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CONTRIBUTIONS TO OUR KNOWLEDGE OF SEWAGE.

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In the year 1872, one of us had occasion to report* the results of the chemical examination of a considerable number of samples of the sewage of Boston and of Worcester, Mass. The examinations then made included the determination of the nitrogen existing as ammonia or in the form of ammoniacal salts (tabulated as free ammonia), and of the nitrogen which was given off as ammonia by treatment with an alkaline solution of permanganate of potash, according to the well-known method of Wanklyn. As indicating the total amount of organic nitrogen, this last determination—that of the so-called "albuminoid ammonia"—was felt at the time to be inadequate, but under the then existing circumstances it was the best that could be done.

When Kjeldahl's process for the determination of the total nitrogen in organic substances was published a few years ago,† it suggested itself at once that the method might possibly be conveniently applied to the analysis of sewage. Circumstances have prevented, until recently, the carrying out of this idea; meanwhile, the process has found extensive application, especially in agricultural laboratories, and has been used in the analysis of certain kinds of fertilizers. It is possible that it may have elsewhere been applied to the examination of sewage; if so, we have failed to meet with notice of such application, which we find to be quite practicable and to give satisfactory results.

In order to familarize ourselves with the process and, at the same time, to become satisfied of its substantial accuracy, determinations of

* Fourth Annual Report of the State Board of Health of Massachusetts. Boston, 1873. Pp. 65–81.

† *Fresenius Zeitschrift*, xxii (1883), p. 366; *Chemical News*, xlviii (1883), p. 101.

the total nitrogen were made in sulph-urea, in dried and powdered horse dung, and in dried and powdered human excrement, the amount of nitrogen being checked either by theory or by an absolute determination according to Dumas' method. The results were as follows:

	I. Kjeldahl's method.	II. Dumas' method.	III. Theory.
Sulph-urea	36·89 per cent.	.....	36·84
Horse dung. 1	3·16 "	3·28	.....
" 2	3·12 "	.....	.....
Excrement	6·20 "	6·08	.....

In order to satisfy ourselves as to the constancy of the results obtained in a number of determinations made on the same sample of actual sewage, a sample was procured and analyzed with the following results:

Organic Nitrogen Expressed as Parts in 100,000.

Kjeldahl (after deducting nitrogen as free ammonia).	Dumas.
3·75	3·66
3·50	.....
3·75	.....
3·70	.....
3·75	.....
3·75	.....
3·80	.....

It thus appears that the process gives uniform results, and that these results are sufficiently accurate for the purpose. It has the advantage of requiring only the ordinary apparatus used in water analysis, as generally conducted in this country, and of avoiding a dry combustion, which, in the simplest form, is more or less troublesome, especially where a liquid has to be evaporated, and the solid residue transferred from the evaporating dish.

There is little doubt that the coming decade will see in this country a considerable application of the method of disposing of sewage by irrigation, and it seems to us that Kjeldahl's process will afford a ready

means of determining the amount of that important constituent—the combined nitrogen. The process, as we have used it with sewage is as follows:

From 25 to 50 cubic centimeters of sewage are introduced into a small flask, preferably flat bottomed, made acid with sulphuric acid and evaporated to dryness on a water-bath. This is best and most rapidly accomplished by drawing through the flask a somewhat rapid current of air which has been freed from moisture and ammonia by bubbling through strong sulphuric acid. We have satisfied ourselves that the loss of "free ammonia" by this treatment is inappreciable so that the residue contains the total combined nitrogen* of the sewage. This residue is treated in the flask with 5 cubic centimeters of fuming sulphuric acid which is run in from a glass-stoppered burette. The flask is placed on a piece of wire-gauze over a small gas-flame and heated until a light yellowish-brown liquid is obtained. With sewage this result is sometimes reached in half an hour; usually from one to two hours are required. Permanganate of potash is then added to complete the oxidation, a few crystals being sufficient.†

The contents of the flask are then washed into the distilling apparatus with about 500 cc. of pure distilled water, enough caustic potash is added to give an alkaline reaction, and the nitrogen, which is now all in the form of ammonia, is distilled off in the usual way. The distillate is made up to 250 cc. and aliquot portions are nesslerized as in water analysis. As the sulphuric acid usually contains a trace of nitrogenous compounds, a blank experiment determines a slight correction to be applied.

The process as just given may be modified by evaporating the sewage without first acidulating with sulphuric acid. The evaporated water may be condensed and the free ammonia determined therein and an approximate determination of the total solids may be made by using a tared flask. We prefer, however, to proceed as indicated above and to make a separate determination of free ammonia, with which may be coupled, if desired, a determination of the so-called albuminoid ammonia.

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* The nitrogen which exists in the sewage as nitrites and nitrates is too small to be of practical importance although there is usually a trace.

