RENOVATION IN SWIMMING POOL CONTROL

W. D. STOVALL, M.D., Fellow A.P.H.A., M. STARR NICHOLS and VERA E. VINCENT

Laboratory of Hygiene, Wisconsin State Board of Health, Madison, Wis.

THE IMPORTANCE of swimming pool sanitation is sometimes minimized. However, the work of Atkins,[1] and Burrage,[2] and citations from articles by Manheimer,[3] together with the answers of 500 physicians interrogated in a questionnaire sent out by the Committee on Bathing Places of the American Public Health Association, indicate that there is a problem in this field.

In order to maintain a safe pool of water the water in the pool must be disinfected and this disinfection must be continuous. Filtration and primary sterilization are entirely satisfactory for drinking water protected from infection by storage, but these are not sufficient for swimming pool waters where such protection is impossible.

Evolution of swimming pool sanitation has been going on very rapidly since the introduction of chemical sterilization and it is now possible, by very simple means, to sterilize swimming pool waters. The important problems are:

First: To use a chemical disinfectant which will not only produce primary sterilization, but which can be added in such quantity that a residue is left which acts as a continuous disinfectant and maintains a water in the pool of as good quality as drinking water.

Second: To find some simple, easily applied determination which can be used as a control test to replace the more lengthy bacteriological tests now used.

Manheimer[4] and Perkins[5] were able to produce a water by the use of filtration and ozonation which met the Treasury Department *Standards For Safe Drinking Water*. But the results given do not indicate that such purity was maintained continuously in the pool.

STERILIZATION BY ULTRA-VIOLET RAYS

A review[6] of the use of ultra-violet rays in the sterilization of water is given by Warren. While Walker and Pryer[7] claim some residual bactericidal effect from these rays, using Petri dishes and crucibles, they say: "Considerable experimentation with this equipment—(standard ultra-violet ray equipment for swimming pools)—under normal working conditions of flow, failed to show that any bactericidal property was imparted to the water." In a later publication, Walker[8] gives as his fourth conclusion: "Sterilization by ultra-violet rays of swimming pool water in a recirculation system properly designed and operated gives a water in the pool which compares favorably with the government standard for drinking water."

Ultra-violet rays and ozone undoubtedly sterilize water, but from available published data the residual bactericidal effect is an uncertain quantity. From what is known concerning the activity of the rays absorbed, it seems that if it were possible to supercharge a water to such an extent as to render it bactericidal, then its use for bathing, especially near the charging tubes, possibly might be somewhat harmful to the eyes.

USE OF LIQUID CHLORINE

The results of Whittaker[9] and many others prove that one of the most satisfactory methods of maintaining a safe

WOMEN'S SWIMMING POOL, WOMEN'S GYMNASIUM, UNIVERSITY OF WISCONSIN
Water in use for five months with renovating system operating

pool of water is by the use of liquid chlorine. There have been many conjectures as to how much residuum of chlorine can be safely kept in the pool in order to maintain a safe pool of water. By residuum we mean the amount of chlorine available at all times to render innocuous any added pollution. Stovall and Nichols[10] published a result which indicated that 0.2 part per million of chlorine might be irritating to the eyes. This report was based on evidence gathered from the bathers. But the experience obtained by Nichols, who over a considerable period of time entered the pool daily, with chlorine concentrations varying from 0.0 to 0.25 p.p.m., proved no irritation was caused.

Perkins[5] states that no one complained of smelling chlorine or of experiencing eye irritation from water found to contain 0.5 p.p.m. of chlorine. The fact that these amounts of chlorine are not irritating to the mucous membrane of the eyes is explained on the basis of the probable formation of an alkaline hypochlorite with the alkalinity of the water such as is formed in Dakin's solution. It is a common practice to employ this solution, which has a concentration of chlorine as hypochlorite approximating 4,000 parts per million, in the irrigation of open wounds. In this connection it must be remembered, however, that it is the alkalinity in the water which is important. In the case of our pool water, which has an alkalinity of 140 p.p.m., the chlorine is converted very largely into hypochlorite, or to chloramine type compounds to some extent when organic matter is present in the water.

This paper reports work done on the women's swimming pool of the University of Wisconsin, covering a period of 4 months from February 13, 1925, to June 5, 1925.

