Safety of Iodine as a Disinfectant in Swimming Pools

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RESEARCH was instituted at Stanford University to meet a request of the California State Department of Public Health for an evaluation of the effects of swimming in pools in which iodine is used as a disinfectant.

The study was designed to ascertain if (*a*) blood iodine changes could be expected because of the possibility of the inhalation, ingestion, or absorption of iodine; (*b*) there would be significant evidence in the urine of any inhalation, ingestion, or absorption of iodine; (*c*) eye inflammation might be expected to be associated with swimming in iodine-treated waters, and (*d*) iodine is effective as a disinfectant for swimming pools.

Three outdoor swimming pools at the men's gymnasium of Stanford University were used in this study. These pools consist of a racing pool of 135,000 gallons capacity, a class-instruction pool of 60,000 gallons capacity, and a diving pool of 190,000 gallons capacity. The pools were constructed in 1929 and have been in continuous operation since that time.

The filter system for these pools consists of two cylindrical horizontal sand filters, 14 feet long and 8 feet in diameter. The sand level is from 4 feet to 7 feet in depth, making a surface area of 73 square feet per filter. Under normal operating conditions this allows for an 8-hour turnover, with a flow rate of 800 gallons per minute, or 5.5 gallons per square foot per minute. Scum gutter water is collected and recirculated through the filter. At night the filter rate is reduced one-third of the daytime rate. The pools are normally vacuumed and backwashed once a week.

The subjects of this research were 30 young male Stanford University students who were members of the freshman and varsity swimming teams or of a swimming class. Twenty members of the swimming teams used the pools for from 1 to 3 hours per day 5 times a week; 10 swimming class members used the pool for approximately 40 minutes per day 3 times a week.

None of the subjects were on iodine medication nor had they been submitted to medical or X-ray procedures in recent years that might have involved the use of an iodine compound.

Prior to the beginning of the study the chlorine residual of the pools was lowered to zero, and after an interval of 24 hours the first treatment with potassium iodide (Hio-Dine) was begun.

This product consists of two separate dry powders known as material 1 and material 2. The first is a bacteriologically inert potassium iodide compound, and the second is an activating substance or oxidizing agent (1,3-dichloro-5, 5-dimethyl-hydantoin). These materials were added to the pools along opposite sides by manual feeding once a day. Feeding adjustments were made in order to maintain a residual of 0.4 ppm for a period of 24 hours. The pools were tested on an average of four

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times daily with the iode type 2 pool test kit and the Taylor pool test kit for I_2 and for pH determinations.

Because of storm conditions and other factors, several days were needed before residuals were properly adjusted.

Research Method

A group of 30 male college swimmers were tested for possible blood changes in protein-bound iodine (PBI) and urinary changes in total iodine after swimming exposures of 1 day, 1 week, and 1 month in swimming pools treated with iodine. The purpose of the study was to reveal any potentially harmful inhalation, ingestion, or absorption of iodine by the swimmers. Blood and urine samples were obtained from the swimmers, and standard laboratory techniques were used for PBI and urinary total iodine determinations in a medical laboratory that serves the physicians of the area.

The campus health officer obtained water samples for bacteriological determinations for a total of 75 separate tests of the three pools used in the study. Plate counts and determinations were made for each of the pools in these tests.

A questionnaire was prepared to obtain swimmers' reactions in respect to eye irritations; spontaneous remarks and observations were noted regarding eye discomfort; and three physicians inspected both eyes of each swimmer for any evidence of conjunctivitis.

Protein-Bound Iodine Determinations

Specimens of approximately 5 cc. of blood were obtained from each swimmer at pool side from the antecubital vein and drawn into a 10-ml. disposable sterile syringe with a disposable 21-gauge, 1.5-inch sterile needle. Blood samples were placed immediately in iodine-free, screw-topped collection tubes and taken to the laboratory where the protein-bound iodine determinations were made by the method of Barker and co-workers (*1*).

The normal PBI is considered to range from 4.0 to 8.0 micrograms per 100 ml. of blood serum with a mean of 5.3 micrograms, and all conclusions regarding the findings of this study are made with these standards in mind.

