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Feasibility and efficacy of in-home water chlorination in rural North-eastern Brazil

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SUMMARY

The purpose of this study was to assess the feasibility, acceptability and effect of an in-home water chlorination programme in a rural village. Previous studies at this site showed high levels of faecal coliforms in household water, high diarrhoea rates in children, and enterotoxigenic *Escherichia coli* and rotaviruses were the most common pathogens isolated from patients. Household water came from a pond and was stored in clay pots. No homes had sanitary facilities. A blind, cross-over trial of treatment of household water with inexpensive hypochlorite by a community health worker was carried out over 18 weeks among 20 families. Water in the clay pots was sampled serially, and symptom surveillance was done by medical students. The programme was generally acceptable to the villagers and no change in water use patterns were apparent. The mean faecal coliform level in the chlorinated water was significantly less than in the placebo treated samples (70 *vs* 16000 organisms/dl, $P < 0{\cdot}001$). People living in houses receiving placebo treatment had a mean of 11·2 days of diarrhoea per year, and the highest rate of 36·7 was among children less than 2 years old. Diarrhoea rates were not significantly different among the participants while exposed to water treated with hypochlorite. We conclude that a low-cost programme of this type, which utilizes community resources, is logistically feasible, appears to be culturally acceptable in this setting, and can result in a marked reduction in water contamination. The lack of effect on diarrhoea rates suggests that improvement in water quality may affect morbidity only when other variables relating to faecal–oral agent transmission are ameliorated at the same time.

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INTRODUCTION

Hundreds of millions of people in the less developed countries routinely drink water contaminated with a variety of disease-causing organisms, and morbidity and mortality due to infectious gastrointestinal illnesses are quite high in comparison to the industrialized nations (Mata, 1978; Rahaman *et al.* 1979; Leeuwenburg *et al.* 1978). The problem of gastrointestinal disease is especially acute among children in the developing nations, and diarrhoea and dehydration caused by water-borne agents represent the most important causes of death among children world-wide (Snyder & Merson, 1982).

The optimistic United Nations goal of providing acceptable water supplies for the world's population by 1990 is unlikely to be achieved. The estimated cost of providing community water supplies to all those in need is so large (U.S. $135 to U.S. $360 billion; Burki, Voorhoeve & Layton, 1977) that a large proportion of the world's people no doubt will continue to drink unsafe water for many years. Clearly, in this context relatively simple approaches to reducing water-related illness are needed which could be implemented without the technical expertise and capital investment which are required for centralized water systems. Although considerable research has been carried out on some of the basic questions related to low-cost water supply systems, many issues remain unresolved. Specifically, previous studies of the relationship between water supply contamination and diarrhoea have not resolved the question of whether a reduction in levels of contamination, without changing water handling practices, personal hygiene habits or sanitary facilities, affects the incidence of gastrointestinal illness (Schliessmann *et al.* 1958; Rubenstein *et al.* 1969; Feachem, Burns & Curtis, 1978). Moreover, the issue of implementability of an inexpensive water treatment programme as viewed from logistical and sociologic perspectives, has not been extensively investigated.

The present study was carried out in a rural village in North-eastern Brazil where water treatment facilities are lacking and where diarrhoea rates, especially among children, were determined to be quite high in a prospective study done in 1978–80 by our group (Guerrant *et al.* 1983; Shields *et al.* 1985). In that investigation, 12% of household water samples grew enterotoxigenic faecal coliforms. Enterotoxigenic *Escherichia coli* and rotaviruses were the pathogens most commonly detected in stool specimens from individuals with diarrhoea, and they accounted for 21 and 19% of diarrhoeal episodes, respectively. Diarrhoea rates were highest during the early months of the year when rainfall was the heaviest, and enterotoxigenic *E. coli*-related episodes of diarrhoea predominated during this time of the year.

The purposes of this investigation were to assess the feasibility and acceptability of a community-based in-home water chlorination programme, to measure the effect of the chlorination programme on the levels of faecal coliforms in the water consumed by the study subjects, and lastly to monitor the occurrence of gastrointestinal illness among the participants and quantitate the effect, if any, of the chlorination on incidence rates.

