

OBSERVATIONS ON THE WATER SUPPLY OF PHILADELPHIA.

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It is well known that adverse criticism has of late years frequently been made on the character of the water supply of Philadelphia, both by residents and by visitors from other cities. To residents of Philadelphia it has not been satisfactory for a number of years for several reasons, such as shortness of supply during long summer droughts and consequent risk in case of fire; secondly, the frequent muddiness of the water so as to render it at times quite unfit for household use without domestic filtration, entailing some additional expense and trouble, which induces many to use well water in preference; and thirdly, well-grounded fears that the Schuylkill and Delaware river waters are, year by year, increasingly assuming a character which will eventually prove dangerously unwholesome, by reason of contamination with human sewage and factory refuse. It is admitted that a large amount of sewage passes into the Schuylkill above the several water-works, a fact capable of ocular demonstration; but it cannot be proved that any disease arises at present from that source, and the low death-rate of Philadelphia to a certain extent shows that its health is not materially affected by a contaminated water supply, especially when we consider the fact that many of the deaths are caused by blood-poisoning by sewer air through defective plumbing. Many people rely on the theory that most of the organic matter of sewage is destroyed during the flow of a few miles in the river, and since the Schuylkill water has never appeared to be unwholesome, they are naturally reluctant to approve of the expense of any change in the source of supply on this account.

But will this present wholesomeness continue? Is it true that the sewage of the Schuylkill is actually destroyed during the river-flow; and if so, to what extent does this destruction by oxidation and other means take place? Assuming that this oxidation may occur, may not a something causing infectious disease be liable to accompany this sewage, which will resist all destructive influences; and therefore, may not the mere fact of sewage contamination be a danger signal for

the future? These are questions of vital public interest; yet no effort has been made by Philadelphia for a practical solution of them, as regards the Schuylkill river, and no official examination has ever been made by this city of the experiments conducted in other places, concerning which various conflicting opinions have been expressed by different authorities.

A number of analyses of the Schuylkill water have been made by several chemists at different times, and the samples have been taken at various points. Enough has been given by Dr. Cresson in his report to the Chief Engineer of the Water Department, March 3d, 1875, to make it appear that the condition of the water is very variable, and that these variations do not correspond at all closely with the seasons. Sometimes the pollution is greatest during the summer months, while sometimes it is then at a minimum. The same may be said of the winter months. It is shown also, that the purity of the supply varies according to the location of the different pumping-stations.

From Dr. Cresson's analyses in the paper cited above, I have deduced the following averages, which I have calculated in parts by weight of ammonia in one million parts of water, the metrical form of statement being superior to all others for purposes of comparison:

	Free Ammonia.	Albuminoid Ammonia.
I. Average composition of water in Fairmount forebay from Feb., 1872, to Feb., 1875, by fourteen analyses in different months, . . .	0.09	0.236
II. Average composition of the same from Feb., 1872, to Jan., 1873, by eight analyses in eight different months,	0.05	0.156
III. Average of same, from Jan., 1873, to Jan., 1875, six analyses,	0.12	0.447
IV. Average of same, from Jan., 1874, to Jan., 1875, four analyses,	0.12	0.541

From these results, considered by themselves, it might seem that the statement made by Dr. Cresson to the effect that the amount of sewage has been steadily increasing since 1872, until the water is occasionally charged with an amount of sewage exceeding that carried by the Thames at London is fully justified.

This is certainly an astonishing result considering that this water has been heretofore considered to be of standard good quality. A large

amount of sewage which passed into the river shortly previous to 1875 has since been diverted by a sewer on the west bank of the river. If there had been a sudden increase in this pollution it might partially explain the results of the analyses.

These results are, however, strangely in contrast to the analyses of the Fairmount water, made in 1875 by Booth and Garrett and published in their report for the Water Commission of that year, which gave in parts per million—free ammonia, 0.02; albuminoid ammonia, 0.03. This sample of water was, as they rightly remark, equal in purity to the water from the “artesian” well at Bryn Mawr, and was perhaps even somewhat better than the water from an “artesian” well in Germantown, 300 feet in depth, which I analyzed in August, 1877. It is to be regretted, however, that Messrs. Booth and Garrett give no information whatever as to the exact dates of their analyses, the condition of the weather previous to the collection of the sample, height of river, etc.; nor do they state whether their results are single analyses or averages of several samples; nor, again, the exact place where the sample was collected. These circumstances are so important for the proper comparison of analyses that much of the value of their results is thus destroyed.

It should also be said, that while Dr. Cresson does give some of these particulars, there are others he has not given.