Table 1. Protein-bound iodine determinations [1] on 30 swimmers in pools treated with potassium iodide

Subject No.	Baseline PBI	After 1 exposure	After 1 week	After 1 month
1	4.8	3.9	4.7	4.9
2	5.1	4.1	4.9	4.3
3	4.5	4.1	4.2	3.7
4	4.4	4.1	5.3	4.8
5	4.7	4.8	5.4	5.4
6	5.0	5.0	4.6	4.4
7	4.5	3.9	----	----
8	4.8	4.4	5.7	4.9
9	6.6	5.6	6.8	6.5
10	5.5	4.3	5.2	5.5
11	4.0	----	5.3	4.8
12	4.1	3.8	4.9	4.8
13	4.0	3.8	4.9	4.2
14	4.4	3.6	4.7	3.9
15	4.3	4.6	----	4.0
16	4.4	4.7	5.1	4.6
17	4.6	3.7	4.2	4.9
18	5.9	5.5	7.2	6.3
19	4.2	3.8	4.6	4.2
20	5.0	3.7	5.6	4.5
21	3.9	3.5	4.0	----
22	3.2	3.4	3.8	4.2
23	4.5	4.5	5.0	4.9
24	4.4	4.3	4.1	5.1
25	4.2	4.3	5.5	5.1
26	6.1	6.0	----	6.7
27	3.9	4.3	5.3	5.3
28	6.7	6.3	----	6.0
29	5.5	5.1	4.7	4.9
30	4.5	4.5	4.2	5.4
Group average [2]	4.7	4.4	4.9	4.9

[1] In micrograms per 100 milliliters of blood serum. Normal range of PBI determinations is 4.0 to 8.0, with an average mean at 5.3 micrograms.
[2] Carried to 1 decimal only.

The inherent error in the technique for the determination of protein-bound iodine is usually considered as ranging from 10 to 15 percent.

Baseline PBI determinations were obtained for all 30 swimmers. After the first day of exposure to the iodine-treated pools, a second blood specimen was obtained from 29 of the swimmers. After 1 week of exposure in the treated pools, a third blood specimen was collected from 26 swimmers, and after 1 month of exposure a fourth blood sample was obtained from 28. In all, 113 blood specimens were obtained from the swimmers with only 7 omissions due to absences.

All PBI determinations for the subjects in the study are listed in table 1. The results show that there was no effect on the protein-bound iodine level of the blood caused by swimming in iodine-treated pools. The baseline group average of 4.7 and the 1-month's termination average of 4.9 are virtually identical. The intervening group averages are likewise within the normal range of 4.0 to 8.0 micrograms.

Urinary Total Iodine Determinations

Spot samples of urine for baseline determinations were obtained from the 30 subjects of this study at the gymnasium, from 29 swimmers after a first exposure to the iodine-treated pools, from 26 after 1 week of exposure, and from 28 after 1 month of exposure. It was decided to use spot samples instead of 24-hour specimens because of the expected difficulty of obtaining adequate cooperation and uncontaminated materials from the multiple living quarters of the members of the group.

The urinary total iodine determinations were done in a manner identical to that followed in the protein-bound iodine determinations except that the urine was diluted 1 to 10 and added to the final zinc hydroxide precipitate to which the usual amount of sodium carbonate was added before drying and ashing. On collection the urine samples were put into small iodine-free, plastic screw-topped bottles.

It was expected that individual urinary total iodine determinations would vary considerably because fluctuations are greater than in blood iodine determinations since total urinary iodine reflects to a greater degree the ingestion of iodine in food and drink which varies considerably from day to day. The fact that spot samples were used instead of 24-hour specimens would lead to the expectation of greater fluctuations also. All values were recorded in terms of micrograms per 100 ml. and are indicated in table 2 for each subject.

The average baseline determination was 71 micrograms for the 30 subjects. After an exposure of 1 month the average determination for the group was 74 micrograms, an inconsequential change. Intervening averages reflect, if anything, a lowering of the iodine intake, although the changes appear insignificant.

