Interventions to improve water quality for preventing diarrhoea (Review)

Clasen TF, Roberts IG, Rabie T, Schmidt WP, Cairncross S

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[Intervention Review]

Interventions to improve water quality for preventing diarrhoea

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ABSTRACT

Background

Diarrhoeal diseases are a leading cause of mortality and morbidity, especially among young children in developing countries. While many of the infectious agents associated with diarrhoeal disease are potentially waterborne, the evidence for reducing diarrhoea in settings where it is endemic by improving the microbiological quality of drinking water has been equivocal.

Objectives

To assess the effectiveness of interventions to improve water quality for preventing diarrhoea.

Search methods

We searched the Cochrane Infectious Diseases Group Specialized Register (December 2005), CENTRAL (*The Cochrane Library* 2005, Issue 4), MEDLINE (December 2005), EMBASE (December 2005), and LILACS (December 2005). We also handsearched relevant conference proceedings, contacted researchers and organizations working in the field, and checked references from identified studies.

Selection criteria

Randomized and quasi-randomized controlled trials comparing interventions aimed at improving the microbiological quality of drinking water with no intervention in children and adults living in settings where diarrhoeal disease is endemic.

Data collection and analysis

Two authors independently assessed trial quality and extracted data. We used meta-analyses to estimate pooled measures of effect, where appropriate, and investigated potential sources of heterogeneity using subgroup analyses.

Main results

Thirty trials (including 38 independent comparisons) covering over 53,000 participants met the inclusion criteria. Differences between the trials limited the comparability of results and pooling by meta-analysis. In general, the evidence suggests that interventions to improve the microbiological quality of drinking water are effective in preventing diarrhoea both for populations of all ages and children less than five years old. Subgroup analyses suggest that household interventions are more effective in preventing diarrhoea than interventions

at the 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.

Authors' conclusions

Interventions to improve water quality are generally effective in preventing diarrhoea, and interventions to improve water quality at the household level are more effective than those at the source. Significant heterogeneity among the trials suggests that the actual level of effectiveness may depend on a variety of conditions that research to date cannot fully explain. Rigorous, blinded, multi-arm randomized controlled trials conducted over a longer duration in a variety if settings may help clarify the potential effectiveness.

PLAIN LANGUAGE SUMMARY

Interventions to improve water quality, particularly when implemented at the household level, are effective in preventing diarrhoea in settings where it is endemic

Diarrhoea is a major cause of death and disease, especially among young children in low-income countries. Loss of fluid (dehydration) is the major threat, though diarrhoea also reduces the absorption of the nutrients, causing poor growth in children, reduced resistance to infection, and potentially long-term gut disorders. This review examined trials of interventions to improve the microbiological quality of drinking water. These include conventional improvements at the water source (eg protected wells, bore holes, and stand posts) and point-of-use interventions at the household level (eg chlorination, filtration, solar disinfection, and combined flocculation and disinfection). The review covered 38 independent comparisons from 30 trials that involved more than 53,000 people. In general, such interventions were effective in reducing episodes of diarrhoea. Household interventions were more effective in preventing diarrhoea than those at the source. However, differences in the interventions and the settings in which they were introduced, as well as the methods and measurements of effect, limit the extent to which generalizations can be made. Further research, including blinded trials and longer-term assessments, is necessary to understand the full impact of these interventions.

BACKGROUND

Diarrhoeal disease, disease agents, and pathways

Diarrhoeal diseases kill an estimated 1.8 million people each year (WHO 2005). Among infectious diseases, diarrhoea ranks as the third leading cause of both mortality and morbidity (after respiratory infections and HIV/AIDS), placing it above tuberculosis and malaria. Young children are especially vulnerable, bearing 68% of the total burden of diarrhoeal disease (Bartram 2003). Among children less than five years, diarrhoea accounts for 17% of all deaths (United Nations 2005). For those infected with the human immunodeficiency virus (HIV) or who have developed acquired immunodeficiency syndrome (AIDS), diarrhoea can be prolonged, severe, and life-threatening (Hayes 2003).

Diarrhoea is a symptom complex characterized by stools of decreased consistency and increased number. The clinical symptoms and course of the disease vary greatly with the age, nutritional status, and immunocompetence of the patient, and the aetiological agent infecting the intestinal system and interfering with normal adsorption. Most cases resolve within a week, though a small percentage continue for two weeks or more and are characterized as 'persistent' diarrhoea. Dysentery is a diarrhoeal disease defined by the presence of blood in the liquid stools (Blaser 1995). About 35% of the deaths from diarrhoea in children less than five years old are believed to be attributable to acute non-dysenteric diarrhoea, with 45% from persistent diarrhoea and 20% from dysentery (Black 1993). Though epidemic diarrhoea such as cholera and shigellosis (bacillary dysentery) are well-known risks, particularly in emergency settings, their global health significance is small compared to endemic diarrhoea (Hunter 1997).

The immediate threat from diarrhoea is dehydration — a loss of fluids and electrolytes. Thus, the widespread promotion of oral rehydration therapy (ORT) has significantly reduced the case-fatality rate associated with the disease. Such improvements in case management, however, have not reduced morbidity, which is estimated at four billion cases annually (Kosek 2003). And since diarrhoeal diseases inhibit normal ingestion of foods and adsorption of nutrients, continued high morbidity is an important cause

of malnutrition, leading to impaired physical growth and cognitive function (Guerrant 1999), reduced resistance to infection (Baqui 1993), and potentially long-term gastrointestinal disorders (Schneider 1978).

The infectious agents associated with diarrhoeal disease are transmitted chiefly through the faecal-oral route (Byers 2001). A wide variety of bacterial, viral, and protozoan pathogens excreted in the faeces of humans and animals are known to cause diarrhoea. Among the most important of these are *Escherichia coli*, *Salmonella sp.*, *Shigella sp.*, *Campylobacter jejuni*, *Vibrio cholerae*, rotavirus, norovirus, *Giardia lamblia*, *Cryptosporidium sp.*, *and Entamoeba histolytica (*Leclerc 2002). The importance of individual pathogens varies between settings, seasons, and conditions. While bacterial agents as a group are believed to cause a majority of diarrhoeal disease in developing countries, viral and protozoan agents tend to cause more cases in developed countries (Hunter 1997).

Many of these diarrhoegenic agents are potentially waterborne — transmitted through the ingestion of contaminated water. However, most of the same pathogens are also transmitted by ingestion of contaminated food and other beverages, by person-to-person contact, and by direct or indirect contact with infected faeces. Because of this variety of pathways, interventions for the prevention of diarrhoeal disease not only include enhanced water quality but also steps to improve the proper disposal of human faeces (sanitation), increase the quantity and improve access to water (water supply), and promote hand washing and other hygiene practices within domestic and community settings (hygiene).

While water quality is also adversely impacted by chemical contaminants, the level of disease associated with metals, nitrates, organics, and other chemicals is usually small relative to infectious diarrhoea (WHO 2002). Other important diseases associated with drinking water, such as hepatitis A and E, poliomyelitis, gastroenteritis and typhoid fever, may not cause diarrhoea but are nevertheless associated with potentially waterborne microbes of faecal origin. For this reason, efforts to assess drinking water quality focus primarily on faecal pathogens (WHO 1993).

Because of the difficulty of monitoring water for the presence of all such agents, an indirect approach has been adopted where water is examined for indicator bacteria whose presence implies some degree of contamination. While there is controversy over the preferred indicator (Gleeson 1997), even those that accept the use of the coliform group use different target indicators (total coliforms, thermotolerant coliforms, *E. coli*) and different methods for assaying the level of indicator present (membrane filtration, multiple tube/most probable number) (Clesceri 1998).

Water quality and diarrhoea

Health authorities generally accept that microbiologically safe water plays an important role in preventing outbreaks of waterborne diseases (Hunter 1997). Accordingly, the most widely accepted guidelines for water quality allow no detectable level of harmful pathogens at the point of distribution (WHO 2004).

However, an estimated 1.1 billion people lack access to improved water supplies (WHO/UNICEF 2000). In settings that are not served by reliable water treatment and distribution systems, diarrhoeal disease is often endemic, that is, present or usually prevalent in the population at all times. In such settings much of the epidemiological evidence for increased health benefits following improvements in the quality of drinking water has been equivocal (Esrey 1986; Lindskog 1987; Cairncross 1989). Because of the multiple pathways of diarrheogenic infection, improvements in water quality alone may not necessarily interrupt transmission (Briscoe 1984). There are also questions about the methods and validity of studies designed to assess the health impact of such interventions (Blum 1983; Briscoe 1986; Imo State Team 1989).

As part of a larger evaluation of interventions for the control of diarrhoeal disease (Feachem 1983), in 1985, Esrey and colleagues reviewed studies to determine the health impact from improvements in water supplies and excreta disposal facilities (Esrey 1985). They updated the review in 1991 and expanded it to include studies addressing a variety of specific pathogens associated with poor water and sanitation (Esrey 1991a). For almost two decades, these reviews have provided guidance on the relative reduction in diarrhoeal disease that was believed to be possible through improvements in water quality, water quantity, sanitation, and hygiene. Important as these reviews have been, there are reasons to consider anew the extent to which interventions to improve water quality impact diarrhoeal disease. This is largely the result of new evidence from interventions at the household level (Clasen 2004a). However, even the league tables in Esrey's reviews comparing the relative impact of various types of environmental interventions, enticingly simple as they are, may obscure the potentially more important finding — the wide range among the studies in the measure of effect. In the case of water quality improvements, for example, Esrey and colleagues cited a median reduction in diarrhoea disease from nine studies of 16%, but a range in effect from 0% to 90%. Because Esrey and colleagues had a relatively small number of studies on water quality interventions, they could not use subgroup analysis to explore some of the potential reasons for this wide range of effect (Mintz 2001; Clasen 2004a).

An update of Esrey's reviews addresses some of these shortcomings (Fewtrell 2005). By using subgroup analysis, for example, Fewtrell and colleagues found important differences in effectiveness of the intervention based on the point of treatment (source versus household). 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), as well as the apparent absence of a cumulative effect from multiple environmental interventions. At the same time, with respect to interventions to improve water quality, the review omitted a number of studies that would seem to have met the inclusion criteria. Moreover, the review presented certain methodological issues,

such as the inclusion of observational studies (Ghannoum 1981; Sathe 1996; Iijima 2001), studies where the outcome was other than endemic diarrhoea (Ghannoum 1981; Iijima 2001; Colwell 2003), and the homologous treatment of studies with different measures of effect in their meta-analysis.

Water treatment

A number of interventions have been developed to improve the microbiological quality of water and can be grouped into four main categories.

- Physical removal of pathogens (eg filtration, adsorption, or sedimentation).
- Chemically treating water to kill or deactivate pathogens, most commonly with chlorine.
- Disinfection by heat (eg boiling or pasteurization) and ultraviolet (UV) radiation, either using the sun (solar disinfection) or an artificial UV lamp.
- Combination of these approaches (eg filtration or flocculation combined with disinfection).

Water quality can also be enhanced by protecting it from recontamination, for example, by residual disinfection, piped distribution, and safe storage. A combination approach is also common in conventional systems since individual approaches are not effective against the full range of microbial pathogens under all water conditions. Mechanical removal of viruses, for example, presents a challenge to most filters due to their submicron size. Similarly, certain encysted protozoa are resistant to chemical disinfection. The microbiological performance of these approaches may also be impacted by the temperature, pH, turbidity, chemical content, and other characteristics of the water.

In higher income countries, and in many urban settings worldwide, drinking water is treated centrally at the source of supply and is distributed to consumers through a network of pipes and household taps. However, such conventional systems involve significant upfront investment and continued maintenance. In remote and low-income settings, water quality may nevertheless be improved at the source by, for example, providing protected groundwater (springs, wells, and bore holes) or harvested rainwater as an alternative to surface sources (rivers and lakes) that are more susceptible to faecal contamination. Microbial water quality may also be improved at the source or other point in the distribution system by chlorination, filtration, and other means. Improving water at the source is also frequently accompanied by improvements in quantity or access to water by increasing the volume or frequency of water delivery or reducing the time spent in collecting water. This may result in significant benefits not only in health but also in economic and social welfare (Hutton 2004). For purposes of this review, any form of treatment at the water source or otherwise prior to the point of use will be referred to collectively as 'source' water treatment.

For those who have access to sufficient quantities of water but whose water is of poor microbiological quality, an alternative is to treat water at the household or other point of use. Such household treatment may minimize recontamination in the home, a well-known cause of water quality degradation (Wright 2004). At the same time, certain household water filters have been associated with adverse health impacts (Payment 1991a). A review commissioned by the World Health Organization (WHO) identified a wide variety of options for household-based water treatment and assessed the available evidence on their microbiological effectiveness, health impact, acceptability, affordability, sustainability, and scalability (Sobsey 2002). Research on the economics of such interventions also suggests that where adequate quantities of water are already available, household-based water treatment is among the most cost-beneficial and cost-effective approaches in preventing diarrhoeal disease (WHO 2002; Hutton 2004). There is also evidence that the vulnerable population to whom such household-based interventions have been targeted will pay all or a portion of the cost of household water treatment products (Clasen 2004c).

OBJECTIVES

To assess the effectiveness of interventions to improve water quality for preventing diarrhoea.

METHODS

Criteria for considering studies for this review

Types of studies

Randomized and quasi-randomized controlled trials. The unit of randomization may include individuals, families, households, communities, or other clusters.

Types of participants

Children and adults from settings where diarrhoeal disease is endemic.

Types of interventions

Intervention

Interventions aimed at improving the microbiological quality of drinking water, including steps to improve water quality by removing or inactivating microbiological pathogens (eg filtration, sedimentation, chemical treatment, heat, or UV radiation) and protecting the microbiological integrity of water prior to consumption (eg residual disinfection, protected distribution, or improved storage). An intervention that has shown elsewhere to reduce the quantity or pathogenicity of waterborne microbes is deemed, for purposes of the review, as an intervention to improve water quality, even if the particular study did not record such an improvement by microbiological examination.

We include interventions that combine improvements in water quality with other components such as improvements in water quantity or access, sanitation or hygiene. We have excluded studies of interventions designed to reduce diarrhoea through improvements in sanitation, hygiene, water quantity or water access, but which do not include a water quality improvement.

Control

People who are following their usual practices with respect to drinking water rather than the prescribed intervention, or who have received a different type of intervention. For example, where a protected well or borehole is introduced, controls may be consuming water that is obtained from the previously available sources, often untreated surface waters. In trials involving household water treatment, controls normally procure their water from the same source as the intervention group but have not received the intervention to treat water in the home. Appendix 3 provides details on the control groups for each study.