I have made only a very few analyses of the Fairmount water, nevertheless the results may be of some interest. A sample was taken March 1, 1878, from a water-cock in a store at Seventh and Commerce streets, and therefore, represented the water as actually delivered to consumers. It gave in parts per million—free ammonia, 0.014; albuminoid ammonia, 0.056. This result agrees tolerably well with that obtained by Booth and Garrett. I never placed much reliance, however, on the results of a single analysis because *a priori* considerations would lead us to expect considerable variations at different times and seasons. By several analyses made during the present winter, of water collected at No. 315 Willing's Alley, I am lead to believe that the organic matter is often about four times as great as that indicated in my analysis just stated. It is possible, however, that these results may be invalidated if it is true that the water flowing through the city mains consisted of the mingled waters from several sources poured into the same reservoir before distribution.

Were the results given by Booth and Garrett correct as a yearly ave-

rage, their remarks upon the excellent quality of the Fairmount water in their report cited above would be fully justified. But while I have not the slightest doubt as to the correctness of any single analysis by these distinguished chemists, unfortunately I fail to find in their report any evidence that their analyses correctly represent the average quality of the river water, nor do they make any such statement, although their remarks would appear to be based upon this inference.

It may seem to some persons hardly worth while to criticise the report of the Water Commission after a period of five years has elapsed since its publication. But this objection may be disposed of by the consideration that almost nothing has been done toward adopting the recommendations of that report, or indeed, nothing at all to improve the purity of the Schuylkill water, except the construction of the sewer on the west bank of the river. Hence, the whole subject may be considered to be still in suspense.

Moreover, the City Councils have been repeatedly urged to carry into effect the suggestion made in that report to take water for the city supply from the Roxborough water works at Flat Rock dam, on the assumption that the water at this point was purer than the water at Fairmount, because it was taken from the river above the city limits.

Booth and Garrett's analyses, however, make it appear that in 1875. the Fairmount water was purer than that supplied by any of the other pumping works. If it had been stated that the samples were collected on the same day and under precisely similar circumstances, the evidence for this would have been much more conclusive.

My own analyses, although too few to form the basis of any definite conclusions, tend to confirm the impression drawn from those of Booth and Garrett. The amount of pollution was found to be less than the average condition during the whole year, 1872, by Dr. Cresson's analyses. My analysis of March 1st, 1878, given above, represents the state of purity frequently found as regards the water in the service pipes. An analysis of the Germantown supply from the Roxborough works, the sample being collected from the service pipe on the same day as the sample of Fairmount water above referred to, showed that the Germantown water contained twice the amount of organic impurity found in the water from Fairmount.

My analyses of the Germantown water have given the following

results, which are stated in parts per million, and all the samples taken from service pipes :

Date.	Place of Collection of Sample.	Free Ammonia.	Albuminoid Ammonia
June 18, 1877,	Corner of Main st. and Coulter st.,	0.127	0.091
" 22, "	" " "	0.034	0.124
" 23, "	" " "	0.032	0.116
July 13, "	" " "	0.034	0.140
" 13, "	Cor. Main st. and W. Walnut lane,	0.026	0.143
Feb. 4, 1878,	" " Coulter st.,	0.014	0.088
March 1, "	" " "	0.014	0.090
Nov. 21, 1879,	Wayne st. below Queen st.,	0.016	0.096
Dec. 7, 1880,	" " "	0.034	0.100
" 8, "	" " "	0.054	0.126
" 10, "	" " "	0.074	0.180
Jan. 11, 1881,	" " "	0.186	0.096
Average of the above,		0.054	0.116

The following are a few analyses I have made of the city water, the samples also being drawn from the service pipes. Analyses stated in parts per million :

Mar. 1, 1878,	Seventh and Commerce streets,	0.014	0.056
Nov. 26, "	No. 315 Willing's alley,	0.030	0.120
" 27, "	" " "	0.054	0.120
" 27, "	No. 1126 Ridge avenue,	0.066	0.200
" 27, "	Duplicate analysis of same sample,	0.074	0.206

It is thought it would be interesting to compare with these results analyses of the water of the Wissahickon and Wingohocken creeks :

Date.	Description	Free NH_3	Alb. NH_3
May 29, 1880,	Wissahickon creek, short distance above Norristown R.R. bridge,	0.240	0.290
July 14, 1877,	Wingohocken creek, East Branch, just above J. S. Haines' dam,	0.340	0.136
Aug. 1, 1877,	Wingohocken creek, West Branch, at East Walnut lane bridge,	0.112	0.192

The surface water was carefully excluded in taking these samples. The chlorine in each was respectively in the order given : —0.7, —0.85, and 1.15 parts in 100,000. The Wissahickon water was collected during a long continued drought and was quite clear and free from the mud usually found in it. The east branch of the Wingohocken received the drainage of a farm-yard above the place where the sample was taken. The west branch of this creek received the drainage

of pig styes and other surface pollutions. It was used for domestic purposes by a settlement of colored people.