MATERIALS AND METHODS

Study area. The present study was carried out during January–June 1981 in the North-eastern Brazilian village of São João, which is a rural community of approximately 40 households. São João is situated 2 km from Pacatuba, a small town of 2300 inhabitants, and 32 km from Fortaleza, the coastal capital of the state of Ceará. Most houses in São João are constructed of adobe over wooden frames and have dirt floors. Toilet facilities are non-existent. Water for both consumption and bathing comes from a nearby several-acre pond which is impounded by an earthen dam. Animals frequently enter the pond, which is also used for bathing and clothes washing. The water is carried from the pond to homes in 18 l cans, mostly by women and children, and strained through a layer or two of cloth as it is poured into the clay pots in which it is stored. The water is allowed to settle for 24 h before use, because of a belief that water exposed to sunlight is 'hot' and will cause disease if not allowed to sit in the pots overnight and thus become 'cold'. No further filtering of the water is done, and it is not boiled. The average daily water usage was 76·9 l per household and 13·7 l per person.

Population studied. Twenty-five families in São João met the criteria of having at least two children living at home and using water from the pond exclusively. After explanation of the study, obtaining informed consent and an initial one-day trial of hypochlorite treatment of household water, 20 of these families agreed to take part in the trial. There were 112 participants. The median age was 8 years (range 0–62). Thirty-eight children were 0–4 years old and 35 were of ages 5–9. The estimated mean household income was U.S. $77 per month.

Study design. A blind, cross-over study structure was employed. The 20 households were divided geographically into two colour-coded groups of ten (Group 1 = hypochlorite→placebo; Group 2 = placebo→hypochlorite). On a daily basis newly obtained water in each household was treated with either 10% sodium hypochlorite solution (Iontec, Fortaleza, Ceará, Brazil) or distilled water sham (placebo). The community health worker who treated the water simply had to match the colour assigned to each house with the colour code on one of the two bottles of liquid she carried. She was not aware of what the two liquids were, although she was aware that they were different, and had only a general idea about the goals and design of the study. At the end of 9 weeks the hypochlorite and distilled water bottles' colour codes were switched, thus crossing over the treatment and sham houses, and the trial then continued for an additional 9 weeks. A dosage of $1\frac{1}{4}$ drops ($\cong 63\ \mu l$) of the 10% sodium hypochlorite solution for each liter of water was chosen in treatment trials of pond water samples done in the laboratory. This dose was slightly less than that required to impart a detectable smell or taste, and was between the one and two drops per liter recommended by the Center for Disease Control for treatment of clear and cloudy water, respectively (Center for Disease Control, 1980). During each home visit, the community health worker used a medicine dropper to add 1·0 ml of hypochlorite or placebo solution to the water in the clay pots for each can of pond water which the mother indicated had been added that morning. The mixture was stirred after the solution was added.

Water cultures. Approximately three water samples were collected at different times in sterile glass bottles from the clay pots in each house. At least one was collected before and after the crossover in each house. Three samples were also collected directly from the pond. Faecal coliform levels were determined using the most probable number technique (Geldreich, 1975).

Surveillance of diarrhoeal illnesses. Information on gastro-intestinal illnesses was collected by three medical students on thrice-weekly visits to each of the participating households. In almost all families the mother was the primary informant. Diarrhoea was defined as a significant change in bowel habits toward decreased consistency or increased frequency, as identified either by the individual or the primary informant. In the previous study (Guerrant *et al.* 1983) among these households, examination of stool specimens collected in cups defined by the participants as diarrhoea consistently met the criterion of grossly liquid stools that took the shape of the container.

Statistical methods. Illness surveillance data from the first 5 days of hypochlorite therapy of both groups were excluded from the analysis, as were the data collected in the first 5 days after the crossover in the households which were changed from hypochlorite treatment to placebo. The numbers of days of diarrhoea in the hypochlorite treated and placebo groups were compared using the χ^2 statistic. Faecal coliform levels from the samples of hypochlorite and placebo treated water were compared using the median test (Dixon & Massey, 1969).

RESULTS

Water culture data. A total of 61 water samples from the clay pots in the households which participated in the trial for the full 18 weeks were cultured. The mean number of faecal coliforms/dl in the samples of hypochlorite treated water was 70 *vs* 16000 (range: 2–160000 for both groups) in the samples obtained from the placebo households, a difference which is highly significant ($P < 0{\cdot}001$). The mean number of faecal coliforms/dl in the three samples taken from the pond was 9700 (range: 1600–160000), suggesting that considerable contamination of the water was taking place in the homes, an occurrence which has been described previously (Shields *et al.* 1985; Khairy *et al.* 1982).

