



AN INVESTIGATION OF THE BACTERIOLOGICAL
CONTROL OF THE WATER OF A
SWIMMING POOL

by

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A THESIS

Submitted in Partial Fulfillment of the
Requirements for the Degree of
BACHELOR OF SCIENCE

Department of Biology and Public Health
MASSACHUSETTS INSTITUTE OF TECHNOLOGY

1932

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Author's Signature

Departmental Certification

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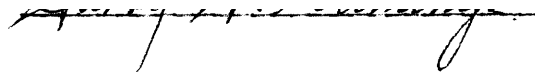
Cambridge, Massachusetts
May 25, 1932

Professor A. L. Merrill
Secretary of the Faculty
Massachusetts Institute of Technology
Cambridge, Massachusetts

Dear Sir:

I hereby submit for your approval this thesis,
entitled, "An Investigation of the Bacteriological
Control of the Water of a Swimming Pool."

Very truly yours

A handwritten signature in dark ink, appearing to be "W. L. ...", written over a horizontal line.

184805

ACKNOWLEDGMENT

I wish to take this opportunity to express my appreciation to Dr. B. E. Proctor under whose supervision I have worked, and who offered me many helpful suggestions and recommendations.

TABLE OF CONTENTS

	Page
Introduction.....	1
Purpose.....	4
Bacteriological Tests.....	4
Chlorination.....	6
Ortho-Tolidine Method.....	13
Reagents.....	13
Alkalinity.....	14
Methods of Testing Alkalinity.....	19
Coagulation.....	20
Determination of Alum.....	25
Filtration.....	26
Foot Bath.....	28
Suggestions.....	29
Directions for the Control of the University Club Swimming Pool.....	30

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Introduction

The sanitary control and supervision of swimming pools has been clearly shown by health officials to be an important phase of health protection. Transmission of a number of diseases has been attributed, on good epidemiological evidence, to the swimming pool. Such diseases as ringworm, conjunctivitis, venereal diseases, respiratory infections, sinus trouble, skin eruptions and intestinal diseases, are frequently transmitted by unsanitary pools.

The United States Public Health Service, realizing the infection and disease that may be spread by infected swimming pools, appointed a committee to investigate swimming pools and postulate standards. The provisional standards for the chemical and bacterial quality of the water are as follows:

1. Whenever liquid chlorine, calcium hypochlorite, or any other chlorine compound is used for swimming pool disinfection, the amount of available or excess chlorine in the water at all times and at all points when the pool is in use shall not be less than 0.2 parts per million nor more than 0.5 parts per million.

2. Whenever alum or sulfate of alumina are used during purification or repurification of swimming pool waters, the water at all times when the pool is in use shall show an alkaline reaction. Whenever artificial alkalinity is added to a swimming pool water, such water should never show a reaction for caustic alkalinity.

3. Bacteria Count on Agar, 48 Hours, 20 C. (This Count Optional). Not more than 10 per cent of samples covering any considerable period shall exceed 1,000 bacteria per cubic centimeter. No single sample should contain more than 5,000 bacteria per cubic centimeter.

4. Bacteria Count on Agar or Litmus Lactose Agar, 24 Hours, 37 C. Not more than 10 per cent of samples covering any considerable period shall contain more than 100 bacteria per cubic centimeter. No single samples should contain more than 200 bacteria per cubic centimeter.

5. B. Coli, Partial Confirmed Test. Not more than two out of five samples collected on the same day, or not more than three out of any ten consecutive samples collected on different dates to show a positive test in 10 cubic centimeters of the water at times when the pool is in use.

Very few cases of infection can be traced to a pool in which the bacterial and chemical condition of the

water is within the limits of the prescribed standards. The importance of competent supervision to perform the necessary bacteriological and chemical tests cannot be too highly stressed. The standards set forth by the United States Public Health Service specify that each swimming pool should be operated under the close supervision of a well trained operator with common sense and good judgment. Many pools are equipped with extensive sand filters, chlorinators and other safety measures but are sadly lacking in trained help. I should go so far as to say one trained supervisor is more valuable than expensive apparatus incorrectly handled; but a trained operator with adequate apparatus is able to produce very desirable results.

My work was carried on at the University Club in Boston. The pool is 75 feet long 25 feet wide and holds 85,000 gallons of water. There are adequate toilet facilities, showers and dressing rooms. The swimming pool itself and the adjoining rooms are well constructed and satisfy the demands postulated by swimming pool construction standards. Purification of the water is accomplished by chlorination, coagulation and filtration. As the water leaves the pool through two outlets situated at the deeper end of the pool, it passes through

a hair filter which removes the heavier coarser materials, then it passes through an alum pot to the filter and finally through the chlorine apparatus and back to the pool, entering the pool through six inlets, three on each side of the tank. The personnel connected with the operation of the swimming pool consists of an engineer and a swimming instructor.

Purpose

The purpose of my work was to investigate by bacteriological and chemical tests the control of a swimming pool, to improve existing conditions and to suggest a program for the sanitary operation of the pool.

