Critical Review

Household Water Treatment in Poor Populations: Is There Enough Evidence for Scaling up Now?

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Household Water Treatment in Poor Populations: Is There Enough Evidence for Scaling up Now?

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Point-of-use water treatment (household water treatment, HWT) has been advocated as a means to substantially decrease the global burden of diarrhea and to contribute to the Millennium Development Goals. To determine whether HWT should be scaled up now, we reviewed the evidence on acceptability, scalability, adverse effects, and nonhealth benefits as the main criteria to establish how much evidence is needed before scaling up. These aspects are contrasted with the evidence on the effect of HWT on diarrhea. We found that the acceptability and scalability of HWT is still unclear, and that there are substantial barriers making it difficult to identify populations that would benefit most from a potential effect. The nonhealth benefits of HWT are negligible. Health outcome trials suggest that HWT may reduce diarrhea by 30–40%. The problem of bias is discussed. There is evidence that the estimates may be strongly biased. Current evidence does not exclude that the observed diarrhea reductions are largely or entirely due to bias. We conclude that widespread promotion of HWT is premature given the available evidence. Further acceptability studies and large blinded trials or trials with an objective health outcome are needed before HWT can be recommended to policy makers and implementers.

Introduction

There is an ongoing debate about the relative benefits to health of water quality and water quantity interventions in low income settings. Historically much emphasis had been given to specific water quality criteria implemented at substantial costs at scale in most industrialized countries. However, during the 1980s and 1990s, researchers began to argue that insisting on strict water quality criteria at the expense of water quantity may be counterproductive in poor settings (*1–3*). The impact of water quality improvements was regarded as limited, based on the assumption that drinking water is just one of several transmission routes of water- and excreta-related conditions, and that the risk attributable to water-borne infections is low.

This assumption was challenged by several recent trials and systematic reviews suggesting that improving water quality at the point of use (household water treatment, HWT) may reduce diarrhea by up to 40% (*4–6*). These findings have gained considerable attention, calling for a shift in current thinking toward greater emphasis on water quality in poor settings, especially by the use of HWT (*7*). The World Health Organization (WHO) concluded that there was now "conclusive evidence that simple, acceptable, low-cost interventions at the household and community level are capable of dramatically improving the microbial quality of household stored water and reducing the attendant risks of diarrheal disease and death" (*8, 9*).

Some researchers have rejected claims about the effectiveness of HWT, suggesting that much of the currently apparent evidence for the effect of HWT may be due to bias and that without other environmental improvements the benefits of HWT may be negligible (*10, 11*). It is crucial to understand what exactly the debate is about. Protagonists of the view that the available evidence supports the widespread adoption of HWT techniques do not contest the important role that easy access to sufficient water quantity plays for disease prevention and socio-economic development. They also do not contest the role of safe storage in improving or maintaining water quality in the household (*9*). What is being claimed is that HWT significantly reduces diarrhea in poor areas; is among the most effective of water, sanitation, and health interventions; is highly cost-effective; and can be rapidly deployed and taken up by vulnerable populations (*9*). In other words, it is being claimed that HWT can offer health benefits in addition to improving water access and safe storage in poor areas, and may significantly reduce diarrhea in the absence of other environmental improvements, in particular sanitation (*5*).

The focus of the debate is whether the claims of health benefits are true, and whether HWT is scalable among poor populations with the highest disease risk, who would benefit most from disease reduction.

This paper reviews the existing evidence for the effectiveness of HWT and for its scalability in order to determine whether or not there is now a solid case for promoting widespread adoption of HWT in poor settings.

This paper does not review the evidence for the benefits of improving access to water. As outlined above, there are few people who dispute its importance for health and economic development. Further, we do not discuss interventions to improve water quality at source, or the use of boiling to treat drinking water at the household level (except for a brief discussion on the potential for HWT to reduce indoor air pollution).

