Early reports

Solar disinfection of drinking water and diarrhoea in Maasai children: a controlled field trial

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Summary

Background Solar radiation reduces the bacterial content of water, and may therefore offer a method for disinfection of drinking water that requires few resources and no expertise.

Methods We distributed plastic water bottles to 206 Maasai children aged 5–16 years whose drinking water was contaminated with faecal coliform bacteria. Children were instructed to fill the bottle with water and leave it in full sunlight on the roof of the hut (solar group), or to keep their filled bottles indoors in the shade (control group). A Maasai-speaking fieldworker who lived in the community interviewed the mother of each child once every 2 weeks for 12 weeks. Occurrence and severity of diarrhoea was recorded at each follow-up visit.

Findings Among the 108 children in households allocated solar treatment, diarrhoea was reported in 439 of the 2-week reporting periods during the 12-week trial (average 4·1 [SD 1·2] per child). By comparison, the 98 children in the control households reported diarrhoea during 444 2-week reporting periods (average 4·5 [1·2] per child). Diarrhoea severe enough to prevent performance of duties occurred during 186 reporting periods in the solar group and during 222 periods in the control group (average 1·7 [1·2] *vs* 2·3 [1·4]). After adjustment for age, solar treatment of drinking water was associated with a reduction in all diarrhoea episodes (odds ratio 0·66 [0·50–0·87]) and in episodes of severe diarrhoea (0·65 [0·50–0·86]).

Interpretation Our findings suggest that solar disinfection of water may significantly reduce morbidity in communities with no other means of disinfection of drinking water, because of lack of resources or in the event of a disaster.

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Introduction

Sunlight has been used to purify water for centuries—in India, in about 2000 BC, water was filtered through charcoal and exposed to the sun. In 1877, Downes and Blunt[1] established that the beneficial effect of sunlight was bactericidal. Acra and colleagues' studies[2–4] of *Escherichia coli* showed that this bactericidal effect was due mainly to the long-wave ultraviolet component of sunlight. Morley[5] has recommended the use of solar irradiation in areas affected by disasters, since most disasters occur in tropical and subtropical regions.

In-vitro studies carried out at the Royal College of Surgeons in Ireland confirmed the bactericidal effect of solar radiation and showed that transparent plastic bottles allow passage of more ultraviolet light than do transparent glass bottles. Although glass transmits ultraviolet light more readily, the thinness of plastic bottles compensates for plastic's greater absorption of ultraviolet light. This finding suggested that non-returnable plastic bottles, which are widely available and even a source of pollution, may be used for the disinfection of drinking water.

We have previously reported a significant reduction in bacterial counts in turbid, contaminated water that is exposed to sunlight for several hours.[6] This reduction was due to the pasteurising effect of the heat rather than to penetration by ultraviolet light. When contaminated water was heated to temperatures similar to those of the water in plastic bottles left in full sunlight in Kenya (maximum temperature 55ºC), full disinfection occurred in 7 h. We carried out a pilot trial of solar disinfection among 200 Maasai children and found that the frequency of diarrhoea was lower in children who used solar disinfection than in those who drank normal domestic water. We, therefore, designed a controlled trial to assess the effect of solar disinfection on diarrhoeal disease in Maasai children aged 5–16 years in the Kajiado province of Kenya.

Methods

Between December, 1995, and March, 1996, all Maasai children aged 5–16 in three adjoining areas of Kajiado province, Kenya, were assigned a method of water storage—full exposure to sunlight (solar group) or no exposure (controls). The method of water storage was allocated by alternate household. This procedure ensured that the groups were directly comparable.

