tions. A perfect list of his contributions to chemistry has not, I think, been prepared; but it would be by no means a short one. No brilliant or startling discovery fell to his lot, but then few chemists are so favored. A large volume of good work, well done, is all that most men can aspire to, and in that respect Dr. Prescott's reputation is secure. Those who knew him will think most of the man himself, rather than of his achievements. He was kindly, modest, sincere and lovable; and what better can be said of any one?

Dr. Prescott was married to Abigail Freeburn in 1866. His widow and one son survive him.

F. W. CLARKE.

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*THE USE OF COPPER IN THE PURIFICATION OF WATER SUPPLIES.**

DR. GEORGE T. MOORE, physiologist and algologist, Bureau of Plant Industry, said: Probably the best way in which to present the question of the use of copper salts in the purification of water supplies, is to give briefly a history of the subject, outlining in a general way how the method came to be used, and some of the results obtained by the Department of Agriculture. It may seem a little out of the province of this department to experiment upon the purification of water; but, as you know, the present Secretary of Agriculture is so ready to take up anything new that promises profitable results along any line not already occupied, that he was very glad and willing to allow an investigation to be undertaken which promised to afford relief to so many. Consequently, with the consent of Congress and with the very able cooperation of Dr. Galloway and Mr. Woods, of the Bureau of Plant Industry, this particular investigation was undertaken in the Laboratory of Plant Physiology. Those of you who have had any experience with attempting to drink water where it has the so-called pigpen or fishy taste will readily recognize the importance of finding some means of preventing this disagreeable condition. New England is probably the most notorious region for having this fishy odor and taste in its water supplies, but this difficulty is by no means confined to any particular part of the country. There is practically no state in the union which has not reported the greatest trouble due to the plants producing bad odors and tastes in water, for in almost all cases it is the growth of certain aquatic plants called algæ which is responsible for the difficulty.

I will not try to give you a list of the towns and cities in the United States which, because of the presence of these plants, have had most serious times with their water reservoirs. The importance of the subject is so great that at least one water commission considered it worth $4,000,000 to take precautions against the appearance of algæ in their reservoir, and in many instances hundreds of thousands of dollars have been expended in a vain attempt to prevent the bad odors and tastes which have occurred annually.

It so happens that in my mail to-day there came a letter from a town, the name of which I will not mention, which perhaps describes the general situation incident to having a water polluted by these vegetable growths, as well as a long discussion.

> The reservoir of T—— is (to put it in plain Anglo-Saxon) fierce. We are able to drink it only in the winter and early spring. During the summer and fall of the year it is so foul that it can not be used even to wash clothes. Never in all my experience in various towns and cities have I found such water, and yet physicians have analyzed it and found it all right. In the summer it is yellowish in color and the odor is rank, being perceived at once on opening the faucet.

There are many similar communities where the water, during the summer

* Report of meeting held January 5, by the Washington Academy of Sciences.

months, at least, is so foul that people have to discontinue sprinkling the lawns and in some cases the reservoir can be detected—by the nose—over a half mile away. Now, as this letter says, examinations of an algal-polluted water usually show it to be harmless so far as man is concerned, but because of the odor and taste it might just as well be poisonous. People can not use it, and for this reason they are frequently driven to use polluted wells and springs, or bottled waters, which by no means are always free from disease germs. In this way, epidemics have been known to arise, due to the presence of algæ in the city water which, of itself, contained no pathogenic organisms. A problem of so much sanitary and financial importance has naturally received much attention from water engineers and others. However, the recommendations usually made of aerating the water or covering the reservoir have been either ineffective or too expensive, and up to within a short time the problem of how to get rid of the bad odors and taste in water has been considered impossible of solution. The principal means of avoiding such difficulties has been to abandon the reservoir, create a new system of supply and hope the old condition would not return until the water company or the town could afford to install another plant. Filtration offered little or no relief; indeed, filtered water, stored in an open reservoir, is often more subject to algal pollution than any other kind. Consequently, this problem of how to prevent the growth of algæ in water for domestic purposes had been practically abandoned as impossible by many of those most closely concerned with water supply work.

It seemed necessary, therefore, to take up the question along some entirely new line and, consequently, careful investigations were undertaken regarding the life history of the particular organisms concerned and an attempt was made to find some toxic element which, although fatal to the plants, would yet be absolutely harmless to man. It is not necessary to consider the large number of substances that were experimented with, but, of course, it was very soon found that the heavy metals were more effective than anything else that could be used on a practical scale. The fatal effect of copper upon algæ has been known for a long time and our own experiments seemed to demonstrate that it was more efficient than anything else sufficiently cheap and easily obtained. Therefore, it was decided to carry on experiments on a large scale with this metal alone.

The three points, of course, necessary in determining a means of destroying algæ is that it shall be thoroughly efficient; that it shall be cheap—for, of course, there must be no limit to the amount of water treated—and finally it must be harmless to man.

First, in regard to the efficiency, I will give the result of a few experiments which demonstrate what high dilutions of copper sulphate will do to algæ.

The first opportunity which presented itself for experimenting on a large scale was in the cress beds of the South. Here the conditions were such that after the cress had been cut and before the new growth could start, a thick heavy mat of algæ would form over the surface of the water sufficient to prevent the growth, if not entirely smother out the delicate cress plants. Since water cress at that time of the year was worth about $20 a barrel, and the demand was considerably greater than the supply, a large amount of money was being lost in this way, and it seemed worth while to experiment with these beds and see if it would not be possible to exterminate the algal growth without destroying the cress. Consequently, a solution of copper sulphate was prepared of a strength of about one to fifty million parts of water,

and this was applied to the algal mass in hopes that it would accomplish the desired result. In a very short time all of the algal growth was exterminated, and although the first application was made in the fall of 1901, it has never been necessary to apply copper more than once a year to these beds. Naturally, the degree of success attained in this work, while not in any way demonstrating that a similar method would be efficacious in large reservoirs, seemed to warrant a more thorough investigation of the subject.

In June, 1903, our attention was called to the condition of the reservoir at Winchester, Ky. This supply was constructed in 1890, and after the first three years a strong odor and taste were noticeable in the water during the hot summer months. This condition gradually increased until the water attained such a degree of offensiveness as to make its use for any purpose almost intolerable. Aeration and mechanical filtration were tried without effect, and it seemed that the only hope for relief was to abandon the entire reservoir and go ten miles to the Kentucky River for the source of a new supply. The cost, however, was too great to be considered, and for this reason the difficulty was considerably increased. A microscopical examination of the water showed that the odor and taste were due to the presence of one of the blue-green algæ, and it was believed that the application of copper sulphate at the rate of about 1 to 5,000,000 would be sufficient to destroy these forms; consequently, there being no objection on the part of either the water board or the health authorities, a treatment was made, and the results have been everything that could be desired. Within three or four days the odor disappeared and the water was perfectly clear. This summer at about the same time it was feared that the algal growth was reappearing, and for this reason another slight treatment was made, but with this exception, no copper has been added to the water since the original treatment in June, 1903, and it has remained perfectly clean and sweet.

In 1892 the Butte (Montana) City Water Company began the construction of a large impounding reservoir for the purpose of storing the water of a mountain stream having its source in the summit of the Rocky Mountains. The next year the stored water became badly contaminated and was unfit for domestic use on account of its disagreeable odor and taste. In 1894 the dam was increased so that the capacity of the reservoir was 180,000,000 gallons, but the same trouble was experienced as during the previous year, and further work was stopped on the dam until some remedy could be discovered. An extensive study of the conditions to discover the cause and find a remedy for the trouble was undertaken, and, besides a resident chemist and bacteriologist, consultations were held with water engineers of note in all parts of the country. It was finally decided to increase the water supply flowing into the reservoir and more thoroughly clean the bottom of all organic matter which might contain vegetable organisms. Notwithstanding the efforts made in this line, the water was so infected with algæ as to be absolutely nauseating in odor and taste, and it became so offensive that the odor was continually present in the city on account of the water being used in sprinkling carts. On July 7 of this year copper sulphate was added to this reservoir in the proportion of 1 part to 8,500,000 parts of water. During the first twenty-four hours the water in the reservoir gave off a most pronounced and disagreeable odor, and at the end of the second and third days changes were noticed in the color and taste of the water, particularly in the lower depths. By the end of the fifth day the water assumed a natural

color and only a slight odor and taste were noticeable on the surface. On Sunday, July 24, the water in the reservoir, being absolutely pure, for the first time in ten years, during the summer months, was turned into the city mains, and since this date has been in constant use.

