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Water, sanitation and hygiene interventions to combat childhood diarrhoea in developing countries

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WATER, SANITATION AND HYGIENE INTERVENTIONS TO COMBAT CHILDHOOD DIARRHOEA IN DEVELOPING COUNTRIES

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About 3ie

The International Initiative for Impact Evaluation (3ie) works to improve the lives of people in the developing world by supporting the production and use of evidence on what works, when, why and for how much. 3ie is a new initiative that responds to demands for better evidence, and will enhance development effectiveness by promoting better informed policies. 3ie finances high-quality impact evaluations and campaign to inform better program and policy design in developing countries.

3ie Synthetic Reviews examine the range of available evidence regarding a particular intervention.

SUMMARY

This report is a synthetic review of impact evaluations examining effectiveness of water, sanitation and hygiene (WSH) interventions in reducing childhood diarrhoea. The review has been conducted to Campbell/Cochrane Collaboration standards of systematic review, as well as employing mixed methods of data analysis to assess not only which interventions are effective, or not, but why and under what circumstances. The review provides an update of previous reviews conducted in this area, notably Fewtrell and Colford (2004).

A comprehensive search was conducted of published and unpublished materials. Studies were identified for inclusion which employed rigorous impact evaluation techniques, using experimental (randomised assignment) and quasi-experimental methods, and which evaluated the impact of water, sanitation and/or hygiene interventions on diarrhoea morbidity among children in low- and middle-income countries. 65 rigorous impact evaluations were identified for quantitative synthesis, covering 71 distinct interventions assessed across 130,000 children in 35 developing countries during the past three decades. Each study was coded for a range of variables relating to type of intervention, effect size and precision, internal validity (relating to evaluation quality) and external validity (relating to context and behavioural mechanisms). Interventions were grouped into five categories: water supply improvements, water quality, sanitation, hygiene and multiple interventions involving a combination of water and sanitation and/or hygiene. Data were collected and synthesised on both quantitative and qualitative information presented in the evaluations.

The results challenge the notion that water quality treatment in the household (at point-of-use) and sanitation 'software' (hygiene) interventions are necessarily the most efficacious and sustainable interventions for promoting reduction of diarrhoea.

While point-of-use water quality interventions appear to be highly effective – and indeed, more effective than water supply or source treatment in reducing diarrhoea – much of the evidence is from trials conducted over small populations and short time periods. More evidence is needed on sustainability, as water quality interventions conducted over longer periods tend to show smaller effectiveness, while compliance rates, and therefore impact, appear to fall markedly over time.

Hygiene interventions, particularly provision of soap for hand-washing, are effective in reducing diarrhoea morbidity, and there does not appear to be evidence that compliance falls over time. The analysis suggests that sanitation 'hardware' interventions are also highly effective. However, relatively few studies have been conducted in this area to-date and studies are particularly needed that quantify the possible environmental spillovers from sanitation provision.

Evidence on the combined impact of multiple interventions is mixed. Further primary studies employing factorial design – that is, comparing different interventions using multiple treatment arms – are needed for more conclusiveness on whether water and sanitation/hygiene interventions are substitutes or complements in the health production function.

The study highlights the importance of behavioural factors in determining up-take and sustainable adoption of WSH technologies. Insights from diffusion theory suggest that preventive interventions tend to be adopted more slowly as benefits are difficult to observe and users presumably discontinue treatment as they perceive that the costs of using the intervention outweigh the benefits. These problems are more relevant for interventions aiming to reduce disease prevalence which do not have additional benefits, for example time savings. Unfortunately, few impact evaluations addressing sustainability collect data on the reasons for the levels of compliance and acceptance found among beneficiaries. This information is an essential guide to fostering long-term impact.

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ACRONYMS

BLDS	British Library for Development Studies
3ie	International Initiative for Impact Evaluation
C2	Campbell Collaboration
CLTS	Community-led total sanitation
DALY	Disability-adjusted life year
DHS	Demographic and health survey
ES	Effect size
ESA	East and southern Africa
GTZ	Deutsche Gesellschaft für Technische Zusammenarbeit (German Technical Cooperation Agency)
IDEAS	Internet Documents in Economics Access Service
IEG	Independent Evaluation Group (World Bank)
ITT	Intention-to-treat
JOLIS	World Bank and IMF library catalogue
LAC	Latin-America and Caribbean
LILACs	Latin American and Caribbean Literature on Health Sciences Database
MENA	Middle-east and north Africa
POU	Point-of-use
PSM	Propensity-score matching
RCT	Randomised-controlled trial
SA	South Asia
TOT	Treatment-on-the-treated
UN	United Nations
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UN-HABITAT	United Nations Human Settlements Programme
UNICEF	United Nations Children's Fund
UNRISD	United Nations Research Institute for Social Development
USD	United States Dollars
TBIE	Theory-based impact evaluation
WCA	West and central Africa
WHO	World Health Organisation
WSH	Water, sanitation and hygiene

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TABLES AND FIGURES

1. INTRODUCTION AND OBJECTIVES

The Joint Monitoring Programme for Water Supply and Sanitation estimates 1.1 billion people live without improved water sources, while over half of the developing world population – representing 2.6 billion people – lack access to improved sanitation (WHO/UNICEF, 2004). Water, sanitation and hygiene (WSH) have important social and economic benefits, with implications for environmental cleanliness, health, poverty reduction and (gender) equity. One of the most important benefits of WSH is by providing barriers to transmission from the environment to the human body of diarrhoeal disease, which is responsible for an estimated 21 per cent of fatalities of under-fives in developing countries or 2.5 million deaths per year (Kosek et al., 2003). Interventions to effect improvements in WSH are therefore an important focus of efforts to improve quality of life around the world.

This report, the first product of 3ie's synthetic review programme, provides the results of a synthetic review of the effectiveness of interventions in water, sanitation and hygiene (WSH) in promoting better health outcomes in developing countries as measured by the incidence of diarrhoea among children. The study updates the existing systematic reviews and meta-evaluations in WSH (Esrey et al., 1991; Curtis and Cairncross, 2003; Fewtrell and Colford, 2004; Clasen et al., 2007b; Ejemot et al., 2008; and IEG, 2008), drawing on new evidence and rectifying methodological shortcomings.

The review has been conducted to Cochrane/Campbell Collaboration standards of systematic review. It synthesises quantitative data on effectiveness using meta-analysis and meta-regression. It also draws on a programme theory of change, examining evidence quantitative and qualitative on adoption (compliance) and evidence on the context and behavioural mechanisms underlying the interventions. It aims to provide information relevant to programme planners, by collecting and analysing information on effectiveness, compliance and sustainability. It draws on theoretical insights, including from diffusion theory, in explaining the results.

Section 2 provides the background and literature review, while section 3 presents the theoretical model. Section 4 presents the methods, including inclusion criteria, search strategy and data collection. Section 5 presents the search results and sections 6 to 8 present results from quantitative and qualitative analysis of effectiveness, behaviour change and sustainability. Section 9 concludes.

2. BACKGROUND

There is a large and growing impact evaluation literature examining the effects of water, sanitation and hygiene interventions on quality of life outcomes in developing countries, utilising a range of study methodologies. Most of this literature focuses on direct health outcomes, in particular childhood diarrhoea risk (IEG, 2008). In recent years, a number of reviews have been conducted to examine the results of these studies systematically, using literature review, meta-analysis and/or meta-evaluation (Esrey et al., 1991; Curtis and Cairncross, 2003; Fewtrell et al., 2005; Clasen et al., 2007b; Aiello et al., 2008; Arnold and Colford, 2007; Ejemot et al., 2008; IEG, 2008; Schmidt and Cairncross, 2009). In most cases, reviews assess the internal validity of each study design and pool estimates using meta-analytic techniques with the objective of making generalisations on the relative effectiveness of different interventions. The main results of the reviews conducted thus far are summarised in Table 1.

Table 1 - Impact of WSH on diarrhoea morbidity: existing survey evidence

	Pooled effect	95% CI		# obs	Comments
Water supply					
Esrey et al. (1991)	0.73			7	
Fewtrell et al. (2005)	0.75	0.62	0.91	6	
Water quality					
Esrey et al. (1991)	0.83			7	
Fewtrell et al. (2005)	0.69	0.53	0.89	15	
Clasen et al. (2007b)	0.65*	0.59	0.71	33	
Arnold and Colford (2007)	0.71	0.58	0.87	10	Chlorination
Schmidt and Cairncross (2009)	1.09*	0.98	1.22	4	Placebo-controlled trials
Sanitation					
Esrey et al. (1991)	0.78			11	
Fewtrell et al. (2005)	0.68	0.53	0.87	2	
Hygiene					
Esrey et al. (1991)	0.67			6	
Curtis and Cairncross (2003)	0.53	0.37	0.76	17	Hand-washing with soap
Fewtrell et al. (2005)	0.63	0.52	0.77	11	
Ejemot et al. (2008)	0.68	0.52	0.90	4	Hand-washing with soap
Aiello et al. (2008)	0.66	0.53	0.82	12	Hand-washing
Multiple interventions					
Fewtrell et al. (2005)	0.67	0.59	0.76	5	

Note: * authors' own calculations based on reported data. Pooled effect measures the ratio of diarrhoea morbidity in treatment group to the control group; effects are pooled using meta-analysis, with the exception of Esrey et al. (1991) which reports median effects.

Esrey et al. (1991) survey 144 studies and calculate median percentage reductions in diarrhoea morbidity across studies of 33 per cent for hygiene interventions, 27 per cent for water supply interventions, 22 per cent for sanitation interventions and 17 per cent for water quality interventions. They conclude that "safe excreta disposal and proper use of water for personal and domestic hygiene appear to be more important than drinking water quality in achieving broad health impacts" (Esrey et al., 1991: 31).

Fewtrell and Colford (2004, also published as Fewtrell et al., 2005) conduct meta-analysis of 60 studies, finding that both hygiene education and water quality interventions reduce diarrhoea risk on average by about 40 per cent each, while sanitation provision or water supply reduce risk by only around 20 per cent each. The difference in findings with respect to water quality improvements between the two reviews is due to the former being based on studies examining water quality treatment at source, while the latter includes many studies of water quality improvements at point-of-use (POU). Since there are multiple ways in which clean water may be contaminated between source and POU, most recent interventions have focused on household water treatment and safe storage, with beneficial results. Wright et al.'s (2004) systematic review finds substantial evidence for (re-) contamination between source and POU.

A meta-analysis of 33 studies conducted by Clasen et al. (2007b) also supports the finding that water treatment at POU, particularly flocculation or disinfection, is more effective in reducing diarrhoea risk than water source improvements.

Three other meta-analyses examine the impact of hand-washing on diarrhoea risk. Curtis and Cairncross (2003) analyse 17 studies and find a reduced risk of 50 per cent. Aiello et al. (2008) find reduced risk of gastrointestinal illness of 34 per cent across 12 studies conducted in developing countries, and also report that longer-term trials tend to have lower impact on reducing diarrhoea risk. Ejemot et al. (2008) find a reduced diarrhoea risk of one-third across five randomised-controlled trials (RCTs) in developing countries.

The World Bank's Independent Evaluation Group (IEG, 2008: 17) concludes that there is "overwhelming evidence that hand washing, sanitation, and point-of-use water treatment improve health outcomes… However, there do not appear to be health gains for water treatment at the source. Furthermore, the health impact of combined methods has not been found to be stronger than any single approaches."

Calculations of cost-effectiveness have placed more weight behind water quality and hygiene interventions (Cairncross and Valdmanis, 2006; Clasen et al., 2007a). In terms of dollars (USD) per disability-adjusted life year (DALY) averted, estimates from improved hygiene and sanitation suggest that hygiene promotion is the most efficient, at USD 3/DALY averted, followed by sanitation promotion, at USD 11/DALY, and finally sanitation construction, at up to USD 270/DALY (Cairncross and Valdmanis, 2006). Estimates of cost-effectiveness of improved water suggests the impact of community connection in terms of disability-adjusted life years, estimated at USD 94/DALY, is less than half that for household connection, but substantially above comparable estimates of point-of-use water treatment – for example Clasen et al. (2007a) estimate USD 53/DALY averted from chlorination. The evidence on water quality appears to be so convincing that the World Health Organisation (2002) concluded that point-of-use water treatment is the most cost-effective approach to reach the Millennium Development Goal of halving the number of persons with no access to safe water.

However, while often showing strong impact on disease risk, much of the evidence on water quality and hygiene interventions comes from impact evaluations conducted under trial conditions, at zero or negligible cost to participants, with plenty of within intervention follow-up and possibilities for bias, and over relatively short periods of time and small samples of beneficiaries. Schmidt and Cairncross (2009) examine bias in POU water treatment trials, finding zero impact across five placebo-controlled trials, three of which were conducted in developing country settings. They conclude that "widespread promotion of household water treatment is premature given the available evidence" (p. 986). Arnold and Colford (2007) provide some evidence linking length of trial to reduced effectiveness in water chlorination interventions. Indeed, as this report shows, sustainability is an important issue not adequately addressed by these evaluations. There is therefore considerable controversy as to the scalability of water quality interventions, as well as a need for better understanding of what determines use and performance in the long term (Sobsey et al., 2009).

This review takes the existing systematic reviews of WSH interventions to reduce diarrhoeal risk as its starting point, notably Fewtrell and Colford (2004). However, our survey of previous reviews has identified some methodological weaknesses associated with combining effect estimates, which may reduce validity of pooled estimates of effect size. For example, previous reviews have synthesised effect sizes in which:

- The outcome variable varies across studies, with most studies measuring diarrhoea morbidity, but some measuring incidence of cholera.
- The comparison group used in the effect estimate computation method varies, with most estimates taken from studies reporting differences between treatment and control group, but some measuring differences between self-selected groups in the treatment group.
- Estimates are reported from different estimation procedures, including risk ratios, rate (incidence density) ratios, prevalence ratios and odds ratios, which may bias pooled effect sizes across interventions.
- Internal validity is sometimes questionable: use of low quality studies, such as case-control design, or studies in which comparability of treatment and control groups is questionable or not assessed explicitly, or using self-selected treatment groups.

Moreover, the systematic reviews surveyed focus on estimating net benefits of interventions, but often stop short of evaluating in detail why such interventions have been effective or not, and, moreover, do not assess adequately sustainability. These are of overriding importance to programme planners.

3. INTERVENTIONS AND THEORETICAL MODEL

Water, sanitation and hygiene improvements can be classified into four groups of related interventions (Esrey et al., 1991; Fewtrell et al., 2005). Water supply improvements include provision of an improved source of water and/or improved distribution, such as piped water or standpipes, provided either at public (source) or household (point-of-use) levels. Sanitation ('hardware') improvements provide improved means of excreta disposal, through latrines or connection to the public sewer. Table 2 lists the types of water and sanitation facilities classified as basic and improved in WHO/UNICEF (2000).

Table 2 - Definition of basic and improved water and sanitation facilities

	Water	***Sanitation***
Basic	Unprotected well	No facilities
	Unprotected spring	Service or bucket latrines (where excreta are manually removed)
	Vendor-provided water	Public latrines
	Bottled water	Latrine with an open pit
	Tanker-truck provided water	
	Rivers, canals, ditches	
Improved	Household connection	Connection to a public sewer
	Public standpipe	Connection to a septic system
	Borehole	Pour-flush latrine
	Protected dug well	Simple pit latrine
	Protected spring	Ventilated improved latrine
	Rainwater collection	

Source: WHO/UNICEF (2000).

Water quality interventions provide the means to protect or treat water for the removal of microbial contaminants and/or safe storage, at source or POU. Examples of water treatment technologies include filtration, chlorination, flocculation, solar disinfection, boiling and pasteurising. Hygiene ('software') interventions include hygiene and health education and the encouragement of specific behaviours such as hand washing.[1]

WSH interventions reduce the risk of contracting gastrointestinal illnesses, such as diarrhoea, dysentery and cholera, by providing barriers to pathogens carried from faeces into the body via fingers, flies, fields, food and unclean water. Figure 1 illustrates the specific transmission pathways along which WSH minimise disease risk. The figure is highly simplified. Factors moderating disease risk at individual level include household size, age, nutritional and health status and personal immunity.

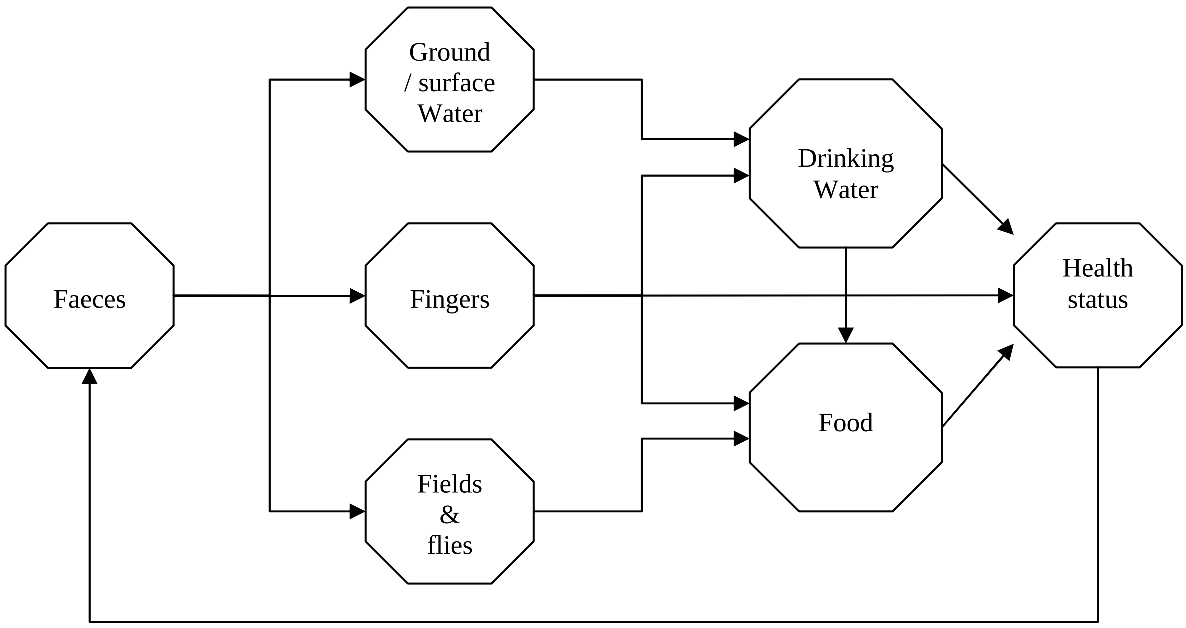
[1] Methods to reduce faecal contamination of the environment such as fly spraying are not included in this review. See, for example, Chavasse et al. (1999).