Types of outcome measures

Primary

- Diarrhoea episodes among individuals, whether or not confirmed by microbiological examination.

The WHO definition of diarrhoea is three or more loose or fluid stools (that take the shape of the container) in a 24-hour period (WHO 1993). We defined diarrhoea and an episode in accordance with the case definitions used in each trial.

Secondary

- Death.
- Adverse events.

Note: We excluded trials that had no clinical outcomes; for example, trials that only report on microbiological pathogens in the stool.

Search methods for identification of studies

We attempted to identify all relevant trials regardless of language or publication status (published, unpublished, in press, and in progress).

Databases

We searched the following databases using the search terms and strategy described in Appendix 1: Cochrane Infectious Diseases Group Specialized Register (December 2005); Cochrane Central Register of Controlled Trials (CENTRAL), published in *The Cochrane Library* (2005, Issue 4); MEDLINE (1966 to December 2005); EMBASE (1974 to December 2005); and LILACS (1982 to December 2005).

Conference proceedings

We searched the following conference proceedings of the following organizations for relevant abstracts: International Water Association (IWA) (1990 to December 2005); and Water, Engineering and Development Centre, Loughborough University, UK (WEDC) (1973 to December 2005).

Researchers and organizations

We contacted individual researchers working in the field and the following organizations for unpublished and ongoing trials: Water, Sanitation and Health Programme of the World Health Organization; World Bank Water and Sanitation Program; UNICEF Water, Environment and Sanitation (WES); and IRC International Water and Sanitation Centre; Foodborne and Diarrhoeal Diseases Branch, Division of Bacterial and Mycotic Diseases, Centers for Disease Control and Prevention (CDC); US Agency for International Development (USAID), including its Environmental Health Project (EHP); and the UK Department for International Development (DFID).

Reference lists

We checked the reference lists of all studies identified by the above methods.

Data collection and analysis

Selection of studies

Thomas Clasen (TC) and Tamer Rabie (TR) independently reviewed the titles and abstracts located in the searches and selected all potentially relevant studies. After obtaining the full articles, we

independently determined whether they met the inclusion criteria. Where we were unable to agree, we consulted Sandy Cairncross (SC) and arrived at a consensus. Those potentially relevant studies that were ultimately excluded are listed together with the reason for exclusion in the 'Characteristics of excluded studies'.

Data extraction and management

TC and TR used a pre-piloted form to extract and record the data described in Appendix 2, and TC attempted to contact authors to supply missing data. TC entered the extracted data into Review Manager 4.2.

TC and TR or Wolf-Peter Schmidt (WS) independently extracted, and where necessary calculated, the measure of effect of the intervention on diarrhoea. We extracted and reported the measure of effect as reported by the authors of each trial, whether it be risk ratios, rate ratios, odds ratios, longitudinal prevalence ratios, or means ratios. In this context, longitudinal prevalence is the number of days with diarrhoea divided by the number of days under observation (Morris 1996). In using these various measures of effect, we note the design effect in treating all such measures of effect as equivalent for common outcomes such as diarrhoea and the debate about methodologies for converting such measures of effect into a single measure (Zhang 1998; McNutt 2003). While it would be possible to calculate a single measure of effect for most trials based on the raw study data, we elected not to do so for the following reasons. Although all trials included in the review assess outcomes on an individual level, the unit of randomization is not the individual but a household, group of households, neighbourhood, or village. As described below, most included trials correct for this design effect by adjusting for the inter-cluster variance. Studies of diarrhoeal disease also frequently adjust for other common covariates, including age and repeated episodes within the same participant. Because these adjustments are generally deemed appropriate, a re-calculation of a measure of effect based on raw data would ignore these important adjustments. In order to avoid the homologous treatment of these different measures of effect, we include the pooled measures of effect in the comparisons only across trials reporting the same measure of effect. In the subgroup analyses, when there were too few trials with the same measure of effect, the comparisons show the forest plots only, with no calculation of pooled measures of effect.

As discussed more fully below, a number of the included trials had multiple intervention arms (eg treating water with bleach or with a flocculant and disinfectant) and compared two or more intervention groups against a single control group. In such cases, a meta-analysis that treats each intervention arm as a separate trial results in counting the control group once for each arm. This violates the important principle in the methodology of meta-analysis that each individual be included only once. However, for the reasons noted in the preceding paragraph, it was not possible to return to the raw data from the trials and thus correct for this by dividing the control group. Because this review is largely descriptive, we elected to include all trial arms but to note this problem. We note, however, that this has occurred and the meta-analysis result will be artificially precise.

Assessment of risk of bias in included studies

TC and TR independently assessed the risk of bias in the trials. We classified the generation of allocation sequence — the process used to generate the randomization list — as 'adequate' if the method used is described and the resulting sequences are unpredictable (eg computer-generated random numbers, table of random numbers, coin toss, drawing lots); 'unclear' if stated that the trial is randomized, but the method is not described; or 'inadequate' if sequences could be related to outcomes (eg according to case record number, date of birth, alternation). We classified allocation concealment — the process used to prevent foreknowledge of group assignment — as 'adequate' if the participants or the investigators enrolling participants cannot foresee assignment; 'unclear' if method is not described; or 'inadequate' if participants and investigators enrolling the participants can foresee their upcoming assignment. We classified blinding — whether the participant or outcome assessor is blind to the intervention group — as 'double blind' if the trial uses a placebo or double-dummy technique such that neither the participants nor the assessor knows whether or not the participants receive the intervention; 'single blind' if the participant or the assessor knows whether or not the participant receives the intervention; or 'open' if both participant and assessor know whether or not the participant receives the intervention. We classified the inclusion of randomized participants in the analysis as 'adequate' if 90% or more of all participants randomized to the trial were included in the analysis; 'unclear' if it is not clear what portion of participants randomized to the trial were included in the analysis; or 'inadequate' if less than 90% of all participants randomized to the trial were included in the analysis.

Additionally, we assessed quasi-randomized controlled trials using the following criteria:

1. Comparability of characteristics between intervention and control groups with respect to relevant baseline characteristics such as water quality, diarrhoeal morbidity, age, socioeconomic status, access to water, hygiene practices, and sanitation facilities. We classified this as 'adequate' if no substantial differences were present, 'unclear' if not reported or not known whether substantial differences exist, or 'inadequate' if one or more substantial difference exists.
2. Data collection for intervention and control groups at the same time. We classified this as 'adequate' if data were collected at similar points in time, 'unclear' if the relative timing was not reported or not clear from trial, or 'inadequate' if data were not collected at similar points in time.

Data synthesis

We entered the estimates of effect using the generic inverse variance method on the log scale (Higgins 2005a), and analysed the data using Review Manager 4.2.

We performed tests for heterogeneity by visually examining the forest plots and by using the chi-squared test for heterogeneity with a 10% level of statistical significance (Egger 2001) and the I^2 test for consistency (Higgins 2003). In accordance with our protocol, where there was evidence of heterogeneity we performed the following subgroup analyses: age (all ages versus children less than five years old); intervention point (source versus household); intervention type; water quality only versus compound interventions (ie with hygiene message, vessel, improved sanitation, improved supply); ambient water quality (ie water testing results at pre-intervention or of control group based on log scale levels of thermotolerant coliform per 100 mL); compliance with intervention (< 50% versus ≥ 50%), and effectiveness under various water supply, sanitation, and water access conditions. In the subgroup analyses based on water supply, we followed terminology used by the WHO/UNICEF Global Assessment (WHO/UNICEF 2000), using 'unimproved' to extend to unprotected wells or springs, vendor- or tanker-provided water or bottled water, and 'improved' to extend to household connections, public standpipes, boreholes, protected dug wells or springs, or rainwater collection; we categorized trials as 'unclear' with respect to water supply if they contained insufficient information. We used the same definitions from the WHO/UNICEF Global Assessment to classify sanitation conditions as 'improved' (connection to a public sewer or septic system, pour-flush latrine, simple pit latrine, ventilated improved pit latrine) or 'unimproved' (service or bucket latrines, public latrines, open latrines); where the necessary information was unclear or unreported, we categorized the sanitation facilities as 'unclear'. To subgroup trials based on access to water source, we used the classifications defined by The Sphere Project 2004, classifying access as 'sufficient' if a consistently available source was located within 500 metres, with queuing no more than 15 minutes and filling time for a 20 litres container no more than three minutes, 'insufficient' if any access failed any such criteria, and 'unclear' if such criteria was unreported or unclear. The quantity of water available to study participants was considered 'sufficient' if consisting of a minimum of 15 litres per person per day. We also used subgroup analyses to compare effectiveness based on methodological quality of the trials.

Where appropriate, we used meta-analyses to derive pooled estimates of effect. Because of the substantial heterogeneity in study results, we used the random-effects model (rather than the fixed-effect model) in such pooling. However, because of important differences in trial methodology, settings, and intervention types, we caution that such pooling of results may be misleading.

Finally, we produced a funnel plot to explore publication bias. We chose not to present results from statistical analysis of publication bias since they are not yet fully accepted as clear evidence of publication bias (Egger 2001).

RESULTS

Description of studies

See: Characteristics of included studies; Characteristics of excluded studies; Characteristics of studies awaiting classification.

Search results

Execution of the search strategy elicited 976 titles and abstracts, 939 from the databases and 37 from the other sources. These titles and abstracts were screened, and the full text articles of 68 studies were obtained for further assessment. Of these 68 studies, 30 met the review's inclusion criteria (*see* 'Characteristics of included studies'), 34 were excluded for the reasons given in the 'Characteristics of excluded studies', and four studies were identified after this review was prepared and are awaiting assesssment (see 'Characteristics of studies awaiting classification'). One of the trials that met the inclusion criteria had inadequate information on disease morbidity to include in the analysis (Torun 1982); we were unable to contact the trial authors and therefore only provide a description of this trial. Four of the included trials had two relevant intervention arms, one had three arms and one had four arms (described as i to iv), making a total of 38 discrete comparisons (excluding Torun 1982) from the 30 included trials.

Of the 30 included trials, 18 were published in journals, one in a book, two were included in PhD dissertations, and nine were unpublished as of 31 December 2004. All but three trials were reported in English; we worked from the original French and Spanish text for Messou 1997 and URL 1995-i, and from a translation for Xiao 1997. Most of the trials were conducted recently: 10 were completed or published in 2004 alone, and 16 since 2000; only three are from the 1980s and none before 1982.

Study design and length

Nineteen trials were randomized and 11 were quasi-randomized. Study design varied with the type of intervention: 19 of 23 trials of household interventions were randomized controlled trials; and the all seven trials of interventions at the water source or other point prior to distribution used quasi-randomization. Most randomized controlled trials used households as the unit of randomization, while some used neighbourhoods or other clusters of households (Chiller 2004; Doocy 2004; Luby 2004b-i), or villages or other communities (Austin 1993-i).

The intervention period ranged from 9.5 weeks to 3 years. The duration of the randomized controlled trials (median 5 months, range 9.5 weeks to 12 months) tended to be shorter than in the

quasi-randomized controlled trials (median 12 months, range 3 to 60 months). Trials of interventions at the point of distribution (used mainly in the quasi-randomized controlled trials) were also longer (median 36 months, range 12 months to 60 months) than those of point-of-use interventions (median 5 months, range 9.5 weeks to 12 months).

Most of the trials were undertaken to investigate the effectiveness of the intervention and not as an assessment of an ongoing programme.

Participants and settings

The 30 trials included at least 53,476 participants (the number of participants in Garrett 2004 was not reported). The 19 randomized controlled trials included at least 29,920 participants (median 607, range 112 to 6650), and the 11 quasi-randomized controlled trials included 23,556 participants (median 972, range 150 to 9600). The seven trials of point-of-distribution interventions included 18,336 participants (median 804, range 150 to 9600), while the 23 trials of point-of-use interventions included at least 35,140 participants (median 875, range 112 to 6650).

Fifteen trials enrolled and presented results for all ages of participants, and nine trials included only children under five years or a subgroup thereof (Alam 1989; Austin 1993-i; Mahfouz 1995; URL 1995-i; Handzel 1998; Gasana 2002; Jensen 2003; du Preez 2004; Garrett 2004). The other trials used alternative age criteria for participants, but we extracted data on children less than five years old where available.

Except for one trial that took place in the USA (Colford 2002), all trials were undertaken in developing countries: Bangladesh (Alam 1989; Aziz 1990; Handzel 1998), Bolivia (Quick 1999; Clasen 2004b; Clasen 2004c), Brazil (Kirchhoff 1985), China (Xiao 1997), Guatemala (Torun 1982; URL 1995-i; Reller 2003-i; Chiller 2004), Gambia (Austin 1993-i), Ivory Coast (Messou 1997), Liberia (Doocy 2004), Kenya (Conroy 1996; Conroy 1999; Crump 2004-i; Garrett 2004), Malawi (Roberts 2001), Pakistan (Jensen 2003; Luby 2004a-i; Luby 2004b-i), Rwanda (Gasana 2002), Saudi Arabia (Mahfouz 1995), South Africa/Zimbabwe (du Preez 2004), Uganda (Lule 2005), Uzbekistan (Semenza 1998), and Zambia (Quick 2002). Two trials took place in urban settings (Semenza 1998; Colford 2002), two in peri-urban settings (Quick 1999; Quick 2002), three in urban informal or squatter settlements (Handzel 1998; Luby 2004a-i; Luby 2004b-i), two in camps for refugees or displaced persons (Roberts 2001; Doocy 2004), one in multiple settings (URL 1995-i), and the others in villages or other rural settings.

Primary drinking water supply and sanitation facilities (Appendix 3)

The primary drinking water supply before the intervention, and which was continued as the control in the trials, was 'unimproved' in 18 trials, 'improved' in 8 trials, and 'unclear' or not reported in three trials. Sanitation facilities in trial settings were 'improved' in eight trials, 'unimproved' in nine trials, and 'unclear' or unreported in 13 trials. Access to a water source was deemed 'sufficient' in eight trials and 'unclear' or unreported in the remainder; no trials reported a setting that provided insufficient access to a water source. The quantity of water available to study participants was considered 'sufficient' in seven trials, 'insufficient' in three trials, and 'unclear' in 20 trials.

Twenty-three of the trials measured the microbial contamination of the drinking water before the introduction of the intervention as an indication of the ambient risk and the microbiological quality of the water consumed by the control group. Eighteen measured colony-forming units (CFU) of thermotolerant coliforms, faecal coliforms, or *E. coli*. Other trials measured the frequency of samples containing such bacteria, or the CFU of total coliforms or other indicators of microbial contamination. None continually measured the microbiological performance of their interventions against the full range of bacterial, viral, and protozoan pathogens known to cause diarrhoea.