Starting February 21, I was given complete charge of the operation of the swimming pool and the various apparatus connected with it. In an attempt to determine the exact condition of the pool I made the following bacterial and chemical tests: chloride determination, hydrogen ion concentration, chlorine content, alum content and bacteriological determinations on nutrient agar and lactose broth tubes.

Bacteriological Tests

Samples were taken from the filter, hair filter,

foot bath and three samples from the pool itself.

Number of organisms per c.c., 48 hours, 37 C.

	Pool	Hair filter	Filter	Foot bath
1	295	240	100	2500
2	250	280	120	3000
3	300	---	---	----

Gas formation in lactose broth tubes

	Pool	Hair filter	Filter	Foot bath
1	50%	20%	5%	50%
2	25%	10%	8%	25%
3	30%			

Chemical Tests

Chlorine content	Chloride content	Alum	p.H.
absent	10 P.P.M.	traces	5.8

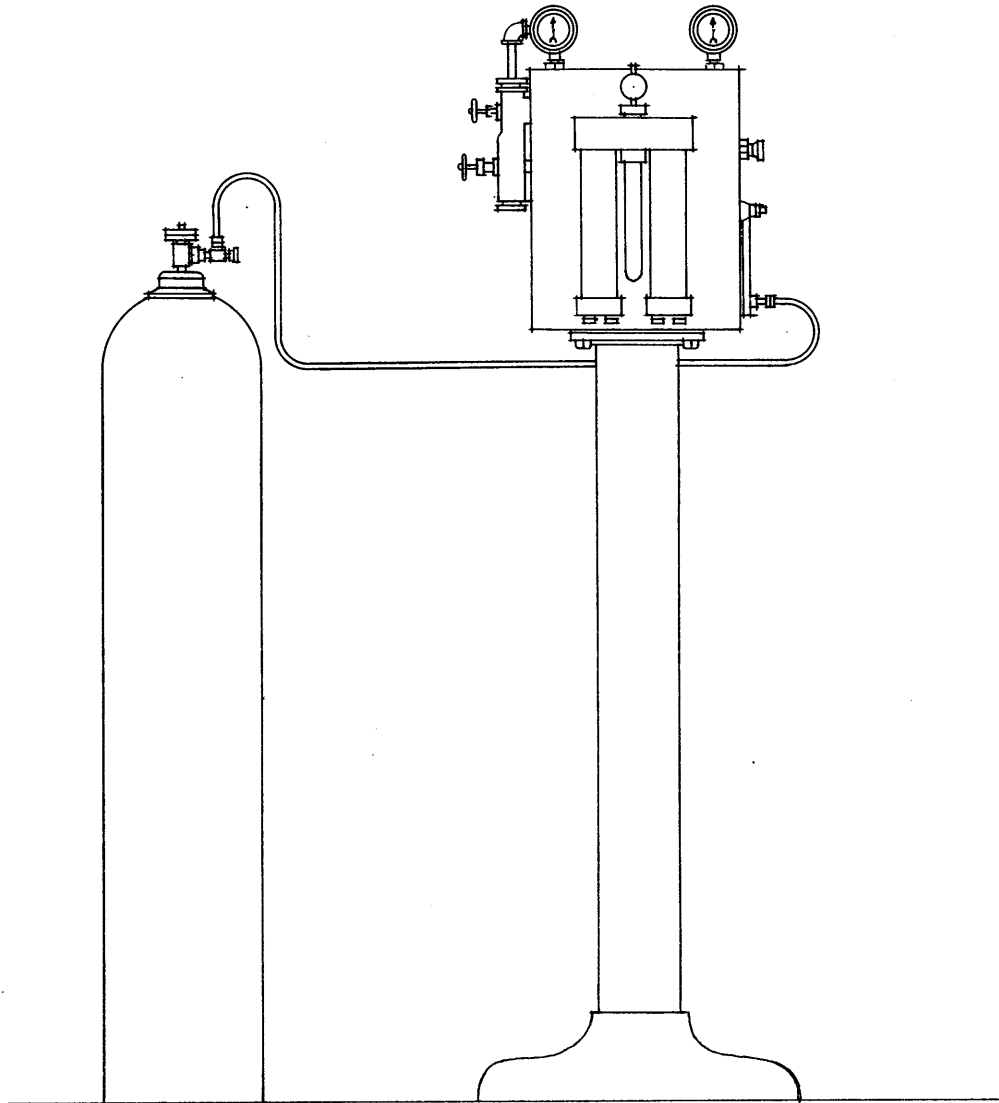
It can be easily determined from the above figures that the condition of the pool was far from being satisfactory. The slight reduction in bacterial counts after the water had passed through the filter shows trouble either with the filter itself or with the coagulating apparatus. High results in the gas tubes show probable presence of B. Coli or other intestinal bacteria. The foot bath as a sanitary precaution against athlete's foot is useless. The hydrogen ion concentration is too

high to permit the proper coagulation of the aluminum sulphate and finally the residual chlorine content is far below standard. No chemical or bacteriological tests were made except by city officials. Fortunately, careful supervision of swimmers and the necessary washing before entering the pool was enforced, thereby assisting materially in keeping the bacterial count within the standards.

