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THE WATER SUPPLY OF ALLEGHENY.

ENGINEERS' SOCIETY OF WESTERN PENNSYLVANIA,

At the regular meeting of the Society held October 19th, 1886, Mr. Dempster in the chair, discussion was continued on "The Water Supply in Allegheny."

Mr. PHILLIPS: I do not know that I can say anything at all to throw light on the present question. I carried out some examinations of the water in the spring of 1883 and fall of 1884. The conditions were so different then from what they are now, that what was true then would not be true now.

I understand that one of the questions that come up at the last meeting was, where the source of the supply could be looked for, if not from the Allegheny river. If you take the census of population from some of the different water-sheds, as well as I remember now, the city of Rochester has the first place among the large cities, with a population of thirty-six to the square mile of water-shed. Then the next one is Pittsburgh. Taking the census of 1880, and counting the population very carefully, dividing the counties in the whole region drained by the Allegheny, I estimate it as 52.6 to the square mile. Now New York City is supplied from a region where there is a population of sixty-five to the square mile. Philadelphia has two hundred. Of course, this is not counting the population in the cities themselves, that is, Pittsburgh, Philadelphia, New York, etc. It is the population higher up the stream that would affect the water.

If the Allegheny water has so small an amount of drainage, relatively speaking, why should it not be perfectly good yet? I do not see that we need go very far to look for a source. My examination of the water led to the following result: I found that the Pittsburgh water, if the quantity of nitrogenous matter in the Pittsburgh water is represented by the number 11, that of Allegheny would be represented by the number 12. That is, there is a very slight difference in favor of Pittsburgh—12 parts of nitrogenous organic matter in the water as it comes down from the Allegheny, where there are about 11 in the water supply of Pittsburgh. These figures represent the average of seventy-seven tests of Pittsburgh water and of about one hundred and fifty tests of Allegheny City water. The Pittsburgh sewers help to add to the impurities of Allegheny City water. According to Wanklyn, drinking water should not contain much more than ten to twelve parts of albuminoid ammonia in one hundred millions.

I am afraid that I am simply going over old ground in mentioning these facts, that I am saying nothing new at all, so that you will have to excuse me; but as I said, I have not made any tests of water lately. I consider single tests as of doubtful value, because the quantities looked for are so infinitesimal as compared with ordinary chemical work. To determine one part of any substance in a hundred millions is a very delicate operation, and here in the case of the water supply it is often a question of one or two parts of nitrogenous matter in a hundred millions.

There is a more important reason, however, that is, the daily variation of the amount of such nitrogenous matter in the same water. In the Allegheny City water I have found it to vary from two parts to more than twenty parts in one hundred millions.

Mr. DAVIS: My idea of the Allegheny water is, that it is good. Very few cities have as good source of supply as is afforded by this river. Some years ago, when city engineer of Allegheny, I had occasion to give this matter some study.

In 1870 Councils appointed a committee, consisting of Water Committee, Superintendent of Water Works, and City Engineer, to examine the subject of water supply. They submitted a report (this was printed in pamphlet form) and recommended that for future supply of the city the water should be taken from Huling's eddy, at the Narrows, a point up the river some ten miles above the present pumping works. I still believe this to be the best place to draw water from. The water has better depth here than at any point below. The deep water comes in close to shore. The hills are high and precipitous. There is no room on the shore for any large collection of dwellings or manufactories to foul the water. The river water as supplied now cannot be regarded as unwholesome. It contains considerable sediment after heavy rains. This condition of water continues longer than it otherwise would on account of the interruption of the

current, imposed by the operation of the dam in the Ohio below the city. This dam makes a pool which extends at least a half mile above the pumping works.

Before the dam was erected the muddy water was soon carried past the city by the current; now it is held back, and as a consequence turbid water is supplied for a longer time.

The appearance of the water in the vicinity of the water works, when the dam has been up for any length of time, is not inviting. The light refuse and waste thrown in the stream floats on the surface, and as there is no sensible current this soon forms a considerable accumulation, especially near the shores, and gives the impression of foul water. Of course the increased depth given by the dam makes the supply comparatively free from such surface impurities, as the water can be drawn from a depth below the surface.

The contamination of water by sewage is as yet hardly appreciable, as the quantity of sewage discharged is so small compared with the volume of water running in the river; but as the districts in the valley above become more thickly settled and manufactories are extended, the river will receive a great deal more waste, and the dam, in periods of drouth, will, by retarding the flow and creating a pool, retain the sewage and seriously affect the purity of water.

The low water flow of the Allegheny is estimated at 10,000 gallons per second. The minimum flow of the two rivers, Allegheny and Monongahela, as measured in 1879, by Mr. William Martin, Assistant Engineer Davis Island Dam, is 12,267 gallons per second. The area of the drainage basin of the Allegheny is about 12,900 square miles.

The dam, at low water stages, as before mentioned, affects the purity of the Allegheny water to some extent, by making the movement of water sluggish, and by giving more time for the filth entering the river above to permeate the mass. This turbid condition of water promotes deposit also, which in course of time will be a source of annoyance.

Summer freshets will not have the same effect in scouring the river bed and cleansing the margins they otherwise would. On this account, and in view of the probability of the early construction of a dam in the Allegheny at the head of the present pool, above the water works, which will back the water above Sharpsburg, or to a point near Pittsburgh pumping station, making a second pool some six miles in length, I think it would be desirable to have the supply drawn from the point named. The valley on the right bank for some eight miles above Allegheny, will in the near future be taken up with manufactories and dwellings (the opposite bank, for the greater part of this distance is already so occupied).

There are now competing railroads in part of this valley, and there are three main gas supply lines extending through it.

The sewage of the settlements on both sides of the river will naturally be discharged into it. It is a difficult matter to prevent the streams from being made the receptacles of sewage. In England efforts have been made to prevent the pollution of streams by stringent legislation, but without avail.

It has been suggested that the water might be filtered. Artificial filtering beds were proposed for the St. Louis water works in connection with settling reservoirs at Bissel's Point, but that feature was never carried out, the settling basins doing the work very satisfactorily.