Methodology. For the purposes of this review, household water treatment means treatment of water in the household with filtration, chlorination, chlorination with flocculation, or solar disinfection. Because of the availability of previous review articles on the different issues around HWT we did not need to conduct a formal systematic review or meta-analysis. Using existing reviews, HWT is assessed based on an approach originally used for judging evidence for HIV interventions (*12*), which we adapted to the case of water interventions. For our purposes, this approach basically comprises three steps:

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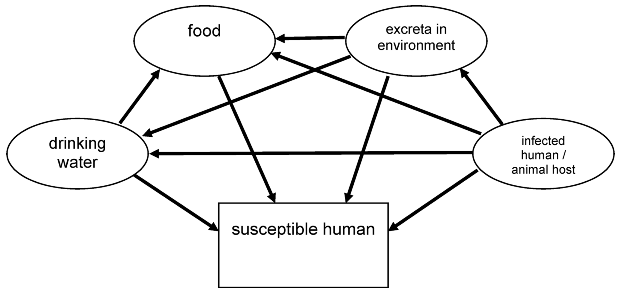

FIGURE 1. Transmission pathways of intestinal pathogens.

(I) Define the strength of evidence that would be needed to justify widespread implementation of HWT, based on the potential size and biological plausibility of a health effect, and the intervention's scalability, acceptability, risk of adverse outcomes and nonhealth benefits.

(II) Summarize the strength of the evidence on the effectiveness of HWT to reduce diarrhea, by critically reviewing published studies and systematic reviews.

(III) Compare the strength of the evidence available against the threshold of evidence that would be needed to recommend widespread implementation.

Results

Defining the Strength of Evidence Required for HWT. In principle, an intervention that is potentially very effective (in terms of biological plausibility), scalable, acceptable, of low risk, and associated with nonhealth benefits requires relatively little evidence with regard to its effectiveness to reduce disease. In contrast, an intervention that is characterized by a small potential health effect (based on biological plausibility), doubtful or unproven acceptability and scalability, potential for adverse outcomes, and lack of nonhealth benefits requires a high level of evidence before large scale implementation should be promoted (*12*). In the following section, we will examine where HWT stands in respect to these criteria. Importantly, the following considerations are made irrespective of whether HWT is truly effective or not. Effectiveness will be discussed later.

Biological Plausibility and Potential Size of the Health Effect. There is no doubt that many water and excreta related pathogens can be transmitted by contaminated drinking water. The question is, "How important is water-borne transmission, in particular of diarrhoeal or intestinal pathogens, in relation to other transmission routes by which these pathogens are spread?" This question is difficult to study, and there is a scarcity of high quality data. However, it is generally accepted that water and excreta-related pathogens can be spread by person to person contact (*13*), contact with contaminated soil and surfaces, food, and flies (*14, 15*). Transmission in drinking water is just one of several pathways for diarrheal pathogens and is not a dominant pathway for trachoma, intestinal helminths, and schistosomiasis, or even necessarily a pathway at all for these conditions. With this in mind, one would expect a priori that in most settings HWT may be unlikely to reduce disease substantially. However, it is likely that water-borne transmission may be much more important in some settings than in others, either throughout the year or during a particular season (often the wet season, but in some settings the dry season when drinking water may be more heavily contaminated with wastewater used for irrigation). The different pathways may also interact: for example, bacterial pathogens transmitted by water may at times come into contact with food where they can multiply and reach an infective dose. Figure 1 shows the major transmission pathways of intestinal pathogens.

HWT has been shown to dramatically improve microbiological quality of drinking water, usually measured in terms of certain indicator bacteria like thermotolerant coliforms. Presence of these coliform indicators does not necessarily mean that the water is unsafe to drink. Likewise, many HWT techniques (especially chlorination and filtration) have limited effectiveness in reducing viruses and parasites. Although it could be argued that microbiological effectiveness is a poor marker of the actual health benefit, it still appears that from the perspective of biological plausibility a potentially large effect size of HWT cannot be excluded for selected settings.

