Research

Keeping clean water clean in a Malawi refugee camp: a randomized intervention trial

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Objective This study was undertaken to assess the ability of a water container with a cover and a spout to prevent household contamination of water in a Malawian refugee camp.

Methods A randomized trial was conducted in a refugee population that had experienced repeated outbreaks of cholera and diarrhoea and where contamination of water in the home was found to be a significant cause of cholera. Four hundred Mozambican refugee households were systematically identified and followed over a 4-month period, one fourth of the households were randomly assigned to exclusively use the improved container for water collection.

Findings Water flowing from the source wells had little or no microbial contamination although the water collectors quickly contaminated their water, primarily through contact with their hands. Analysis of water samples demonstrated that there was a 69% reduction in the geometric mean of faecal coliform levels in household water and 31% less diarrhoeal disease ($P = 0.06$) in children under 5 years of age among the group using the improved bucket. Regression models examining diarrhoea among under 5-year-olds confirmed the protective effect of the bucket and found that visible faeces in the family latrine and the presence of animals were significantly associated with an increased diarrhoeal incidence in children.

Conclusion Household contamination of drinking-water significantly contributed to diarrhoea in this population. Proper chlorination is a less expensive and more effective means of water quality protection in comparison with the improved bucket, but was unpopular and rarely utilized by the camp inhabitants.

Keywords: Water pollution/analysis; Drinking water/microbiology; Water quality; Diarrhea/etiology; Households; Refugees; Randomized controlled trials; Regression analysis; Mozambique (*source MeSH*).

Mots clés: Pollution eau/analyse; Eau potable/microbiologie; Qualité de l'eau; Diarrhée/étiologie; Ménages; Réfugié; Essai clinique randomisé; Analyse régression; Mozambique (*source: INSERM*).

Palabras clave: Contaminación del agua/análisis; Agua potable/microbiología; Calidad del agua; Diarrea/etiología; Hogares; Refugiados; Ensayos controlados aleatorios; Análisis de regresión; Mozambique (*fuente: BIREME*).

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Background

Considerable efforts have been made to compare the benefits of providing increased quantities of water to impoverished populations with providing better quality water. From an engineering perspective, investments to provide more water, such as digging more wells, are often different in nature and

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expensive compared to measures such as chlorination which improve water quality.

Many studies have documented the process of contamination of drinking-water within the home (1–7), an issue which demonstrates the interwoven nature of the water quality and water quantity. Some of these studies have shown increased contamination over time of water in the home (1–3) and described factors influencing this contamination such as season (4, 5), whether water had been transferred between vessels, proximity of stored water to animals (1), type of water supply (6), and whether the container was open and/or refrigerated (7). While none of these studies documented precisely how this contamination was occurring, several stated that improved hygiene education needed to accompany water provision efforts (2–4, 7). One response to this has been to place taps on water storage vessels. These have been shown to reduce

contamination during storage (*5, 8*) and to reduce the incidence of diarrhoeal disease (*9*).

During 1993, 65 000 Mozambican refugees resided in Nyamithuthu Camp in southern Malawi. The conditions of constrained resources and crowding in the camp were typical or even better than the conditions for most of the 5.8 million refugees in Africa during that year (*10*). In 1988, a case-control study conducted during a cholera outbreak in a neighbouring camp had found that case families were less likely to possess a water container than control families (OR = 0.02) and that there was an increasing protective effect with an increased number of containers per family (*11*). During a cholera outbreak investigation in Nyamithuthu Camp in 1991, water collected at wells was shown to be safe but *Vibrio cholerae* could readily be isolated from water stored in the home (*12*). In an attempt to limit this household contamination, the United Nations High Commissioner for Refugees (UNHCR), in conjunction with Médecins Sans Frontières (MSF), France and the Centers for Disease Control and Prevention (CDC), Atlanta, conducted the following study. It was hypothesized that the provision of a water vessel with a constricted opening could reduce household contamination of water and diarrhoeal disease among those consuming that water.

