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Short Report: Use of Ceramic Water Filtration in the Prevention of Diarrheal Disease: A Randomized Controlled Trial in Rural South Africa and Zimbabwe

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Abstract. To determine the effectiveness of ceramic filters in reducing diarrhea, we conducted a randomized controlled trial in Zimbabwe and South Africa, in which 61 of 115 households received ceramic filters. Incidence of non-bloody and bloody diarrhea was recorded daily over 6 months using pictorial diaries for children 24–36 months of age. Poisson regression was used to compare incidence rates in intervention and control households. Adjusted for source quality, intervention household drinking water showed reduced *Escherichia coli* counts (relative risk, 0.67; 95% CI, 0.50–0.89). Zero *E. coli* were obtained for drinking water in 56.9% of intervention households. The incidence rate ratio for bloody diarrhea was 0.20 (95% CI, 0.09–0.43; $P < 0.001$) and for non-bloody diarrhea was 0.17 (95% CI, 0.08–0.38; $P < 0.001$), indicating much lower diarrhea incidence among filter users. The results suggest that ceramic filters are effective in reducing diarrheal disease incidence.

Many people living in developing countries are still reliant on water of poor quality. Figures reported in 2004 by the Joint Monitoring Program showed that, of a population of 734.6 million in sub-Saharan Africa, 56% had no access to a water supply.[1] In South Africa, 34% of households did not have access to a water supply in 2000.[2] For children younger than 5 years of age in South Africa, diarrhea is the third most important cause of death, after HIV/AIDS and low birth weight, representing 11% of all deaths in that age group.[3] Worldwide diarrheal disease is one of the leading causes of morbidity and mortality in developing countries, accounting for 21% of all deaths in children younger than 5 years old and a total of 2.5 million deaths per year.[4]

The magnitude of the task of providing people without sustainable access to improved water supply with the ultimate option, piped water, in the near future has initiated studies into alternative technologies. Point of use interventions are fast becoming the preferred method for providing improved water quality[5] and consequently reduction in diarrheal disease.[6,7] A meta-analysis[8] confirmed that point-of-use water treatment is more effective than had been previously thought. Among 37 treatment technologies reviewed for a variety of their characteristics, which included maintaining and improving microbial water quality, health impact, and costs, gravity filtration using ceramic filters was indicated as one of the five most promising technologies.[9] When used appropriately, ceramic filters provide an immediate source of drinking water with reduced turbidity and up to 99.99% removal of bacteria and protozoan parasites.

To our knowledge, there have been only four field trials published that document diarrhea reduction in households using ceramic filters.[7,10–12] A number of field trials using home-based chlorination methods,[13,14] various combinations of flocculation and chlorination,[15–17] and solar disinfection[18–20] also documented the effectiveness of these water treatment methods for reduction of diarrhea incidence. However, these trials and others did not differentiate between non-bloody and bloody diarrhea.

Bloody diarrhea is often associated with shigellosis. Infections associated with *Shigella* spp. comprise a considerable portion of the diarrheal burden of disease. The most recent report on the global burden of *Shigella* infections estimated the annual number of diarrheal episodes related to *Shigella* spp. to be 164.7 million, of which 163.2 million were in developing countries.[21] Recent studies on the Asian continent showed that incidence of *Shigella* diarrhea is more ubiquitous in Asian impoverished populations than previously thought[22] and that the incidence is substantially underestimated in children and older people in impoverished communities.[23] *Shigella* infections are often, but not exclusively,[24] associated with bloody diarrhea and are also referred to as shigellosis or dysentery.[25] Except for *ad hoc* outbreaks that are reported in the literature, information on the prevalence and incidence of *Shigella* infections on the African continent is limited.

To determine how effective point of use ceramic filtration is in preventing non-bloody diarrhea and bloody diarrhea, we conducted a controlled trial in two rural areas in southern Africa, assessing the incidence of non-bloody diarrhea and bloody diarrhea in children 24–36 months of age. Our study made use of pictorial diaries[26] that enabled distinguishing between non-bloody diarrhea and bloody diarrhea and enumeration of each.

The study was conducted in two districts, Mutale in the Vhembe district, Limpopo province, South Africa, and the Zaka district, Masvingo province, Zimbabwe. The population of the Limpopo province was 5,227,432 in 2000, with a density of 43 persons/km^2.[27] Forty percent of the population of 69,313 residing in the South African municipality of Mutale in 2001 had no access to sanitation.[28] The majority (53%) of the population used public standpipes, with a further 14% using rivers, dams, boreholes, and springs as sources of water.