We will now quote analyses by Booth and Garrett of the Schuylkill river waters given in their report of 1875, translating their figures into parts per million for the sake of comparison with the foregoing analyses.

	Free Ammonia.	Albuminoid Ammonia.
Fairmount,	0.020	0.030
Belmont,	0.100	0.087
Spring Garden,	0.299	0.149
Flat Rock (Roxborough works),	0.125	0.087
Perkiomen creek,	0.125	0.125

From Wanklyn's Water Analysis:

Thames and River Lea water, supplied by London companies, average of 44 samples,	0.010	0.090
Thames water at Hampton court (London supply) before filtration, average of 2 samples,	0.025	0.255
Thames river at London bridge at high tide, average of 3 samples,	1.020	0.550

Dr. Cresson's analyses give the following as the average composition of the Schuylkill water at the Spring Garden, Belmont and Roxborough works:

Spring Garden, average of two analyses,	0.61	0.835
Belmont, average of five analyses,	0.45	0.454
Roxborough, average of two analyses,	0.37	0.327

From this discussion the following conclusions may, I think, be legitimately drawn.

That the analyses by Booth and Garrett and Dr. Cresson of the water in the river at the works, and my own analyses of the water as delivered in the service pipes, all coincide in showing that the average quality of the water contained in Flat Rock pool is not likely to be any better than that of the water pumped at the Fairmount works; provided we exclude from this calculation Dr. Cresson's analyses for the year 1874, when, even if the results were not very approximately correct, there must have been some enormous and temporary pollution of the river. The figures in the analyses of July 24th of that year are, however, so very extraordinary that they excite the most serious

doubts as to their correctness, and they therefore cast suspicion on several of the other analyses also. For, to make this more evident, it may be said that the albuminoid ammonia in the analysis of the Spring Garden water of that date is equivalent to that in the average of twenty-seven samples of actual sewage taken at night from the sewers of Worcester, Mass., during prevalence of dry weather.*

	Free NH_3 .	Alb NH_3 .
I. Average of 27 samples of sewage from three sewers in Worcester, Mass., taken at 6 A.M., 9 P.M. and 12 P.M. Night sewage, .	7.45	1.44
II. Average of 27 samples of the same taken at 9 A.M., 12 M. and 6 P.M. Day sewage, .	18.76	3.16
III. Dr. Cresson's analysis of the water at Spring Garden inlet, July 24, 1874, .	0.29	1.45

These results are expressed in parts per million as heretofore in this paper

What is equally remarkable the water at Belmont inlet and Fairmount forebay were, according to Dr. Cresson's analyses, nearly as bad.

Bearing in mind that this albuminoid ammonia represents relatively the nitrogenous organic matter actually present both in solution and in suspension, Dr. Cresson's analyses appear altogether incredible. It will be impossible, we are sure, to make Philadelphians believe that at that time they were drinking liquid out of a veritable sewer. Moreover, his figures would represent the Fairmount water as twice, and the Spring Garden water nearly three times, as bad as the Thames river water at London bridge, which Wanklyn characterizes as "vile and stinking," having received a large part of the sewage of London.

For these reasons we must believe that some great mistake was made either in the mode of collecting the samples, concerning which the most scrupulous care is absolutely essential, or, in the mode of conducting the analysis, or in the calculation of the results.

In the comparison of the water from the different pumping stations, Dr. Cresson's analyses of November 7th, 1874, of the Fairmount and Roxborough waters collected on the same day, show a difference in favor of the former. Yet here again the amount of albuminoid ammonia in the Roxborough water is about five times as great as the amount found in the average of my own twelve analyses made in all

* *Vide* Fourth Report of Mass. State Board of Health, 1873., page 79. Compare also analyses of Boston Sewage. *Idem* p. 70.

seasons, from 1877 to 1881. It is about four times as great as Dr. Cresson found it to be only seven months afterwards. We must therefore consider the correctness of these particular analyses also as very doubtful, so far as representing the true condition of that part of the water supply of this city. Variations in quality from day to day and from month to month will undoubtedly occur according to the variations from time to time in the amount and character of the waste material of all sorts from the numerous factories, and also according to the amount of rainfall and consequent flushing of stagnant sewers, etc. But that these variations should be of the extent indicated by Dr. Cresson's analyses is incredible, especially in comparison with the results of the examination of a considerable number of the rivers of Massachusetts by authority of the Board of Health of that State, and where the pollution is of a somewhat similar character.