The children were given two 1·5 L plastic bottles for their drinking water. Children in the control group were told to keep the bottle indoors. Solar-group children were told to keep the bottle on the roof of the hut throughout the day in full sunlight—they were asked to place the bottle on the roof at dawn and wait until midday before drinking from it. All instructions and information were translated into Maasai and crosschecked by retranslation. Children were told about the trial in the presence of their mothers. All fieldwork was carried out in Maasai by a

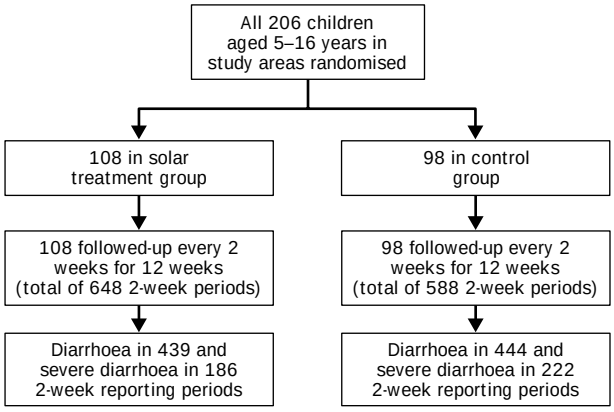

Figure 1: **Trial profile**

fieldworker (a Maasai elder) who lived in the area. The completeness and accuracy of follow-up information was verified independently by two Maasai project workers who made random checks during routine visits to the homesteads. Since the fieldworker was a Maasai elder, his instructions would be obeyed by the women and children and non-participation in the study or non-compliance with protocol would not be expected. The primary outcome measure was occurrence of diarrhoea.

Follow-up visits were done every 2 weeks for 12 weeks and mothers were asked whether any of their children had had diarrhoea since the previous follow-up visit. The Maasai word *enchelele* (repeated watery stools) was used for diarrhoea. An episode of diarrhoea was defined as occurrence of loose, watery stools "more times than the fingers on one hand". Severe diarrhoea was defined as that serious enough to prevent the child from doing his or her duties for 1 day or more at each fortnightly visit. Diarrhoea was recorded as present or absent; we did not distinguish between separate episodes of diarrhoea because such complexity would not have provided more reliable data, particularly from younger children.

Data were added to the database after each follow-up visit. Logistic regression was used to model the occurrence of diarrhoea in any 2-week reporting period. Because there were six follow-up visits for each child and water storage allocation was by household, conventional calculation of standard errors would have produced biased estimates. Thus, we used Taylor-series linearisation methods to calculate design-based variance estimates. This method ensures a robust estimation for data derived from clusters of intercorrelated observations.[7] We used the Strata procedure svylogit in the analysis.[8]

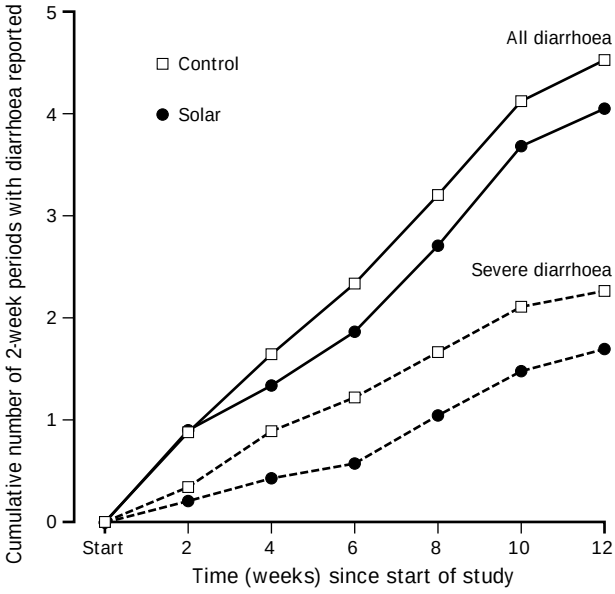

Figure 2: **Cumulative frequency of diarrhoea since start of study**

Results

206 children took part in the study: 108 lived in households assigned solar treatment and 98 in control households (figure 1). Random checks by project workers uncovered no evidence of non-compliance with the instructions given.

All the children were aged between 5 and 16 years; 120 (58%) were 8 years or younger and 175 (85%) were 12 years or younger. The 90 girls in the study were significantly younger than the 116 boys (mean 8·1 [SD 2·7] *vs* 9·0 [3·3] years, p=0·0034). The children lived in six areas of the province. There were no differences between the study groups in distributions of age, sex, or area of residence. Water was supplied from three main sources—two open water-holes and one tank fed from a piped supply. All water sources were repeatedly positive in tests for faecal coliform bacteria, with counts of more than 10^3 colony-forming units per mL.