Many other examples might be given of the efficiency of copper sulphate as a preventative of algal pollution, but it is probably sufficient to say that over fifty large water supplies have been successfully treated during the last six months, and in no instance where a supply was in actual use and the method applied according to directions has it failed to accomplish the desired result.

It is not necessary to dwell upon the question of cost. In general this may vary from ten cents to fifty cents per million gallons, and no water company is likely to hesitate at this amount if it enables them to get rid of a difficulty which often causes them an annual expense of thousands of dollars, to say nothing of the complaints of consumers.

The fact that copper has been used in a number of water supplies in quantities of from one to a million to one to ten or fifteen millions without causing any perceptible difficulty might be regarded as evidence in favor of the harmlessness of copper to man, or at least as demonstrating that this metal is not poisonous in the generally accepted sense of the word. There is, however, a deep-seated prejudice against copper in the popular mind, and it is difficult to convince the public that the cases of poisoning supposed to have been due to eating food from copper utensils were due to other causes, now well recognized. Perhaps there will always be a certain amount of opposition to the use of copper, just as there is to antitoxin and vaccination. After all, the question is a local one which must be decided by the local authorities, and if there is any question about the method it should not be resorted to. Certainly, the Department of Agriculture does not wish to insist upon the use of copper sulphate without the hearty consent of the authorities who have the control of the water supply, and this consent has always been obtained before any work of this kind has been carried on.

The fact that we daily consume in our food quite as much, if not more copper, than would ever be added to a water supply is not generally known by the public; not only in peas and other canned goods, where copper has been added for a purpose, but in meats, fruits, vegetables, etc., where this metal occurs naturally. There is often five times as much copper in a pound of wheat as would ever be found in a gallon of water treated for the destruction of algæ. But there is so much evidence in favor of the harmlessness of copper that it is impossible to even refer to it here. After all, it should be borne in mind that it is not a question of an absolutely pure water as compared with water containing a small amount of copper. It is typhoid- or cholera- or algæ-laden water *versus* copper water.

When the efficiency of copper for the destruction of algæ had been fully demonstrated, it became a matter of interest, at least, to determine the effect of this metal upon typhoid, cholera and similar disease germs often conveyed by water. As the result of a large number of experiments we were able to determine that while copper was not quite so toxic to these pathogenic bacteria as to algæ, still the results were sufficiently satisfactory to make it seem probable that, under certain circumstances, the method might prove of considerable value for the rapid and efficient sterilization of large bodies of water.

The conditions governing pollution by algæ and bacteria are, of course, very different. Furthermore, there are methods already in use, which, if properly applied,

will remove germs from water, whereas copper is the only means thus far known which accomplishes the desired effect with algæ.

It should be most clearly understood that it was not supposed for a moment that the copper method could be substituted for efficient sand filtration or any other means now in use which has been demonstrated as doing the work thoroughly. It was believed, however, and practical tests since made have proved it, that in cases where no system of filtration existed, or where the filter failed, owing to the storage basin being flooded by surface drainage, or because of leakage or other cause, this method was not efficient, that in copper sulphate we had the only remedy for such emergency cases. It should be borne in mind that nothing is more delicate or requires more intelligent and conscientious supervision than a filter plant. Any one who has had an opportunity to visit many such plants throughout the country and really knowing their inside workings, as it were, can not help being astonished at the low rate of efficiency frequently maintained. Consequently, the application of copper sulphate under such circumstances for the purpose of reducing the bacteriological content has been used successfully in enough cases to demonstrate that it has a distinct place in water purification. Whether it would be efficient and proper to use copper continuously during a considerable period awaiting the completion of a filtration system, is a question to be decided by the conditions governing the case. There is no doubt in my own mind that under certain circumstances such use would be justified, and the results would more than repay any outlay of money and labor.

Others will discuss more particularly the effect of copper upon typhoid, etc., so it is not necessary for me to refer in detail to the work carried on by the department along this line. One other point regarding the effect of copper when used upon a practical scale is of interest, however. That is, that the theoretical strength, or the amount of copper used to destroy algæ and bacteria in the laboratory, is considerably greater than the amount needed on a practical scale. This may be due to the fact that the organisms used in laboratory tests are of necessity more resistant than those occurring under natural conditions; at any rate, results show that where it may require one part in a million of copper to destroy certain algæ under experimental conditions, it only takes one tenth or even less than this amount to accomplish the same result in a reservoir containing millions of gallons of water.

Dr. Henry Kraemer, Philadelphia College of Pharmacy, said: The purification of water supplies containing pathogenic organisms being a subject of such vital importance, it seems to me that any method proposed for this purpose should receive careful consideration, not only at the hands of water engineers, water companies, health officials and physicians, but by all those who are in a position to test the method, or contribute information regarding it, or to foster a sentiment in favor of it if found to be efficient. It was in this spirit that I undertook to test the method proposed by Dr. Moore and Mr. Kellerman.

On account of the false sentiment which had been engendered in Philadelphia with regard to the purification of water by means of copper, and recognizing that the city authorities would not be apt to apply the method so long as there was this prejudice against it, I determined to consider the method in relation to its application for household purposes.

It is, of course, manifestly impracticable for the average householder to use copper sulphate in the purification of drinking water, and my experiments have, therefore,

been mostly with metallic copper. I first tried to obtain copper vessels for my experiments, but finding that I should have to wait some time to have these made, those on the market being tin-lined, I decided to use copper foil instead, which perhaps is fortunate, as this is more convenient and less expensive.

In my earlier experiments I had a number of my students in bacteriology carry on the work, using pieces of copper foil about 25 centimeters square to each 2,000 c.c. of water, allowing this to stand from four to eight hours at room temperature, the copper foil being cleansed with pumice for each operation. Agar plates were made and it was found that there was a reduction in the total number of organisms of from 85 to 97 per cent. For some time past one of my special students has been carrying on this work under my direction, and I may say that in all of those experiments where copper has been used the reduction in the number of organisms has been equivalent to what would be obtained by an efficient filtration system, with the advantage in the case of the copper treatment that the organisms are completely destroyed.

In filtration processes it is generally understood that both typhoid and colon organisms are the first to be eliminated, and without waiting to complete a systematic study of the organisms which persist as well as those which are killed in the copper treatment of water, I thought it well to test the method by using water containing these organisms alone.

Inasmuch as results depend in some measure upon the method used, I will try briefly to outline my method before giving my results.

1. Water under three different conditions was employed: (*a*) Distilled water, which was prepared from tap water by first treating it with potassium permanganate and then distilling it two or three times by means of apparatus constructed entirely of glass. (*b*) Filtered tap water, prepared by means of a Berkefeld filter attached to a copper spigot. (*c*) Tap water collected after being allowed to run through a copper spigot for five minutes. All of these were sterilized in an autoclave at 110 degrees for thirty minutes.

2. The cultures of typhoid and colon which were used were pure cultures developed in bouillon for eighteen to twenty-four hours.

3. To 200 c.c. samples of water prepared as above, and contained in sterile Erlenmeyer flasks, were added two three-millimeter loops of the fresh bouillon cultures of typhoid and colon bacilli, respectively. Counting the duplicate experiments provided for, we thus had a series of twelve flasks, six of them containing typhoid bacilli, and six colon bacilli.

