A WELL FACTSHEET

The effectiveness of water quality interventions in preventing diarrhoea

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This fact sheet describes the results of a systematic review of 41 controlled trials among some 56,000 participants to assess the effectiveness of water quality interventions to prevent endemic diarrhoea. Although there were substantial clinical and methodological differences in the studies, the evidence for the effectiveness of water quality interventions was compelling. Household-based interventions were generally more effective at preventing diarrhoea than those at water source. Effectiveness was positively associated with compliance. Effectiveness was not conditioned on the presence of improved water supplies or sanitation in the study setting, and was not enhanced by combining the intervention to improve water quality with other common environmental interventions intended to prevent diarrhoea.

Introduction and background

Diarrhoeal diseases kill an estimated 1.8 million people each year, the majority children under five (WHO 2005). Young children are especially vulnerable, bearing 68% of the total burden of diarrhoeal disease (Bartram 2003). Among children under 5 years in developing countries, diarrhoeal disease accounts for 17% of all deaths (WHO 2005a).

Health authorities generally accept that safe water plays an important role in preventing outbreaks of diarrhoeal disease. Accordingly, the most widely accepted guidelines for water quality allow no detectable level of harmful pathogens at the point of distribution (WHO 2004). However, in those settings in which diarrhoeal disease is endemic, much of the epidemiological evidence for increased health benefits following improvements in the quality of drinking water has been equivocal (Cairncross 1989). Since many of these same waterborne pathogens are also transmitted via ingestion of contaminated food and other beverages, by person-to-person contact, and by direct or indirect contact with faeces, improvements in water quality alone may not necessarily interrupt transmission (Briscoe 1984).

Two decades ago, Esrey and colleagues reviewed previous studies on the impact of environmental interventions on diarrhoea, and found improvements in water quality to be considerably less effective than those aimed at water quantity, accessibility and sanitation (Esrey 1985). The median reduction in diarrhoea from interventions to improve water quality was 16% (9 studies), compared to 22% (10) for sanitation, 25% (17) for water quantity and 37% (8) for water quality and availability. The review was subsequently updated and expanded to include hygiene interventions where the median reduction was 33% (6 studies) (Esrey 1991). Important as these reviews have been, there are reasons to consider anew the extent to which interventions to improve water quality impact diarrhoeal disease. First, recent evidence suggests that interventions (e.g., chlorination, filtration, solar disinfection, combined flocculation/disinfection) at the household level or other point of use are considerably more effective in preventing diarrhoea than conventional non-piped interventions at the source or point of distribution (e.g., protected wells, boreholes, communal tap stands) (Clasen & Cairncross 2004). These household-based interventions were described in a recent WELL Fact

Sheet (Clasen 2005). As Esrey's conclusions about the impact of water quality improvements were based exclusively on studies involving interventions at the point of distribution, they did not reflect interventions designed to ensure the microbial integrity of water at the point of use. Second, the Esrey reviews presented a number of methodological issues, including, i) the limited scope of the reviews' search strategies and the resulting number of studies included, ii) their reliance on observational studies rather than higher-quality interventional studies, iii) their simple use of the median (rather than meta-analysis) to pool study results, and (iv) their homologous treatment of studies despite important differences in settings, study populations, risk factors, case definitions, measures of effect, etc.

An update of Esrey's reviews addresses some of these shortcomings (Fewtrell 2005). By using subgroup analysis, for example, Fewtrell and colleagues found that interventions to improve water quality at the household level reduced the relative risk of diarrhoea by 35% (12 studies), compared to only slight, statistically non-significant improvement for source-based interventions. They also observed that interventions were effective even in the absence of improved sanitation (a new finding that challenged the view expressed by Esrey 1986 and VanDerslice 1995) and that there was apparently no cumulative effect from multiple environmental interventions. At the same time, this review also omitted a number of studies that would seem to have met the inclusion criteria and presented certain methodological issues, such as the inclusion of observational studies and studies where the outcome was other than endemic diarrhoea.

Cochrane review

A new systematic review, conducted under the auspices of the Cochrane Collaboration, provides perhaps the most complete evidence to date regarding the effectiveness of water quality interventions in preventing diarrhoea (Clasen 2006). This section summarizes the methods, results and conclusions of the review and includes 3 new studies published since the date of the review. Access to the complete review is available from the Collaboration (http://www.cochrane.org/index.htm).