Methodology

The 20-litre container evaluated in this study, referred to hereafter as an improved bucket (Fig. 1), had a constraining lid to dissuade hand entry or the scooping of water with a cup or small can but the opening was large enough to permit efficient filling with hand pumps. The improved buckets had a spout, and a handle on the bottom of the opposing side in order to facilitate pouring. Finally, a symbol of a hand with a line through it was painted on the lid to discourage hand entry.

Every fourth hut which appeared to be inhabited in the southernmost portions of Nyamithuthu Camp was marked with a red blaze of paint approximately 3 cm by 10 cm. All marked houses were visited by a Malawian field worker who requested to conduct an interview with the household's female head or whomever else may have been available. A questionnaire was then administered which contained 42 questions regarding family demographics, household conditions, and hygiene habits. Presence of a latrine was visually confirmed by the interviewers, who inspected it to determine whether or not there were visible faeces on the floor of the latrine. Interviews were conducted in the languages of Chichewa often intermixed with Sena, both of which were spoken by all interviewers. The interviewing continued until the residents of 400 households had been interviewed. If no one was home at a given hut, it was revisited the following day. If after the second visit, no one was found to interview, the hut was passed over and not revisited.

Fig. 1. **The improved bucket**
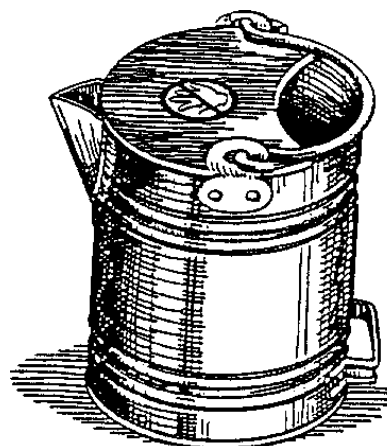
WHO 01.41

The questionnaire was re-administered and the latrine inspection redone for the included households at the end of the study period. Continuous variables (such as self-reported 24-hour water collection, frequency of hand washing and face washing by the head of household and of the children under 5 years of age, number of water containers) were entered into the database as an average value of the initial and final estimates.

Each hut in which a household member had been successfully interviewed was assigned a number, which was written across the red blaze on the house's wall and on the water collection containers of the household. A map was drawn recording the exact position of each numbered hut.

One fourth of the interviewed households were selected at random to receive the improved buckets. If the selected household chose to participate in the study, all of their water collection vessels were exchanged for improved buckets to avoid people consuming water from a traditional pot (10 to 25 litres in volume) or a 20-litre standard ration bucket. They were offered 1 improved bucket in exchange for 1 vessel, 2 for 2, and 3 improved buckets for any number of containers greater than two. Recipients were asked never to put their hands in the improved buckets and were shown how to rinse the bucket without hand entry. This educational message generally took less than one minute and was never reinforced or restated throughout the study.

Water samples

Wells in the vicinity of the numbered huts were visited beginning a week after the final distribution of the improved buckets. As numbered buckets were filled at the wells, the bucket number, the time of filling, the type of bucket, and the sex and approximate age of the water collector were recorded. A lag time was systematically assigned to each bucket after which the investigators would visit the household and sample water from that particular bucket. The assigned lag periods were as follows: 6, 4,

2, 1 hours after collection, when the bucket reached home (typically 20 minutes), and 0 hours (as soon as the bucket was filled). If no water remained from a specific collection, no sample was taken even if water was stored in the house from some other collection. If water had been transferred to a different container, this was recorded and the sample was taken. Water sampling spanned 10 weeks from late January through March 1993.

Water samples were collected in sterilized 125ml plastic nalgene bottles which were placed on ice and analysed that evening. Water from wells was pumped directly into sample bottles without flaming the outlet. Water from all types of buckets and vessels was poured directly into the sample bottles without use of a funnel or other devices.

Water samples were passed through a 0.45 micron filter and incubated on laurel sulfate media at 44 $^{\circ}$C for 18 hours. Yellow colonies greater than 1 mm were counted as individual faecal coliforms. Comparison of some of these values was made using mF-C pre-packaged ampules of media. Blanks were obtained by boiling well water, pouring it into a sample bottle in the field, and then processing this water as a typical sample. Duplicates were obtained during field sampling by pouring a second aliquot of water into a second sample bottle.