Lowell and Providence have had some experience with filtering galleries. In both cases they have proved unsatisfactory. Newark used a natural filtering bed, but it did not work well; the fine sand and clay soon silted up the gravel, and made the filter inoperative.

In the neighborhood of the point proposed for source of supply and pumping works, there is favorable ground for reservoir purposes.

The storage and settling reservoir should have a capacity of eighty or one hundred million gallons, so as to give four or five days' supply to a population of one hundred and fifty thousand.

This reservoir should be placed at an elevation of some two hundred and sixty or two hundred and eighty feet above the river, so that the water after settlement could be delivered to the Troy Hill basin. This latter should be enlarged to double its present capacity, or to hold at least eighteen million gallons. This would give a good distributing reservoir in the heart of the distribution, at an elevation of some two hundred and twenty feet above the river.

This basin will give a good head of water, without causing extra strain on the plumbing, in the thickly built up parts of the city. It commands a district of about three and a half square miles, or one-half of the present city area. The enlargement can be made by extending the reservoir out to the point of the hill and raising the flow line. The slopes of hill should be protected and the reservoir grounds beautified.

Above that level there should be separate pumping works similar to those now used on some of the hills; these are isolated points, and should be treated independently.

Mr. Harlow mentioned in connection with filtering water, that the supply should be brought to present works by conduit and then pumped to a large reservoir located on one of our hills. In my examination of grounds for reservoir sites, I found very few places suitable.

The elevations of hills back of city range from four hundred to five hundred and fifty and even to six hun-

dred feet, and most of these are a long distance back from river. The intervening ravines or depressions, where they reach the proper elevation, are too broad, or are objectionable in other ways, to take advantage of for reservoir sites, as has been done elsewhere, notably at Cincinnati.

Reineman's Hill gives a good location in some respects, though it has the objection of excessive height, and the further objection of being, in part, honeycombed in mining for coal. Pittsburgh has had some experience in this line, I believe, at Herron Hill reservoir.

The delivery main from the reservoir up the river to the Troy Hill reservoir would supply the settlements along the line above the city. The route for this main would be, preferably, by the line of the West Penn. Railroad.

A supply can be obtained from the head waters of the Kiskeminetas and Conemaugh, but it would be at a cost disproportionate to its advantages; there is fall enough, and by the use of large storage reservoirs at the sources, excellent water can be obtained.

Such a project will not likely be seriously considered soon. I think we have good water near us in the Allegheny. We have only to go above the thickly settled districts and above the proposed pool to reach it.

As a sanitary measure, the local sewage, or the bulk of it at least, should be intercepted and carried to a point beyond the limits of the city, below Davis Island dam.

This is especially necessary now since the dam is in operation, as the river, during the period of low water, is made a sluggish pool.

The small streams discharging into the river in vicinity of present pumping works, and above on both sides of the river, are used as sewers.

Mr. DANSE: I rise for information. I would like to ask the gentleman what the distance is to Huling's eddy?

Mr. DAVIS: About ten miles, or scarcely ten miles. I would like any of the gentleman who are visiting up that way to inspect this place. I think it the proper place, and you would be pleased with the location.

Mr. SCAIFE: I noticed in the report of the last meeting, that the Superintendent of the Allegheny Water Works had said that he believed the Allegheny water was purest when it was muddiest. If I understood Mr. Phillips aright in conversation with him today, he said that in his chemical examination of the water he found more nitrogenous matter in it when the river was high than when it was low.

Moreover, Mr. Davis has expressed the idea that when the wickets of the Davis Island dam are up, the water is not as pure as when they are down, owing to the back water. Now, if the muddy water drags along nitrogenous substances, and therefore becomes more impure, will not the river water be purer when the dam is raised and a settling is going on in the back water, than it would be in a strong current?

Mr. PHILLIPS: I found that with very muddy water there was about five times as much nitrogenous matter as in the clearer water. That was specially at the time of the great flood in 1884—in February or the beginning of March, 1884.

I have found that the water, when so low as to be below the lowest mark at the bridge, was very pure. It did not look so, but it was very pure, purer than when it was very high. In fact the amount of impurity is in direct proportion to the rainfall and depth of water. The deeper the water the less the purity.

The less the current the less the impurities, the greater the current the greater the impurities. It was so when I made my tests, in June, and was so during October, November and December, of the same year, 1883.

Mr. DEMPSTER: Mr. Phillips, how do you account for that, was it an eddy?

Mr. PHILLIPS: The water was taken from a hydrant in the city, on North Avenue. It only shows that when there are floods, more of the general drainage is washed down.

Mr. DANSE: Don't you think that was due to the fact that where the water was very shallow there was greater opportunity for oxidation?

Mr. PHILLIPS: Yes, I think it was (although I do not know that that would fully account for it), because when the water is running very fast, the movement of eddies should promote oxidation.

Mr. WICKERSHAM: It was once said, in the presence of Benjamin Franklin, that if a tub was filled with water and a ten pound fish put in, it would not weigh any more, and Franklin was asked why it was so. Well, he said, before I give a decision on that point, I would like to see the experiment tried. I would ask the gentlemen if there is any instance of any person in Allegheny, having been poisoned or made sick by the impurity of the water, that is through any poison supplied through the hydrants. I never heard of a case of that kind, and I don't think a case has ever occurred unless through local causes in the pipes. Water may stand for a long time in a lead pipe and gradually, not being drained off, may take up some of the deleterious matter from the lead and may make a little sickness, but the people have never been injured by taking water from our river. I have no evidence of it.

It was said at our last meeting that the water after a freshet was purer than after a long drouth, and I think it is very reasonable to think it may be so, for the very current will remove impurities that otherwise would be in the water. And I can readily conceive that muddy water after it has settled a little

may be better than before it was muddied. I do not think it is a hard thing to conceive of it at all.