Table 2. Urinary total iodine determinations [1] on 30 swimmers in pools treated with potassium iodide

Subject No.	Baseline PBI	After 1 exposure	After 1 week	After 1 month
1	60	9	50	64
2	28	15	41	65
3	54	12	81	101
4	130	38	122	89
5	67	30	77	80
6	266	11	108	105
7	25	27	--------	--------
8	41	45	76	95
9	68	77	77	125
10	21	29	41	73
11	121	--------	43	100
12	75	41	61	94
13	73	23	18	50
14	70	6	101	62
15	74	25	--------	26
16	140	12	16	99
17	108	13	147	62
18	102	19	66	55
19	73	24	109	98
20	57	15	68	99
21	94	14	31	--------
22	56	25	40	87
23	37	9	24	83
24	46	31	56	44
25	36	8	44	71
26	2	13	--------	38
27	54	40	41	66
28	69	34	--------	48
29	45	16	10	84
30	25	15	24	19
Group average [2]	71	23	60	74

[1] In micrograms per 100 ml. Under normal conditions the urinary total iodine fluctuates considerably from day to day because of the consumption of iodine in food and drink.

[2] Carried to 1 decimal only.

Disinfection of Pools

To ascertain whether iodine was effective as a swimming pool disinfectant during the interval of the study, the campus health officer obtained water samples in sterile containers for 75 separate bacteriological tests.

The bacteriological quality of the samples was recorded in terms of total plate counts after incubation for 48 hours at 37° C. and reading with an approved counting aid. Total plate counts are recorded in table 3.

The first week of samples showed excessive counts when the chlorine had been removed from the pools and the iodine residual had not been stabilized. After stabilization of the residual even with adverse weather conditions only 1 sample showed a total plate count in excess of the 200 maximum allowed by the California State Department of Health.

Tests were also made for the presence of bacteria of the coliform group. Presumptive tests were conducted by dividing the samples into five 10-ml. lactose broth fermentation tubes and incubating at 37° C. for 24 hours. None of the samples contained gas so it was not necessary to complete confirming tests and the results were recorded as negative for coliform organisms.

There was no evidence of any growth of algae during the 1 month of the research despite the fact that no algicide was in use during this period of time.

Eye Irritation

The possible effect of swimming in iodine-treated pools was investigated in several ways. Notes were made on any voluntary, unsolicited, spontaneous comments comparing the pools with those treated with iodine or chlorine. All 20 members of the freshman and varsity swimming teams were asked to submit their preference in respect to swimming in a pool treated with iodine or chlorine. All members of the swimming teams of five universities who participated in AAWU swimming championships that were held in the Stanford pools were asked to express their opinions of iodine-treated water as compared with chlorine-treated water. Finally, medical observations were made on the subjects who participated in the Stanford study for evidence of conjunctivitis.

Table 3. Plate counts of bacteriological samples taken from swimming pools during testing with potassium iodide, Feb. 13–Mar. 7, 1962

Date of samples	Varsity pool	Diving pool	Class pool	Conditions
Feb. 13	7,000	1,400	1,200	Raining. Few leaves on bottom.
Feb. 14	900	2,000	1,000	Raining.
Feb. 19	950	800	1,000	Sunny.
Feb. 21	8	2	30	Cloudy.
Feb. 26	16	7	5	Windy. Some dust in pool.
	18	20	8	
	10	60	80	
Feb. 27	11	10	45	Sunny.
	25	5	5	
	25	15	8	
Feb. 28	25	600	10	Raining.
	35	30	30	
	80	80	40	
Mar. 1	9	25	30	Do.
	60	30	40	
	200	40	30	
Mar. 5	150	30	45	Windy. Mate-terial from pine trees in pools.
	35	10	200	
	80	50	15	
Mar. 6	15	8	15	Raining.
	10	8	15	
	10	12	10	
Mar. 7	40	15	70	Clear.
	29	25	75	
	5	25	60	

NOTE: The pH level was 7.9 in all pools until Mar. 5, when it changed to 8.0 and remained constant in all pools for the remainder of the study period.

