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The effect of saline on the eye irritation caused by swimming-pool water

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SUMMARY

In laboratory experiments the acute eye irritation produced by exposure to tap water was not significantly increased when chlorine compounds were added to the water at concentrations of 1 mg./l. The greatest irritation was produced by 2 mg. Cl_2/l. as NH_2Cl. The addition of NaCl at concentrations above about 0·5% abolished the irritant effect of tap water, and prevented irritation even when 1 mg. Cl_2/l. was present.

In a field experiment involving two swimming baths, one with fresh and the other with saline water (0·5% NaCl), eye irritation in the saline bath was significantly lower than in the freshwater bath only when the swimming time did not exceed 30 min.

INTRODUCTION

Eye irritation after swimming in chlorinated swimming-pool water is a well-known phenomenon. Extensive discomfort may occur especially among swimmers who train for several hours daily. Theoretically, the agents responsible for the eye irritation are the water temperature, pH, the chlorine concentration, the concentration of organic matter especially nitrogen compounds and the total and even the relative concentrations of various inorganic salts, including residues of the aluminium salts used in chemical purification. In addition, swimmers may have an individual sensitivity to any factor.

Despite the importance of the problem only a few papers have been published on the significance of the various agents mentioned above. Mood, Clarke & Gelperin (1951) reviewed earlier investigations and reported their own results. In the first of these, available chlorine over 0·7 mg Cl_2/l. was found to result in eye irritation for swimmers; in the second report no eye irritation attributable to chlorine was noted at concentrations up to and including 1 mg. Cl_2/l.; and in the third report free available chlorine of 2·0 mg Cl_2/l. was stated not to cause skin or eye irritation.

In Mood's own investigation subjects were asked to swim free-style for approximately 11 min. in a swimming-pool where the water was treated by means of aluminium sulphate coagulation and pressure filtration through sand, a soda ash additive and sterilization with chlorine gas. Before and after the swim the eye irritation was measured both objectively and subjectively. By increasing the total

available chlorine from 0·05 to 0·5 mg. Cl_2/l. (of which 0·4 was free available chlorine) an increased frequency of complaints from subjects on eye irritation was obtained. When the pH was lowered from 8·0 to 7·0, an even higher frequency of eye irritation was found. The objective eye examinations showed no correlation with chlorine concentration or pH.

Schein, Tammelin & Zetterström (1951) compared three pools with different water-treatment processes. In one the water was treated by means of $AlSO_4$ coagulation, rapid filtration through sand, alkalization to pH 7·0 and chlorination to 0·25 mg. Cl_2/l. combined available chlorine. In the second the treatment was by filtration through alkaline $MgCO_3.CaCO_3$ to pH 9·7 and break-point chlorination up to 2·3 mg. Cl_2/l. free available chlorine. The third process involved filtration through sand, soda ash additive to pH 8·8 and break-point chlorination to 2·3 parts per million (p.p.m.) free available chlorine. School-children were used as subjects and asked to swim for 10 min., after which their eyes were examined. Subjective reactions were not recorded. The frequency of reddening of the conjunctiva was found to be about equal among the swimmers in the three different pools while the frequency of mild swelling and slight bleeding of the conjunctiva was significantly lower in the pool where the water was treated by the second process described above.

The purpose of the present investigations was to study the acute effects of pH, chlorine concentration, various chlorine compounds, and the salt concentration for the eye irritating properties of water under standardized laboratory conditions. In addition, a limited field study was performed to test the hypothesis derived from the laboratory experiments.

LABORATORY STUDY

Materials and methods

In the experiments two different water solutions were held against either eye for 1·5 min. in eyewash cups. The subjective feeling of irritation was determined and the difference between the two eyes was recorded. Various solutions were applied at random to the right and left eyes to avoid any systematic error based on a difference in sensitivity between the eyes. The studies were made on 7–10 subjects for each type of water tested. Hypochlorite, monochloramine and chloramine B (sodium benzenesulphochloramide) were studied in different concentrations with varying concentrations of NaCl added. In all experiments the pH was kept at 8·3, except in one experiment when it was 7 and 9 in the two solutions to be compared.

