Health Aspects of Waters at Public Health Resorts

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Abstract

Microbiological investigations were carried out at the request of the Board for Public Resorts on drinking-waters, mineral waters, rheumatic treatment bath waters and recreational hot and cold swimming-pool waters at resorts under their control. Results showed that, provided proper management and control was maintained over water treatment procedures with disinfection to a 0,4 mg/ℓ free chlorine residual, these waters did not exceed the accepted limits for the microbiological quality of swimming-pool waters and, therefore, they should not constitute a health hazard.

Introduction

There has been a steady increase in caravan-, camping- and resort-type recreation during the past decade, primarily due to the steeply rising cost of family holidays at commercially owned hotels. More recently, the petrol shortage and the resultant large increase in petrol costs has promoted the need for reasonably priced inland holiday resorts. The Board for Public Resorts has established several mineral-baths and other resorts in the Transvaal, including a new modern mineral-bath treatment complex constructed during 1977/79. The Board decided to instigate an investigation under the guidance of the Department of Health, Welfare and Pensions into the quality of the drinking-waters, mineral waters, swimming-pool waters, rheumatic treatment bath waters and treatment muds at the various resorts under their jurisdiction, to ensure that the use of these facilities should have no adverse effect on the health of the public. Of special importance was the control of effective disinfection of indoor rheumatic treatment baths and mud baths, which may present a health hazard if no, or inadequate, disinfection is practised.

In South Africa swimming-pools are disinfected almost exclusively by chlorination. When chlorine dissolves in water, hypochlorous acid and hypochlorite ions are formed, which oxidize organic and inorganic matter to form chloramine and nitrochloride compounds. Sufficient chlorine must be added to oxidize all the organic and inorganic material in the water and leave a residual of free chlorine for further disinfection. Free chlorine in the form of hypochlorous acid, which is formed at lower pH values than the hypochlorite ion, is the more effective bactericide and virucide (White, 1972). Obviously the organic and inorganic load of a swimming-pool is closely related to the number of swimmers and therefore also to the concentrations of chloramines formed. Eicheldorfer *et al.* (1976) found the high concentration of combined chlorine compounds in water to be the cause of irritation to the eyes and mucous membranes of swimmers. Volatile combined chlorine compounds are also responsible for the odour associated with disinfection in indoor swimming-pools (Wyatt and Wilson, 1979).

Bacteriological testing of swimming-pools is used primarily to evaluate the efficiency of the disinfection practised. Total plate counts (TPC) and faecal coliform counts were suggested as indicators of the safety of swimming-pool waters as early as 1924 (Committee on Bathing Places, 1924) and research over the intervening years still confirms their usefulness. According to Mood (1977) the most significant bacterial indicator of swimming-pool water is the total 35 °C agar plate count. Properly designed, constructed, and operated swimming-pools with an adequate level of residual disinfectant can be maintained with TPC's which are less than 100 colonies per mℓ. The recommended levels of free available chlorine (Victorin, 1974) should be $\geq$0,4 mg/ℓ at pH 6,5 to 7,5; $\geq$0,8 mg/ℓ at pH 7,5 to 8,5; and $\geq$1,5 mg/ℓ at pH levels above 8,5; but in practice these levels do not always ensure a total plate count of less than 100 colonies per mℓ at 35 °C.

Two epidemics of pharyngoconjunctival fever have been reported in bathers swimming in insufficiently chlorinated swimming-pools where free chlorine levels were below the above recommended levels. The outbreaks were caused by Adenovirus type 3 (Foy *et al.*, 1968) and Adenovirus type 4 (D'Angelo *et al.*, 1979).

Other bacterial test organisms have been included in this study as research indicates that there may be an increase in disease incidence in swimmers as compared with non-swimmers mostly related to infections of the upper respiratory tract, eyes and ears (Dutka, 1978; Hoadley and Knight, 1975). These infections can be due to *Staphylococcus aureus* (Oritz, 1977), and the use of this bacterium as an indicator of swimming-pool safety has been advocated (Robinton *et al.*, 1957; Palmquist and Jankow, 1973; Boccia and Montanaro, 1974). *Pseudomonas aeruginosa* has also been implicated in swimming-pools in relation to the spread of otitis externa infections (Seyfried and Fraser, 1978; 1980) and outbreaks of skin rash associated with whirlpool bath waters (Kush and Hoadley, 1980). In addition, because of its relatively high resistance to inactivation by chlorine, this organism is also useful for the evaluation of swimming-pool disinfection (Fitzgerald and Der Vartanian, 1969). *Candida albicans* has been included as it is the causal agent of a variety of superficial mycotic infections of the skin, mouth and vagina (Beneke and Rogers, 1970).

