Journal of Tropical Medicine and Hygiene 1995, **98**, 126–130

Impact of chlorination of water in domestic storage tanks on childhood diarrhoea: a community trial in the rural areas of Saudi Arabia

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SUMMARY

During the period September 1991 to February 1992 standard chlorination packages of calcium hypochloride were provided for the first time to 171 families residing in the catchment area of the Sabt-Bany Bishr Primary Health Care Centre in the rural areas of the Asir region, south-western Saudi Arabia. The villagers added the packages to their home storage water tanks each time they added water from the 220 nearby wells. Analysis of the water samples taken from these wells showed that all of them were bacteriologically unfit for human use. By the end of the study period there were no bacteriologically unfit water samples taken from the tanks of the participating families. Children under 5 years of age whose families were not using chlorinated water had twice the risk of diarrhoea compared to children from the participating families (odds ratio=1.98, P=0.047). The use of chlorinated water was associated with a 48% reduction in diarrhoea. These results indicate that the chlorination of water can be successfully carried out locally in rural areas to improve the health of the population.

Keywords: water chlorination, diarrhoea, community trial, Saudi Arabia

INTRODUCTION

The Kingdom of Saudi Arabia undertook a massive programme of constructing large-scale desalination plants for municipal and industrial water supplies (MAW 1984). By the end of 1992, a total of 22 conversion plants (multistage flash system and reverse osmosis plants) along the Red Sea and the Gulf were supplying potable water (about 500×10^6 m^3 per year) to the major cities of the Kingdom (MAW 1992).

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The Asir region is located in south-western Saudi Arabia. Major cities in the region used desalinated water from the Al-Shuqaiq plant on the Red Sea. The majority of people in the rural areas used unchlorinated ground well water as the main (even the sole) source of drinking water. Improvement in water supply can substantially reduce the rate of morbidity from intestinal parasites and reduce childhood diarrhoea (Esrey *et al.* 1991). The aim of the present work was to introduce to the local inhabitants in the rural areas of the Asir region the idea of using at home a simple way to chlorinate water in their storage water tanks and to study the impact of such intervention on childhood diarrhoea.

Table 1. Socio-economic background of participating (Group I) and non-participating (Group II) families in the chlorination study

Variable	Group I (n=171)	Group II (n=154)	Significance
Crowding index (mean ± s.d.)	0.94 ± 0.48	0.88 ± 0.47	t=1.25, P=0.21
Monthly income per capita in SR (mean ± s.d.)	875.61 ± 471.9	889.31 ± 482.7	t=1.47, P=0.29
Family head occupation			
Agriculture and trade workers (no. (%))	119 (69.6)	105 (68.2)	χ^2=0.07, P=0.78
Family head education			
Illiterate (no. (%))	95 (55.6)	78 (50.6)	χ^2=0.68, P=0.41

MATERIALS AND METHODS

The Sabt-Bany Bishr Primary Health Care Centre (PHCC) in the Asir region was randomly chosen for the present study. The centre provides PHC services to 325 Saudi families including 2387 persons living in 17 villages which were far away from the desalinated water/pipeline. All villages had electricity. In the area there were 220 shallow wells used for irrigation purposes and as the main source of drinking water. Local houses were provided with adequate toilet facilities. Excreta disposal was mostly (98.8%) through septic tank and flush latrines. Each house had its own underground (or ground) and roof water storage tanks (metal drums). Tank trucks transported water from the nearby water wells to the ground water storage tanks. Electric pumps were subsequently used to pump water to the roof storage tanks when needed.

Water samples were taken from the 220 wells in the area. The samples were examined chemically and bacteriologically following the Guidelines of WHO (1984).

Nine villages were chosen randomly. All heads of families in the chosen families were contacted and all agreed to participate in the study. A non-significant difference was found between families who participated in the chlorination study (171) and those who did not (154) regarding socio-economic background (Table 1). The dimensions of the water storage tanks were measured accurately. Standard packages of 50 g calcium hypochloride 70% in labelled plastic containers were prepared. Each package was sufficient to chlorinate 10 m^3 of water. The PHCC sanitarians trained the heads of participating families regarding the proper use of these packages. During the period September 1991 to February 1992 sufficient packages were provided to the enrolled families each time they were going to add well water to their house water storage tanks. Water samples were taken from the tanks the day after chlorination to determine the residual chlorine and examine the sample bacteriologically (WHO 1984).