The Zaka district in Zimbabwe had a population of 184,814.[29] Forty-five percent of the population in the district had no access to protected water sources, and 70% had no access to any type of sanitation facility.[30] More recent 2002

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census data are not available. Both study sites therefore are below national averages in access to improved water supplies and sanitation.

During a previous study,[31] we investigated the change in water quality between source and point of use and the linkages between water quality and diarrhea among children 12–24 months of age. To recruit households to this earlier study, health centers in the study areas were ranked by rates of diarrhea in children ≤ 5 years of age. Two villages, associated with each of the worst five health centers in each area, were selected. From each of the 10 selected villages, 12 households with children 12–24 months of age were randomly chosen. These households were drawn from lists from local birth registers in South Africa and lists drawn up by community health workers in Zimbabwe. Any households with an in-house piped water connection were excluded from this earlier study. For the intervention trial, 115 households that formed part of the earlier study were randomly selected from six villages in each of the two study areas.

The selected households were randomized into two groups by a senior researcher (RC). One half was provided with a commercially available ceramic water filter (British Berkefeld, England), whereas the other half formed the control group and continued using their usual in-house storage containers. The control group was given water filters at the end of the study. Each intervention household received four ceramic filter candles that were impregnated with silver and contained carbon for the removal of unwanted tastes. The flow rate for four candles is 80 L in 24 hours. Each household member was shown how to assemble, fill, and clean their filters. They were instructed not to open or clean the lower part of the vessel containing the filtered water. For practical reasons common to other published home water treatment interventions, neither participants nor enumerators or researchers were blinded to group assignment. This was because some source water in both our Zimbabwean and South African study areas had high turbidity levels or floating particles in the water apparent to the naked eye. The British Berkefeld filters reduced turbidity completely. Sham filters would not be able to completely reduce the turbidity, which would have made them easily identifiable, both to participating households and project staff.

Water samples were analyzed for the presence of *Escherichia coli* using the Colilert-18 method. Water samples were collected once at the end of the study from the storage containers in the control households and directly from the tap after filtration from intervention households. Baseline information regarding the type of household, level of education, hygiene practices, and access to sanitation, water source, and rubbish disposal methods were also documented.

All children in each household between 24 and 36 months of age were followed to determine the incidence of non-bloody diarrhea and bloody diarrhea. Adult care givers were trained to daily record episodes of diarrhea using a pictorial "smiley" diary.[26] The diary recorded frequency of diarrhea episodes and distinguished between loose watery stools and stools containing blood or mucus. Trained enumerators collected the sheets at the end of each week, after which the sheets were checked by a project researcher and captured electronically. Days when a child experienced three or more loose or watery stools or one loose stool containing mucus or blood were considered as diarrhea-days, following guidance from earlier studies.[32] This information was collected for the period October 2003–April 2004 in South Africa and November 2003–June 2004 in Zimbabwe. We also recorded the rate of bloody and non-bloody diarrhea for each participating child in the observation period before the trial started (average: 117 days of observation per child) to allow us to adjust for pretrial disease rates.

The trial was approved by the Research Ethics Committee of the Royal College of Surgeons in Ireland and by the appropriate regional bodies in RSA and Zimbabwe. Household participation was subject to informed consent from the head of the household. Community consent was also obtained by consulting with community elders. All participant information was translated into local languages.

Baseline demographic information and other information were analyzed with Systat version 8, using the Pearson's χ^2 test and the two-tailed Fisher exact test when appropriate.

Presence of *E. coli* contamination in household drinking water was modeled by Stata's binomial regression command, which allows the calculation of relative risks as a measure of effect size.

Diarrheal data were analyzed using Poisson regression, with robust variance estimation to account for clustering of diarrhea at village and household level, using Stata/SE release 10. Poisson regression is suited to the analysis of events with low incidence rates. The use of Poisson regression allowed us to account for the differences between children in number of recorded days, giving greater weight to children with more complete follow-up. The Poisson distribution is characterized by a single parameter: the incidence rate. This makes it easily interpretable in the reporting of risk data. Groups can be compared by calculating an incidence rate ratio. To check for a differential effect of filtration in the two countries, an interaction term was added to the model. Results are expressed as predicted 30-day incidence rates, and the filter and control groups were compared using incidence rate ratios with their associated 95% confidence intervals (CIs). In each case, comparisons were adjusted for differential incidence rates in the two countries and for diarrhea incidence in the pretrial observation phase. We defined an "event" as a day on which diarrhea occurred. The 30-day incidence rates are therefore the predicted number of days of diarrhea in a 30-day period. This does not take into account clustering of days into arbitrarily defined "episodes."