The chief complaint of the bathers after using the pool was sore and irritated eyes. The condition was believed by the operators of the swimming pool to be due to a high chlorine content. In order to alleviate conditions, therefore, the rate of flow of chlorine into the tank was diminished. That was the reason for the low chlorine content when I started work. Conditions, however, did not improve and sore eyes among swimmers were continually being reported. I did not attack this problem immediately but started to improve the chemical and bacteriological condition of the pool even though it involved increasing the residual chlorine content. My first work involved the adjustment of the chlorinating apparatus.

Chlorination

The sterilizing agent employed was chlorine gas.



Chlorinating Apparatus

Chlorine gas is generally accepted by sanitarians as being the most satisfactory disinfecting agent. There are several chemical agents which may be used to kill the bacteria in pool water. The most commonly used now, excepting chlorine, are ozone and ultra-violet light. Of the three, chlorine is most widely used. It has one great advantage over ozone and ultra-violet light, the fact that more may be added than is needed at one time and the residual chlorine will remain, taking care of bacteria which may later be added to the pool water. In fact, as I have already stated, a residual chlorine content is demanded by public health authorities.

The chlorinator used at the University Club pool is a Wallace and Turnan apparatus of recent design. The pool water passes directly from the filters to the chlorinator and thence back to the pool. The rate of flow of chlorine is adjusted by means of regulating the number of pulsations of the chlorinator.

Previously the chlorinator had been running at various rates of speed and no record had been kept which enabled me to determine accurately the amount of chlorine used or the rate of flow of water through the chlorinator.

As chlorine is a dangerous gas to handle and as

excess may cause serious difficulties, it was necessary for me to increase the chlorine content in very small doses, making frequent chemical tests. With this point in mind, I speeded up the chlorinator to 1 pulsation every 2 minutes, allowing it to continue at this rate for four days, running between the hours of 8:30 A.M. and 9:00 P.M. daily. Chlorine determinations by the orthotolidin test showed traces of residual chlorine. Bacterial counts at the end of this time showed the following results:

Number of organisms present on nutrient agar after incubation at 37 C. for 48 hours. Samples taken from pool and the filter outlet.

	Filter	Pool
1	100/c.c.	250/c.c.
2	110/c.c.	275/c.c.

Lactose broth tubes inoculated with 1 c.c. pool water showed 30 per cent gas formation.

Although there was a slight reduction in bacterial count, nevertheless the gas tubes did not show much improvement.

Therefore I speeded up the pulsations of the chlorinator to one pulsation per minute. I allowed the chlorinator to continue at this rate for about four days, making frequent residual chlorine determinations to prevent over-

dosing. At the end of this period I again made bacteriological determinations from pool and filter. The chlorine content was approximately .1 P.P.M.

Number of organisms per c.c.

	Pool	Filter
1	130	60
2	180	80

The lactose broth tubes showed less than 10 per cent gas in every case. A marked reduction, therefore, in bacteriological counts is brought about by a slight increase in the residual chlorine content.

The next step was to increase the dosage of chlorine to one pulsation every 30 seconds. The chlorinator was allowed to run at this speed for about four days as before. At the end of this time the residual chlorine content was .2 P.P.M. Bacteriological examinations of water from the pool and filter outlet were made. These results were as follows:

Number of organisms per c.c.

	Pool	Filter
1	80	20
2	100	25

The chlorinator was then allowed to run at 1 pulsation every 20 seconds. Running at this speed the

residual chlorine content varied between .4 and .45 P.P.M. Bacteriological examinations made of pool water and water after having passed through the filter showed very satisfactory results.

Number of organisms per c.c., 48 hours, 37 C.

	Pool	Filter
1	4	--
2	2	1

With a residual chlorine content of .4-.4.5 P.P.M. I secured what I thought to be satisfactory conditions. However, I did not think it wise to allow the chlorine content to be at this figure without having orthotolidin tests for free chlorine made in order to prevent overdosing. Therefore I set the chlorinator back to one pulsation every 30 seconds. Arrangements were made to have the speed of the chlorinator checked four times a day.

In an effort to determine a direct relationship between the chlorine content and the number of organisms in the pool I increased the rate of pulsations of the chlorinator until the residual chlorine content was about .5 P.P.M. I then shut off the chlorinator and took samples from the pool as the chlorine content decreased. There was little change in the chlorine con-

tent for three hours. At this time it dropped to .45 P.P.M. It required two more hours to drop to .4 P.P.M. then it dropped more rapidly to .3 P.P.M., probably due to the increased number of swimmers. By this time it was too late for me to stay at the pool any longer and next morning the chlorine content was .15 P.P.M. I allowed the chlorine content to drop until the orthotolidin test showed only traces. This whole process required approximately 30 hours.