Interventions (Appendix 4)

Each trial investigated an intervention to improve the microbial quality of drinking water, either at the source or at the household level. The source-based interventions were improved wells or bore holes (Alam 1989; Aziz 1990; Xiao 1997), improved sources and distribution to public tap stands (Torun 1982; Gasana 2002; Jensen 2003), and one an unspecified improvement leading to a public tap stand (Messou 1997); none involved piped-in (reticulated) household connections. We grouped the point-of-use interventions around improved storage (Roberts 2001) or one of four basic technologies for treating water in the home: chlorination (Kirchhoff 1985; Austin 1993-i; Mahfouz 1995; Handzel 1998; Semenza 1998; Quick 1999; Quick 2002; Reller 2003-i; Crump 2004-i; Garrett 2004; Luby 2004a-i; Luby 2004b-i; Lule 2005); solar disinfection (Conroy 1996; Conroy 1999); filtration (URL 1995-i; Colford 2002; Clasen 2004b; Clasen 2004c; du Preez 2004); and combination flocculation-disinfection using the Procter & Gamble PUR(r) product (Reller 2003-i; Chiller 2004; Crump 2004-ii; Luby 2004b-i). It must be noted, however, that apart from singular interventions such as solar disinfection and PUR, these groups are not homologous; for example, filtration interventions varied by filter medium and pore size, and chlorination varied by chlorine source, dose, and contact time.

Many trials also used other interventions, such as some type of supplemental hygiene education or instruction beyond the use of the intervention itself (Alam 1989; Chiller 2004; Crump 2004-i; Luby 2004b-ii), in some cases combined with an improvement in sanitation facilities (Aziz 1990; Messou 1997; Xiao 1997) and oral rehydration therapy (Messou 1997). Among point-of-use interventions, household-based water treatment was often combined

with some form of improved storage (Doocy 2004; Luby 2004a-i; Luby 2004b-i; Lule 2005), hygiene support for the intervention (URL 1995-ii; Chiller 2004), or both (Handzel 1998; Semenza 1998; Quick 1999; Quick 2002); and in one case together with improved supply and sanitation (Garrett 2004). In only one multiple-intervention arm trial did investigators establish different intervention groups with and without hygiene or other non-water improvement steps in order to isolate the impact of water quality (URL 1995-i; URL 1995-ii). The remaining 14 trials did not use other material interventions, although the ceramic filters (Clasen 2004b; Clasen 2004c; du Preez 2004) and solar disinfection (Conroy 1996; Conroy 1999) used in some may have also improved storage.

Seven trials did not report actually having measured microbial water quality (Alam 1989; Aziz 1990; Conroy 1999; Garrett 2004; Luby 2004b-i; Messou 1997; Xiao 1997). Thus, it cannot be concluded definitively that the interventions investigated in these trials actually resulted in an improvement in drinking water quality. Nevertheless, in accordance with the decision expressed in the protocol for this review — that interventions such as protection of wells or springs that have generally been shown to improve water quality will be included even without measuring the same — they are included in this review. Among the seven trials investigating interventions to improve water quality at the point of distribution, only three tested microbial water quality (Torun 1982; Gasana 2002; Jensen 2003). Because these tests were at the source or point of distribution and not the point of use, their results do not reflect possible post-collection contamination.

Compliance with the intervention (ie consumption of the improved quality water) is an important factor in assessing potential impact of the intervention. Nevertheless, none of the trials assessed this directly. Trials of source water interventions tended to assume compliance based on the fact that the primary water supply had been improved. Some trials of household water treatment undertook indirect assessments of compliance by measuring residual chlorine levels in stored household water (Austin 1993-i; Mahfouz 1995; Handzel 1998; Semenza 1998; Quick 1999; Quick 2002; Reller 2003-i; Chiller 2004; Crump 2004-i; Doocy 2004; Garrett 2004), comparing microbial water quality of intervention and control households (Kirchhoff 1985; Chiller 2004; Clasen 2004b; Clasen 2004c; Crump 2004-i), conducting periodic or post-study surveys (Reller 2003-i; Chiller 2004; Doocy 2004), or counting the amount of intervention product used (Reller 2003-i). Most other trials measured compliance only by occasional observation, while seven did not report on compliance (Torun 1982; Alam 1989; Xiao 1997; Conroy 1999; Gasana 2002; Luby 2004a-i; Lule 2005). The trials of chorine residuals reported compliance ranging from a high of 95% (Doocy 2004) to a low of 27% (Reller 2003-i). Even among these trials, however, investigators acknowledged that it was not possible to know to what extent intervention group participants actually consumed treated water or avoided consuming untreated water. None of the trials reported on differences in outcome based on level of compliance within that trial's population itself.

Most interventions at the point of distribution also involved improvements in supply that probably also increased water quantity or access, or both, though none of these trials reported any measurements. Such improvements may be a separate and possibly more significant contributor to health than water quality.

Generally the controls continued to use their pre-trial water supply and treatment practices. In the two trials of solar disinfection (Conroy 1996; Conroy 1999), however, both intervention and control households received plastic bottles for storing their drinking water. The intervention group was instructed to place the bottles on roofs to expose them to the sun, while the control group was told to keep the filled bottles indoors. The investigator did not explain whether this was designed to assist in blinding, to comply with ethics conditions, or had some other objective. It is important to note that since improved storage even in the absence of treatment has been shown to improve microbial water quality (Wright 2004) and prevent diarrhoea (Roberts 2001), the comparison between the intervention and control in these trials may understate the effectiveness of the intervention when compared to the controls following customary water handling practices.

Outcome measures

The trials' main outcome measure was diarrhoeal disease, but different methods were used to define, assess, and report it. Eighteen trials used the WHO's definition of diarrhoea, while the other trials used the mother's or other respondent's definition (Austin 1993-i; Messou 1997; Gasana 2002; Reller 2003-i; Chiller 2004; Crump 2004-i), watery diarrhoea as a component of gastroenteritis (Colford 2002), the local term (Conroy 1996; Conroy 1999), or a "significant change in bowel habits towards decreased consistency or increased frequency" (Kirchhoff 1985). Two trials did not report the case definition used for diarrhoea (Torun 1982; Xiao 1997).

The method of diarrhoea surveillance and assessment also varied. In most cases, participants were visited on a periodic basis, either weekly (13 trials), biweekly (five trials), or more infrequently (four trials), and were asked to recall and report on cases of diarrhoea during a previous period, usually seven days (16 trials) or 14 days (six trials). The other trials asked each participant or a designated householder to keep a log or record to indicate days with or without diarrhoea (Austin 1993-i; Colford 2002; du Preez 2004), procured data on diarrhoea from family records and disease registries (Mahfouz 1995), or used paediatricians to assess the participants during regular medical checkups (Gasana 2002). Only one trial did not report the method (Xiao 1997).

Using these data, investigators reported diarrhoeal disease using one or more of the following epidemiological measures of disease frequency: incidence (19 trials); period prevalence (six trials); and longitudinal prevalence (six trials). The trials also reported other

measures of disease, including incidence of persistent diarrhoea (Chiller 2004), gastrointestinal illness, including specific symptoms thereof (Colford 2002), incidence or prevalence of bloody diarrhoea (Doocy 2004; du Preez 2004), and days of work or school lost due to diarrhoea (Lule 2005). Two trials also reported on death associated with diarrhoea (Messou 1997; Crump 2004-i). None reported on other adverse outcomes.

Data presentation

The different means of assessing and reporting diarrhoea led to a variety of effect measures, including risk ratios (10 trials), rate ratios (5 trials), longitudinal prevalence ratios (seven trials), odds ratios (six trials), and a ratio of means (Quick 1999). As noted above, Torun 1982 did not include sufficient information on diarrhoea to estimate the measure of effect.

Results were presented for the different age groups: 10 trials presented results both for children under five years (or a subgroup thereof) and for all ages or older age groups (Kirchhoff 1985; Semenza 1998; Quick 1999; Roberts 2001; Reller 2003-i; Chiller 2004; Clasen 2004b; Clasen 2004c; Crump 2004-i; Doocy 2004); nine presented results only for all ages or older age groups (Aziz 1990; Conroy 1996; Xiao 1997; Conroy 1999; Colford 2002; Quick 2002; Luby 2004a-i; Luby 2004b-i; Lule 2005); and 10 presented results only for children under five years (or a subgroup thereof) (Alam 1989; Austin 1993-i; Mahfouz 1995; URL 1995-i; Messou 1997; Handzel 1998; Gasana 2002; Jensen 2003; du Preez 2004; Garrett 2004).

Most of the trials adjusted raw data to account for possible covariates, including age (Conroy 1996; Handzel 1998; Conroy 1999; Reller 2003-i; Clasen 2004b; Clasen 2004c; Luby 2004a-i; Lule 2005), seasonality (Aziz 1990; Messou 1997; Jensen 2003; Reller 2003-i), sex (Conroy 1996; Conroy 1999; Reller 2003-i), sanitation or hygiene practices (Alam 1989; Jensen 2003; Lule 2005), area of residence (Conroy 1996; Conroy 1999), household income or proxies thereof (Handzel 1998; Reller 2003-i), education (Alam 1989), age and occupation of the head of household (Alam 1989; Handzel 1998), maternal literacy (Reller 2003-i), number of participants in the household (Semenza 1998) or absent there from (Aziz 1990), or other variables associated with the household environment and participant behaviour (Roberts 2001). Most trials of interventions at the household level also used statistical methods to adjust their results for repeated episodes of diarrhoea by the same participant (Quick 1999; Quick 2002; Clasen 2004b; Clasen 2004c; Lule 2005) or for clustering within the household – the four trials that did not adjust for clustering may receive excess weight in meta-analysis due to artificial precision (Kirchhoff 1985; Austin 1993-i; Mahfouz 1995; URL 1995-i).

Risk of bias in included studies

Randomized controlled trials (Table 1)

The allocation sequence was generated using an 'adequate' method in 12 of the 19 trials, 'inadequate' in four, and 'unclear' in three. The method of allocation concealment was 'adequate' in 15 trials and 'inadequate' in the other four. Only three trials used blinding (Kirchhoff 1985; Austin 1993-i; Colford 2002;); the others followed an open design. One of the principal objectives of Colford 2002 was to assess the effectiveness of its blinding methodology; it therefore provides the most comprehensive analysis of these issues. Colford 2002 used a sham water filter that even the installer could not know was not effective. Austin 1993-i and Kirchhoff 1985, which were assessing the effectiveness of home-based chlorination, provided placebos to control households. While one trial suggests ethical and other reasons for its decision not to blind the trial (Clasen 2004c), it is not clear why so few of the household-based interventions failed to use a placebo control.

Twelve of the trials used 'adequate' methods to generate the allocation sequence and conceal allocation, and eight of these were also 'adequate' for the inclusion of all randomized participants. Only Colford 2002 met all criteria for methodological quality including blinding, though Austin 1993-i failed only by falling 0.6% short of the follow-up criterion.

Quasi-randomized controlled trials (Table 2)

Of the 11 trials, eight were 'adequate' for the comparability of characteristics between intervention and control groups, two were 'inadequate', and one was 'unclear'. Except for Gasana 2002, which was 'unclear', all the trials met the contemporaneousness of data collection criterion.

Note regarding comparisons of randomized and quasi-randomized controlled trials

The methods of this review established separate and customary criteria for assessing the risk of bias in trials. While these criteria may be used for purposes of comparing the risk of bias in trials of the same design, we urge caution with respect to comparing randomized with quasi-randomized controlled trials. A randomized controlled trial that fails to meet certain quality criteria may nevertheless be of greater methodological rigour than one using quasi-randomization that meets its applicable criteria.

Effects of interventions

Note regarding meta-analysis

Some of the meta-analyses include the following trials, which, by comparing multiple intervention groups with a single control

group, count the controls more than once in violation of the principles of meta-analysis and provide overly precise confidence intervals widths around pooled estimates: URL 1995-i; Reller 2003-i; Crump 2004-i; Luby 2004a-i; and Luby 2004b-i.

1. Diarrhoea episodes

1.1. Overall effectiveness

The data suggest that interventions to improve the microbial quality of water are effective in preventing diarrhoea among people of all ages and young children. However, not all pooled measures of effect are statistically meaningful, and most results are characterized by substantial heterogeneity. None of the 38 trials found a statistically significant increase in diarrhoea with the intervention. There were statistically significantly fewer diarrhoea episodes with the intervention when the data were pooled using rate ratios (all ages 0.73, 95% CI 0.63 to 0.85, 10 trials, Analysis 1.1.1; under fives 0.78, 95% CI 0.65 to 0.94, 6 trials, Analysis 1.2.1) and risk ratios (all ages 0.45, 95% CI 0.33 to 0.62, 7 trials, Analysis 2.1.1; under fives 0.54, 95% CI 0.43 to 0.69, 5 trials, Analysis 2.2.1). Both analyses included a comparison of a single control arm against two interventions from one trial, Luby 2004a-i in Analysis 1.1 (all ages) and URL 1995-i in Analysis 2.1 and Analysis 2.2 (all ages and children under five, respectively), which means that the statistical significance of these analyses must be interpreted with caution.

There was no statistically significant difference in the pooled longitudinal prevalence ratios between the water treatments and the controls for the trials reporting data for all ages (11 trials, Analysis 3.1.1) or children less than five years old (11 trials, Analysis 3.2.1). However, excluding Doocy 2004, which reported a very large and statistically significant effect for both age groups and is a possible outlier, the results favoured the intervention both for all ages (0.68, 95% CI 0.55 to 0.84, 10 trials) and the under fives (0.74, 95% CI 0.65 to 0.85, 10 trials).

The pooled odds ratios were statistically significantly in favour of the water treatment (at the household level; no trials using this statistical outcome investigated treatment at source) for nine trials reporting data for all ages (0.68, 95% CI 0.59 to 0.79, Analysis 4.1.1) and the six trials reporting data for children under five years (0.70, 95% CI 0.50 to 0.99, Analysis 4.2.1). Caution should be taken when interpreting the statistical significance of both results because a single control arm from one trial, Reller 2003-i, is compared against four interventions.

Only one trial reported means ratios. It reported statistically significant results in favour of household water treatment for people of all ages (0.57, 95% CI 0.52 to 0.62, Analysis 5.1) and for children under five years (0.75, 95% CI 0.65 to 0.86, Analysis 5.2).

