A REPORT

OF

ANALYSES OF SAMPLES OF WATER AND ICE

FROM THE

MISSISSIPPI, MINNESOTA and ST. CROIX RIVERS,

MADE IN THE

Laboratory of the State Board of Health

OF MINNESOTA,

IN NOVEMBER AND DECEMBER, 1886.

BY

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Dr. Charles N. Hewitt,
Secretary State Board of Health,
Red Wing, Minnesota.

Washington, D. C., Dec. 29, 1886.

Dear Sir:—I herewith send you a report of the work done by me in water analysis in the laboratory of your Board during the latter part of the last and early part of the present month. In transmitting this, I desire to express my appreciation of, and thanks for, the unflagging interest which you manifested in the progress of this analytical work, by giving me your personal assistance in carrying out its details,—an assistance which your familiarity with the processes adopted in the investigation rendered peculiarly valuable, and which enabled me to accomplish much, satisfactorily, in a comparatively short time. It is gratifying to know that the results of the analyses heretofore made in your laboratory, and published in the reports of your Board, 1879–84, confirm, and are confirmed by, those which form the subject of the present report.

Very sincerely yours,
Charles Smart.

Waters were examined from the Mississippi River in the vicinity of Aitkin, Brainerd, St. Cloud, Minneapolis, Fort Snelling, St. Paul, Red Wing, and Winona; from the large tributary streams, the Minnesota River at Mankato and Fort Snelling, and the St. Croix at Stillwater City, and from certain lakes, wells, etc., concerned in the water-supply of these and other towns in the State.

Several analytical processes were used, with the view of determining the animal or vegetable origin of the dissolved organic matter, and the stability or putrefactive tendency of its constitution. In a few instances the amount of saline and other solids contained in the water, was noted as a matter of record, and in others as incidental to observations on the appearance and properties of the organic residue. Oxidation by permanganate in acid solution, was used to estimate the relative proportion of carbon in the organic matter, and by permanganate in alkaline solution to give, by the resulting quantity of albuminoid ammonia, an approximate view of the organic nitrogen. The nitrates were estimated to show the quantity of the latter that had been decomposed by natural processes, and the ammonia and nitrous acid to indicate whether these nitrates were recently or remotely connected with the nitrogen of existing organic matter. Chlorine also was determined on account of its association with the excreta of animal life.

Naturally the first question asked by those interested in local results will be: Is the water a good or wholesome water? In no case may this query be answered positively in the affirmative. A water may be shown by analysis to contain nothing more than is found by the same processes in other waters that are known by experience to be wholesome, yet the water in question may not be affirmed to be equally wholesome. A presumption in favor of wholesomeness may be stated, but beyond this the analyst's opinion cannot with propriety go, for it is well known that typhoid fever has been propagated by waters that have yielded fair results on analysis. Nor may a positive assertion be made as to unwholesomeness, although here the restrictions are weaker, resting as they do on the fact that many waters known to have sewer or privy-vault connections, have been used for long periods with impunity. Contamination and possible danger may be affirmed, but not unwholesomeness. To many this may seem like a verbal refinement, and it would be well if it were so regarded by all; but so long as corporations and municipalities have money invested in pumping up supplies that are known to be contaminated, and therefore possibly dangerous, so long will the distinction between contamination and unwholesomeness be painted in the most striking colors.

The following table gives a synopsis of the analytical results:

ANALYTICAL RECORD OF CERTAIN WATERS

Examined in the Laboratory of the State Board of Health of Minnesota during November and December, 1886.

(RESULTS ARE EXPRESSED IN PARTS PER 100,000 OF THE WATER.)