Then another thing was said at our last meeting, that the influent pipes were placed in the middle of the river, that in times of high water the water that runs down, all runs over the influent pipes, that the impurities were carried over it and none sunk down, and in times of low water these things all kept near the shore.

Mr. Armstrong told us that the water, in very low water, was good at the influent pipe, and clear. Now, if that is so, it seems to me the whole question is narrowed down to, where is the best place to get water with the least impurities? It is a matter of importance because it concerns the health of the people. If you can get above the source of impurity, so much the better.

In Allegheny we have to look forward to supplying a much larger district than at present. Our line will soon embrace Sharpsburg on the one river, and I do not know how far down the river, but I think to Lowery's run. It is likely we shall have to supply in a few years a population of at least 150,000 people, and we need some more extensive supply than we have now; but when we think of the immense amount of water that flows down the Allegheny river, and compare it with the quantity required for the city's use, we need not fear any bad results from the impurities which find their way into it; but an increased quantity we must have, and we ought to go for it, to whatever point required, where it is now uncontaminated and not likely to be for some time to come.

Mr. A. E. HUNT: The analyses referred to by Mr. Brown, in the paper that was sent out of the transactions of the last meeting, were relative to the comparative purity of the water furnished through the city conduits of Pittsburgh and Allegheny City. The samples from which the analyses were made, were taken on August 6th, 1886; the one at 32 Federal street, Allegheny City, and the other at our laboratory, at 98 Fourth avenue, Pittsburgh.

Before discussing the relative merits of the two samples, I will first explain what the measures of impurity in samples of water really are.

Chemists analyze suspected waters for free ammonia, albuminoid ammonia and chlorine, as indicating, or rather as evidence of impurity. I say evidence of impurities because these chemical substances are not the impurities, are not the poisonous elements in the water.

I have read quite a number of articles lately, in which the writers expatiate learnedly on various water analyses, and talk of the poisonous and deadly amounts of ammonia and chlorine in the waters. These are not the poisons that are in the water—they are simply the evidences that show how much poison, how much sewage, how much animal or vegetable refuse in a state of putrescent fermentation is in solution in the water, and with this explanation, I would claim that the analyses of the Pittsburgh and Allegheny waters, neither of them show an alarming state of affairs, but rather a comparative freedom from impurities. I make this statement qualifiedly, that is, that *these analyses* show the comparative freedom from impurities; however, I certainly agree with Prof. Phillips, that these two analyses are too few to generalize on; but I would, however, take exceptions to the inference which is implied by the professor—that the almost infinitesimal amounts, as in the few parts per million, is very difficult to determine analytically, for the wonderfully delicate test of Nessler has made these determinations, in the hands of a reasonably skillful analyst, certain and reliable.

The following are the results of the analyses, placed side by side for comparison:

	Allegheny Water. Parts per million.	Pittsburgh Water. Parts per million.
Free Ammonia	.05	.02
Albuminoid Ammonia	.03	.04
Chlorine	13.00	12.00
Total Solids	137.50	87.30
Silica	32.10	13.80
Oxide of Iron	2.10	1.80
Carbonate of Lime	40.00	30.00
Sulphate of Magnesia	5.00	5.50
Carbonate of Magnesia	15.40	8.10
Carbonate of Soda & Potash.	21.50	8.40
Chloride of Soda & Potash	21.40	19.70

Before I sit down I would call the attention of the members of the Society to something that ought to be of interest to us all, and that is now being worked up by eminent chemists. What has been found out by experts so far, is, that the ammonia indicates sewage, and that the sewage has in it minute germ growths that can be seen by a microscope. It is a question not yet settled by chemists and biologists, whether these germs are a vegetable or animal growth, but they are similar to the germs that cause fermentation—you know that there are several kinds of fermentation, one of them is the alcoholic, requiring the yeast germs to produce it in saccharine solutions; this kind of fermentation I need not say anything more about to the members of this Society, as many of them have experimented with it in many ways. The second is the acetic fermentation, as in making vinegar with its superinducing germs, existing in the gelatinous substance, the housewife calls the "mother;" another form is what is called the putrescent. In any one of these forms of fermentation there needs to be a germ or spore. It is a little organism that is needed to cause

the fermentation to start. It is something that sometimes exists in the air, that finds a fertile home in water fouled by impurities, and is transmitted in many ways; and it is the cause of the fermentation.

Pasteur says that it is the inoculation of the system with these germs that causes rabies in dogs, that in a varied form causes typhoid fever. He says that in the blood there is something of the same form going on in consumption, and he believes that many of the forms of disease, which man is cursed with, are really due to these minute organism, which exist in nature, in putrescent matter.

Certain it is, that the particular poisonous ingredients in water, which we are now discussing, are not the ammonia salts nor the chloride of soda, which are harmless; it is not the free ammonia, or the albuminoid ammonia, but it lies in these things which the chemists cannot get into such shape as to be able to separate and determine chemically; so that I have a further reason for qualifying my statement that the analyses given above do not condemn the samples of water for portable purposes, for I do not believe that the chemical analyses alone should be taken as indicative of the purity of the water, but simply as an indication of its character.

Mr. SCAIFE: I am glad that Mr. Hunt has brought up that last point. I was about to ask a question in regard to it. Should we not look beyond salts and mere chemicals, as poisons in the water, to the organic germs it may contain?

Some years ago, I visited a meteorological observatory in Paris. The gentleman in charge showed me an arrangement for collecting the germs floating in the air. He said that the air at all times contained germs in greater or less numbers, and that he could tell the general condition of health in the city by the germs which came floating to the observatory. They were first examined under the microscope; then subjected to a kind of culture in order to develop them, and to show what they would grow to. After that it was proposed to inoculate animals with them, and by watching the results, to determine their probable influence upon the health of the people; and finally, to learn by experiment what would destroy the germs.