DESCRIPTION OF POOL AND EQUIPMENT

The above illustration shows the pool, which is located in a spacious room with high ceilings and an abundance of light from north, south and west.

The pool is rectangular in shape and has a capacity of approximately 50,000 gallons when filled to the scum trough. It is lined with white tile throughout and is surrounded by a walkway of red tile and in the edge of this next to the pool is a slight depression which carries away the surface water, preventing contamination of the pool water from this source. Overlooking the pool is an observation balcony, only a section of which shows in the picture.

The pool is equipped with pressure filters, centrifugal pump for recirculation of the water, automatic heat control by means of a pool thermostat and steam additions, and a chlorinator of the pulsating type.

RENOVATION

Renovation is accomplished by means of refiltration and chlorination. A vacuum cleaner is used weekly to remove the sediment from the pool.

By this renovation system we are able to reduce the cost of operation $540 per year over the cost of the former method of a complete renewal of the water weekly.

It will be seen from the following analyses that the Mendota Lake water used in this pool is very desirable from both a physical and a chemical standpoint, being clear, low in organic matter and having a satisfactory alkalinity.

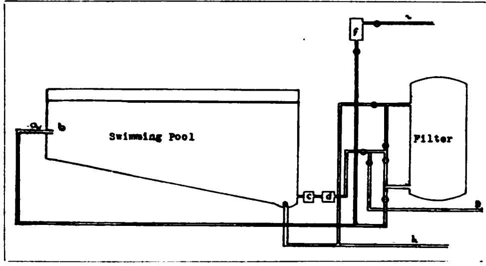
MINERAL ANALYSIS

	p.p.m.
Silica	15.2
Aluminum and Iron Oxides	2.2
Calcium	19.8
Magnesium	21.6
Sodium	3.6
Potassium	2.2
Carbonate radicle	77.2
Sulphate radicle	15.3
Chlorine as chlorides	3.0

SANITARY ANALYSIS

	p.p.m.
Turbidity	none
Odor	none
Color	none
Nitrogen as free ammonia	0.022
Nitrogen as albuminoid ammonia	0.192
Nitrogen as nitrites	0.0
Nitrogen as nitrates	0.7
Hardness by soap method	172.0
Alkalinity to methyl orange	149.0
Oxygen consumed	2.7
Total solids	214.0

FIGURE I



POOL AT UNIVERSITY OF WISCONSIN

Diagram of pool and renovation system (not drawn to scale) (o) operating valves; (a) inlet pipe; (b) distribution pipe across pool (not shown); (c) centrifugal circulating pump; (d) steam water heater; (e) sewer drain (for cleaning pool); (f) chlorinating apparatus; (g) lake water main; (h) to sanitary sewer; (i) water for dissolving chlorine gas; (j) water height in pool.

BATHERS

Bathers are required to take a soap and water shower bath before entering the pool and in addition a foot douche immediately before entering. They wear gray woolen suits. There is a weekly average of 1,000 persons using the pool, each for one-half hour periods.

EXPERIMENTAL WORK

To secure information on the problems involved in the sanitary control of such a pool, experiments were designed to answer these questions:

How much chlorine residuum is necessary to maintain an unquestionably safe pool of water continuously?

Is there a correlation between the bacterial results and residual chlorine content?

Can sanitary control of the pool be effected by the ortho-tolidine test alone?

Is the distribution of the chlorine in the pool water uniform throughout the pool?

What chemical changes take place in the pool water after continuous use over long periods of time?

How long may the water of a pool be safely used without renewal?

Samples for analysis were taken from two sources, one from the central part of the pool at the shallow end approximately 6 inches beneath the surface of the water, and the other from the deep end at a similar point. As the chlorinated water enters the shallow end through a distrib-