	Total solids	Loss on ignition	Nitrites	Nitrates	Chlorine	Oxygen required	Free Ammonia	Albuminoid Ammonia	Remarks.
Waters from AITKIN, Minnesota:									
Mississippi River above city	19.0	6.0	none	.015	.21	1.204	.005	.044	Water clear and almost colorless; carbon in residue dissipated with difficulty, but with little odor.
" " opposite city			none		.21	1.160	.006	.027+4	
" " below "			none	.023	.21	1.228	.026	.022+4	
Village well	40.0	12.0	.01	.037	3.40	.161	.009	.008	Clear and colorless; faint darkening on ignition.
Waters from BRAINERD, Minnesota:									
Mississippi River below city	15.0	6.5	none	.0074	.17	1.083	.003	.037+4	Clear; carbon dissipated with diffi'lty.
Waters from ST. CLOUD, Minnesota:									
Creek above water-works					1.20	.900	.004	.094+4	Clouded and with much sediment.
Missi'ppi Riv'r, tap in wat'r-w'ks			.005		.15	1.132	.022	.0255	Clear and colorless.
" " household tap	24.0	3.5				.868	.0105	.017+4	Clear and colorless. No marked taste or odor.
" " below city					.20	1.224	.027	.026	Clear and colorless.
Waters from STILLWATER, Minnesota:									
St. Croix River ¼ mile above city	16.0	2.0	none	.004	.15	.604	.0025	.013+4	Yellowish but clear.
" " opposite city			trace	.019		.741	.0055	.0215	Yellowish but clear.
" " 1 mile below city.			none	.004	.14	.750	.005	.014	Yellowish but clear.
Lake McKusick			trace	.005	.10	.317	.002	.0175	Clear; faintly yellow.
Spring entering lake	16.0	1.0	none		.20	.135	.012	.005+3	Clear and colorless.
Hydrant water	21.0	3.0	present	.005	.10	.341	.035	.010+4	Faintly yellow; clear.
Well on the flats	43.0	5.0	trace	present	6.20	.097	.038	.004	Clear and colorless.
Well in residence part of city	19.5	2.5	trace	trace	.25	.063	.015	.002	Clear and colorless.
Waters from MINNEAPOLIS, Minn.:									
Missi'ppi River, 2 miles above city	23.0	6.0	none	.030	.16	.731	.013	.0135	Clear but somewhat yellow tinged; no marked taste or odor.
" " 2 " "			none	.0074	.16	.785	.006	.023	
" " above water-w'ks.			none	.01	.13	.914	.012	.014+4	
" " " "			trace	.0046	.23	.794	.020	.014+4	
" " tap in "	23.0	5.0	none	.01	.13	.687	.0045	.026	
" " " "			none	.0046	.14	.643	.025	.014+4	
" " household tap			none	.013	.13	.736	.0185	.010+4	
" " " "			none	.0046	.17	.726	.020	.010+4	
" " below flats			trace	.013	.18	.717	.009	.025	
* " " "	21.0	5.0	present	.017	.47	.848	.0615	.026+4	
Well, unknown	148.0	42.0	trace	present	10.80	.307	.076	.012+3	Clear; faint darkening on ignition; nitrous odors.
Ice from Cedar Lake			trace		.19	.297	.025	.025	Clear and colorless.
" Mississippi River			trace		.14	.219	.015	.015	
Waters from MANKATO, Minnesota:									
Blue Earth River	45.0	6.0			.20	.332	.014	.017	
Minnesota River above city	45.0	5.0			.25	.480			
" " opposite city			trace		.34	.375	.024	.023	
" " below city			trace		.80	.609	.059	.035+5	

ANALYTICAL RECORD OF CERTAIN WATERS.—Concluded.