Systemic candida infections may involve the circulatory, respiratory, digestive and urinary systems (Gentiles and La Touche, 1969). This yeast has also been cultured from swimming-pool waters which had a free chlorine content of 0,35 mg/ℓ (Krans and Tiefenbrunner, 1975).

Resorts Investigated

Two separate investigations were carried out at different times of the year on the mineral water, drinking-water, rheumatic treatment pool waters and swimming-pool waters at Resorts A, C, D and F; three investigations were carried out at Resorts B and E and only one at Resort G.

Resort A

Raw drinking-water is supplied from a canal coming from a dam, 32 km away, and also from a well on site. The raw water is conventionally treated and chlorinated. Water from a hot mineral water spring (54 °C) pumping at 40 m^3/h, is pumped directly into two enclosed treatment baths, one for men and one for women. No official facilities are provided for drinking this water. There is a large outdoor swimming-pool, a children's pool and a high-diving pool supplied with mineral water. The waters of all three pools are sand filtered and chlorinated. Water from the large hot pool is the supply source of another large cold swimming-pool, the water of which is also sand filtered and chlorinated.

Resort B

Raw water from a nearby river, which runs through a game park, is treated by an outside authority and supplied to the Board for drinking and domestic use.

Hot mineral water (40 °C) is pumped from a spring situated directly under the rheumatic bath treatment centre into a drinking fountain and into the indoor treatment pool. At the time of the first and second monitoring of this water, chlorine was added on an *ad hoc* only basis. The results of the tests done led to the installation of approved chlorination facilities. Mineral water from this treatment pool is supplied to a large hot swimming-pool, which in turn supplies a large cold swimming-pool. The water of both pools is filtered and chlorinated. A children's pool is also supplied from the hot pool, but here the water is chlorinated manually each morning.

Resort C

The raw water supply comes mainly from a reservoir situated in a game park which is fed by a mountain stream. Animals drink from both the stream and the reservoir. This raw water source is augmented in winter by water from a nearby river which runs through a rural area of small farms. These waters are conventionally treated for domestic use.

Hot mineral water (50 °C) is stored in an open reservoir just prior to being fed into two (male and female) open air enclosed treatment pools. Originally the undisinfected water from these rheumatic treatment facilities flowed into a small shallow swimming-pool mostly used by children. After the first monitoring this practice was changed and the treatment baths were chlorinated and the water eventually allowed to run to waste, the water turnover being 15 times per day. The shallow swimming-pool is now filled directly from the mineral source. This mineral source is also used to fill a large hot swimming-pool which in turn supplies another cold swimming-pool. Both of these swimming-pools are treated by sand filtration and chlorination.

Resort D

Vaal River water is conventionally treated and chlorinated by a municipal authority and supplied to the resort for drinking purposes. Cold mineral water is pumped from a closded well to a storage reservoir from which it is fed to various facilities. In a series of private rheumatic treatment baths, the mineral water is heated to 60 °C and mixed with cold mineral water to suit the individual bather's requirements. This water is drunk occasionally for health reasons. Heated (37 °C), filtered, chlorinated mineral water is also supplied to two indoor swimming-pools (one for adults only). An outdoor children's shallow swimming-pool and a further adult's swimming-pool are filled with municipal water; both of these pools are treated by the same filtration-disinfection plant.

Resort E

Purified drinking water is supplied by the local Municipality. Hot mineral water is used in three outdoor public swimming-pools, one large and two small. There is also a fresh water swimming-pool with a separate diving pool. Recently built is a new Water Therapy Centre, incorporating a rheumatic pool, a large indoor massage pool which is linked to an outdoor swimming-pool and individual private treatment baths, all supplied with hot mineral water. The waters in all the above amenities are treated by sand filtration and chlorination.