Occurrence of diarrhoeal illnesses. There were 112 participants and 12248 person-days of surveillance during the study period. The number of days of diarrhoea and the number of days of risk during the hypochlorite treatment and placebo periods are given by age category in Table 1. An incidence rate of 12·0 days of diarrhoea per person-year was found among the participants drinking the hypochlorite treated water, and 11·2 days of diarrhoea per person-year among the individuals in the placebo group, a difference which is not significant ($P = 0{\cdot}48$). Seventy-six percent of the days of diarrhoea occurred in children less than 5 years old, and the incidence rates in days of diarrhoea per year for these children in the hypochlorite treatment and placebo groups were 26·9 and 27·7 respectively. The highest rates of 42·7 and 36·7 were observed among children less than 2 years old. Comparison of these rates, as well as those for the 10 and over age groups, also showed no significant differences. In the 5–9 age group the participants had significantly more days of diarrhoea during the hypochlorite treatment period ($P = 0{\cdot}04$), but this difference primarily was due to one 12-day episode.

Bi-weekly diarrhoea incidence rates in the two groups of participants during the

Table 1. *Days of diarrhoea and days at risk for study participants in São João, Ceará, Brazil, whose household water was treated with hypochlorite or placebo, by age group*

		Water treatment				
		Hypochlorite		Placebo		
Age group	Number of participants	Days of diarrhoea	Days at risk	Days of diarrhoea	Days at risk	*P*
< 2	19	99	843	102	1011	0·25
2–4	19	38	1010	57	1082	0·10
5–9	35	32*	1875	19	2000	0·04
10+	39	27	2228	15	2199	0·07
All ages	112	196	5956	193	6292	0·48

* One participant had a 12-day episode of diarrhoea during the period of hypochlorite water treatment.

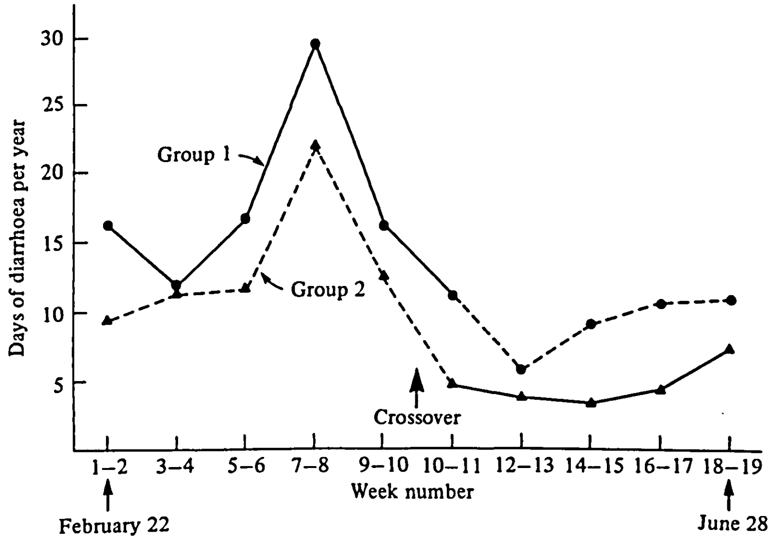

Fig. 1. Bi-weekly incidence rates of diarrhoea, expressed in days of diarrhoea per year, of two groups of individuals in the village of São João, Ceará, Brazil, whose household water was treated with either hypochlorite or placebo solutions. Water treatment in Group 1 households (●) was done with hypochlorite solution (——) during the first one-half of the study period, and was crossed over to placebo (---) for the second one-half. In Group 2 households (▲) the sequence was reversed.

18 weeks of the study are shown in Fig. 1. In both groups a seasonal pattern of decreasing overall rates of diarrhoea as the trial progressed is suggested, as was the case with the rates found in surveillance during this season in the three preceding years in the same village (Guerrant *et al.* 1983). Although incidence rates varied considerably from week to week, the trend during the study period was toward decreasing rates. More importantly, there was no overall difference in the number of days of diarrhoea between the treatment and placebo groups during the pre- and post-crossover periods.

Attrition. Twenty-five families initially consented to participate in the water treatment trial. Twenty of these agreed to enter the trial after an initial pre-test involving hypochlorite treatment of all household water on a single day. At the end of the first week of daily water treatment with hypochlorite or placebo, an additional three households dropped out of the trial. Two of these were in the hypochlorite treatment group and one was receiving placebo. A final household dropped out 11 weeks after the trial began, which was 2 weeks after being switched from placebo to hypochlorite treatment.