1.2. Exploration of heterogeneity: subgroup analyses

1.2.1. Interventions at the water source

The six trials reporting on interventions at the water source used three different effect measures. There was no difference in diarrhoea episodes when measured using rate ratios (all ages, 4 trials, Analysis 1.1.2; under fives, 3 trials, Analysis 1.2.2). The interventions were favoured in the trials that reported a risk ratio (all ages 0.45, 95% CI 0.43 to 0.47, 1 trial, Analysis 2.1.2) or a longitudinal prevalence ratio (all ages 0.56, 95% CI 0.37 to 0.84, 1 trial, Analysis 3.1.2; under fives 0.63, 95% CI 0.49 to 0.81, 1 trial, Analysis 3.2.2).

1.2.3. Interventions in the household

Thirty-two trials reported on household-based interventions, which included chlorination, filtration, solar disinfection, combined flocculation and disinfection, and improved storage. Overall, the household interventions significantly reduced diarrhoea episodes amongst people of all ages and in children under five years as measured with rate ratios (all ages 0.56, 95% CI 0.42 to 0.74, 6 trials, Analysis 1.1.3; under fives 0.42, 95% CI 0.19 to 0.95, 3 trials, Analysis 1.2.3), risk ratios (all ages 0.43, 95% CI 0.27 to 0.70, 6 trials, Analysis 2.1.3; under fives 0.54, 95% CI 0.43 to 0.69, 5 trials, Analysis 2.2.2), odds ratios (all ages 0.68, 95% CI 0.59 to 0.79, 9 trials, Analysis 4.1.2; under fives 0.70, 95% CI 0.50 to 0.99, 6 trials, Analysis 4.2.2), and means ratios (all ages 0.57, 95% CI 0.52 to 0.62, 1 trial, Analysis 5.1; under fives 0.75, 95% CI 0.65 to 0.86, 1 trial, Analysis 5.2). The longitudinal prevalence ratios (Analysis 3.1.3 and Analysis 3.2.3) only reached statistical significance when a possible outlier, Doocy 2004, was excluded from the analysis for all age groups (0.70, 95% CI 0.56 to 0.88, 9 trials) and for the under fives (0.76, 95% CI 0.66 to 0.88, 9 trials). As mentioned above, caution must be taken when interpreting these results because some of the analyses use the control arms more than once (URL 1995-i; Reller 2003-i; Luby 2004a-i).

Household chlorination

Sixteen trials reported on household-based chlorination, and the overall results varied with the measure of effect and age group. Chlorination was statistically significantly better than the control among all age groups when measured using rate ratios (4 trials, Analysis 1.1.4), though this pooled estimate uses the control arm of one trial twice (Luby 2004a-i), risk ratios (3 trials, Analysis 2.1.4), and means ratio (1 trial, Analysis 5.1.3); and children under five using risk ratios (2 trials, Analysis 2.2.3) and means ratio (1 trial, Analysis 5.2.3). There was no statistically significant advantage for people all ages when measured with longitudinal prevalence ratios (5 trials, Analysis 3.1.4) and odds ratios (3 trials, Analysis 4.1.3);

or for children under five as measured with rate ratios (2 trials, Analysis 1.2.4), longitudinal prevalence ratios (5 trials, Analysis 3.2.4), and odds ratios (2 trials, Analysis 4.2.3).

Household filtration

Of the six trials that reported on household-based filtration, two used rate ratios (Analysis 1.1.5 and Analysis 1.2.5), two arms of a single trial used risk ratios (single control group used twice in Analysis 2.1.5 and Analysis 2.2.4; URL 1995-i), and two used odds ratios (Analysis 4.1.4 and Analysis 4.2.4). All estimates for people of all ages and children under five were statistically significantly in favour of the intervention.

Household solar disinfection

Solar disinfection was statistically significantly better than the control for reducing diarrhoea episodes in people of all ages (2 trials, odds ratios, Analysis 4.1.5). Since the controls also received bottles that may have provided some protection against diarrhoea by means of improved storage, the measure of effect in these trials may understate the effectiveness of the intervention.

Household combined flocculation and disinfection

Seven trials reported on the effectiveness of combined flocculation and disinfection. Pooled estimates of the five trials reporting longitudinal prevalence ratios found no statistically significant difference in the number of diarrhoea episodes compared with the control, either for people of all ages (Analysis 3.1.5) or for children under five (Analysis 3.2.5). Excluding Doocy 2004, which has been identified as a possible outlier, changes the effect to become statistically significantly in favour of the intervention, both for all ages (0.60, 95% CI 0.43 to 0.83) and for the under fives (0.66, 95% CI 0.43 to 0.76), though the meta-analyses use the control arm of Luby 2004b-i twice. The two trials using odds ratios reported a statistically significant reduction in diarrhoea episodes for people of all ages (Analysis 4.1.6) and not the under fives (Analysis 4.2.5), though these estimates must once again be interpreted with caution as they are arms of a single trial with only one control group (Reller 2003-i).

Household improved storage

The one trial that involved improved storage found no significant difference in diarrhoea episodes, measured with risk ratios, for people of all ages (Analysis 2.1.6) or the under fives (Analysis 2.2.5) (Roberts 2001).

1.2.4. Compliance with household interventions

We divided the trials reporting on compliance between those reporting compliance of less than 50% and 50% or greater. In both the trials reporting risk ratios (Analysis 6.1) and those reporting odds ratios (Analysis 7.1), the effect of the intervention was stronger in the group with higher compliance. This was especially true for trials reporting odds ratios (< 50% 0.80, 95% CI 0.71 to 0.89, 4 trials, Analysis 7.1.1; ≥ 50% 0.40, 95% CI 0.28 to 0.57, 3 trials, Analysis 7.1.2). This must be interpreted with caution since the Reller 2003 trial compares a single control arm against four interventions.

Compliance could help explain the disparity in results between the same interventions in different circumstances. For example, for the combined flocculant and disinfectant product, Doocy 2004 reported a longitudinal prevalence ratio of 0.12 (95% CI 0.11 to 0.13) in a programme where compliance was 95%, while Reller 2003-i reported an odds ratio of 0.79 (95% CI 0.63 to 0.99) from a programme where compliance reached only 27%. At the same time, it cannot be the only explanation: Crump 2004-i reported a longitudinal prevalence ratio of 0.83 (95% CI 0.67 to 1.03) from an intervention in which compliance was also fairly high (86%).

1.2.5. Ambient water quality

In these comparisons (Analysis 8.1 to Analysis 11.1), we treated each of the indicators of microbial water quality (coliforms or a subset thereof) homologously and grouped them on a log scale that corresponds to the WHO risk category (WHO 1993) that ranges from 'complying' (0 CFU/100 mL) to 'high or very high risk' (> 100 CFU/100 mL). The results provide little evidence that the effectiveness of the interventions is associated with ambient water quality.

1.2.6. Water quantity and access

Few trials used the same measure of effect for reporting on water quantity. Using longitudinal prevalence ratios (Analysis 12.1), there was no statistically significant difference in the effectiveness of the interventions based where water was reported to be 'sufficient' (1 trial) or 'insufficient' (4 trials) according to established criteria (Sphere Project 2004). No trials reported access to a water source to be 'insufficient'.

1.2.7. Water supply

Pooling of results based on 'improved' or 'unimproved' water supply levels, according to established criteria (WHO/UNICEF 2000), was possible for nine trials reporting rate ratios (Analysis 13.1), six trials reporting risk ratios (Analysis 14.1), 11 trials reporting longitudinal prevalence ratios (Analysis 15.1), and nine trials reporting odds ratios (Analysis 16.1). Overall, these results provide little evidence that the effectiveness of the interventions

is associated with water supply level, particularly when excluding Doocy 2004, the possible outlier. It is noteworthy, however, that the pooled estimates show a statistically significant effect in favour of the interventions even in settings without improved water supply.

1.2.8. Sanitation

Some trials reported on sanitation levels as 'improved' or 'unimproved' using the established criteria (WHO/UNICEF 2000). We were able to pool these results for seven trials reporting rate ratios (Analysis 17.1), four trials reporting risk ratios (Analysis 18.1), and seven trials reporting longitudinal prevalence ratios (Analysis 19.1). These results provide little evidence that the effectiveness of the interventions is associated with sanitation level. At the same time, they suggest that the interventions are effective in preventing diarrhoeal disease even in settings in which sanitation has not yet been improved, even when excluding Doocy 2004, a possible outlier that is responsible for much of the heterogeneity in the results of trials reporting longitudinal prevalence ratios.

1.2.9. Water quality only versus compound environmental interventions

In general, there is no clear evidence that water quality interventions are more effective in preventing diarrhoea when combined with any of the additional interventions: hygiene promotion; separate vessel for water treatment or storage, or both; or improvements in sanitation or water supply (Analyses 20 to 23).

1.2.10. Trial methodological quality (risk of bias)

In the randomized controlled trials (Analysis 24 to Analysis 27), the interventions were generally more effective among the higher quality trials with respect to allocation sequence, allocation concealment, and inclusion of randomized participants in the analysis. Only four trials used double blinding (Kirchhoff 1985; Austin 1993-i; Austin 1993-ii; Colford 2002), and, significantly, none of them (and hence, none of the pooled estimates thereof) found a statistically significant protective effect from the water quality intervention.

In the quasi-randomized controlled trials (Analyses 28 and 29), the interventions appear more effective amongst those that met the review's criteria for methodological quality. However, since few trials actually failed such criteria, these subgroup analyses did not suggest that study quality is an explanation of the heterogeneity of results.

1.2.11. Potential outlier

Forest plots of the measures of effect from all 38 trials suggest at least one possible outlier. By definition, an outlier is an observation that differs so widely from the rest of the data as to suggest a possible error or that the observation comes from a differently population (Last 2001). Doocy 2004, a randomized controlled trial that lasted 12 weeks, studied a combined flocculant and disinfectant water treatment for displaced persons living in temporary shelters in a Liberian camp. The intervention was exceptionally protective (RR 0.12, 95% CI 0.11 to 0.13). While data supplied suggest the trial to be well designed and to meet this review's quality criteria, it has not yet been published and thus subjected to peer review. It seems possible that the population and conditions presented in the camp may not be strictly comparable with those of the other studies comprising this review.

2. Death

Two trials reported on death. Crump 2004-i reported a risk ratio of 0.53 (P = 0.052) for the flocculant and disinfectant arm of a household-based water treatment and 0.61(P = 0.108) for the disinfectant-only arm. No physical or verbal autopsies were performed, and no association between deaths and diarrhoea was established. Messou 1997, which involved a combination of source water improvement with an oral rehydration intervention and hygiene instruction, reported an 85% reduction (from 27% to 4%) in the proportion of deaths related to diarrhoea in the villages with the intervention (P = 0.04) compared with no reduction in control villages. That trial also reported an 85% reduction (from 5.3% to 0.8%) in the death rate associated with diarrhoea morbidity among intervention villages (P = 0.04) with no correspondingly decline in control villages. We emphasize that neither trial was primarily designed to investigate the impact of the intervention on death, and that such studies may require important differences in study design, sample size, and other parameters.

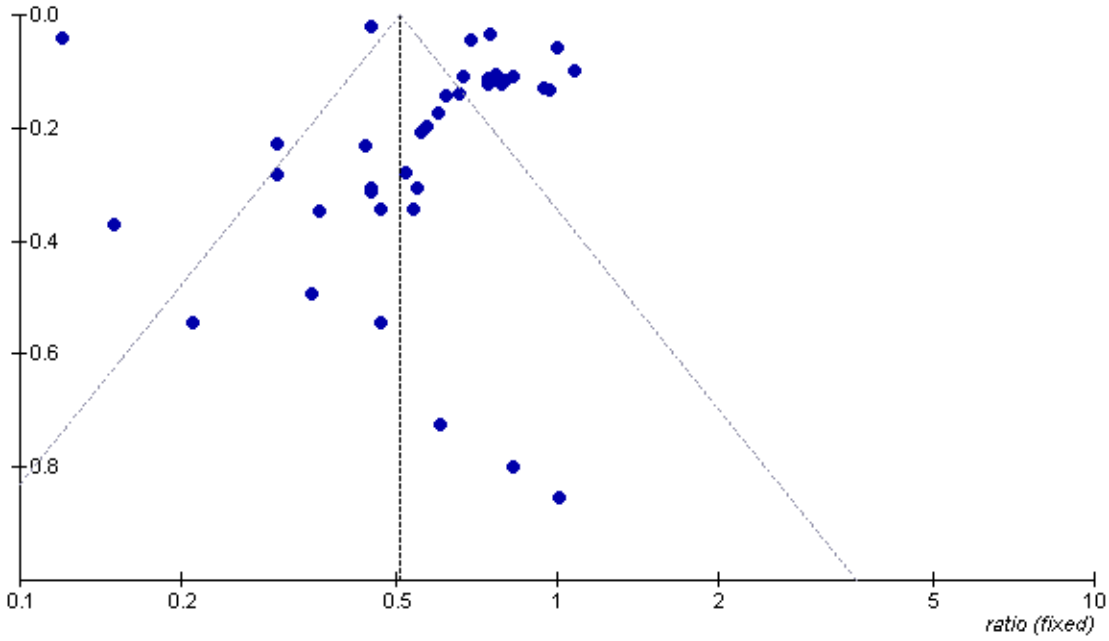
3. Adverse events

No trial reported adverse events from the interventions.

4. Publication bias

Figure 1 presents a funnel plot of the estimate of effect of the trials and the standard error of such estimate of effect (reflecting the study size). The asymmetrical shape of such funnel plot is suggestive of publication bias. It is noted, however, that funnel plot asymmetry may also be due to clinical and methodological heterogeneity. Since we found substantial evidence of such heterogeneity, we cannot conclude that the funnel plot demonstrates evidence of publication bias in this case.

Figure 1. Funnel plot to explore publication bias



5. Sensitivity analysis

We endeavoured to conduct a sensitivity analysis to explore the effect of combining randomized controlled trials and quasi-randomized controlled trials in a meta-analysis and to investigate the effect of including trials that were not adjusted for clustering. However, as all source-based interventions were investigated in the quasi-randomized controlled trials, it was not possible to compare the trials on the basis of point of intervention or type of intervention if the quasi-randomized controlled trials are excluded. Comparisons based on subgroups do not include pooled estimates. Similarly, while 19 of 24 trials involving household-based interventions adjusted for clustering, none of the six trials with analysable data from source interventions did so. Accordingly, no comparison on this criterion was possible.

DISCUSSION

This review assesses the impact of interventions to improve microbial water quality on diarrhoeal disease. Thirty trials covering 38 interventions and more than 53,000 participants met the review's inclusion criteria. Substantial clinical and methodological heterogeneity among the trials allowed only limited pooling of the results in meta-analyses. Our focus, therefore, has been largely descriptive. Where appropriate, however, we have tried to interpret the evidence, while at the same time noting some of the issues that necessarily limit this.