	Total solids	Loss on ignition	Nitrites	Nitrates	Chlorine	Oxygen required	Free Ammonia	Albuminoid Ammonia	Remarks.
Waters from FT. SNELLING, Minn.									
Mississippi River			trace	.010	.16	.877	.008	.033	Clear; yellowish.
Minnesota River			trace	.015	1.18	.327	.0045	.026-|-4	
Waters from ST. PAUL, Minnesota.									
Mississippi River at city	13.5	2.0	none	.010	.45	.714	.044	.012-|-4	Yellow but clear.
* " " "	30.0	6.0	.01	.026	.58	.770	.192	.060	Somewhat yellow and with a dark colored flocculent sediment.
" " opp. water-wks.			none	.023	.22	.750	.0035	.021	Yellow but clear.
* " " at Wacouta St.			trace		.66	1.028	.321	.066-|-5	Faintly yellow with a dark colored flocculent sediment.
" " below city			present	.036	.45	.773	.026	.014-|-3	Yellow but clear.
* " " "			trace	.030	.66	1.062	.241	.052-|-4	Faintly yellow with a sediment of dark colored flocculi.
Lake Phalen	14.0	5.5	trace	?	.075	.336	.002	.006-|-3	Clear and colorless.
" Vadnai	9.5	3.0	none	?	.075	.432	.033	.012-|-3	
Ice, Mississippi at city			trace	.016		1.316	.100	.069	Nearly colorless; a sediment of greyish flocculi.
" " below city			trace	.011		.687	.074	.084	
" " at city			present		.25	.302	.011	.028-|-5	
" Lake Phalen			none		.13	.117	.011	.017	Clear, colorless; a whitish pulverulent sediment.
" " Como			trace		.14	.200	.010	.028	Colorless but somewhat clouded; a flocculent sediment.
Waters from RED WING, Minnesota.									
Mississippi River, bay above city			trace	.014	.30	.816	.010	.024	Yellow, clear; no odor; alluvial taste
" " opposite city			trace	.013		1.024	.0125	.018	
" " at intake of w.w.	19.0	3.0	none	.012	.20	.897	.007	.010-|-3	
" " at water-works					.27	.816	.013	.012-|-4	Brownish, clear; alluvial & ferruginous taste; sediment reddish from iron.
" " tap "	17.5	3.5	none	.011	.27	.778	.002	.018-|-5	
" " " "	16.5	5.5	.02		.30	.528	.0135	.0155	
Well, artesian, at R. R. station	39.0	10.0			8.60	.000	.0195	.002	Faintly clouded white and with sulphuretted taste and odor.
" "Scandinavian"	38.0	10.0		2.042	3.60	.029	.0095	.0015	Transparent and colorless; no taste nor odor.
Cistern, private residence	16.5	2.5	present	present	.22	.360	.087	.008	
Ice, Mississippi River at intake			trace		.12	.220	.002	.008-|-4	
Waters from WINONA, Minnesota.									
Mississippi River above city	20.0	5.0	none	.0074	.22	.897	.035	.0155-|-4	Yellowish but clear.
" " opposite city			none	.0074	.22	.868	.014	.018-|-4	
" " below "			trace	.01	.25	.777	.0025	.034	
" " " "			none	.0074	.22	1.102	.001	.0185	
Lake Winona			none	.017	.21	.809	.004	.052	
Well, general supply	34.0	13.0			2.30	.120	.023	.002	Clear and colorless.
" Windom's	32.0	10.0			2.00	.110	.012	.006	
" Fourth Ward	25.0	4.0	present	present	1.60	.097	.020	.001	
" Wilson & Sarnia	8.5	3.0	none	.565	.40	.197	.002	.0015	
" Park House	25.0	4.0	present	present	1.60	.117	.007	.001	
Waters from ROCHESTER, Minnesota:									
Well, unknown	20.0	6.0			.25	.000	.002	.001	

In examining the waters of the upper Mississippi, singular and unlooked-for results were obtained by the process for determining the amount of oxygen required to oxidize the dissolved organic matter. These will be of much interest to those engaged in the study of natural surface-water, showing, as they do, in waters that are free from sewage, factory refuse, or other matters usually considered to be of dangerous quality, an amount of oxidizable organic matter such as would warrant an unhesitating condemnation of the water for domestic use. The rule which experience has hitherto educed, may be expressed as follows: Well waters which require .2 parts of oxygen per 100,000 of the water, are usually dangerously charged with the products of animal waste; but a surface water which has no manifest sewage inflow, may decolorize the equivalent of .4 parts of oxygen without being considered as of doubtful quality. The organic matter of surface waters is of a carbonaceous or vegetable nature, and is derived from decaying vegetation found on the water-shed. This is generally regarded as harmless; but when the amount of oxygen required exceeds .4, the water yielding this result approximates in character to that of swamps and marshes, and must be viewed with proportionate suspicion, or it is connected with some source of contamination which should be discovered and shown to be of a harmless nature before the water is warranted as wholesome in this respect. The water of the Mississippi River at Aitkin, Brainerd and St. Cloud contained an amount of vegetable organic matter largely in excess of that regarded as coming within the limits of wholesomeness in a surface water; Aitkin waters required 1.204 of oxygen; Brainerd, 1.083; St. Cloud, 1.132. The water from a Louisiana swamp required 1.354.