Among the 108 children in households allocated solar treatment, diarrhoea was reported in 439 of the 2-week reporting periods during the 12-week trial (average 4·1 [SD 1·2] per child). By comparison, the 98 children in the control households reported diarrhoea during 444 2-week reporting periods (average 4·5 [1·2] per child; figure 2). Diarrhoea severe enough to prevent performance of duties occurred during 186 reporting periods in the solar group and during 222 periods in the control group (average 1·7 [1·2] *vs* 2·3 [1·4]).

The number of periods in which diarrhoea was reported was inversely related to age: the odds ratio for a 1-year decrease in age was 0·90 (95% CI 0·85–0·95) for all diarrhoea, and 0·94 (0·90–0·98) for severe diarrhoea. Sex and area of residence had no effect on the number of periods during which diarrhoea (all or severe only) was reported. After adjustment for age, solar treatment of drinking water was associated with a reduction in all diarrhoea episodes (odds ratio 0·66 [0·50–0·87]) and in episodes of severe diarrhoea (0·65 [0·50–0·86]).

Discussion

Control of bacterial contamination of water in areas such as Maasailand is difficult because most water comes from water-holes or small springs, which are not suited to chlorination or other forms of chemical treatment. Because much of the water is highly turbid, filtration is difficult and would also require material resources that the Maasai do not possess. Furthermore, fuel is scarce and the indoor air pollution that would result from boiling water inside a hut makes this method of disinfection impractical. By contrast, the use of solar disinfection requires only sunlight and plastic bottles, which are freely available. Many of the bottles we used had held commercial table water and were collected for us by Nairobi schoolchildren. These bottles would otherwise have been disposed of as domestic waste. Thus, solar disinfection may be a cheap and realistic alternative to other methods of water purification; however, further studies are needed to provide more evidence of its effectiveness.

The reduction in diarrhoea associated with solar

treatment of drinking water may have practical implications not only in terms of sanitation and hygiene for children aged 5–16 years, but, more importantly, in the prevention of diarrhoeal disease among children younger than 5 years, in whom diarrhoea is the main cause of death in many regions of the developing world.

We have begun a study of solar disinfection of drinking water among children younger than 5 years. We carried out this study among older children, because a study of those aged younger than 5 years would require a much larger study area to include a large enough sample size. Our objective was to test our methods under field conditions. Since the role of bacteria and viruses in drinking water as a cause of diarrhoeal disease is less important among older children than among those under 5 years, we were not surprised that the reduction in diarrhoeal disease in the age-group in this study was small, though statistically significant.

This was our third attempt to investigate the effect of solar disinfection on diarrhoeal disease in Maasai children. The first was a feasibility study and had an open design. The second used a similar protocol to this study, but failed because of several errors—for example, fieldworkers were given clear and opaque bottles (control) which they distributed in a highly selective way, with the result that some areas had most children in the control group and others had most children in the treatment group. In this study, we sought to avoid unequal distribution by assigning the two methods of water storage to alternate households. This approach achieved a satisfactory balance within areas of residence and was also easy to implement and check. Since all children in one household were given the same instructions there was little confusion about the method to be used.

We used Maasai fieldworkers in the three studies and their training improved with each study. The use of indigenous fieldworkers reduced the possibility of inaccurate communication with the children. In addition, refusal to participate in the study or overt non-compliance did not arise because no Maasai child would refuse a request from an elder of the community. All instructions were translated into written Maasai and crosschecked by fieldworkers—all were literate, educated Maasai who were respected members of their communities.

Our definition of diarrhoea did not include the duration of each episode of diarrhoea because the long distances travelled by the fieldworker on foot to reach the children made frequent visits impossible, and estimates of duration would have introduced a spurious precision into the data. Moreover, in regions where diarrhoeal disease is widespread, isolation of a discrete episode is generally not possible.

Public-health interventions in developing countries are only rarely subjected to a formal trial design. We hope that future studies will attempt to replicate our findings in other settings.

Our findings are important because they show that the bactericidal effect of sunlight, shown under laboratory conditions, may have a substantial beneficial effect on the health of children. A further study of diarrhoea in children aged younger than 5 years is under way to investigate whether a reduction in diarrhoeal disease can lead to a corresponding reduction in associated mortality.

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