THE
QUARTERLY JOURNAL
OF THE
CHEMICAL SOCIETY.

VII.—*Chemical Composition of the Waters of the Metropolis
during the Autumn and Winter of 1854.*

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THE important bearing of the composition of the waters supplied to the inhabitants of the metropolis on the public health, may serve as a sufficient apology for the addition of another to the many previous investigations which have been instituted on this subject. The valuable report communicated to this Society in 1851, details researches which were made under particular circumstances during the winter season, and at a time when the diluting influence of recent rain had tended to modify the constitution of the metropolitan waters. In the present paper it is intended to comprise a summary of an extensive series of analyses which were made from the 1st of September, 1854, to the beginning of the present year. From these results it is apparent that the waters supplied to London possess in many respects a fluctuating character, which may tend in some measure to explain the antagonistic views that have at different times been entertained with regard to their adaptation to domestic purposes.

In order to determine the composition of the waters as supplied to the inhabitants, specimens of water were taken from houses generally in which the epidemic had proved fatal, and these were compared,

when the object could be conveniently accomplished, with samples obtained from the sources of supply.

In the course of the inquiry it was observed that the composition of the Chelsea and Southwark Companies' waters depended so much on the state of the river under different circumstances, that it was found necessary to examine the Thames at various periods of the tidal flow, so as to obtain a basis for the explanation of remarkable apparent discrepancies. The following table gives the composition of the river in different parts of its course at high and low waters, the Vauxhall samples having been obtained at a point intermediate between those from which the Chelsea and Southwark Companies derive their supply. The amounts are stated in grains per gallon, convertible into degrees of impurity.*

TABLE I.
High Water.

	Vauxhall.	Hungerford.	London Bridge.	Greenwich.
Mechanical impurity . . .	60°50	64°64	63°44	—
Organic impurity . . .	5·28	5·80	4·72	—
Inorganic impurity . . .	36·64	45·24	45·08	—
Total impurity . . .	102·42	115·68	113·24	—
Chlorine . . .	22·00	24·00	24·00	—

Low Water.

Mechanical impurity . . .	10·26	16·80	3·52	3·70
Organic impurity . . .	4·34	8·40	7·36	19·44
Inorganic impurity . . .	12·54	23·64	21·20	72·54
	27·14	48·84	32·08	95·68

In collecting these specimens, care was taken that each series should be obtained on the same day, and as nearly as possible at each locality at the corresponding periods of the tide.

When this table is compared with that which now follows, the varying composition of the Thames waters, taken from the lower portion of the river's course, obviously depends on the chemical state

* I have proposed, in concurrence with the opinion of some eminent engineers of water-works, to designate pure distilled water by 0, and to express by degrees equivalent to grains per gallon the mechanical and soluble matters contained in water.

of the water in the river as affected by the tidal flow at the period when the Company's engines are in action.

TABLE II.
Total Residue in Thames Waters.

		Grains per Imperial Gallon.				
		Lambeth Company.	Grand Junction Company.	West Middlesex Company.	Chelsea Company.	Southwark Company.
August, 1854	. . .	—	—	—	—	56·26
September, „	. . .	13·37	14·42	19·04	60·17	48·18
October, „	. . .	—	—	—	—	43·50
November, „	. . .	17·40	17·92	18·97	—	41·78
December, „	. . .	—	—	—	36·96	—
March, 1855	. . .	—	—	—	—	23·15

According to these data, which are the means of many experiments, the Southwark and Vauxhall water is more than twice as impure in August as in March. These numbers, however, do not convey a correct idea of the highest extreme obtained, since in September the water has been found to contain 72·66 grains per gallon on one occasion in Walworth. A similar observation applies to the water of the Chelsea Company. But it will be observed that the higher sources of supply from the river afford the purest water during the dry seasons, and the largest amount of matter in solution during the wet seasons, as the rains bring down the soluble constituents of the soil from the agricultural districts, and add to the total amount both of earthy and alkaline salts. In the following series, the analyses are divided into two groups, Tables III. and IV., the first comprising the Thames waters, and the second those obtained from other sources. The total water supplied to the metropolis by the various companies in 1853, amounted to 60,614,420 gallons, of which 28,638,576 gallons were derived from the Thames. Considerable modifications in these works have been introduced by some of the water companies within a recent period, which have contributed to improve the quality of the waters. Thus, the Lambeth Company's water is now obtained from Thames Ditton, while important new cuttings have been made by the East London Company, so as to avoid the influence of contaminating sewage. As the object in view in making the present investigation, was to determine the nature of the water as used in the

several localities from which the samples were taken, the specimens were usually collected from the cisterns, if possible, at the time when the service-pipe was delivering the supply. This may account for some differences in the amount of carbonate of lime, which is well known to precipitate to some extent by exposure.