Free and combined chlorine residuals were determined using DPD1 and DPD3 and a standard swimming pool chlorine testing kit. Investigators did not have the needed reagents for neutralizing chlorine in the field. Therefore, for chlorinated samples, faecal coliforms were measured by the usual membrane filtration procedure, except that (a) the sample was filtered at the time of collection, and (b) an additional 50 ml of boiled well water was passed through the filter in an attempt to remove any chlorine that might be in it. Six non-chlorinated samples were processed by the same method to make sure that this method did not dramatically kill off the bacteria.

To assess the source of the initial bacterial contamination in buckets, the level of contamination on the interior surfaces of buckets and on the hands of women was measured. As women arrived at the wells, any remaining water in the bucket was poured out and 125 ml. of well water was poured into the bucket. The water was swirled around so that approximately 80% of the bucket's interior surface was rinsed. The rinse water was then poured back into the sample bottle.

To assess the cleanliness of water collectors' hands, as women arrived at wells their hands were rinsed in 125ml of well water. The rinse water was poured into a plastic bag in which the study participant was asked to place her hand, and the investigator gently swirled the hand in the water for 5 seconds. This water was analysed by membrane filtration as described above.

To determine if the increase in faecal coliform concentrations over time observed in the buckets was occurring from continuous contamination or the growth of bacteria, the following trial was undertaken. Five containers (3 ration buckets, 1 clay pot,

and 1 improved bucket) were filled with the rinse water discarded by women at a well which was known to be coliform free. Buckets were carefully transported to a nearby hut where they were guarded by a field worker. Samples were taken at the time of water collection, when the pails arrived at the hut, and 1, 2, 4, and 6 hours after water collection.

Diarrhoea and soap surveillance

All study households were visited twice per week and the inhabitants were asked if anyone had experienced diarrhoea, defined as three or more loose stools in a 24 hour period, and if the household possessed soap. Surveillance lasted from late January though the end of May 1993.

Data analysis

Descriptive data regarding faecal coliform counts in water samples was analysed using Dbase. Models for determining risk factors for contamination were developed by the General Estimating Equations (GEE) technique using SPIDA (Statistical Package for Interactive Data Analysis). This technique accounts for the correlation between repeated measures from individual households when measuring the influence of covariates on the outcome variable.

The association between the presence of the improved bucket and the incidence of diarrhoea was measured by a 2 x 2 analysis using a 2-tailed t-test. The association between the measured covariates and diarrheoa incidence was assessed by a Poisson regression technique using SPIDA. Both the GEE and Poisson regression models were built step-wise using the behavioural and environmental factors included in the questionnaire. All variables were then removed one at a time. Those which explained at least 5% of the variance in the data or which were significant at the $P = 0.1$ level for both steps were included in the final models.

Results

None of the marked households refused to be interviewed. Of 401 households initially interviewed, 34 (8.5%) were lost to follow-up and an additional 11 (2.7%) were known to have repatriated. Households which were lost to follow-up or which repatriated were similar to those households followed with regard to all measured attributes except intervention status. Eighty-six households were identified to receive the improved buckets. No households refused the offer to exchange buckets although one household was excluded because they were attempting to hide some of their ration buckets. Of the 85 which received an improved bucket none were lost to follow-up or repatriated compared with 45 of 315 control houses ($P < 0.001$).

Over the course of the study, approximately 700 samples were measured for faecal coliforms. These included 39 duplicates which had an average

discrepancy of 9.1% (95% CI, +/–19.6%). Only 12 blanks were included in the sampling, all of which were negative for coliforms. Twenty-nine samples were measured using both Laurel Sulfate and pre-packaged ampules of mF-C media. On average, the mF-C media grew 11% (95% CI, +/–16.9%) more colonies than did the Laurel Sulfate.

No bacterial growth was observed in the control bucket trials. It was therefore assumed that any increases in coliform levels observed in house-hold buckets were due to ongoing contamination. Source water was quite clean: 29 of 41 well samples (71%) contained 1 or fewer faecal coliforms per 100 ml. All well samples contained less than 100 coliforms per 100 ml.