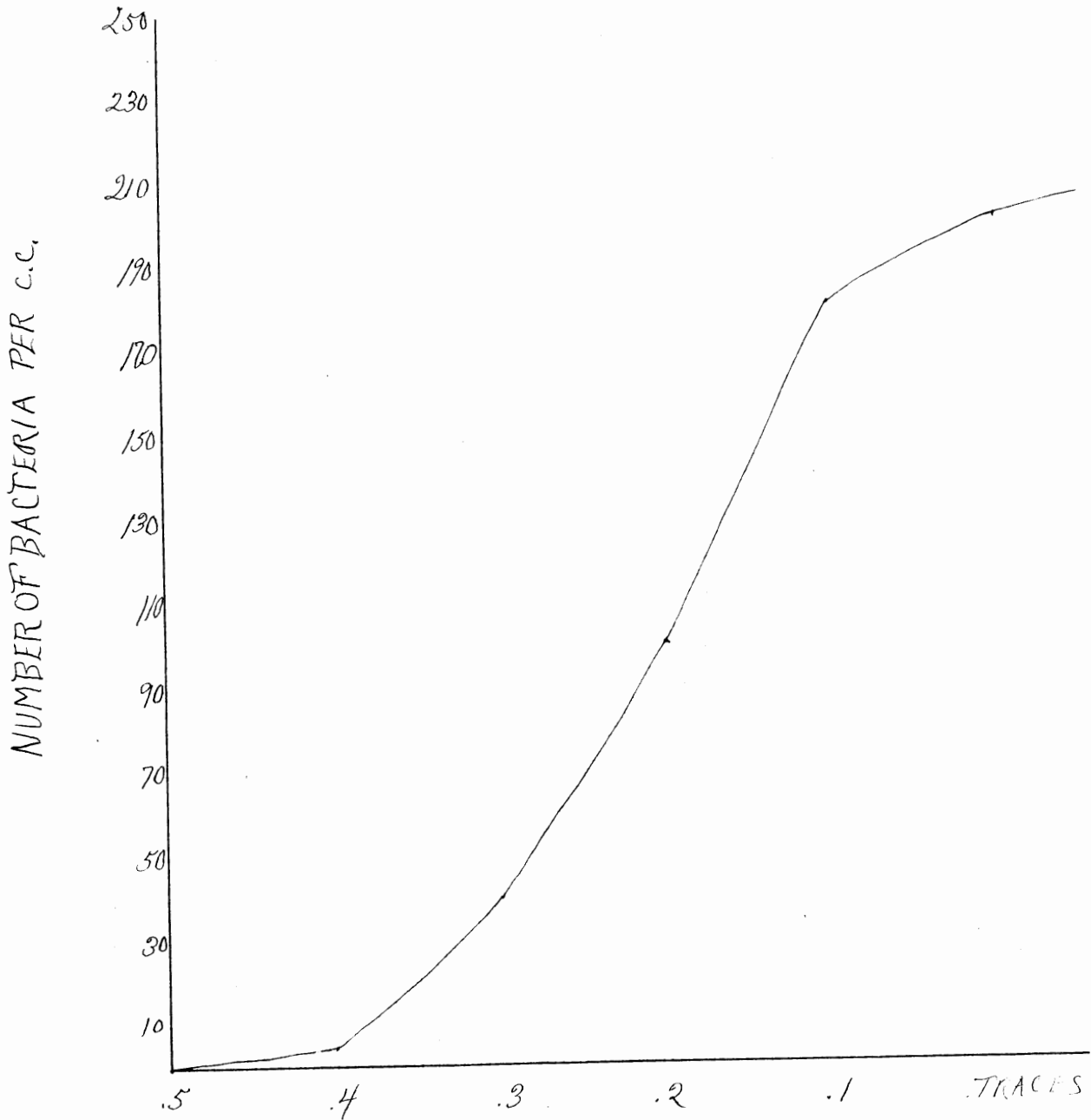
The results are shown as follows:

Chlorine content	.5	.4	.3	.2	.1	Traces	Traces
No. organisms/c.c. 48 hours, 37 C.	1	4	40	100	180	200	250

In order to make bacterial counts at .2 P.P.M. I ran the chlorine content up the next morning until I reached .2 P.P.M.; then I made a test.

The graph of this relationship shows a leveling of the curve at 200 organisms per c.c. I believe this is because the filters themselves prevent a vary rapid increase of bacteria.

A very interesting result of these chlorine experiments was the marked reduction in the cases of sore eyes as the chlorine content was increased. In order to check these results I stopped the chlorinator and found that



CHLORINE CONTENT IN P.P.M.

Relation between the Bacterial and Chlorine Content
of Pool Water

the swimming instructor received increased complaints of sore and irritated eyes due to "chlorine." As soon as I increased the chlorine content back to .3 P.P.M. the complaints would decrease. At the completion of my work there was an average of about 5 complaints a day while the average attendance in the pool was 50-60 swimmers daily.

The reason for the decrease of sore eyes and other irritations in a water that contains a sufficient amount of chlorine, is rather difficult to explain. It is known that when a solution of chlorine is added to a water a variety of reactions may occur depending on the nature of the mineral and organic matter in the water. In general the reactions may be divided into 3 types: (1) oxidation of organic or mineral matter; (2) direct chlorination of the organic matter; (3) bacteriacidal action. The first factor mentioned is the one most likely to produce substances that will irritate the eyes or other sensitive mucous surfaces. It has been shown moreover that direct chlorination of organic compounds does take place. The chloro-derivatives and substitution products formed have in a number of cases been the cause of irritations and objectionable tastes and odors. In practical application in the majority of instances this

chloro-derivative may be destroyed upon a further increase of chlorine.