As our river waters are likely to contain similar germs, may not their presence account for a portion, at least, of these nitrogenous substances? To determine the quantity of the latter is the province of the chemist; but then, should not the physician step in with his microscope and examine the germs themselves, subject them to culture, and find what effect they may have on the human system? If that were done, perhaps some remedy might be discovered to counteract them, so as to prevent and cure diseases resulting from them. The absence of such germs might also account for the fact which Prof. Phillips mentioned to me to-day, that epidemics do not always occur when the water is bad—that is, when chemical examination shows the water to be bad, according to the standards that have been given, wherein their presence might produce much sickness in water chemically potable. I think, therefore, it might be well for our chemists to take competent physicians into partnership; and when called upon for an analysis of water, as to its hygienic properties, to give not only a chemical analysis, but also what might be called a biological analysis.

Mr. PHILLIPS: I think Mr. Scaife is exactly right, but one difficulty is the quantity and variety of these organisms, so great that no one can define their effects. In connection with the work of the London Commission on the Thames water, they have employed some of the first biologists in England, among them Dr. Lancaster, who stated that he found, I think, over thirty-two to thirty-eight different kinds in a single sample of water, and that is nothing unusual. Many of them are known to be absolutely harmless. The great difficulty with the chemical methods of determining the nitrogenous matter, would make this all the more desirable if it could be done, because the nitrogenous matter of the Allegheny water will vary from day to day, and from two parts in a hundred million to twenty, which is an enormous variation, so great that a biological method of examination would be very desirable. At present the biologists are not prepared to settle the question as to the safety of drinking water, although it is desirable to know something about, and we must fall back upon the chemical methods.

Mr. DEMPSTER: I am a little practical. We have the Allegheny river water—that is the best we have and all we have. The question will be, however, where, in the Allegheny river, is the best place to get pure water—the best and cheapest. Now, if I were a member of Allegheny Councils I would look at both those elements. The water up about Claremont is as good as any place on the river. I have seen the place, and I think a very economical arrangement can be made by making use of the unfortunates who go up to Claremont, and with their aid the citizens of Allegheny City could find no better way.

The question as to the purity of water in the time of freshets or in currents—the fact is, that currents over pebbly beds will purify the water, and that stagnation will hold the water and will hold the impurities in the water. In times of floods the impure matter is washed down from the banks of every little stream and is carried with the current, and the amount of impure matter will be at maximum; while in the time of low water there is very little in it. The water from the

head waters is pure, because in coming down it flows over pebbles, as you can learn by taking water from above and below a riffle.

Mr. Danse gave some experience and some data he had gathered while boating on the Allegheny, to the effect that the water was very much better at some times than at others, and that he had seen no perceptible coloring or trace of impurity at the mouth of the influent pipes; after which the Society adjourned.

THE WATER SUPPLY OF ALLEGHENY.

NOVEMBER 16TH, 1886.

The Engineers' Society of Western Pennsylvania, E. B. Taylor, President, in the chair, met, and after their routine business, continued the discussion of "The Water Supply of Allegheny." Mr. T. P. Roberts, Chief Engineer of the Monongahela Navigation Company, read the following paper:

THE OXYGEN TEST.

When is Water Unfit to Drink?

The following brief paper, by Prof. Albert R. Leeds, I have never seen elsewhere in print, save in the report of the Philadelphia Water Department for 1875. In the belief that it will prove interesting to those who have not seen it, I venture to read it here. A careful study of it, in connection with Prof. Phillips' able paper read before our society some time ago, supplemented by his remarks and those of Prof. Hunt at our last meeting, will, I am sure, assist in allaying the feeling of alarm manifested by many citizens in regard to the character of the water in the Allegheny river. That stream, I am quite convinced, is to-day, six or seven miles above its mouth, as pure and wholesome as when Washington stood on the site of the future Fort Duquesne, and pronounced it a "good place for a fort."

"There is perhaps no question more important to the inhabitants of many cities, nor one which more severely taxes the resources of applied science, than the determination of the fitness or unfitness of a water supply. The difficulty arises from the fact that, in some cases, a water may have taste, smell, color, and a considerable amount of foreign matter, and at the same time be drank with little or no injury;* while another water, which is agreeable to the taste, limpid, colorless, and with little foreign matter, may yet contain abundant sources of disease.

"The literature of the subject shows that there are two classes of thinkers, one of which puts great faith in the efficacy of natural agencies to bring about the purification of polluted streams; the other which contends that the only safe plan is to reject water which has ever been contaminated by sewage, etc. The evidence elicited by the Royal Commission on the water supply of London is that principally quoted by both classes, and cannot be regarded as conclusive. The rapid extension of our knowledge in this branch of sanitary chemistry is such, however, that we may anticipate greater certainty in these matters, and imparts great interest to some recently published methods of investigation. Any one who refers to analyses made a few years back, will find that it was deemed sufficient to give the character and amount of the mineral substances contained in the water, while the organic and volatile substances were expressed in a sum total, no attempt being made to determine their precise character. But, except in cases where the mineral substances were positively deleterious or excessive in quantity, this did not settle the question. Of late, the greatest attention has been paid to the organic constituents, and the analyses state what amount of putrefiable matter is present. A careful determination is also made of the amount of ammonia and of nitrous and nitric acids. These are regarded as the forms which the organic matter in large part assumes after it has passed through the putrefiable stage, and indicate, therefore, the degree of previous contamination.

"But it is said, and with truth, that all these things may be known to a wonderful degree of nicety, and yet there may be substances present capable of rendering the water altogether unsafe for drinking. It is urged that the living organism is exceedingly sensitive to substances whose capacity for injury is fatal, even when present in amount so small as to render their weighing, and even detection, impossible. But of late the fauna and flora of water courses have been studied, with a view of learning what assistance they could be in the matter, and the results are highly encouraging.*

"It has long been known that *dissolved oxygen* played

*Allegheny City draws its water supply from a point less than a mile above the mouth of the river. At times, it is possible, some of the manufacturing refuse, etc., from sewers on that side of the river, above this point, may reach the influent pipe, Hence the complaint of the "smell" to the water, sometimes heard, etc. Others, however, drawing from different hydrants, will deny that there is any such smell. Both may be right. To settle this point in dispute, regard must be had FIRST to the *time* in which the water has had to ferment in the pipes; SECOND, to the difference in temperature of the respective hydrants. Thus I know of hydrants in Pittsburgh, probably near "dead ends" little drawn upon, with the pipes laid deep, or in the shade more than usual, which furnish potable water in the hottest days of summer. On the route of mains largely drawn upon, the earth surrounding the pipes late in the summer approximates in temperature that of the water in the river. The pipe lines are certainly distributors of heat. T. P. R.