Interventions act to minimise risks of transmission along dashed pathways in Figure 1. Improved sanitation aims to break the cycle of disease transmission from faeces to the environment in the first round. Water and hygiene interventions aim to break second round transmission routes. As the various transmission pathways demonstrate, any one water, sanitation or hygiene intervention will only minimise risk along certain pathways. As implied in the figure, multiple interventions comprising a mix of water, sanitation and/or hygiene would have complementary effects. For example, drinking water can be easily (re-) contaminated between source and point-of-use in unhygienic environments in the process of transport and storage or at point-of-use.

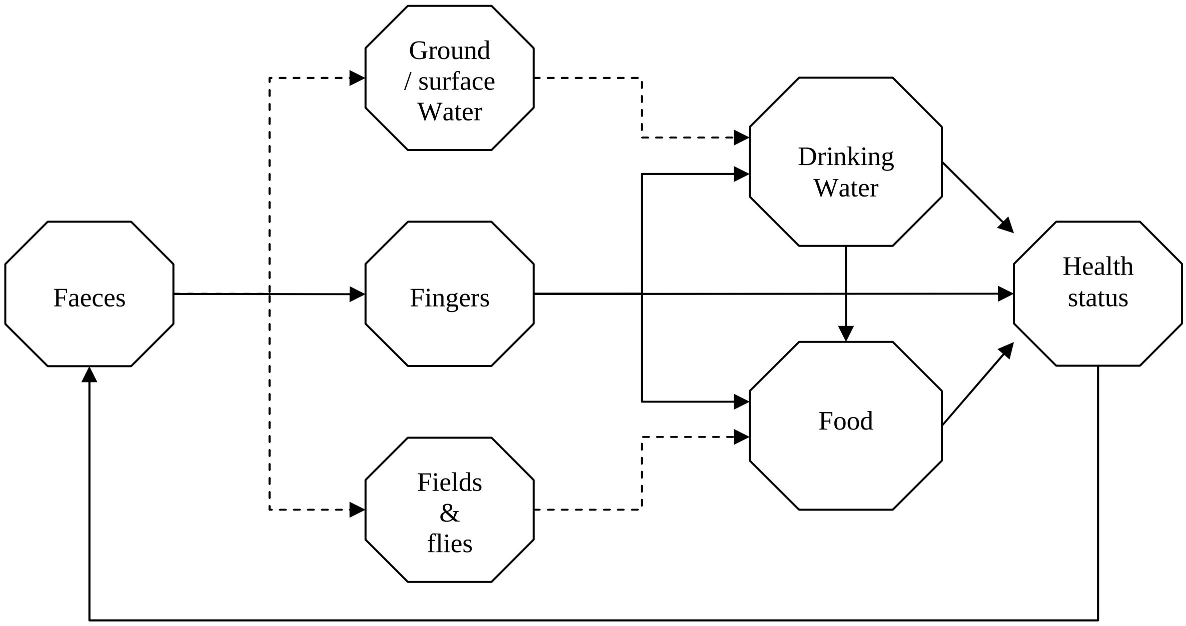
The health impact has second-round effects, for example, on household income, through reduced health expenditures and increased production and productivity of labour; on children's educational attainment, through fewer sick days or provision of adequate sanitation facilities at schools for girls; as well as on gender equity, where interventions reduce time spent, typically by women and girls, collecting water for the household.

Figure 1 - Water treatment, sanitation and hygiene barriers to disease transmission

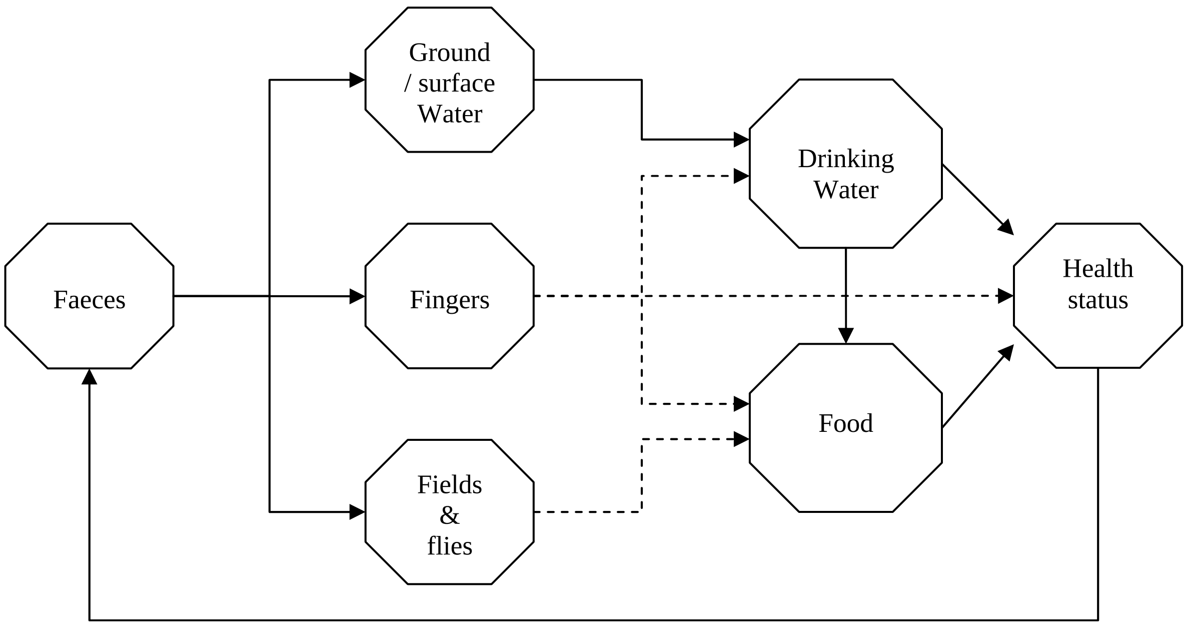
(a) Faecal-Oral contamination: arrows represent transmission routes for pathogens



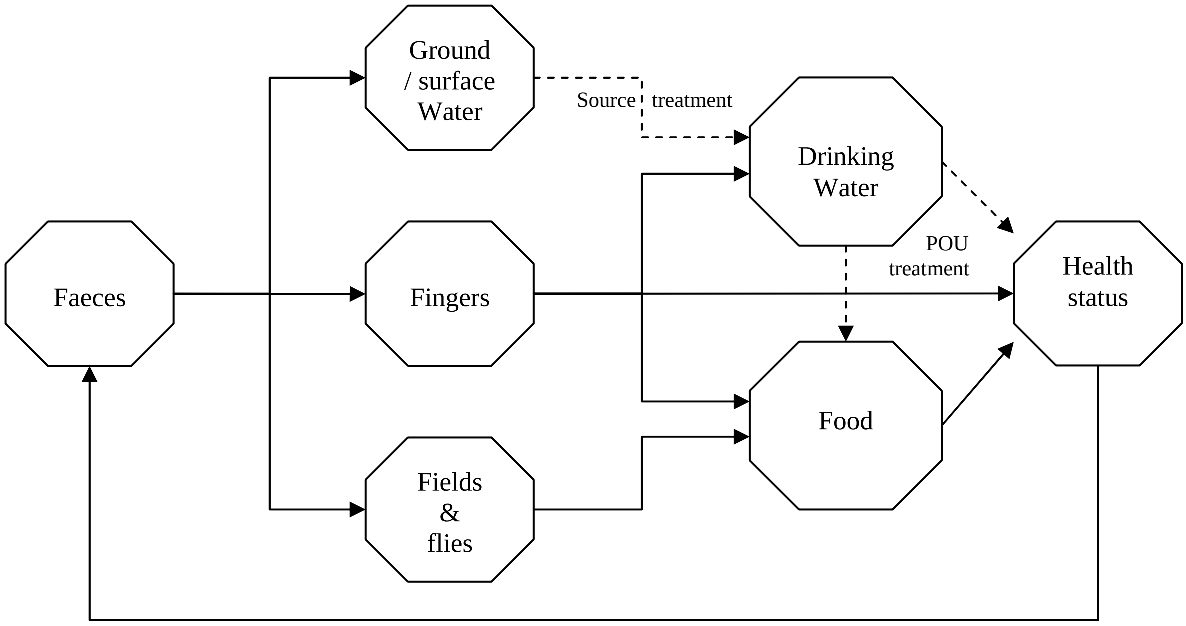
(b) Sanitation barriers to transmission



(c) Hygiene barriers to transmission



(d) Water treatment at source or point-of-use (POU) as a barrier to transmission



Note: dashed arrows represent routes along which pathogen transmission risk is reduced by intervention.
Source: adapted from Prüss et al (2002).

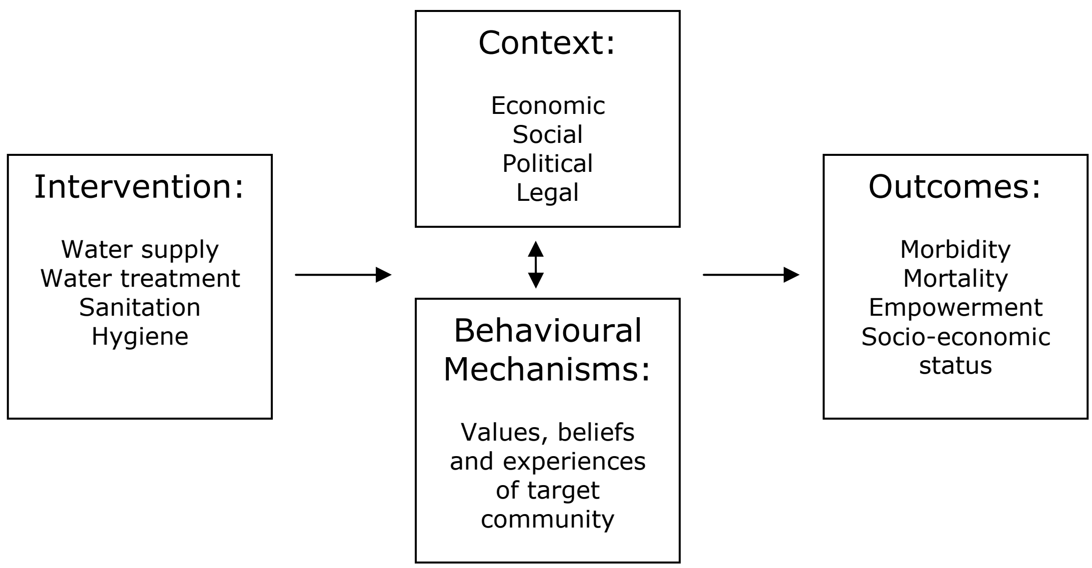
While the programme theory is clear and logical, interventions are embedded in social systems which have a strong bearing on their uptake and impact in the real world. As Pawson et al. (2005, S1: 23) note, "rarely, if ever, is a programme equally effective in all circumstances because of the influence of context". Behavioural mechanisms, the beliefs, values and experiences of the treatment population and the socio-economic environment are important determinants of the adoption and sustainability of interventions. We return to this point throughout the report.

For example, water treatment and hygiene interventions work by engendering substantial behavioural change among beneficiary communities and within households. Safe hygiene involves hand washing throughout the day – after defecation and washing children, before preparing food and so forth – as well as safe disposal of human and animal waste. Similarly, water quality interventions may require systematic, time-intensive water treatment and safe storage by the household.

While improved water supply and sanitation do require some behaviour modification in that facilities need to be used and maintained hygienically, it is arguably change of a more limited nature. Moreover, water supply and sanitation entail other benefits – for example, improved water supply enables safe hygiene practices such as hand washing, and there may be substantial community spillovers in terms of environmental health benefits from sanitation, as documented by Root (2001) and Buttenheim (2008). Benefits from time savings may also be substantial, particularly for women and girls (Hutton et al., 2006; IEG, 2008), but are rarely factored into impact evaluations. Only three of the evaluations reviewed here collected information on time-savings. Pattanayak et al. (2007) estimate a reduction of 17 minutes per family member per day in walking for defecation associated with improved sanitation in rural India. In rural Nigeria, Blum et al. (1990) estimate reduced time from six hours to 45 minutes per household per day during the dry season associated with hand-pump installation, mainly benefiting adolescent girls and young women (although an increase of zero to 12 minutes in the wet season due to less reliance on the sole use of rainwater). In addition, Wang et al. (1989) estimate time savings of 20 minutes per household per day from a village water supply improvement in China.

Which factors determine whether a WSH intervention will be effective in improving outcomes and why? To answer these questions one has to examine the behavioural mechanisms through which the intervention works and the context in which it is based (Figure 2). A recent review (van der Knapp et al., 2006) aims to answer the 'why' question by combining systematic review methods with the context-mechanism-outcome model of Realist Evaluation promoted by Pawson (2006). They argue that the effectiveness of a programme depends on the combined action of the behavioural mechanisms underlying it and the context in which it takes place. Behavioural mechanisms operate through the values, beliefs and past experiences of individuals in the social system. Thus, factors such as interpersonal networks and individual agency are important in the adoption and rejection of an intervention. The action of mechanisms depends in part on the context in which they are used. Behavioural change is achieved via the entire system of social relationships (the context) and, therefore, an intervention geared towards the achievement of behavioural change must be aligned with the context in which it is used.

Figure 2 - Effects of intervention on outcomes are mediated by context and behavioural mechanisms



The importance of taking into account the context and behavioural mechanisms in programme design is highlighted in an example from an intervention to supply clean drinking water through public spigots in villages in Egypt (Rogers, 2005). Despite provision of piped water and government media campaigns warning people of the risks from drinking canal water, the level of use of spigots was low. Surveys and interviews conducted subsequently found that users complained of a chemical taste of the chlorinated water and reported rumours that the government's family planning programme had added chemicals to decrease population growth. Moreover, villagers had a vessel for water collection which they perceived as purifying the water. Socially, the women preferred gathering water from the canal banks where they also washed their clothes and dishes; and because of long queues and low water pressure there were reports of fighting in the queues. Ultimately, the piped water was perceived as unreliable. It was also highlighted that village religious leaders could have played a role in promoting pure drinking water, but this strategy was not pursued by the authorities.

4. METHODS

This report contributes to the literature examining WSH impact on diarrhoea morbidity by providing an updated synthesis of rigorous impact evaluations that have been conducted in developing countries. Building on the existing surveys, we undertook extensive study search and identification, applying stringent inclusion criteria. We coded and synthesised effect size and variables relating to internal and external validity for each included evaluation, rectifying methodological shortcomings identified in previous surveys. We aimed to provide information relevant to programme planners, thus we paid particular attention to impact heterogeneity, behaviour change (compliance) and sustainability, using quantitative and qualitative data analysis. The methods used in our analysis were also set out in the study protocol (Waddington et al., 2009a). The review was conducted using Cochrane/Campbell Collaboration (C2) standards of systematic review (Higgins and Green, 2008). Building on the causal chain analysis, data were also collected and analysed on behavioural mechanisms at work and the context in which interventions are conducted.

4.1. Inclusion criteria

Impact evaluations selected for our review used experimental design – randomised controlled trials (RCTs) with assignment at individual level or community (cluster) levels – or quasi-experimental design, including non-RCTs with baselines and concurrent control groups matched by confounding variables, studies applying statistical matching methods (propensity-score matching, PSM) to survey data, and studies employing a pipe-line approach to identify beneficiaries scheduled to receive treatment in future as the control group.

Excluded studies were those which do not control for endogeneity of programme placement or self-selection into the intervention group. Unfortunately, much of the existing evidence is from such observational studies which compare self-selected exposure groups and are thus at risk of serious problems of confounding. Owing to concerns of external validity, we also excluded from quantitative synthesis studies based on disease reporting to health facilities, including deWilde et al. (2008) and Wang et al. (1989) and those based on case-control design (e.g. Clemens and Stanton, 1987; Daniels et al., 1990). Those seeking formal health care are unlikely to be a representative sample of the general population.

Impact evaluations were selected that:

- report specific water, sanitation and/or hygiene intervention(s);

- were conducted in developing (low- or middle-income) countries;
- use an infant or child as the unit of observation, defined as aged under 12 and 71 months in most cases;
- estimate impact on diarrhoea morbidity, measured under endemic (i.e. non-outbreak) conditions.

4.2. Search methods for identification of studies

Following Fewtrell and Colford (2004), relevant studies were identified by searching academic databases pairing the following terms: 'sanitation', 'water quality', 'water quantity' and 'hygiene' against 'diarrhoea' or 'diarrhea' and 'sanitation', 'drinking-water', and 'hygiene' against 'intervention'.