Influence of improved buckets

Water contamination

On average, the mean faecal coliform values measured at the 6 times of sampling were 53.3% lower (geometric mean was 69% lower) in the improved buckets than the ration buckets. The influence of the improved bucket on faecal coliform levels is shown in Fig. 2. The greatest difference between the coliform levels in the two types of vessels was seen at the time of initial water collection.

In a Generalized Estimating Equations regression model which looked at multiple measures within each household to assess the household water contamination profile, only the variables, "hours since collection" and "improved bucket" were significantly associated with faecal coliform levels in a household's water (Table 1). No other variables were associated with coliform levels, including individual household which only explained <5% of the variation in the data. This implies that, aside from the ownership of an improved bucket, a household with clean water on a given day was no more likely to have clean water on another day.

Efficacy of chlorination

When chlorination was conducted by the investigators by adding 2.5 mg/l chlorine to the buckets, microbial contamination was virtually eliminated for the first 4 hours (99% reduction) but was consider-able after 6 hours (Fig. 3). Local health committees were observed chlorinating buckets on approximately 8 occasions over the 2 months of water sampling in Nyamithuthu South. On one occasion, the health committee member's stock solution was 27% of the appropriate concentration and on a second occasion, 8% of the proper concentration. The quantity of concentrate added to the buckets was also insufficient. Nonetheless, this inadequate chlorination (average initial free chlorine level = 0.16mg/l) produced a 40% reduction in faecal coliform levels over the initial 6 hours after water collection ($n = 22$ samples). Six samples of unchlorinated water which were processed by filtration and rinsing in the field yielded coliform levels typical of those samples

Table 1. Generalized Estimating Equations model describing faecal contamination in household buckets

Factor	Coefficient*	P-value
Constant	194.2	<0.001
Hours	18.2	<0.001
Improved bucket	−102.2	<0.001

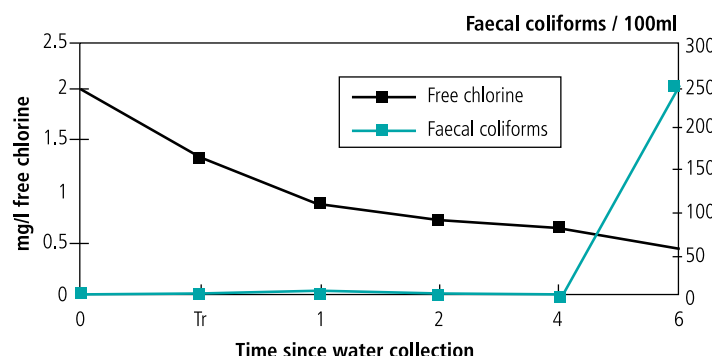* In units of faecal coliforms (per hour for hours).

Fig. 2. Faecal coliform levels 0 to 6 hours after collection. Standard versus improved bucket
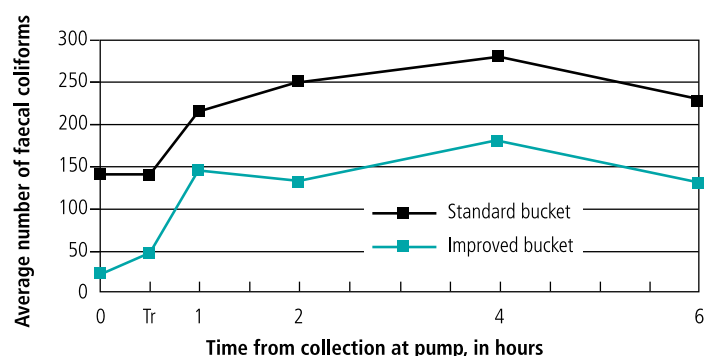
N = 604 - arithmetic means.
Tr = after transportation.

WHO 01.42

Fig. 3. Free chlorine and coliform levels from 0 to 6 hours after collection

Controlled dose n = 24.
Tr = after transportation.

WHO 01.43

processed in the laboratory. In spite of this, it needs to be noted that the chlorinated samples were processed differently from most other samples in this study, and the relative effectiveness of chlorine may be influenced by this fact.