4. For studying the number of organisms 1 c.c. of the respective solutions was transferred directly to a Petri dish by means of a sterile 1 c.c. pipette, and to this was added 10 c.c. of Heyden's nutrient agar which had been kept at a temperature of 40° C. for some time. Three separate plates of the water in each of the twelve flasks were made immediately upon the addition of the cultures, and both the plates and the flasks were kept at a temperature of 35°–37° C. To six of the flasks were then added strips of copper foil about 15 mm. wide and 18 cm. long, these being corrugated in such a manner that the entire surface was exposed to the water.

5. Plates were made from all the twelve flasks at the end of four and eight hours, and one, two and six days, even in the cases where no organisms remained, and in the cases where they continued to develop, at the end of fourteen, twenty-one and twenty-eight days. The results are given in the following tables:

TABLE I. EXPERIMENTS WITH BACILLUS COLI.

	Water *without* Copper Foil.		
	Triple Distilled Water.	Filtered Tap Water.	Tap Water.
Plates made at time of adding culture...	7,746	11,246	8,283
Plates made at end of four hours.....	7,655	5,075	7,665
Plates made at end of eight hours.....	7,735	3,115	7,000
Plates made at end of twenty-four hours...	1,000,000	1,000,000	1,500,000
Plates made at end of forty-eight hours...	1,200,000	1,600,000	2,000,000
Plates made at end of 6 days.....	1,200,000	1,000,000	1,200,000
Plates made at end of 14 days.....	1,060,000	910,000	2,245,000
Plates made at end of 21 days.....	700,000	462,000	650,000
Plates made at end of 28 days.....	700,600	462,466	649,666
Plates made at end of 53 days.....	602,000	456,000	693,000
	Water *with* Copper Foil.		
	Triple Distilled Water.	Filtered Water.	Tap Water.
Plates made at time of adding culture...	8,866	4,410	6,790
Plates made at end of four hours.....	No organisms.	No organisms.	No organisms.
Plates made at end of eight hours.....	"	"	"
Plates made at end of twenty-four hours...	"	"	"
Plates made at end of forty-eight hours...	"	"	"
Plates made at end of 6 days.....	"	"	"
Plates made at end of 14 days.....	"	"	"
Plates made at end of 21 days.....	"	"	"
Plates made at end of 28 days.....	"	"	"
Plates made at end of 53 days.....	"	"	"

TABLE II. EXPERIMENTS WITH BACILLUS TYPHOSUS.

	Water *without* Copper Foil.		
	Triple Distilled Water.	Filtered Tap Water.	Tap Water.
Plates made at time of adding culture...	3,740	4,750	3,675
Plates made at end of four hours.....	2,835	No organisms.	3,815
Plates made at end of eight hours.....	3,850	"	1,995
Plates made at end of twenty-four hours..	3,750	"	1,435
Plates made at end of forty-eight hours...	3,815	"	1,540
Plates made at end of 6 days.....	1,850	"	—
Plates made at end of 14 days.....	16,380	—	3,920
Plates made at end of 21 days.....	39,690	—	65,500
Plates made at end of 28 days.....	153,600	—	221,867
Plates made at end of 60 days.....			
	Water *with* Copper Foil.		
	Triple Distilled Water.	Filtered Water.	Tap Water.
Plates made at time of adding culture...	3,986	127	1,400
Plates made at end of four hours.....	No organisms.	No organisms.	No organisms.
Plates made at end of eight hours.....	"	"	"
Plates made at end of twenty-four hours...	"	"	"
Plates made at end of forty-eight hours....	"	"	"
Plates made at end of 6 days.....	"	"	"
Plates made at end of 14 days.....	"	"	"
Plates made at end of 21 days.....	"	"	"
Plates made at end of 28 days.....	"	"	"
Plates made at end of 60 days.....	"	"	"

I may say that every single experiment which we have conducted, not only those given in the foregoing tables, but all others, shows that copper foil is exceedingly toxic to colon and typhoid bacilli, particularly the latter.

* Bowlton cultures of the different samples of water gave at the end of sixty days with Widal's test the characteristic behavior of typhoid organisms.

It will be seen by consulting the table that in the filtered water to which no copper foil had been added, the typhoid organisms did not grow and multiply as was the case with the tap water and distilled water, although there were a larger number of organisms to begin with. This also applies in a measure to the colon bacilli, where there is a very marked inhibiting

action in those growing in filtered water.

At first I was inclined to attribute this to minute traces of copper in the flasks, but subsequent experiments showed that this was not the cause of the diminution of the organisms. I am, therefore, inclined to attribute these rather anomalous results to the presence of extremely small quantities of copper dissolved by the water in its necessarily slow passage through the copper spigot to which the filter was attached.

Some time ago I was asked if I thought that a copper plate placed at the intake of a reservoir would be effective in destroying typhoid organisms. At that time I felt such a result was almost too marvelous to be within the range of probability. But in view of the results which I have just given it seems that copper exerts a marked oligodynamic action on typhoid and other intestinal organisms, although this action is not so marked as in the case of algæ and some of the saprophytic fungi.

It is extremely fortunate that in the copper treatment of water, a method has been devised which is so effective in destroying intestinal microorganisms and which can be applied so easily on a large scale and so safely even in the average household. Of course the proper place to purify the water supply of a city is in the reservoirs, before the water reaches the consumer, as thus the distribution of organisms like typhoid is brought within the narrowest limit, and individual carelessness in the community is overcome.

In a city like Philadelphia, which depends for its water supply upon a river which has tributaries in the coal region and subject to contamination of all kinds, including sewage and waste products from manufacturing establishments, it is, of course, very necessary that the water be freed from gross impurities by sedimentation and filtration.

At time of freshets the amount of suspended matter may be as much as 500 parts per million and it is not unusual to see a statement like the following in the daily papers:

> Philadelphia is to receive another dose of the inky water from the coal regions of Pennsylvania. Already the water is of a yellowish-red color, and by to-morrow the coal dust residue is expected. The rains in the Schuylkill valley are responsible, the deposits from the culm piles about the mines being washed into the tributaries of the Schuylkill River and into the main stream as well.

But even in Philadelphia, where the necessity for a filtration system is so urgent, there are times when the application of a method like the one proposed by Dr. Moore would be highly advantageous. I may cite two examples in this connection:

1. Only last September a certain section of Philadelphia required 28,000,000 gallons of water, and the filters for that section delivered only 22,000,000 gallons, and in order to provide the necessary supply 6,000,000 gallons of unfiltered water were added. This deliberate 'repollution' of the water supply, as it was termed by Director Martin, of the Department of Public Health, could readily have been corrected by the use of the copper method of purification.

2. Some years ago while flushing one of the large sewers, by an unfortunate accident there was an overflow at a point along the Schuylkill River just above one of the pumping stations, and as a result of this contamination of the water supplied to that section of the city there were 258 cases of typhoid fever in this section in two weeks afterward, and nearly 1,500 cases within the next two months.

Instances could be multiplied where the copper method of purification of water could be applied as an emergency method, if not regularly in connection with filtration.

Even granting the efficiency of the boiling of water for domestic purposes, I believe that the copper-treated water is more

natural and more healthful, inasmuch as the various inorganic constituents, particularly the salts of calcium and magnesium, are in a more soluble and assimilable condition, being furthermore less concentrated, at the same time the natural gases of the water being retained.

From the experiments thus far conducted the following conclusions may be drawn:

1. The intestinal bacteria, like colon and typhoid, are completely destroyed by placing clear copper foil in the water containing them.

2. The effects of colloidal copper and copper sulphate in the purification of drinking water are in a quantitative sense much like filtration, only the organisms are completely destroyed.