The vegetable character of the organic matter in question was indicated by the relatively small amount of nitrogen evolved from it as ammonia; a dilution of sewage or other foul liquids of animal derivation that required this quantity of oxygen, would have been rankly ammoniacal or putrefactive in its odor. The vegetable matter in a swamp water is decomposed more readily, and yields a proportionately larger quantity of albuminoid ammonia than was obtained from the water of the upper Mississippi. Moreover this vegetable matter was of a stable or non putrescible nature, as shown by the slow manner in which the albuminoid ammonia was evolved from it during the Wanklyn process. Some of these samples yielded so small a quantity of organic ammonia in the first measure of the distillate, that many analysts would have felt warranted in concluding the experiment at that point and reporting the water as comparatively free from nitrogenous substances; but a continuance of the distillation gave time for the gradual decomposition of the organic matter, and added to the quantity of albuminoid ammonia evolved until the process could be carried no further without risk to the retort. In these instances the experiment had to be concluded without having demonstrated the complete destruction of the nitrogenous matters. There remained an undetermined residuum, which has been expressed in the table by the *plus* sign, +, after the figures indicating the evolved ammonia. In waters of this character the amount of albuminoid ammonia will depend largely on the length to which the distillation is carried. As a record of this the number of measures of 50 c. c. each distilled from the water has been printed in connection with the *plus* sign.

Previous laboratory work had obtained results of this kind from such substances as Irish peat, and pine shavings, or sawdust. It is not unlikely, therefore, that the large quantity of permanganate required for the oxidation of the organic matter in these waters indicates no unwholesome constituent, but a carbonaceous and probably resinous contribution from the timbered lands of the water-shed. The St. Croix River contains a similar vegetable product which, although in smaller proportion than in the Mississippi, is nevertheless sufficient to raise doubts concerning the quality of the water, unless the harmlessness of its nature be demonstrated. The Minnesota River contains considerably less vegetable matter than the St. Croix, although more than is commonly found in Eastern rivers having a naturally clean water-shed. Evidently the Minnesota drains a country that is comparatively barren of the vegetation which so strongly charges the waters of the Mississippi and St. Croix.

The Mississippi River down to the lowest point at which its waters were examined, contained much of this carbonaceous matter,—sufficient to condemn its waters for potable use in the absence of a demonstration of the harmlessness of its nature.

This peculiarity of the waters of the upper Mississippi was, I found, well known in the laboratory of the State Board of Health of Minnesota, where the carbonaceous matter was considered related to "pine juice,"—the sap of the pine.

Another point in the natural history of these rivers is of interest,—the presence of an excess of chlorine in the waters of the Minnesota. Chlorine exists in small quantity in the Mississippi, the St. Croix, and the Minnesota as far down as Mankato; but at Fort Snelling the last mentioned river contains 1.18 parts, which must be referred to some other source than sewage contributions.

It was hoped that this series of analyses, in addition to indicating the influence of the sewers of Minneapolis and St. Paul on the character of the river water, would throw light on the subsequent operation of natural processes engaged in its purification. It was hoped, also, that the results would enable the analyst to give expression to the existence and probable amount of the sewage-inflow after the sewage had ceased to exist as such in the water. To this end waters were collected above, at and immediately, and distantly, below these cities, and the nitrates contained in the samples were carefully determined to show, if possible, the relation between the disappearance of organic nitrogen and the development of inorganic salts.