A report has lately been made on the character of the Ohio river water at Cincinnati, used for city supply; but it appears that, although the variations are exceedingly great the deductions to be drawn from them cannot properly apply to the Schuylkill, because the conditions affecting the flow and pollution of these two rivers are so very different. During September and October of the past year the water was, perhaps, what might be called tolerably good, which is stated to represent about the average condition for the greater part of the year; but during the latter half of November, and especially during December, it became frightfully bad—actually nearly as bad, according to the same series of analyses, as the water was at about the same time at the mouth of a sewer.* One of the ways in which the Ohio river is polluted is the frequent practice of the railroad men on the cattle trains of throwing the carcasses of animals, that have died on the way, into the river at the bridges. Large numbers of these dead bodies are sometimes seen floating down the river. Analyses of water from wells several hundred feet deep on the river "bottoms," or flood ground, show this water to be as bad as the river itself, and that this earth contains enormous quantities of organic matter deposited during the frequent floods.

To return to the condition of the Schuylkill river my analyses show that a considerable amount of pollution exists at certain times in the supply from the Roxborough works. Yet the results of these analyses may possibly be affected in some degree by vegetable growth in the

* *Vide* Report of Analyses of Ohio river water by order of the Board of Health, Cincinnati, Dec. 20, 1880. By Prof C R Stuntz.

reservoirs and distributing mains, which is known sometimes to occur. On reference to these analyses it will appear that the largest amount of albuminoid ammonia for 1877 was 0.14 parts per million, and for 1880, 0.18, while the average for all was 0.11 parts per million. On referring to the analyses by Prof. Nichols of the water of Cochituate Lake, the purest water supply of Boston, published in the fifth report (1874) of the Massachusetts State Board of Health, page 117, we find that the maximum amount of albuminoid ammonia during the summer, autumn and early winter of 1873, was 0.13 parts per million, with an average of 0.11 parts. The samples in this case also were taken from service pipes at the Mass. Inst. Technology. While the average is the same in the two cases, the maximum is greatest in the Roxborough supply. If it be said that the difference is very insignificant it may be replied, that just this apparently insignificant difference in albuminoid ammonia will in the case of shallow wells constitute the difference between a well water which is passably good and one which may be dangerously polluted. In river waters, however, as has been explained in a preceding paper on this subject, we should not judge quite so strictly as in the case of shallow wells.

We should also consider in this connection the fact, which we believe to be true, that the Cochituate water contains extract of peat, since the gathering grounds for the supply of the lake are of a peaty character, and consequently a part of the albuminoid ammonia probably represents extract of peat which is by most observers considered quite innocent when in not very excessive amount. It will thus appear that the sewage contamination of the Roxborough supply is, in all probability, quite perceptibly greater than the Boston supply, inasmuch as no beds of peat are, I believe, to be found on the banks of the Schuylkill and its tributaries.

There is some reason to believe that either the Schuylkill river water was purer in 1875 than it has been during the period of my analyses, and perhaps, better than it was for the two years, 1873 and 1874, or else that the water at all the different pumping stations was at the time of Booth and Garrett's analyses perceptibly better than its average condition for 1875.

It should be stated that the maximum pollution indicated in my analyses was coincident in time with extremely low water in the river which had continued for some time, causing a probable concentration of the sewage, and therefore, not necessarily indicating an increase in

the absolute amount of sewage poured into the river. We cannot regard the water at these maximum periods as being of satisfactory character, since at such times a disagreeable taste, and even an odor, is perceptible and sufficiently marked to cause some people in Germantown to prefer well waters for drinking purposes.

It is proper to state that my own analyses have been conducted throughout with very great care as regards perfect cleanliness of apparatus, etc., and purity of reagents and with strict adherence to the directions given by Wanklyn in the third and fourth editions of his manual. The samples were collected according to the directions of Wanklyn and Frankland, the absolute cleanliness of sample bottles being especially regarded.

One point of some importance, to which, it is believed, no allusion has been made in published reports, is the probability that the quality of the water in Fairmount forebay usually may be said to be an average of that of the whole stream opposite to that pumping station, while this cannot be said of the water at any of the other works. This is owing to the fact that frequently during more than half the year no water flows over the comb of Fairmount dam, and consequently the whole stream, exclusive of a very small proportion necessary for the canal locks, passes through the forebay of these works to drive the turbines and supply the pumps, the whole flow of the river being utilized for these purposes, with the exception of what leakage occurs.