Effectiveness

Interventions to improve the microbiological quality of drinking water are protective against diarrhoea, both for people of all ages and for the vulnerable population of children less than five years old. But the evidence is not absolute and the actual level of effectiveness of such interventions varies considerably. Underlying clinical heterogeneity appears to be responsible for the heterogeneity. The aetiology and epidemiology of diarrhoea is complex and variable, and even the portion of diarrhoea that is waterborne is probably different at different times and places (Luby 2004). Nevertheless, the subgroup analyses provide possible explanations for the differences.

First, household interventions, though also varying considerably in results, are considerably more effective at preventing diarrhoea than interventions at the water source. The reviews from Esrey and colleagues (Esrey 1985; Esrey 1991a) included only studies investigating improvements of water quality at the source, not at the household level. The 15% to 17% median reduction in diarrhoea that they reported is within the range of our findings for source-based interventions. The effectiveness of household-based interventions, on the other hand, is significantly greater than those at the source, and is comparable to certain other environmental

interventions to prevent diarrhoea, such as improved sanitation, hygiene (hand washing with soap), and improved water supply (Curtis 2003; Fewtrell 2005). Among household interventions, there is some evidence that filtration offers the most consistent and effective results. It is important to note, however, that none of the source-based interventions included in this review involved piped-in household connections. Thus, the effectiveness of the source systems described herein should not be generalized to reticulated systems.

Second, there is some evidence that effectiveness is enhanced by compliance with the intervention. While this may appear intuitive, it suggests a dose-response association between compliance and results that provides additional evidence of a causal relationship. It also implies the need to address compliance as part of any intervention to improve water quality. This may involve both the inherent acceptability and appeal of the hardware components of the intervention as well as programmatic support to increase utilization. To the extent that interventions are deployed at the household rather than community level, this also implies the need to address compliance during routine activities outside the home such as school and work.

Third, the evidence does not suggest that an 'improved' supply of water (ie household connection, public standpipe, borehole, protected dug well, protected spring, rainwater collection) is essential for water quality interventions to prevent diarrhoea. This finding affirms the WHO's strategy to pursue household water treatment and safe storage as a means of accelerating the health gains of safe drinking water, even though it may not reduce the 1.1 billion currently without access to improved water supplies.

Fourth, water quality interventions appear to be effective in preventing diarrhoea regardless of whether they are deployed in settings where sanitation is 'improved' (ie connection to a public sewer or septic system, pour-flush latrine, simple pit latrine, or ventilated improved pit latrine) or 'unimproved'. This is in contrast to conclusions that interventions to improve water quality are effective only where sanitation has already been addressed (Esrey 1986; VanDerslice 1995).

The subgroup analyses did not demonstrate that the effectiveness of a water quality intervention to prevent diarrhoea is enhanced by adding hygiene instruction, a separate vessel to treat or store water, or by improving sanitation or water supply. This is consistent with our finding that the effectiveness of a water quality intervention does not depend on the baseline conditions in regard to other environmental parameters that are associated with diarrhoea. At the same time, it implies that the cost and effort of combining the water quality intervention with improved hygiene, water storage, water supply, or sanitation may not be justified on the basis of the a synergistic effect on diarrhoeal disease.

Ultimately, the value of water quality interventions in preventing diarrhoeal disease depends not only on their effectiveness but also on their affordability, acceptability, sustainability and scalability within a vulnerable population. Comprehensive cost-effectiveness and cost-benefit analyses will help establish the priority that should be attached to water quality interventions by the public sector and non-governmental organizations. Finally, since household interventions appear especially effective, the private sector, which has particular capacity for addressing the needs of householders, should be explored as a potential source for developing effective, low-cost water treatment interventions on a wide scale.

Trial methodological quality (risk of bias)

The trials with good methodological quality show a greater overall level of effectiveness than those that do not. However, this review included both randomized and quasi-randomized controlled trials, and by necessity, employed different quality criteria for each. Because household-based interventions tended to be randomized controlled trials design while source-based interventions exclusively used quasi-randomization, there is an important bias that may affect the comparison. If, as suggested, the criteria for methodological quality for the two trial designs are not strictly comparable, this bias would affect the comparison of household versus source water interventions. With four criteria for assessing the quality of randomized controlled trials, conclusions about methodological quality could also lead to an unintentional bias. For example, among the three trials that used blinding, only one was deemed adequate on even two other quality criteria. The application of these criteria would thus skew the results against blinded trials.

Only three of 19 randomized controlled trials were blinded, and in each case the intervention had no statistically significant protective effect. This must give pause to any definitive conclusion about the potential value of water quality interventions in the prevention of diarrhoea. The authors of each of these trials suggested possible explanations for their findings. Colford 2002 was the only trial conducted in a developed country setting, and the water there already complied with US standards. Kirchhoff 1985, though a pioneering trial of a potentially important household intervention, had a study population of only 112 persons (smallest of all the included trials) and was rated low on three other criteria of methodological quality. Austin 1993-i also suggested possible methodological issues and used dilute sodium hypochlorite in the control group, an approach that probably improved their water quality thus resulting in an understatement of the intervention's effectiveness. While one trial, Clasen 2004c, cited ethical and other reasons for the decision not to blind the trial, it is not clear why so few of the household-based interventions failed to use placebo controls. Future trials should take steps to address this issue by using blinding design wherever possible.

Trial design and methodology

Subgroup analyses suggest that there are clinical sources of heterogeneity based on the intervention point and also among the dif-

ferent household interventions. However, given the heterogeneity within most of these subgroups, we cannot rule out the possibility that it may be due to differences in the trials' design and methodology.

The design of the trials is not independent of the type of intervention. All six trials involving interventions at the source used quasi-randomization, while 19 of 23 point-of-use interventions were randomized controlled trials. Although this mainly reflects the difficulty in randomizing users of source water interventions, the skewing of design between the two types of interventions could possibly account for differences in the results observed.

The length of the trials was not independent of the point of intervention. The median duration of trials of interventions at the source was more than six times longer than those involving interventions at the household level. Four of six such source-based intervention trials were of three years' duration or longer, while only three of the 32 household-based interventions lasted even one year. Seasonality plays a major role in diarrhoea incidence (Blum 1983), and failure to include at least 12 months' data on diarrhoea may overstate or understate the annual burden of disease in the underlying population and correspondingly influence the measure of effect.

Compliance with the intervention was probably not independent of the point of intervention. Household-based interventions all require some effort on the part of the participants to treat their water, to have treated water consistently available, to avoid recontamination, and to refrain from drinking from untreated sources. Each of these conditions creates an opportunity for non-compliance. Most source-based interventions, on the other hand, extended to the household's entire water supply without any additional compliance steps on the part of the intervention population. Thus, compliance was probably higher among groups using source-based rather than household-based interventions. If compliance is naturally lower among household-based interventions, than this bias may be a natural concomitant. But if compliance can be improved (as it apparently was in some trials), then the higher natural compliance with source interventions may overstate their effectiveness compared to interventions at home.

Participants are more conscious of interventions carried out in their home than those at a distant water source or treatment works. This could lead to bias in trials that are not blinded. Courtesy bias (the tendency of participants who know they are in the intervention group to overstate the effect to please the investigator) and Hawthorne effect (the effect, usually positive, of being under investigation generally) may conspire to overstate or understate the effectiveness of the interventions covered by this review. This is particularly true for the non-blinded trials of household-based interventions that were often research-driven with perhaps more intensive investigator presence.

The availability of water is also an important factor. Interventions at the source are frequently designed primarily to improve the water quantity and availability rather than quality. On the other hand, such improvements in water supply may be a separate and possibly more significant contributor to health than water quality. In the case of the household-based interventions, most appeared to have been conducted in settings with sufficient water, which may mean that these results cannot be generalized to locations where water supplies are inadequate.

The interventions have varying levels of microbiological performance against different types of diarrhoegenic organisms, particularly under different water conditions. In a setting in which diarrhoea was mainly viral, ceramic filters would be only marginally protective. Similarly, where *Cryptosporidium* or another chlorine-resistant agent is an important cause of diarrhoea, chlorination may provide little if any protection. Even within these categories of interventions, there are important differences in microbiological performance. For example, the filtration subgroup includes ceramic filters that are not generally effective against viruses, and reverse-osmosis filters that are. Similarly, while the sodium hypochlorite used in most chlorination studies has certain antimicrobial capacity, other chlorine studies used mixed oxidants (Quick 1999) that have been shown to have broader biocidal effect (Venczel 1997). Since none of the trials continuously monitored the full range of diarrhoea-causing pathogens present in the drinking water of the study population and few trials attempted to determine clinically the apparent causes of diarrhoea in such population, it is difficult to compare the interventions based on their microbiological performance. This difference in field performance also illustrates another potential flaw in pooling for analysis seemingly similar interventions such filtration and chlorination.

Many of the trials reported results on selected age groups, and not on all ages of persons who would have been affected by the intervention. It is common for research on diarrhoeal disease to specifically target children less than five years of age, a group that is particularly vulnerable to diarrhoea, and many of the trials did provide data for this group. Many others, however, reported results only for a subset of this group, or for some other segment of the population. In most cases, it appears that results were reported for the full population on which data were collected. It is possible, that by omitting a portion of the population affected by the intervention, the design or reporting of results is a source of bias.

Finally, it appears that many if not most of the trials were undertaken primarily for the purpose of investigating the effectiveness of the intervention, and not as an assessment of an ongoing programme. This seems particularly true of the household interventions. While investigators often took special steps to minimize the effect that such a research focus may have had on the study results, the continuous onsite participation of investigators, many of whom were foreign to the study settings, in implementing and assessing the intervention could be a source of possible bias. It may also raise questions about whether the results obtained would be representative of the effectiveness of the interventions outside a research context. Future trials should include assessments of ongoing programmes implemented outside a research context.

AUTHORS' CONCLUSIONS

Implications for practice

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. Household interventions may be as effective at preventing diarrhoea as other environmental approaches, such as improved sanitation, hygiene (hand washing with soap), and improved water supply. 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.

Our results also make clear, however, 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. Studies have shown a wide range of results, including a number of trials where no statistically significant protective effect was observed.

Implications for research

Rigorously conducted randomized controlled trials that compare various approaches to improving drinking water quality will help clarify the potential for water quality interventions to prevent endemic diarrhoea. It is particularly important that such trials be blinded, if possible, not only for the methodological reasons that favour blinded trials generally but also because of the mixed effectiveness achieved in blinded studies of water quality interventions to date. There is also a need for longer-term studies in programmatic (non-research driven) settings, especially on household-based interventions. The suggestion, first observed by Fewtrell 2005, that water quality interventions are effective even in the absence of improved sanitation, and that water quality interventions are not materially enhanced by compounding them with improved hygiene, sanitation, water supply or storage, should also be verified in a rigorous trial since they also challenge previous conclusions. Our results also demonstrate a need for more trials on the extent to which these water quality interventions affect mortality and not just morbidity. The difference in results between source and household interventions, and the range of results among the various core household approaches themselves, suggest the need to understand better how water quality interventions with similar microbiological performance nevertheless may result in different levels of effectiveness in preventing diarrhoea. This also implies the need to explore and assess the extent to which new technologies for improving water quality may be suitable for use among remote and low-income settings where the burden of diarrhoeal disease is highest. Differences in programmatic approaches to optimize the adoption and long-term utilization of these interventions should also be investigated.

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* *Indicates the major publication for the study*

CHARACTERISTICS OF STUDIES

Characteristics of included studies *[ordered by study ID]*

Alam 1989

Methods	Quasi-randomized controlled trial
Participants	Number: 623 children Inclusion criteria: aged 6 to 23 months
Interventions	1. Improved water supply + hygiene education (3 subunits) 2. Primary drinking supply (2 subunits)
Outcomes	1. Incidence of diarrhoea among children aged 6 to 23 months by water source, hygiene practices, and household socioeconomic characteristics
Notes	Location: 5 political subunits in a village in rural Bangladesh Length: 3 years Publication status: journal

Austin 1993-i

Methods	Randomized controlled trial
Participants	Number: 287 children Inclusion criteria: aged 25 to 60 months (group B) from villages primarily using open, shallow wells for drinking water
Interventions	1. Sodium hypochlorite solution used at household level (11 villages) 2. Primary drinking supply (11 villages)
Outcomes	1. Longitudinal prevalence of diarrhoea 2. Change in nutritional status using weight-for-height Z-score
Notes	Location: 22 rural villages in The Gambia Length: 20 weeks Publication status: PhD dissertation

Austin 1993-ii

Methods	As above
Participants	Number: 144 children between 6 and 24 months
Interventions	As above
Outcomes	As above

Austin 1993-ii (*Continued*)

Notes	As above

Aziz 1990

Methods	Quasi-randomized controlled trial
Participants	Number: about 9600 people of all ages from 1570 households
Interventions	1. Improved water supply + sanitation + hygiene education 2. Primary drinking supply
Outcomes	1. Longitudinal prevalence of diarrhoea: • portion of among children < 5 years • portion of episodes classified as persistent • percentage of days with diarrhoea • odds ratios of frequent diarrhoea • related to environmental factors
Notes	Location: 2 villages in rural Bangladesh Length: 3 years Publication status: journal

Chiller 2004

Methods	Randomized controlled trial
Participants	Number: 3401 persons Inclusion criteria: all ages from 514 households with at least one child under 1 year
Interventions	1. Flocculant-disinfectant sachets used at household level + hygiene education 2. Primary drinking supply
Outcomes	1. Longitudinal prevalence of diarrhoea (portion of total days of diarrhoea out of total days of observation) among all ages 2. Incidence of persistent diarrhoea
Notes	Location: 42 neighbourhood clusters in 12 rural villages in Guatemala Length: 13 weeks Publication status: unpublished

Clasen 2004b

Methods	Randomized controlled trial
Participants	324 persons of all ages from 60 households
Interventions	1. Household gravity water filter system using imported ceramic filter elements 2. Primary drinking supply
Outcomes	1. Period prevalence of diarrhoea (7-day recall) among all ages 2. Microbial water quality
Notes	Location: rural Bolivian community Length: 5 months Publication status: unpublished

Clasen 2004c

Methods	Randomized controlled trial
Participants	Number: 50 households with 280 persons, of which 32 (11%) were under age 5
Interventions	1. Household gravity water filter system using imported ceramic filter elements 2. Primary drinking supply
Outcomes	1. Period prevalence of diarrhoea (7-day recall) among householders assessed at approximately 6-week intervals
Notes	Location: rural Bolivia Length: 6 months Publication status: journal