Bucket and hand rinses

The fingers of 10 women arriving at a well were rinsed in 125ml of well water for 5 seconds. All of these women possessed open ration-type (control) buckets. The average rinse recovered more than 2000 faecal coliforms (range 950 to >2500). The buckets of these same 10 women were simultaneously rinsed with 125ml of clean well water. On average, the 10 rinsed buckets yielded over 300 coliforms (range 70 to > 400). As this trial was conducted on a breezy day, it is possible that some of the faecal

matter in the buckets was windblown. However, it is more likely that the contamination in the bucket was caused by the hands of the women who typically arrived at the well with the bucket on their heads, often with their hand inside the rim. This may explain why the greatest difference in coliform levels seen between the two bucket types occurred at the time the buckets were filled.

Diarrhoea

The 310 study participants whose homes received improved buckets experienced 60 episodes of diarrhoea between 25 January and 31 May, an attack rate of 44.5 episodes/1000/month. The 850 individuals in control households who remained throughout the study experienced 207 diarrhoeal episodes for an attack rate of 48.6 episodes/1000/week. Thus, improved bucket users experienced 8.4% fewer diarrhoeal episodes although this difference is not statistically significant ($P = 0.26$).

The 51 under-five-year-olds whose households received the improved buckets experienced 18 episodes of diarrhoea for a rate of 84.3/1000/month. The 157 children in the control households experienced 82 episodes (122.4/1000/month). This is a 31.1% reduction ($P = 0.06$) associated with use of the improved bucket.

Poisson regression models found that among all age groups families which possessed a greater number of huts, an increased number of buckets, and the presence of a latrine in a household were all associated with less diarrhoea. Only the presence of animals in the household was significantly associated with increased diarrhoeal incidence (Table 2). Among children up to 5 years of age, having an improved bucket, a latrine, a change of clothing, and more buckets were protective against diarrhoea. Among these, only the association with the improved bucket was statistically significant. Having animals in the household and visible faeces on the floor of a household's latrine were significant risk factors for diarrhoea (see Table 3).

It was observed that households which consumed more water experienced less diarrhoea ($P < 0.01$ chi-squared for trend). This finding did not appear as significant in the models, perhaps because other variables such as number of buckets in the household, or huts in the household were correlated with per capita water consumption.

Discussion

While many efforts to improve water quality have been shown to reduce the incidence of diarrhoeal disease (13, 14), the findings of our study are important in that a modest 69% reduction in the geometric mean coliform count resulted in an apparent 31% reduction in diarrhoeal episodes in children under 5 years of age. If this is indeed a cause and effect relationship, the link between water quality and diarrhoeal rates is more strongly correlated than

previously estimated (15, 16). For this link to be spurious, the bucket, or the brief educational message which accompanied it, would have had to alter participant behaviours unrelated to the processes of water contamination as measured in the buckets. For example, the educational message could have affected the contamination of water between the time it was removed from the bucket and the time it was ingested or other non-water related hygiene behaviours such as food preparation. Likewise, the presence of the bucket, with the painted line through a hand on the lid, could have induced an increased level of hygiene awareness. Reasons to suspect that the link between improved water quality and diarrhoea is real include the following: the random assignment technique reduced the chance of behavioural differences related to water handling and consumption; the previous association seen in this camp between placing hands in the household bucket and developing cholera; no behavioural differences were observed; and the sampling method employed may have underestimated the difference in faecal coliform levels between the two types of containers.

With reference to this last point, the marked decline in coliform levels between 4 and 6 hours in both control and intervention containers inspired investigators to undertake a secondary investigation. One day, 5 improved buckets and 5 control buckets were sampled after 6 hours, as usual, and then resampled after profuse agitation. After shaking, coliform levels increased by 16% in the improved buckets and by 327% in the control buckets. This implies that the decreases seen between 4 and 6 hours were due primarily to bacterial settling and that if household members stirred the contents while withdrawing water, the water they ingested may have been of worse quality than our samples indicated, particularly in the control buckets. Finally, the period within our 6-hour sampling cycle when water appeared to be primarily consumed was when it first arrived at home, a period when the improved buckets produced a 71% reduction in the geometric mean of faecal coliform levels.