Acceptability and Scalability. Acceptability and scalability of HWT has been subject to much debate and are closely linked. Most research has been done on disinfection with sodium hypochlorite. Programmes that included widespread mass media promotion and other communication channels reached large parts of the population in several countries, with 27−42% of respondents reporting having used household chlorination, although persistent use was much less common (*16, 17*). Solar disinfection (which requires a substantial behavior change for users) has also achieved some coverage in areas where it has been promoted, although the coverage figures vary widely among settings (between 9 and 66%, although persistent use is less clear) (*16, 17*). Ceramic filters and biosand filtration have also been found to achieve some coverage and persistent use (*16, 17*). Other products like flocculants have been less successful in terms of reach as shown by a study in Guatemala (*18*). A recent review conducted by Sobsey et al. suggested that only ceramic filters and biosand filtration have the potential for sustained uptake and use (*17*). A common finding of acceptability studies is that uptake and use is much less among poor and uneducated people who are most at risk of disease (*16*). However, if one assumes that it takes poor people longer to change to HWT methods than richer people, it could be argued that current studies (with time spans of up to 5 years since program introduction) may not fully describe the potential for long-term behavior change. Overall, it has been estimated that at the current pace, HWT will cover up to 100 million users by 2015 (*16*). Thus it seems that sustained marketing and promotion efforts at least have the potential to bring HWT techniques to some scale in the long term. On the whole there is evidence that sustained promotion efforts may increase coverage and persistent use to significant levels, but it seems likely that increasing coverage among the poor who are most at risk will be difficult if not unfeasible and will require substantial additional efforts.

Adverse Effects. HWT may have adverse effects in three dimensions: risk to the consumer (e.g., toxicity), diversion of household income and time/effort from other activities, and the risk that political attention is diverted from water supply.

There is little evidence that the use of HWT is associated with health risks. Taste will usually preclude chlorine overdosage. There is some evidence that inappropriate use of HWT can lead to an increase in microbiological contamination of water supplies (*19*), although the relevance for health is unclear.

Uptake of HWT will cause additional costs to households. However, except for flocculants and the capital costs for filters, costs for households and therefore the risk of substantial diversion of spending are relatively low, although the true costs may need to be reduced by subsidies (*20*).

Finally, there is the risk that HWT may divert the attention of policy makers and donors from the promotion of other environmental interventions, such as sanitation or improved access to water, which of course would only be a problem if HWT were ineffective. HWT has indeed attracted widespread recognition, especially in the context of the Millennium Development Goals. HWT appears to be widely accepted within WHO as a means to reduce child mortality (*9*). WHO support is also highlighted by the WHO-led creation

TABLE 1. Comparison of Four Different Environmental Health Interventions Using Critical Criteria for Public Health Decision Making[a]

	Potential effect size	Acceptability	Scalability	Potential for adverse effects	Potential for non-health benefits
HWT	Small in most settings, large in selected settings	Unclear	Unclear	Small to moderate	Small
Water quantity/ access	Moderate	Very high	Unclear in remote settings	Small	Large
Sanitation	Large in dense, moderate in rural settings	High in dense, variable in rural settings	Variable	Small	Large
Handwashing promotion	Moderate	Unclear	High	Small	Small

[a] **Potential effect size**: Expected effect size based on biological plausibility only; large effect size means a substantial effect on (largely) diarrhoea in excess of 20%; moderate reduction means reduction between 10% and 20%; small effect means a reduction below 10%. These figures are indicative only. **Acceptability**: The extent to which an intervention is accepted and used by the target population. **Scalability**: The extent to which an intervention can be delivered on a large scale taking into account promotion activities and materials needed. For example, both HWT and hand hygiene can be promoted by mass media. While soap for handwashing is available almost everywhere, HWT requires in addition establishing a product distribution system or market. **Potential for adverse effects**: Any effect of an intervention harmful for health or economic development, including potential waste of resources. **Potential for nonhealth benefits**: Beneficial effects of an intervention not directly related to disease (although disease may improve indirectly, e.g. by savings in costs and time which can be allocated to other activities like work and education associated with health improvements).