Twenty-eight of the subjects who had been exposed to the iodine-treated water for 1 month were examined by the three physicians of the research staff, each of whom made his observations independently of the others. Twenty-seven of the swimmers examined received a completely negative rating for eye irritation. In only one student was a mild conjunctivitis found on medical examination. This student wears contact lenses and stated that his eye irritation had improved in a miraculous way since the pool had been treated with iodine.

Seventeen of the twenty freshmen and varsity swimming team members expressed a preference for the iodine-treated pool in respect to eye irritation. The other three had no preference, but none preferred the chlorine treatment.

Of the championship swimming contestants 48 preferred the iodine-treated pool, 5 had no preference, but none preferred the chlorine-treated pool.

Unsolicited expressions included such comments as: "I had extreme eye irritation every day from the chlorine. With the new system there is none. It's great!" Three members of the swimming teams who formerly wore protective goggles during most of each daily training period in order to prevent eye irritation discontinued use of the goggles during the time of iodine treatment. One student commented that after his daily workouts in the chlorine-treated pool he had so much eye irritation that he could not study properly in the evenings, but he no longer had this handicap during the month of the study.

On the basis of the foregoing evidence the investigating team concluded that iodine is superior to chlorine in the treatment of swimming pools so far as eye irritation is concerned.

This conclusion is in agreement with the findings of others such as Campbell and co-workers (*2*) that eye irritation is greatly reduced in iodine-treated swimming pools. Black and coworkers (*3*) also observed in their study of eight pools in Florida that no irritation of the eyes was produced by iodine treatment of these pools.

Summary

After an iodine compound was used as a disinfecting agent in three outdoor swimming pools at Stanford University there was no evidence of inhalation, ingestion, or absorption of iodine by 30 male students who swam in the pools for 1 month.

Baseline protein-bound iodine and urinary total iodine determinations were made for all swimmers. Determinations were repeated after one exposure, after 1 week, and after 1 month. The PBI average for the group before exposure was 4.7; after 1 month it was 4.9. The urinary total iodine determinations for the group averaged 71 before exposure and 74 after 1 month.

During 11 days of sampling, only one sample showed a total plate count in excess of the California State standards for swimming pools. All presumptive tests for the presence of bacteria of the coliform group were negative.

Medical examinations of both eyes of 28 swimmers exposed to the pools for 1 month revealed no evidence of conjunctivitis in 27, and only minor eye irritation in 1.

Of 20 Stanford swimmers, 17 preferred iodine to chlorine as a pool disinfectant, as did 48 of 53 swimmers at an intercollegiate meet. The remainders of both groups had no preference.

The authors concluded that iodine as a swimming pool disinfectant is safe, effective, and superior to chlorine in regard to eye discomfort and irritation.

REFERENCES

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Speech Defects From Cleft Palate

Research on surgical techniques to correct nasal speech in persons with cleft palate will be conducted at the Eastman Dental Dispensary, Rochester, N.Y., under a grant from the National Institute of Dental Research, Public Health Service. Dr. J. Daniel Subtelny, head of the department of orthodontia at the dispensary and two University of Rochester faculty members, Dr. Robert M. McCormack, professor of plastic surgery, and Dr. Daniel W. Healy, professor of electrical engineering, will collaborate on the 3-year study.

The investigators plan intensive clinical studies of children with cleft palate, including X-ray motion pictures of various parts of the mouth and throat during speech and measurements of air flow.

Many of the 8,000 babies born each year with cleft palate eventually suffer severe speech defects. The cleft causes the air which normally passes through the mouth to pass instead through the nasal cavity. As a result, speech becomes nasal and sounds which require pressure in the mouth become weak and distorted.

"Modern surgery is usually effective in closing the cleft during early childhood," Dr. Subtelny said, "but as the child grows older, the speech often becomes more nasal because of changes in the size and position of the palate and its changing relationship to surrounding structures important to speech production. Since further surgery is not always possible, an artificial dental appliance may be needed to improve speech. The primary purpose of the new research project is to study various surgical methods to eliminate this problem."

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