*Profs. Phillips and Hunt both refer to the value of microscopic research in conjunction with chemical analysis in the investigation of drinking waters.

a great part in the purification of streams, and was the principal agent by which putrefiable substances were broken up and were converted into harmless inorganic compounds. A recent essay by M. Geradin, to which the prize was awarded by the Paris Academy of Sciences, contains some striking results obtained by the above mentioned methods of investigation. These methods, to summarize, were:

"1. A determination of the amount of oxygen held in solution.

"2. An observation of green plants and aquatic mollusks.

"3. A microscopic examination of algæ and infusoria.

"It is claimed that the results obtained by these three methods were identical, and that, where the water was clear, with abundance of fish, water-cress, etc., the water contained a correspondingly large amount of oxygen; while in places where the dissolved oxygen was small, fish and the higher types of aquatic plants were wanting, and certain low forms of vegetable growth had taken their place. The river Vesle, in France, from Rheims to Braisne, was taken as the field of observation. It was studied over a distance of thirty-seven and a half miles, during which it received the sewage of one large town (that of Rheims, the daily flow of which amounts to 4,180,000 gallons), and other impurities. Above Rheims, the water (which was clear, wholesome, and with abundance of fish, charas, water-cress, ivis, etc.,) contained 0.66 cubic inch oxygen in sixty-one cubic inches of water. In passing through a suburb above Rheims, the Vesle received the refuse of some dye works, which colored the water, and in place of the fish and water-cress, *sparganium simplex* makes its appearance. At a point where the water had received the contents of the five principal sewers of Rheims, the water was thoroughly polluted and contained but 0.03 cubic inch of oxygen in sixty-one cubic inches. Two species of *algæ*, the *biggiatoa alba* and the *oscillaria nataus*, were developed largely, the latter to such an extent that the whole surface of the sluggish water was covered with a thick blackish coat.

"Above the mill at Macan, where the oxygen had increased to 0.45 cubic inches, the two varieties *algæ* above mentioned had disappeared, and the bed of the Vesle was covered with a long whitish *alga* called *hyphæthrix*.

"At Compensé mill the oxygen had increased to 0.5 cubic inch, the *hyphæthrix* had almost completely disappeared, and the *sparganium simplex* was again abundant. Below this point, the amount of oxygen increased, and with it a corresponding change took place in the vegetation, until at Braisne the water contained 0.66 cubic inch of oxygen per litre, all traces of pollution had disappeared, and fish and water cress flourished.*

"From this it would appear that a properly areated and pure water showed, when polluted, the amount of pollution by a corresponding diminution of oxygen. by the appearance of *sparganium simplex, spirogyra, hyphæthrix, biggiatoa* and *ossilaria*, and progressive improvement by a corresponding increase of oxygen, and the appearance of these plants in the reverse order. It remains for us to apply and extend this knowledge to our own streams. Fortunately, the means are not wanting, since the great monograph on the fresh water *algæ*, magnificently illustrated with plates, by Dr. H. C. Flood, which was not published by the American Philosophical Society, has been recently printed by the Smithsonian Institute."

I have for ten years, in the course of travel, and while engaged in surveys along streams, kept in mind the oxygen test for the purity of their waters, by observation on their fish life—necessarily confining myself to this division of the subject for want of the facilities and time to devote to the vegetable and microscopic organisms in the water, but I would commend these departments to those who have the time and the instruments, as promising fields for the development of information of the greatest practical value to the people of our country.

Our country is so rapidly being populated and covered with great cities and towns, that the question of a pure water supply for them demands in many cases the application of all our means of knowledge. Too often the question of the source of water supply is left to engineers for settlement, whose sole care is that the pipes be large and strong enough, the reservoirs tight, and the engines equal to every demand—and it is a great thing to know how to do all this.

Allied with his practical knowledge, the hydraulic engineer should acquaint himself with every known means to guard the health of the community he is called upon to serve; and if he feels himself deficient in any respect, should not hesitate to call in the aid of the specialists. "All things work together for the advancement of knowledge," and our profession at large is doing yeoman's service in the good cause.

These remarks have little to do with the fish test question, but they seem to be justified by the times which demand a definition of the duties and position of the hydraulic engineer, whom it is generally conceded, occupies the topmost rung of the broad and high ladder of engineering science.

The fish in the Allegheny river afford, I think, an exemplification of M. Geradin's theory, for they appear

*It is unfortunate that distances from point to point, original volume of streams, and volume of tributaries, if any, are not here given. T. P. R.

to be competent judges of its purity as far as concerns their own welfare, as I will proceed to show.

During the years 1878-9 I conducted surveys and works for the improvement of this stream for the government, under Col. Merrill, U. S. Corps of Engineers, which included all the distance between Pittsburgh and Olean, N. Y. 255 miles. It is to be recollected that at Pittsburgh this river drains approximately 13,000 square miles of comparatively sparsely populated country, not a single town upon it possessing a sewage system, and that in its lowest stages it discharges not less than 500,000 gallons per minute.* It has about four times the area of water-shed and discharge that the Schuylkill has, and as compared with that stream receives certainly not one-twentieth of the amount of sewage matter above our city limits. We should say, therefore, having regard to these facts, that it is contaminated to the extent of only one-eightieth of that stream, if indeed so much. If, thus, the Schuylkill still furnishes water not yet proved to be unwholesome at Philadelphia (though there are grounds for doubt on this point), we need have no fear concerning the purity of the Allegheny as a source of water supply for generations to come. I would say this even if the stream was slack-watered. Philadelphia draws her supply from a dam. No river of its size in the world has ever been dangerously contaminated by sewage matter. The slight indications of ammonia found in it by Profs. Phillips and Hunt, from samples gathered from a point suspected of being bad, could doubtless be found in nearly equal proportions at its head-waters, the product of the decay of pure forms of vegetable matter.†

Yet notwithstanding the purity of the river, the fish in its waters seem to be gradually disappearing over certain areas of its course in a peculiar manner, but in a way easily to be explained, and preventable by the exercise of a little backbone in our Legislature.

