I will merely point out (without attempting to account for) the remarkable diminution in the amount of oxygen required to oxidise the organic matter of the river waters soon after the sudden rise due to the heavy rain-fall in October—the actual proportion of organic matter exhibiting no corresponding decrease.

The constituents of the well waters are, as above mentioned, subject to less variation than those of the river waters. To this rule however the organic matter contained in the former offers a notable exception. The curves of these waters representing the total solid residue and oxygen required to oxidise the organic matter (given in Tables E and G), give some indications of following the rain-fall curve, although those in Table F₍₂₎, representing the organic and other volatile matters, exhibit no such tendency.

TABLE A.
Solid Matter in 100,000 parts of the Waters.

Names of Water Companies.	1865.											1866.	Mean.
	Feb.	March.	April.	May.	June.	July.	August.	Sept.	Oct.	Nov.	Dec.	Jan.	
THAMES COMPANIES.													
Chelsea	31·72	29·47	26·62	26·60	24·43	23·53	23·75	24·45	23·67	24·98	28·00	30·12	26·44
West Middlesex	30·63	30·16	26·70	25·70	24·27	22·42	23·22	23·75	24·16	25·30	28·91	32·02	26·43
Southwark	32·62	30·14	26·79	27·33	24·63	22·76	23·68	25·45	18·78	29·32	31·32	29·90	26·89
Grand Junction	32·11	29·85	26·58	27·85	24·95	22·94	23·18	24·50	24·56	26·99	29·51	30·70	26·97
Lambeth.....	31·36	29·10	25·69	27·60	25·34	23·15	25·18	25·35	25·26	22·76	29·06	27·10	26·41
OTHER COMPANIES.													
Kent	38·07	38·50	36·20	37·52	38·82	37·63	39·03	39·60	34·92	38·08	37·45	37·70	37·79
New River	29·60	27·20	23·42	24·02	22·60	22·94	22·40	23·85	19·40	27·59	30·02	29·92	25·24
East London	34·62	32·70	25·57	27·40	22·59	22·17	22·50	25·70	24·32	29·14	33·90	35·15	27·98
South Essex	43·36	42·36	42·40	38·50	40·19	41·25	40·69	37·75	37·68	40·54	38·10	40·59	40·23
Columns	1	2	3	4	5	6	7	8	9	10	11	12	13

TABLE B.
Organic and other Volatile Matter in 100,000 parts of the Waters.

Names of Water Companies.	1865.											1866.		Mean.
	Feb.	March.	April.	May.	June.	July.	August.	Sept.	Oct.	Nov.	Dec.	Jan.		
THAMES COMPANIES.														
Chelsea	3.05	2.05	1.33	2.02	1.10	0.93	0.87	1.20	0.72	1.83	1.52	1.44	1.50	
West Middlesex	3.07	2.20	1.46	1.45	1.50	0.96	1.08	1.00	0.97	1.96	1.49	1.80	1.57	
Southwark	3.40	2.45	1.65	1.70	1.40	1.16	1.18	1.40	0.84	2.32	1.98	1.85	1.77	
Grand Junction	2.72	2.27	1.30	1.90	1.37	0.85	1.12	0.95	0.81	1.67	1.91	1.65	1.54	
Lambeth	2.70	2.00	1.14	1.95	1.55	0.97	1.12	1.45	1.34	2.17	1.08	1.94	1.61	
OTHER COMPANIES.														
Kent	1.55	2.66	1.85	1.94	1.57	1.67	1.66	2.30	1.74	1.04	0.61	1.26	1.65	
New River	2.00	1.73	0.95	0.65	1.05	0.55	0.93	0.65	0.77	0.73	0.54	1.30	0.98	
East London	3.30	2.48	1.35	1.65	0.88	1.03	0.88	0.90	0.86	2.42	1.56	2.24	1.62	
South Essex	2.70	2.48	1.75	1.65	2.23	2.50	2.56	1.20	0.84	1.44	0.86	1.69	1.82	
Columns	1	2	3	4	5	6	7	8	9	10	11	12	13	

TABLE C.
Amount of Oxygen required to oxidise Organic Matter in 100,000 parts of the Waters.