Children under 5 years of age were identified. Families who participated in the chlorination process had 159 children (group I) while those who did not participate had 152 children (group II). A non-significant difference was found between the groups regarding age and sex distribution (Table 2).

A diarrhoeal disease registry was established in the Asir region in 1989. Bouts of diarrhoea were defined as three or more loose stools occurring on one day with or without blood or mucus, preceded by a diarrhoea-free period of at least 3 days. Family health records and the diarrhoeal disease registry of the centre were reviewed to determine the frequency of recorded bouts of diarrhoea among both groups of children during the chlorination period (September 1991 to February 1992) and compared to those for the corresponding period in the previous year (September 1990 to February 1991).

Stool samples were taken from both groups of children (100 samples from group I, 62.9% and 97 samples from group II, 63.8%) and examined for parasites (as a possible cause of childhood diarrhoea) just before implementing the study. Stool samples were taken again after the 6 months study period from both groups of children (112 samples from group I, 70.4% and 14 samples from group II, 9.2%). Due to the low response rate of group II (due to lack of interest) their results at that stage were omitted from statistical analysis. Stool samples were processed using the qualitative

Table 2. Age and sex distribution of children below 5 years of participating (Group I) and non-participating families (Group II) in the chlorination study

	Group I				Group II			
	Males		Females		Males		Female	
Age group	No.	%	No.	%	No.	%	No.	%
<1	27	31.4	15	20.5	20	25.6	20	27.0
1–<2	20	23.3	17	23.3	18	23.1	16	21.6
2–<3	21	24.4	21	28.8	18	23.1	25	33.8
3–<5	18	20.9	20	27.4	22	28.2	13	17.6
Total	86	100.0	73	100.0	78	100.0	74	100.0

$\chi^2=6.38$, $P=0.71$.

merthiolate–iodine–formaldehyde concentration technique (WHO 1980).

Data analysis was done on a microcomputer using SPSS PC+software package (Norusis 1990). Student's *t*-test, chi-squared and *Z*-test of proportions were used as tests of significance at the 5% level of significance. The crude estimate of the odds ratio (cOR) was used to study the association between diarrhoea morbidity and use of chlorinated water (Rimm *et al.* 1980).

RESULTS

Analysis of water samples taken from the local wells showed that all were bacteriologically unfit for human use (92.3% positive for *Escherichia coli* and 100% positive for coliforms). Twenty wells (9%) were chemically unfit having high levels of sulphates and total hardness much above the WHO recommended values. Through the PHCC these 20 wells were marked and closed for drinking purposes.

During the study period, the chosen families chlorinated water in their storage tanks 576 times with an average of 3.4 ± 0.9 times. The frequency of chlorination depended on tank size and the water consumption. Analysis of water samples taken from the tanks showed that the residual chlorine ranged from 0.05 to 0.4 p.p.m. with an average of 0.13 ± 0.08 p.p.m. and median of 0.1 p.p.m. Bacteriological examination showed that only 3.3% (19) were positive for coliforms and 2.6% (15) were positive for *Escherichia coli*. A dose–response effect was found in the association between compliance and water bacteriology. The percentage of samples positive for coliforms and *Esch. coli* decreased successively from 4.1 and 3.1 among those who chlorinated their tanks for the first time to zero by the end of the study among those who chlorinated their tanks more than 3 times. On the other hand, bacteriological examination of water samples taken randomly during the study period from tanks of non-participating families showed that all were positive for coliforms and *Esch. coli*.

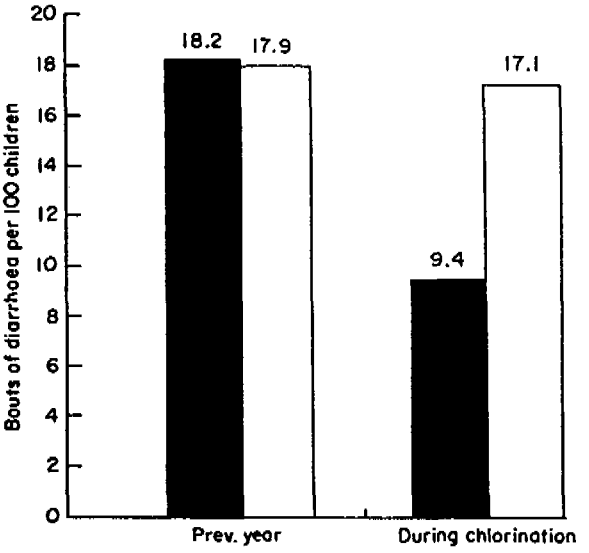

Figure 1. Reported bouts of diarrhoea (per 100 children) during the 6 months period of water chlorination (1991/1992) and during the same period in the previous year (1990/1991) among ■, users and □, non-users of chlorinated water.