of the "International Network to Promote Household Water Treatment and Safe Storage". The Network includes UN agencies, Ministries of Health, bilateral development agencies, international nongovernmental organizations (NGOs), research institutions, international professional associations, the private sector, and industry associations. The substantial investment made by the Gates Foundation ($17 million) to scale up HWT (rather than to conduct efficacy trials) also suggests that efforts to scale up HWT are diverting funds from other areas (*21*). Overall, it is possible that HWT diverts attention from other areas, although the extent to which this may happen is not clear and may be small. A potentially more damaging possibility is that local or national governments of low income countries may use the promotion of HWT to actively or inadvertently divert attention from failures in public water supplies. Water may be seen as a household problem rather than a public good for which governments have a clear responsibility, despite efforts made by WHO and most other agencies to emphasize that HWT does not diminish the important role of water supply (*9*). There is no evidence in support of such a possibility, which in any case would be difficult to obtain. In conclusion, the potential for adverse effects due to the widespread promotion of HWT is difficult to quantify and largely depends on whether HWT is (cost-) effective or not. Overall, the risk of adverse effects due to HWT is unlikely to be substantial.

Benefits other than Diarrhea Reduction. Apart from a potential reduction in diarrhea, benefits of HWT cited in the literature comprise improved aesthetic appeal of drinking water, and (for households that have been converted from boiling water to other HWT methods) cost savings, convenience and a reduction in indoor air pollution (*16*).

Filtration and flocculation improve the appearance of drinking water, and possibly its taste. In contrast, chlorination and solar disinfection do not improve appearance and can negatively affect taste.

In households which have converted from boiling to other HWT techniques indoor air pollution may be decreased, but only by a small amount since only about 14% of fuel consumption may be due to boiling; the rest is from cooking and other activities (*22*). Improving stoves would therefore be a much more effective way to reduce indoor air pollution than HWT, which has not been shown to actually reduce indoor air pollution so far.

Biosand filters are able to produce large amounts of water (up to 80 L/day) and may therefore allow households which rely on grossly contaminated surface water access to sufficient amounts of more appealing water for bathing and washing. All other HWT methods provide only small amounts of water. Ceramic filters are relatively slow. Solar disinfection of sufficient amounts of water for washing would require an excess of 20 water bottles a day. Flocculants and chlorination methods also provide rather small amounts of water that are primarily used for consumption rather than personal hygiene.

Many water and sanitation interventions can strengthen the social status of users. Water access and sanitation have clear effects on gender equality (*23*). They allow women and other household members to save time which may be devoted to other (e.g., economic or educational) activities. HWT is unlikely to contribute significantly to any of these issues since it does not affect water supply. Rather, HWT may increase the work load of household members, especially women, although probably not to a very substantial extent. On the whole, the benefits of HWT unrelated to diarrhea are negligible.

Determination of the Strength of Evidence Needed. A synthesis of the findings is shown in Table 1, along with examples of other water and sanitation interventions with the aim of putting HWT into context. We did not conduct a formal review for the other interventions. Individual items, such as the plausibility of effect sizes may be subject to debate. However, even if we take this uncertainty into account, the table illustrates an important difference between HWT and other water and sanitation interventions. Improving water access is associated with nonhealth benefits (especially savings in time and costs) (*24*), and is highly acceptable. Likewise, especially in dense urban settings, sanitation is a basic necessity and always worthwhile to implement even