Baseline data for the aggregate control and intervention groups are shown in Table 1. Forty-one of the total number of intervention and control South African households used standpipes. The remaining households used unprotected springs and unprotected wells, protected boreholes, and river and canal water. The majority of the households in Zimbabwe used unprotected springs. Only three households had access to standpipes, 14 used boreholes, and the remaining households used river water and unprotected wells.

Baseline data showed no statistical differences between the control and intervention households for the household types, level of education of the carers, hygiene practices, sanitation facilities, type of water source, type of water storage container, and rubbish removal methods. Similarly, there were no significant differences between intervention and control households within each country in the rates of bloody diarrhea ($P = 0.205$) or non-bloody diarrhea ($P = 0.171$). However, between the two sites, a number of statistically signifi-

TABLE 1

Baseline data for each site and for the aggregate intervention and control groups

			Combined			
Characteristics	South Africa	Zimbabwe	Total	Intervention	Control	Difference
House type: total households	53 (50.0%)	53 (50.0%)	106 (100.0%)	57 (53.8%)	49 (46.2%)	–
Modern multi-room	12 (22.6%)	19 (35.8%)	31 (29.2%)	15 (26.3%)	16 (32.7%)	NS
Modern multi-room round house, courtyard	20 (37.7%)	0 (0.0%)	20 (18.9%)	8 (14.0%)	12 (24.5%)	NS
Round house and brick building, corrugated roof	11 (20.8%)	0 (0.0%)	11 (10.4%)	6 (10.5%)	5 (10.2%)	NS
Round houses	10 (18.9%)	33 (62.3%)	43 (40.6%)	27 (47.4%)	16 (32.7%)	NS
Single round house	0 (0.0%)	1 (1.9%)	1 (0.9%)	1 (1.8%)	0 (0.0%)	NS
Demographics—education mothers: total mothers	47 (45.6%)	56 (54.4%)	103 (100.0%)	54 (52.4%)	49 (47.6%)	–
No schooling	15 (31.9%)	12 (21.4%)	27 (26.2%)	18 (33.3%)	9 (18.4%)	NS
Some schooling	32 (68.1%)	44 (78.6%)	76 (73.8%)	36 (66.7%)	40 (81.6%)	NS
Hygiene and sanitation: total households						
Handwashing method adults	54 (50.0%)	54 (50.0%)	108 (100.0%)	57 (52.8%)	51 (47.2%)	–
Water only	28 (51.9%)	34 (63.0%)	62 (57.4%)	32 (56.1%)	30 (58.8%)	NS
Water and soap	26 (48.1%)	20 (37.0%)	46 (42.6%)	25 (43.9%)	21 (41.2%)	NS
Handwashing method children	52 (49.1%)	54 (50.9%)	106 (100.0%)	56 (52.8%)	50 (47.2%)	–
Water only	9 (17.3%)	29 (53.7%)	38 (35.8%)	23 (41.1%)	15 (30.0%)	NS
Water and soap	43 (82.7%)	25 (46.3%)	68 (64.2%)	33 (58.9%)	35 (70.0%)	NS
Sanitation	49 (48.0%)	53 (52.0%)	102 (100.0%)	54 (52.9%)	48 (47.1%)	–
Sanitation available	24 (49.0%)	39 (73.6%)	63 (61.8%)	38 (70.4%)	25 (52.1%)	NS
Sanitation not available	25 (51.0%)	14 (26.4%)	39 (38.2%)	16 (29.6%)	23 (47.9%)	NS
Water source protection and storage: total households						
Water source protection	58 (52.3%)	53 (47.7%)	111 (100.0%)	59 (53.2%)	52 (46.8%)	–
Protected water source	47 (81.0%)	17 (32.1%)	64 (57.7%)	36 (61.0%)	28 (53.8%)	NS
Unprotected water source	11 (19.0%)	36 (67.9%)	47 (42.3%)	23 (39.0%)	24 (46.2%)	NS
Water storage type	52 (49.1%)	54 (50.9%)	106 (100.0%)	56 (52.8%)	50 (47.2%)	–
Metal—open	0 (0.0%)	9 (16.7%)	9 (8.5%)	5 (8.9%)	4 (8.0%)	NS
Plastic—open	8 (15.4%)	16 (29.6%)	24 (22.6%)	13 (23.2%)	11 (22.0%)	NS
Plastic—small hole	30 (57.7%)	28 (51.9%)	58 (54.7%)	31 (55.4%)	27 (54.0%)	NS
Plastic—big hole	14 (26.9%)	1 (1.9%)	15 (14.2%)	7 (12.5%)	8 (16.0%)	NS
Rubbish disposal: total households	55 (50.5%)	54 (49.5%)	109 (100.0%)	58 (53.2%)	51 (46.8%)	–
Rubbish pit	38 (69.1%)	51 (94.4%)	89 (81.7%)	45 (77.6%)	44 (86.3%)	NS
No rubbish pit	17 (30.9%)	3 (5.6%)	20 (18.3%)	13 (22.4%)	7 (13.7%)	NS