By bacteriological tests I found that when the residual chlorine content of the pool reached .3 P.P.M. the staphylococcus and streptococcus strains of bacteria were destroyed. Organisms found in the pool with a chlorine content above .4 P.P.M. usually proved to be spore formers.

During all these experiments on chlorination the p.H. of the pool was about 7.2

Ortho-Tolidine Method

The chemical test employed in determining the chlorine was the orthotolidin test. This reagent used for the estimation and detection of chlorine is not specific, but gives similar reactions with oxidizing agents, reducible substances and chlor-addition products. Nitrates, and ferric compounds in large quantities, organic coloring matter, and chlorates are interfering substances, but as none of these chemicals were present in large quantities in the pool water, the test was not seriously hindered.

Reagents

The reagents used were made up as follows:

(a) Orthotolidin solution: Dissolve one gram of o-tolidine in one liter of dilute hydrochloric acid (100 c.c. concentrated acid diluted to one liter).

(b) Copper sulphate solution: Dissolve 1.5 grams of copper sulphate and 1 c.c. concentrated sulphuric acid in distilled water and make up to 100 c.c.

(c) Potassium dichromate solution. Dissolve .025 grams of potassium dichromate and 0.1 c.c. of concentrated sulfuric acid in distilled water and make up to 100 c.c.

Procedure: Mix 1 c.c. of the toloidine reagent with 100 c.c. of the sample to be tested in a Nessler tube and allow the solution to stand at least five minutes. Smaller amounts of free chlorine give a yellow, and larger amounts an orange color. For the quantitative estimation, the color developed is compared with that of standards in similar tubes prepared from the solutions of copper sulphate and potassium dichromate.

Alkalinity

The alkalinity of a water is a vital factor in securing satisfactory purification. Chlorine works most effectively as a disinfectant of water which is

not acid, but on the contrary slightly alkaline. The aluminum sulphate used as a coagulant will not precipitate in acid medium. The floc or film will not form and the alum will go through the filter in solution. Therefore the use of a chemical to overcome the effect of the acid on the water will serve two purposes: it will counteract any irritation and and discomfort due to acid water and will also increase the efficiency of the purification apparatus.

Previous to my assignment at this swimming pool the hydrogen ion concentration had varied between a p.H. of 4.5 and 6.5. No hydrogen ion determinations on alkalinity tests were being made. The engineer was adding about one-half pound of sodium carbonate a day to the water. This low alkalinity value was another factor which produced an irritating effect on the eyes of the swimmers.

I immediately increased the dose of sodium carbonate to three-fourths of a pound of soda ash per day. By gradually increasing the amount of soda ash I finally reached a p.H. of 7.6. The pool became slightly clearer and of a lighter color. With a chlorine content of .25 P.P.M. and the chlorinator running one pulsation every 30 seconds, I was unable to see any difference in the numbers of organisms per

cubic centimeter of pool water. By shutting down the chlorinator and allowing the p.H. to remain at 7.6 I was able to throw the load of the purification process on the filters themselves. As a second part to this experiment I shut the chlorinator off and allowed the p.H. of the pool to reach 6.0. Under these conditions bacteriological examinations showed an increase of organisms per cubic centimeter.

The bacteriological examinations showing increase of organisms as the alkalinity decreases gave the following result:

p.H.	Pool Organisms/c.c.	Filter
7.6	100	12
6.6	200	25

The p.H. was then raised again to 7.6 and allowed to remain at this point one week. At the end of this time I had the filters blown back by reversing the flow of the water and forcing water up through them, observing the color of the water through the sight glass on the discharge pipe and noting the time required before the water became clear. Then I discontinued the soda ash until the p.H. of the pool water was 6.0 and allowed it to remain in this condition for one week as before. The filters were then washed at

the end of this period. The material washed from the filter was lighter in color and a shorter period of washing was required to clean the filters. From these observations, with the p.H. on the acid side of neutrality, proper floc formation was prohibited and the material was carried right through the filter, while a p.H. on the alkaline side of neutrality favored the precipitation of the aluminum sulphate, forming a satisfactory schmutzdecke on the surface of the filter beds, thus increasing the efficiency of the filters.

While experimenting with the efficiency of the filters the p.H. had dropped to 6.8 due to the lack of sodium carbonate. At this time the water in the swimming pool began to appear dirty and cloudy. I was unable to account for this condition as the water had never appeared this way at a p.H. of 6.8. In order to determine the cause for this condition I checked the alum pot, to see if it were filled and functioning properly. I opened it and put in a fresh supply of alum. I had the filters backwashed. I noticed also that bacteriological examinations at this time showed 300 organisms per c.c. and chemical tests disclosed the fact that the chlorine content had dropped to .1 P.P.M. This fact alone proved that the filters were out of order and the chlorine had combined with the

organic matter thereby reducing the free chlorine content to traces. I then added 5 pounds of soda ash to the pool and continued this for about three days; at the end of this time the pool had started to clear and at the end of five days the p.H. was 7.7 and the water as clear as before.