3. Pending the introduction of the copper treatment of water on a large scale the householder may avail himself of a method for the purification of drinking water by the use of strips of copper foil about three and a half inches square to each quart of water, this being allowed to stand overnight, or from six to eight hours, at the ordinary temperature, and then drawn off or the copper removed.

Dr. Mary E. Pennington, bacteriologist, Department of Public Health, Philadelphia, said: In the city of Philadelphia, work on an extensive sand filtration system is being pushed just as rapidly as possible. Portions of the city are now being supplied with filtered water and in the course of a few years such water will be distributed over its entire area. Until this time arrives there will, almost certainly, be outbreaks of typhoid fever of greater or less severity and extent. The problem of an efficient, wholesome and rapid purification of water, primarily for the general city supply, secondarily for use in the household, is, therefore, temporarily but emphatically, before the health authorities of Philadelphia. Any method which offers a possibility of success must be carefully weighed by them.

Among the methods considered by the city and worked upon in its laboratories is that of the purification of water by copper, either in the form of salts or as metal, the aim being to eliminate typhoid and colon bacilli.

Dr. Stewart, working from the standpoint of household purification more especially, has had constructed copper vessels of varying sizes in which he has placed typhoid germs suspended in distilled water, sterile filtered water and raw river water. In very clean, brightly polished copper vessels the organisms of typhoid fever were soon killed, sometimes in less than two hours, and the common river water germs were considerably reduced in number, but never exterminated. In glass or tin, on the contrary, all the organisms showed a decided increase.

The city laboratory has also conducted some experiments to determine the germicidal efficiency of copper plates charged with very low electric currents—less than 4 volts and 0.01 ampère—over which the water to be purified was allowed to flow.

The suspension of copper electrodes in water which is not agitated causes a more rapid reduction in the number of organisms than is accomplished by copper without the current. When, however, the apparatus is arranged to simulate a reservoir, with inlet and outlet and of such construction that the entering polluted water must come into intimate contact with several electrified copper surfaces, the reduction in the number of both typhoid and colon bacilli is very great almost immediately. When such an effluent has stood at room temperature for an hour it is practically sterile.

The copper, too, which, when germ-free water is used, may be found in traces, is, apparently, entirely eliminated from water containing a large number of organisms.

Unfortunately, these experiments have been confined to laboratory quantities and conditions. It is hoped that an opportunity will offer to try them on a larger scale.

Mr. Alfred M. Quick, chief engineer, Baltimore Water Department, said: The subject under consideration here to-night involves so much more of chemistry, bacteriology and entomology than it does of water-works engineering, with which I am more familiar than I am with the sciences I have referred to, that I would very much prefer to have appeared here simply in the rôle of listener.

I have been very much interested in the extremely valuable discussion of this subject from the scientific standpoint of all the previous speakers. The only excuse for my speaking or appearing here in any other rôle than as a listener is, I suppose, because I have had some experience in the practical application of copper sulphate in the treatment of large reservoirs in use in a water department.

As to the experiments that we made, while they were probably not so valuable in illustrating the success of this method of treatment as some other cases where the proportion of algæ in the reservoir was very much greater than it was in our case, or where the trouble had been experienced from the presence of these organisms for a longer time than it has been in Baltimore, still they give results that are none the less emphatic and conclusive. As I have said, we have not had any trouble with these organisms for any long period, and we had no reason to suppose that they are present in any large quantity in our reservoirs. We have had trouble, however, with complaints of bad water, water of bad odor, bad taste and discolored water, but in every case—practically every case—we have been able to get rid of the complaint by flushing the mains, our conclusion being that the trouble was caused by the numerous dead ends in the distribution system and also by bad management of previous years in allowing muddy water to be sent to the city and thus filling our water mains with sediment.

As I say, we had been able to get rid of these complaints in previous years by flushing the pipes, but this past summer there was a continual complaint by a large artificial ice manufacturing concern that the ice had a bluish-green color which practically made it unmarketable. Supposing that the cause was the same as in the most of the previous cases, we started to flushing the pipes and connecting up some dead ends in that vicinity, hoping by that means to get rid of the complaint, but it still continued. I, therefore, made a personal examination of the matter and found that the ice was badly discolored and that there was apparently no evidence of sediment in the water, so that the complaint was undoubtedly due to the presence of some vegetable organisms in the water. It immediately occurred to me to try Dr. Moore's suggested method of treating the water in reservoirs to eliminate the algæ by the application of copper sulphate.

I had read his pamphlet and was convinced of the value of the method of treatment which he suggested, and so I communicated with Dr. Moore, and he sent his assistant, Mr. Kellerman, over to Baltimore and he examined the water in the reservoirs, Lakes Clifton and Montebello, which feed the district from which the complaints came. He also made some analyses of samples of the water in these lakes, which showed that the particular species of algæ which cause the disagreeable odor and discoloration, and other species, were present in such considerable numbers as to justify an experiment with the copper sulphate.

However, before attempting to make such an experiment, not because I had any doubt

as to the merits of Dr. Moore's suggested method or as to its leaving the water absolutely safe for potable purposes, but because, holding a political position, it was well to fortify myself before attempting anything unusual, I, therefore, communicated with all the leading chemists of the city, particularly the chemists in the health department, and one other gentleman, whose name I am not at liberty to mention, but who is probably one of the three or four greatest biological chemists in this country, and had them all committed beforehand—not as agreeing that the experiment would be a successful one in eliminating the algæ, but as emphatically agreeing that if the method Dr. Moore had suggested was adopted, there would be absolutely no danger to any consumer in drinking the water.

So we proceeded to put the copper sulphate in the two large reservoirs, using our own employees for the purpose. For Lake Clifton 300 pounds of sulphate was used, or about one part to 6,390,000 by weight. The method of application was as follows: The lake was first shut off entirely, both at the inlet and outlet. The sulphate was in four bags of 75 pounds each. One bag at a time was suspended from the stern of a rowboat, and as soon as it was about three quarters dissolved another bag was put out. The boat was rowed around the lake in concentric courses about 40 or 50 feet apart, and at such a rate as to cover the lake completely by the time the four bags of sulphate were dissolved. It took 128 minutes to dissolve the 300 pounds applied. A sample of the water was taken near the center of the lake just previous to the application of the sulphate and samples were taken at the same place in the lake at intervals of 24 hours after the application. These samples were for biological analyses. Samples of the lake water were also taken in sterilized bottles, both before and after application of the sulphate, for bacteriological analyses.

The biological analyses indicate a very great reduction in the number of algæ in the first 48 hours after treatment, and practically a complete elimination of algæ in 120 hours. On account of rain falling in the reservoir during treatment, unfortunately the bacteriological analyses give no correct indication of the action of the sulphate on the bacteria in the lake. These analyses were all made by Dr. Wm. R. Stokes, the city bacteriologist. An analysis of the samples was also made by the city chemist to determine the proportion of copper present, and no trace of copper was found in the water as early as 24 hours after application of the sulphate.

The method of treatment of Lake Montebello was exactly the same as at Lake Clifton, except that a larger amount of copper sulphate was used; 600 pounds were applied, or about one part in 6,685,800 by weight. As with Lake Clifton, the analyses showed a very considerable reduction in the number of algæ in 48 hours after application of the sulphate, but the analyses of samples taken at intervals of 24 hours thereafter showed a slight increase in the number of algæ until the eighth day after treatment, when the number per cubic centimeter dropped to 14. At that time it was found necessary to turn Lake Montebello into consumption, and therefore no further analyses were made. It is possible that if the examination had been continued we should have found the algæ practically eliminated, the same as at Lake Clifton.

A chemical analysis showed no trace of copper in the water five days after application of the sulphate.

We had no bacteriological analyses made of the water in Lake Montebello because our experience with Lake Clifton tended to substantiate the intimation by Dr. Moore that the proportion of copper sulphate

which we used would be too weak to have much, if any, effect in reducing bacteria.