In the case of the other works the supply is taken from along shore, obviously the most impure part of the stream, and the water is pumped by steam power. It is evident that the Roxborough supply is also different from that at Fairmount, for although the former works are situated above Flat Rock dam, the water supply is here also pumped entirely by steam power and the river water flows quite continuously over the comb of that dam and the current is not therefore diverted to any great extent.

Hence, supposing that no polluting material were poured into the river between Flat Rock and Fairmount, and also supposing that the sewage was not oxidized to any extent during this flow we should naturally expect the water supplied from the Fairmount works to be of purer quality than that supplied from any of the other pumping stations.

This consideration will at once suggest a plan of obtaining a better

supply at all the upper works by extending the inlet pipe out into the middle of the river stream.

Setting aside the question of a more abundant supply for this city as not being within my province, and *considering solely its purity*, a very obvious method of improving its character is presented in the plan of constructing large covered sewers *on both sides* of the river, into which it shall be made compulsory to discharge every kind of artificial drainage and house-sewage and all factory refuse. These sewers to be effective at all should extend from near Flat Rock to a point below Fairmount, and were it not for engineering difficulties it would be better to extend them above Flat Rock dam. In this way the special pollution of Fairmount pool would be prevented and opportunity would be given for the oxidation of the sewage of Norristown, Conshohocken and other towns above Philadelphia. If it be true that this oxidation does take place and these intercepting sewers having been constructed, it would be possible to furnish the city with a purer supply than at present by drawing nearly the whole of the water from near Fairmount dam. By going up the river for the supply we would then only meet the sewage of Norristown, etc., which has been less thoroughly oxidized.

It is true that since the valley of the Schuylkill is destined in the far future to be densely populated, this plan will necessarily be only a temporary one. For we must look forward to a day when, if sewage irrigation is not soon established for all large towns, all our rivers will become no better than foul open sewers. It will also be only a question of time, of somewhat greater length, when the amount of sewage will counterbalance the effect of the greater volume of water in the Delaware river also.

Moreover, we have no reason to suppose at the present time that the specific cause of infectious disease may not co-exist with a small amount of organic pollution as well as with a large amount of it. We do not know whether this specific cause may not be capable of resisting all oxidizing influence for long periods of time, although the probabilities in some cases seem to be against this.

There is a marked tendency, of latter times, to give up rivers as a source of public water supply and to seek for it in natural and artificial lakes or large reservoirs in hilly districts. By this plan use is made of the storm waters of the region, and a water is obtained as nearly pure from the clouds by natural distillation as can be done on

a large scale. The hill country from which the supply is taken must be chiefly in woodland or pasture ground, and should not be in active cultivation. It is also to be noted that sewage contamination is less likely to occur in such a lake than in a river, for it has been observed in many places and among them, Massachusetts, that the centres of population extend usually along the river courses and seldom settle on the shores of small lakes. Hence, the plan of building an immense impounding reservoir on the drainage area, or, what is improperly termed the "water-shed" of Perkiomen creek, appears in some respects to be the best for the permanent future supply of Philadelphia, not only as regards its purity but also in regard to quantity of water. But the whole subject of this plan requires a far more thorough and extensive investigation than has yet been made. The teachings of sanitary science in all its bearings must be applied and investigations must be made as to what pollutions appear to exist at the present time in the Perkiomen creek and what is probable in the distant future. The question of the necessity of a State Board of Health must be considered, and the requisite control such a board should have in maintaining the purity of the water supply. For should polluting material enter this artificial lake, that which will not subside will be less likely to be thoroughly oxidized than in the river, and the pollution is, therefore, more important in the former case. Moreover, the continual subsidence of organic impurity in a reservoir which cannot be cleaned is an element of danger.

Comparative Expense of Lighthouse Service.—Emile Allard has published a comparison of the principal expenditures for lighthouse service in France, the United States and England. He finds the average annual cost of each light to be 3580 francs (\$716) in France and 11,790 francs (\$2358) in the United States. A large part of the economy in the French service is undoubtedly due to the difference in the cost of labor; but he also thinks that much of it is owing to the vigorous economy which the engineers of the department of bridges and highways bring to the execution of their labors, and to their careful avoidance of introducing luxurious arrangements, which do not contribute to manifest utility.—*Annales des. Ponts et Chaussées.*