Then working in the other direction I increased the amount of soda ash added to the pool until I had a p.H. of 8.0. I noticed that as the alkalinity increased above 7.7 the pool again started to cloud and became dirty. I attributed this at first to the filters again. I believed at this time that the high alkalinity might have produced such a heavy mat on the surface of the filter that the collected sediment had worked its way deeply into the top layer of the bed thus preventing satisfactory filtration. In order to counteract this effect I had the filters washed once a day but this repeated backwashing did not help clear the pool. Then I discontinued the soda ash and allowed the water to reach a p.H. of 7.5. I noticed that as soon as the alkalinity of the water dropped below p.H. 7.8 the pool water began to clear and become lighter. I have been unable to account for this cloudiness at a high alkalinity, the only possible explanation being that the increased amount of soda ash may have clouded the pool.

In order to check this I again increased the alkalinity of the pool water, all other factors being equal, and just as in the previous case the water became cloudy at a p.H. of 7.7 and upon stopping the addition of soda ash the pool cleared up. I therefore concluded that to maintain optimum conditions the p.H. of the water should be between 7.4 and 7.6. The water at this hydrogen ion concentration represents an alkalinity varying between 30 and 40 P.P.M. expressed as calcium carbonate. The water should be tested regularly and if found at or below this point, sufficient soda ash should be added to raise it to the proper level. In the operation of this pool, using seven pounds of aluminum sulphate a week, three pounds of soda ash are required to neutralize the acid formed by the addition of the alum. The above experiments have definitely proved that a distinct alkaline reaction is not only desirable but absolutely necessary in order to expect the maximum in results from the process of filtration.

Methods of Testing Alkalinity

In performing the above experiments in testing the alkalinity I used the colorimetric method and the test which gives the results in parts per million of calcium carbonate. I made more use of the colorimetric method

as it could be performed at the pool, there being no facilities there for the operation of a test involving chemical apparatus.

Colorimetric Test: This test is very simple to perform. Add .5 c.c. of Brom thymol blue indicator to 10 c.c. of the water to be tested and the resulting color is compared with the prepared color standards and the p.H. of the water is read off directly from the standard which comes nearest to matching the color of the water undergoing the test.

Alkalinity Test: This test is usually considered more scientific and accurate than the colorimetric method. Two drops of methyl orange indicator are added to 100 c.c. of the sample, in a white porcelain dish. Then add from a burette .02 N sulfuric acid until the faintest pink coloration appears. The methyl orange alkalinity in parts per million of calcium carbonate is equal to the total number of cubic centimeters of .02 N sulfuric acid used multiplied by 10.

Coagulation

To have an efficient filtration system there must be some type of coagulation to bring the minute particles of suspended matter into groups or "flocs" so that they can be removed in the filtering process. Aluminum sul-

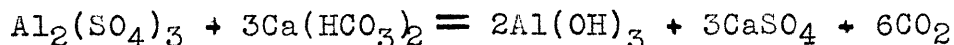
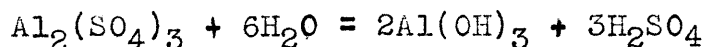
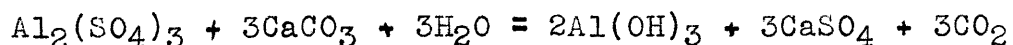
phate is most generally used as a coagulant. The preliminary preparation of the water for filtration is very necessary when using rapid sand filters. This process is not so vital in the case of slow sand filtration.

When aluminum sulphate is used as the coagulant a reaction takes place with the alkalinity already present in the water or with the soda ash added to make up the deficiency of the alkalinity. This reaction results in the formation of an aluminum hydroxide which is an insoluble compound. The precipitate is flocculent or gelatinous in nature and suspended matter and bacteria in the water readily adhere to it, both during and after its formation; and being heavier than the water it tends to settle down, dragging with it the trapped suspended matter originally present in the water.

In the case of larger purification plants sedimentation basins are used to allow the deposition of the aluminum hydroxide precipitate carrying down with it bacteria, dirt, etc. However, swimming pool purification plants of the smaller types are not equipped with sedimentation basins and the aluminum sulphate is used merely to film the filter, providing a heavy gelatinous mat which greatly increases the efficiency of the filter. This advantage has made rapid sand filtration possible.

Through a sand bed filmed with coagulated matters, water may be allowed to travel a hundred times more rapidly than it does in general in the slow sand filter. I have described experiments earlier in this paper stressing the importance of having water showing an alkaline reaction. The efficiency of the coagulants depends more upon the alkalinity of the water than upon any one factor.

Reactions taking place when alum is added may be more clearly understood by the following equations:



The aluminum hydride formed in each case precipitates out and settles to the bottom. Sulfuric acid is formed, thereby necessitating the addition of soda ash to maintain proper conditions of alkalinity.

An interesting explanation involving the colloidal theory is applied to the process of coagulation. Raw water is colloidal in nature and the particles of silt and earthy matter have the same electrical charge; as a result the particles repel one another. When the charges on the particles are neutralized they collect together forming larger aggregates which are visible to the eye and either settle to the bottom or remain

floating as large masses or flocs in the clarified liquid. The charge may be neutralized in a number of ways. The method that is of interest in water purification is by electrolysis. In this case the ions of opposite charge on the electrolyte will neutralize the charges on the colloidal particles and cause precipitation. In the case of aluminum sulphate we have an electrolytic action plus the formation of the gelatinous precipitate which results in a high efficiency. The coagulated colloidal matter may be considered as of a spongy formation, which enables it to absorb liquids and gases during coagulation.