1. Methods. The review employed a comprehensive search strategy in an attempt to identify all randomized and quasi-randomised controlled trials of interventions to improve microbiological water quality for the prevention of diarrhoeal disease, regardless of language, publication status or date of study. Participants were adults and children in settings where diarrhoeal disease is endemic. Interventions in response to epidemic diarrhoea were excluded. Where possible, meta-analysis - a statistical method used to combine studies of the same interventions and outcomes to arrive at a weighted "average" measure of effect - was used to arrive at an "average" measure of effectiveness for studies.[i] In order to try to explore the heterogeneity among study results, the review used sub-grouping based on the following: age (all versus children <5 years); point of intervention (source versus household); type of intervention (water quality only versus compound interventions including hygiene messages, improved sanitation, improved supply); compliance (< 50% versus ≥ 50%), and effectiveness under various water supply, sanitation, and water access conditions. For the latter, it used WHO/UNICEF Global Assessment definitions (WHO/UNICEF 2000).

2. Interventions. The interventions to improve the quality of drinking water were either at the water source or at the household level. Water source interventions included wells or bore holes with or without distribution to public tap stands. None included piped-in (reticulated) household connections. Household interventions comprised improved water storage or one of four approaches for treating water in the home: chlorination, solar disinfection, filtration or flocculation-disinfection. Apart from interventions such as solar disinfection and combined flocculation-disinfection using the PUR system®, there was substantial heterogeneity in the types of interventions. For example, filtration interventions varied by filter medium and pore size, and chlorination varied by chlorine source, dose, and contact time. In many, the water quality interventions were accompanied by hygiene education or other education beyond the use of the intervention itself. In some this was combined with improvement in sanitation facilities and promotion of re-hydration therapy. Among household interventions, water treatment was often combined with some form of improved storage, hygiene instruction, or both. In one trial the water quality intervention was combined with improved supply and sanitation. However, 14 trials consisted solely of water quality interventions, although ceramic filters and solar disinfection interventions may also improve storage.

3. Description of Studies. Thirty-three studies covering 41 trials and more than 56,000 participants were identified as a result of the search strategy. The intervention period ranged from 9.5 weeks to 5 years. All but two trials were conducted in developing countries, but the trials ranged significantly in setting (urban, peri-urban, rural, slum, refugee camp), ambient water quality, sanitation facilities and water supplies. Seventeen studies enrolled and presented results for all ages of participants, and ten included only children under five years or a subgroup thereof. Each trial investigated one or more intervention to improve the microbial quality of drinking water, either at the source or at the household level. Many trials also used other interventions, such as some type of supplemental hygiene education or instruction beyond the use of the intervention itself, in some cases combined with an improvement in sanitation facilities and oral rehydration therapy. Among household interventions, water treatment was often combined with some form of improved storage, hygiene instruction or both. Trials of source-based interventions assumed compliance; most trials of household-based interventions measured compliance indirectly. Methodologically, trials varied considerably in the manner in which they defined and collected data on diarrhoea and reported the effectiveness of the intervention (risk ratios, rate ratios, odds ratios, longitudinal prevalence ratios).

4. Results.

(a) Overall Effectiveness. Overall, water quality interventions were associated with marked reductions in occurrence of endemic diarrhoea. Most trials found substantial protective effects from the intervention, both among all age populations and for children under 5 years, though many trials were too small to render their results statistically significant. Despite the overall evidence of effectiveness, however, pooled estimates of effect among the trials were characterized by considerable heterogeneity - i.e. differences in results that are unlikely to be attributable solely to chance. Sub-grouping was therefore used in an attempt to explore these differences in results. As this heterogeneity was not explained by the different outcome measures used (risk ratios, rate ratios, odds ratios and longitudinal prevalence ratios), the pooled measures of effect reported below combine such measures of effect for simplicity.

(b) Source versus household. Trials of conventional, non-piped interventions to improve water at the source or point of distribution reduced the risk of diarrhoea by 0% to 55% among all age populations (6 trials) and 0% to 37% among children under 5 years (4 trials). As shown in Table 1, however, pooled estimates of 0.73 for all ages and 0.85 for children under 5 years were still highly heterogeneous. Moreover, the small number of clusters and the failure to take clustering into account in the analysis must raise doubts about the validity of such estimates. While trials of household-based interventions also demonstrated a wide range of effectiveness, pooled estimates of effect of 0.54 among 35 trials reporting results for all ages suggest such interventions to be more effective than those at the source. Once again, however, such estimates were characterized by substantial heterogeneity.