Colford 2002

Methods	Randomized controlled trial
Participants	236 children 12 years or older from 77 households
Interventions	1. Household reverse osmosis filters 2. Primary drinking supply
Outcomes	1. Incidence of watery diarrhoea 2. Gastrointestinal illness and various other symptoms 3. Water consumption 4. Effectiveness of blinding
Notes	Location: urban community in California, USA Length: 4 months Publication status: journal

Conroy 1996

Methods	Randomized controlled trial
Participants	206 Maasai children aged 5 to 16 years in 3 adjoining areas of single province
Interventions	1. Solar disinfection in plastic bottles at household level 2. Primary drinking supply
Outcomes	1. Period prevalence of diarrhoea
Notes	Location: single province of rural Kenya Length: 12 weeks Publication status: journal

Conroy 1999

Methods	Randomized controlled trial
Participants	349 Maasai children < 6 years in 140 households
Interventions	1. Solar disinfection in plastic bottles at household level 2. Primary drinking supply
Outcomes	1. Period prevalence of diarrhoea
Notes	Location: rural Kenya Length: 1 year Publication status: journal

Crump 2004-i

Methods	Randomized controlled trial
Participants	6650 persons of all ages in 604 family compounds; participation limited to family compounds with at least 1 child < 2 years and likely to be using highly turbid source water
Interventions	1. Sodium hypochlorite used at household level + hygiene education 2. Primary drinking supply
Outcomes	1. Longitudinal prevalence (weeks with diarrhoea/weeks of observation) among all ages 2. Breastfeeding and consumption of food and water for children < 2 years 3. Deaths 4. Use of intervention 5. Mothers' knowledge of and acceptance of intervention (weeks 5 and 15) 6. Microbial water quality and turbidity 7. Mothers' knowledge of and attitudes to intervention

Crump 2004-i (*Continued*)

Notes	Location: 49 rural villages in western Kenya Length: 20 weeks Publication status: unpublished

Crump 2004-ii

Methods	See Crump 2004-i
Participants	As above
Interventions	1. Flocculant-disinfectant sachets used at household level + hygiene 2. Primary drinking supply
Outcomes	As above
Notes	As above

Doocy 2004

Methods	Randomized controlled trial
Participants	2191 persons of all ages (1138 intervention, 1053 controls), of which 735 are children < 5 (395 intervention, 340 controls) from households in settlement area not using treated water for drinking
Interventions	1. Flocculant-disinfectant sachets used at household level, plus water storage vessel 2. Primary drinking supply; also received vessel
Outcomes	1. Longitudinal prevalence (days with diarrhoea/total days of observation) 2. Prevalence of bloody diarrhoea 3. Utilization and acceptability data from exit survey
Notes	Location: Liberian camp for displaced persons Length: 12 weeks Publication status: unpublished

du Preez 2004

Methods	Randomized controlled trial
Participants	115 children < 5 years
Interventions	1. Household commercial ceramic filter using imported components (60 children) 2. Primary drinking supply (55 children)

du Preez 2004 (*Continued*)

Outcomes	1. Incidence of diarrhoea 2. Incidence of bloody diarrhoea and non-bloody diarrhoea 3. Microbiological water quality
Notes	Location: rural South Africa and Zimbabwe Length: 6 months Publication status: unpublished

Garrett 2004

Methods	Quasi-randomized controlled trial
Participants	960 children < 5 years
Interventions	1. Household chlorination using sodium hypochlorite solution + improved water supply + sanitation + hygiene education + improved storage (618 children) 2. Primary drinking supply (342 children)
Outcomes	1. Incidence of diarrhoea
Notes	Location: rural Kenya Length: not reported Publication status: unpublished

Gasana 2002

Methods	Quasi-randomized controlled trial
Participants	150 children < 5 years (in intervention group, controls)
Interventions	1. Improved source: pipes to stand post; sedimentation tank; ceramic filter; storage tank; and communal tap (95 children) 2. Primary drinking supply (55 children)
Outcomes	1. Incidence of diarrhoea
Notes	Location: rural Rwanda Length: 1 year Publication status: journal

Handzel 1998

Methods	Randomized controlled trial
Participants	447 children aged 3 to 60 months from 276 households using municipal water (household taps) as primary source of drinking water which had tested positive at baseline for Escherichia coli
Interventions	1. Household chlorination using sodium hypochlorite solution, special storage vessel and hygiene instruction about why and how to treat water (140 households) 2. Primary drinking supply (136 households)
Outcomes	1. Incidence of diarrhoea 2. Microbial water quality
Notes	Location: informal settlement in urban Bangladesh Length: 8 months Publication status: PhD dissertation

Jensen 2003

Methods	Quasi-randomized controlled trial
Participants	226 children < 5 years
Interventions	1. Village level chlorination of water supply using calcium hypochlorite (82 children) 2. Primary drinking supply (144 children)
Outcomes	1. Incidence of diarrhoea 2. Microbial water quality
Notes	Location: 2 villages in Pakistan Length: 6 months Publication status: journal Controlled for sanitation and water storage status of households, and for seasonality

Kirchhoff 1985

Methods	Randomized controlled trial
Participants	112 persons (all ages) from 20 families with at least 2 children living at home and using water from pond exclusively
Interventions	1. Household level chlorination with sodium hypochlorite 2. Primary drinking supply
Outcomes	1. Longitudinal prevalence of diarrhoea 2. Microbial water quality 3. Acceptability of intervention to study population

Kirchhoff 1985 (*Continued*)

Notes	Location: rural Brazil Length: 18 weeks Publication status: journal

Luby 2004a-i

Methods	Quasi-randomized controlled trial
Participants	2365 persons < 15 years from 285 households
Interventions	1. Bleach + regular vessel (640 people) 2. Primary drinking supply (1027 people)
Outcomes	1. Longitudinal prevalence of diarrhoea 2. Use of intervention by certain household characteristics
Notes	Location: 3 neighbourhoods in squatter settlements in Karachi, Pakistan Length: 6 months Publication status: journal

Luby 2004a-ii

Methods	See Luby 2004a-i
Participants	See Luby 2004a-i
Interventions	1. Bleach + insulated vessel (697 people) 2. Primary drinking supply (1027 people)
Outcomes	See Luby 2004a-i
Notes	See Luby 2004a-i

Luby 2004b-i

Methods	Randomized controlled trial
Participants	5520 persons of all ages
Interventions	1. Dilute bleach + vessel (1747 people) 2. Primary drinking supply (1852 people)
Outcomes	1. Incidence and longitudinal prevalence of diarrhoea

Luby 2004b-i (*Continued*)

Notes	Location: 47 squatter settlements of Karachi, Pakistan Length: 8 months Publication status: unpublished

Luby 2004b-ii

Methods	See Luby 2004b-i
Participants	See Luby 2004b-i
Interventions	1. Flocculant-disinfectant + soap (1806 in flocculant-disinfection group) 2. Primary drinking supply (1852 people)
Outcomes	See Luby 2004b-i
Notes	See Luby 2004b-i

Luby 2004b-iii

Methods	See Luby 2004b-i
Participants	See Luby 2004b-i
Interventions	1. Flocculant-disinfectant + vessel (1833 in flocculant-disinfection group) 2. Primary drinking supply (1852 people, 40.0%)
Outcomes	See Luby 2004b-i
Notes	See Luby 2004b-i

Lule 2005

Methods	Randomized controlled trial
Participants	2201 persons of all ages among 458 households without access to chlorinated municipal water; at least 1 resident of each household was HIV+
Interventions	1. Household level chlorination using sodium hypochlorite + special vessel (1097 people) 2. Primary drinking supply (1104 people) Note: hygiene education was provided to both groups
Outcomes	1. Incidence of diarrhoea 2. Days with diarrhoea (longitudinal prevalence) 3. Days lost from work or school 4. Aetiology of diarrhoea 5. Frequency of clinic visits and hospitalization

Lule 2005 (*Continued*)

	6. Mortality
Notes	Location: households in rural Uganda Length: 5 months Publication status: unpublished Succeeded by 18-month Randomized controlled trial that included cotrimoxazole prophylaxis

Mahfouz 1995

Methods	Quasi-randomized controlled trial
Participants	311 children < 5 years (among intervention households, among controls) among 171 families
Interventions	1. Household level chlorination using calcium hypochlorite (159 children) 2. Primary drinking supply (152 children)
Outcomes	1. Reported cases of diarrhoea in intervention year compared with previous year
Notes	Location: 9 villages in rural Saudi Arabia Length: 6 months Publication status: journal

Messou 1997

Methods	Quasi-randomized controlled trial
Participants	Approximately 985 to 1260 (depending on study year) children < 5 years
Interventions	1. Improved water supply + sanitation + hygiene education + oral rehydration therapy for those suffering from diarrhoea (2 villages) 2. Primary drinking supply (2 villages)
Outcomes	1. Incidence of diarrhoea 2. Reduction in deaths attributable to diarrhoea 3. Utilization of oral rehydration solution
Notes	Location: 4 villages in rural Ivory Coast Length: 5 years Publication status: journal

Quick 1999

Methods	Randomized controlled trial
Participants	791 persons of all ages from 127 households
Interventions	1. Household level chlorination + vessel + hygiene education (400 people, 64 households) 2. Primary drinking supply (391 people, 63 households)
Outcomes	1. Mean episodes of diarrhoea per person 2. Microbiological water quality
Notes	Location: 2 peri-urban communities in Bolivia Length: 5 months Publication status: journal

Quick 2002

Methods	Quasi-randomized controlled trial
Participants	1584 persons of all ages from 260 households
Interventions	1. Household level chlorination + vessel + hygiene education (166 households) 2. Primary drinking supply (94 households)
Outcomes	1. Incidence of diarrhoea 2. Microbiological water quality
Notes	Location: 2 peri-urban communities in Zambia Length: 3 months Publication status: journal

Reller 2003-i

Methods	Randomized controlled trial
Participants	492 households each with a child < 12 months or mother in last trimester of pregnancy
Interventions	1. Flocculant-disinfectant (102 households) 2. Primary drinking supply (96 households)
Outcomes	1. Incidence of diarrhoea 2. Intervention knowledge and acceptability 3. Microbiological water quality 4. Intervention utilization
Notes	Location: 12 villages in rural Guatemala Length: 12 months Publication status: journal

Reller 2003-ii

Methods	See Reller 2003-i
Participants	See Reller 2003-i
Interventions	1. Bleach only (97 households) 2. Primary drinking supply (as above)
Outcomes	See Reller 2003-i
Notes	See Reller 2003-i

Reller 2003-iii

Methods	See Reller 2003-i
Participants	See Reller 2003-i
Interventions	1. Bleach + vessel (97 households) 2. Primary drinking supply (as above)
Outcomes	See Reller 2003-i
Notes	See Reller 2003-i

Reller 2003-iv

Methods	See Reller 2003-i
Participants	See Reller 2003-i
Interventions	1. Flocculant-disinfectant + vessel (100 households) 2. Primary drinking supply (as above)
Outcomes	See Reller 2003-i
Notes	See Reller 2003-i

Roberts 2001

Methods	Randomized controlled trial
Participants	1160 persons of all ages; of these, 208 were children < 5 years
Interventions	1. Improved storage: bucket with spout and narrow opening to limit hand entry (310 people including 51 children, 100 households) 2. Primary drinking supply (850 people including 157 children, 300 households)

Roberts 2001 (*Continued*)

Outcomes	1. Incidence of diarrhoea 2. Microbiological water quality 3. Incidence of diarrhoea by selected environmental factors
Notes	Location: Malawi refugee camp Length: 4 months Publication status: journal

Semenza 1998

Methods	Randomized controlled trial
Participants	1583 persons of all ages from 240 households, half with access to piped water (first control group) and half without (of which 62 received intervention, and 58 served as a second control group); these included 344 children < 5 (176 from piped water households, 88 intervention and 80 no-chlorination)
Interventions	1. Household level chlorination + vessel + hygiene education 2. Primary drinking supply
Outcomes	1. Incidence of diarrhoea 2. Incidence of diarrhoea by selected household and water management practices
Notes	Location: urban Uzbekistan Length: 9.5 weeks Publication status: journal

Torun 1982

Methods	Quasi-randomized controlled trial
Participants	2103 persons of all ages from 2 villages
Interventions	1. Source protection (spring), chlorination facilities, "adequate storage", and water mains with faucets to yards of intervention village (1006 people) 2. Primary drinking supply (1097 people)
Outcomes	1. Incidence of diarrhoea
Notes	Location: 2 small villages in Guatemala Length: 12 months Publication status: book

URL 1995-i

Methods	Randomized controlled trial
Participants	1120 children < 5 years (265 and 289 allocated to the water quality intervention arms, 297 to an education only arm, and 269 to the control arm) from 680 families from three demographic regions
Interventions	1. Locally fabricated ceramic filters (265 children or 23.6%) 2. Primary drinking supply (269 children)
Outcomes	1. Incidence of diarrhoea 2. Nutritional status (weight/age)
Notes	Location: 3 demographic regions of Guatemala Length: 12 months Publication status: unpublished

URL 1995-ii

Methods	See URL 1995-i
Participants	See URL 1995-i
Interventions	1. Locally fabricated ceramic filters + hygiene education 2. Primary drinking supply (as above)
Outcomes	See URL 1995-i
Notes	See URL 1995-i

Xiao 1997

Methods	Quasi-randomized controlled trial
Participants	4649 persons of all ages
Interventions	1. Improved water supply + sanitation + hygiene education (2363 people) 2. Primary drinking supply (2286 people)
Outcomes	1. Incidence of diarrhoea
Notes	Location: 2 villages in rural China Length: 3 years Publication status: journal

Interventions: details on controls and interventions in Appendix 3 and Appendix 4.