TABLE I
ANALYTICAL RESULTS FOR FOUR MONTHS' PERIOD

1925	Bacteriological Data: Results of *B. Coli* Tests in X c.c. water, 0.1 c.c.	1.0 c.c.	10 c.c.	10 c.c.	10 c.c.	Counts on Lactose Agar 1 c.c., 37° C.	22° C.	Chemical Results (p.p.m.): Free Chlorine Found, Deep End	Shallow	Oxy. Con.	Tot. Solids	Nitrogens: Free NH_3 N.	Alb. NH_3 N.	NO_2 N.	NO_3 N.
2–13	0	0	0	0	0	0	0	0.1	0.5	2.7	214	.022	.192	0	0.7
2–20	0	0	0	0	0	4	0	0.12	0.16	2.6	224	.068	.198	0	0.6
2–27	0	0	0	0	0	1	0	0.15	0.17	2.5	206	.050	.228	0	0.9
3–6	0	0	0	0	0	3	1	0.31	0.33	1.9	204	.036	.155	.001	0.7
3–13	0	0	0	0	0	137	7	0.17	0.18	3.2	210	.055	.133	0	0.8
3–20	0	0	0	0	0	17	1	0.19	0.20	2.5	222	.095	.232	.001	0.8
3–27	0	0	0	0	0	18	3	0.14	0.14	3.3	202	.048	.112	0	0.8
4–4	0	0	0	0	0	5	5	0.08	0.12	2.9	220	.057	.196	0	1.2
4–10	0	0	0	0	+	9,370	11,500	0.02	0	1.3	204	.086	.170	.001	1.4
4–17	0	0	0	0	0	1	6	0.40	0.40	2.9	214	.011	.150	0	1.0
4–24	0	0	0	0	0	1,540	10,500	0.06	0.06	1.9	194	.109	.145	0	0.4
5–1	0	0	0	0	0	2	0	0.16	0.16	2.5	192	.070	.165	0	0.8
5–8	0	0	0	0	0	1	30	0.21	0.11	3.0	214	.054	.155	0	1.0
5–15	0	0	0	0	0	1	0	0.18	0.22	2.2	216	.070	.173	0	1.2
5–22	0	0	0	0	0	1	6	0.16	0.21	1.5	224	.062	.132	0	1.2
6–5	0	0	0	0	0	1	1	0.26	0.32	2.6	266	.160	.200	0	0.6

uting pipe extending across the end of the pool and two feet beneath the surface of the water, it was thought that the samples collected at this end represent one extreme of the chlorine content of the entire body of water and samples from the deep end the other extreme.

Bacterial counts, *B. Coli* tests and complete sanitary chemical analyses were made of the deep end samples and free chlorine test of samples from both ends weekly during the 16 weeks covered by the report in this paper. The *Standard Methods of Water Analysis* of the American Public Health Association was used in making the analyses and tests.

During the entire period the pool was operated as a recirculating purification system and no new water was added except to make up losses due to evaporation, splashing over scum rail and in vacuum cleaning. (Table I gives results of these tests.)

DATA OF OPERATION

Operating capacity of pool	50,000 gal.
Rate of chlorination by pulsations	$5^1/_3$ per min.
Amount of chlorine. Rate per 24 hours	2 lb.
Actual time chlorinator in use per day	9 hrs.
Actual amount of chlorine applied daily	0.75 lb.
Pump rate per minute	85 gal.
Total pumpage for 9 hours	45,000 gal.
Chlorine added	2.1 p.p.m.
Intended residuum at all times in pool	0.15 to 0.2 p.p.m.
Actual residuum	(See results & tables)
Number bathers weekly	1,000
Cost chlorine gas	$0.09 per lb.
Cost chlorine gas+freight, etc.	$0.15 per lb.
Weekly consumption of chlorine gas	4.5 lbs.
Cost chlorine per week	$0.68

DISCUSSION

The results show that the bacterial counts were well within the Treasury Department *Standards For Safe Drinking Water* at all times when the residuum of chlorine was kept between 0.15 and 0.2 p.p.m. Likewise *B. Coli* was absent at all times except on April 10 when the residuum of chlorine dropped to 0.02 p.p.m. This drop occurred during the spring vacation (April 4 to 10), at which time no chlorine was added to the pool. The high counts of April 24 are explained by the fact that the chlorinator was set at $1^1/_3$ pulsations per minute instead of $5^1/_3$ as directed.

It is not possible to state what amount of chlorine is necessary to maintain a residuum of from 0.15 to 0.2 p.p.m. in all pool waters. Our bathing load was only 20 per cent of the maximum allowed by the Committee on Bathing Places of the A.P.H.A. With waters of different chemical character and with a pool accommodating different bathing loads it is obvious that the amount of chlorine added must vary, but the residuum necessary probably will not vary from that given above. In the case of this pool and the men's pool at this institution we have found it possible to depend upon the ortho-tolidine test as an indicator of the sanitary quality of the water.