† For fuller details, see Kjeldahl's original paper, referred to above.

BOSTON SEWAGE.

Since the examinations of sewage made in 1872, the Boston system of sewerage has undergone an entire change. Instead of being discharged from short sewers emptying at intervals along the water-front, the sewage is now collected into one encircling sewer, carried by means of a tunnel to Moon Island and allowed to flow into the outer harbor on an ebb tide.

We have examined a number of samples taken from the pumping station at City Point where the sewage is lifted in order that it may flow through the tunnel to Moon Island. The sewage was received as a rule in a fresh condition; the heavier suspended particles were allowed to subside and no attempt was made to determine their amount. In fact, the determination of suspended matters in small samples is of little value and a more practical idea of their amount could be obtained on a large scale by estimating the amount deposited in the settling-tanks. The following table contains the results of the examination of various samples of sewage from the pumping station. It will be noticed that the samples taken at different times vary very much from each other. The large amount of total solids and chlorine are said to be due to the fact that a considerable quantity of sea-water is used in certain manufactories for cooling purposes and to the infiltration of salt water into the sewers which are below the tide level.

NITROGEN AS UREA.

The rapidity with which urea is converted into carbonate of ammonia and water in the presence of the urea ferment which is probably always present in sewage, would prevent its existence in stale sewage, but as the Boston sewage reaches the point from which our samples were taken in a fresh condition, we might expect to discover some of this substance still unchanged.

The evidence that urea was present in several samples which were tested is as follows: Two portions of 50 cc. each were boiled in small flasks to expel the free ammonia and to kill any of the ferment present, and the necks of the flasks then stopped with cotton wool. When the contents had become cool one of the flasks was infected by dipping a glass rod first into a fermenting solution of urea, or into stale sewage and then into the boiled sample. The two samples were allowed to stand side by side for several days, and then examined for free

Examination of Boston Sewage.

[Results expressed in parts in 100,000.]

Number.	Date of Collection.	Ammonia	Albuminoid Ammonia	Total Nitrogen, reckoned as Nitrogen.	Total Nitrogen, reckoned as Ammonia	Total Solids.	Chlorine.	Chlorine reckoned as common salt.	Phosphoric Acid. (P_2O_5.)
1	1885. May 12, 7.30 P. M.	2·80	0·27	2·80	3·40	592	275	453	0·480
2	13, 8.20 A. M.	3·18	0·44	3·46	4·20	548	258	425	0·096
3	13, 7.20 P. M.	3·42	1·15	5·76	7·00	254	82	135	0·672
4	14, 7.20 A. M.	1·32	0·35	1·81	2·20	570	247	407	0·704
5*	15, 1.00 A. M.	1·29	0·87	4·63	5·62	482	133	219	1·343
6*	15, 8.15 A. M.	1·59	0·25	6·00	7·30	416	194	320	0·512
7	15, 4.00 P. M.	3·08	0·55	3.76	4·57	358	145	239	0·192
8	16, 7.30 A. M.	0·95	0·55	2·14	2·60	630	311	513	0·288
9	17, 4.25 P. M.	5·68	5·96	14·53	17·65	551	215	354	7·035
10	18, 8.00 A. M.	6·23	5·84	13·82	16·78	528	?	?	6·490
11	24, 7.50 P. M.	11·94	3·32	17·15	20·82	178	59	97	3·325
12	23, 12.40 A. M.	?	2·62	4·32	5·30	378	178	293	0·992
13	26, 12 hour day average†	5·71	4·22	11·32	13·75	460	177	292	4·893
14	27, 12 " " " †	5·71	3·31	9·55	11·60	610	288	475	6·188
15	28-29, 24 " average‡	3·13	5·49	9·82	11·93	588	240	396	4·702
	1872. Average of 33 day samples§	2·72	0·73	.....	.....	59	19	31	1·69‖
	" " 4 night "	1·33	0·23	.....	.....	17	4·5	7·4	.....

* Samples 5 and 6 contained a good deal of storm water. † Samples taken every four hours. ‡ Samples taken every two hours.
§ Samples from sewers near the water front, which evidently contained much sea-water, were not included in these averages.
‖ Average of 19 samples.

ammonia is a similar fashion. In one case the flask which had not been impregnated was free from ammonia, generally, however, a small amount of ammonia had developed itself,* in all cases the impregnated flasks showed a much greater amount of ammonia than was contained in the companion flasks. This certainly points to the presence of urea or some similar fermentable nitrogenous compound in the sewage as it reaches City Point.

In conclusion we desire to acknowledge our indebtedness to the Department of Improved Sewage for facilities in collecting samples, especially to Mr. Barnes, at Chester Park, and to Mr. M. H. Holmes, at the pumping station.