The following databases were searched: PubMed, Embase, LILACs, Web of Science (including Science Citation Index Expanded; Social Sciences Citation Index; Conference Proceedings Citation Index- Science), in addition to JOLIS, IDEAS, the British Library for Development Studies (BLDS) and the Cochrane Library. Moreover, Google Scholar, which has the advantage of covering all disciplines and unpublished material, was also searched, using the same search terms as above. As the Google searches generated a large number of results which were ordered by relevance, we limited our reviews to the first 1,000 results. The searches in the databases included in the Fewtrell and Colford (2004) review (Pubmed, Embase, LILACs and the Cochrane Library) were limited to papers published since 2003, which was the date at which the previous authors had searched until. The Web of Science databases, JOLIS, IDEAS, BLDS and Google Scholar were searched back to 1998.

In addition to contacting key researchers working in the field of water, sanitation and hygiene, we also contacted or searched the websites of the following organisations: Asian Development Bank, Australian Aid Agency, Canadian International Development Agency, Swedish development agency, Danish Development Agency, Department for International Development, GTZ, Japan International Cooperation Agency, Japan Bank for International Cooperation, US Agency for International Development, European Commission, the World Bank (Office of Evaluation and Development), Pan American Health Organization, World Health Organization, UN, (UNICEF, UNEP, UNDP, UN-HABITAT, UNRISD), Inter-American Development Bank, International Water Management Institute, African Development Bank, Red Cross, WaterAid, Christian Aid, Oxfam, IRC International Water and Sanitation Centre, International Rescue Committee, African Medical and Research Control, Fresh Water Action Network, Centers for Disease Control and Prevention.

Finally, we conducted bibliographic back-referencing of papers identified for inclusion and a hand-search of journals and relevant book shelves of the library of the University of Birmingham, UK. No limitations were placed on language of publication.

4.3. Data collection and coding

Meta-analysis aims to combine similar studies of sufficient quality (internal validity) with the aim of generating credible, generalisable (externally valid) results. Its origins lie in the medical literature, though it is increasingly being applied to the social sciences, under the auspices of organisations such as the Campbell Collaboration (C2), and more recently in the developing country context, advocated by organisations such as the International Initiative for Impact Evaluation (3ie).

Problems with internal validity of WSH intervention designs have been well-documented previously (Blum and Feacham, 1983). Determining the external validity of studies – that is, relating to the context and the behavioural mechanisms underlying the intervention – is particularly problematic in the field of socio-economic interventions, and vital to the credibility of conclusions. In the case of WSH interventions, studies vary in type of intervention, how they are conducted and by whom, social, political, cultural and legal backgrounds, characteristics of target groups, not to mention measures of outcome variable, base-line situations and study designs, all of which will reasonably impact on effect estimates. We have attempted to minimise validity concerns in a number of ways, as explicated in the following section.

Interventions

WSH interventions are classified into groups and sub-groups of related interventions (Fewtrell and Colford, 2004):

- Hygiene interventions: including hygiene and health education and the encouragement of specific behaviours, such as hand-washing.
- Sanitation interventions: providing improved means of excreta disposal, usually latrines.
- Water supply interventions: including provision of an improved water supply and/or distribution, such as the installation of a hand pump or household connection, either at the public or household level.
- Water quality interventions: water treatment for the removal of microbial contaminants and/or clean storage, either at the source or at the household level.
- Multiple interventions: those which introduced a combination of water and sanitation and/or hygiene elements to the study population.

There remains substantial variation in the types of interventions within each of the five strata. We therefore performed sub-group meta-analysis where sufficient studies existed on a particular intervention sub-category.

Effect sizes

We transformed all effect size (ES) ratios into a common metric, expressed such that ES<1 means the intervention reduced the frequency of diarrhoea in the treatment group in comparison to the control group, with precision measured at 95 per cent confidence. In the calculation of ES precision, while most studies appear to have adjusted for clustering at community level where relevant, not all studies adjusted for clustering at household level, where multiple observations were from the same household, or at individual level, where multiple observations were taken from the sample individual over time. It appears that the techniques for doing so, based on generalised-estimating equations analysis, have only recently become available.

Studies report effect sizes calculated as relative risk ratios, rate ratios, longitudinal prevalence ratios and/or odds ratios. Risk measures the probability of being ill during the measurement period, rate or incidence density measures the average risk over the measurement period measured in average number of 'episodes', and longitudinal prevalence is more closely associated with duration of illness, usually measured as the proportion of days of illness during the measurement period. Odds ratios are calculated as the conditional probability of illness divided by the probability of not being ill over the measurement period. Both odds and longitudinal prevalence ratios will tend to be further away from the value of one (the point of no effect) than risk or rate ratios, this difference being larger the greater the disease incidence in the sample. It was not possible to convert these into a common ratio type. However, we note that where the risk of disease is low, as in the majority of studies included in this review, the measures produce similar results (Kleinbaum et al., 1982). We also examined whether ratio type accounts for differences in effects observed across interventions.

Effect sizes, whether measured in terms of disease incidence or prevalence,[2] are reported from intention-to-treat (ITT) analysis. ITT measures the effect of treatment irrespective of compliance, and thus is of more policy relevance than treatment-on-the-treated (TOT) in analysis of voluntary programmes (Bloom, 2006). For some studies, the effect sizes were adjusted using multivariate regression with control variables, often due to concerns of confounding. Some of the control variables used, for example carers' education and observed hygiene practices, may be instruments for compliance, which would tend to inflate ITT impact estimates towards the TOT effect. We examine whether adjustment systematically affects impact estimates. The results therefore provide lower bound estimates of the impact that could be realised if all complied with the treatment and there was no control group contamination.

To allow examination of impact heterogeneity, we collected multiple effect estimates per study, where these were reported for different intervention types or confounding factors, although we have only included one result from each study in each individual meta-analysis.

For the majority of evaluations, the ES and confidence intervals extracted were as reported in the original paper, although we checked the calculations where sufficient data enabled this. However, a number of evaluations reported estimates for multiple treatment arms (based on factorial impact evaluation design) of water supply, water quality or hygiene (Reller et al., 2003; Crump et al., 2005; Luby et al., 2005; Luby et al., 2006; Brown et al., 2008; Khanna, 2008), multiple age groups (Luby et al., 2005; Luby et al., 2006; Quick et al., 1999; Stauber et al., 2009) and multiple time periods (Aziz et al., 1990; Luby et al., 2004; Messou et al., 1997). There are two fundamental problems in including multiple effect estimates from any one study in a single meta-analysis (Higgins et al., 2008). First, studies with multiple results would receive greater weight than studies with only one effect estimate. Second, the effect estimates from multiple treatment arms with a single control group are positively correlated, and not accounting for this positive correlation would lead to an underestimation of summary variance (Borenstein et al., 2009).

In order to reduce loss of information and offset charges of results-related choices, we combined estimates prior to meta-analysis, by calculating an average effect (weighted by sample size) of the relevant pair-wise comparisons in these studies and variance accounting for the correlation between correlated comparison groups from the same study. The correlation between estimates was calculated as the sample weighted mean of the correlation of treatment groups and the correlation of the

[2] Longitudinal prevalence of diarrhoea is preferred on theoretical grounds and empirically is more strongly associated with child mortality and weight gain than incidence (Morris et al., 1996). Different interventions may affect measures of incidence and prevalence differently – for example, Gross et al. (1989) note that hygienic practices such as removal of faeces from the yard may have greater impact on spell duration than incidence.

control groups. The correlation between control arms was assumed 1 where the same control group is used as comparator and 0 otherwise. The correlation between treatment arms was assumed to be 0 when combining results from different treatment groups and 1 when combining results from the same treatment groups over time. When combining results across different individuals with the same treatment group the correlation was assumed 0.5, which estimates variance at the mid-point between the two extreme cases of treating comparisons as independent (with correlation coefficient equal to 0) and most likely underestimating the variance, or treating them as perfectly correlated (correlation coefficient of 1) and most likely overestimating the variance. See Borenstein et al. (2009, Chapters 24 and 25) for more on this. Meta-analysis results were not sensitive to these assumptions.

In addition, two multiple arm trials report separately the impact of water treatment or water treatment plus safe storage against a single control group (Luby et al., 2006; Reller et al., 2003). Two multiple arm sanitation studies report separate impact of sewer connection or latrine provision versus a single control group (Pradhan and Rawlings, 2002; Walker et al., 1999), while one reports separately improved drainage or improved drainage and sewer connection versus a single control group (Moraes et al., 2003). For each study, we calculate a weighted mean effect size for pooled meta-analysis, but conduct additional sub-group analysis of separate arms.

Where possible, we collected or synthesised estimates for children. However, we were obliged to include estimates for all ages for six evaluations which did not provide separate effect sizes for children (Doocy and Burnham, 2006; Iijima et al., 2001; Khan, 1982; Quick et al., 2002; Walker et al., 1999; Xiao et al., 1997). Inclusion of these estimates did not alter meta-analysis results significantly.

For studies reporting effect sizes for diarrhoea and dysentery separately, combined measures were made where possible, although not all studies differentiate between the two types.

Effect sizes were synthesised by inverse variance-weighted random effects meta-analysis and meta-regression using STATA software (STATA Corporation, College Station, TX, USA). The choice of random effects model was made given likely heterogeneity arising from contextual factors, including location of the study, baseline environmental risk and diarrhoea incidence, and underlying behavioural factors, all of which would likely invalidate the assumption that the 'true' effect of the intervention is fixed across studies.

Internal validity

Key sources of internal validity bias arise from use of incomparable treatment and control groups (arising from our inclusion of both experimental and quasi-experimental evaluation designs), recall period and disease definition (Fewtrell et al., 2005). Evaluations that demonstrated treatment and control group comparability according to key confounding variables at baseline (or which were able to control for this in multivariate analysis), used a recall period of two weeks or less, and provided a clear definition of diarrhoeal disease, such as 'three or more loose stools in a 24-hour period,' were classified as of 'high quality'. Studies were classified as of 'low quality' if they did not meet any one of these criteria, or if they did not report on statistical precision of effect estimates; in such cases, where possible, we approximated confidence interval based on information reported on sample size.

A recall period of two weeks is usually the limit of what is considered as a reasonable period in reporting disease morbidity before significant bias sets in, as used for example in household surveys such as the Demographic and health survey (DHS). There are studies arguing that a recall period greater than 48 hours is unreliable, particularly when providing data on family members other than oneself (Boerma et al., 1991). Arguably, the risk of bias would be less when care givers are asked about young children.

There are of course biases inherent in experimental data including those arising from the Hawthorne effect, courtesy bias and researcher bias.[3] We therefore collected information on the use of placebo-control and disclosure of potential conflicts of interest. We also test for publication bias (Rothstein et al., 2005).

An additional source of bias which we are unable to examine here is censoring of observations due to mortality: where WSH interventions save lives, which are more prone to disease than average, a positive impact on mortality could yield perverse outcomes in terms of morbidity. Indeed, a number of impact evaluations have found positive impacts of WSH interventions on child survival, including Galdo and Briceño (2005), Fuentes et al. (2006) and Gamper-Rabindran et al. (2008).

External validity

To address concerns about external validity, we collected information relating to context – including location, season, baseline water supply and sanitation provision, sample size and study length – and process information relating to compliance among beneficiaries (measurement of outputs). Baseline water and sanitation facilities were categorised according to likely risk of faecal-oral pathogen intake. Very high risk baseline conditions are those with both basic water and basic sanitation, or improved water and basic sanitation. High risk conditions are identified as those with basic water and improved sanitation, or both improved water and improved sanitation (Prüss et al., 2002). Where baseline data on pre-intervention water and sanitation provision were not available for extraction, the study followed Fewtrell and Colford (2004) in applying the water and sanitation provision of the majority of the population according to WHO/UNICEF (2000) in each relevant country and location as a baseline scenario.

Both quantitative and qualitative data were collected. For the qualitative data, studies were searched for evidence or speculation on why the interventions have been effective, or not, and whether issues of sustainability had been considered. Annex 2 provides the study codes used.

[3] The Hawthorne effect occurs where participants change their behaviour in response to being observed, courtesy bias occurs where participants give answers that they think the questioner wants to hear, and researcher bias occurs due a vested interest in a certain outcome to the experiment.

5. SEARCH RESULTS

The searches returned over 19,000 potentially relevant papers, including over 19,000 from database searches, 19 from hand searches and 11 from contact with organisations and researchers. The majority of papers were excluded after reviewing titles and the abstracts of the remaining 278 papers were downloaded into Refworks.[4] Two researchers then systematically reviewed the abstracts in the database and obtained full text copies of 68 studies. These papers were then reviewed and 11 papers met the inclusion criteria and were included in the review. In addition to this 110 studies were identified from bibliographies of previous reviews. Full text copies of all these papers were obtained and 54 of these papers met the inclusion criteria and were included in the review. All papers identified for inclusion were published in English, with the exception of two in Chinese (Lou et al., 1990; Xiao et al., 1997), one in French (Messou et al., 1997) and one in Spanish (Universidad Rafael Landivar, 1995).

Figure 3 provides a detailed outline of the search strategy and review process, while the count of all unique papers identified in the initial search is provided in Annex 1, together with details of the organisation and journal searches carried out. The reference list includes studies which assessed the effect of WSH interventions on gastrointestinal illness in developing countries, but which were excluded either because they did not use rigorous impact evaluation methods or because they did not examine the impact specifically on diarrhoea.

Detailed information on each included intervention is given in Annex 3. The 66 impact evaluations which met our inclusion criteria covered a total of 76 distinct interventions. Figure 4 shows the geographical distribution of the interventions evaluated.

[4] http://www.refworks.com/

Figure 3 - Search and review process

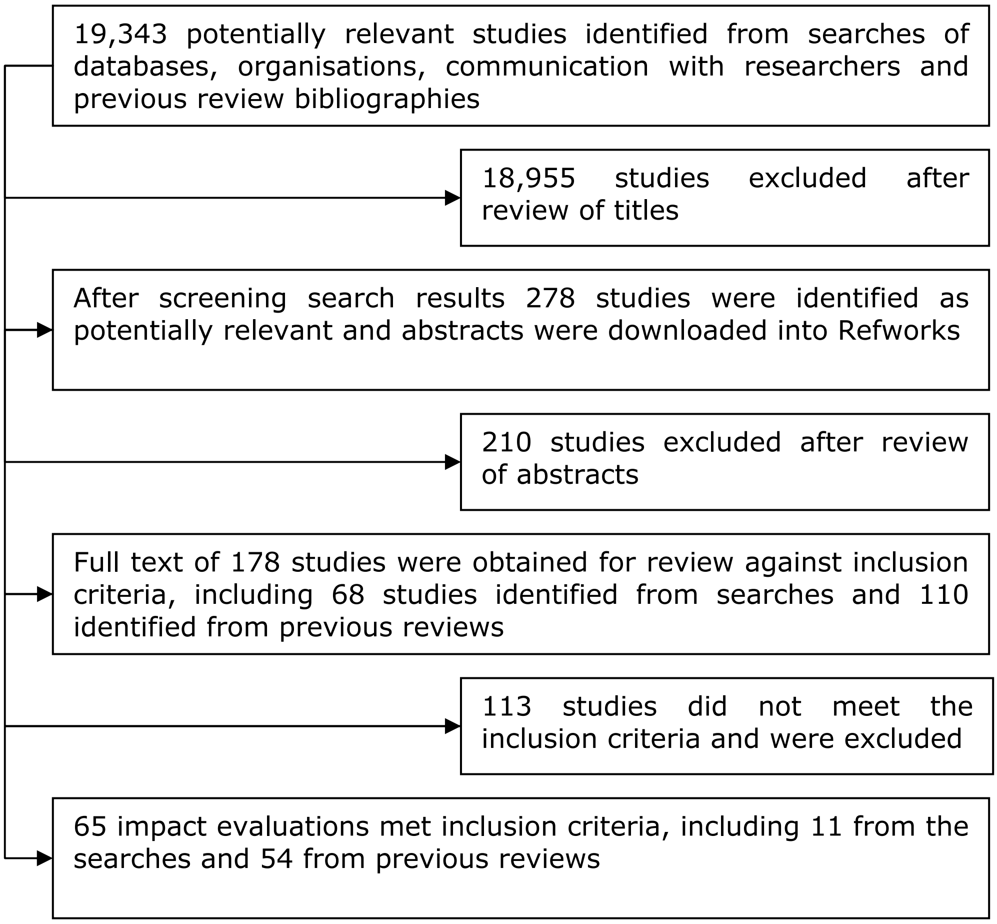
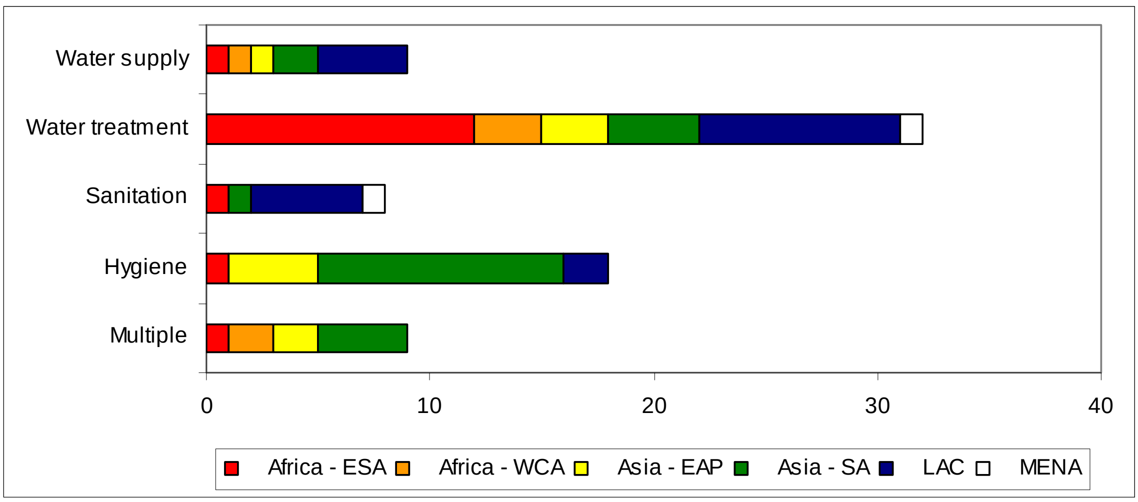


Figure 4 - Geographical distribution of interventions



We were able to synthesise the results from 61 of these evaluations, or 71 interventions, in meta-analysis; Table 3 provides summary information on these interventions by category. The evaluations were assessed over 130,000 children in 35 countries across Africa, Asia and Latin America. Almost two-thirds were designated as of 'high quality' internal validity, and half used experimental methods (RCTs), though these were almost solely water treatment and soap trials. We include results from one blinded cross-over trial (Kirchhoff et al., 1985). Of the remaining evaluations, the majority used matching methods, including four based on propensity-score matching (Pradhan and Rawlings, 2002; Jalan and Ravallion, 2003; Khanna, 2008; Bose, 2009) and one employing a pipe-line approach (Walker et al., 1999). Only eight studies used placebo-controls (Kirchhoff et al., 1985; Haggerty et al., 1994; Conroy et al., 1996, 1999; Luby et al., 2004, 2005, 2006; Blanton et al., 2008).