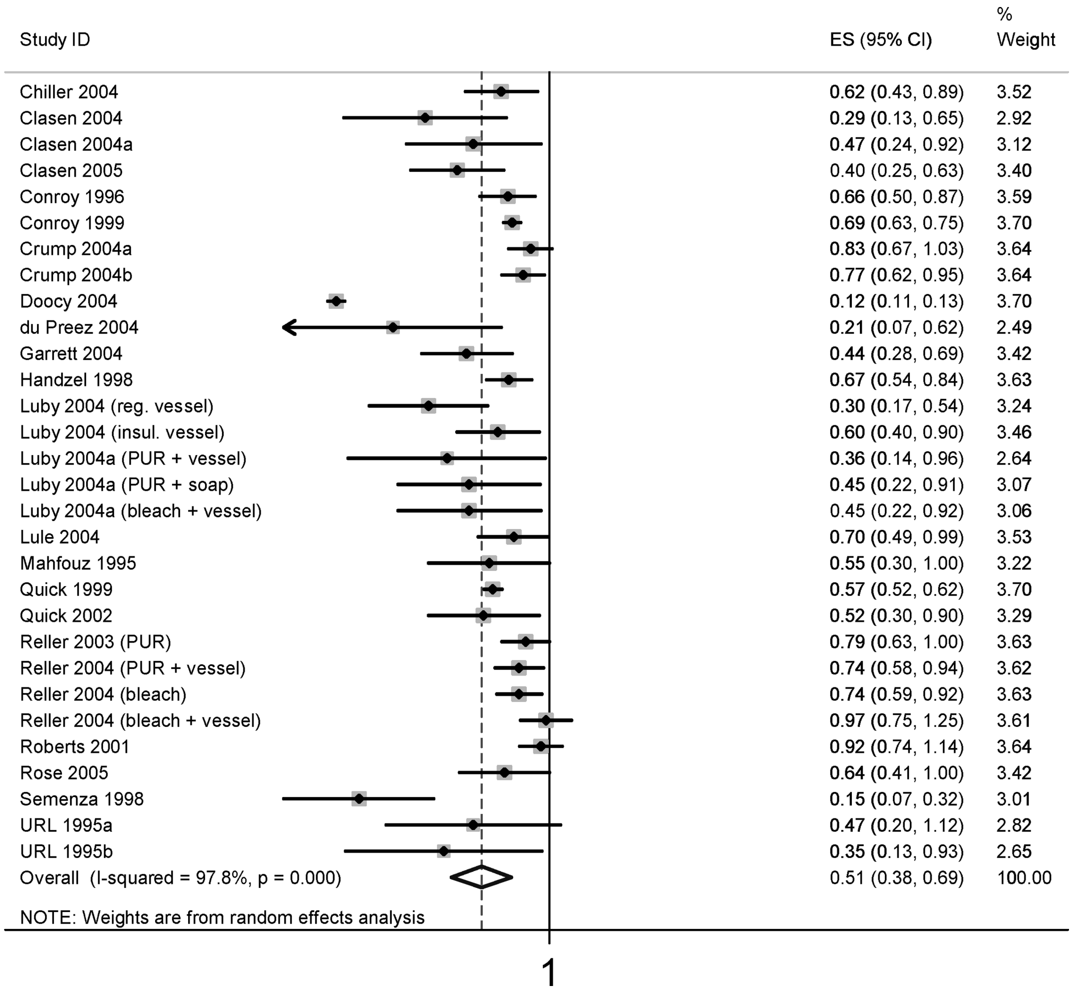

FIGURE 2. Systematic review of household water treatment trials − unblinded trials: Forrest plot of unblinded household water treatment trials as published in ref *5*. Vertical solid line indicates risk ratio (RR) of 1, corresponding to no effect, dotted line indicates pooled effect of RR = 0.51, corresponding to a 49% reduction of diarrhea.

if the true effect on health was small (*23*). Little evidence on disease reduction is needed to justify implementing these interventions.

This stands in contrast with HWT. From the table we can see that the case for HWT largely depends on the existence of a health benefit and reasonably precise figures on the size of this effect. Without a health benefit there would be little reason to promote HWT for public health purposes.

In line with the principles of the approach used here to evaluate the role of HWT, the absence of nonhealth benefits, the rather small potential to reduce indoor air pollution and the questions with regard to acceptability and scalability mean that before scaling up there needs to be high quality evidence on the size of the health effect in different settings (*12*). As an aside, handwashing promotion may also require quite strong evidence on its health effect, as there are few nonhealth benefits, and questions regarding its acceptability.

The Strength of the Evidence That HWT Reduces Disease. A number of systematic reviews and meta-analyses have looked at the effect of different HWT interventions on diarrheal diseases. In general, HWT was found to be effective with average effect sizes suggesting a 30% to 40% diarrhea reduction (*4*−*6*). A striking finding is the large heterogeneity of effect estimates ranging from no effect at all to an 85% reduction (Figure 2) (*5*).