Women often queue for hours in order to fill their buckets in Nyamithuthu Camp. Almost always, as a woman steps up to the pump for her turn, she will rinse her bucket with a small amount of water and rub her hand around the inside of the pail. This attempt to be hygienic is almost certainly responsible for the dramatic contamination or water in the standard "control" buckets between the time when it flowed coliform free from the pump outlet and seconds later when the Time = 0 samples were taken. Future educational messages should reinforce that generally, human hands are much more contaminated than dry surfaces. Therefore, in this type of setting, without the use of soap, it is difficult to see how rubbing a hand on a dry bucket surface could make it "cleaner" in a microbiological sense.

Vanderslice & Briscoe (17) have indicated that bacterial contamination which comes from sources distant from the home, such as in piped water

supplies, pose a particular threat to human health. Our study implies that the converse may be true: it is believed that water contamination in Nyamithuthu Camp, as indicated by faecal coliforms, is caused primarily by the hands of family members, and that this contamination causes measurable amounts of diarrhoea in young family members.

Because few families shared latrines, the findings regarding latrines also indicate that intra-household transmission of faeces is hazardous to children. Latrine ownership was generally protective, yet in those households where interviewers observed faeces on the floor of the latrine, the children of less than 5 years old were at risk of developing diarrhoea compared to those houses with a clean latrine. In fact, this effect more than negated the benefit to children of having a latrine.

The improved buckets evaluated in this trial were very popular among the refugees. At the end of the study period, the households with improved buckets were asked if they wished to trade their improved buckets for those which they had initially surrendered. Only 7 families wished to do so. This is striking because the improved buckets were not suitable for many household tasks such as washing clothes, dishes, children, or construction activities.

While the small handle near the pail's bottom to facilitate pouring, and the "no hand entry" symbol on the lid were features which were effective and appreciated within this culture, the specific characteristics of this bucket were less important than the hygiene problem which it displayed. Hand-induced contamination appeared to be the primary source of water contamination and a significant cause of diarrhoea in under-five-year-olds in Nyamithuthu Camp. In large part because of this study, UNHCR have made it their policy that when possible, narrow-necked containers should be utilized for water collection and storage. Oxfam UK, the Pan American Health Organization (PAHO), and the CDC have been publicizing the benefits of airtight water containers to be used in conjunction with home chlorination (*18–20*). Three trials involving water storage vessels with taps and household chlorination have been associated with reductions of 44%, 48%, and 82% in the incidence of diarrhoea (*21–23*). Our study is important in displaying that:

– protection of water can produce a health benefit even without chemical disinfection;
– in this population where people objected to MSF's chlorination efforts, often to the point of violence, there are acceptable alternatives for protecting water quality;
– there is one model of vessel suitable for collection with the broad stream which flows from hand

Table 2. **Environmental factors influencing diarrhoea incidence, all ages**

Factor	RR	P-value
Constant	–	0.000
Huts making up the household	0.75	0.042
Buckets in household	0.85	0-021
Latrine	0.87	0.051
Animals in household	1.11	0.003

RR = relative risk.

Table 3. **Environmental factors influencing diarrhoea incidence in children <5 years of age**

Factor	RR	P-value
Constant	–	0.334
Visible faeces on latrine floor	3.36	0.001
Animals in household	1.16	0.004
Improved bucket	0.57	0.040
Children had change of clothes	0.67	0.078
Latrine	0.86	0.188
Buckets in household	0.86	0.222

RR = relative risk.

pumps and where vessels are exposed to hours of bright sunlight each day (which UNHCR has found quickly destroys plastic containers).

Finally, refugees differ from other populations. They have crossed an international border because of fear for their well-being. They are usually surrounded by a new culture and social infrastructure. They often have few material resources. It is believed that this is the first published report of an environmental intervention that was randomly allocated on the household level to a refugee population. This study underwent ethical review by the Ministry of Health in Malawi and the CDC in Atlanta. It is believed that the vast majority of houses classified as "lost to follow-up" actually repatriated. As 0 of the 85 the intervention households were lost to follow-up or repatriated, in contrast to 45 of the 315 control households (p <0.001), the question arises of how to account for this difference. Future researchers and those implementing programmes for refugees need to ponder the unintentional behavioural or psychological effects their efforts may have. ■

Conflict of interests: none declared.