Thus, for a long distance below Olean we found but few game fish; thence for some distance above Oil City they appeared to be more plenty, and were at their maximum just above that point. Below Oil City for a distance of seventy-five miles not a single bass or salmon was to be found; gradually, however, they began to make their appearance again, and just above Freeport, 100 miles below Oil City, they were seen in astonishing numbers as though penned up in the pools (unfortunately for us they would seldom offer to take our minnow bait). At Freeport they again suddenly disappeared, and were just beginning to be seen again twenty miles below when we crossed the city line, and then they disappeared again.

There are oil refineries at Olean, Oil City and Freeport, and the refuse acid from these establishments clearly accounts for the entire trouble in the fish family. We observed that the habitat of common fish, such as sun fish and suckers, was nearer to the source of contamination than the high mettled salmon and bass, and that the so-called alligator—fish or reptile, which ever it is—could exist close to the establishments. I have no doubt they would flourish in a sewer, for they seem to have wonderful vitality, and probably consume little oxygen. During all the time I was engaged on this work the river was low, and I could frequently see the bottom of the river in the long, deep pools where it was sixteen feet deep.

I mention these Allegheny fish merely to illustrate the possible value of fish in determining the constituency of the water. The chemist takes but a gallon or two for analysis; but the fish spend their entire lives in it, swimming miles daily and breathing it continually, and to them its percentage of free oxygen is of the most vital importance. Human invalids experience a benefit very frequently by "a change of air," so called, though possibly no chemical analysis would show that in moving from place to place the constituents of the atmosphere they breathe had changed, still we cannot assert confidently that the air is the same at two points of equal altitude, etc. The lungs very likely are capable of noting differences too delicate for the chemist's measure, so in the case of our fish, it is problematical whether even five miles below Oil City the most careful analysis would have indicated the presence of any sulphuric acid in the water.

Several years ago, upon the starting up of the coal washers after a period of idleness, on Jacob's creek, a branch of the Youghiogheny river, the discharge of pyritous water into that stream caused the precipitate retreat of all the fish, many thousands dying as though actually poisoned—I will not undertake to say whether they were poisoned, or simply asphyxiated Be this as it may, the water of the Yough though visibly discolored in this instance, for ten miles below the mouth of Jacob's creek, was not injurious to human beings or cattle. However, on this point of acid in our rivers, I can mention that it is noticeable in the pools of the Monongahela Navigation, that the iron parts of lock gates below water surface oxidize more rapidly now than formerly, when the coal mines were not so numerous, and also, that this effect is more noticeable in the lower than in the upper dams.

Acid instead of being injurious to us in our drinking water, may be really beneficial. This argument should not be taken as an endorsement of a too free indulgence in "Old Monongahela."

*Several years may pass before the river reaches so small a discharge.

†When a man thinks his water smells and tastes bad, it does do it so far as he is concerned. We are the creatures of imagination more than we can readily believe. On moral grounds, therefore, it would be safe—if no other presented—to urge the removal of the Allegheny water works higher up the river.

But to return to the fish—if they are such expert judges of the acidulation of water, they are no doubt equally exact analysts of its degree of oxygen at times. Is it not possible, also, that sometimes the acids from coal mines absorb the oxygen of the rivers to such an extent as to suffocate them?

And on the general merits of M. Geradin's proposition, can oxygen be in normal proportion in water, in the presence of vegetable or animal impurities? It would appear to me the irresistible tendency of oxygen to combine with them, and form innocuous salts, or mineral compounds, would make this impossible. If Geradin is right, it would follow that we have no more certain and positive test of the purity of the water in any stream, than can be afforded by a study of its animal and vegetable life.

MR. PHILLIPS: Certainly oxygen in the water would be a condition in the life of fish; there is no doubt about that. There is a fixed normal quantity of oxygen held in solution in water under given conditions of pressure and temperature. The ratio of oxygen to nitrogen is constant only in pure water, however. In one hundred parts (volumes) of air dissolved in water the oxygen is 36 per cent. the remainder nitrogen. This is true of pure water exposed to air.

They have made tests as to this on the Thames. Wanklyn records results obtained there. Samples of Thames water were taken from different parts of the river. It was found that above the city the proportion of oxygen was about the normal. When they came within the city limits of London, the oxygen diminished and gave place to carbonic acid. The carbonic acid was the product of the oxidation of the organic matters of the water; that is, London sewage. Going down below the city the proportion of carbonic acid increased and the oxygen fell off almost to nothing. Going still further along the stream, they found that the oxygen increased again and the carbonic acid diminished, so that in the main the proportion of oxygen was a very curious and accurate measure of the degree of purity. Where the oxygen was the greatest in quantity there was the least amount of carbonic acid.

But in this case, as in a great many others, the true method has not yet been devised. No one can exactly fix the limit of safety. I have not heard of any tests being made, based on this method, very recently, except those that Mr. Roberts speaks of. They found, as he said, in the case of London, that the great difficulty was to fix the limit of safety. While it could be safely said that water that contains the normal quantity of oxygen is perfectly safe, and water that contains no oxygen at all is absolutely dangerous, because in that case it contains more organic matter than is enough to destroy life, still no one can say just where the safe limit is between these two extremes.

MR. ROBERTS: I would like to call Prof. Phillips' attention more particularly to the fish. You are speaking of the proportion of oxygen found by chemical analysis. Now, I think a good deal of what the fish find. They seem to get away very soon from water that is contaminated. Can we not learn something by observation of their actions?

