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The Water of the Mississippi River

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[*Paper D.*]

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Mr. Chairman and Members of the Academy:

By way of contributing something in the nature of a report of the section of Chemistry at the present meeting, as appointed for that section, I have thought it proper to present some results of recent analyses of the water of the Mississippi river from different points in this State. It should be premised however, that the winter or early spring season cannot be regarded as a very satisfactory time for making analyses of the water of the river, with a view to comparison of the purity, or impurity, of the water at different points. The river has been closed over, for the most part, by a thick covering of ice, excluding to a considerable extent the action of the air; while the frozen and snow-covered condition of the banks has prevented the inflow of surface drainage and thus greatly diminished the amount of contamination derived from these sources. Actual sewers have continued to send down their impurities into the river during the cold weather, very much as at other seasons.

The plan of the investigation was to secure samples of water from a number of points along the course of the river, and submit these waters to analysis. The results of the analyses were thought likely to have an interest as bearing on the question of the self purification of river waters by processes in the regular course of nature. It is now a commonly known and generally accepted proposition that flowing water,—and water otherwise moving—purifies itself from organic matters of a foul or objectionable nature, chiefly through the action of the oxygen of the air, the movement of the water being regarded as promoting this action by increasing the admixture of the air with the water and thus giving greater opportunity for the contact of the oxygen with the organic matters. This I have mentioned as a generally accepted proposition. And it rests upon abundant proof. The only points of difference in connection with the subject are in regard to the extent or completeness of the process of self-purification. It has appeared from occasional paragraphs and communications which I have noticed in the daily papers, that people express quite commonly a belief in the *complete*, or almost complete, removal of the foul matters in question, and that within a very limited distance from the point of influx of these matters. On the other hand, eminent authorities on the subject hold that when the foul matters have been introduced into the water of a river, though a part of them is oxidized and destroyed during the onward flow of the stream, yet the process of self-purification is never so complete as to render the dietetic use of the water free from risk.

In starting upon the analysis of a number of samples of water from properly chosen points along the stream, I had an expectation of finding the above mentioned proposition confirmed more or less decidedly. To proceed at once to a statement of my results, I will present the accompanying table.

	Water from above Minneapolis. Parts per Million.	Water from below St. Paul. Parts per Million.	Water from above Hastings. Parts per Million.	Water from above Winona. Parts per Million.
Free Ammonia.	.110	.165	.090	.070
Albuminoid Ammonia.	.230	.405	.250	.140
Chlorine....	1.09	1.87	1.82	1.69
Nitrogen as Nitrates and Nitrites	.130	.140	.109	.090
Permanganate Test....	1.75 oxygen	2.05 oxygen	1.60 oxygen	1.67 oxygen
Total Residue.........	205.	207.	203.	190.

In order that the comparison of a series of water analyses should be perfectly just, it is of course necessary that they be made throughout under the same conditions. In collecting the samples from the river, they should be taken simultaneously. It was impossible to conform strictly to this condition; but the samples whose analyses are presented were taken during a period of two weeks at the latter part of February and the early part of March. Those from Hastings and Winona were kindly procured for me by Professor C. W. Hall. In all other respects the samples of water were examined under the same conditions.