Running water is generally credited with the ability to purify itself, and indeed, it is certain that much of the dissolved matter of sewage is readily destroyed by the agencies operating on it during its flow. Urea, for instance, is speedily decomposed into ammonia, which, with the ammoniacal products of putrefaction, is as speedily converted into nitric acid. But it seems probable that dilution has as much, if not more, to do with the disappearance of the sewage of Minneapolis and St. Paul in the Mississippi River, than the chemico-vital processes. The nitric acid in fifteen samples of river water, collected at various points above the inflow of sewage at Minneapolis, averaged .0113 per 100,000 of the water; in eight samples collected below Minneapolis, and at and immediately below St. Paul, the average quantity was .020; in nine samples from Red Wing and Winona, the average was .0110. Nitric acid is a stable compound and does not disappear from its solution as do ammonia and organic nitrogen. The reduction in its quantity at Red Wing and Winona to the average contained in the waters above Minneapolis, notwithstanding the polluted inflow at that city and St. Paul, must therefore be attributed wholly to the immensity of the dilution.

The same thing is shown by the chlorine estimations. Sixteen samples taken from above the inflow of the Minneapolis sewers, gave an average of .168 per 100,000 of the water; nine samples from Minneapolis and St. Paul yielded an average of .425, and ten samples from the river at Red Wing and Winona gave .246. The decrease by dilution is at first sight less in this case than in that of the nitrates; but when it is remembered that the Minnesota River contributes to the Mississippi, between Minneapolis and St. Paul, a large quantity of chlorine without a relatively corresponding quantity of nitrates, the persistence of a larger proportionate amount of the former at Winona may be easily understood.

This dilution is also indicated by the decrease in the quantity of the carbonaceous vegetable matter as the stream is followed down from Aitkin. The amount of oxygen required for the destruction of organic matter, is decidedly less at Winona and Red Wing than at the upper settlements, notwithstanding the out-put of oxidizable substances by the two large intervening cities.

The daily inflow of sewage from Minneapolis and St. Paul must be regarded as a dangerous pollution of the waters of the Mississippi River, although chemical processes fail to show its presence at the lower settlements on account of the enormous mass of water in which it is diffused. I am unfortunately unable to present in figures the proportion which the inflowing sewage bears to the passing current, but evidently from the dilution of the inorganic salts, it must be very great. It should be remembered, however, in this connection, that dilution does not destroy the germs of disease that are present in sewage, nor, so far as experience has shown, does it impair their pathogenic activity. It merely lessens the likelihood of their presence in a particular draught of the water. The draught that does contain them is as dangerous to the individual who swallows it as though there had been no dilution.

Certain of the waters from St. Paul and Minneapolis, those marked in the table with an asterisk, cannot be considered fair samples of the river water at those cities. They appear to have been taken from near the mouth of the sewers before the occurrence of a thorough diffusion, as the chemical results obtained from them are similar to those yielded by an ordinary city-sewage diluted with three or four volumes of water.

Three specimens of ice from the river at St. Paul were found unfit for use, two of them being, in fact, solidified sewage, showing but few signs of having undergone the certain amount of purification which usually results from a gradual congelation. The specimen of Lake Como ice was decidedly inferior to that from Lake Phalen, although the latter appeared to have met with some accidental contamination, as it was less pure than the waters of the lake. Ice from Cedar Lake was less satisfactory in its character than that cut from the Mississippi at Minneapolis. The best specimen of river ice examined, was taken from near the in-take of the Red Wing water-works. The chemical characters of ice are related to those of the water from which it is formed. The worst specimen of a series of Syracuse ice samples recently examined by Dr. Willis J. Tucker, yielded only .005 of free ammonia, and .001 of albuminoid ammonia in 100,000 parts of the water, and required only .04 of oxygen for the destruction of its organic matter. But the Red Wing sample may be accepted as a fair specimen of Mississippi river ice, the slow evolution of its albuminoid ammonia being held in remembrance.