MR. PHILLIPS: That, very likely, is a safe criterion. There is no doubt that the higher forms of life, like fish, are a very sure indication that there must be an abundant supply of oxygen there. It is well known that fish come up to the surface to breathe if the water is deprived of much of its oxygen.

MR ROBERTS: It occurred to me that this suggestion was a very simple way, from observation, to determine the purity of water. The fish can easily be seen and examined, and it will not require very much skill. Of course we can go further than that with the aid of the microscope, and investigate the lower forms of life, and thereby probably arrive at some point where one can say the water is safe or unsafe. Swimming over the whole river, as they do, they necessarily must test it as a whole, whereas the chemist examines only a small sample.

MR. PHILLIPS: There is one reason for believing in what Mr. Roberts says—that it is known that the solubility of the gases in water varies with the amount of salt dissolved, and it has been supposed that one reason why fresh water fish are unable to live in salt water is, that the oxygen dissolved there is less. I do not know whether that has ever been demonstrated or not, but that is the supposition. It is not the saltness, but the diminished oxygen.

MR. TAYLOR: These tests of the Allegheny water—were they made in the winter season or summer season, or both?

MR. PHILLIPS: The tests I made were in May and June, then in October, November and December, every day.

MR. TAYLOR: Were any tests made while the river was frozen over?

MR. PHILLIPS: There was a great deal of ice there, but not entirely closed.

MR. ROBERTS: In regard to the ice, I have heard it stated that that was the only time when we could taste the oil, from the oil regions. When the river was frozen over the oil running underneath the ice would be "churned" up and would be mechanically mixed with the water, whereas at other seasons it would flow on the surface. I doubt if you could ever get any taste of oil in the summer time. The refuse from the refineries is very heavy and sinks like gas tar to the bottom, and when our water works were further down the river, distinct traces of it were frequently observable in the pipes. This stuff has done thousands of dollars worth of damage to

rafts and boats, but we don't see so much of it in our rivers in late years.

MR. MILLER: I would like to know from Mr. Roberts or Prof. Phillips, if they have made experiments or tested the water below the city, below the two cities, and if so, what was the condition or difference from the water above the cities.

MR. PHILLIPS: I have made no tests.

MR. MILLER: Judging from the description of the test on the Thames, I inquired to know what was the condition of our rivers after they formed the Ohio.

MR. ROBERTS: I can tell you, Mr. Miller. I was talking to Mr. Martin on that point some two months ago. I was down at the Davis Island Dam, and I noticed he had a pump arranged to supply the house. On my asking regarding the water, he said it was very foul near the shore, and was very offensive. It looked perfectly clear, but he said it would not do at all for drinking. But I do not think the whole river was in that condition, because I have noticed the Allegheny water distinct from that from the Monongahela. You can recognize it distinctly at some stages until it has reached a point twenty-five miles below the city. The shore water from Allegheny city, with its impurities, would keep on probably for a number of miles below Davis Island Dam, but in the middle of the river I think no one would notice it. Steamboat men do not complain of the water. The people of Wheeling drink the river water, so do those in Cincinnati, etc.

MR. TAYLOR: How are the fish below?

MR. ROBERTS: In regard to the fish, I have seen seines drawn at the foot of the island at McKee's Rocks, four miles down. That was fifteen years ago, during the height of the oil refining business in this city; salmon and bass could be caught in no other way at that time. There are very few now. These salmon and bass very likely have passed the city during times of high water. They sometimes migrate, though not regular migratory fish, but move from one pool to another if they get scared, and may go miles, and they could easily find opportunity to get past the city here without injury.

I have never thought that the center of the Allegheny river was foul, although Prof. Phillips mentioned in his paper at last meeting, that the Pittsburgh sewers slightly contaminated the water supply of Allegheny City. But I have observed this fact, living on a steamboat for four years, when I was in the government service, and being up along the Allegheny in low water, that in a very sluggish current the sewage matter remained near the shores. I have noticed running from the sewers an inky black water, that would come along the Pittsburgh side and out for a distance of 200 or sometimes nearly 300 feet, so that with the sewage from both ities it would make each side of the river inky black; still a "blue streak" fully 100 yards wide remained down the center all the time. For this reason I would never believe that sewage matter from any Pittsburgh sewer could reach the other side of the river. To do it the current of the sewer would have to cross-thread a flowing river 1000 feet wide.

MR. DAVIS: Mr. Roberts considers that fish will only live in pure water. I recollect hearing Mr. C. B. Brush, Superintendent of the Hackensack Water Co. give his experience with their water in 1884 and 1885. It was at the annual convention of the American Society of Civil Engineers, at Deer Park. They draw their supply from the Hackensack, pumping it about fourteen miles through an iron pipe to a reservoir at Hoboken. There is also a larger reservoir about three miles from the source. In the summer of 1884 the people began to complain of the water, and as the season advanced it kept getting worse.

He mentioned that these reservoirs were full of fish, well stocked with carp and bass, and that fish were removed from time to time as they became too numerous. It was ascertained that the contamination of the water was from a vegetable growth. This had no injurious effect on the fish, though the people could not use the water.

This water from the Hackensack is drained from an area of about 100 square miles, and there was supposed to be no sewage contamination. It got, towards the latter part of the summer, green; a green scum formed. Then I think they put air compressors on the river bank and pumped air into the mains, thinking that would remedy the matter. For a time it did seem to improve it, then the scum would appear again and for a month would stay, and then disappear. In the following summer they had the same trouble. Some thought if the reservoirs were covered it would make a difference. He answered that by saying, they had one of the reservoirs covered and it was just as bad.

MR. ROBERTS: What was the depth of the water in the reservoir?

MR. DAVIS: The large one about sixteen feet, and was kept that depth all the time. In reference to the fish in the Ohio, I may state I have had occasion several times during the past summer to cross the river down about Sewickley, twelve miles below Pittsburgh, and old fishermen there say the fish are returning; that they now get good fish. They told me they could catch bass and perch in large numbers. They attributed the change to the absence of the refuse of the refineries, the oil and waste products of oil formerly discharged in the rivers.