In terms of design and trial replication, the evidence base is strongest for water quality and hygiene interventions. In terms of study length and sample size, the evidence base is stronger for water supply and, to a lesser extent, sanitation interventions.

Table 3 Description of interventions included in meta-analysis

	# interven-tions	# RCTs	# high quality	Total sample size	Ave. sample size	Ave. length (months)
Water supply	8	0	1	61,000	7,700	19
POU	5	0	1	52,000	10,500	23
Source	2	0	0	1,100	500	20
Water quality	31	27	25	14,500	450	11
POU*	28	25	23	12,000	400	8
Source	3	2	2	2,500	800	12
Sanitation	8	0	3	13,500	2,200	30
Latrines	4	0	1	8,000	2,000	33
Sewer connection	4	0	2	5,500	1,400	31
Hygiene	17	5	11	18,000	1,100	8
Soap	9	3	7	5,000	600	9
Education	8	2	4	13,000	1,600	7
Multiple	7	2	4	13,000	2,200	23
Water supply + sanitation/hygiene	4	0	2	11,500	2,900	32
Water quality + sanitation/hygiene	3	2	2	1,500	800	5
Total	71	34	44	136,000	1,900	15

*Note: * POU water quality evaluations frequently comprise multiple trial arms (totalling over 40 separate intervention arms). Sample sizes are rounded.*

6. EFFECTIVENESS

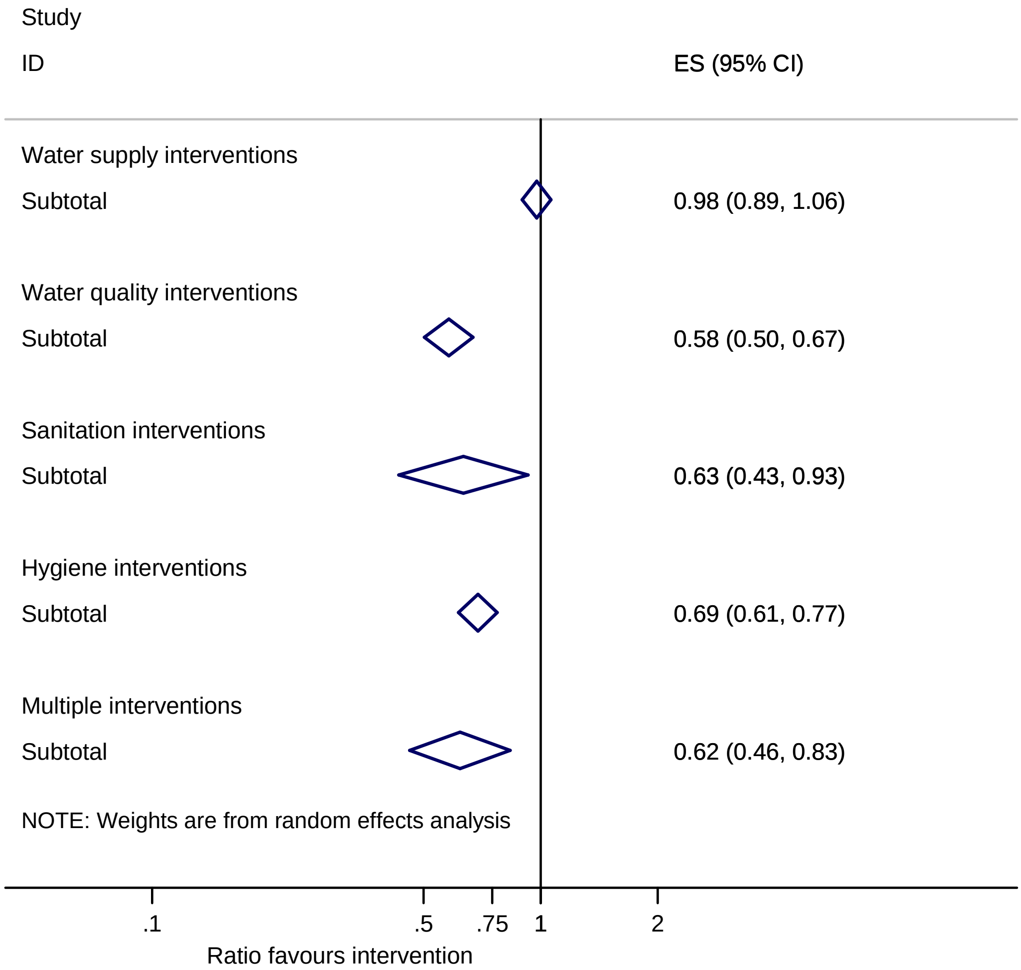
This section presents results of the pooled quantitative synthesis of impacts using meta-analysis, the analysis of impact heterogeneity based on meta-regression analysis and the tests for publication bias.

6.1. Pooled estimates

Pooled effect sizes estimated using meta-analysis of WSH impact on child diarrhoea morbidity, measured by the ratio of diarrhoea morbidity in the treatment group to that in control group, are summarised in Figure 5. Annex 4 presents the forest plots for all meta-analyses included in this report. With the exception of improved water supply, for which the only high quality study did show a significant impact (Jalan and Ravallion, 2003), the estimates are not broadly affected by inclusion of 'high quality' studies only.

The results are generally consistent with previous reviews, suggesting that, comparing interventions indirectly, water quality interventions are significantly more effective than interventions to improve water supply. While water supply interventions appear ineffective – averaging a negligible and insignificant impact on diarrhoea morbidity compared to controls – water quality interventions on average effect a 42 per cent relative reduction in child diarrhoea morbidity (95% confidence interval = 0.50, 0.67).

Figure 5 - Summary meta-analysis results



Sub-group analysis (Table 4) suggests greater effectiveness of both POU water supply and POU water quality over source water supply and source water quality respectively in reducing diarrhoea, among evaluations which report specifically on either. One evaluation which made direct comparison of source and POU water quality interventions noted the interventions to be substitutes in the reduction of diarrhoea morbidity (Kremer et al., 2008). Furthermore, meta-analysis suggests that POU interventions involving provision of safe storage containers are effective in reducing diarrhoea morbidity, but no more so than those providing POU water treatment alone. An evaluation which made direct comparison of two POU water treatments with and without safe storage (Reller et al., 2003) suggested additional benefit of safe storage over flocculant-disinfectant alone among infants, but not among the general population, nor for the trial arms involving bleach.

Hygiene interventions lead to an estimated 31 per cent relative reduction in child diarrhoea morbidity, with high precision (95% confidence interval = 0.61, 0.77).

Analysis by sub-group (Table 4) suggests provision of soap is more effective in reducing diarrhoea morbidity than education campaigns alone.

In contrast with previous surveys, the point estimate suggests sanitation hardware interventions are as effective as hygiene software and water quality, leading to a 37 per cent relative reduction in diarrhoea morbidity, albeit with less precision (95% confidence interval = 0.43, 0.93) reflecting the fewer number of sanitation evaluations. This result reflects the inclusion of additional publications since 2003 or impact evaluations of quasi-experimental design such as those applying propensity-score matching to survey data (Pradhan and Rawlings, 2002; Bose, 2009).

Are water, sanitation and hygiene interventions complements or substitutes in the production of better health status? While the pooled meta-analysis suggests the latter, the sub-group analysis suggests that sanitation and/or hygiene do exert additional impact on diarrhoea morbidity when combined with either water supply or water quality interventions (Table 4). However, there are few such evaluations examining multiple interventions, and the results presented here rely mainly on indirect comparisons of interventions across different studies. This is a major gap in the primary evidence.

Only three rigorous impact evaluations examining multiple interventions, involving a combination of water and sanitation and/or hygiene, made direct comparisons using factorial design – that is, multiple treatment arms (Lou et al., 1990; Luby et al., 2006; Khanna, 2008). Universidad Rafael Landivar (1995) examined water treatment, hygiene education and a combination of the two, using factorial ('a, b, a+b') design, finding some evidence for complementarity. Treatment arms involving hygiene education were excluded from our analysis because inclusion in the hygiene education treatment was based on self-selection. Kremer et al. (2008) also examine water treatment at source and at POU and combined, using factorial design, finding no additional impact when the interventions were combined; this result was not included in our analysis of multiple interventions, defined as those combining water, sanitation and/or hygiene. More evaluations making direct comparisons of multiple WSH interventions are needed to provide more conclusive evidence (see also IEG, 2008).

The few evaluations which do make direct comparisons of the additionality of water, sanitation and/or hygiene interventions versus water intervention alone do not provide conclusive results. Khanna (2008) finds an additional impact of access to sanitation on top of well and pumped water supply; Luby et al. (2006) estimate soap provision and POU water treatment to be more effective than soap provision alone, but not POU water treatment alone. Lou et al. (1990) also report substantial additional benefits of improved sanitation in reducing diarrhoea morbidity among the general population, although not among children; diarrhoea morbidity is reduced by 25 per cent as a result of water supply provision, and by 68 per cent as a result of water supply and sanitation provision. Lou et al. (1990) was excluded from meta-analysis because we were unable to estimate the precision of reported estimates.

With regard to the perceived lack of complementarity between WSH interventions, IEG note that "diarrhoea is reduced but not eliminated, so there are further transmission channels still to be addressed. Second, the conclusion may be reversed if sustainability is considered… It may well be that, while complementary interventions are not necessary to have a positive impact, they may be necessary for those benefits to be sustained" (IEG, 2008: 21-22). However, as discussed below, there is very limited evidence on sustainability of interventions.

Table 4 - Pooled and sub-group meta-analysis results

Intervention	ES	95% CI		Sample size
Water supply pooled	0.98	0.90	1.06	8
POU water supply *	0.79	0.63	0.98	4
Source water supply	0.95	0.90	1.00	2
Water quality pooled **	0.58	0.50	0.67	31
POU water quality	0.56	0.48	0.65	28
Source water quality	0.79	0.62	1.02	3
Storage device provided	0.66	0.56	0.77	10
Sanitation pooled ***	0.63	0.43	0.93	6
Sewer connection	0.69	0.38	1.26	4
Latrine provision	0.66	0.42	1.01	4
Hygiene pooled	0.69	0.61	0.77	17
Soap provision	0.63	0.51	0.79	9
Education	0.73	0.63	0.84	8
Multiple interventions pooled	0.62	0.46	0.83	7
Water supply + sanitation/hygiene	0.81	0.70	0.94	4
Water quality + sanitation/hygiene	0.43	0.33	0.55	3

*Notes: * Two evaluations report additional POU water supply results (Jalan and Ravallion, 2003; Khanna, 2008); meta-analysis excludes outlier (Ryder* et al.*, 1985). ** Two evaluations report combined impact of POU water treatment and storage device, as well as POU water treatment only (Luby* et al.*, 2006; Reller* et al.*, 2003). *** Pooled meta-analysis sample size reduced by combining latrine and sewer estimates in Pradhan and Rawlings (2002) and Walker* et al.*, (1999).*

6.2. Impact heterogeneity

We tested for impact heterogeneity using both meta-analysis and meta-regression, according to factors which may reasonably impact on estimated effectiveness. Some variables related to the study design, including the use of experimental or quasi-experimental methods, the 'quality' of the study design as defined previously, and whether there was participation of beneficiaries in the design or implementation of the intervention. Others related to the estimate calculation, including the methods used to calculate the morbidity change over baseline (risk/rate ratio, prevalence ratio or odds ratio), and adjustment for confounders using multivariate analysis. Further variables related to the underlying disease exposure associated with the environment in which the intervention was conducted, including baseline water and sanitation coverage, location (rural or (peri-) urban) and season (whether study was conducted 'year round' or in rainy or dry seasons). Finally, we examined whether effect estimates were moderated by study length and sample size. Each meta-regression was performed separately, using multivariate analysis controlling for intervention type to ensure that coefficient estimates were not simply picking up differences in effect size associated with intervention type.

Table 5 reports the meta-regression results in exponentiated form. A regression coefficient of less than one indicates the variable is associated with bigger effect on diarrhoea reduction in the treatment group relative to the control group while a coefficient greater than one indicates less effectiveness in reducing diarrhoea in the treatment group than control group. Water quality, sanitation, hygiene and multiple interventions are significantly more effective in reducing diarrhoea risk than water supply interventions, irrespective of the evaluation quality. The results also suggest that, controlling for intervention type to ensure that coefficient estimates were not simply picking up differences due to intervention type, the results are indeed moderated by factors relating to study design, baseline disease exposure and study length.

Table 5 - Meta-regression results

#	Independent variables	Coefficient (e^{β})	P-value		# obs
1	Intervention type:				71
	Water supply (reference group)				
	Water quality	0.58	0.00	**	
	Sanitation	0.63	0.00	**	
	Hygiene	0.67	0.00	**	
	Multiple interventions	0.62	0.00	**	
2	Intervention type (high quality studies):				44
	Water supply (reference group)				
	Water quality	0.60	0.00	**	
	Sanitation	0.63	0.02	**	
	Hygiene	0.68	0.00	**	
	Multiple interventions	0.59	0.00	**	
3	Study design:				71
	Experimental design	0.87	0.31		
	High quality	1.06	0.63		
	Placebo-control	1.25	0.09	*	
	Conflict of interest declared	0.83	0.13		
4	Study design (water quality, hygiene interventions):				48
	Experimental design	0.92	0.59		
	High quality	1.12	0.50		
	Placebo-control	1.25	0.09	*	
	Conflict of interest declared	0.82	0.13		
5	Beneficiary participation	0.94	0.63		71
6	Ratio calculation:				71
	Prevalence ratio	0.96	0.70		
	Odds ratio	1.11	0.55		
	Risk/rate ratio (reference group)				
	Ratio adjusted	0.91	0.41		
7	Baseline water supply and sanitation improved	0.88	0.20		71
8	Baseline water supply and sanitation improved (water supply, water quality, hygiene interventions)	0.83	0.07	*	56

#	Independent variables	Coefficient (e^{β})	P-value	# obs
9	Rural	1.07	0.51	56
10	Rural (water supply, water quality interventions)	1.23	0.13	33
11	Rainy season Dry season Year-round observation (reference group)	0.78 0.78	0.02 ** 0.07 *	71
12	Study length in months (logged) Multiple diarrhoea observations collected	1.15 0.91	0.01 *** 0.43	71
13	Data collection length (logged) Multiple diarrhoea observations collected	1.19 0.87	0.01 *** 0.30	71
14	Sample size (logged)	1.03	0.33	71

Notes: Dependent variable = ln(ES); all 11 regressions control for intervention type (results not reported for regressions 3 through 14) and were estimated separately using random effects meta-regression.
**** Significance > 99%; ** significance > 95%; * significance > 90%.*

Study design does not appear to moderate impact across the full sample of interventions, but among water quality and hygiene evaluations, those using placebo-control and those not disclosing conflict of interest tend to show smaller impact on diarrhoea morbidity. Table 6 presents the results of meta-analysis by evaluations using placebo-control and reporting conflicts of interest, for water quality and hygiene interventions separately. These results understate the placebo-effect documented by Schmidt and Cairncross (2009), who find a stark contrast between placebo-controlled and non-placebo-controlled water quality interventions (as demonstrated in Table 1). We were unable to obtain full text copies of two randomised placebo-controlled trials reported therein of POU water quality interventions which demonstrated zero impact on diarrhoea morbidity (Austin, 1993; Blanton et al., 2009).

Table 6 - Impact heterogeneity meta-analysis results: water quality and hygiene

	Water quality				Hygiene			
	ES	CI		# obs	ES	CI		# obs
Sources of bias:								
Placebo-controlled trials	0.68	0.56	0.83	5	0.76	0.59	0.97	5
No placebo-control	0.56	0.47	0.67	26	0.67	0.59	0.76	13
Possible conflict of interest	0.50	0.36	0.69	9	0.67	0.55	0.81	3
No conflict of interest declared	0.64	0.57	0.72	22	0.69	0.61	0.78	14

Water supply, water quality or hygiene interventions appear significantly more effective when conducted in environments in which baseline water supply and sanitation provision was classified as improved according to WHO/UNICEF (2000) (Table 5). This result suggests there may be complementarities between water supply and sanitation in the reduction of diarrhoea morbidity. Water supply and water treatment interventions appear to be marginally insignificantly less effective when conducted in rural areas.