So much for the results shown by the analyses. The practical value of the treatment was observed in the very great diminution in the number of complaints of bad water, which had been unusually large just previous to the experiment.

The cost of the experiment was between $60 and $70, which was for the copper sulphate used, or less than ten cents per million gallons treated.

Dr. C. L. Marlatt, entomologist, Bureau of Entomology, said: In the original publication on the use of copper sulphate against algæ, a paragraph was given indicating the results of certain incidental experiments with mosquito larvæ. These experiments indicated that a strength of 1 to 40,000 was apparently necessary to kill presumably nearly full-grown larvæ. The strength indicated is greater than is practicable for water to be used for domestic purposes, but a distinct toxicity of the copper sulphate for mosquito larvæ was shown. A series of experiments was immediately instituted in the laboratory of the bureau to determine the exact value of copper sulphate in this field. The common method of destroying mosquito larvæ in comparatively still bodies of water is in the use of kerosene oil. This, however, has the objection of rendering the water unpalatable, and the copper salt seemed to offer a possibility of the use of a substance which would not injure water for domestic consumption.

During the spring and summer of 1904 more than 75 experiments were made with copper sulphate, beginning with the first larvæ available in the spring, and continuing until autumn. Tests were made with various kinds of water, namely, distilled water, hydrant water, foul water from old rain-water barrels of long standing, and water from outdoor ponds more or less soiled with earthy matter and animal and vegetable life. The mosquito larvæ subjected to the different tests were various species of *Culex* and *Anopheles;* the former the common biting mosquito, and the latter representing the species responsible for the conveyance of malaria.

The importance of the water conditions was at once evident. The copper sulphate showed very considerable effectiveness in comparatively pure water, and lost its action very quickly in foul water or water containing much earthy matter, in the latter cases the copper being quickly precipitated with the foreign matter in the water. The use of distilled water and comparatively pure hydrant water was of value in determining the direct toxicity of copper sulphate; in other words, in such water the killing of the larvæ could not be charged to the destruction of the food in the water, which might reasonably be offered as the explanation in the case of more or less foul water in which mosquitoes ordinarily breed, containing quantities of vegetable and animal life. Mosquito larvæ were killed in distilled and pure hydrant water quickly, and in the check jars in which no poison was placed they remained in healthy condition indefinitely, or at least exceeding a week or ten days.

The larval conditions also exerted a very marked influence on the results. The young larvæ are killed with minute additions of copper sulphate. The strength necessary to effect the prompt death of the larvæ increases very quickly with the age of the larvæ. In comparatively pure water, such as hydrant water, a strength of from 1 to 100,000 to 1 to 5,000,000 killed newly hatched larvæ with promptness, that is, within 24 to 48 hours. Any strength of copper sulphate between 1 to 100,000 and upwards is stated to be a practicable strength for use in water for domestic purposes. One to 500,000 was almost as effective as

1 to 100,000, and is probably as high a strength as need be used for killing newly hatched larvæ in clear water. In the case of half or two thirds grown larvæ the immediate death of the larvæ was not secured, but they were held in arrested development for several days and slowly perished, some few surviving two weeks, and this at strengths between 1 to 100,000 and 1 to 500,000. The effect on full-grown and nearly full-grown larvæ is to hasten their transformation to the pupal stage, such larvæ transforming within a few hours to one day after the application of the copper sulphate. Once in the pupal stage, no practicable strength of copper sulphate is effective against them. Strengths as great as 1 to 1,000 were employed, and the pupæ so treated were seemingly completely immune from its effect, and ultimately transformed to adult insects. The reason for the almost absolute immunity of the pupal stage is probably because in this stage no food is taken, and the poison is purely external and has no opportunity to act.

It was further shown that copper foil was very effective in destroying newly hatched larvæ. A piece of copper foil less than six inches square killed, in two quarts of water, the majority of young larvæ within 24 hours, and all within 48 hours. The possibility of using copper foil, therefore, to keep mosquito larvæ out of small bodies of comparatively pure water is shown. In all of these tests check experiments, without the addition of copper, were carried out.

The general results shown are that newly hatched mosquito larvæ are killed in comparatively pure water by practicable additions of copper sulphate, namely, between 1 to 100,000 and 1 to 5,000,000, the necessary strength varying with the purity of the water; that copper foil exerts a remarkable effect upon young larvæ; that the very highest practicable strength, namely, 1 to 100,000, will check the development of half and two thirds grown larvæ, and cause their ultimate death; that nearly full-grown and full-grown larvæ are induced to promptly pupate, and that in the pupal stage absolute immunity to copper salts is shown.

The practical application of copper sulphate seems, therefore, limited to the protection of small bodies of comparatively pure water. It is further possible that in the tropical countries, where much of the drinking water is kept in cisterns, it will have a distinct field for usefulness, and possibly particularly against the yellow-fever mosquito. Field tests in open ponds failed to show any special value for copper sulphate; it seemed to be precipitated too quickly to have any important effect on the larvæ. The value of copper sulphate against mosquitoes needs for its demonstration further tests, and particularly under the tropical conditions referred to.

Dr. H. W. Wiley, chief chemist, Bureau of Chemistry, said: In regard to the use of copper for purifying water, I have nothing whatever to say except as it may pertain to water as a food. It is recognized by all physiological chemists that water is one of the principal foods and one of the most necessary. The act of Congress authorizing the investigation by the Bureau of Chemistry of the adulteration of foods includes beverages in the list of the articles to be studied. The whole matter, therefore, of the addition of copper to water which is to be used for food purposes is intimately related to other problems of a similar nature which we have had under study in the Bureau of Chemistry for the past twenty years. There are two ways of considering the evidence which has been accumulated on this subject. One is to consider the addition of certain substances, copper sulphate among them, to foods, as a process involving the use of harmless substances; the other view is to regard the substances

themselves as harmful. In the latter case there must be an abundant justification on the part of the user to excuse their introduction. I think we may assume, for the purposes of this argument, that copper sulphate is in itself an injurious substance. This does not relate to its use in a medicinal sense. It is well known that the great majority of drugs which are used in disease are not harmless to health; in other words, the fact that any given substance may be used as a remedy in disease is no justification whatever for its use by persons in health.

The fact that a substance may be naturally found in a food product accidentally or otherwise, which in itself is harmful, is no excuse for adding more of the substance to the food product. For instance, hydrocyanic acid is found in certain food products, such as peaches and cassava; borax is found almost uniformly in grapes and wines; benzoic acid occurs in considerable quantities in cranberries, and copper is occasionally found in some food products in weighable quantities. It requires no argument to show that the accidental presence of bodies of this kind is no justification whatever for adding additional quantities thereto. In other words, foods themselves are often injurious, but that does not imply that more injurious substances should be added to them. The attitude of experts in regard to these matters is the most puzzling problem of all. Men of equal honesty, equal ability and with equal skill as experimenters entertain diametrically opposed views on these subjects. It appears that the one safe position each layman can take in the matter is to demand protection from being compelled, without his knowledge, or even with his knowledge, to consume substances in foods which a very respectable part, or perhaps even a majority of expert evidence, condemns. The right of any one to consume antiseptics and coloring matters in his food should not be denied, but it is not fair that those who hold a contrary opinion should find it almost impossible to secure food products devoid of the substances to which he objects. This principle, it appears to me, applies particularly to water, which is a substance of universal consumption. The principal excuse for the use of a substance like sulphate of copper, aside from the effect which it has on the living organisms in the water, is found in the statements which have been made that no copper remains in the water. Any residual quantity remaining, be it ever so small, is objectionable. The argument *de minimis* is in my opinion wholly fallacious.