Resort F and Resort G

Neither of these two resorts have mineral water resources. At Resort G, dam water is conventionally treated for domestic use. A cold water swimming-pool is filtered and chlorinated and water from this pool is piped into a children's pool which receives no further treatment.

At Resort F, river water runs through a populated rural trust area prior to its use as a raw water supply, as the water is very hard, softening precedes conventional drinking water treatment. There is a filtered chlorinated cold water swimming-pool and a children's pool which receives manual chlorination only.

Materials and Methods

Sampling Procedures for Swimming-pools

Swimming-pool water samples were taken opposite the water supply inlet, 24 cm from the side of the shallow end, at a depth of 10 cm. Temperatures were measured directly in the swimming-pool at all sampling times. Samples for on site analyses for total coliform counts, pH and chlorine were taken three times daily during Saturdays and Sundays (peak loading days). On Monday mornings, pH and chlorine analyses were done on large sample volumes prior to their transport at 10 °C to the NIWR laboratories, Pretoria, for more detailed microbiological and chemical analyses. The maximum time lapse between sampling and analyses was 6 h. Sodium thiosulphate was used to neutralize the chlorine in samples where necessary.

Bathing Load

An attempt was made to estimate the number of swimmers using the pools during the sampling periods.

Analyses

pH analyses were done on site using Merck universal strips. Free and total chlorine levels were measured colorimetrically with standard DPD tablets using a Lovibond 1000 comparator. Bacteriological analyses for total plate counts, total coliform counts, faecal coliforms, *P. aeruginosa, Clostridium perfringens, Staph. aureus, C. albicans* and viruses were carried out by the standard methods of this laboratory (Grabow *et al.*, 1980; Nupen *et al.*, 1980).

Epidemiological data

Available epidemiological data were insufficient for water quality and disease outbreaks to be correlated.

Results

The results of the average bacteriological counts of raw and treated drinking-waters at the various resorts in relation to their chlorine concentrations are recorded in Table 1. The bacteriological quality of the various mineral waters is recorded in Table 2, and the average bacteriological counts of rheumatic baths and hot and cold recreational swimming-pool waters are given in Tables 3 and 4.

No viruses were isolated from either recreational or drinking-waters. *C. albicans* was not isolated from waters tested at any of the resorts except for one isolate in the mineral water at Resort C, therefore, reports on this organism and on viruses have been omitted from the published tables. For the same reason, no figures for *C. perfringens* are recorded in Tables 3 and 4.

Discussion of Results

Drinking-Water Supplies

The bacteriological quality of the drinking water at Resorts D, E, F and G was excellent, with satisfactory chlorine residuals even when the raw water sources were heavily polluted (Resorts D, F and G).

TABLE 1
AVERAGE BACTERIOLOGICAL COUNTS OF RAW AND TREATED DRINKING WATERS AT PUBLIC RESORTS IN RELATION TO CHLORINE CONCENTRATIONS

Resort and type of water	Total Plate Count per mℓ	Total Coliforms per 100 mℓ	Faecal Coliforms per 100 mℓ	*Pseudomonas aeruginosa* per 100 mℓ	Acid-fast bacilli per 100 mℓ	*Clostridium perfringens* per 100 mℓ	*Staph. aureus* per 100 mℓ	Free Chlorine (mg/ℓ)	Total Chlorine (mg/ℓ)
Resort A									
Canal water	$92x10^2$	$13x10^2$	122	0	(a)	0	$13x10^2$		
Well water	41	0,3	0	1	1,7	0	1		
Drinking-water	$34x10^2$	421	6	25	4	0	19	0	0
Resort E									
Drinking-water	18	0	0	3	ND	0	1	0–0,1	0–0,1
Resort C									
River water	$93x10^2$	21	16	0	90	0	0		
Mountain spring	562	71	16	1	160	0	17		
Drinking-water	55	40	0,1	0	2,7	0	0	<0,1	<0,1
Resort F									
River water	$61x10^2$	$68x10^2$	$18x10^2$	0	103	12	0		
Drinking-water	139	0	0	0	1	0	0	0,1	0,1
Resort B									
River water	$21x10^2$	$17x10^2$	56	31	(a)	4	230		
Drinking-water	$12x10^2$	20	0	5	6,3	0,5	26	0	0
Resort G									
Dam water	343	443	153	0	ND	12	0		
Drinking-water	63	0	0	0	ND	0	0	0	0,2
Resort D									
River water	$30x10^3$	153	34	<10	ND	145	57		
Drinking-water	5	0	0	0	ND	0	0,15	0,1–0,4	0,3–0,5