Fourteen evaluations highlighted participation of the treatment population in the design and/or implementation of the intervention as a factor bearing on intervention outcome (Aziz et al., 1990; Ahmed et al., 1993; Bateman et al., 1995; Conroy et al., 1999; Chiller et al., 2006; Garrett et al., 2008; Haggerty et al., 1994; Hoque et al., 1996; Huttly et al., 1990; Pattanayak et al., 2007; Pinfold and Horan, 1996; Pradhan et al., 2002; Stanton et al., 1988; Torun, 1982). While this conclusion is supported by additional studies evaluating the determinants of success of community based approaches to water supply (Narayan, 1995; Isham and Kahkonen, 2002), none of the evaluations included in this review collect primary data to support these conclusions. Meta-regression analysis found a marginally positive, but highly insignificant, effect of participation in WSH interventions on diarrhoea disease reduction (Table 5).

The use of risk, rate, prevalence or odds ratios does not impact significantly on the effect estimates across evaluations, nor does calculation of adjusted ratios using multivariate regression analysis (Table 5). Differences in average effect size estimated from incidence, prevalence or odds ratios are consistent across intervention type, as confirmed by additional meta-analysis, and therefore are unlikely to account for the observed differences in effectiveness.

We did not find evaluations conducted in rainy or dry season to demonstrate significantly different results (Table 5). Of the studies which collected diarrhoea morbidity data across wet and dry seasons (not separately reported in meta-analysis here), a number found bigger impact of WSH interventions on diarrhoea morbidity during rainy season (e.g. Ahmed et al., 1993; Aziz et al., 1990; Luby et al., 2006), while others found bigger impacts during dry season (e.g. Jensen et al., 2003; Stauber et al., 2009; Tiwari et al., 2009). Indeed, while one may expect greater impact of an intervention in the rainy season when water-borne disease may be more prevalent, there may also be increased consumption of relatively safe rain water during wet season or consumption of contaminated water from other sources as a result of water scarcity in the dry season (Ahmed et al., 1993; Clasen et al., 2004) and Stanton et al. (1988) note that heavy rains, which wash away debris, may have resulted in an overall decrease in environmental garbage seen during this period compared with the dry season.

On the contrary, interventions conducted during part of the year (either in rainy or dry season) tended to show more effective impact on diarrhoea morbidity than those conducted year-round, suggesting that, as the analysis controlled for intervention type, study length was the driving factor behind these results. Meta-regressions using as independent variable length of study – measured from beginning of intervention to end of data collection, or by length of diarrhoea data collection – confirm that studies conducted over longer time periods tend to have smaller impact on diarrhoea morbidity.[5] Finally, the meta-regression results suggest that evaluations conducted over larger samples tend to exhibit less effectiveness, although not significantly.

[5] Where intervention date was not reported we used length of data collection period (Jalan and Ravallion, 2003; Khanna, 2008; Bose, 2009).

6.3. Publication bias

We examined publication bias formally, using statistical tests. However, we note that the statistical tests used are inconclusive given they are at best only moderately powered under the present study sample sizes (Begg and Mazumdar, 1994), and the substantial heterogeneity in context across studies.

The results of statistical tests (presented in the forest plots in Annex 3), suggest some evidence for publication bias among water quality evaluations using the Begg-Mazumdar test (p-value = 0.09). Formann's (2008) correction method, which assumes the distribution of studies is truncated due to suppression of unfavourable outcomes, suggests that 25 per cent of the results of water quality evaluations were not published due to selection bias and, based on this, the 'true' effect size is 0.71 (95% confidence interval = 0.27, 1.86).

7. BEHAVIOUR CHANGE

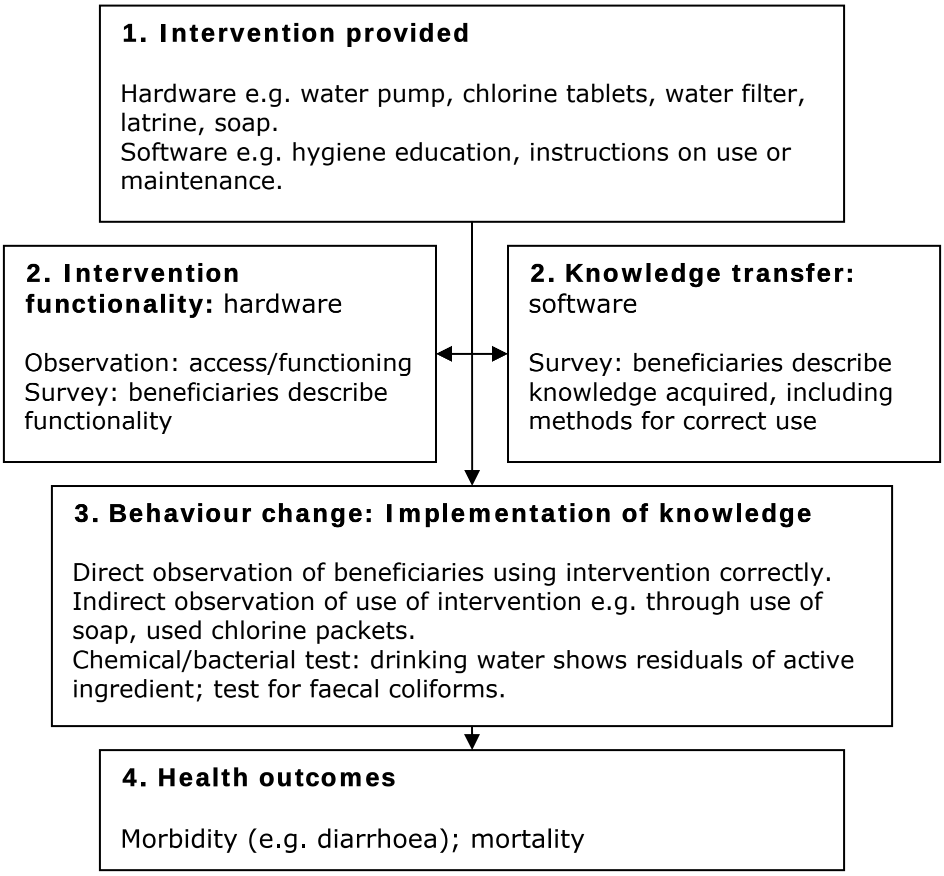
In this section we attempt to shed light on the reasons for differing levels of effectiveness, using theory-based impact evaluation (TBIE) analysis. TBIE helps to understand why an intervention has, or has not, been effective among immediate beneficiaries, by examining behavioural mechanisms and contextual factors influencing outcomes, thus providing crucial information for evidence based policy making and the design of interventions that effectively reduce diarrhoeal disease.

For an intervention to be effective, the beneficiaries need access to a functioning intervention, they need to know how to use it, and, crucially, must practice this knowledge. Evaluations typically collected some process data – that is, on functionality, knowledge transfer and/or compliance – although the type of information collected varies widely. This discussion is therefore complicated by the fact that only interventions involving water components assessed compliance using comparable measures. Moreover, the extent to which the studies engage with the question of why an intervention is effective or not is often very limited. The majority of the studies in this review make some comment on this issue, but rigorous evaluations of the determinants of effectiveness are relatively rare.

As noted above, water quality and hygiene interventions are particularly interesting interventions because, while trial results usually show strong impact on disease risk, they also require substantial behavioural change to be effective, usually within the household and often at the level of the individual. Unlike the water supply and sanitation evaluations, water quality and hygiene interventions are usually evaluated under trial conditions, with greater possibilities for follow-up by intervention fieldworkers and opportunities for bias arising from the Hawthorne effect, as well as being more often carried out across small populations and for shorter periods of time.

Figure 6 shows the types of process data collected in the studies we reviewed, highlighting the steps of theoretical model. Note that there will be additional risk factors bearing on success or failure of the intervention in achieving outcomes, not described here. All of these theoretical steps need to be validated for the intervention to impact favourably on outcomes. Some studies collected information on functioning of the intervention, others on knowledge transfer, still others compliance or use (behavioural change) among the population. The methods used to measure these factors also vary, depending on whether data collection utilised beneficiary survey, direct observation of practice, biological assessment of pathogen contamination, or some assessment of presence of the purification agent in water samples in the case of chlorination.

Figure 6 - Measuring WSH outputs along the causal chain



It is not possible to determine the extent to which participants consume safe water or avoid consuming untreated water. Therefore, indirect assessments of compliance are made in most evaluations, through assessment of product consumption or through testing of water samples for bacterial contamination or, in the case of chlorination treatment, for presence of the purification agent.

Two evaluations of water supply interventions, which found at best an insignificant impact on diarrhoea morbidity, collected information on the quality of the water by measuring the pathogen content, reporting substantial contamination between source and point-of-use (Gasana et al., 2002; Ryder et al., 1985). A third evaluation reported indirect evidence for contamination of piped water – the evaluation found at best an insignificant impact on diarrhoea morbidity for piped water provided at source, noting that only one-quarter of households had reported boiling their water before drinking (Khanna, 2008).

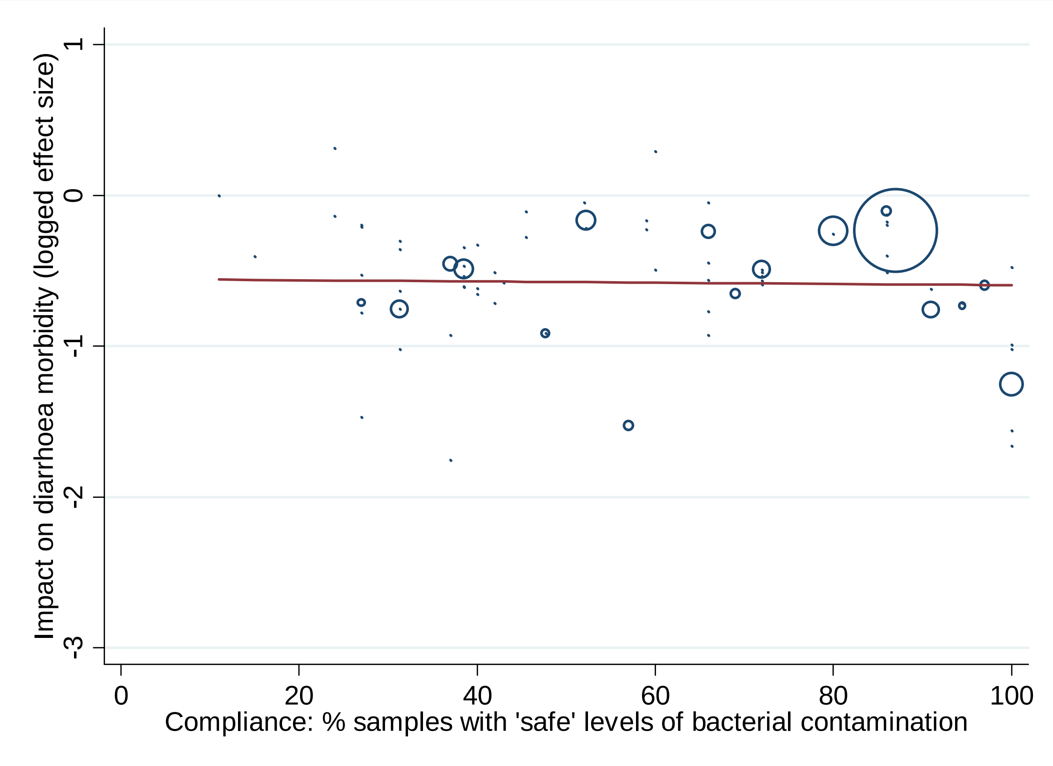
The evaluations of source water quality interventions provide evidence as to why the intervention tends to be less effective than POU interventions. In Rwanda, Gasana (2001) finds low contamination in water measured at source but significantly higher contamination levels at POU (Gasana, 2001). Kremer et al. (2009) find substantially higher pathogen content in household water compared to source water, arguing that the recontamination is "due both to households' collection of water from multiple water sources and to partial recontamination of water in transport and storage" (p. 2). They suggest, however, that the reduced contamination by one-quarter in home water remained sufficient to account for the estimated 25 per cent reduction in child diarrhoea. An additional study examining source water treatment in Mexico (de Wilde et al 2008) is discussed in detail below. Studies examining water contamination show that safe storage can be an effective barrier (Roberts et al., 2001), although one study (Jensen et al 2003) found that it was not enough to prevent occasional extreme contamination of drinking water.

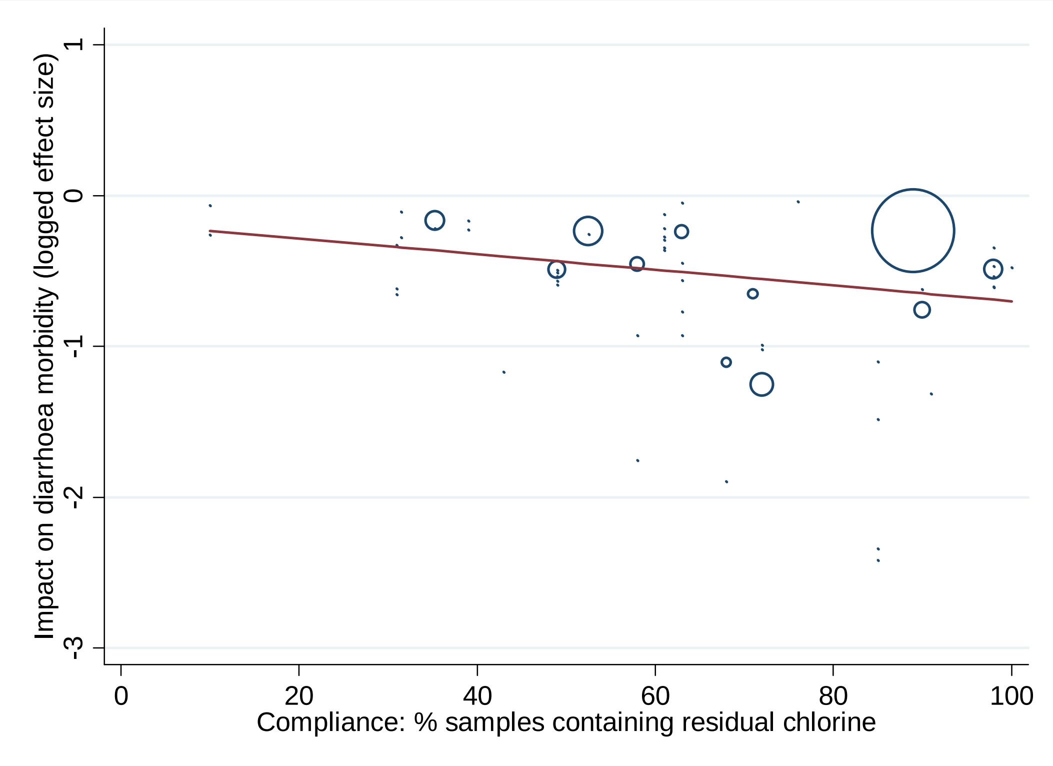
With regard to POU water quality evaluations, four studies of flocculant-disinfectant measured compliance through product consumption (Reller et al., 2003; Crump et al., 2005; Chiller et al., 2006; Luby et al., 2006). Luby et al. (2006), who report the biggest impact on diarrhoea, also note that average sachet consumption was more than double that observed in the three other trials. Other evaluations of water quality interventions cite contextual factors, such as high population density (Gasana et al., 2002) and high turbidity of water (Crump et al., 2005), as influencing low intervention effectiveness. Doocy and Burnham (2006) who find a big effect (approximately 70% reduction over control) of a point-of-use flocculant-disinfectant in a Liberian refugee camp suggest this was due to an 85 per cent compliance rate among beneficiaries as well as the relatively short time required for performing the water treatment.

Nevertheless, the evidence linking impact and compliance in water quality evaluations is far from compelling. Three trials of chlorination estimated over 40 per cent reductions in diarrhoea morbidity although chlorine residuals were measured in less than 50 per cent of water samples (Chiller et al., 2006; Brown et al., 2007; Garrett et al., 2008). Eight evaluations estimated reductions in diarrhoea morbidity of around 40 per cent or more, despite unsafe pathogen contamination in over half of water samples (Chiller et al., 2006; Brown et al., 2007; Brown et al., 2008; Clasen et al., 2005; Garrett et al., 2008; Iijima et al., 2001; Stauber et al., 2009; Tiwari et al., 2009).

Meta-regression analysis of water quality treatment demonstrates the limited relationship between diarrhoeal disease impact and intervention compliance, measured by bacterial contamination of water (exponentiated meta-regression coefficient $e\beta = 0.96$, p-value $p = 0.92$, number of observations $n = 17$) or by presence of residual in stored water in chlorine trials ($e\beta = 0.59$, $p = 0.41$, $n = 11$) (Figure 6). Together with the smaller effect observed in placebo-controlled trials and those in which conflicts of interest are not declared and the evidence for publication bias, these results support the conclusion that water quality estimates may be strongly biased (Schmidt and Cairncross, 2009).