It seemed to me, considering the purpose in view, namely the purpose of ascertaining if the results of my analyses would support the proposition that the river purifies itself as it flows onward, that the stretch of river between St. Paul and Hastings offered a favorable example. For, between St. Paul and Hastings there are no considerable streams flowing into the Mississippi and thereby complicating the question; there are on the other hand no towns or settlements of importance along that distance and hence no influx of impurity on the way. The distance is one of about thirty miles, a sufficiently long one to offer a fair test of the point in question. If the change in the character of the water by oxidation or other natural causes within the distance of thirty miles be not enough to shew itself through the ordinary methods of water analysis, then it would be rather too unimportant to be referred to in connection with sanitary matters. Now, on referring to the table, we observe in the case of each test that the water from the river above Hastings (it was in fact taken *just above* that town) shows itself better than the water from just below St. Paul. Setting aside the determinations of chlorine and of the total residue from evaporation, as from the nature of the case of little concern here, since there are evidently no special causes for their diminution, we observe that the water from above Hastings gives us lower figures than the water below St. Paul. The free ammonia has suffered a very considerable diminution. The albuminoid matters from which the "albuminoid ammonia" is derived by the method of Wanklyn, are also much less in amount. The explanation of their diminution is to be found mainly in a process of actual oxidation. The amount of nitrogen present in nitrates and nitrites is also less in the Hastings water. I had hardly expected much difference between the two in this respect, as I supposed the oxidation of nitrogenous matter represented by the ammonia would keep up the amount of nitrates and nitrites, so that the nitrogen would remain in the water in another combination. The explanation of the lower figures for nitrogen is, probably, that the nitrates and nitrites which were in the water at St. Paul, mixing with other organic matter also introduced at St. Paul, were reduced by this other organic matter and the nitrogen was set free in the elementary state. The same change must have happened to such nitrates and nitrites as were produced by the above mentioned oxidation of ammonia. Looking at the figures giving the results of the permanganate test (Forschammer's and Tidy's process,) we again find a considerable difference to the advantage of the Hastings water. That is, the amount of oxygen required for performing a work of destruction on organic matter, carbonaceous and nitrogenous, in the Hastings water was much less than in the water at St. Paul. This very convenient and, in the main, satisfactory test (by permanganate) shows at once to the eye that there has been oxidation of organic matter in the water while on the way from St. Paul to Hastings. I will say at this point that, in fact, the difference between, the two samples of water here referred to, as shown by these tests, proved itself greater than I had anticipated. For, seeing that the river was at the time, and for months previously, clothed with a comparatively close covering of ice, it seemed that the mount of air finding access to the water and consequently the degree of oxidation of organic matter therein would be small. Still there have been openings in the ice, made in various ways, through which the air has found entrance

The last column in the table shows the results for the water taken from the river just above Winona. In the case of this water, there are circumstances making conclusions rather less easy. This case is complicated on the one hand by the entrance of the St. Croix river and some other streams into the Mississippi between Hastings and Winona, and on the other hand by the fact that there are several towns along the way which contribute more or less sewage to the river. The inflowing of those streams would undoubtedly make the results of our tests lower, because they would bring a water somewhat purer than that of the Mississippi. The presence of the settlements along the bank will of course raise the results.

Hence, as said, our conclusions must be somewhat uncertain, in regard to the extent of the self-purification of the water in thi case. In fact, on considering the results of the determinations of chlorine and of solid residue, we see that the lower figures all through the column of results for the Winona water are probably due partly to dilution by purer water, namely that of the St. Croix, Chippewa and other streams; still the results under "free" and "albuminoid" ammonia are so considerably different from those of the waters higher up the river that we are disposed to take them as good evidence of the oxidizing process.

It will be noticed that I have a column of figures for the water taken from the river just above Minneapolis also. These are the results which have been already communicated to the Academy in a recent report of a committee. They have very little bearing on the present investigation, but are placed beside the others merely for incidental reference. The real purpose of the analyses outside of Minneapolis was to ascertain if the tests which we can conveniently and without great expenditure of time or complication of apparatus apply to a sanitary examination of water, would show a verification of the theory of self-purification of river waters. The result seems to me fairly satisfactory. It is the result of but one trial at the present time. A repetition of these comparative tests carried through the several seasons of the year, would be more completely satisfactory.