A variety of reasons for not wanting to continue participating in the trial were given by the primary informants. In eight of the nine households which dropped out of the study the primary reason given was that family members did not like the taste of the treated water and that one or more family members had refused to drink it. In two of the families it was reported that a family member had vomited after drinking the water. However, careful interviews of the informants, done at the end of the trial, revealed that there often were more complex reasons underlying the refusal to continue. Three of the mothers stated that they recognized the smell of the treated water as that of household bleach, which they knew could be poisonous, and therefore thought it would make them ill. Another reason given was the belief that the water was already clean and germ-free as it came from the pond and therefore did not need any further treatment. An additional explanation was based on the feeling that the treatment would somehow interfere with the 'cooling' process which takes place when the water is left to sit in the clay pots overnight.

DISCUSSION

In this pilot study, using community-based personnel and inexpensive materials, and with no capital investment, we carried out an in-home water chlorination programme among 16 poor, rural households in North-eastern Brazil for a period of 18 weeks. Thus we demonstrated the feasibility of such a low-cost program from a purely logistical point of view. However, approximately one-third of the families which were initially approached and consented to participate were not in the study when it terminated. Although not liking the taste of the hypochlorite treated water was the most frequently given reason for dropping out, a variety of other reasons, not directly related to the palatability of the treated water, were given in interviews at the end of the study. It should be pointed out that no community-wide educational programmes were carried out prior to the initiation of the trial, and we believe that had efforts to address questions and fears of the participants been made at the time the programme was being organized in the community, the attrition rate might have been much lower.

Another factor which may have affected the attrition rate was the method used for determining the hypochlorite doses. The community health worker simply asked the mothers how many 18 l cans of fresh water had been received in the household each day and determined the total hypochlorite dosage on this basis. Recall of the number of cans brought in, as well as the distribution of the water among the various pots in the house, frequently may have been only approximate. Moreover, the organic content of the water brought from the pond each day may have varied, depending on the time and site of collection, the amount of recent rainfall and other factors. Thus, the adequacy or excess of the hypochlorite dosage may have varied considerably from day to day, and some of the participants may have decided to drop out of the trial due to the taste of the water on the days when a relative excess of hypochlorite was added.

The cultures of water samples collected from the clay pots at variable times after treatment of the household water with hypochlorite or placebo showed that the hypochlorite resulted in a highly significant reduction in the levels of faecal coliforms. The question then arises as to why we did not see a concomitant reduction in the incidence of diarrhoeal illnesses among the participants whose water was being treated with hypochlorite. One possible explanation is that participants may have been drinking water from other sources outside the home, (e.g. children at school or fathers at work) which were as highly contaminated as the water from the pond, thus 'diluting out' any reduction in diarrhoea rates. Another possible reason is that the degree of reduction of levels of contamination achieved, although significant from a purely statistical perspective, may not have been sufficient to reduce disease rates. On the other hand, the lack of suppression of gastrointestinal illness rates may have been due to factors other than methodologic problems in the study. Foremost among these would be the likely possibility that, as suggested by others (Schliessmann, 1959; Feachem, 1984), multiple factors, in addition to water quality, are primary determinants of diarrhoea incidence rates, such as personal hygiene, food and utensil contamination, and cooking and food storage practices in households in the tropics with no refrigeration. Studies done to date which examined the role of water contamination alone (Schliessman *et al.* 1958; Rubenstein *et al.* 1969; Feachem, Burns & Curtis, 1978) have been difficult to interpret because of dissimilarities of the treatment and control groups. Thus the primary issue of the importance of water contamination as a single factor determining rates of gastrointestinal illness in the community remains unresolved.

In conclusion, we feel that the feasibility and acceptibility of a low-cost in-home and community-based program of chlorination, at least in this setting, have been demonstrated in this pilot study. The potential impact of an even marginally effective programme of this type on the morbidity and mortality rates due to diarrhoea in the developing world is enormous. We feel that a large scale trial of the type described here should be performed, in order to determine the effect of changing water quality alone on gastrointestinal illnesses. We suggest that such a trial be considerably larger and longer than the one reported here, that an effort be made to educate participants in such a way that attrition is minimized, and that a more refined method be devised for hypochlorite dosing to reduce the frequency with which excess chlorine can be tasted in treated waters, while maintaining adequate microbicidal levels.

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