Figure 7 - Compliance and impact in water quality interventions: meta-regression plots





A number of hygiene interventions measure knowledge of the hygiene messages included in the intervention or hygiene practices (for example, Alam et al., 1989; Aziz et al., 1990; Bateman et al., 1995; Hoque et al., 1996; Lee et al., 1991; Pinfold and Horan, 1996; Torun, 1982), while others assess pathogen count on fingers (Khan, 1982; Hoque et al., 1996; Luby et al., 2004; Pinfold and Horan, 1996; Roberts et al., 2001; Torun, 1982).

As a number of papers note, knowledge is not enough to change behaviour (for example, Luby et al., 2008; Pinfold and Horan, 1996; Pattanayak et al., 2007) and thus it is useful to measure both knowledge and practice. Quick et al. (2002) provide one example of this, with reference to a POU water quality and storage intervention. They found that by the end of the study, 100 per cent of the intervention group believed that they knew how to prevent diarrhoea, 95 per cent named water treatment as a preventive method, 93 per cent were able to state the correct dose of disinfectant, 89 per cent were using a safe storage technique and 72-95 per cent had measurable levels of chlorine in their water at biweekly testing. They argue these findings suggest that the communication/ behavioural component of the project, combined with easy access to the intervention, succeeded in enhancing the sense of self-efficacy of the population and their knowledge of available treatment methods. However, very few studies go further than this and attempt to provide answers to how and why, or why not, behavioural changes occur.

An evaluation of a community led total sanitation (CLTS) campaign in India (Pattanayak et al., 2007) is a rare exception. The intervention under evaluation was designed to change knowledge, attitudes and practices and by doing so generate a demand for improved sanitation. It aimed to alter the social norm from one of open defecation to universal use of latrines and the evaluation tried to assess what were driving households to change their behaviour and start using a latrine. While the evaluation is still underway, and initial single-difference impact estimates suggest limited impact so far, it found evidence of increased latrine ownership and use in the intervention villages included in the study. It was found that while knowledge of "germ theory" was not enough to change behaviour, latrine uptake increased as a result of discussions of latrine technology options – indicating that improved technical knowledge and ability was a contributing factor for increased latrine adoption. Moreover, the number of households citing cost as a barrier to adoption saw a significantly larger decrease in intervention villages than control villages, suggesting that some of the impact of the intervention was due to subsidies provided under the program. It is also argued that the evidence indicates that it is likely that much of the success of the program was due to the focus on changing social norms and collective action problems at the village level.

It is difficult from a small sample of evaluations, using non-standardised indicators of compliance, to assess whether the perceived lack of complementarity between multiple interventions involving water and sanitation and/or hygiene is due to lack of compliance or lack of efficacy. Messou et al. (1997) report big increases to over 50 per cent of participants in observed compliance of both hygienic sanitation and water storage practices. Aziz et al. (1990) note high rates of compliance among three-quarters of participants with respect to reported hygienic sanitation practices, but less than one-third of participants reporting sole use of the improved water supply. Alam et al. (1989) report compliance rates in excess of 50 per cent of participants observing hygienic water and sanitation practices. Garrett et al. (2008), finding a 70 per cent reduction in diarrhoea morbidity, also observe that 50 per cent of households owned latrines, but only 15 per cent observed hygienic water storage practices and 43 per cent of stored water samples contained residual chlorine. Luby et al. (2006) noting that product consumption was similar in separate and combined water quality and soap treatment trial arms, suggest threshold effects in pathogen reduction as one possible explanation for the apparent lack of additional benefit from combined interventions.

As we have documented, data collection and analysis tends to be limited to assessments of output functioning and compliance with intervention activities among the treatment group. Information on behavioural factors, such as the beliefs, values and experiences of the treatment population and the economic, social, legal and administrative factors related to the local context are important to take into account when trying to explain impacts (Pawson et al., 2005). While 27 studies make comments related to behaviour, rigorous assessment of the success or failure of behavioural change and its impact on intervention effectiveness is an area which needs to be better integrated into future evaluations. Of these studies only 11 back these statements up with any data analysis, with four of these using qualitative data and the remaining seven basing the analysis on quantitative data. Around ten studies comment on contextual factors and no studies apart from de Wilde et al. (2008) systematically collect data on contextual factors other than location and baseline water and sanitation, apart from high population density and high turbidity of water cited as contextual factors influencing intervention effectiveness in Gasana et al. (2002) and Crump et al. (2005) respectively.

De Wilde et al. (2008) is a rare example of an attempt to integrate health impact evaluation and process evaluation in order to provide a rigorous evaluation of why the programme under evaluation produced the outcome that it did. Recognising the importance of identifying "how health outcomes can be improved in existing, underperforming programmes, and improve our understanding of what drives variation in programme performance over space and time" (p. 453) and the lack of an established method for doing so, de Wilde et al. (2008) propose a framework for integrated programme evaluation. When combined with a health impact evaluation it enables an in-debt evaluation of the causes of programme success of failure. The framework contains four steps:

- assessing programme targeting
- evaluating technical performance through analysis of community management capacity and system functionality
- evaluating population usage through analysis of community knowledge of programme benefits and the availability of alternate water sources
- assessing the extent of recontamination through transport and in-home water storage

The framework is applied to an evaluation of a community based water treatment programme in Mexico and was conducted 5 years after the initiation of the programme. The health impact evaluation found no effect on incidence of diarrhoea, but the comprehensive evaluation framework enabled the researchers to draw conclusions as to why this was the case based on rigorous and systematic evidence collected through interviews, maintenance records, inspections and water samples. It was found that only two of 21 communities met all the requirements for effective programme performance; the treatment system delivered a consistent supply of safe water in only six of the communities and only eight communities reported that community members obtained water from the water treatment system. Community capacity, physical faults and under valuing of safe water by users are factors often suggested as explanations for ineffectiveness of safe water systems, but the process evaluation did not find that any of these factors could explain the failure of the water treatment system to have an impact on health. Rather, it was found that household preferences, constraints and choices were the main factors that determined how, by whom and whether the water treatment system was used at all. While community members were aware of the value of safe drinking water and believed this was provided by the water treatment system, the cost of using it in terms of time, money and labour, in addition to the availability of alternative sources of drinking water determined water use decisions, leading households to choose water sources that were seen to be more convenient. Thus, on the basis of this the researchers concluded that increasing use of the water treatment system would be conditional on making it more convenient for the population.

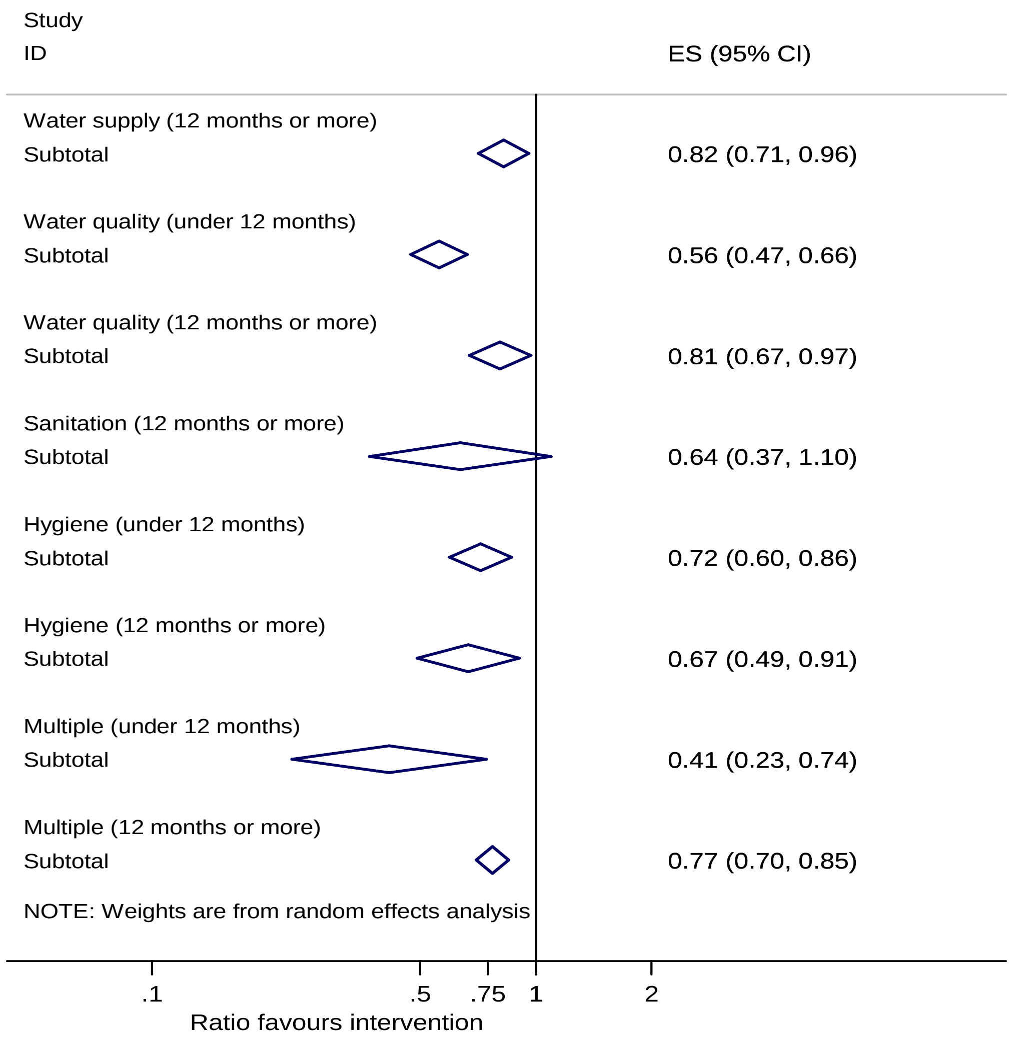
8. SUSTAINABILITY

Our analysis of sustainability is based on examination of quantitative and qualitative data collected on diarrhoea morbidity and compliance from the impact evaluations or follow-up studies conducted thereof. We also draw on evidence from additional studies, which were not collected using systematic search methods as above. Attempts have been made to reduce possible biases from the conclusions drawn from these additional studies.

We presented meta-analysis results suggesting bigger and longer trials tend to show smaller impacts in Table 5 above. In addition, we conducted meta-analysis examining impact heterogeneity for longer-term trials, measured as 12 months or longer from beginning of intervention to end of data collection period. We chose this cut-off to avoid confounding by seasonality. Given the relatively large number of studies at our disposal, we were able to restrict this analysis to high quality studies. The results suggest study period exerts a considerable impact on reducing effectiveness of water quality (Figure 4; detailed results in Annex 2). Study period is also inversely correlated with effectiveness for multiple interventions, although this may reflect that longer-term interventions were those that included water supply components, while shorter-term ones were those that included water quality components. Study length does not appear to be correlated with effect size for hygiene interventions. No high quality evaluations examining water supply or sanitation interventions were conducted over a period of less than 12 months.

Sensitivity analysis suggests this stark contrast is sensitive to cut-off point, since there are four high quality evaluations of water quality interventions lasting between six and 12 months which report 45 per cent reduction in diarrhoea morbidity or more (du Preez et al., 2008; Luby et al., 2006; Stauber et al., 2009; Universidad Rafael Landivar, 1995). In addition, one trial of bleach and safe storage vessel classified as of low quality due to substantial confounding between treatment and control groups, estimated impact to have increased over an 18-month period (Luby et al., 2004). Nevertheless, the observation that longer-term evaluations tend to be less effective remains.

Figure 8 - Summary forest plot by study length – high quality evaluations



Ensuring sustainability over time and diffusion across populations is of fundamental importance if the benefits of water, sanitation and hygiene interventions are to be maintained when intervention activities come to an end. A number of studies comment on the issue of sustainability, but the extent to which studies include a formal evaluation of sustainability over time and in scale-up is limited. Our review identified only five follow-up evaluations conducted more than one year after the initial intervention had ended which assessed sustainability in reducing diarrhoea morbidity (Brown et al., 2007; deWilde et al., 2008; Hoque et al., 1996; Kremer et al., 2009; Wilson and Chandler, 1993) in addition to one evaluation (Luby et al., 2008) assessing compliance of two interventions six months (Reller et al., 2003) and one year (Chiller et al., 2006) after they had ended and another four years later (Iijima et al., 2001).

In rural Bangladesh, a water supply, sanitation and hygiene intervention conducted over a period of four years found that the impact on diarrhoea risk remained significantly below that of the control area throughout the four-year study (Aziz et al., 1990). A follow-up study conducted five years later found that the majority of water pumps were working and most people used and maintained sanitation facilities adequately; hands showed lower level of contamination, although knowledge of hygiene practices and their implications for health remained poor (Hoque et al., 1996). A single 24-hour diarrhoea survey also showed diarrhoea morbidity in the treatment group had remained significantly below that in the control group.

The evidence base on sustainability of hygiene interventions in reducing diarrhoea morbidity is scarce. Wilson and Chandler (1993) follow up a soap intervention (Wilson et al., 1991) two years later, finding that 80 per cent of mothers were buying hand soap and diarrhoea incidence of one episode per child per week was less than in pre-intervention phase (3 per child per week) but more than immediately after intervention (0.33 per child per week). Only one other study included in this review assesses the sustainability in reducing diarrhoea morbidity of an intervention which includes a hygiene component (Aziz et al., 1990; Hoque et al., 1996).

However, Cairncross and Shordt (2004) report on a multi-country study of the sustainability of hygiene interventions. The study included eight countries where data on the sustainability was collected between one and nine years after the end of the intervention. This study does not measure impact on diarrhoea, but focusing on the three hygiene behaviours hand-washing, latrine use and household hygiene it concluded improved hygiene behaviours were sustained after the end of the interventions. Investigating the influence of access to water, women's education and socioeconomic status on hygiene behaviour, women's education was the only factor found to be a determinant of hygiene behaviour. It evaluates the impact of four main categories of hygiene promotion activities: (1) mass activities, such as campaigns, village councils, videos and rallies; (2) group activities, such as meetings and women's groups; (3) formal training sessions and (4) personal communication, such as home visits. All these activities were found to be associated with hygiene behaviour in one context or another when the evaluations were carried out at least one year after the end of the intervention. For instance, both in Ghana and India it was found that more intensive activities such as home visits were required to induce more demanding changes, such as hand-washing, while group meetings were sufficient to promote clean yards in India. The authors conclude that access to water and sanitation is not enough to encourage hygienic behaviour and argue "hygiene promotion and education should not be low-visibility 'add-ons' to water and sanitation programming" (p. 7).

Unfortunately, results from follow-up studies assessing compliance in water treatment evaluations are less encouraging. For instance, a cross-sectional follow-up survey of households that were provided with ceramic filters for household water treatment in Cambodia (Brown et al., 2007) found that only 31 per cent of the follow-up households were still using the filters and that use was strongly associated with time since installation – 59 per cent of the households no longer using the filters had them installed less than 36 months ago. Similarly, a follow-up evaluation in Kenya found that four years later only 30 per cent continued to pasteurise their water (Iijima et al., 2001). Clasen et al. (2006) do find an encouraging 67 per cent of water filters in Bolivia being used regularly and correctly, as measured by bacterial content, but only four months after the intervention trial had ended. Kremer et al. (2009) estimate a 25 per cent reduction in diarrhoea morbidity among children over an approximately 20-month period in Kenya – interestingly only among girls and not among boys – but do not report impacts disaggregated over time among the three rounds in which data are collected.

Luby et al. (2008) survey the households of 12 villages that had participated in two different point-of-use water quality interventions involving the same flocculant-disinfectant in Guatemala (Reller et al., 2003; Chiller et al., 2006). After the end of the second trial an 'aggressive' social marketing campaign involving the distribution of the product and advertising material to local shops, radio advertisement and demonstrations at local fairs was extended to the area. Of the original 460 surveyed households, just 14 per cent reported using the flocculant-disinfectant in the preceding week, while only 5 per cent met the criteria for active repeat use and only 1.5 per cent had detectable chlorine in their drinking water. Despite being familiar with the product from the trials and having had the health benefit of the water treatment demonstrated, the 5 per cent rate of repeat users was the same in the original study villages and the rest of Guatemala where the population had only been subject to the marketing campaign. The authors suggest the time required to use the product, as well as its cost, as possible reasons for the lack of sustained use. Moreover, they argue the recognised reduction in diarrhoea is not sufficient to motivate people to purchase the product and treat their water at home.

Indeed, preventive interventions tend to be adopted more slowly as benefits are difficult to observe (Rogers, 2005). This applies particularly to WSH interventions whose main benefit is to reduce diarrhoeal disease, which at prevalence rates of around 10 per cent, as is typical of studies reviewed here, is relatively infrequent.

Many WSH interventions suffer from what diffusion theory calls discontinuance (Rogers, 2005: 178). Users presumably discontinue as they perceive that the costs of using the intervention outweigh the benefits. It may well be that private costs exceed private benefits, but that the converse is true for social costs and benefits (the latter including spillovers), implying a subsidy is justified to shift the balance in the private calculation. But it may also be the case that both social and private costs exceed the corresponding benefits. The intervention might be efficacious but not cost effective. Such a discrepancy may arise because of improper use of the intervention. Diffusion studies in general find that those who discontinue are most likely to be late adopters, who are also less educated and less well off and consequently may not comply with intervention protocols, and so not realise the full potential benefits (Rogers, 2005: 191).

Diffusion theory is based on empirical research into how innovations spread in a society. It provides useful insights into how new ideas are adopted and the process through which this occurs. Rogers (2005) describes diffusion as:

> "the process by which an innovation is communicated through certain channels over time among the members of a social system. It is a special type of communication, in that messages are concerned with new ideas...Diffusion is a kind of social change, defined as the process by which alteration occurs in the structure and function of a social system. When new ideas are invented, diffused, and are adopted or rejected, leading to certain consequences, social change occurs" (pp. 5 and 6).