Résumé

Préserver la propreté de l'eau dans un camp de réfugiés au Malawi : essai d'intervention randomisé

Objectif La présente étude a été entreprise pour évaluer la capacité d'un récipient à eau muni d'un couvercle et d'un bec verseur à empêcher la contamination domestique de l'eau dans un camp de réfugiés au Malawi.

Méthodes Un essai randomisé a été réalisé dans une population de réfugiés qui ont connu des flambées répétées de choléra et de diarrhée et chez lesquels la contamination domestique de l'eau a été identifiée comme cause importante de choléra. Quatre cents ménages de réfugiés mozambicains ont été identifiés et suivis pendant quatre mois, et un quart d'entre eux, choisis par tirage au sort, devaient utiliser exclusivement le récipient amélioré pour y recueillir et conserver l'eau.

Résultats L'eau des puits ne présentait que peu ou pas de contamination microbienne à la source, mais les usagers la contaminaient rapidement après l'avoir prélevée, principalement par contact avec les mains.

L'analyse de prélèvements d'eau a montré une réduction de 69 % de la moyenne géométrique des coliformes fécaux dans l'eau domestique et une baisse de 31 % des maladies diarrhéiques (p = 0,06) chez les enfants de moins de 5 ans dans le groupe utilisant le seau amélioré. Des modèles de régression portant sur la diarrhée chez les moins de 5 ans ont confirmé l'effet protecteur de ce type de seau et ont révélé que la présence de selles visibles dans les latrines familiales et la présence d'animaux au foyer étaient significativement associées à une incidence accrue de la diarrhée chez les enfants.

Conclusion La contamination domestique de l'eau de boisson était un facteur significatif de survenue de la diarrhée dans cette population. La chloration est une méthode moins coûteuse et plus efficace que le seau amélioré pour préserver la qualité de l'eau, mais elle était impopulaire et rarement utilisée par les habitants du camp.

Resumen

Mantenimiento de la salubridad del agua en un campamento de refugiados de Malawi: ensayo de intervención aleatorizado

Objetivo Se emprendió este estudio con objeto de evaluar la eficacia de un recipiente de agua provisto de tapadera y caño como medio de prevención de la contaminación doméstica del agua en un campamento de refugiados de Malawi.

Métodos Se llevó a cabo un ensayo aleatorizado en una población de refugiados que habían presentado brotes repetidos de cólera y diarrea y entre los que se había observado que la contaminación del agua doméstica era una causa importante de cólera. Se identificaron sistemáticamente 400 hogares de refugiados mozambiqueños, que fueron sometidos a seguimiento durante un periodo de cuatro meses; se seleccionó aleatoriamente una cuarta parte de los hogares para que usaran exclusivamente el recipiente de agua mejorado.

Resultados El agua procedente de los pozos apenas presentaba contaminación microbiana, pero quienes la recogían la contaminaban rápidamente, sobre todo como consecuencia del contacto con las manos. El

análisis de las muestras de agua mostró una reducción del 69% de la media geométrica del nivel de coliformes fecales en el agua doméstica, y un 31% menos de casos de diarrea ($P = 0,06$) entre los menores de cinco años en el grupo que usaba el recipiente mejorado. Los modelos de regresión aplicados a los casos de diarrea registrados entre los menores de cinco años confirmaron el efecto protector del recipiente y revelaron que la existencia de heces visibles en la letrina familiar y la presencia de animales se asociaban de forma significativa a un aumento de la incidencia de diarrea entre los niños.

Conclusión La contaminación doméstica del agua de bebida contribuía de forma significativa a la diarrea en esta población. Una cloración adecuada es una opción más barata y eficaz para asegurar la calidad del agua en comparación con el recipiente mejorado, pero era impopular y los habitantes del campamento rara vez recurrían a ella.

References

1. **Khairy AEM et al.** The sanitary condition of rural drinking water in a Nile Delta village. *Journal of Hygiene*, 1982, **88**: 57–61.

2. **Han AM et al.** Contamination of drinking water during collection and storage. *Tropical and Geographic Medicine*, 1989, **41**: 138–140.

3. **Feachem R et al.** *Water, health, and development: an interdisciplinary evaluation.* London, Tri-Med Books Ltd, 1978.