Names of Water Companies.	1865.											1866.		Mean.
	Feb.	March.	April.	May.	June.	July.	August.	Sept.	Oct.	Nov.	Dec.	Jan.		
THAMES COMPANIES.														
Chelsea	·0856	·0328	·0456	·0760	·0576	·0480	0592	·0368	·0384	·1606	·1942	·1184	·0794	
West Middlesex.....	·0812	·0448	·0400	·0551	·0528	·0560	·0576	·0336	·0304	·1076	·1045	·0336	·0581	
Southwark	·0811	·0544	·0512	·0816	·0840	·0720	·0565	·0408	·0416	·1521	·1972	·0568	·0791	
Grand Junction.....	·0776	·0384	·0504	·0508	·0480	·0480	·0464	·0352	·0400	·0943	·1722	·0627	·0636	
Lambeth.....	·0840	·0488	·0512	·0680	·0720	·0700	·0688	·0392	·0720	·1950	·0842	·1288	·0818	
OTHER COMPANIES.														
Kent	·0892	·0168	·0152	·0096	·0064	·0080	·0088	·0088	·0048	·0156	·0070	·0096	·0149	
New River	·0496	·0248	·0204	·0184	·0264	·0192	·0208	·0152	·0096	·0421	·0396	·0152	·0251	
East London	·0744	·0344	·0200	·0488	·0336	·0336	·0188	·0272	·0240	·1341	·1274	·0291	·0504	
South Essex	·0084	·0160	·0112	·0104	·0080	·0160	·0052	·0096	·0048	·0140	·0112	·0096	·0103	
Columns	1	2	3	4	5	6	7	8	9	10	11	12	13	

Degrees of Hardness.

One degree = one part of CaHCO_3 (or its equivalent) in 100,000 parts of the waters. The columns marked with the letter (a) show the degrees of "Permanent;" those marked (β) of "Temporary;" and those marked (γ) of "Total" hardness.

Names.	1865.															Mean.			
	September.			October.			November.			December.			January.						
	a.	β.	γ.	a.	β.	γ.	a.	β.	γ.	a.	β.	γ.	a.	β.	γ.		Perma- nent.	Tempo- rary.	Total.
THAMES COMPANIES.																			
Chelsea.....	5·7	12·4	18·1	4·5	12·0	16·5	6·7	7·8	14·5	7·0	9·1	16·1	5·5	15·5	9·21·4	5·88	11·44	17·32	
West Middlesex.....	5·6	11·8	17·4	4·4	12·7	17·1	6·4	11·1	17·5	6·8	11·9	18·7	6·7	14·7	21·4	5·98	12·44	18·42	
Southwark.....	5·1	12·7	17·8	3·5	12·9	16·4	8·2	9·5	17·7	7·4	11·5	18·9	6·2	14·0	20·2	6·08	12·12	18·20	
Grand Junction.....	6·0	12·1	18·1	4·2	12·2	16·4	6·8	11·0	17·8	7·4	11·0	18·4	5·7	15·4	21·1	6·02	12·32	18·34	
Lambeth.....	5·0	13·8	18·8	3·7	13·7	17·4	7·6	5·4	18·0	8·8	7·6	16·4	6·4	9·0	15·4	6·30	9·90	16·20	
OTHER COMPANIES.																			
Kent.....	7·9	17·4	25·3	7·8	15·9	23·7	9·7	17·7	27·4	8·8	17·4	26·2	9·2	17·3	26·5	8·68	17·14	25·82	
New River.....	4·1	13·7	17·8	3·4	13·8	17·2	5·5	15·6	21·1	7·0	14·1	21·1	5·7	18·0	23·7	6·14	15·04	20·18	
East London.....	5·3	13·7	19·0	4·0	13·4	17·4	9·0	13·2	22·2	7·2	15·0	22·2	6·1	18·7	24·8	6·32	14·80	21·12	
South Essex.....	6·7	17·7	24·4	6·1	15·0	21·1	8·2	18·3	26·5	5·8	19·0	24·8	7·8	17·9	25·7	6·92	17·58	24·50	
Columns.....	1			2			3			4			5			6			

TABLE E

SHOWING THE MONTHLY VARIATION IN THE AMOUNT OF
SOLID MATTER IN 100 000 PARTS.