There are other coagulants which are used in the place of aluminum sulphate. One of these is alumino-ferric which really is an impure sulphate of aluminum containing a little iron. Generally its composition may be put down at 50 per cent aluminum sulphate and one per cent iron sulphate. Alumino-ferric is made from a species of bauxite which is rather highly charged with iron oxide. The presence of the iron does no harm besides reducing the coagulating power which pure aluminum sulphate possesses. The analysis generally detects a small percentage of free acid in the cheaper substitute but not sufficient to affect the supply to any considerable extent. Other coagulants such as iron oxide, per-

manganates and acid phosphate of lime are used but none of these have proved so efficient as aluminum sulphate.

An interesting phenomenon in connection with the use of coagulants is the method in which the precipitate captures and holds bacteria on a filter bed. Examining a single grain of sand, the particle is jacketed by a slimy fluid. It is known that any droplet of water which comes in contact with the film will tend to fuse and amalgamate with the liquid surrounding the sand. Should the water which is thus added to the original covering of the particle carry any microbes they will also be drawn into the film. In this condition the organisms will have difficulty in escaping. They will probably adhere to the slimy particles in the film. From all appearances it seems that if the rate of filtration is kept constant the organisms do prefer to rest within the filmy coatings of the sand grains. This may be explained by the fact that around each sand grain there is a region of quiet in which the suspended particles and bacteria gather, just as they do in the still places of a water course. However, any acceleration of the current or any disturbance which throws the water into agitation, stirs up the particles deposited, withdraws them from the influence which has been retain-

ing them and bears them along in the direction of the general flow.

The aluminum sulphate used at the University Club is supplied in the lump form. The lump alum is placed into the alum pot, making a solution which enters the main supply line of the filter. As the water and alum solution travel toward the filter the coagulation takes place in the water. A chalky white substance appears which settles to the top of the filter bed forming an extra fine screen for the collection of the suspended matter.

Seven pounds of alum are used a week at this pool. This amount of aluminum sulphate is sufficient to insure efficient coagulation. Chemical tests, in order to determine the amount of alumina in the pool itself after coagulation, disclosed only traces of this chemical.

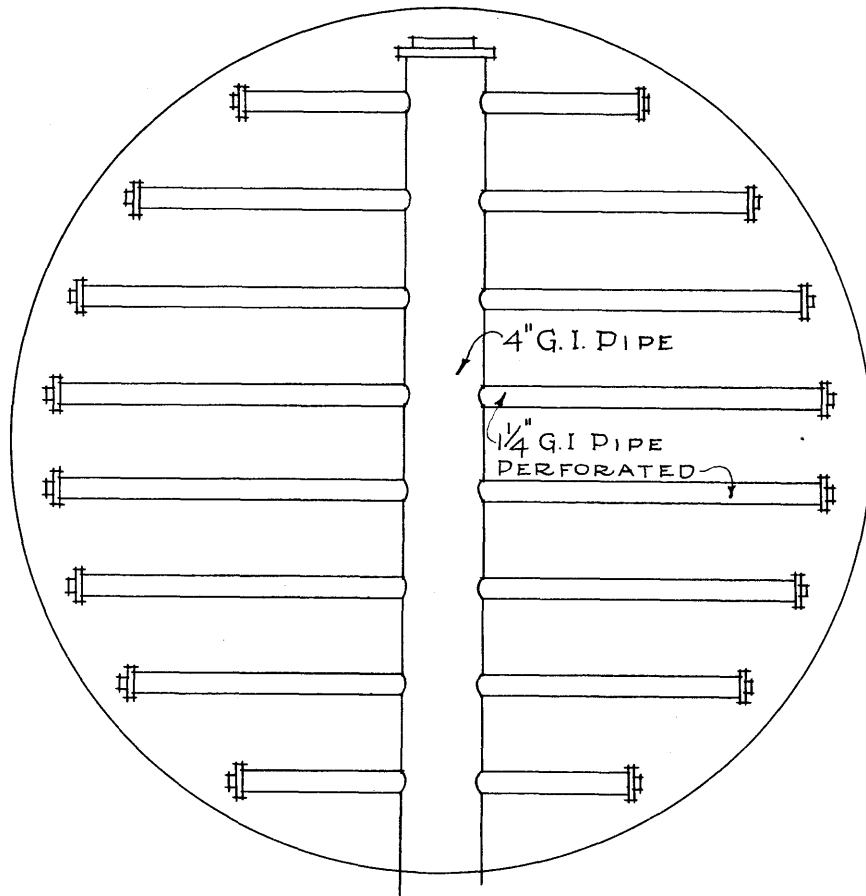
Determination of Alum: The following test was used in determining the alum content: Dissolve .1 gram of pure haemotoxylin in 25 c.c. of water. To 50 c.c. of the water being tested placed in a four inch porcelain dish, add 2 drops of the haemotoxylin solution, allow the solution to stand for one or two minutes, then add a drop of 20 per cent acetic acid. The standards are prepared at the same time using 50 c.c. of distilled

water and the required amount of standard alum solution. The comparison must be made immediately as the color fades on standing.