Interventions in water, sanitation and hygiene are usually innovations in that they tend to include a new technology (the 'hardware') accompanied by information on how to use this new technology (the 'software'). Diffusion research has indicated five characteristics of innovations that are particularly important in explaining their adoption: (1) Relative advantage – the perceived advantage of the innovation compared to existing ideas; speed of adoption depends on the degree of perceived relative advantage; (2) Comparability – refers to the coherence of the innovation with the values, experiences and perceived needs of potential adopters; (3) Complexity – the perceived difficulty of understanding and using an innovation; (4) Trialability – the extent to which potential adopters can try out the intervention on a smaller scale before deciding to adopt it fully; (5) Observability – refers to the extent to which impacts of an intervention can be observed and thereby encourage discussions between adopters and people in their social network.

Communication plays a crucial role in the diffusion process and can take place during channels such as mass media or interpersonal contact. The former has the advantage of reaching a larger number of people, while the latter is more effective in convincing people to adopt a new innovation. Rogers argues that communication is more effective when individuals are homophilous – meaning that they share similar values, education, social status etc and suggests "one of the most distinctive problems in the diffusion of innovations is that participants are usually quite heterophilous" (p. 19). Commonly, the agents who are promoting an innovation often have different characteristics from the people they are trying to get to adopt the innovation.

As all individuals do not adopt innovations at the same time diffusion theory also suggests it is useful to distinguish between five different categories (or ideal types) of adopters on the basis of their degree of innovativeness: (1) Innovators; (2) Early adopters; (3) Early majority; (4) Late majority and (5) Laggards. This categorisation is based on the S-shaped curve of adoption – resulting from plotting the cumulative number of adopters in a curve. In the beginning of the period of diffusion there is a slow increase in the number of adopters, adoption then tend to accelerate until around half of the population in the social system has adopted the innovation, before the rate of adoption slows down as there are less people who have not already adopted the innovation. Of course, not all innovations are successful and the S-shaped curve only refers to cases where an innovation is successfully diffused and become adopted by most potential users in a society. Crucially, while diffusion theory and the S-curve provide useful theoretical guidance for how diffusion of innovations are expected to occur, Rogers stress "the shape of the adopter distribution for an innovation ought to be regarded as an open question, to be determined empirically" (p. 261)

A number of evaluations refer to diffusion theory in explaining their results. In a trial of household chlorination and safe storage in Zambia, Quick et al. (2002) cite these factors as possible explanations for the improvement in water disinfectant and storage behaviours exhibited in a 9.5-week trial, which observed a 78 per cent utilisation rate in the intervention group, as compared to 14 per cent in the control group (measured by detection of chlorine residuals in stored water). The technology had a relative advantage over the alternative – boiling, which was time consuming and expensive – and was made readily available during the trial. It was compatible with the perceived needs of the target population. It was simple to understand and use and therefore of low complexity. It had a high degree of trialability. Only in observability of results was the technology argued to be lacking, which applies to all technologies aimed at reducing diarrhoeal disease risk. In addition, they argue that the study population already possessed "a sense of self-efficacy, a characteristic which encourages the process of behaviour change" (p. 588) since at the beginning of the study over 80 per cent felt they knew how to prevent diarrhoea and could name one correct method for doing so.

Luby et al (2004) evaluate the impact of home drinking water disinfection and hand-washing with soap in a squatter settlement in Karachi. They found that it took three to four months after the introduction of the interventions before a difference in the diarrhoea rates between treatment and control groups was registered, suggesting that it takes time to achieve the necessary behavioural changes after the introduction of new technologies. They also found that when reductions in diarrhoea started to occur this was concentrated in the treatment households that had a refrigerator and that it took longer time before an impact on diarrhoea was found in the treatment households without a refrigerator. Thus it appeared that some households adopt new behaviour sooner than others. Drawing on Rogers' (2005) theory of diffusion of innovations, which suggests that adopters can be divided into different groups with different individual and social characteristics, the researchers suggest:

> "Refrigerator owners behaved like early adopters, that is, their early reduction in diarrhea incidence suggests they quickly adopted the necessary behavior change to benefit from the interventions. If early adopters find an innovation useful, they communicate the value of the innovation to other persons in their community. As more and more people try the innovation and find it useful, there are more change agents in the community who can demonstrate the innovation's effectiveness and encourage others to adopt. The late majority and the laggards are the latest groups and the most difficult to change. They typically have lower socioeconomic status, and learn about new ideas from peers via interpersonal communication" (p. 425).

Thus, the authors conclude that in contexts like the squatter settlements in Karachi it might be useful to target households with a marginally higher socio-economic status in order to optimise methods for behavioural change and achieve more rapid and cost-effective health outcomes.

Quick (2003) reports on the implementation of the Safe Water System (SWS) at household level in Zambia, Madagascar and Kenya. These interventions included three components: water disinfection, safe storage and behavioural change. The behavioural change strategies included social marketing, combined with either motivational interviewing (Zambia) or community mobilisation (Madagascar and Kenya). While the effectiveness of the SWS in reducing diarrhoea and improving water quality had been demonstrated in many previous studies, a focus on behavioural change was viewed as necessary to facilitate scale-up. The design of the behavioural change component of the intervention was based on various theories, including diffusion theory and fact that behavioural changes are influenced by several factors. This includes factors like different groups of people, such as innovators, early adopters and sceptics, poverty, cultures, customs, infrastructure, education and trigger events, such as seasonal rains. The evaluations of the SWS field trials showed different rates of adoption, from a high rate of 78 per cent observed adoption in the social marketing and motivational interviewing group in Zambia, to 37-64 per cent in Kenya and a relatively low rate of 11 per cent and 20 per cent for the social marketing only and community mobilisation groups in Madagascar. The authors conclude:

> “Social marketing is a very effective tool for disseminating product awareness, motivating those individuals who are hygiene conscious and early adopters to test promising new products, creating access to these inexpensive products, and enabling a response to behaviour change triggers, such as natural disasters and disease outbreaks. Motivational interviewing and community mobilisation prod some of the sceptics or cynics to consider product adoption and thereby enhance the effect of social marketing” (p. S120).

Systematic analyses and comparisons are required to improve our knowledge of why the impact of similar interventions varies between different contexts. Stockman et al. (2007), while falling short of providing a systematic comparison and process evaluation, compares the rates of adoption of water disinfectant in Malawi and Zambia. They report results of a national survey of mothers’ awareness, perception and reported use of the water disinfectant WaterGuard three years after the initiation of a national-level SWS social marketing campaign for the disinfectant in Malawi. The survey found that among mothers in Malawi who had heard of and tried the disinfectant, only 22 per cent were current users at the time of the survey. Awareness and use were found to be lower among both poor and rural mothers and only 12 per cent of the mothers who had heard of WaterGuard reported they used it. This was much lower than the 42 per cent who reported current use in Zambia, where product sales were much higher. The two countries have similar poverty levels and development ranking, in addition to similar rates of awareness and past use. The authors suggest this difference might have been due to problems with low and inconsistent levels of funding in Malawi, while the SWS program in Zambia had more stable and higher levels of funding.

9. CONCLUSION

This report has presented results from the most systematic search to-date of impact evaluation literature examining the effectiveness of WSH in reducing diarrhoea morbidity in developing countries. The results call into question some received wisdom, particularly with regard to the sustainability of water quality interventions and more limited effectiveness of sanitation.

The review has identified important gaps in the literature, in particular the need for bigger, longer-term evaluations of water treatment technologies, as well as the need for more evaluations of sanitation provision and multiple interventions using factorial design. The review also highlights the relevance of causal chain analysis using mixed methods in examining compliance and sustainability. The discussion emphasises the importance of behavioural mechanisms, particularly where they are likely to be of overriding importance to adoption and sustainability, and therefore impact.

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ANNEX 1: SEARCH RESULTS

Detailed search results:

Search term: 'sanitation' and 'diarrhea' or diarrhoea'

Database	Hits	Date
PubMed	108 (abstract/title)	28/11-08
Embase	272 (keyword)	2/12-08
Web of Science (Science Citation Index Expanded, Social Sciences Citation Index)	230 (topic, limited to studies published between 1998-2008)	8/12-08
Web of Science (Conference Proceedings Citation Index-Science, Conference Proceedings Citation Index-Social Science & Humanities)	28 (topic, limited to papers published between 1990-2008)	8/12-08
LILACs	4 (subject descriptor)	26/11-08
Cochrane Library	9 (Cochrane reviews: 3; clinical trials: 5; economic evaluations: 1) (Title, abstract and keywords)	2/12-08
Google Scholar	12,700 (limited to studies between 1998-2008)	3/12-08
JOLIS	5/3 (keywords anywhere; 3 published since 1998, 1 reference saved in before 1998 folder)	9/12-08
BLDS	0 (subject)	9/12-08
BLDS (using macrothesaurus, searching of diarrhoeal diseases)	6 (subjects)	9/12-08

Search term: 'water quality' and 'diarrhea' or diarrhoea'

Database	Hits	Date
PubMed	26 (abstract/title)	28/11-08
Embase	137 (keyword)	2/12-08
Web of Science (Science Citation Index Expanded, Social Sciences Citation Index)	87 (topic, limited to studies published between 1998-2008)	8/12-08
Web of Science (Conference Proceedings Citation Index-Science, Conference Proceedings Citation Index-Social Science & Humanities)	29 (topic, limited to papers published between 1990-2008)	8/12-08

LILACs	2 (subject descriptor)	3/11-08
Cochrane Library	16 (Cochrane reviews: 4; other reviews: 2; clinical trials: 9; economic reviews: 1) (title, abstract and keyword)	2/12-08
Google Scholar	5,020 (limited to studies between 1998-2008)	3/12-08
JOLIS	1 (keywords anywhere)	9/12-08
BLDS	0 (subject)	9/12-08
BLDS (using macrothesaurus, searching of diarrhoeal diseases)	8 (subject)	9/12-08

Search term: 'water quantity' and 'diarrhea' or 'diarrhoea'

Database	Hits	Date
PubMed	0 (title/abstract)	28/11-08
Embase	0 (keyword)	2/12-08
Web of Science (Science Citation Index Expanded, Social Sciences Citation Index)	3 (topic, limited to studies published between 1998-2008)	8/12-08
Web of Science (Conference Proceedings Citation Index-Science, Conference Proceedings Citation Index-Social Science & Humanities)	3 (topic, limited to papers published between 1990-2008)	8/12-08
LILACs	0 (subject descriptor, abstract)	3/12-08
Cochrane Library	2 (clinical trials: 2) (title, abstract and keyword)	
Google Scholar	362 (limited to studies between 1998-2008)	4/12-08
JOLIS	0 (keywords anywhere)	9/12-08
BLDS	0 (subject)	9/12-08
BLDS (using macrothesaurus, searching of diarrhoeal diseases)	0 (subject)	9/12-08

Search term: 'hygiene' and 'diarrhea' or 'diarrhoea'

Database	Hits	Date
PubMed	167 (title/abstract)	28/11-08
Embase	526 (keyword)	2/12-08
Web of Science (Science Citation Index Expanded, Social Sciences Citation Index)	370 (topic, limited to studies published between 1998-2008)	8/12-08

Web of Science (Conference Proceedings Citation Index-Science, Conference Proceedings Citation Index-Social Science & Humanities)	44 (topic, limited to papers published between 1990-2008)	8/12-08
LILACs	1 (subject descriptor)	3/12-08
Cochrane Library	15 (Cochrane reviews: 2; clinical trials: 12; economic evaluations: 1) (title, abstract and keyword)	2/12-08
Google Scholar	About 19,600 (limited to studies between 1998-2008)	4/12-08
JOLIS	9 (keywords anywhere)	9/12-08
BLDS	0 (subject)	9/12-08
BLDS (using macrothesaurus, searching of diarrhoeal diseases)	5 (subject)	9/12-08

Search term: ‘sanitation’ and ‘intervention’

Database	Hits	Date
PubMed	89 (title/abstract)	1/12-08
Embase	144 (keyword)	2/12-08
Web of Science (Science Citation Index Expanded, Social Sciences Citation Index)	130 (topic, limited to studies published between 1998-2008)	8/12-08
Web of Science (Conference Proceedings Citation Index-Science, Conference Proceedings Citation Index-Social Science & Humanities)	28 (topic, limited to papers published between 1990-2008)	8/12-08
LILACs	0 (subject descriptor)	3/12-08
Cochrane Library	10 (Cochrane reviews: 4; clinical trials: 6)(title, abstract and keyword)	2/11-08
Google Scholar	20,000 (limited to studies between 1998-2008)	4/12-08
JOLIS	2 (keywords anywhere)	9/12-08
BLDS	0 (subject)	9/12-08

Search term: ‘drinking-water’ and ‘intervention’

Database	Hits	Date
PubMed	120 (title/abstract)	1/12-08
Embase	117 (keyword)	2/12-08
Web of Science (Science Citation Index Expanded, Social Sciences Citation Index)	201 (topic, limited to studies published between 1998-2008)	8/12-08

Web of Science (Conference Proceedings Citation Index-Science, Conference Proceedings Citation Index-Social Science & Humanities)	45 (topic, limited to papers published between 1990-2008)	8/12-08
LILACs	0 (subject descriptor)	3/12-08
Cochrane Library	24 (Cochrane reviews: 3; clinical trials: 21)(title, abstract and keyword)	3/12-08
Google Scholar	20,000 (limited to studies between 1998-2008)	4/12-08
JOLIS	0 (keywords anywhere)	9/12-08
BLDS	0 (subject)	9/12-08

Search term: ‘hygiene’ and ‘intervention’

Database	Hits	Date
PubMed	368 (title/abstract)	1/12-08
Embase	552 (keyword)	2/12-08
Web of Science (Science Citation Index Expanded, Social Sciences Citation Index)	526 (topic, limited to studies published between 1998-2008)	8/12-08
Web of Science (Conference Proceedings Citation Index-Science, Conference Proceedings Citation Index-Social Science & Humanities)	74 (topic, limited to papers published between 1990-2008)	8/12-08
LILACs	0 (subject descriptor)	3/12-08
Cochrane Library	124 (Cochrane reviews: 14; clinical trials: 107; methods studies: 2; economic evaluations: 1) (title, abstract and keyword)	3/12-2008
Google Scholar	22,800 (limited to studies between 1998-2008)	4/12-2008
JOLIS	6 keywords anywhere	9/12-08
BLDS	0 (subject)	9/12-08

Search term: 'sanitation' and 'evaluation'

Database	Hits	Date
PubMed	59 (title/abstract)	9/12-08
Embase	196 (keyword)	9/12-08
Web of Science (Science Citation Index Expanded, Social Sciences Citation Index)	127 (topic, limited to studies published between 1998-2008)	8/12-08

Web of Science (Conference Proceedings Citation Index-Science, Conference Proceedings Citation Index-Social Science & Humanities)	56 (topic, limited to papers published between 1990-2008)	9/12-08
LILACs	1 (subject descriptor)	11/12-08
Cochrane Library	1 (clinical trials:1;title, abstract and keyword)	9/12-08
Google Scholar	20,900 (limited to studies between 1998-2008)	9/12-08
JOLIS	52 (keywords anywhere; 17 published since 1998)	9/12-08
BLDS	46 subject	9/12-08

Search term: 'drinking-water' and 'evaluation'

Database	Hits	Date
PubMed	376 (title/abstract)	9/12-08
Embase	484 (keyword)	11/12-08
Web of Science (Science Citation Index Expanded, Social Sciences Citation Index)	1012 (topic, limited to studies published between 1998-2008)	8/12-08
Web of Science (Conference Proceedings Citation Index-Science, Conference Proceedings Citation Index-Social Science & Humanities)	323 (topic, limited to papers published between 1990-2008)	9/12-08
LILACs	0 (subject descriptor)	11/12-08
Cochrane Library	2 (clinical trials: 2; title, abstract and keyword)	9/12-08
Google Scholar	19,700 (limited to studies between 1998-2008)	11/12-09
JOLIS	0 (keywords anywhere)	9/12-08
BLDS	9 subject	9/12-08

Search term: 'hygiene' and 'evaluation'

Database	Hits	Date
PubMed	518 (title/abstract)	9/12-08
Embase	844 (keywords)	11/12-08
Web of Science (Science Citation Index Expanded, Social Sciences Citation Index)	856 (topic, limited to studies published between 1998-2008)	8/12-08
Web of Science (Conference Proceedings Citation Index-Science, Conference Proceedings Citation Index-Social Science & Humanities)	147 (topic, limited to papers published between 1990-2008)	9/12-08

LILACs	1 (subject descriptor)	11/12-08
Cochrane Library	1 (Cochrane review: 1; title, abstract and keyword)	9/12-08
Google Scholar	22,100 (limited to studies between 1998-2008)	11/12-08
JOLIS	53 (keywords anywhere))	9/12-08
BLDS	4 subject	9/12-08

Organisation searches carried out:

Organisation	Website	Searched/ Results:
Asian Development Bank	www.adb.org	Searched catalogue and evaluation reports using diarrhea or diarrhoea as keyword, in addition to browsing through evaluation reports for water and sanitation. No results. Evaluation of Punjab Rural Community Water Supply underway, but report not scheduled before mid-2009.
Australian Aid Agency	www.ausaid.gov.au	Searched website, no relevant studies.
Canadian International Development Agency	www.acdi-cida.gc.ca	Searched website, no relevant studies.
Swedish development agency	www.sida.org	Searched website and publications, 3 studies identified.
Danish Development Agency	www.um.dk	Searched through evaluation studies on website, 1 study identified.
Department for International Development	www.dfid.gov.org	Searched publications and evaluations, no relevant studies available
GTZ	www.gtz.de/en/	Searched website using both the sites search function and google advanced search, no results.
Japan International Cooperation Agency and Japan Bank for international Cooperation	www.jica.go.jp/english/ www.jbic.go.jp	Searched website, no relevant studies.
US Agency for International Development	www.usaid.gov	Searched through website, no results.
European Commission	http://ec.europa.eu/index_en.htm	Searched through website, but no relevant references.
The World Bank +Office of Evaluation and Development	www.worldbank.org	Searched World Bank documents and evaluations by the office of evaluation and development.
Pan American Health Organization	http://devserver.paho.org/	Searched website, any relevant references were to studies already collected.
World Health Organization	http://www.who.int/en/	Searched database on website and browsed website. No new relevant studies.
UN: UNICEF UNEP UNDP UN-HABITAT	www.un.org	UNICEF website searched, including the evaluation database and the Innocenti Research Centre catalogue. 2 references identified. UNDP searched library and projects

UNRISD		database. UN-Habitat reference library and publications searched, in addition to the Water and Sanitation section. UNRISD searched, no results. UNEP website also searched.
Inter-American Development Bank	http://www.iadb.org/	Searched publications on website, one new reference identified.
Centre for Disease Control	www.cdc.gov	Searched website, including the safe water section using a variety of keywords. No new references.
International Water Management Institute	www.iwmi.org	Searched website. No additional studies identified.
African Development Bank	http://www.afdb.org	Browsed through evaluation reports, found nothing of relevance.
Red Cross	www.ifrc.org	Searched website, no results. Contacted Water and Sanitation Officer, who informed of no relevant evaluations available.
WaterAid	www.wateraid.org	Telephoned and emailed. No response.
Christian Aid	www.christianaid.org.uk	Telephoned. No response.
Oxfam	www.oxfam.org	Emailed. No relevant studies.
Water for people	www.waterforpeople.org	Emailed. No relevant studies
IRC International Water and Sanitation Centre	http://www.irc.nl/page/104	Searched website, 2 additional references collected.
International Rescue Committee	www.theirc.org/	Searched website, no relevant studies.
Amref	www.amref.org	Searched Amref's document data base, no relevant studies identified. Google advanced search using diarrhea and diarrhoea also performed.
Fresh Water Action Network	www.freshwateraction.net/fan/web/w/www_1_en.aspx	Searched website, no evaluations.