Heterogeneity of effect sizes may be due to many reasons such as differences in the efficacy of different HWT methods; the adherence of study participants to different methods; the study design and execution; the importance of water-borne transmission in different settings; the extent of responder and observer bias for outcome assessment; bias introduced by issues of conflict of interest (publication bias, selective reporting of results). For our analysis, systematic bias is of highest interest.

Randomized controlled trials are often regarded as the "gold standard" to evaluate the effect of health interventions. However, randomized controlled trials using a subjective outcome measure, such as self-reported gastro-intestinal symptoms usually do not provide an unbiased estimate (*25*). The term "gold standard" for randomized unblinded studies with reported diarrhea as outcome measure is misleading and should be avoided. The limitations of current effect estimates due to responder and observer bias have been acknowledged by recent reviews (*4*−*6*). However, it appears that they are given only marginal consideration at the political level (*9*).

When judging the evidence for HWT, it is of critical importance to determine whether it is plausible that bias can be responsible for inflating effect estimates to suggest a disease reduction of 30−40% given no true effect. Empirical studies in medical research have shown that bias can indeed lead to vastly exaggerated effect sizes (*25*−*27*).

There is some evidence that responder and observer bias (which are difficult to identify separately) play a strong role in HWT trials. An unblinded study of reverse osmosis household water filtration conducted in Canada found a 35% reduction in self-reported diarrhea but no effect on health care seeking due to diarrhea (*28*). The power of the study is

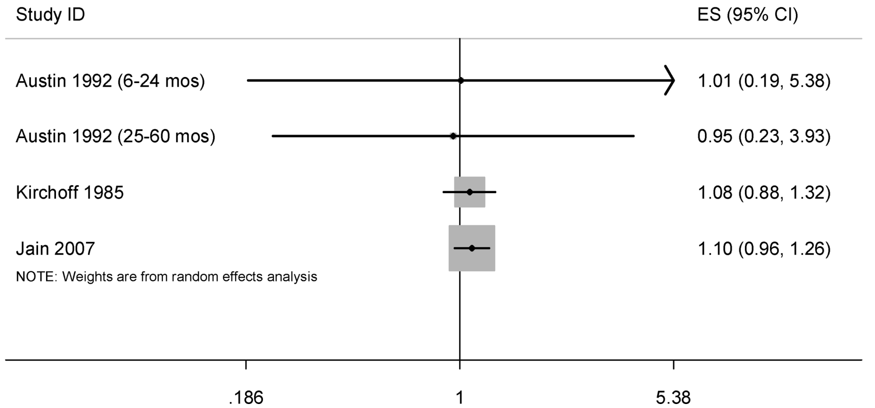

FIGURE 3. Systematic review of household water treatment trials − blinded trials: Forrest plot of blinded household water treatment trials as published in ref *5*, updated with ref *33*. Vertical solid line indicates risk ratio (RR) of 1, corresponding to no effect. Austin only published effect sizes stratified by age group. The confidence intervals of the Jain and Kirchhoff studies are not adjusted for clustering at the household level, and are likely to be too narrow. No pooled effect is given because of this uncertainty.

reduced if health care seeking is used as an outcome, but this is a more objective measure than self-reported diarrhea. There is little reason to assume that study participants or field workers in poor settings would be less prone to biased reporting.

