

To begin with, it includes all those combinations of the chemical elements whose formation depends upon the processes of life; and which, therefore, occur either in plants or animals. Its history is cyclical, consisting of a constructive phase or period of growth, and a destructive phase or period of decay; the death of the plant or animal forming the dividing line between the two phases. The cycle begins by the appropriation of inert, purely mineral substances from the earth by the green plants, which derive the necessary energy from the sunlight; and ends with the complete disintegration of the more or less complex structures which constituted its organic character, and the return of the elements to the earth. With regard to the nature of the changes it may have undergone, it is only with those in the second or destructive phase that we are concerned. At the beginning of this phase, at the death of the plant or animal, we find that all organic matter is composed mainly of carbon, oxygen, hydrogen and nitrogen. The more nitrogen it contains, the more objectionable it is from a sanitary point of view. This destructive process is essentially one of oxidation. The first step is the oxidation of the carbon by the oxygen of the body itself, or by that from without forming carbonic acid gas, and leaving the nitrogen and hydrogen to unite to form ammonia. As decomposition proceeds, the ammonia is itself oxidized—the hydrogen to form water, and the nitrogen to form nitrous acid. The last step is the reduction of the nitrous acid to nitric acid. The nitrous and nitric acids do not remain free but combine with some base present, as soda or potash, to form nitrites and nitrates, the latter being purely mineral substances; so that the final results of the decomposition process are carbonic acid, water, and nitrates. Thus the dead inorganic materials needed for the formation of organic structures are only borrowed, and ultimately are returned to the earth again as inert as when they were taken from it. Returning now to the chemical analysis, we find the results given in some such form as the following, which is the one used by the Massachusetts State Board of Health:

--Residue on-- Evaporation.		—Ammonia.—		—Albuminoid.—		
Sample.	Total.	Loss on Ignition.	Free.	Dissolved.	Suspended.	Chlorine.
A	3.85	1.00	.0002	.0048	.0012	.49
B	40.25097	.0316	.0222	6.32
C	10.50	2.40	.027	.0156	.0120	2.78

—Nitrogen as—					
Sample.	Nitrites.	Nitrates.	Hardness.		
A	.0050	.0000	1.6		Average surface water.
B	.3500	.0300	5.3		Private well.
C	.1400	.013	3.6		Mystic Lake.

Now it has been found that a very accurate, and at the same time comparatively easy method of determining the organic matter in water by a chemical analysis is to determine the amount and condition of the nitrogen present. Thus, under the head of Albuminoid Ammonia are entered amounts which are proportional to that part of the nitrogen which is derived from fresh organic matter, i.e., from organic matter which has not yet begun to decompose. These columns, therefore, represent the possibilities of putrefaction still existing in the water. The amounts under Free Ammonia represent decay begun; under Nitrous Acids (or Nitrites) decay still further advanced; while under Nitrates the amounts entered represent the nitrogen derived from that portion of the original organic matter which has passed through all the stages of decay, and which has been converted into purely mineral matter again. The importance of the determination of the chlorine is, that an excessive amount points to contamination by sewage which always contains a con-

siderable proportion of common salt. The actual amounts of the different substances as they occur in water supplies are exceedingly minute, as will be seen by referring to the above table of analysis, one of which samples (B) is a highly polluted one. Hence, in themselves these substances are of very little importance. It is in the history of the water which their presence indicates that their significance lies. Thus the chemical analysis can tell us not only what is in the water, but also a great deal about what is going on in it. It is only within recent years, however, that the methods of organic analysis have been capable of producing such results; when the first attempts at water purification were made, very little was known of the organic matter in solution, and the object aimed at was simply the clarification of the water, or the removal of suspended matter visible to the eye.

This was the condition of things when James Simpson, in 1839, constructed a sand filtration plant for one of the London water companies. Each of the beds of this system consisted of a broad shallow basin or reservoir with water-tight bottom and sides. The depth was about 12 feet, and it was filled to about half this depth with the filtering material, which consisted of uniform layers of small stones, gravel and sand, the stones on the bottom and the finest sand on the top. Through the bottom layer of stones and gravel extended a number of branch drains leading into a larger central drain which was connected to the outlet. The inlet to the filter bed opened above the surface of the sand, and both it and the outlet were provided with gates. The process of filtering consisted in flooding this bed of sand and gravel, and drawing off the water from beneath by means of the system of under drains, which were built with open joints. The rate could be regulated by the gates or other apparatus on the inlet and outlet pipes.

As filtration progressed the surface of the sand became gradually choked up by the formation upon it of a layer composed of material removed from the water. When this layer became so impervious as to prevent the water passing in sufficient quantities, the filter was stopped, the water level drawn down below the surface of the bed, and the deposit layer removed, together with from $\frac{1}{2}$ to 1 inch of sand. When the surface was smoothed and levelled, the bed was ready to be put in action again. The frequency of the scrapings depended upon the condition of the water and the rate at which it was filtered; and when the sand layer had become reduced in thickness to what was considered a proper minimum, the whole amount removed was placed at one time, either by new sand, or by the scrapings after they had been thoroughly washed. The results from the use of these filters were so satisfactory according to the ideas of purified water then in vogue, that in the following years several others were built in England, and a little later on the continent, especially in Germany. Some of the most important of the continental filters built during this period were designed by the English engineers Gill and Lindley. They were all built on the same general lines as the Simpson filter described above, the details varying somewhat with the individual notions of the designers.

In America practically no attention was paid to the matter. The late Jas. P. Kirkwood was employed by the city of St. Louis to report upon the condition of its water supply. His report included the result of his personal observations of the working of several European filters, and was translated and widely read on the continent of Europe. But his recommendations to St. Louis, so far as filter-beds were concerned, were not adopted. And between that time and 1892, only two plants were built in America, one at Poughkeepsie, N.Y., in 1872, the other in 1874 at Hudson, N.Y., both being after designs by Kirkwood. A little earlier, in 1870, the English chemists Wanklyn and Frankland invented new and improved methods of organic analysis which led to more attention being paid to the organic matter in solution in water. A new importance was also attributed to it at this time by reason of the ideas which were then held concerning the processes of fermentation and decomposition. It was supposed that decay could be communicated to sound organic matter by contact with other organic matter already in process of decomposition; this being the theory advanced by the chemist Liebig, who held that ordinary alcoholic fermentations were produced by the dead and decaying yeast cells, instead of by the action of the living and grow-