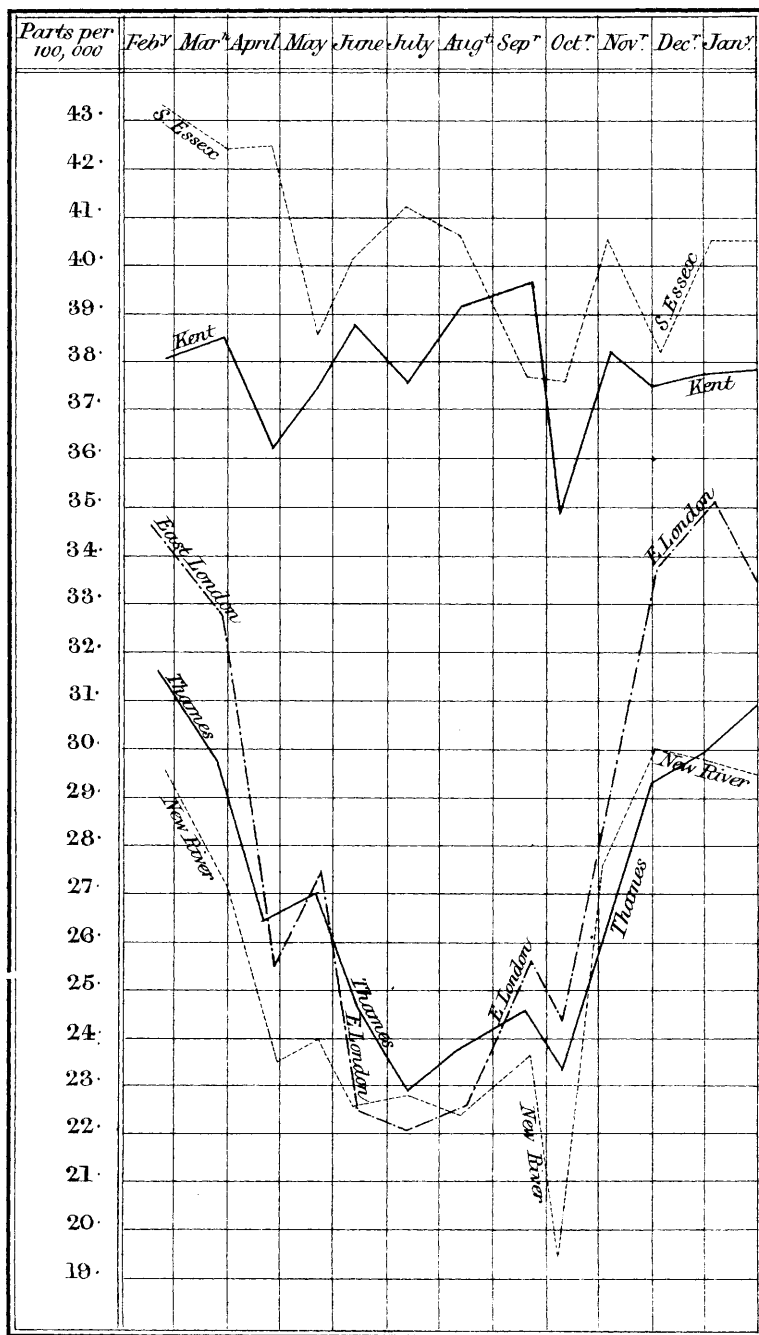


TABLE F (1)

SHOWING THE MONTHLY VARIATION IN THE AMOUNT OF ORGANIC
AND OTHER VOLATILE MATTER IN 100,000 PARTS.

RIVER WATERS.