A large *blinded* trial on reverse osmosis in the U.S. found no evidence for an effect on gastro-intestinal diseases. The risk ratio (RR) found in this study, i.e. the incidence of diarrhea in the intervention group divided by the incidence in the control group, was 0.98 (95% confidence interval: 0.86−1.10) (*29*), after a small pilot study to test trial procedures had suggested a trend toward diarrhea reduction (RR = 0.75, 95%, confidence intervale (CI): 0.42−1.33) (*30*). A similar large blinded filtration trial in Australia also found no effect (RR = 0.99, 95% CI: 0.85−1.15) (*31*). These studies were conducted in settings with fairly good ambient water quality and therefore are not suitable to inform on the true effect of HWT on diarrhea in settings with poor quality water. However, they provide evidence that HWT is ineffective given good water quality, which suggests that the effect on diarrhea seen in the Canadian study (*28*) may be due to bias, though it is possible that the microbiological water quality in this study may have been inferior to the U.S. and Australian studies. This evidence suggests that in HWT trials even large observed effect sizes do not exclude lack of true effect, and that the subjectivity of the outcome measure (self-reported diarrhea) may be the driving factor in causing bias (*25*).

Three blinded trials conducted in low income settings have been published. Austin conducted a placebo controlled village-cluster randomized trial in 20 villages in The Gambia and found no effect of HWT (chlorination) on diarrhea (*32*). Likewise, Kirchoff et al. (*11*) found no reduction of diarrhea in a small placebo controlled blinded study in Brazil. Recently, a placebo controlled blinded trial was conducted in Ghana comparing diarrhea in (a) households using Isocyanurate (Aquatab) water disinfection plus a hygienic storage vessel with (b) households using only the storage vessels. This study also showed no effect on diarrhea (*33*). However, in this study ambient water quality was better than expected, thus perhaps limiting the potential for HWT to reduce transmission, but also highlighting the difficulty in targeting the right population. On the other hand, a large systematic review on (mostly) unblinded studies found no association between ambient water quality and the effectiveness of HWT (*5*), suggesting that according to this review the intervention in the Ghana trial should have reduced diarrhea, e.g., by preventing recontamination. However, it failed to do so.

Remarkably, several unblinded HWT studies have reported substantial reductions in diarrhea despite low use of the intervention. A study in India found that solar disinfection was associated with a 36% reduction in diarrhea among children <5 despite 86% of them consuming untreated water regularly (*34*). Another study in Guatemala found a 25% reduction among households that had used sodium hypochlorite although only 36% of them had residual chlorine in their water containers (*35*). Figures 2 and 3 show the results of unblinded and blinded studies conducted in low income settings, demonstrating the marked contrast.

Further sources of bias come from selected reporting of results and publication bias. As can be seen from the large number of industry partners in the WHO-sponsored International Network to Promote Household Water Treatment and Safe Storage (*9*), there are commercial interests that could jeopardize the objectivity of studies conducted on commercially available HWT products. Empirical studies in medical research have shown that industry funding can lead to substantial bias in favor of the product under investigation (*26*), arising primarily from selective reporting of trial results and publication bias. It would be speculation to guess to what extent estimates of the effect of HWT on diarrhea are influenced by these biases. Given that trials in the field of water and hygiene and the products that come out of such trials do not undergo a strict regulatory process, and are rarely registered at a trial registry (as is the case for drugs, for example), it is possible that selective reporting and publication bias are an issue in HWT trials, although evidence is lacking.

On the whole, there is a clear possibility that the large effect sizes seen in unblinded trials are largely or even entirely due to responder and observer bias, selective reporting and publication bias, but the evidence for this (which can only be further strengthened by conducting larger blinded trials or unblinded trials with an objective outcome) is currently insufficient to reach a definite conclusion.

Synthesis of the Evidence. We found (I) that for a number of reasons, most importantly the absence of a clear nonhealth benefit and questions with regard to acceptability, HWT requires a high level of evidence for health benefits before being promoted on a large scale. We also show (II) that this high level of evidence is not yet achieved. What are the implications of this mismatch in the evidence basis of HWT? The approach taken in this analysis proposes that policy makers need to decide between four basic options when deciding whether or not to implement an intervention (*12*):

(1) Role out the intervention now at a large scale (“go”).

(2) Role out the intervention now at large scale but under careful evaluation of its effect (“ready”).

(3) Test the intervention in small or medium scale efficacy and effectiveness studies to obtain higher quality evidence ("steady").

(4) Reject the intervention due to strong evidence for lack of effect or evidence for harmful effects ("don't go").