(a) = Overgrown ND = not done

TABLE 2
AVERAGE BACTERIOLOGICAL QUALITY OF MINERAL WATER AT PUBLIC HEALTH RESORTS

Resort	TPC per mℓ	TC per 100 mℓ	FC per 100 mℓ	*Pseudomonas aeruginosa* per 100 mℓ	Acid fast bacilli per 100 mℓ	*Clostridium perfringens* per 100 mℓ	*Staph. aureus* per 100 mℓ	Temp (°C)	pH
A	70	0	0	0	0	0	2	55	7,0
E	21	0	0	0	ND	0	10	47	7,0
C	410	7	0	8	2,3	0	98	48	7,0
B	30	0	0	0	0	0	0,3	40	7,5
D									
Cold water	248	2	0,5	13	ND	2	122	15	7,0
After heating	6	0	0	0	ND	0,4	6	60	7,0

ND = Not done
TPC = total plate count at 35 °C
TC = total coliform count
FC = faecal coliform count

TABLE 3
AVERAGE BACTERIOLOGICAL COUNTS OF COLD SWIMMING POOLS IN RELATION TO CHLORINE CONCENTRATIONS, TEMPERATURE AND NUMBERS OF SWIMMERS

Resort and type of facility	TPC per mℓ	TC per 100 mℓ	FC per 100 mℓ	*Pseudomonas aeruginosa* per 100 mℓ	Acid-fast bacilli per 100 mℓ	*Staph. aureus* per 100 mℓ	Temp °C	No. (a)	No. (b)	Free Cl_2 (mg/ℓ)	Total Cl_2 (mg/ℓ)
A											
Swimming-pool	$13x10^2$	0	0	+	0	0	23	9	7	0,1–1,0	0,2–1,5
Diving pool	$20x10^2$	0	0	+	0,6	0	24	7	6	0,1–0,4	0,3–0,5
Children's pool	ND	86	0	ND	ND	ND	23	6	3	0,15	0,25
E											
Swimming-pool	10	0	0	0	ND	5	23	50	3	0,4	0,6
Diving pool	10	0	0	0	ND	63	24	2	2	0–1,5	0–1,5
C											
Swimming-pool	6	0	0	0	0	1	18	1	3	0,5	0,6
F											
Swimming-pool	18	0	0	0	1	0	15	3	3	0,5–0,7	0,5–0,8
Children's pool 1978	3	0	0	6	ND	0	15	2	1	0,4	0,4
G											
Swimming-pool	510	0	0	ND	ND	ND	20	NT	1	0	0,1
Children's pool	$25x10^3$	0,3	0	ND	ND	ND	20	NT	1	0	0,1
B											
Swimming-pool	533	0,5	0	0	0	0,25	18	100	3	0,2–2,0	1,0–3,0
D											
Swimming-pool 1978	$21x10^2$	0,3	0	+	ND	0	NT	NT	1	0,1	0,2
1979	0,6	0	0	0	ND	0	12	0	6	0,4–1,5	0,4–1,5
Children's pool	3	0	0	0	ND	0	13	0	6	0,3–2,0	0,4–2,0

ND = Not done
NT = not taken
No.(a) = average number of swimmers at any one time throughout the day
No.(b) = average number of tests done
TPC = total plate count at 35 °C
TC = total coliform count
FC = faecal coliform count
\+ = present in 100 mℓ by enrichment, no count/100 mℓ by membrane filtration

TABLE 4

AVERAGE BACTERIOLOGICAL COUNTS OF RHEUMATIC TREATMENT BATHS AND HOT SWIMMING POOLS IN RELATION TO CHLORINE CONCENTRATION, TEMPERATURE AND NUMBER OF USERS