2

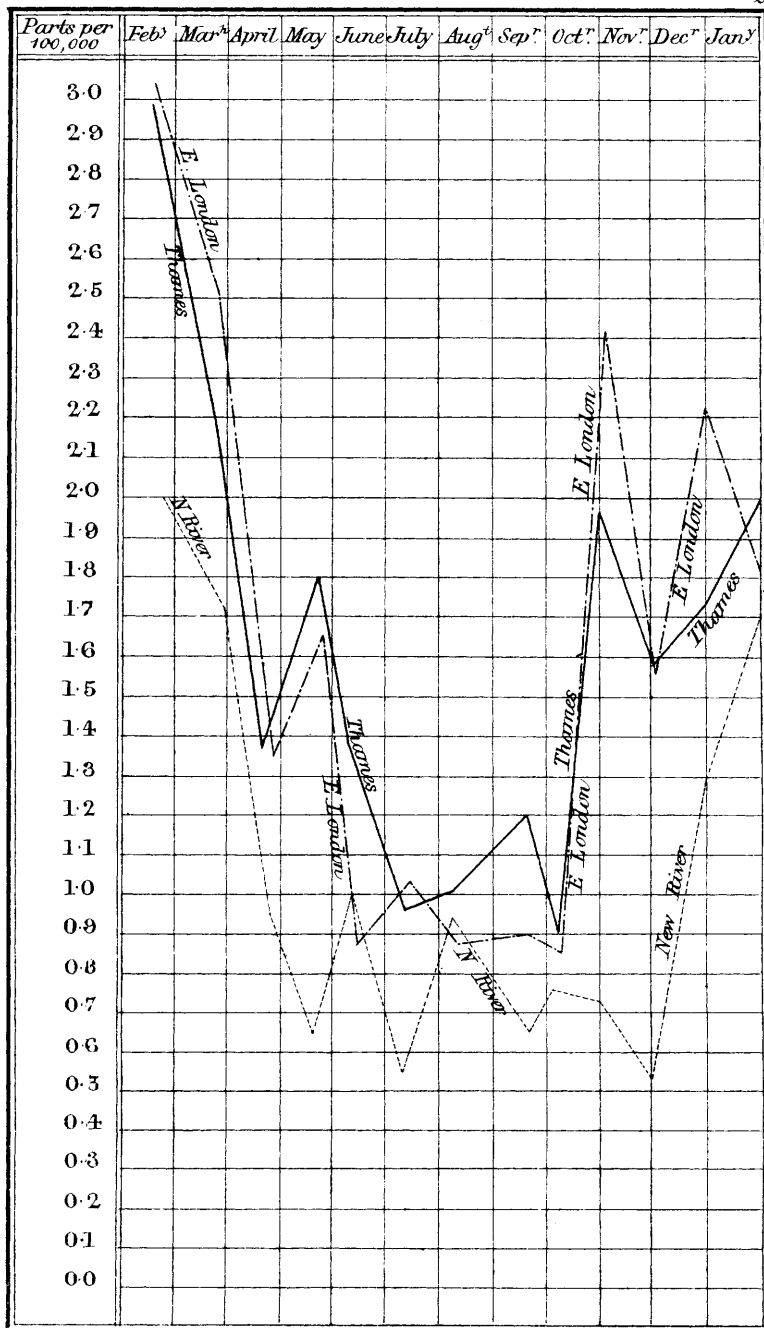


TABLE F (2)

SHOWING THE MONTHLY VARIATION IN THE AMOUNT OF ORGANIC
AND OTHER VOLATILE MATTER IN 100,000 PARTS
WELL WATERS.