Our chemical analyses show very little change in the sanitary quality of the water during the entire period of the test.

Free ammonia nitrogen showed a small increase but it was not constant enough to indicate progressive pollution. The oxygen consumed, while somewhat erratic in amount, gives no hint of the least deterioration in the quality of the water. The alkalinity, hardness, iron and manganese although determined regularly showed no radical change. No color nor turbidity was present at any time and the black marking lines on the white tile bottom could be clearly seen throughout the period of the test. There was a slight chlorine-like odor discernible in the bottles of water, when they were opened for analysis, but this odor was not noticeable in the pool room. Chlorides were determined regularly, but aside from an increase from 3.0 p.p.m. in the unchlorinated water to 18 p.p.m. in the chlorinated lake water during the first week, no further change was noticed. We have no explanation to offer for this unexpected result, unless it is that the chlorine unites with proteins to form compounds allied to the chloramines, thus removing it from action with silver nitrate in test titration.

Free chlorine in the pool water remained quite constantly near the 0.2 p.p.m. mark, except on April 17, when the bathing load was very low, and once in the shallow end, when the centrifugal pump stopped working. On these dates the chlorine content increased; in the former instance to 0.4 p.p.m. and in the latter to 0.5 p.p.m. in the shallow end of the pool.

DISTRIBUTION OF CHLORINE

It is regrettable that the distribution of free chlorine in a still body of water has not been studied more closely. From the results here recorded, it appears that with the entry of heavily chlorinated water in one part of the pool only, the distribution is not always uniform. We attempted to obtain this distribution but realized that only an approximation was obtained. In one test we sampled 69 points and in another 199 points, taking our samples just beneath the surface for the surface samples and within one foot of the bottom for the bottom samples. According to the charts these tests show a considerable variation in the concentration.

Chart I represents the distribution of free chlorine in the pool when it had not been in use for 24 hours. The chlorination and refiltration apparatus was run from 8 A.M. to 5 P.M. the day the tests were made, and the sampling and testing were done between 3 P.M. and 5 P.M. The chlorine varied between 0.04 p.p.m. for the low concentration to 0.28 p.p.m. for the high.

Charts II and III show the distribution after the pool had been standing quiescent for 44 hours without the introduction of chlorine, except that chlorination and re-

CHART I

Shallow End of Pool

	0.22	0.24	0.28	0.22	0.18	Chlorinated Water Enters Here
	0.12	0.20	0.18	0.18	0.05	
	0.18	0.14	0.18	0.10	0.10	0.18
0.20	0.10	0.10	0.05	0.10	0.10	0.22
0.20	0.12	0.12	0.08	0.08	0.09	0.24
0.22	0.12	0.12	0.08	0.05	0.06	0.26
0.22	0.12	0.12	0.12	0.09	0.06	0.24
0.18	0.12	0.07	0.07	0.09	0.05	0.20
0.07	0.05	0.10	0.10	0.11	0.09	0.12
0.09	0.10	0.09	0.10	0.06	0.08	0.06
		0.07	0.07	0.04		Outlet to Filters

Deep end of the pool.

FREE CHLORINE IN POOL AFTER 24 HOURS QUIESCENCE

Outside squares give results of free chlorine at bottom of the pool. Inside squares—surface. Pool quiescent for 24 hours previous to tests but renovation system in operation continuously for 7 hours previous to test.

CHART II

Shallow end of pool

0.13	0.21	0.13	0.13	0.13	0.13	0.06
0.15	0.16	0.16	0.14	0.16	0.14	0.12
0.21	0.14				0.14	0.15
0.15	0.14				0.14	0.13
0.15	0.15				0.14	0.13
0.16	0.15				0.14	0.13
0.13	0.20				0.14	0.11
0.14	0.19				0.12	0.10
0.14	0.13				0.13	0.11
0.14	0.14				0.13	0.10
0.12	0.16				0.13	0.10
0.12	0.18				0.13	0.11
0.12	0.18				0.14	0.12
0.13	0.17				0.14	0.11
0.13	0.15				0.13	0.10
0.14	0.15	0.13	0.12	0.12	0.14	0.11
0.15	0.13	0.13	0.12	0.13	0.13	0.10

Deep end of pool

CHLORINE IN BOTTOM SAMPLES AFTER 44 HOURS QUIESCENCE IN P.P.M.