The well water from Aitkin does not give good results: it contains an excess of chlorine, and the free ammonia and nitrates indicate the proximity of the well to the source whence the chlorine was derived.

The creek above the water-works at St. Cloud contains putrescent matters of both animal and vegetable derivation; its waters are wholly unfit for admixture with that which is to be used for domestic purposes.

Of the waters from Stillwater, that from the well on the flats should not be used; that from the well in the residence portion of the city contains more ammonia than should be found in a pure well water. Lake McKusick furnishes a fairly good surface water, by no means so pure, however, as the spring water which forms part of its source.

The well at Minneapolis, if shallow, has sewage connections; but if an artesian well, as suggested by the stability of its nitrogenous matters, the excess of chlorine and ammonia would be satisfactorily accounted for.

The water of Lake Phalen is of good quality; its organic matter is vegetable and non-putrescent, as is that of Lake Vadnai. A limited excess of free ammonia, such as is found in the latter water, is not, as in the case of well waters, an indication of ureal contamination; it is a contribution from the atmosphere, and depends on recent rains or snow falls.

The artesian well at Red Wing gives a water which is organically pure, notwithstanding its chlorine and free ammonia, but its sulphuretted character renders it undesirable as a drinking supply. The water of the "Scandinavian" well contains an excess of chlorine and free ammonia, but the soil in which the well is sunk appears to act efficiently as a purifier at the present time; in other words, the water is good but the well untrustworthy. The large quantity of nitrates in one of the tap waters of this city, must be viewed in connection with an excess of iron in the water, this particular sample having been drawn from pipes that had not been in use for several weeks. The large amount of free ammonia in the Red Wing cistern water must be attributed to sooty deposits on the house-roof, as the trifling quantity of chlorine present negatives the idea of a sipeage from the soil; the solids are derived from the cement lining.

Of the Winona wells, that on Wilson and Sarnia streets furnishes an unusually good water; but all the others, including that of the water-works, are of doubtful character as represented by the samples. Although containing little recent organic matter, the presence of free ammonia and nitrites indicates that sources of contamination exist in the track of the water supply. The Winona general supply should be examined from time to time to determine whether its free ammonia is a permanent characteristic derived from the area of drainage, or an accidental contamination affecting that particular sample. Lake Winona gives a water which approximates to marsh water in its characters. The Rochester well furnishes an excellent water.

In conclusion, I desire to urge upon the State Board of Health of Minnesota the desirability of continuing these investigations into the character of the water supplies of the State. In England, where the relations of the water supply to the public health are thoroughly understood, a constant supervision is exercised over the quality of city supplies, and any alteration from the normal standard is followed by an inquiry into its bearing on the wholesomeness of the water. This is as it should be. But in our country public health work of this character is only beginning to be appreciated. Minnesota does well in acting as a pioneer in this comparatively neglected section of sanitary science, in developing the natural history of the organic constituents of public water-supplies. There are seasonal variations in the quality of all surface waters. These should be determined from month to month until the normal condition of streams, lakes and other sources of general supply at any period of the year may be known from the record, and that any deviation from the normal may meet with corresponding inquiry. Chemical supervision of the quality of the surface waters will tend to preserve their purity and react favorably on the public health. The best water, so far as our present ability to discriminate enables us to judge, will always be chosen for general supplies. In time, also, the best waters will be selected for individual supplies; and many wells now in use, the unsuspected cause of continued and paroxysmal fevers, and other dangerous and disabling diseases that break out in localized epidemics, will cease to contribute to the lists of sickness and mortality. The laboratory work that demonstrates the connection between a deadly epidemic of typhoid, and a polluted water, is excellent in itself; but the objective of all sanitary inquiries is *prevention*, and this, in the case of diseases propagated by the water supply, can only be effected by a continued and general supervison which will throw out of use the dangerous waters and suggest precautions for those that are of doubtful quality, before either of them have forced themselves upon the public attention by unmistakable evidence of their character.