Resort and type of facility	TPC per mℓ	TC per 100 mℓ	FC per 100 mℓ	*Pseudomonas aeruginosa* per 100 mℓ	Acid-fast bacilli per 100 mℓ	*Staph. aureus* per 100 mℓ	Temp °C	No. (a)	No. (b)	Free Cl_2 (mg/ℓ)	Total Cl_2 (mg/ℓ)
A											
Male rheumatic bath	$12x10^2$	21	5	+	0	15	42	4	6	0	0
Female rheumatic bath	702	24	6	+	0	6	43	4	6	0	0
Swimming-pool no Cl_2 1978	$12x10^5$	220	66	+	35	34	37	100	2	0	0
Swimming pool c Cl_2 1979	$21x10^3$	20	0	+	ND	ND	37	150	1	0,1	0,2
E											
Hot pool (1978)	190	0	0	+	ND	10	37	40	2	0	0
Hot pool (1979)	3	0	0	+	ND	0	38	50	1	2,0	2,2
Small pools (1978)	$18x10^3$	9	0,8	+	ND	530	41	12	2	0	0
Small pools (1979)	54	5	0,3	+	ND	2	41	10	1	0	0,1
Indoor rheumatic bath	750	1,7	1,7	+	ND	0	40	23	1	0,05	0,1
Outdoor rheumatic bath	19	0	0	0	ND	0	39	41	1	0,05	0,1
C											
Male rheumatic bath	$15x10^3$	98	49	7	0,3	68	42	5	5	0	0
Female rheumatic bath	$15x10^3$	83	61	8	3	7	42	9	5	0	0
Children's pool (1978)	$91x10^2$	6	0,7	+	ND	126	37	10	5	0	0
Children's pool (1979)	317	1,7	0,3	10	0,3	95	36	13	5	0	0
Hot pool	16	3	2	0	0	4	34	66	5	0,1	0,2
B											
Rheumatic bath (1978)	$>20x10^3$	>472	252	>600	46	$>10x10^2$	37	20	5	0	0
Rheumatic bath (1979)	$85x10^2$	0	0	0	ND	0	38	9	2	0,1	0,2
Hot pool	$16x10^3$	3,2	0,5	200	12,3	2	35	100	10	0,1	0,2
Children's pool	$>10x10^2$	0,5	0,5	1	12	35	35	10	6	<0,1	0,5
D											
Hot pool c Cl_2 1979	$26x10^2$	0,2	0	<10	ND	21	35	7	3	0	0,2
Hot pool no Cl_2 1978	$>50x10^3$	$>20x10^2$	0,6	$33x10^2$	ND	26	36	7	1	0	0
Adult pool c Cl_2 1979	114	9	0,7	<10	ND	114	30	25	3	0	0,2
Adult pool no Cl_2 1978	$>50x10^3$	35	0	$23x10^2$	ND	4	36	3	1	0	0

TPC = Total plate count at 35 °C
TC = total coliform count
FC = faecal coliform count

No.(b) = average number of tests done
No.(a) = average number of swimmers at any one time throughout the day
ND = not done
\+ = present in 100 mℓ by enrichment, no count/100 mℓ by membrane filtration

At Resort C, where a heavily polluted raw water supply is treated, the drinking water did not always have the required levels of 0,5 mg/ℓ free residual chlorine.

The drinking-water at Resort A was of an unsatisfactory quality, but the Board has recently installed new chlorinators to rectify this fault. Unfortunately the treatment of the drinking-water supply at Resort B is not under the Board's control. The raw water river supply, from which enteric viruses were isolated on one occasion, is very polluted and too often no chlorine residuals could be recorded in the final drinking-water supply (Table 1).

Mineral waters

Bacteriological counts on the mineral water from Resort D reservoir were high, with evidence of faecal pollution. Although heating of this water to 60 °C (before use in the private treatment baths) reduced most of the counts to acceptable levels, the resistant *C. perfringens* and *Staph. aureus* were still isolated (Table 2). Samples of mineral water at Resort C could only be taken from an open holding dam under overhanging trees. Dust and organic pollution from rotting leaves probably accounted for the high total plate and other counts. No faecal coliforms were isolated.

The mineral waters at Resorts A, B and E were of excellent microbiological quality (Table 2).

Cold Swimming-pools

All the swimming-pool waters tested (Table 3) fell within the pH range 6,5 to 7,5 and therefore a free chlorine residual of ≥0,4 mg/ℓ was the prerequisite for effective chlorination (Mood, 1977).