I wish now to make some further reference to that other question connected with this subject which was mentioned at the beginning, the question as to the *completeness* of this process of oxidation and destruction of organic matter which we see going on in our rivers. If we were to place an unqualified reliance upon the results of our chemical tests for the sanitary character of water, we should be obliged to say that the water taken from the river at Winona is purer than that taken at any point above, in our series of analyses: and this, in spite of the fact that the river has received on the way the sewage of Minneapolis and St. Paul. Even within the short distance between Minneapolis and Hastings, the self-purification of the water appears to be such that the water at Hastings is scarcely more contaminated and in some respects less contaminated, than that above Minneapolis, although the river at St. Paul shows itself highly impure by our tests. Shall we then say that the water at Hastings would be as wholesome and safe for drinking as that above Minneapolis? Is the water at Winona better than that above Minneapolis? In seeking to give an answer to these questions, I can hardly do better than quote a few paragraphs from Professor Frankland of London, one of the leading chemists of the world, and one who has given a great deal of special attention to the sanitary analysis of waters. In speaking of the contamination of water by sewage matters, Professor Frankland says: "The excrementitious matters which exist in sewage are sometimes possessed of intensely infectious properties; and sewage mixing with water, even in the minutest proportion, is likely by such properties to spread epidemic diseases among populations which drink the water. Thus is explained the peculiar power which impure waters have been shown to exercise on many occasions, in promoting epidemics of typhoid fever and cholera. The existence of an infectious property in water *cannot be proved by chemical analysis*, and is only learned, too late, from the effects which the water produces on man. But though chemistry cannot prove any existing infectious property, it can prove, if existing, certain degrees of sewage contamination. And every sewage contamination which chemistry can trace ought, *prima facie*, to be held to include the possibility of infectious properties. * * * There is always a risk lest some portion (not detectable by chemical or microscopical analysis) of the noxious constituents of the original animal matters should have escaped that decomposition which has resolved the remainder into innocuous compounds. * * * In the case of river water there is great probability that the morbific matter sometimes present in animal excreta will be carried rapidly down the stream, escape decomposition and produce disease in those persons who drink the water, as the organic matter of sewage undergoes decomposition very slowly when it is present in running water. The researches of Chauvean, Burdon, Sanderson, Klein and others leave no room for doubt that the specific poisons of the so-called zymotic diseases consist of organized and living organic matter; and it is now certain that water is the medium through which some at least of these diseases are propagated. It is evident, therefore that an amount of exposure to oxidizing influences which may resolve the *dead* organic matter present in water into innocuous mineral compounds, may, and probably will, fail to affect those constituents which are endowed with life." Again, in speaking of the possibility of rendering polluted waters again wholesome, the same authority says: "When the sewage of towns or other polluting organic matter is discharged into running water, the suspended matters may be more or less perfectly removed by subsidence and by filtration, but the foul organic matters in solution are very persistent. They oxidize very slowly, and they are removed only to a slight extent by sand filtration. * * The most efficient artificial filtration leaves in water much invisible matter in suspension (as well as in solution) and constitutes no effective safe-guard against the propagation of epidemic diseases by polluted water. Boiling the water for half an hour is a probable means of destroying its power of communicating these diseases." Since this last paragraph was published, more reliance, I will say, has come to be placed on filtration and especially filtration through spongy iron, that is metallic iron reduced from a porous oxide of iron, as a means of purifying water. An application of the filtering process through layers of spongy iron and sand has recently been made on a large scale at the public water-works of Antwerp in Belgium, whereby a badly contaminated river water is said to be made thoroughly wholesome. It is asserted that living germs as well as dead organic and inorganic matter are destroyed and removed from the water. Perhaps the people of Minneapolis, and other populations along the Mississippi, may in time avail themselves of such filtering processes. Scientific authority tells us that we run great risk in drinking water which has at any time been contaminated with animal excreta unless we apply to that water the most thorough methods of destroying organized microscopic impurities. The people of Winona, for example, and the people of Hastings, would run great risk of infection from impurities that enter the river at Minneapolis and St. Paul, although chemical tests as at present known and applied give the water at Winona and Hastings such comparatively good credit for purity. The best known methods of purification may not remove all this risk. But it would be the part of prudence to apply them when practicable.

JAMES A. DODGE.

[*Paper E.*]

CHANGES IN THE CURRENTS OF THE ICE OF THE LAST GLACIAL EPOCH IN EASTERN MINNESOTA. —*Warren Upham.*

Read before the Minnesota Academy of Natural Sciences, May 8, 1888.

When the ice of the last glacial epoch attained its maximum extent, it appears that the ice-current moving southwestward from lake Superior across the northeast part of Minnesota, spreading a reddish till containing boulders and pebbles peculiar to the region from which it came, had its limit at a line reaching from lake St. Croix southwesterly across the Mississippi and through the north part of Dakota county, thence bending to a northwest direction and continuing by lake Minnetonka and through Wright and Stearns counties. At the same time another portion of the ice-sheet was pushed from the region of lake Winnipeg and the Red river valley toward the south and southeast, meeting and opposing the ice-current from lake Superior along a line from Stearns county southeast by lake Minnetonka to Crystal lake in Dakota county: beyond which its eastern limit farther south was