Bottom samples in free chlorine tests. Central bottom samples not taken. No chlorine for 44 hours before samples were taken except that the renovation system was started 1 hour before sampling was begun.

CHART III

Shallow end of pool

0.20	0.19	0.13	0.13	0.16	0.15	0.10
0.22	0.20	0.14	0.14	0.17	0.16	0.15
0.21	0.19	0.13	0.14	0.14	0.14	0.14
0.21	0.19	0.14	0.14	0.14	0.20	0.15
0.21	0.18	0.14	0.14	0.13	0.20	0.18
0.15	0.16	0.13	0.14	0.12	0.18	0.12
0.15	0.16	0.14	0.14	0.12	0.12	0.11
0.17	0.16	0.13	0.14	0.13	0.11	0.10
0.15	0.16	0.15	0.14	0.12	0.10	0.11
0.15	0.15	0.15	0.14	0.12	0.11	0.09
0.15	0.16	0.14	0.14	0.13	0.12	0.10
0.16	0.17	0.14	0.14	0.14	0.14	0.11
0.18	0.17	0.14	0.14	0.14	0.14	0.11
0.18	0.18	0.13	0.14	0.14	0.15	0.11
0.17	0.17	0.15	0.14	0.15	0.15	0.13
0.18	0.16	0.15	0.14	0.14	0.14	0.15
0.17	0.16	0.14	0.13	0.15	0.15	0.14

Deep end of pool

CHLORINE IN SURFACE SAMPLES AFTER 44 HOURS QUIESCENCE IN P.P.M.

Same conditions as for chart II, showing chlorine distribution in surface water of pool.

filtration were started 1 hour before the sampling was begun. Distribution was much better in these tests than at the time the results shown in Chart I were obtained. That was to be expected because of the 44 hour period of quiescence, which allowed the effect of convection currents to be demonstrated.

CONCLUSIONS

1. From an economic standpoint, renovation by filtration, chlorination, and recirculation is a distinct advance in swimming pool operation.

2. For the pool of water in the women's gymnasium at the University of Wisconsin a residuum of from 0.15 to 0.2 p.p.m. of chlorine is sufficient to maintain a pool of water continuously which meets Treasury Department *Standards for Safe Drinking Water*.

3. While the distribution of chlorine in the pool water is not entirely uniform it is satisfactory for practical purposes.

4. There is so satisfactory a correlation between the chlorine content as determined by the ortho-tolidine test and the bacterial purity of the water that we believe that adequate sanitary control of a pool may be effected by dependence upon the ortho-tolidine test for the required residuum of chlorine. The lack of uniformity of chlorine distribution is not marked enough to interfere with the ortho-tolidine test as a control test. The test should be made daily on water samples taken from both the deep and shallow ends of the pool.

5. No outstanding chemical changes take place in the water used continuously when the renovation system of refiltration and chlorination is employed. This would seem to indicate that once the amount of chlorine necessary to secure the required residuum (.2 p.p.m.) was determined, no change thereafter would be necessary unless there was a marked change in the bathing load.

We have not extended our work to the point where we are able to say how long a pool may be used without renewing with fresh water but our results show that at the end of 4 months' time the water is as satisfactory as at the beginning of the run.

REFERENCES

1. Atkins. *Proc. Illinois Water Sup. Assn.*, 3:73. 1911.
2. Burrage. *Eng. News-Rec.*, 63:740, 1911.
3. Manheimer, W. A. *J. Infect. Dis.*, 15:159–186, 1914.
4. Manheimer, W. A. *Pub. Health Rep.*, 33, 9:267–273 (Mch. 1), 1918.
5. Perkins, R. N. *J. Am. W. W. Assn.*, 9:284–294, 1922.
6. Warren. *Pub. Health Rep.*, 34, 50:2831–2834 (Dec. 12), 1919.
7. Walker and Pryer. *A. J. P. H.*, 11, 8:703, (Aug.), 1921. Simons, *A. J. P. H.*, 12, 2:121 (Feb.), 1922.
8. Walker, W. F. *A. J. P. H.*, 12, 4:320 (Apr)., 1922.
9. Whittaker, H. A. *Jour. A. M. A.*, 70:1901–1905 (June 22), 1918.
10. Stovall, W. D., and Nichols, M. Starr. *A. J. P. H.*, 13, 6:478 (June), 1923.