A very full discussion of the subject of the presence of copper in foods is found in the report of the committee on food preservatives, presented to both Houses of Parliament by command of the King in 1901. The report was signed by Herbert Maxwell, chairman, T. E. Thorpe, H. Timbrell Bulstrode and F. W. Tunnicliffe. On page xxx, article 136 of this report, section F, under recommendations, it is stated 'That the use of copper sulphate in the so-called greening of preserved foods be prohibited.' This part of the report, it is but fair to say, was not concurred in by Mr. Tunnicliffe. After stating his reasons for not signing the recommendation as given, he states, page xxii: "I am, however, satisfied that often an unnecessarily large amount of copper is present in vegetables permanently colored by means of it, and although in spite of diligent investigation no injurious results have been known to have occurred even from these quantities, yet, nevertheless, only the necessary amount should be added. I should, therefore, recommend that the presence of copper in these preserved vegetables be in every case declared and that its amount be restricted

to one half grain of metallic copper per pound.''

If it be proved that copper sulphate is a preservative by reason of its germicidal character, then it falls under the general rule of preservative substances.

In this case the findings of the International Congress of Hygiene and Demography which met at Brussels in September, 1903, would apply. The third resolution adopted by that congress in the section of alimentary hygiene is as follows: 'The employment of antiseptics should be prohibited in the preservation of alimentary substances.'

Rideal states in his recent work, entitled 'Disinfection and Preservation of Food,' on page 156, that the soluble salts of copper have a distinct poisonous action on bacteria. The coagulated albumen combines with most of the organic acids present to form non-putrescible salts. They absorb sulphur, hydrogen, ammonia and compound ammonias and, therefore, combine with ptomaines. In fact, copper salts rank next to mercury in power as antiseptics. Kroncke proposed a method for purifying water with copper salts in volume 36 of the *Journal für Gasbeleuchtung,* page 513. He used cuprous chloride in connection with ferrous sulphate, and, finally adding a small quantity of lime, succeeded in entirely removing any residual copper. In 1892 the French authorities decided to adopt as their official disinfectant in combating cholera sulphate of copper.

These few illustrations are given out of many hundreds which might be cited to show that in general the opinion of experts regarding the presence of copper in food is decidedly unfavorable. To state particularly my attitude respecting the use of copper in water, it appears that, in the first place, only bad water needs treatment, just as only bad milk needs to be pasteurized or sterilized. I think that it is the general opinion among physicians, hygienists and physiological chemists that the pasteurization or the sterilization of milk is distinctly prejudicial to the digestive processes and should only be practised where greater dangers, namely, those arising from infected milk, are to be feared. This principle, it seems to me, applies also to water. There is practically no such thing as pure water available for consumption. Water is the scavenger of nature and tends to dissolve or carry away mechanically all kinds of refuse matter. Every spring and stream is only a sewer. Nature, however, provides means for at least partial purification. These means are found in the germs which water contains. The activity of such germs is beautifully shown in the processes which take place in the septic tank. A polluted stream, and every stream is more or less polluted, is only a septic tank of a different character, and the reservoirs which hold the waters which supply our cities are also septic tanks. To add to water in a reservoir or other container a chemical reagent which paralyzes germ activity by coagulating the protoplasm, or in other ways, renders waters powerless for self-purification. There is also another point to be kept in view, namely, the possible relaxation in care in controlling the water supplies by the use of a sterilizing agent. Just as the milk dealer may fail to wash his cans or keep his cows clean, if he uses formaldehyde, so the officials of a city in charge of the water supply may fail to care for or supervise the purification of the water sources if a cheap and efficient sterilizing agent can be employed. It appears, therefore, that in most cases a sufficiently pure water supply can be secured without the aid of a sterilizing agent. If, however, a sterilizing agent is to be used, there are great difficulties connected with its control and the universal tendency in such cases is always to use it in excess. This has been

illustrated so thoroughly in the case of antiseptics in foods that it needs no further elaboration. If water for potable purposes is sterilized with sulphate of copper the actual quantity necessary could only be determined by most careful observation at each time the reagent is used. If too little is used the object is not secured. If too much, the excess remains in the water. Copper is nearly related to those metallic substances which produce cumulative effects in the system, such as arsenic, mercury and lead. Careful physiological researches have shown that minute quantities of copper long ingested produce great disturbances, especially in the liver. It should be the object, then, of the health officer to furnish water as pure as possible, and, if sterilization is necessary, to have it accomplished by means which are not likely to introduce harmful substances. There appear to be two unobjectionable processes capable of being used, one the application of heat and the other ozone.

In fact, in view of the well-known properties of copper and its salts in relation to electricity, the query may arise whether the germicidal effects which have been proved to ensue from the introduction of metallic copper into ordinary drinking water may not possibly be related to the production of ozone. Dr. Kraemer has conclusively shown the germicidal properties of copper when placed in ordinary water. These properties must arise either from a solution of the copper itself or from the electrical activity developed, including, possibly, the production of ozone. If the germicidal properties are due to the solution of the copper, then there is always danger of excessive copper going into solution, thus rendering the use of such water objectionable.

One point which has been brought out by the papers read to-night is worthy of careful consideration, namely, that copper sulphate may be used in quantities sufficient at least to kill algæ without leaving any excess of the copper in the water. If copper salts can also be used in sufficient quantities to kill pathogenic germs and the residual excess of copper be entirely precipitated thereafter, the principal objection to the indiscriminate use of copper in water would be removed. At any rate, it seems to me that it would be preferable during times of epidemic, especially, to drink water with a little excess of copper, rather than to drink water containing the germs of typhoid fever.

The question is one of great interest from many points of view, and my particular purpose in speaking to-night is to say a word of caution against the use of chemical germicides and antiseptics which may themselves be sources of contamination.

Copper sulphate is known to be one of the strongest disinfectants and was adopted as long ago as 1892 as the official disinfectant against cholera by the French authorities. Disinfectants have their uses, as we all know, but they should, if possible, be kept out of foods, especially in cases where there is no danger of epidemics.

Mr. M. O. Leighton, hydrographer, Division of Hydroeconomics, U. S. Geological Survey, said: The application of copper sulphate to storage reservoirs for the purpose of destroying algæ has been quite thoroughly investigated by several men of good standing and it has received sincere endorsement. I have not, however, until to-night, heard any detailed statements concerning actual experiments upon its bactericidal properties. Until the investigation of Dr. Moore was made public, I had always been of the opinion that copper sulphate was an excellent disinfectant when used in solutions of a comparatively high concentration, and in fact during a period in which I was engaged in public health work I made extensive use of such solutions in drains,

vaults and infected places where crude methods were ineffective. That it is highly toxic in so extremely dilute solutions seems almost beyond belief, yet the experiments outlined by the speakers successfully bear all the scrutiny which I have been able to give them and seem to substantiate all conclusions drawn from them.

In connection with the application of copper sulphate to storage reservoirs for the purpose of destroying algæ, the possibility of rendering such organisms more resistant to the toxic effects of this substance suggests itself. Organisms of this low type readily adapt themselves to environment and it is a common observation among bacteriologists that an organism can be made immune against the toxic effects of an amount of substance which under ordinary conditions would prove fatal to it. This can be readily accomplished in the laboratory by applying to such organisms a subtoxic amount of germicide, and if the experiment is repeated several times the resistance of the organisms to that substance can be raised to a surprising degree.

In discussing certain objections to the use of copper sulphate in public water supplies, Dr. Wiley has justly observed that the zeal of certain poorly informed water superintendents will lead them to apply more copper sulphate to the water than is necessary for the purposes in view, and thereby possibly increase the amount contained in the water to a point at which it would have an unfavorable effect upon the consumers of that water. The reverse of this is also true. It is no easy matter in many cases to determine the amount of water contained in a reservoir or pond, and even the most careful measurements will vary occasionally by fifty and sometimes even one hundred per cent. Now if a water superintendent like that mentioned by Dr. Wiley should determine in his customary arbitrary fashion the amount of water in a reservoir and apply to it a proportion of copper sulphate, based upon his incorrect estimate of the contents of the reservoir, either more or less than is absolutely necessary will be used, according to the error in the estimate. Every time an insufficient amount is applied it will undoubtedly have the effect of raising the resistance of the algæ to this germicide and there will come a time when it will be impossible to exterminate them without the addition of a prohibitive amount of the sulphate.