4. **Lindskog RUM, Lindskog PA.** Bacterial contamination of water in rural areas: an intervention study from Malawi. *Journal of Tropical Medicine and Hygiene*, 1988, **91**: 1–7.

5. **Hammad ZK, Dirar HA.** Microbiological examination of Sebeel Water. *Applied and Environmental Microbiology*, 1982, **43**: 1238–1243.

6. **Young B, Briscoe J.** A case-control study of the effect of environmental sanitation on diarrhoea morbidity in Malawi. *Journal of Epidemiology and Community Health*, 1987, **42**: 83–88.

7. **Molbak K et al.** Bacterial contamination of stored water and stored food: a potential source of diarrhoeal disease in West Africa. *Epidemiology and Infection*, 1989, **102**: 309–316.

8. **Quick R et al.** Impact of narrow-necked water vessels and home chlorination on fecal coliform and *E. Coli* colony counts in drinking water. In: *Program abstracts of the 33rd Interscience Conference on Antimicrobial Agents and Chemotherapy, New Orleans, LA, October 17–20, 1993* (Abstract 1459).

9. **Yeager et al.** Transmission factors and socioeconomic status as determinants of diarrhoeal incidence in Lima, Peru. *Journal of Diarrheal Disease Research*, 1991, **9**: 186–193.

10. *World refugee survey — 1994*. Washington, DC, US Committee for Refugees, 1994.

11. **Hatch DL et al.** Epidemic cholera during refugee resettlement in Malawi. *International Journal of Epidemiology*, 1994, **23**: 1292–1299.

12. **Swerdlow DL et al.** Epidemic of antimicrobial resistant *Vibrio Cholerae 01* infections in a refugee camp, Malawi. In: *Program and Abstracts of the 31st Interscience Conference on Anti-microbial Agents and Chemotherapy; Chicago, IL, September 29 – October 2, 1991* (Abstract 529).

13. **Esrey SA, Habicht TP.** Epidemiologic evidence for health benefits from improved water and sanitation in developing countries. *Epidemiological Reviews*, 1986, **8**: 117–128.

14. **Esrey SA et al.** Effects of improved water and sanitation on ascariasis, diarrhoea, dracunculiasis, hookworm infection, schistosomiasis, and trachoma. *Bulletin of the World Health Organization*, 1991, **69**: 609–621.

15. **Haas CN.** Estimation of risk due to low doses or microorganisms: A comparison of alternative methodologies. *American Journal of Epidemiology*, 1983, **118**: 573–582.

16. **Briscoe J.** Intervention studies and the definition of dominant transmission routes. *American Journal of Epidemiology*, 1984, **120**: 449–455.

17. **Vanderslice J, Briscoe J.** All coliforms are not created equal: a comparison of the effects of water source and in-house water contamination on infantile diarrheal disease. *Water Resources Research*, 1993, **29**: 1983–1995.

18. **Mintz ED et al.** Safe water treatment and storage in the home. A practical new strategy to prevent waterborne disease. *Journal of the American Medical Association*, 1995, **273**: 948–953.

19. **Macy JT, Quick RE.** Evaluation of a novel drinking water treatment and storage intervention in Nicaragua. *Revista Panamericana de Salud Publica*, 1998, **3**: 135–136.

20. **Quick RE et al.** Narrow-mouthed water storage vessels and in situ chlorination in a Bolivian Community: a simple method to improve drinking water quality. *American Journal of Tropical Medicine & Hygiene,* 1996, **54**: 511–516.

21. **Quick RE et al.** Diarrhoea prevention in Bolivia through point-of-use water treatment and safe storage: a promising new strategy. *Epidemiology and Infection*, 1999, **122**: 83–90.

22. **Mahfouz AA et al.** Impact of chlorination of water in domestic storage tanks on childhood diarrhoea: a community trial in the rural areas of Saudi Arabia. *Journal of Tropical Medicine and Hygiene*, 1995, **98**: 126–130.

23. **Semenza JC et al.** Water distribution systems and diarrheal disease transmission: a case study in Uzbekistan. *American Journal of Tropical Medicine and Hygiene*, 1998, **59**: 941–946.