Characteristics of excluded studies *[ordered by study ID]*

Study	Reason for exclusion
Asaolu 2002	Study not RCT or quasi-RCT; outcome measures not include diarrhoea
Azurin 1974	Outcome measures not include diarrhoea
Bahl 1976	Study not RCT or quasi-RCT
Bersh 1985	Study not RCT or quasi-RCT
Chongsuvivatwong 94	Study not RCT or quasi-RCT
Colwell 2003	Outcome measures not include diarrhoea
Conroy 2001	Outcome measures not include diarrhoea
Deb 1986	Outcome measures not include diarrhoea
Esrey 1991b	Study not RCT or quasi-RCT
Fewtrell 1994	Study not RCT or quasi-RCT; outcome measures not include diarrhoea
Fewtrell 1997	Study not RCT or quasi-RCT; outcome measures not include diarrhoea
Ghannoum 1981	Study not RCT or quasi-RCT; outcome measures not include diarrhoea
Hellard 2001	Outcome measures not include diarrhoea
Hoque 1996	Study not RCT or quasi-RCT
Iijima 2001	Study not RCT or quasi-RCT
Jensen 2002	Outcome measures not include diarrhoea
Khan 1984	Outcome measures not include diarrhoea
Macy 1998	Study not RCT or quasi-RCT; intervention not an improvement in water quality; outcome measures not include diarrhoea
Maeusezahl 2003	Study not RCT or quasi-RCT
McCabe 1957	Intervention not an improvement in water quality
Mertens 1990	Study not RCT or quasi-RCT; intervention not an improvement in water quality; outcome measures not include diarrhoea
Nanan 2003	Study not RCT or quasi-RCT

(*Continued*)

Payment 1991a	Study not RCT or quasi-RCT Outcome measures not include diarrhoea
Payment 1991b	Outcome measures not include diarrhoea
Pinfold 1990	Intervention not an improvement in water quality; outcome measures not include diarrhoea
Rubenstein 1969	Study not RCT or quasi-RCT
Sathe 1996	Study not RCT or quasi-RCT
Shiffman 1978	Study not RCT or quasi-RCT
Shum 1971	Study not RCT or quasi-RCT; intervention not an improvement in water quality; outcome measures not include diarrhoea
Sorvillo 1994	Outcome measures not include diarrhoea
Tonglet 1992	Study not RCT or quasi-RCT
Trivedi 1971	Study not RCT or quasi-RCT
VanDerslice 1995	Study not RCT or quasi-RCT; intervention not an improvement in water quality
Varghese 2002	Study not RCT or quasi-RCT

RCT: randomized controlled trial

Characteristics of studies awaiting assessment *[ordered by study ID]*

Clasen 2005

Methods	-
Participants	
Interventions	
Outcomes	-
Notes	-

Colford 2005a

Methods	-
Participants	-
Interventions	-
Outcomes	-
Notes	-

Colford 2005b

Methods	-
Participants	-
Interventions	-
Outcomes	-
Notes	-

Rose 2006

Methods	-
Participants	-
Interventions	-
Outcomes	-
Notes	-

DATA AND ANALYSES

Comparison 1. Water quality intervention versus control: point and type of intervention (rate ratios)

Outcome or subgroup title	No. of studies	No. of participants	Statistical method	Effect size
1 Diarrhoea: all ages	10		Rate ratio (Random, 95% CI)	Subtotals only
1.1 Source or household treatment	10		Rate ratio (Random, 95% CI)	0.73 [0.63, 0.85]
1.2 Source treatment	4		Rate ratio (Random, 95% CI)	0.87 [0.74, 1.02]
1.3 Household treatment	6		Rate ratio (Random, 95% CI)	0.56 [0.42, 0.74]
1.4 Household treatment: chlorination	4		Rate ratio (Random, 95% CI)	0.61 [0.46, 0.81]
1.5 Household treatment: filtration	2		Rate ratio (Random, 95% CI)	0.37 [0.15, 0.92]
2 Diarrhoea: children < 5 years	6		Rate ratio (Random, 95% CI)	Subtotals only
2.1 Source or household treatment	6		Rate ratio (Random, 95% CI)	0.78 [0.65, 0.94]
2.2 Source treatment	3		Rate ratio (Random, 95% CI)	0.93 [0.82, 1.05]
2.3 Household treatment	3		Rate ratio (Random, 95% CI)	0.42 [0.19, 0.95]
2.4 Household treatment: chlorination	2		Rate ratio (Random, 95% CI)	0.53 [0.23, 1.23]
2.5 Household treatment: filtration	1		Rate ratio (Random, 95% CI)	0.21 [0.07, 0.61]

Comparison 2. Water quality intervention versus control: point of intervention (risk ratios)

Outcome or subgroup title	No. of studies	No. of participants	Statistical method	Effect size
1 Diarrhoea: all ages	7		Risk ratio (Random, 95% CI)	Subtotals only
1.1 Source or household treatment	7		Risk ratio (Random, 95% CI)	0.45 [0.33, 0.62]
1.2 Source treatment	1		Risk ratio (Random, 95% CI)	0.45 [0.43, 0.47]
1.3 Household treatment	6		Risk ratio (Random, 95% CI)	0.43 [0.27, 0.70]
1.4 Household treatment: chlorination	3		Risk ratio (Random, 95% CI)	0.34 [0.17, 0.68]
1.5 Household treatment: filtration	2		Risk ratio (Random, 95% CI)	0.41 [0.21, 0.79]
1.6 Household treatment: improved storage	1		Risk ratio (Random, 95% CI)	0.79 [0.61, 1.03]
2 Diarrhoea: children < 5 years	5		Risk ratio (Random, 95% CI)	Subtotals only
2.1 Source or household treatment	5		Risk ratio (Random, 95% CI)	0.54 [0.43, 0.69]
2.2 Household treatment	5		Risk ratio (Random, 95% CI)	0.54 [0.43, 0.69]

2.3 Household treatment: chlorination	2	Risk ratio (Random, 95% CI)	0.48 [0.33, 0.68]
2.4 Household treatment: filtration	2	Risk ratio (Random, 95% CI)	0.41 [0.21, 0.79]
2.5 Household treatment: improved storage	1	Risk ratio (Random, 95% CI)	0.69 [0.47, 1.01]

Comparison 3. Water quality intervention versus control: point and type of intervention (longitudinal prevalence ratios)

Outcome or subgroup title	No. of studies	No. of participants	Statistical method	Effect size
1 Diarrhoea: all ages	11		Long. prev. ratio (Random, 95% CI)	Subtotals only
1.1 Source or household treatment	11		Long. prev. ratio (Random, 95% CI)	0.56 [0.27, 1.16]
1.2 Source treatment	1		Long. prev. ratio (Random, 95% CI)	0.56 [0.37, 0.84]
1.3 Household treatment	10		Long. prev. ratio (Random, 95% CI)	0.56 [0.25, 1.23]
1.4 Household treatment: chlorination	5		Long. prev. ratio (Random, 95% CI)	0.82 [0.60, 1.11]
1.5 Household treatment: flocculation and disinfection	5		Long. prev. ratio (Random, 95% CI)	0.40 [0.14, 1.16]
2 Diarrhoea: children < 5 years	12		Long. prev. ratio (Random, 95% CI)	Subtotals only
2.1 Source or household treatment	11		Long. prev. ratio (Random, 95% CI)	0.61 [0.29, 1.26]
2.2 Source treatment	1		Long. prev. ratio (Random, 95% CI)	0.63 [0.49, 0.81]
2.3 Household treatment	10		Long. prev. ratio (Random, 95% CI)	0.60 [0.27, 1.36]
2.4 Household treatment: chlorination	5		Long. prev. ratio (Random, 95% CI)	0.91 [0.82, 1.02]
2.5 Household treatment: flocculation and disinfection	5		Long. prev. ratio (Random, 95% CI)	0.42 [0.13, 1.37]

Comparison 4. Water quality intervention versus control: point and type of intervention (odds ratios)

Outcome or subgroup title	No. of studies	No. of participants	Statistical method	Effect size
1 Diarrhoea: all ages	9		Odds ratio (Random, 95% CI)	Subtotals only
1.1 Source or household treatment	9		Odds ratio (Random, 95% CI)	0.68 [0.59, 0.79]
1.2 Household treatment	9		Odds ratio (Random, 95% CI)	0.68 [0.59, 0.79]
1.3 Household treatment: chlorination	3		Odds ratio (Random, 95% CI)	0.77 [0.58, 1.02]
1.4 Household treatment: filtration	2		Odds ratio (Random, 95% CI)	0.35 [0.23, 0.53]

1.5 Household treatment: solar disinfection	2	Odds ratio (Random, 95% CI)	0.69 [0.63, 0.74]
1.6 Household treatment: flocculation and disinfection	2	Odds ratio (Random, 95% CI)	0.77 [0.65, 0.90]
2 Diarrhoea: children < 5 years	6	Odds ratio (Random, 95% CI)	Subtotals only
2.1 Source or household treatment	6	Odds ratio (Random, 95% CI)	0.70 [0.50, 0.99]
2.2 Household treatment	6	Odds ratio (Random, 95% CI)	0.70 [0.50, 0.99]
2.3 Household treatment: chlorination	2	Odds ratio (Random, 95% CI)	0.90 [0.65, 1.25]
2.4 Household treatment: filtration	2	Odds ratio (Random, 95% CI)	0.32 [0.11, 0.90]
2.5 Household treatment: flocculation and disinfection	2	Odds ratio (Random, 95% CI)	0.86 [0.57, 1.29]

Comparison 5. Water quality intervention versus control: point and type of intervention (means ratios)

Outcome or subgroup title	No. of studies	No. of participants	Statistical method	Effect size
1 Diarrhoea: all ages	1		Means ratio (Random, 95% CI)	Totals not selected
1.1 Source or household treatment	1		Means ratio (Random, 95% CI)	Not estimable
1.2 Household treatment	1		Means ratio (Random, 95% CI)	Not estimable
1.3 Household treatment: chlorination	1		Means ratio (Random, 95% CI)	Not estimable
2 Diarrhoea: children < 5 years	1		Means ratio (Random, 95% CI)	Totals not selected
2.1 Source or household treatment	1		Means ratio (Random, 95% CI)	Not estimable
2.2 Household treatment	1		Means ratio (Random, 95% CI)	Not estimable
2.3 Household treatment: chlorination	1		Means ratio (Random, 95% CI)	Not estimable

Comparison 6. Water quantity intervention versus control: by compliance with intervention (risk ratios)

Outcome or subgroup title	No. of studies	No. of participants	Statistical method	Effect size
1 Diarrhoea: all ages	4		Risk ratio (Random, 95% CI)	Subtotals only
1.1 < 50%	1		Risk ratio (Random, 95% CI)	0.44 [0.28, 0.69]
1.2 50% or >	3		Risk ratio (Random, 95% CI)	0.28 [0.14, 0.57]

Comparison 7. Water quality intervention versus control: by compliance with intervention (odds ratios)

Outcome or subgroup title	No. of studies	No. of participants	Statistical method	Effect size
1 Diarrhoea: all ages	7		Odds ratio (Random, 95% CI)	Subtotals only
1.1 < 50%	4		Odds ratio (Random, 95% CI)	0.80 [0.71, 0.89]
1.2 50% or >	3		Odds ratio (Random, 95% CI)	0.40 [0.28, 0.57]

Comparison 8. Water quality intervention versus control: by ambient water quality (rate ratios)

Outcome or subgroup title	No. of studies	No. of participants	Statistical method	Effect size
1 Diarrhoea: all ages	4		Rate ratio (Random, 95% CI)	Subtotals only
1.1 0 colony-forming units (CFU)	1		Rate ratio (Random, 95% CI)	0.54 [0.28, 1.06]
1.2 10 to 99 CFU	3		Rate ratio (Random, 95% CI)	0.79 [0.65, 0.95]

Comparison 9. Water quality intervention versus control: by ambient water quality (risk ratios)

Outcome or subgroup title	No. of studies	No. of participants	Statistical method	Effect size
1 Diarrhoea: all ages	4		Risk ratio (Random, 95% CI)	Subtotals only
1.1 10 to 99 colony-forming units (CFU)	2		Risk ratio (Random, 95% CI)	0.36 [0.07, 1.81]
1.2 > 99 CFU	2		Risk ratio (Random, 95% CI)	0.41 [0.21, 0.79]

Comparison 10. Water quality intervention versus control: by ambient water quality (longitudinal prevalence ratios)

Outcome or subgroup title	No. of studies	No. of participants	Statistical method	Effect size
1 Diarrhoea: all ages	5		Long. prev. ratio (Random, 95% CI)	Subtotals only
1.1 10 to 99 colony-forming units (CFU)	2		Long. prev. ratio (Random, 95% CI)	0.80 [0.69, 0.93]
1.2 > 99 CFU	3		Long. prev. ratio (Random, 95% CI)	1.07 [0.88, 1.29]

Comparison 11. Water quality intervention versus control: by ambient water quality (odds ratios)

Outcome or subgroup title	No. of studies	No. of participants	Statistical method	Effect size
1 Diarrhoea: all ages	22		Odds ratio (Random, 95% CI)	Subtotals only
1.1 0 colony-forming units (CFU)	1		Odds ratio (Random, 95% CI)	0.54 [0.28, 1.06]
1.2 10 to 99 CFU	14		Odds ratio (Random, 95% CI)	0.70 [0.60, 0.80]
1.3 > 99 CFU	7		Odds ratio (Random, 95% CI)	0.69 [0.49, 0.96]

Comparison 12. Water quality intervention versus control: by sufficiency of water quantity (long. prev. ratios)

Outcome or subgroup title	No. of studies	No. of participants	Statistical method	Effect size
1 Diarrhoea: all ages	5		Long. prev. ratio (Random, 95% CI)	Subtotals only
1.1 Sufficient	1		Long. prev. ratio (Random, 95% CI)	0.62 [0.47, 0.82]
1.2 Insufficient	4		Long. prev. ratio (Random, 95% CI)	0.53 [0.15, 1.96]

Comparison 13. Water quality intervention versus control: by water supply level (rate ratios)

Outcome or subgroup title	No. of studies	No. of participants	Statistical method	Effect size
1 Diarrhoea: all ages	9		Rate ratio (Random, 95% CI)	Subtotals only
1.1 Improved water supply	3		Rate ratio (Random, 95% CI)	0.75 [0.56, 1.00]
1.2 Unimproved water supply	6		Rate ratio (Random, 95% CI)	0.75 [0.63, 0.89]

Comparison 14. Water quality intervention versus control: by water supply level (risk ratios)

Outcome or subgroup title	No. of studies	No. of participants	Statistical method	Effect size
1 Diarrhoea: all ages	6		Risk ratio (Random, 95% CI)	Subtotals only
1.1 Improved water supply	3		Risk ratio (Random, 95% CI)	0.60 [0.36, 0.99]
1.2 Unimproved water supply	3		Risk ratio (Random, 95% CI)	0.36 [0.20, 0.64]

Comparison 15. Water quality intervention versus control: by water supply level (longitudinal prevalence ratios)

Outcome or subgroup title	No. of studies	No. of participants	Statistical method	Effect size
1 Diarrhoea: all ages	11		Long. prev. ratio (Random, 95% CI)	Subtotals only
1.1 Improved water supply	4		Long. prev. ratio (Random, 95% CI)	0.39 [0.28, 0.55]
1.2 Unimproved water supply	7		Long. prev. ratio (Random, 95% CI)	0.62 [0.23, 1.67]