Dr. Moore assumes that by the addition of a proper amount of copper sulphate the algæ will be driven from a reservoir for all time and states that up to the present time in no case has the organism been found to persist. There is, however, a notable case in which a second application has been necessary. The work was carried on by one of the foremost water biologists of the United States who has given long years of study to the microorganisms which give offense in public supply. In this case the operator possessed an accurate knowledge of the amount of water in the reservoir. The water was infested with the organism '*Anabæna.*' One application conducted according to Dr. Moore's directions failed to exterminate the organism and a second treatment was applied which was effectual. Almost immediately, however, the organism '*Chlamydomonas,*' which is in some respects far more objectionable, developed in the reservoir, flourishing apparently upon the '*Anabæna*' debris, the result being that the conditions were far worse than those which existed previous to the first application of copper sulphate. This experiment indicates that one application is not always effectual and that an amount of copper sulphate toxic for an ordinary alga may not destroy the more uncommon varieties.

These observations are cited merely for suggestion. They do not by any means dispute the value of the highly successful

work which has been described by the previous speakers, nor do they detract in any important degree from the usefulness of this discovery. They are presented merely to show that copper sulphate must be used with discretion, and like all other good things it may fail at critical times.

Dr. A. H. Doty, health officer, port of New York, said: As the result of my own investigations with sulphate of copper, I am convinced of its value in sanitation, particularly as a deodorant and for the clarification of water when used either alone or in combination with lime. So far as its germicidal value is concerned, I do not believe that at present we are in possession of sufficient data to present definite and satisfactory information on the subject. Tests which have already been made at the New York State Quarantine Laboratory with the typhoid and cholera organisms in distilled water, tap water, contents of street sewers and broth indicate that the germicidal value of this agent may equal our expectations. I have been interested in Dr. Moore's valuable publication relative to the purification of reservoir water by copper sulphate. During the past summer I witnessed practical demonstrations of the value of this agent in the direction just referred to, and have recently suggested the use of it in a small reservoir in the western part of New York, where the water was so offensive by the reason of a fishy odor and taste that it could hardly be used for drinking purposes. The report of the health officer who had the matter in charge leaves no room for doubt as to the successful result. Within a few days after the introduction of the copper in accordance with Dr. Moore's suggestion, the offensive odor and taste of the water had disappeared and since that period there have been no further complaints. In experiments which were made during the past summer with water containing mosquito larvæ taken from pools in districts where this insect was actively propagated and placed in large wooden tanks, I found that the copper alone and in combination with lime promptly deodorized and clarified the contents of these receptacles even when large amounts of decomposed organic matter were added. However, in these instances more copper was used, usually from five to twelve grains for each gallon of water experimented with. Even with this amount,—chemical examination at the end of twenty-four hours failed to detect the presence of copper in the clarified water. I am satisfied that Dr. Moore's suggestions as to the use of copper in small amounts for the destruction of algæ, and for removing the offensive odor and taste which frequently occur in reservoirs, is safe, practical, economical and very effective. However, I am unable to endorse the recommendation made by Dr. Moore as to the use of sulphate of copper as a disinfectant in reservoirs presumed to contain pathogenic organisms, particularly the typhoid bacilli. As a result of a sudden and formidable outbreak of typhoid fever in a community, and in the absence of some known cause, we are justified in assuming that the water supply, if a common one, is the medium of infection, although we rarely have positive proof of this as a result of bacteriological examinations. There are but few instances where the organism has been detected in drinking water. Therefore, if present we can not as a rule determine when they disappear. In this there is a great difference between the satisfactory results obtained in laboratory experiments where we know that the bacilli are present, and know when they are destroyed. Furthermore, in treating the contents of a reservoir we are dealing with factors which are not present in experimental work. For instance, the uncertainty as to the exact character of the media which presumably contain the organ-

ism. Reservoirs are constantly receiving water which is not always of a certain standard; besides, the organic matter also varies in amount. This alone would tend to throw doubt on the value of sulphate of copper in the disinfection of reservoir water, notwithstanding the argument that the water may be frequently tested to ascertain its contents. It must be remembered that we have before us for consideration the use of copper in exceedingly minute amounts which may be easily neutralized and rendered useless by different constituents of the water.

As a matter of fact, the disinfection of reservoir water on the occurrence of an outbreak of typhoid fever is not the most important consideration. Our first duty should be to ascertain the origin of infection, which is not in the reservoir itself, but in some way connected with the reservoir supply. The most exhaustive inspection is frequently required to discover this contamination, as it is commonly due to mild or ambulant cases of typhoid fever which have escaped detection or have been mistaken for some other disease. Until we have accurately determined the origin of infection or have used every effort to do so, and if possible have isolated the cases, have performed and maintained thorough disinfection at the seat of infection, we have not properly performed our duties as public health officials. In these instances other means of preventing the extension of typhoid fever must of course be employed. The character of these depends somewhat on the conditions present in each outbreak, and it is likely that in this connection the sulphate of copper can be used advantageously. Whatever future investigation may disclose as to the value of this agent as a disinfectant, I am certain that our present knowledge of it does not justify us in depending upon it in outbreaks of typhoid fever to the extent recommended by Dr. Moore.

Dr. Moore said: In concluding this discussion it does not seem necessary to make any further reference to the efficiency of copper sulphate and metallic copper. That it really does all that is claimed for it at tremendously high dilutions seems to have been abundantly demonstrated both by laboratory experiments of independent workers and by its use in a practical way upon a large scale.

The one point about which there is naturally the most question is the effect of copper upon the human system. It is difficult for any of us to abandon any prejudice, whether it has any foundation in fact or not, and to expect a universal acceptance of the use of a metal which for years has been looked upon with fear and distrust in this country is out of the question.

However, since there has been such a unanimous expression of opinion from all the speakers that they would unquestionably prefer a copper-treated water to one containing algæ or typhoid or cholera germs, it seems that it may be worth while to use the few moments at my disposal in an attempt to point out some of the facts that are well known regarding the effect of copper upon man. For, contrary to the idea of some, we have a very large accumulation of facts along this line, as the result of experiment upon the lower animals as well as man.

Certainly, the argument that our daily food naturally contains comparatively large amounts of copper is not one in favor of using the same substance in any quantity for the purpose of adulteration or sophistication. Nor was it intended that a reference to this fact should be so interpreted. The only point that it seemed desirable to make was that since we had such a tremendous amount of practical evidence, all tending to demonstrate the harmlessness of

copper, that it could not be the dangerous poison popularly supposed. No amount of theoretical evidence regarding the innocuousness of a substance will convince the man who has been made violently ill by eating it, and so, on the other hand, the fact that we have all been consuming copper for years without any known deleterious effect is to the average mind a point in favor of the harmlessness of minute quantities used for specific remedial purposes. The situation is well illustrated by the action of the English judge who had listened to the conflicting evidence of experts in a case regarding the use of copper for greening peas until he could tell nothing whatever about it. Finally he discovered that the brand of peas under discussion had been upon the market for thirty-six years, and there were now sold some 20,000,000 cans per year. He then asked the prosecution to produce evidence of a single instance of sickness or injury which in the remotest way could be traced to these vegetables, and as this could not be done, he considered the evidence of experience so great as to warrant dismissing the case.