NS = not significant.

cant differences were observed. Housing in South Africa was different to that in Zimbabwe ($P = 0.001$). Modern multi-room houses with traditional round huts and courtyards (South Africa, 37.7%; Zimbabwe, 0%) and round houses with additional brick buildings with corrugated roofs (South Africa, 20.8%; Zimbabwe, 0%) were more evident in South Africa. Traditional round houses with no modern buildings (Zimbabwe, 62.3%; South Africa, 18.9%) were more evident in Zimbabwe. Zimbabwean carers were better schooled than the South African carers ($P = 0.002$). Children were more often washed with soap in South Africa ($P = 0.001$). More people in Zimbabwe had access to toilets ($P = 0.01$) than in South Africa. Eighty-one percent of the South African households and only 32.1% of Zimbabwean households had access to protected water sources ($P = 0.001$). The profile observed for types of water containers was significantly different ($P = < 0.001$). Ninety-four percent of the households in Zimbabwe made use of a rubbish pit, whereas only 69.1% South African households made use of a rubbish pit ($P = 0.001$). Bloody diarrhea had a higher incidence rate in Zimbabwe (incidence rate ratio [IRR] = 3.0, $P < 0.001$). Non-bloody diarrhea had a somewhat higher rate in Zimbabwe also (IRR = 1.7), but this was not statistically significant ($P = 0.095$).

Although there was no follow-up study beyond 6 months to determine sustained use of the filters, acceptance during the trial was very high. When questioned during the trial about filter use, only one household refused to use the filter. No breakage was reported during the trial. Forty-three were asked their opinion about the speed of the filtration process: 90.7% said it was "about right," 4.7% found it slightly too slow, and 4.7% found it too slow. Two of the 43 respondents had a few difficulties when cleaning the filters. The remaining 41 respondents had no difficulties. The filters were therefore well received by almost all participants.

The water was tested once for the presence of *E. coli* at the end of the study through an unannounced visit. Table 2 summarizes the percentage compliance of *E. coli* counts with the World Health Organization's 2004 drinking water quality guidelines for control and intervention households in South Africa and Zimbabwe and for combined control and intervention groups. As shown in Table 2, we were unable to obtain water samples for 12 of 106 households, either because filters were empty or because households were absent on the day of the visit. A higher rate of compliance, 55% and 73.9%, was observed for both the control and intervention households in South Africa, respectively. In comparison, water in Zimbabwe showed compliance for 30.2% of the control households and 56.9% for the intervention households. We

TABLE 2

Percentage compliance of *E. coli* counts with the WHO* drinking water quality guidelines for control and intervention households in South Africa and Zimbabwe and for combined control and intervention groups

Site	Control	Intervention
South Africa	55% (11/20)	73.9% (17/23)
Zimbabwe	8.7% (2/23)	42.9% (12/28)
South Africa and Zimbabwe combined	30.2% (13/43)	56.9% (29/51)

* World Health organization (WHO 2004).

also examined the predictors of presence of *E. coli* in household drinking water using binomial regression. Presence of *E. coli* in source drinking water was associated with a 6-fold increase in risk of *E. coli* contamination in household water (relative risk [RR] = 6.1; 95% CI = 2.4–15.6). Adjusted for source contamination, there was a marginally lower rate of contamination in South African households compared with Zimbabwe (RR = 0.77; 95% CI, 0.57–1.03). Adjusted for both of these variables, households with filtered water had a lower risk of *E. coli* in household drinking water, with a relative risk of 0.67 (95% CI = 0.50–0.89; $P = 0.006$).