Chlorine demand-free water was produced by adding sodium hypochlorite to tap water to 4 mg. Cl_2/l., and leaving it for 3 days to oxidize all chlorine-binding substances. The main part of the active chlorine was then removed with a saturated sodium sulphite solution and the last traces by boiling the water for approximately 20 min. De-chlorinated and chlorine demand-free tap-water of this kind was used in all the experiments. The pH was regulated with NaOH or HCl. The temperature of the water was about 22° C. in all experiments. The saline content was regulated using sodium chloride (P.A. quality). The chloride ion concentration in the tap-

Table 1. *Experimental design for testing of water with different composition*

Basic test solution	Variables		
Water	pH	Chlorine concentration	Chlorine compounds
Water + 0·7 % NaCl	pH	Chlorine concentration	Chlorine compounds
Water	NaCl concentration	NaCl concentration in 2 mg. Cl_2/l. HOCl	NaCl concentration chlorine concentration

Table 2. *Reaction to various types of water*

Variable	Reaction
NaCl concentration	No irritation at ⩾ 0·5 %
NaCl concentration in 2 mg. Cl_2/l. HOCl	No irritation at ⩾ 0·7 %
pH variation with or without chlorine	Irritation not related to pH except perhaps with 0·7 mg. HOCl
Chlorine concentration in	
(*a*) Water	Slight additional irritation in certain subjects at 1·0 mg Cl_2/l. Strong additional irritation at 2·0 mg. Cl_2/l. as NH_2Cl
(*b*) Water + 0·7 % NaCl	Almost no irritation at 1·0 mg Cl_2/l. Irritation at 2·0 mg Cl_2/l. as NH_2Cl
Chlorine compounds	NH_2Cl more irritating than HOCl and Chloramine B

water was 10 mg./l., which equals about 0·0014 % NaCl. Free available chlorine was obtained by adding commercial sodium hypochlorite solution. The inorganic chloramine solutions were produced by mixing 1 mg. NH_4^+/l. as NH_4Cl. with the corresponding prediluted hypochlorite concentrations. The organic chloramine (chloramine B) was obtained from a solution of a commercial product. The concentrations of chlorine compounds were expressed as measured available residual chlorine in mg. Cl_2/l.

The test solutions for the eyes were varied according to the experimental design model shown in Table 1.

Results

Tap-water by itself was found to be unpleasant and irritating when tested experimentally. The results of testing various types of water according to Table 1 are summarized in Table 2. The results show that the acute eye irritation produced by tap-water was not significantly increased when hypochlorite monochloramine, or chloramine B was added at 1 mg. Cl_2/l.: 2 mg. Cl_2/l as NH_2Cl caused very strong irritation, but 2 mg. Cl_2/l. as HOCl did not significantly increase the irritation produced by water.

When NaCl was added at concentrations above about 0·5 % the irritating proper-

Table 3. *Chemical characteristics of the water at the two baths*

	Bath 1 (tap-water)	Bath 2 (saline water)
Permanganate no. ($KMnO_4$ mg./l.)	10	13
NH_4 (mg./l.)	0·6	0·4
NO_3-N (mg./l.)	1·2	0·6
Total N (mg./l.)	1·2	0·6
NaCl (%)	0·01	0·49
pH	7·9	7·8
Free Cl_2 (mg./l.)	0·05	0·3
Combined Cl_2 mg./l.	0·2	0·5

ties of the water disappeared almost completely even with 1 mg. Cl_2/l. added; 2 mg. Cl_2/l. as NH_2Cl produced irritation, whereas 2 mg. Cl_2/l. as HOCl had no significant irritant effect.

Variation of pH between 7 and 9 showed no significant influence.

Different individuals showed, however, different sensitivities to irritation of the eye. One person, for example, had to be excluded from the experiments because of extreme sensitivity.

QUESTIONNAIRE STUDY

Material and methods

In order to test the hypothesis developed in the laboratory experiments that the saline concentration of swimming-pool water was of importance in the prevention of eye irritation, a limited questionnaire survey was performed in two indoor public baths, one with and the other without saline in the water. The chemical characteristics of the water at the two baths is given in Table 3. The pools are both 25 × 14 m. and have about 400–500 visitors every day. The water treatment process is $AlSO_4$-coagulation 2–3 times a week and filtration through sand. The saline water comes directly from the Baltic.