In all the waters collected during the course of the inquiry, abundance of animal and vegetable life was detected in mechanical suspension, and although the experiments were in some measure in abeyance before the cold weather set in, remarkable examples were incidentally noticed, during the severest frost, of the persistence of vitality among some of the larger animal forms familiar to those who have microscopically examined the Southwark water. The fibrine of the fæces has also constantly been obtained from service-pipes of the Southwark Company,—a fact which has led to further investigation in reference to the presence of other products of animal origin in the Lambeth and Southwark waters, these two waters being derived from the two extremes of the river, so far as the Thames Companies are involved. The results of these inquiries are included in Table III., under the head of carbonate of ammonia, and under Table V. As the waters from Thames Ditton and from the Thames at Vauxhall were tested for ammonia on the same day, the difference in the amount of ammonia in favour of Vauxhall water is obviously due to the influence of human excretions. And it would also appear from experiments on other rivers not subject to the reception of sewage, that the Thames Ditton water is supplied with an excess of ammonia due to the influence of different sources of pollution. In a chemical paper no attempt to discuss the nature of the organised matter diffused through the waters has been made. The analyses were made from quantities of the residual ash obtained by evaporation.

TABLES III. and IV.

Composition of Metropolitan Waters.

	Grains per Imperial Gallon.							
	Thames Waters.					Other Waters.		
	I.	II.	III.	IV.	V.	I.	II.	III.
	Lambeth Company.	Grand Junction Company.	West Middlesex Company.	Chelsea Company.	Southwark Company.	New River Company.	East London Company.	Kent Company.
Organic matter.....	1·390	1·920	2·080	5·410	3·560	2·330	1·940	1·480
Silica	·350	·090	·520	1·511	·240	·180	·320	·420
Sesquioxides of iron, alumina, and phosphates.	·215	·730	·460	·639	·460	·400	·520	·130
Insoluble lime	5·680	4·967	5·555	5·348	5·992	6·712	6·718	5·342
Soluble lime	·944	·975	·868	2·649	2·374	·918	·549	1·254
Insoluble magnesia	·281	·343	·342	·209	·238	·407	·354	·100
Soluble magnesia	·260	·228	·157	1·283	·886	trace	·100	·400
Sodium	·379	·372	·643	11·708	5·967	·942	9·951	·343
Potassium	·328	·249	·259	1·304	1·086	·320	·307	·518
Ammonia	·023	—	—	—	·297	—	—	—
Sulphuric acid	1·599	1·647	1·504	6·043	2·980	1·393	·841	2·344
Chlorine	1·020	0·980	1·160	19·554	12·160	1·430	·860	1·240
Nitric acid.....	—	—	—	—	·050	—	—	—
Carbonic acid	9·550	8·560	9·880	9·106	9·941	11·442	11·336	8·616
Organic matter.....	1·390	1·920	2·080	5·410	3·560	2·330	1·940	1·480
Silica	·350	·090	·520	1·511	·240	·180	·320	·420
Sesquioxide of iron, alumina, and phosphates.	·215	·730	·460	·639	·460	·400	·520	·130
Carbonate of lime.....	10·144	8·870	9·919	9·550	10·700	11·985	11·997	9·540
Sulphate of lime	2·149	2·368	2·109	6·432	3·179	1·812	·897	3·085
Nitrate of lime	trace	trace	trace	trace	·076	trace	trace	trace
Chloride of calcium	—	—	—	—	2·108	—	—	—
Carbonate of magnesia...	·592	·720	·720	·438	·500	·855	·743	·210
Sulphate of magnesia	—	—	—	1·390	—	—	—	—
Chloride of magnesium...	·617	·542	·360	1·947	2·101	trace	·237	·949
Sulphate of potash	·730	·553	·577	2·903	2·413	·712	·682	1·153
Chloride of potassium	—	—	—	—	trace	—	—	—
Sulphate of soda	—	—	—	trace	trace	—	—	—
Carbonate of soda.....	—	—	—	—	trace	—	—	—
Chloride of sodium	·966	·947	1·637	29·797	16·001	2·355	1·125	·874
Total	17·153	16·740	18·443	60·017	40·593	20·629	18·461	17·841
Residue by evaporation	17·440	16·920	18·970	60·170	41·780	20·780	18·300	17·760
Carbonate of ammonia...	·064	—	—	—	·840	—	—	—
Hardness	13·2	12·6	12·8	18·4	18·2	14·	14·2	12·2

AMMONIA IN THE LAMBETH AND SOUTHWARK COMPANIES' WATERS.

As the absolute and relative amount of ammonia present in water, in addition to the quantity of nitric acid, is a question of vital importance in regard to the sources of the contaminating influences to which waters are subjected, it seemed desirable to make the experiments upon such a scale of magnitude, that minor difficulties occurring on the small scale of operations might be obviated. In the subsequent tables, exhibiting the amount of ammonia present in Southwark water, the quantity operated on was always 50 gallons, which were introduced into a copper still, and boiled for a considerable time in order to precipitate the carbonate of lime. About 2 gallons of distilled water were usually drawn off, and were never found alkaline; from which it might be inferred that no carbonate of ammonia existed in the water: but the distillation was scarcely protracted sufficiently long to decide this question. About half a pint of strong caustic soda was then poured into the boiler, and the 2 gallons of distilled water returned. When the amount of ammonia present in the water was considerable, the distilled fluid gave evidence of an alkaline reaction in about two minutes after the addition of the soda, which accounts for the facts exhibited in the table, of the largest amount of ammonia being found to exist in the second half gallon, as in Nos. 1 and 2. When the quantity of ammonia was feeble, as in No. 4, no alkalinity was detected till the fourth half gallon was distilled. The rate at which the ammonia distilled was found to depend, in a great measure, on the mode of the application of the heat to the still, the higher the temperature the more rapid being the evolution of the ammonia, as in Nos. 1 and 2; while in No. 5, the gradual application of the heat caused the alkalinity to be appreciable even in the eighteenth half-gallon of distilled water.