Two children in whom no follow-up was available were dropped. The study sample was made up of 58 households in Zimbabwe, of whom 31 were randomized to receive filters, and 56 in South Africa, of whom 29 received filters. The median number of days of follow-up for which there was diarrheal information was 140. Ten percent of children had < 105 days, and 90% had < 175 days. There was no significant difference in mean follow-up between the intervention and control groups ($P = 0.672$, *t* test).

We modeled the effect of filtration using Poisson regression. We first examined the data for a potential differential effect in the two countries by using an interaction term in the regression model. The interaction effect between filtration and country was not statistically significant for total diarrhea ($P = 0.77$) or for non-bloody diarrhea ($P = 0.90$) alone or bloody diarrhea alone ($P = 0.08$), indicating that the effect of filtration did not differ between the two countries. Poisson regression showed a significant difference in the incidence rate of all types of diarrhea between Zimbabwe and South Africa. Adjusted for this difference, children receiving filtered water had a significantly lower incidence of bloody, non-bloody, and total diarrhea. Table 3 shows the 30-day incidence rate of all three endpoints in the filter and control groups, together with the associated incidence rate ratios.

The presence of home filtration had a significant effect on the incidence rates of all forms of diarrhea, reducing incidence of both bloody and non-bloody diarrhea by 80%. The incidence rate ratio for bloody diarrhea was 0.20 (95% CI = 0.09–0.43; $P < 0.001$) and for non-bloody diarrhea was 0.17 (95% CI = 0.08–0.38; $P < 0.001$).

The provision of ceramic water filters was associated with a lower incidence of both non-bloody and bloody diarrhea in children living in rural South Africa and Zimbabwe. During the 6-month intervention the filtered water was associated with a significant reduction in both bloody and non-bloody diarrhea and the provision of drinking water with a reduced *E. coli* count.

Baseline information showed no significant differences between the aggregate control and intervention households. However, significant differences between the two study sites for the type of house, level of education of carers, availability of soap for washing hands of adults and for washing children, water source type, in-house storage methods, and access to a rubbish pit were evident. This is to be expected because the sites were situated in different countries representing different circumstances and political dispensations. The South African households enjoyed a slightly higher degree of economic status as shown by better housing facilities, availability of soap, and a greater number of protected water sources compared with Zimbabwe. Political unrest in Zimbabwe was already rife when the study took place and contributed to the lower economic status of the households in Zimbabwe.

TABLE 3

Predicted number of days of diarrhea in a 30-day period in relation to use of filtration, adjusted for pretrial diarrhea rates and incidence ratios

	All diarrhea	Bloody diarrhea	Non-bloody diarrhea
Control	2.35	1.14	1.20
Filter	0.51	0.23	0.28
Incidence rate ratio	0.21	0.20	0.17
95% CI	0.12–0.36	0.09–0.43	0.08–0.38

Calculated using Poisson regression.

Although this study's focus was not to test the performance of the filter for the removal of bacteria, a one-off measurement for the presence of *E. coli* indicated that the ceramic filters reduced the risk of having *E. coli* present in the drinking water of the intervention households. Much effort has gone into the provision of greater quantities and better microbiological quality of water over the last 10 years in both rural and peri-urban areas of South Africa. Piped water, in the households, on site, or from a communal tap, was available in 78% of the households in the Limpopo Province.[33] The majority of households taking part in the South African study had access to standpipes. The higher compliance rate to the 2004 World Health Organization's drinking water quality guidelines for *E. coli* counts, observed in both storage and filtered water in South Africa may be concomitant to their access to standpipes.

There was no follow-up study to determine sustained use of the filters, but acceptance during the trial was very high. Only one household refused to use the filter. Generally the filters were perceived as prized items by the study participants and non-participants. This agrees with previous work, such as the high acceptance and continued use of ceramic filters showed in a study conducted in response to severe flooding in the Dominican Republic.[34]

Household water filtration reduced the incidence of both bloody and non-bloody diarrhea by 80%. Other studies using ceramic filters at point-of-use showed a reduction of 70%,[11] 45.3%,[7] 60%,[10] and 46%.[12] This is somewhat higher than the median reduction of 42% that was observed for an analysis of 21 studies consisting of water quality interventions at the point-of-use regardless of the nature of the intervention.[6]