(c) Type of household intervention. Table 1 summarizes the pooled estimates of effect across all outcome measures for all age populations and for children under 5 years. In general, filtration was the most effective of household interventions. Excluding a recent filter study conducted in a high income study (Colford 2005) increases the estimate of effect and also removes the heterogeneity associated with the pooled estimate for both all ages and children under 5. Trials of household chlorination also generally reported the intervention to be protective against diarrhoea for both all ages and children under 5, though with a large number of studies reporting on this intervention, pooled estimates remained highly heterogeneous. Three trials of solar disinfection, on the other hand, were consistently protective, yielding homogenous pooled estimates for both all ages and children under 5. Household interventions using flocculation/disinfection were also effective in reducing diarrhoea (-52%), but the pooled effect as well as the strong heterogeneity were driven by a single study (Doocy 2004) which the Cochrane review identified as a possible outlier. Household chlorination.

Table 1. Summary of pooled estimates (random effects) for 41 randomized controlled trials and quasi-randomized controlled trials by point of intervention (source or household) and by type of household treatment (chlorination, filtration, solar disinfection, flocculation/disinfection)

Point and type of intervention	All ages		
	No. Trials	Pooled Estimate (and 95%CI)	Heterogeneity (Chi2)[ii]
Source treatment	6	0.73 (0.53 – 1.01)	P<0.0001
Household treatment	35	0.54 (0.40 - 0.73)	P<0.0001
Household chlorination	16	0.63 (0.52 - 0.76)	P<0.0001
Household filtration	8	0.45 (0.27 - 0.74)	P<0.0001
Household solar disinfection	3	0.68 (0.63 - 0.74)	P=0.85
Household flocculation/ disinfection	7	0.48 (0.20 - 1.19)	P<0.0001

(d) Compliance and other factors. For point-of-use interventions reporting compliance, the pooled estimate was significantly higher when the compliance with the intervention was 50% or above than for studies with a compliance below 50% suggesting that compliance might be a factor in causing heterogeneity among the point estimates. In contrast, the presence of improved water supply and improved sanitation had no apparent influence on the size of the point estimates. The fact that interventions to improve water quality reduced the occurrence of diarrhoea even in settings where water supplies and sanitation were not yet improved confirms Fewtrell's conclusions challenging conventional wisdom (Fewtrell, 2005). The review also found no evidence that water quality interventions are more effective when combined with other components (hygiene education, provision of a special vessel, improvements in water supplies or sanitation) than when implemented alone, another finding first reported by Fewtrell.

(e) Methodological quality. Trials of household-based interventions tended to be shorter in duration than source-based interventions, a factor that could bias these results. Moreover, all five point estimates from blinded studies showed the lowest reductions in diarrhoea (if any) in the respective subgroups, with four of them resulting in no effect on diarrhoea at all. This must give pause to any final conclusions about the impact of water quality interventions. On the other hand, the other pre-specified criteria of methodological quality (sequence generation, allocation concealment, loss to follow-up, RCT design vs. quasi RCT) had no major influence on the point estimates.

Conclusions

Interventions to improve the microbiological quality of drinking water, particularly at the household level, are more effective in preventing diarrhoea in endemic settings than previously reported. There is strong evidence that household interventions are as effective at preventing diarrhoea as other environmental approaches, such as improved sanitation, hygiene (handwashing with soap), and improved water supply (Curtis 2003; Fewtrell 2005). Thus they should be strongly encouraged, particularly because of evidence that they are cost-effective and that the target population may in fact be willing to pay for all or a portion of their cost. At the same time, however, substantial heterogeneity in pooled estimates of effect make clear that single estimates of the effectiveness of water quality interventions against endemic diarrhoea, appealing as they may be to policy makers, donors, and programme implementers, are not warranted by the evidence. Rigorous, longer-term, blinded trials should help clarify the circumstances under which water quality interventions may be most effective.

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(i) Such pooled estimates are expressed as relative risks with a corresponding 95% confidence interval (CI). Estimates of less than 1 mean that the intervention was associated with a reduction in the occurrence of diarrhea. To compare these estimates of effect with the percentage reductions reported by Esrey, subtract the measure of effect from 1 (ie a spooled estimate of 0.75 is equivalent to a 25% reduction (1-0.75).

(ii) In the Chi^2 test for heterogeneity, a low p-value (eg <0.10) suggests an actual underlying difference in effect between studies that is unlikely to be attributable to chance.

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