Coming directly to the results of experiments designed to show the effect of copper upon man, I can refer in only the briefest way to the large mass of evidence accumulated along this line. For fourteen months Gallipe and his family used food containing amounts of copper easily determined, without any noticeable effect. Kobart's experiments show that an average man can take 1 gram of copper per day with perfect safety. This is a thousand times more than could be obtained from water treated with copper sulphate. Lehmann, Burcq and many other careful investigators have demonstrated that the ingestion of copper even in considerable amounts has no effect other than producing results similar to an overdose of table salt. Bernatzik determined that after entering the stomach only small quantities of copper are absorbed by the blood and a toxic action is only possible when a considerable amount accumulates in the circulation. Silver, copper and zinc have almost the same medicinal properties, the difference being that of degree rather than kind. These metals differ markedly from the other heavy metals, having no harmful effect upon the tissues, and producing no fatal functional injury, hence they are not poisonous in the same sense as are lead, mercury, arsenic, antimony and phosphorus.

Dr. Paull, editor of the *Pharmaceutical Journal* of England, was able to trace 99 per cent. of the copper as passing away from the body and many other investigators have established the fact that there is no cumulative action with this metal.

Strange as it may seem, there does not exist an authentic case of copper poisoning either in this country or abroad. At the congress at Brussels, where this subject was discussed for more than six months and which was attended by the strongest opponents of copper there was not a single instance of copper poisoning which could be brought forward that would stand the scrutiny of the congress.

In our own country, those toxicologists and physiologists who have given the subject sufficient attention to be competent to pass judgment are, without exception, agreed that copper in the amount used for the purification of water is without harm. I can not quote these here, but both in private letters and in published statements their verdict is in favor of the harmlessness of copper. I wish there were opportunity to quote at length from these men, but it is impossible at this time. It is, perhaps, sufficient to state that one of the best known of these authorities refers to the very point that was brought out to-night by one of the speakers. That is, that the finding of copper in the human body is one argument

which may be used in demonstrating its universal distribution as well as its innocuousness to man. It is a well-known fact, of course, that a great many analyses have shown copper present in the body as high as forty to fifty parts per million. In the flesh of other animals, in milk and eggs, copper has been detected in varying quantities a number of times.

Finally, the reversal of the opinion of those who have such matters in charge in other countries is worthy of notice. The Italian government now allows 100 mg. per kilo in preserved vegetables and the following letter from the Prefecture of Police shows the change in position of the French Government:

> Up to the year 1899 the subject of the possible bad effects on the health of the people by the introduction of sulphate of copper in the preparation of preserved vegetables had not been so much studied as it has of late, the scientific opinion being divided. But since that time the consulting committee has been renewed, and has again taken up the question and passed on the experiments made by private parties both as to the quantity of copper that the human body can consume without danger to health, and the proportion that the various preserved foods that are colored green may contain. From these experiments they came to the conclusion that there was no longer any reason to oppose the system of greening preserved vegetables by means of the salts of copper.

Consequently it is now allowable in France to use salts of copper for preserving the green color in food products in any amount, although until the harmlessness of this metal became known it was forbidden to even use a copper vessel for preserving purposes.

After all, the question is not a new one in this country, the introduction of Bordeaux mixture as a fungicide some years ago necessitating the fighting over of the whole subject of the effect of copper upon man. At that time one board of health ordered tons of grapes that had been treated with Bordeaux mixture to be dumped into the water, and it was not until Dr. Galloway and others connected with the Department of Agriculture at that time, showed how impossible it was to do any injury with this solution that the popular prejudice began to die out. Nowadays no one thinks anything about whether the fruit he is eating has been treated with copper or not.

The objections to the use of copper sulphate, because careless or ignorant people in charge of water supplies might add too much, hardly seems to require an answer. Since there would be no difficulty in tasting the copper long before an amount sufficient to cause inconvenience could be consumed, and since by the addition of lime we can almost immediately eliminate any excess of copper, it would seem that we had as many safeguards for this method as for any which could ever be introduced. Certainly, the danger of mismanagement and fatal error is nothing like so great as for sand filtration. It might be a good plan to encourage any method that would emphasize in any way the importance of putting the public water supplies of this country into the most competent hands possible. That the public is unable to detect failures in filtration plants until the death rate begins to rise, might be urged against this system of water purification. Certainly it is time we realized that filtration is one of the most delicate operations in sanitary science and that neglect or ignorance is constantly causing a reduction in the efficiency of this method. The man who makes public the cases of adding unfiltered to filtered water, the running of filters at too high a rate, the leaks in basins, conduits, etc., and the many other defects which are constantly occurring with this method may appear to be an enemy of sand filtration. In reality he would probably do more to compel authorities to raise this method to the efficient place it ought to have, but does not occupy

at the present time, and would be of more real service to his country than many of us are able to realize.

Any one who has read the published accounts of the copper sulphate method as devised by the Department of Agriculture can not but admit that a most conservative stand has been taken regarding it. Over and over again is the statement made that it was not designed or intended to replace efficient methods now in use. The only claim made for it by its originators has been that it in one case furnishes a remedy for a condition previously considered hopeless, and in the other case as an emergency method, owing to the failure of means already in use, it offers the best way of quickly, thoroughly and cheaply sterilizing a large body of water that has yet been devised.

Copper sulphate is a remedy designed to correct a specific difficulty of great importance from the standpoint of comfort and public health. Each water supply requires a specific prescription and, if properly treated, I believe the evidence brought out here to-night guarantees a cure.

Contributions to the discussion were also made by Dr. G. Lloyd Magruder, Dr. Geo. M. Kober, Dr. Wm. C. Woodward, health officer, and Hon. H. B. C. Macfarland, president, Board of Commissioners, District of Columbia.

SCIENTIFIC BOOKS.

REPORTS OF THE BELGIAN ANTARCTIC EXPEDITION. *Résultats du Voyage du S. Y. Belgica en 1877–8–9, sous le commandement de A. de Gerlache de Gomery.* Rapports Scientifiques, publiés aux frais du Gouvernment Belge, sous la direction de la Commission de la Belgica. Anvers, J. E. Buschmann, 1904. 4to, illustrated.

Additional volumes of the reports of the *Belgica* expedition have reached us as follows: *Hydroiden* von Professor Dr. Cl. Hartlaub (September 15, 1904, pp. 1–19, pl. I.–IV.); *Nemertinen* von Dr. Otto Burger (August 30, 1904, 12 pp., pl. I.–II.); *Poissons* par Louis Dollo (October 15, 1904, 240 pp., pl. I.–XI.); and *Observations Météorologiques horaires* par Henryk Arctowski (August 20, 1904, 201 pp., pl. I.–XXIII.).

The journal of the *Belgica* wintering among the Polar floes has furnished the first meteorological record taken during an entire year which has been obtained from the Antarctic. It is true that observations, taken at an isolated spot in a vast area of which the conditions are unknown, have only a relative importance, which however will grow with the increase in reports from other stations. But, as the pioneer in a virgin field, the observations possess intense interest to the meteorologist.

The volume contains preliminary chapters on the outfit, the special difficulties encountered, the general results, the complete record of observations and plates showing graphically the automatic records and the results displayed as wind-roses, etc.

Space fails for a complete analysis of the conditions encountered, but a few notes may be given. The mean annual pressure of the atmosphere was 744.4 mm., with a June maximum observation of 772.1 and a March minimum of 711.7. The minimum monthly mean occurred in February (735.68) and the maximum in June (750.55). The extreme maximum diurnal variation was 21.4 mm. in September, the minimum in the summer months, 8.6 mm. in December. In examining the profile for the year two maxima (June and December) and two minima are distinctly indicated, corresponding to the solstices and equinoxes.

The mean temperature for the year was minus 9°.64 C. with a maximum of plus 2°.5 and a minimum of minus 43°.1. The mean diurnal variation was 7°.57 and the maximum for a single day 27°.4.

The winds from the west and east predominate markedly over those from the north and south. It is noticeable that the northeast and and southeast winds were much more common than those from the northwest and southwest,