Comparison 16. Water quality intervention versus control: by water supply level (odds ratios)

Outcome or subgroup title	No. of studies	No. of participants	Statistical method	Effect size
1 Diarrhoea: all ages	9		Odds ratio (Random, 95% CI)	Subtotals only
1.1 Improved water supply	1		Odds ratio (Random, 95% CI)	0.47 [0.24, 0.92]
1.2 Unimproved water supply	8		Odds ratio (Random, 95% CI)	0.69 [0.59, 0.80]

Comparison 17. Water quality intervention versus control: by sanitation level (rate ratios)

Outcome or subgroup title	No. of studies	No. of participants	Statistical method	Effect size
1 Diarrhoea: all ages	7		Rate ratio (Random, 95% CI)	Subtotals only
1.1 Improved sanitation	4		Rate ratio (Random, 95% CI)	0.56 [0.38, 0.83]
1.2 Unimproved sanitation	3		Rate ratio (Random, 95% CI)	0.80 [0.64, 1.00]

Comparison 18. Water quality intervention versus control: by sanitation level (risk ratios)

Outcome or subgroup title	No. of studies	No. of participants	Statistical method	Effect size
1 Diarrhoea: all ages	4		Risk ratio (Random, 95% CI)	Subtotals only
1.1 Improved sanitation	3		Risk ratio (Random, 95% CI)	0.48 [0.31, 0.75]
1.2 Unimproved sanitation	1		Risk ratio (Random, 95% CI)	0.44 [0.28, 0.69]

Comparison 19. Water quality intervention versus control: by sanitation level (longitudinal prevalence ratios)

Outcome or subgroup title	No. of studies	No. of participants	Statistical method	Effect size
1 Diarrhoea: all ages	7		Long. prev. ratio (Random, 95% CI)	Subtotals only
1.1 Improved sanitation	4		Long. prev. ratio (Random, 95% CI)	0.39 [0.28, 0.55]
1.2 Unimproved sanitation	3		Long. prev. ratio (Random, 95% CI)	0.43 [0.09, 2.09]

Comparison 20. Water quality intervention versus control: simple and compound interventions (rate ratios)

Outcome or subgroup title	No. of studies	No. of participants	Statistical method	Effect size
1 Diarrhoea: all ages	10		Risk ratio (Random, 95% CI)	Subtotals only
1.1 Water quality only	3		Risk ratio (Random, 95% CI)	0.55 [0.26, 1.17]
1.2 Water quality + hygiene promotion	3		Risk ratio (Random, 95% CI)	0.85 [0.70, 1.03]
1.3 Water quality + vessel	4		Risk ratio (Random, 95% CI)	0.61 [0.46, 0.81]
1.4 Water quality + sanitation	1		Risk ratio (Random, 95% CI)	0.75 [0.70, 0.80]
1.5 Water quality + improved water supply	2		Risk ratio (Random, 95% CI)	0.77 [0.71, 0.84]

Comparison 21. Water quality intervention versus control: simple and compound interventions (risk ratios)

Outcome or subgroup title	No. of studies	No. of participants	Statistical method	Effect size
1 Diarrhoea: all ages	6		Risk ratio (Random, 95% CI)	Subtotals only
1.1 Water quality only	2		Risk ratio (Random, 95% CI)	0.52 [0.32, 0.86]
1.2 Water quality + hygiene promotion	3		Risk ratio (Random, 95% CI)	0.29 [0.14, 0.59]
1.3 Water quality + vessel	2		Risk ratio (Random, 95% CI)	0.36 [0.07, 1.81]
1.4 Water quality + sanitation	1		Risk ratio (Random, 95% CI)	0.44 [0.28, 0.69]
1.5 Water quality + improved water supply	1		Risk ratio (Random, 95% CI)	0.44 [0.28, 0.69]

Comparison 22. Water quality intervention versus control: simple and compound interventions (longitudinal prevalence ratios)

Outcome or subgroup title	No. of studies	No. of participants	Statistical method	Effect size
1 Diarrhoea: all ages	11		Long. prev. ratio (Random, 95% CI)	Subtotals only
1.1 Water quality only	3		Long. prev. ratio (Random, 95% CI)	1.07 [0.88, 1.29]
1.2 Water quality + hygiene promotion	4		Long. prev. ratio (Random, 95% CI)	0.71 [0.59, 0.86]
1.3 Water quality + vessel	3		Long. prev. ratio (Random, 95% CI)	0.26 [0.10, 0.69]
1.4 Water quality + sanitation	1		Long. prev. ratio (Random, 95% CI)	0.56 [0.37, 0.84]
1.5 Water quality + improved water supply	1		Long. prev. ratio (Random, 95% CI)	0.56 [0.37, 0.84]

Comparison 23. Water quality intervention versus control: simple and compound interventions (odds ratios)

Outcome or subgroup title	No. of studies	No. of participants	Statistical method	Effect size
1 Diarrhoea: all ages	13		Odds ratio (Random, 95% CI)	Subtotals only
1.1 Water quality only	6		Odds ratio (Random, 95% CI)	0.64 [0.53, 0.77]
1.2 Water quality + hygiene promotion	1		Odds ratio (Random, 95% CI)	0.52 [0.30, 0.90]
1.3 Water quality + vessel	3		Odds ratio (Random, 95% CI)	0.77 [0.58, 1.03]
1.4 Water quality + sanitation	3		Odds ratio (Random, 95% CI)	0.60 [0.43, 0.84]
1.5 Water quality + improved water supply	4		Odds ratio (Random, 95% CI)	0.70 [0.59, 0.84]

Comparison 24. Water quality intervention versus control for RCTs: by methodological quality (rate ratios)

Outcome or subgroup title	No. of studies	No. of participants	Statistical method	Effect size
1 Diarrhoea: by allocation sequence	4		Rate ratio (Random, 95% CI)	Subtotals only
1.1 Adequate	2		Rate ratio (Random, 95% CI)	0.37 [0.15, 0.92]
1.2 Unclear	2		Rate ratio (Random, 95% CI)	0.73 [0.61, 0.87]
2 Diarrhoea: by allocation concealment	8		Rate ratio (Random, 95% CI)	Subtotals only
2.1 Adequate	4		Rate ratio (Random, 95% CI)	0.65 [0.49, 0.86]
2.2 Inadequate	4		Rate ratio (Random, 95% CI)	0.79 [0.63, 0.99]
3 Diarrhoea: by follow up	18		Rate ratio (Random, 95% CI)	Subtotals only
3.1 Adequate	4		Rate ratio (Random, 95% CI)	0.65 [0.49, 0.86]
3.2 Unclear	3		Rate ratio (Random, 95% CI)	0.28 [0.14, 0.57]
3.3 Inadequate	11		Rate ratio (Random, 95% CI)	0.81 [0.73, 0.89]

4 Diarrhoea: by blinding	4	Rate ratio (Random, 95% CI)	Subtotals only
4.1 Double blind	1	Rate ratio (Random, 95% CI)	0.54 [0.28, 1.06]
4.2 Open	3	Rate ratio (Random, 95% CI)	0.66 [0.47, 0.92]

Comparison 25. Water quality intervention versus control for RCTs: by methodological quality (risk ratios)

Outcome or subgroup title	No. of studies	No. of participants	Statistical method	Effect size
1 Diarrhoea: by allocation sequence	4		Risk ratio (Random, 95% CI)	Subtotals only
1.1 Adequate	3		Risk ratio (Random, 95% CI)	0.28 [0.14, 0.57]
1.2 Inadequate	1		Risk ratio (Random, 95% CI)	0.79 [0.61, 1.03]
2 Diarrhoea: by allocation concealment	4		Risk ratio (Random, 95% CI)	Subtotals only
2.1 Adequate	3		Risk ratio (Random, 95% CI)	0.28 [0.14, 0.57]
2.2 Inadequate	1		Risk ratio (Random, 95% CI)	0.79 [0.61, 1.03]
3 Diarrhoea: by follow up	4		Risk ratio (Random, 95% CI)	Subtotals only
3.1 Unclear	3		Risk ratio (Random, 95% CI)	0.28 [0.14, 0.57]
3.2 Inadequate	1		Risk ratio (Random, 95% CI)	0.79 [0.61, 1.03]
4 Diarrhoea: by blinding	4		Risk ratio (Random, 95% CI)	Subtotals only
4.1 Open	4		Risk ratio (Random, 95% CI)	0.39 [0.17, 0.90]

Comparison 26. Water quality intervention versus control for RCTs: by methodological quality (longitudinal prevalence ratios)

Outcome or subgroup title	No. of studies	No. of participants	Statistical method	Effect size
1 Diarrhoea: allocation sequence	10		Long. prev. ratio (Random, 95% CI)	Subtotals only
1.1 Adequate	9		Long. prev. ratio (Random, 95% CI)	0.51 [0.23, 1.14]
1.2 Inadequate	1		Long. prev. ratio (Random, 95% CI)	1.07 [0.88, 1.30]
2 Diarrhoea: by allocation concealment	10		Long. prev. ratio (Random, 95% CI)	Subtotals only
2.1 Adequate	9		Long. prev. ratio (Random, 95% CI)	0.51 [0.23, 1.14]
2.2 Inadequate	1		Long. prev. ratio (Random, 95% CI)	1.07 [0.88, 1.30]
3 Diarrhoea: by follow up	9		Long. prev. ratio (Random, 95% CI)	Subtotals only
3.1 Adequate	4		Long. prev. ratio (Random, 95% CI)	0.54 [0.43, 0.67]
3.2 Inadequate	5		Long. prev. ratio (Random, 95% CI)	0.89 [0.76, 1.04]
4 Diarrhoea: by blinding	10		Long. prev. ratio (Random, 95% CI)	Subtotals only
4.1 Double blind	3		Long. prev. ratio (Random, 95% CI)	1.07 [0.88, 1.29]
4.2 Open	7		Long. prev. ratio (Random, 95% CI)	0.45 [0.18, 1.08]

Comparison 27. Water quality intervention versus control for RCTs: by methodological quality (odds ratios)

Outcome or subgroup title	No. of studies	No. of participants	Statistical method	Effect size
1 Diarrhoea: by allocation sequence	9		Odds ratio (Random, 95% CI)	Subtotals only
1.1 Adequate	7		Odds ratio (Random, 95% CI)	0.66 [0.52, 0.83]
1.2 Inadequate	2		Odds ratio (Random, 95% CI)	0.69 [0.63, 0.74]
2 Diarrhoea: by allocation concealment	9		Odds ratio (Random, 95% CI)	Subtotals only
2.1 Adequate	7		Odds ratio (Random, 95% CI)	0.66 [0.52, 0.83]
2.2 Inadequate	2		Odds ratio (Random, 95% CI)	0.69 [0.63, 0.74]
3 Diarrhoea: by follow up	9		Odds ratio (Random, 95% CI)	Subtotals only
3.1 Adequate	4		Odds ratio (Random, 95% CI)	0.48 [0.32, 0.71]
3.2 Inadequate	5		Odds ratio (Random, 95% CI)	0.75 [0.68, 0.84]
4 Diarrhoea: by blinding	9		Odds ratio (Random, 95% CI)	Subtotals only
4.1 Open	9		Odds ratio (Random, 95% CI)	0.68 [0.59, 0.79]

Comparison 28. Water quality intervention versus control for quasi-RCTs: by methodological quality (rate ratios)

Outcome or subgroup title	No. of studies	No. of participants	Statistical method	Effect size
1 Diarrhoea: by comparability of characteristics	6		Rate ratio (Random, 95% CI)	Subtotals only
1.1 Adequate	4		Rate ratio (Random, 95% CI)	0.67 [0.54, 0.83]
1.2 Unclear	1		Rate ratio (Random, 95% CI)	1.0 [0.89, 1.12]
1.3 Inadequate	1		Rate ratio (Random, 95% CI)	0.94 [0.73, 1.21]
2 Diarrhoea: by contemporaneous of data collection	11		Rate ratio (Random, 95% CI)	Subtotals only
2.1 Adequate	10		Rate ratio (Random, 95% CI)	0.59 [0.46, 0.75]
2.2 Unclear	1		Rate ratio (Random, 95% CI)	1.0 [0.89, 1.12]

Comparison 29. Water quality intervention versus control for quasi-RCTs: by methodological quality (risk ratios)

Outcome or subgroup title	No. of studies	No. of participants	Statistical method	Effect size
1 Diarrhoea: by comparability of characteristics	3		Risk ratio (Random, 95% CI)	Subtotals only
1.1 Adequate	2		Risk ratio (Random, 95% CI)	0.45 [0.43, 0.47]
1.2 Inadequate	1		Risk ratio (Random, 95% CI)	0.44 [0.28, 0.69]
2 Diarrhoea: by contemporaneous of data collection	11		Risk ratio (Random, 95% CI)	Subtotals only
2.1 Adequate	10		Risk ratio (Random, 95% CI)	0.59 [0.46, 0.75]
2.2 Unclear	1		Risk ratio (Random, 95% CI)	1.0 [0.89, 1.12]

WHAT'S NEW

Last assessed as up-to-date: 21 January 2006.

Date	Event	Description
18 August 2008	Amended	Converted to new review format with minor editing.

HISTORY

Protocol first published: Issue 2, 2004

Review first published: Issue 3, 2006

CONTRIBUTIONS OF AUTHORS

Conceived review: SC. Co-ordinated review: TC. Designed review: TC, IR, TR, WS. Drafted protocol: TC. Executed search strategy: TC and Cochrane Infectious Diseases Group (CIDG). Screened search results: TC, TR. Retrieved papers: TC. Applied inclusion criteria: TC, TR, SC. Extracted data: TC, TR, WS. Computed estimates of effect: TC, TR, WS. Applied quality criteria: TC, TR, IR. Contacted authors for additional information: TC. Addressed statistical issues: TC, TR, WS, CIDG. Entered data into Review Manager: TC. Drafted review: TC. Commented on review: IR, TR, WS, SC. Prepared tables: TC. Prepared figures: WS, TC. Guarantor of review: TC.

DECLARATIONS OF INTEREST

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DIFFERENCES BETWEEN PROTOCOL AND REVIEW

2006, Issue 3 (first version of review): Wolf-Peter Schmidt became a co-author of the review in June 2005.

INDEX TERMS

Medical Subject Headings (MeSH)

Diarrhea [*prevention & control]; Randomized Controlled Trials as Topic; Water Purification [*methods; standards]; Water Supply [*standards]

MeSH check words

Adult; Child; Humans