3

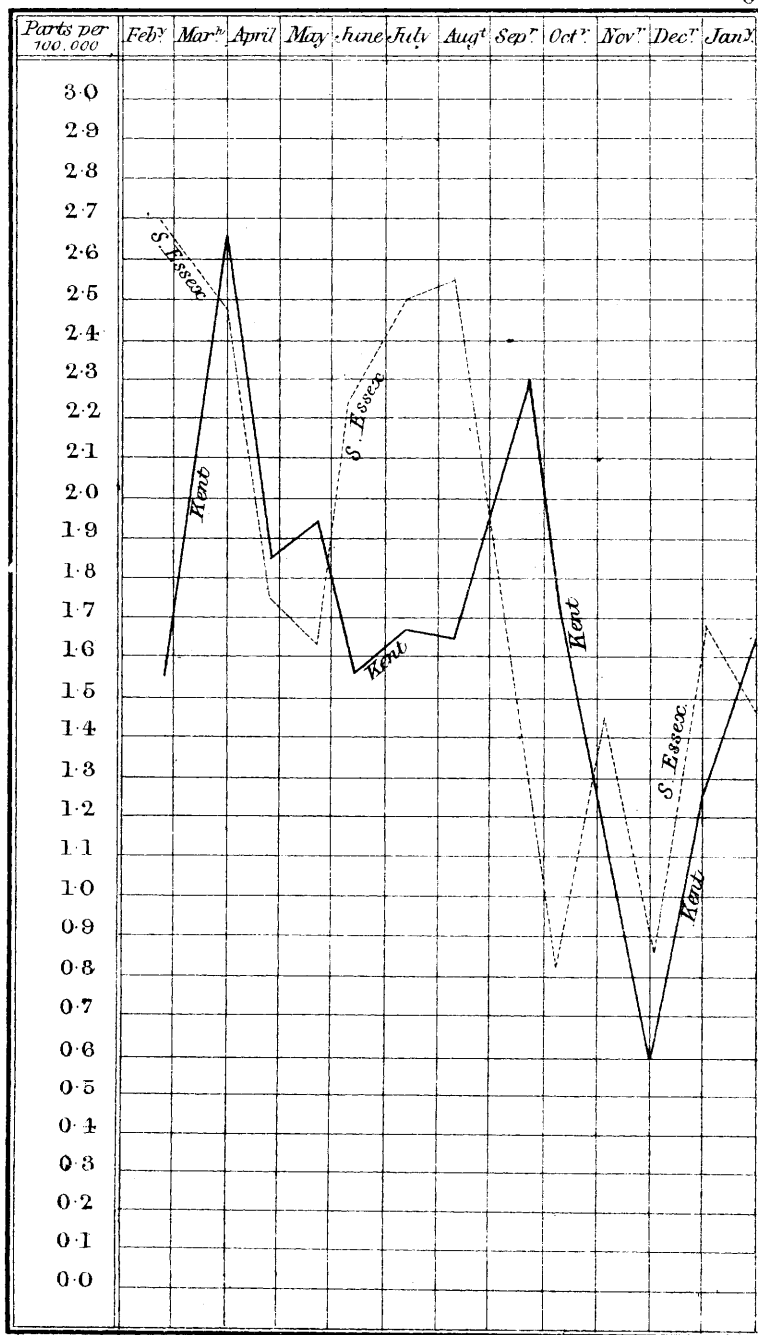
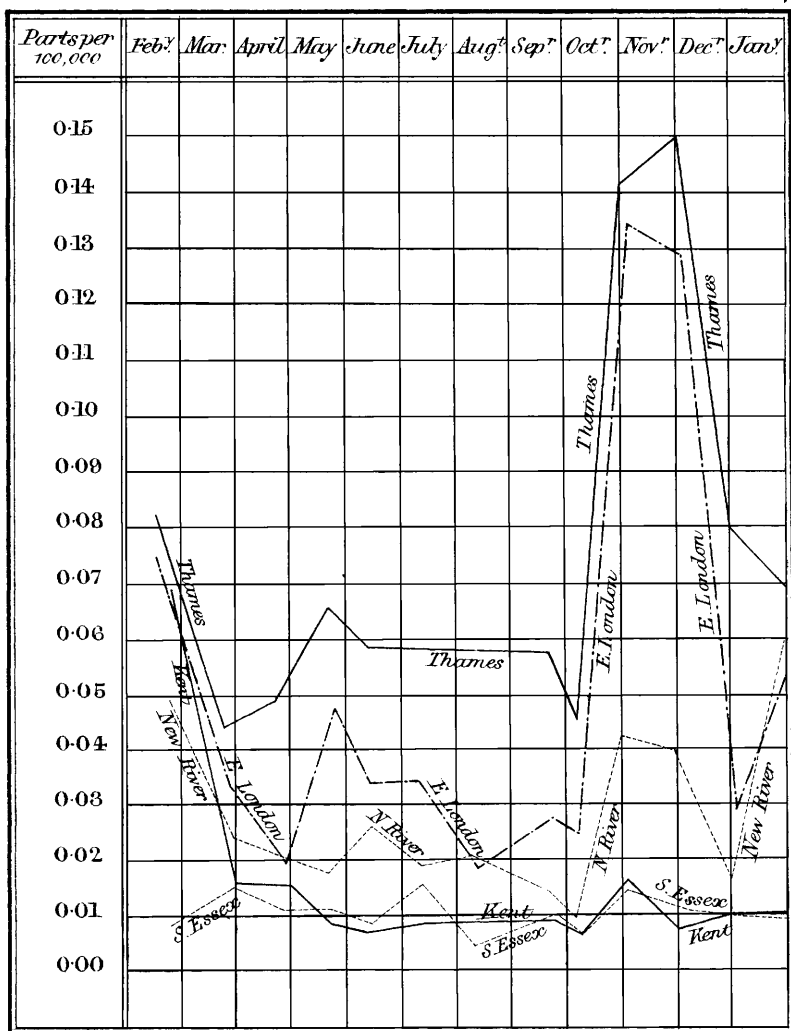