The alkalinity was neutralised in all the experiments in the table by sulphuric acid diluted to such a degree, that 100 alkalimeter measures saturated 38·46 of soda, or 21·112 of ammonia. Each 100 measures, therefore, contained 49·67 parts of sulphuric acid. In order to check the numbers determined by the neutralising acid, the whole of the fluids, after the addition of a slight excess of acid, were evaporated to dryness, and the residual sulphate of ammonia, freed from a small portion of lime with which it was usually contaminated, dried cautiously in a dry atmosphere and weighed. The controlling numbers thus obtained are exhibited in Table VI. Generally they exceed the quantity procured by means of the acid process, because several additional gallons which were drawn off, although destitute of

any appreciable alkalinity, were acidified and boiled down to obtain their residue, which was added to the rest of the sulphate. The Southwark and Vauxhall water was examined on this extensive scale, because the operation could be conveniently performed; but in the case of the Lambeth water, as the fluid required to be brought from a distance, the distillation was made with 10 gallons; acid was added to the distillate until the reaction indicated an excess; the water was cautiously evaporated; and the ammonia determined as platino-sal-ammoniac. In the case of the St. Thomas's Well, the amount distilled from was 50 gallons.

TABLE V.

Southwark.

Half-Gallons.	Measures of Acid.				St. Thomas's Well.
	I. Nov. 30, 1854.	II. Dec. 22, 1854.	III. January 5, 1855.	IV. March 17, 1855.	V. March 17, 1855.
1st	8.5	11.0	6.0	0.0	8.0
2d	11.5	13.0	6.0	0.0	6.0
3d	6.0	9.0	4.0	0.0	6.0
4th	5.5	7.0	4.0	2.0	5.0
5th	5.5	6.0	4.0	1.5	4.0
6th	5.5	6.0	4.0	1.5	3.5
7th	5.5	5.0	5.0	1.0	3.5
8th	—	4.0	5.0	1.0	3.0
9th	—	4.0	2.0	1.0	3.0
10th	—	3.0	0.0	1.0	2.5
11th	—	2.5	0.0	0.5	2.0
12th	—	—	0	0.5	2.5
13th	—	—	—	—	2.0
14th	—	—	—	—	1.5
15th	—	—	—	—	1.0
16th	—	—	—	—	1.0
17th	—	—	—	—	0.5
18th	—	—	—	—	0.5
	48.0	70.5	40.0	10.0	55.5

TABLE VI.

Amount of Ammonia in Southwark and Lambeth Waters.

	Nov. 30 1854.	Dec. 22. 1854.	Jan. 5, 1855.	Mar. 17 1855.	St. Tho. Well. Mar. 17 1855.
Southwark and Vauxhall Water, and St. Thomas's Well:—					
Ammonia (NH_3) in 50 gallons, deter- mined by an acid	10·134	14·884	8·444	2·111	11·717
Ditto, by evaporation as sulphate . . .	—	—	—	2·575	11·874
Ammonia (NH_3) per gallon, determined by acid	·203	·298	·169	·042	·234
Ditto, by evaporation as sulphate . . .	—	—	—	·0515	·2375
Carbonate of ammonia ($\text{NH}_3 \text{CO}_2 \text{HO}$), per gallon	·573	·850	·477	·119	·661
Lambeth Water Company:—					
Ammonia, per 10 gallons	·2290	—	—	—	—
Ditto, 1 gallon	·0229	—	—	—	—
Carbonate of ammonia, per gallon . . .	·0640	—	—	—	—

SOFTENING PROCESS FOR WATERS.

Having had an opportunity of witnessing on an extended scale at Plumstead, under the management of Mr. Homersham, the efficiency of Dr. Clark's softening process, it may be satisfactory to subjoin analyses of two chalk-waters in their natural and softened conditions:—

	Watford.		Plumstead.	
	Hard.	Soft.	Hard.	Soft.
Organic matter	1·400	1·420	2·720	2·800
Silica	·480	·680	·720	·720
Alumina and phosphates	·240	·120	·340	·280
Carbonate of lime	14·131	·520	11·400	·400
Carbonate of magnesia	·870	·390	1·450	·400
Sulphate of lime	1·887	·500	8·864	8·976
Nitrate of lime	1·521	1·580	—	—
Sulphate of potash	·569	·569	·284	·284
Sulphate of soda	—	—	1·235	1·445
Chloride of sodium	1·153	1·548	3·558	3·034
Total	22·251	7·327	30·577	18·359
Residue by evaporation	22·400	8·030	30·900	18·28

These data are sufficient, if any were required, to demonstrate that practically the softening process is as successful as theory would indicate.