The large reduction we observed relative to previous studies may in part be attributed to the high quality of the British Berkefeld ceramic filters used in the study. They have been independently tested and have absolute filtration ratings of 0.9 μm. The filters used in the study were impregnated with silver and contained carbon. They effectively remove *Salmonella typhi*, *Shigella* spp., *Vibrio cholerae, Klebsiella, E. coli,* and protozoan parasites such as *Cryptosporidium* and *Giardia.* Viral pathogens such as rotavirus, hepatitis A and E, and poliovirus are, however, not removed. If used appropriately, filtered water of good microbial quality can be obtained. Observations in the field suggested that the study had an additional effect of heightening awareness with regard to water contamination, bacteria, and hygiene practices such as hand washing. This may have also contributed to the large reduction observed in diarrhea incidence. Because safe water and sanitation provision are particularly poor in the two study sites relative to the national averages, the findings of this trial may not therefore be generalizable to the wider population in the two countries.

The statistically significant reduction of bloody diarrhea in this study, which is predictive of the presence of *Shigella* infection,[35] although not exclusively,[24] shows that ceramic filters can reduce the devastating effects of *Shigella* infections. Diarrheal infections caused by *Shigella* in particular affect malnourished children younger than 5 years old in impoverished areas and account for proportionately greater morbidity and mortality than non-bloody diarrhea.[22] The possibility of outbreaks caused by one of a growing number of antibiotic-resistant strains[23,24] and costly vaccination campaigns can be minimized or averted by interventions with the advantages of ceramic filters. The filter can easily be moved to new locations if necessary, introduce no chemicals into the water or environment, improve the water aesthetically, remove taste and odors, and is easy to use and readily accepted.

Dilute hypochlorite solution and solar disinfection, a zero cost technology, are the least expensive methods for treatment of water at the point of use. Approximate cost for chlorination has been estimated at \$1.60 to \$8 for initial cost of hardware (per capita; per household) and \$0.60 to \$3.00 for annual operating cost per capita per household.[9] Both dilute hypochlorite solution[16,36] and solar disinfection[19,20] are effective in reducing the incidence of diarrhea. Ceramic filters treat water at the point of use, immediately providing water free of bacteria and parasites and consequently reduce diarrhea more effectively than the former methods. Providing people with ceramic filtration, however, is costly at present. The ceramic filter used for this study costs approximately \$60 (€46), one candle costs approximately \$6 (€4.60), and replacement parts are not readily available in the areas the study was conducted. Most rural households will not have the financial means for the initial purchasing costs of a water filter. Although increased demand and local manufacture may drive down unit costs, it is possible that the technology will remain too expensive for some communities in poorer regions. However, in regions where financial security is increasing, promotion of manufacture of ceramic filtration systems may be warranted. Given the easy acceptance, easy use, and low maintenance of the filters and the possible provision of affordable replacement parts, long-term sustainability is perhaps not unattainable.

A limitation of the study was that it was not blinded, a shortcoming common to many intervention studies of home water filtration and storage. A recent systematic review,[37] for example, found only four double-blinded intervention studies of home water treatment among 33 published reports. Because none of the double-blinded trials identified in this review found significant protective effects, it is possible that the observed improvements in waterborne disease are because of a placebo effect caused by lack of blinding. However, the impact of filtration on the presence of *E. coli* contamination in household drinking water is not explainable as response bias and would argue that the reported reduction in diarrhea rates is attributable to improved water quality. The extent to which the provision of filters may have changed household health behaviors, and thus had an indirect effect on diarrhea through, for example, an increased awareness of the importance of hygiene practices, is unknown, but would provide a suitable area for future research.

Ceramic filters were effective in reducing incidence of bloody and non-bloody diarrhea in this study. However, providing people with ceramic filtration is costly at present and out of reach for those living in some of the poorer regions. A higher percentage reduction in diarrheal disease was recorded using the ceramic filters than reported using solar disinfection, but the very low cost of solar disinfection still makes it a better choice in very poor regions. Ceramic gravity filters effectively improve water quality and reduces diarrheal disease, which make them an attractive alternative for households without safe water supply and in emergency conditions. Ceramic filters can provide safe water at the point of use within minutes. They are durable and easy to use, only minimum training is necessary in their use, and they are easily maintained. They effectively remove diarrheal-causing bacteria and parasites from unsafe water and consequently contribute to the overall health of people exposed to unsafe water.

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