The waters from Resort E swimming- and diving pools, Resort C swimming-pool, Resort F swimming-pool and children's pool and Resort D swimming-pool (1979) and children's pool all had adequate chlorine residuals, and total plate counts were below 100 per mℓ (Table 3). At Resort A, chlorine levels were marginally below 0,4 mg/ℓ, TPC's were slightly above 100 per mℓ and *P. aeruginosa* was recovered from both the swimming- and diving pool waters, and the more chlorine resistant acid-fast bacilli were present in the diving pool water (Table 3). Although total coliforms per 100 mℓ were recovered from the children's pool, no faecal coliforms were isolated from this water or that of the other two pools.

Table 3 shows that the water in the swimming- and children's pools at Resort G, and the swimming-pools at Resorts B and D (1978), had either no chlorine residuals or chlorine residuals which were well below 0,4 mg/ℓ, resulting in raised microbiological counts. However, at no time were any of these counts alarmingly high and at no time was faecal contamination detected.

Rheumatic Treatment Baths and Hot Swimming-Pools

Rheumatic treatment bath waters tested at Resorts A and C had total plate counts of over 100 per mℓ, and total and faecal coliforms, *P. aeruginosa* and *Staph. aureus* per 100 mℓ were also present. The rheumatic bath water at Resort B in 1978 gave similar results but, after the installation of chlorination facilities in 1979, the total plate counts were considerably lower and the counts of other test organisms were reduced to zero. The waters in the rheumatic treatment baths in the new Resort E complex were generally of a good microbiological quality, the outdoor pool was excellent and the indoor pool had only slightly elevated counts. Free and total residual chlorine levels were still lower than those required to obtain consistently reliable disinfection.

The recreational hot pool waters tested during 1978 at all resorts usually had insufficient residual chlorine levels with resultant high total plate counts and the presence of coliform bacteria, faecal coliform bacteria, *P. aeruginosa* and *Staph. aureus* and acid-fast bacilli per 100 mℓ. Consequently, because of these tests, chlorination practices were upgraded, resulting in a marked improvement in the microbiological quality of these waters at Resorts A, C, D and E (Table 4), although in most cases the free chlorine levels did not reach the 0,4 mg/ℓ recommended. The high chlorine figures of 2,0 mg/ℓ free chlorine and 2,2 mg/ℓ total chlorine (Table 4) recorded in the water of the large hot pool at Resort E (1979) illustrated the excellent bacteriological quality which can be obtained with proper management, even in hot water pools with a fair bathing load (50). The effect of a high load of swimmers and high temperature is apparent at Resorts A and B, where the number of swimmers averaged over 100 for any one count throughout the day. Free and total chlorine levels of 0,1 and 0,2 mg/ℓ respectively at temperatures of 37 to 38 °C were insufficient to control bacterial contamination. These residuals were effective at Resort C when the loading was only 66 and the temperature 34 °C. At Resort D, lower temperatures (30 °C) and loadings (25) together with a zero free chlorine and 0,2 mg/ℓ total chlorine resulted in a water with a reasonable microbiological quality (Table 4).

Conclusions

1. *Candida albicans* in this study did not prove a useful organism for the monitoring of swimming-pool waters.

2. Drinking-waters at resorts need to be constantly monitored for free and total chlorine residuals as their bacteriological quality is of vital importance in safeguarding the health of the consumer.

3. Hot mineral waters were of drinking-water microbiological quality if used straight from their source. The cold mineral supply at Resort D was not fit for drinking purposes.

4. Cold recreational swimming-pools were well run and, provided that the required level of free chlorine is maintained, should not constitute a public health hazard even during peak loading periods. Children's pools, however, should be linked to a filtration-disinfection system and not be chlorinated on an *ad hoc* basis, as too often no chlorine residuals were present.

5. Bacterial pollution was evident in many rheumatic treatment baths but the installation of chlorination facilities at Resort B demonstrated that this pollution could be controlled, thus providing a safe treatment water.

6. Recreational hot pools generally had the highest load of swimmers, yet they too could be effectively disinfected at all times by efficient filtration and chlorination to a free chlorine level of 0,4 mg/ℓ.

7. The quality of recreational and drinking-waters at public health resorts can be controlled by good management of water treatment practices, so that they do not exceed the accepted limits for the microbiological quality of swimming-pool waters

and therefore they should not pose a health hazard to the community.

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