From the discussion above it is immediately clear that options (1) and (4) cannot be recommended yet. Neither is there sufficient evidence for HWT to justify large scale implementation without careful and sufficiently funded evaluation, nor is there sufficient evidence for rejecting HWT altogether as a means to reduce diarrhea in poor populations. This leaves us to decide between options (2) and (3). Attempts to scale up HWT are already happening in many countries, with support from WHO and the Gates Foundation. This speaks in favor of option (2): widespread implementation of HWT under careful evaluation of the health effect. Another argument in favor could be based on the claim that we have already learned what we can from the many small scale trials on HWT, so that further studies at that scale are unlikely to produce additional useful evidence.

However, there are many unanswered questions around HWT that require small or medium scale epidemiological studies and randomized controlled trials, especially with regard to effectiveness, acceptability and identifying suitable target populations. Thus, it seems difficult to escape the conclusion that option (3)—further dedicated research studies—should be the preferred option at this stage given the lack of health effect in blinded studies, the lack of clear nonhealth benefits, the questions around acceptability and persistent use of HWT, and perhaps, potential adverse effects at the political level.

Conclusions and Policy Recommendations

The findings of this review suggest the following conclusions and policy recommendations:

(1) Widespread promotion of HWT, especially without targeted evaluation of its health effect, is premature. The ongoing efforts in HWT risk contributing to a situation similar to drinking bottled water in rich countries, a commercial success in the absence of a measurable effect on health.

(2) It is possible and plausible that HWT may be effective in reducing diarrhea in some poor populations, where water-borne transmission is a dominant transmission pathway. High quality studies are needed to prove this and to estimate the size of the effect. Future studies should either be blinded or include as the primary outcome measure an objective outcome such as mortality, weight gain, or growth. Several studies have demonstrated that HWT can successfully be tested using these rigorous approaches (*11, 32, 33*). Before widespread promotion of HWT with the aim of reducing diarrhea in populations with inadequate access to water can be recommended, some of the most urgent questions to be resolved are (1) How much of the currently cited disease reduction of HWT is due to bias? (2) What is the effect of HWT on nutritional status (weight gain and growth)? (3) At which populations should HWT be targeted? Implementers should demand evidence-based answers to these questions from the research community before they consider scaling up.

(3) A critical question that needs to be answered is whether HWT involving commercial products offers *additional* advantages over safe water handling and storage. Among over 40 studies on household water treatment identified by a recent review (*5*), only one described the effect of safe storage alone on diarrhea (*36*). Apart from the few studies on solar disinfection, most other studies were on interventions that require some sort of purchasable product (often requiring repeat purchases). Safe water handling and storage practices can be promoted, requiring little investment from households. In other words, there can be little harm in promoting them.

(4) Given the strong industry involvement in HWT, registration of trials prior to their start and strict adherence to a study protocol specifying in detail a primary outcome measure should be mandatory. Implementers, policy makers and ethics committees must insist on such prerequisites of good scientific conduct, which in the field of environmental health are often not followed.

(5) Given the current available evidence, there may be a case for implementing HWT as a preliminary method in emergency settings, or temporarily during an epidemic of water-borne diseases such as cholera. Under these circumstances issues of sustainability, diverting funds, and lack of nonhealth benefits may be less of a problem, while the potential effect size of HWT may be large. In this case, if there is little evidence in favor of HWT, there may also be few reasons against it, although results from a study on use of HWT after the Asian Tsunami were not encouraging (*37*).

(6) Improving water access and sanitation remain the top priorities in the water, hygiene and sanitation sector. However, similar to the household water treatment studies, the pooled effect estimates on different water, hygiene and sanitation interventions frequently cited are probably only marginally useful in guiding decision making. For example, based on randomized controlled trials it has been suggested that simple hand washing with soap may reduce reported diarrhea and pneumonia by up to 50% (*38, 39*). Hand washing is linked to social status, carries moral connotations, and is therefore particularly prone to responder and observer bias, perhaps even more than HWT. Accepting the lack of good evidence may be preferable to deciding on the basis of misleading evidence.

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