TABLE G.

SHOWING THE MONTHLY VARIATION IN THE AMOUNT OF
OXYGEN REQUIRED TO OXIDISE THE ORGANIC MATTER IN
100,000 PARTS.

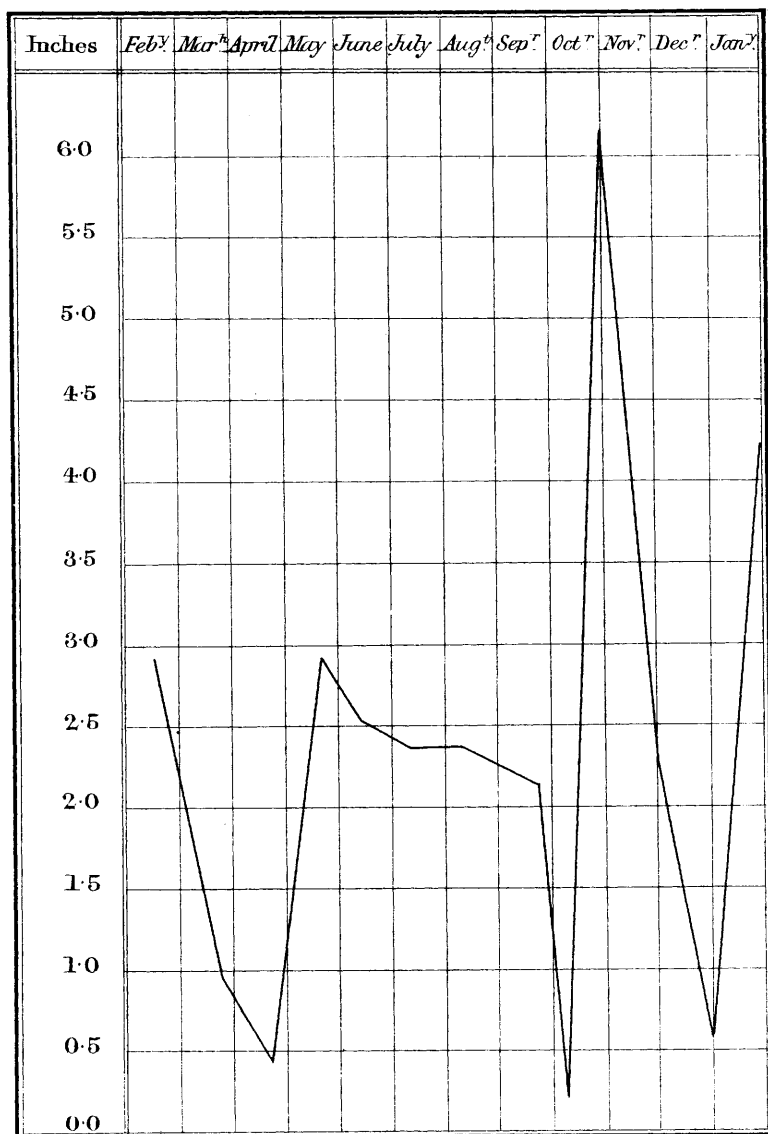
4



Harrisons Lib. St. Martins Lane

TABLE H

SHewing THE RAIN-FALL AT GREENWICH DURING
THE YEAR COMMENCING FEBRUARY 1865 & ENDING
JANUARY 1866.



Harrison's Wh. 8^o Martins Lane.