Filtration

The water filtration at this pool is carried out by two rapid sand filters working in parallel. Both of these filters are pressure filters, the water being forced into the filters under the impetus of a pump. The filter bed itself is made of a coarse sand. A layer of coarse material to a depth of about 15 inches is placed on the bottom of the filter shell covered by approximately two feet of sand made up to four or five layers of material graded to different degrees of fineness, the top layer being about twelve inches thick. The diameter of the filter is five feet.

The water is collected at the bottom in a series of laterals into which are screwed a number of strainer heads evenly distributed over the entire flow of the shell. These strainer heads have two functions. They prevent the filtering material from escaping with the water during the filtering process, and they spread the backwash water to all parts of the under surface of the bed. This water traveling upward at a rate equal to four times the rate of filtration, thoroughly cleanses



Base of Filter showing underdrain system

the filter material of all sediment and dirt which has been collected during filtration. The backwashing of the filters is accomplished by merely reversing the flow of water through the filter. A sight glass is installed on the wash discharge line, the purpose of this sight glass being to indicate when the filter has been sufficiently washed. When the filter is clean the back wash water flowing through the sight glass becomes clear and the direction of flow can be changed to the filter again. This provides a check on the condition of the filter bed which would otherwise have to be blindly accepted as satisfactory.

The filters were being washed once a day by the engineer in charge. There is no pressure gauge which would enable an operator to determine when the filter should be backwashed. The filters were allowed to run three weeks without washing. During this period the pool water was clearer than ever before. However, at the end of this period the material that had accumulated had become so firmly embedded on the filter that it was difficult to remove. I did not find it necessary to wash the filters once every second day but found that back washing once a week would be sufficient. If the filter is back washed so frequently the mat is no sooner

formed satisfactorily before it is disturbed.

Before the water reaches the filter it passes through a hair filter which filters out the coarser materials. Hair and lint, if allowed to pass freely into the filters, form a clinging mat on top of the sand bed which causes clogging of the filters and which cannot be washed off. A hair filter retains the hair and lint, thereby removing all possibilities of trouble from these sources.

Foot Bath

The use of a foot bath in swimming pools has become rather common as a precaution against athlete's foot and other foot infections. A strong hypochlorite solution is used as the disinfectant. Calcium hypochlorite had been used but bacteriological examination of the water in the bath after this had been used for one day revealed heavy contamination. Sodium hypochlorite was then substituted as the disinfectant. One hundred c.c. of disinfectant was added to the bath when half full of water. This dilution proved satisfactory as bacteriological examinations after one day's use showed a total absence of any microorganisms. Personally I cannot see the value of a foot bath in this

case. The location of the dressing rooms necessitates the bathers' walking down a flight of stairs after stepping in the foot bath. If the bath were situated in the dressing rooms so that the swimmers could bathe their feet immediately before dressing the danger of contracting an infection between the pool and the dressing room would be eliminated. There have been no cases of foot infection reported but this has probably been due to the clean habits of the men and women using the pool.

Suggestions

The water in the pool should be about four inches below the lip of the scum gutter. As it is now the water line of the pool is about on a level with the lip of the scum gutter, therefore defeating the main purpose of this device.

The following directions are an exact copy of the instructions to be followed by the swimming pool operator. I did not include bacteriological examinations in this set of instructions due to the absence of trained operators. However, I believe if these instructions are faithfully carried out the quality of the pool water will be satisfactory.

DIRECTIONS FOR THE CONTROL OF THE UNIVERSITY
CLUB SWIMMING POOL

Alkalinity

Add approximately 3 pounds of soda ash to the pool daily.

Test p.H. of the pool every night, keeping the p.H. between 7.4 and 7.6

The test is performed as follows: The water to be tested is added to a small test tube and filled up to the mark. .5 c.c. of Brom Thymol blue indicator is drawn up in a pipette and added to the water in the test tube. The color of the water is then compared with color standards and the p.H. determined from the standard having the same color.

Increase or decrease the dose of soda ash as necessary.

Chlorine

Run chlorinator at one pulsation every 20 seconds, checking the rate about four times a day.

Test chlorine content twice a day, preferably at 11 A. M. and 6 P. M.

Keep chlorine content between .3 and .5 P.P.M.

The test is performed as follows: The water to

be tested is added to a 100 c.c. Nessler tube and filled up to the mark. One c.c. of toloidin solution is added, the mixture is shaken and allowed to stand at least five minutes. Then compare with color standards, reading the chlorine content off of the standard having the same color.

Filters

Blow filters out once every week.

Check alum pot once every week, adding 7 pounds of alum at that time.

What to do when the Pool Becomes Cloudy

1. Stop the addition of soda ash if p.H. becomes to high.
2. Blow out filters immediately.
3. Check alum pot immediately, noting whether or not the alum is being used.
4. Do not increase chlorine cont as chlorine does not clear up a pool.

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