During one afternoon all persons above the age of 12 who used the pool were asked to complete a questionnaire concerning eye irritation, swimming habits and duration of swim. A total of 207 interviews were performed in the bath with tap-water and 161 in the bath with saline water. Very few respondents refused to take part in the investigation.

Results

The swimming habits for different age groups in the two baths are given in Table 4. It is seen that the proportion of younger swimmers was larger at the saline bath. In both baths the younger age groups were found to swim more frequently under water, dive, have the eyes open under water and swim for longer periods. In the saline bath more than 30 min. was spent in the pool by a higher proportion of both age groups than in the bath without saline. These results show that age and length of time in pool are two main determinants for the exposure of the eye to water.

The proportion of respondents in various age groups reporting eye irritation for

Table 4. *Swimming habits of two age groups at pools with and without saline*

	Tap-water		Saline water	
	Age 12–15	Age 16–72	Age 12–15	Age 16–72
Number of respondents ...	54	153	70	91
Percentage who:				
Swim under water	87	41	90	36
Dive	85	43	87	31
Open eyes under water	72	41	89	45
Stay in pool for				
Less than 30 min.	15	72	4	58
More than 30 min.	85	28	96	42

Table 5. *Number of respondents in different age groups, and the proportion reporting eye irritation in baths with and without saline*

	Tap water		Saline water	
Age	Number	Irritation (%)	Number	Irritation (%)
12–15	54	63	70	76
16–72	152	64	88	29

Table 6. *Relation between proportion of swimmers reporting eye irritation and time spent in pool*

	Tap water		Saline water	
Time in pool	Number	Irritation (%)	Number	Irritation (%)
< 30 min.	119	61	55	24
> 30 min.	87	66	106	62

the two baths is shown in Table 5. It is seen in the table that a higher percentage of the respondents recorded irritation in the bath without saline, except for the youngest age group where the extent of irritation was slightly higher in the saline bath. The proportion of respondents recording irritation of long duration was 41 % for the non-saline bath as compared to 31 % for the saline bath.

Table 6 shows the relation between length of time spent in the pool and irritation. It is seen in the table that the difference in extent of irritation between the two baths was present only among respondents spending less than 30 min. in the pool. For those spending a longer time in the pool, no difference in the extent of eye irritation was shown.

DISCUSSION

The method used to evaluate eye irritation in the laboratory experiments involved a relatively short-term exposure. The irritation was evaluated by means of the subjective impression of the person tested. With the pair comparison technique, however, the probability that methodological factors have influenced the results

are diminished. The present experiments comprised relatively few persons in the test groups, but as the results are consistent certain conclusions can be drawn.

The results from the laboratory study demonstrated that the addition of 0·7% NaCl totally decreases the irritating effect of water or moderately chlorinated water on the eyes during a 1·5 min. exposure. For higher chlorine concentrations, however, a certain degree of irritation remains. The results indicate that NH_2Cl is more irritating than HOCl and Chloramine B.

The results also support the general observations by Mood *et al.* (1951) that an increase in chlorine concentration will cause an increase in irritation. The concentration at which the irritation increases was not, however, the same. The finding that pH is a determinant for eye irritation is not supported by the present results.

The questionnaire survey performed to study the extent of irritation in saline and non-saline baths should only be regarded as preliminary and must be followed by larger-scale investigations with an experimental design before any final conclusions can be drawn. Certain data from the study are, however, of interest in evaluating the importance of the saline content of swimming-pool water.

Concerning swimming habits, a clear difference was found between young and old age groups. As might be expected, younger groups spent more time in the water and kept their eyes open under water to a larger extent. The results show that the eye irritation in the older group was considerably less in the saline water.

The decrease of eye irritation due to salinity was found to be closely correlated with the time spent in the pool. When the time was less than 30 min. a difference was found between the saline water and the non-saline. When the time spent in the pool exceeded 30 min. the saline provided no protective effect. This explains why no protective effect against eye irritation was found in the young age group. The saline content was, however, only 0·5%. A higher degree of protection might be expected with 0·7–0·8% NaCl.

The results from the present laboratory and field studies indicate a possibility of reducing eye irritation due to swimming-pool water exposure. If 0·7% NaCl is added to the water and the exposure time is limited to less than 30 min. at a time, there is reason to believe that less eye irritation will occur.

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