MR. PHILLIPS: In that connection there is one matter of interest. The water may be unfit to drink and yet fish may live in it. There is a peculiar fresh water sponge that often forms in the reservoirs and gives

the water a cucumber taste. It was observed in the drinking water of Boston a few years ago, and it happened to a good many towns of New England, and no one could account for it. They had analyses made, and determined all the fixed solids, the ammonia and so on, but all this went for nothing. The analyses seemed to show that the water was good, and yet it had that cucumber taste and was perfectly unbearable. The doctors thought in some places it was causing sickness, although they did not know positively. At last it was found out that this fresh water sponge was growing in large quantities in the water, and when they cleaned out this sponge the water became good. Now there is an instance where water may be unsafe to drink, at least unfit to drink, from the taste of the branches of this sponge, and yet it did not affect the fish at all. It was stated that the water was perfectly good in every other particular. They had spent so many years in studying it, and so much money had been appropriated that it was looked upon as a problem that could not be solved; but Ransom of Baltimore discovered the whole trouble was due to these sponges.

MR. DAVIS: This Hackensack water had the cucumber taste. In Rochester, N. Y., in 1876, the water was affected the same way, and in Philadelphia in 1883.

MR. ROBERTS: Mr. William J. McAlpine, two years ago, was called upon by a company in New York to propose a new scheme of water works to supply that city. He recommended the Ramapo district in southern New York, on the Jersey line. I have forgotten how many square miles there were, but there are a number of small lakes in the district. In his report he refers to these lakes as being at different elevations, and at certain seasons, according to elevation and temperature, some of these lakes would have this spongillæ and other ephemeral life forms. His idea was to use the water in one lake while the spongillæ, etc. would be dying in the lower lake, say, and by that time the water in the other lakes would be clear. The Allegheny river is not afflicted with any such disease.

However, I can not but return to my position that the merits of this question of the purity of the water is decided by the fish.

MR. SCAIFE: In this connection there is one point I have been waiting to hear touched upon, but no one has mentioned it. It is that of purifying the sewage water before putting it into the river again. It seems to me that this is a question that must be solved where the population is very dense.

Some years ago in Paris, my attention was called to this matter. The people below Paris complained very much of the sewage that was discharged into the river. They said it produced sickness in the towns lying along the river. Reports on the subject were made by the engineers, and finally, it was concluded to purify the sewage water before putting it into the river. At considerable expense a pumping station was formed, and a large part of the sewage (not all of it, because they could not handle it all) was pumped to a place where there was a large tract of sandy soil, of no use at that time. This sewage was put into reservoirs, and from there it was given to the people of that neighborhood, or anyone who wished to have it, to distribute over the land. The soil was prepared by the farmers, who made channels and furrows through it with a plow. The water was allowed to run in these furrows and to soak into the ground, fertilizing it. At the time I visited the place it was just like a garden with extremely luxuriant vegetation. There were garden vegetables, fruit trees, etc. These were finer than could usually be found on most of the farms around Paris.

At first the people of that neighborhood were very much opposed to this sewage water. They said it was contaminating all their wells. At that time, however, no sickness had been traced directly to this water, and at a distance of several hundred yards from this fertilized tract, I went to a spring from which some of the filtered sewage water was flowing. It was perfectly clear—as clear as we have here (when not muddy). I tasted it, and could find no trace of anything disagreeable in it; so that at any rate when this water was returned to the river it was in much better condition than when it went on the ground. I examined the sewage water flowing along these furrows. It was dirty and unpleasant. One could see old garments and hats and all sorts of material, yet the water which came out after the absorption seemed pure, at least to the eye and to the taste.

The engineers were so well satisfied with the trial, although the expense was very great, that it was proposed to fertilize a still larger tract near Paris by the same means. It was a most instructive example of how poisonous materials may be rendered harmless, and also be made to contribute to the sustenance of life.

MR. ROBERTS: We have below this city an island called Neville or Seven Mile Island, six miles long, naturally rich on one-half of its length. The other half is high and very sandy. The elevation of that half is about forty-five feet above the river, consequently never reached when the river overflows, while the other half is covered at intervals, probably once every ten years, which makes it a very fertile bottom, and I have often thought the people of that island, if they would utilize the sewage of the city, would make the whole of it a much more fertile garden than it is now. There is an opportunity there to try this experiment. The material could be taken down in scows or boats That obtained from the night soilers' wagons would be particularly valuable.

MR. WICKERSHAM: I would like to ask Prof. Phillips or Mr. Roberts, in reference to these impurities, if the human system is not so constructed as to reject that which is impure and take only that which is good. I could not help letting my mind run back to the time when I was in business in New Orleans, some forty years ago. There they collected the rainwater in cisterns—upright cisterns about six to twelve feet in diameter, and sixteen feet high. Every house had a system of pipes running from the roofs to the cistern. That water very soon would collect dirt and dust floating in the air, until there would be a scum of probably three or four inches on the surface of the water. It would be covered with vegetation, until after a while the tanks looked like a small garden. The water swarmed with wigglers. They drew this water from underneath, strained and put it on the fire and boiled it, and put it in a pitcher with a lump of ice, and better water I never drank These insects in the water would not be the same as the bactria spoken of, but it was animal life.

MR. ROBERTS: The more animal life, *ergo* the more oxygen, in the water the better it is. We do not know what the disease germs are exactly; typhus, typhoid and yellow fever each are supposed to have specific forms of germs, possibly, and it is to be hoped all of them are of such a low type that they will not germinate in areated water.

MR. PHILLIPS: There is a German authority who declares sewage water is perfectly safe to drink, and proves it by drinking it himself. This is probably an example of the "survival of the fittest," for the system that is broken by disease would probably be easily affected by such impurities, while one of strong vitality would not be affected.

On motion, the further discussion was postponed, and Society adjourned.

S. M. WICKERSHAM,

Secretary.