Figure 1 shows that during the year prior to the study a non-significant difference ($Z=0.109$, $P=0.741$) in diarrhoea prevalence was observed between the two groups of children. On the other hand, during the 6 months chlorination period a significant ($Z=1.97$, $P=0.047$) decrease (48%) was noticed among group I

Table 3. Prevalence (%) of intestinal parasites among children below 5 years of participating (Group I) and non-participating families (Group II) in the chlorination study

Parasite	Group I	Group II	
Giardia lamblia			
Before chlorination	23.0	21.8	$Z=0.17$, $P=0.86$
After chlorination	17.1	*	
	$Z=2.09$, $P=0.035$		
Entamoeba histolytica			
Before chlorination	6.0	7.2	$Z=0.31$, $P=0.58$
After chlorination	1.3	*	
	$Z=2.01$, $P=0.042$		
Entamoeba coli			
Before chlorination	7.0	7.2	$Z=0.26$, $P=0.79$
After chlorination	1.3	*	
	$Z=1.97$, $P=0.048$		

*Low response rate, figures were omitted from statistical analysis.

children using chlorinated water compared to the other group. During the study period, group II children had significantly twice the risk of having diarrhoea compared to group I children (cOR=1.98, $P=0.047$). Table 3 shows that there was no significant difference between the groups before the start of the programme regarding the prevalence of *Entamoeba coli*, *E. histolytica* and *Giardia lamblia*. Stool samples taken at the end of the study period from Group I children showed a significant decrease in the prevalence of intestinal parasites.

DISCUSSION

It has been estimated that globally the percentage of the population covered by adequate water supplies amounted to 71 in urban areas and 41 in rural areas (Esrey & Habicht 1986). The present study showed that the bacteriological quality of water samples taken from all the locally used wells in the study area was unsatisfactory. The high contamination level of the water samples from wells is not surprising in view of the construction of the wells and local sanitation practices. Most of the wells were relatively shallow (<5 m deep) and either totally unprotected or poorly protected. Chlorination treatment can deal with the microbiological contamination but chemically unfit wells cannot be dealt with locally.

The study showed a massive improvement in the bacteriological quality of water after the introduction of water chlorination. Lack of experience in adjusting the chlorination doses for the first time may explain the few positive samples that appeared early in the study. The success of the new system in terms of simplicity and cost effectiveness in providing better water quality can be stressed (Moe *et al.* 1991).

The present study showed that the use of chlorinated water was associated with a reduction in the incidence of reported childhood diarrhoea. Water containing pathogenic bacteria, at levels below those necessary to infect humans, may be used for the preparation of food, at which times the bacteria may incubate and multiply in the food (Esrey & Habicht 1986). It is generally assumed that the provision of a safe water supply results in a corresponding reduction in waterborne diseases. However, in some developing countries the installation of improved water supplies in villages did not produce a consequent measurable decrease in diarrhoeal disease morbidity (Victoria *et al.* 1988). The presence of toilet facilities in a high proportion of households in the present study may play a role in augmenting the beneficial effect of introducing chlorinated water.

Similar to other reports from Saudi Arabia (Qadri & Khalil 1987; Al-Fayez & Khogeer 1989; Al-Madani *et al.* 1989; Omar *et al.* 1991), the intestinal pathogenic protozoans *Giardia lamblia* and *E. histolytica* together with the non-pathogenic commensals *E. coli* were more prevalent infections in the Asir region than infections with helminths. The present study revealed a reduction in the prevalence of these protozoal infections among children following the use of chlorinated water but the prevalence of these infections is still very

high. Factors other than water and sanitation may contribute to the pathogenesis of intestinal parasitic infections. Water and sanitation programmes should complement those in other sectors to reduce disease rates.

Primary health care authorities in the Asir region can adopt this intervention to improve the health of the population. Long-term plans in the form of a system of piped desalinated water supply combined with better sanitation and health education programmes are likely to reduce significantly the problem of water-borne diseases in the Asir region.

ACKNOWLEDGEMENTS

We are greatly indebted to the director of PHC in Sarat Ebeyda health sector for his assistance. Special thanks are due to Professor M.S. Omar, Clinical Microbiology and Parasitology Department, for his valuable comments and suggestions.

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