ANNEX 2: STUDY CODES

	Num	ID	Question	Description	Coding
General	1.01	ID	Study ID number	Unique study identification #	##
	1.02	AUTHOR	First Author	Surname, Initial	Surname, Initial
	1.03	COMMENTS	General comments	Any general comments on study not coded elsewhere	Open answer
	1.04	PUB DATE	Publication date	Year	####
	1.05	PUB TYPE	Publication type		1= Peer-reviewed journal 2= Book chapter/book 3= Unpublished article/evaluation
	1.06	FUNDER	Funding agency	Who is funding the intervention/study?	1= Public institution (e.g. govt, NGO, university, research institute) 2= Private institution (e.g. private company) 8= Not clear 9= N/A
	1.07	CONFLICT	Conflict of interest	Is there a potential conflict of interest associated with study which could influence results collected/reported?	1=Yes 2=No 8=Not clear
Intervention design	2.01	INTERV TYPE	Intervention type	5 types of intervention	Water quantity Water quality Sanitation Hygiene Multiple (types)
	2.02	SUB-TYPE	Intervention sub-type		Open answer
	2.03	INTERV DESCRIPTION	Intervention description	Describe interventions undertaken	Open answer
	2.04	INTERV METHODS	Intervention methods	Describe methods used to intervene: who conducted intervention; if	Open answer

	Num	ID	Question	Description	Coding
				training/education, who were the direct beneficiaries	
	2.05	INTERV START	Intervention start	Start date	##/####
	2.06	INTERV END	Intervention end	End date	##/####
	2.07	LENGTH	Length of intervention	# months	##
Study design	3.01	STUDY TYPE	Design type	Categorise the study design	1= Randomised controlled trial (RCT) 2= Non-RCT (confounder-matched) 3= Survey data (PSM) 4= Other
	3.02	TYPE - OTHER		If other, state what	Open answer
	3.03	RANDOM IND	Individual randomisation	Randomised assignment at individual/households level?	1=Yes 2=No 9= N/A
	3.04	RANDOM GRP	Group randomisation	Randomised assignment at group/strata level?	1=Yes 2=No 9= N/A
	3.05	T&C SELECTION	Comments on treatment and control selection	Comments on treatment and control group selection	Open answer
	3.06	T&C COMPAR	Comparability of treatment & control	Is discussion of treatment and control comparability given?	1=Yes 2=No 9= N/A
	3.07	T&C VARIABLES	Variables used in assessing similarity between treatment and control groups	Does the study state variables on which comparability of treatment and control is assessed?	1=Yes 2=No 9= N/A
	3.08	LIST VARIABLES	List of variables used in control group selection	Variables considered in assessment of similarity (e.g. location, socioeconomic status, baseline watsan conditions; education levels)	Variable 1, variable 2, etc.

	Num	ID	Question	Description	Coding
	3.09	MATCHING	Matching	Are treatment and control groups matched according to explicit criteria (e.g. through pairing)?	1=Yes 2=No 9= N/A
	3.1	MATCHING VARS	Matching variables	List variables used to match	Variable 1, variable 2, etc.
	3.11	CONTROL ADEQ	Control adequate	Control adequate if randomised selection to intervention and control, or data reported on confounders which are sufficiently similar, or adjusted for in multivariate regression analysis. Control inadequate if no data reported on similarity of confounders, no adjustment for dissimilar confounders in multivariate analysis	1= Yes 2= No
	3.12	COMMENTS	Comments on adequacy of control		Open answer
	3.13	SEPAR	Separation	Is control group geographically separated from treatment?	1=Yes 2=No 8= Not clear 9= N/A
	3.14	CONTAM	Contamination	Is contamination of control by intervention or other WSH interventions accounted for?	1=Yes 2=No 8= Not clear 9= N/A
	3.15	CONTAM METHODS	Contamination methods	Describe methods to assess contamination	Open answer
	3.16	BLIND PART	Blinding participants	Blinding of participants?	1=Yes 2=No 9= N/A
	3.17	BLIND OBS	Blinding of observers	Blinding of observers?	1=Yes 2=No 9= N/A
	3.18	PLACEBO	Placebo	Use of placebo?	1=Yes 2=No 9= N/A
	3.19	SURVEY METHOD	Survey method	Describe method(s) used	Open answer; 9=N/A

	Num	ID	Question	Description	Coding
	3.2	RECALL	Recall period	What is the recall period used in outcome data collection?	1= 24 hours 2= 48 hours 3= 1 week 4= 2 weeks 5= more than 2 weeks 6= no information given on recall 9= N/A
	3.21	MULTIPLE	Multiple outcome data	Are outcome data collected at multiple points in time?	1=Yes 2=No 8=Not clear 9=N/A
	3.22	DATA FREQ	Data collection frequency	What is the frequency of outcome data collection?	Open answer; 9=N/A
	3.23	DATA METHOD	Data collection method	What methods are used to collect outcome data?	Open answer
	3.24	STUDY START	Study start	Start date of collection of data on outcome	##/####
	3.25	STUDY END	Study end	End date of collection of data on outcome	##/####
	3.26	SEASONALITY	Discussion of seasonality?	Does the study explicitly mention seasonality as a source of outcome heterogeneity?	1=Yes 2=No 9=N/A
	3.27	SEAS METHOD	Methods for adjusting for seasonality	How does the study adjust for seasonality?	Open answer
Context	4.01	COUNTRY	Country	List countries the study was conducted in	Country 1, Country 2, etc.
	4.02	RURAL	Rural	Is study conducted in rural areas?	1=Yes 2=No
	4.03	URBAN	Urban	Is study conducted in urban areas?	1=Yes 2=No
	4.04	PERI	Peri-urban	Is study conducted in peri-urban areas?	1=Yes 2=No
	4.05	AGE L	Age youngest participant	Age of youngest in months	##
	4.06	AGE U	Age oldest participant	Age of oldest in months	##

	Num	ID	Question	Description	Coding
	4.07	BASE WAT	Baseline water	Type and level of water supply applying to majority of population prior to intervention	Open answer
	4.08	BASE SAN	Baseline sanitation	Type and level of sanitation applying to majority of population prior to intervention	Open answer
	4.09	BASE EXP	Baseline exposure	Environmental pathogen risk associated with baseline water and sanitation conditions	1=basic water, basic sanitation 2=improved water, basic sanitation 3=basic water, improved sanitation 4=improved water, improved sanitation
	4.10	BASE ENV	Baseline environmental contamination assessment	Is estimate of environmental contamination associated with baseline water and sanitation conducted?	1=Yes 2=No 9= N/A
	4.11	ENV RESULT	Baseline environmental contamination result	What is the result of the assessment?	Open answer (e.g. X parts per million; 'very high' or other)
Output	5.01	OUTPUT FUNC	Assessment of output functioning/access	Is an assessment made of functioning/access to intervention?	1=Yes 2=No 9= N/A
	5.02	FUNC RESULT	Result of functioning	What is the result of the assessment of functioning/access?	Open answer
	5.03	OUTPUT KNOWL	Assessment of knowledge	Is an assessment made of beneficiary knowledge?	1=Yes 2=No 9= N/A
	5.04	KNOWL RESULT	Result of knowledge	What is the result of the assessment of knowledge?	Open answer
	5.05	OUTPUT COMPL	Assessment of output compliance	Is an assessment made of compliance with intervention among beneficiaries (behavioural change)?	1=Yes 2=No 9= N/A

	Num	ID	Question	Description	Coding
	5.06	METHOD	Method of assessing output compliance	What method is used to assess intervention/compliance	1= Microbial (pathogen) contaminant assessment 2= Residual treatment in stored water 3= Observation by intervention staff 4= Reporting by participants 5= Other 9= N/A
	5.07	METHOD - OTHER		If other method used to assess functioning/compliance, state what	Open answer
	5.08	OUTPUT CONCL	Output conclusion	What conclusions are made about degree of functioning of intervention or compliance among beneficiaries?	Open answer
Quality	6	QUALITY	Study classified as 'high quality'	Adequate control; Clear definition of health outcome or definition of diarrhoea; recall <2 weeks	1=Yes 2=No
Outcome measure	7.01	OUTCOME DEF	Outcome	Does the study give a precise definition of outcome?	1=Yes 2=No
	7.02	DEFINITION	Definition of outcome	What definition of outcome is given?	1= Standard diarrhoea (one or more loose stools in 24 hrs) 2= severe diarrhoea 3= persistent diarrhoea 4= dysentery 5= other 8= not clear (definition not given)
	7.03	DEF - OTHER		If other, state what	Open answer
	7.04	METRIC	Outcome metric	What metric is used in the calculation of the outcome variable used in estimation?	1= Risk (probability) 2= Rate (incidence) 3= Prevalence

	Num	ID	Question	Description	Coding
	7.05	BASE OUTCOME	Baseline outcome data	Does the study present data on outcome before intervention carried out (in control and treatment groups)?	1=Yes 2=No 9= N/A
	7.06	OUTCOME RESULT	Result of baseline outcome assessment	Result of baseline outcome (e.g. 20% incidence rate of diarrhoea)	Open answer
	7.07	S SIZE METRIC	Sample size metric	Sample size unit of measurement	1= Children 2= Households 3= Groups (e.g. village) 4= Other 5= Sample size not stated
	7.08	OTHER - METRIC		If other, state what	Open answer
	7.09	S SIZE TREAT	Sample size (treatment)	Initial sample size treatment group	#
	7.1	S SIZE CONTR	Sample size (control)	Initial sample size control group	#
	7.11	ATTRIT TREAT	Treatment attrition	Number of drop-outs	#
	7.12	ATTRIT CONTR	Control attrition	Number of drop-outs	#
	7.13	NUM CHILDREN	Data on number of children	Total number of children in study (after attrition)	#
	7.14	EST NUM CHILDREN	Estimated number of children	Where number of children not provided in study, give estimated number	#
	7.15	NUMBER	Estimate number	Multiple estimates from individual studies are listed vertically: 1, 2, 3…	#
	7.16	NUMBER DES	Estimate description	For studies reporting multiple estimates, state sub-sample each estimate applies to	Open answer
	7.17	ADJUSTED	Estimate adjusted for confounders	Is the estimate adjusted for confounding variables?	1=Yes 2=No 9= N/A

	Num	ID	Question	Description	Coding
	7.18	ADJ DESC	Description of adjustment	Describe the methods used to adjust for confounding (e.g. 'logistic regression') and variables employed	Open answer
	7.19	RATIO TYPE	Ratio type		1=Risk 2=Rate (incidence) 3=Prevalence 4=Odds 8=Unclear 9=Ratio not reported
	7.2	RISK RATIO CALC	Calculated risk ratio	X.XX	#
	7.21	RR CI L	CI lower	95% Confidence interval lower bound reported (X.XX)	#
	7.22	RR CI U	CI upper	95% Confidence interval upper bound reported (X.XX)	#
	7.23	P-VAL	P-value	Probability value of estimate reported (0.XXX)	#
	7.24	RR S.E.	Standard error of RR	Standard error of estimate	#
	7.25	CORRECT S.E.'S	Standard errors	Are standard errors appropriately adjusted for?	1=Yes 2=No 8=Not clear 9= N/A
	7.26	S.E. COMMENTS	Comments on S.E. calculation	Comments on standard error calculation, as reported in paper or as calculated from data in paper	Open answer
	7.27	OTHER OUTCOME	Other outcomes	List any other outcomes measured in study	Open answer
Additional information	9.01	WHY	Statements	Are statements or analyses made of why intervention was effective or not?	1=Yes 2=No
	9.02	WHY STATEMENTS		If yes, what	Open answer
	9.03	BEHAVIOUR	Mechanisms	Are beliefs, values or experiences of treatment group	1=Yes 2=No

	Num	ID	Question	Description	Coding
				taken into account in study design or in explaining effectiveness?	
	9.04	BEHAVIOUR STATEMENT		If yes, how?	Open answer
	9.05	CONTEXT	Context	Is relevant information on economic, social, administrative or legal factors taken into account in explaining effectiveness?	1=Yes 2=No
	9.06	CONTEXT STATEMENT		If yes, what	Open answer
	9.07	MODERATOR	Moderators	Is the effect of moderator variables analysed? A moderator or interactive variable modifies the way in which the intervention affects the outcome at different values of the variable	1=Yes 2=No
	9.08	MODER VARS		List moderator variables used in analysis	Variable 1, variable 2, etc.
	9.09	MOD IMPACT		What impact do moderators have on effect? (report effect estimates above in vertical format)	Open answer
	9.10	SUSTAIN	Assessment of sustainability	Is an assessment made of the (likely) sustainability of the output/ outcomes of the intervention?	1=Yes 2=No
	9.11	SUST METHOD	Method	Describe methods used to assess (likely) sustainability	Open answer
	9.12	SUST CONCL	Conclusion	Describe conclusions made of (likely) sustainability	Open answer

	Num	ID	Question	Description	Coding
	9.13	COST	Cost	Are unit cost data / cost-effectiveness estimates provided?	1=Yes 2=No
	9.14	COST DATA	Cost details	If yes, give details of unit cost and/or total cost	Open answer

ANNEX 3: INCLUDED INTERVENTIONS

Study	Study location	Intervention	Study design	Age of participants	Sample size	Length (months)	Baseline water and sanitation	Study quality	Included in meta-analysis?
Water supply interventions									
Galiani et al. (2007)	Argentina, urban	POU water supply	Non-RCT	0-71 months	649	9	W: improved S: improved	Low: recall more than two weeks; definition of diarrhoea unclear	Yes
Gasana et al. (2002)	Rwanda, rural	Source water supply	Non-RCT	0-59 months	150	15	W: basic S: basic	Low: recall more than two weeks; definition of diarrhoea unclear; comparability of treatment and control groups not sufficiently clear	Yes
Jalan and Ravallion (2003)	India, national	Source/ POU water supply combined, POU water supply	PSM, survey	0-59 months	33,216	12	W: basic S: basic	High	Yes
Khanna (2008)	India, national	Source/ POU water supply combined (average calculated of piped/ pump/well), POU water supply	PSM, survey	12-47 months	22,816	12	W: improved S: basic	Low: comparability of treatment and control groups unclear	Yes

Study	Study location	Intervention	Study design	Age of participants	Sample size	Length (months)	Baseline water and sanitation	Study quality	Included in meta-analysis?
Lou et al. (1990)	China, peri-urban	Source water supply	Non-RCT	0-59 months	187	12	W: basic S: improved	Low: recall more than two weeks; definition of diarrhoea unclear; comparability of treatment and control groups not sufficiently clear; confidence interval not provided	No (confidence interval not estimable)
Pradhan and Rawlings (2002)	Nicaragua, national	POU water supply (piped)	PSM, survey	0-71 months	236	48	W: basic S: basic	Low: recall more than two weeks; definition of diarrhoea unclear	Yes
Ryder et al. (1985)	Panama, rural	POU water supply	Non-RCT	0-59 months	178	8	W: basic S: improved	Low: nothing reported on treatment and control groups comparability	Yes
Tonglet et al. (1992)	Zaire, rural	Source water supply	Non-RCT	0-59 months	906	24	W: basic S: basic	Low: comparability of treatment and control groups not sufficiently clear	Yes
Walker et al. (1999)	Honduras, national	Source/ POU water supply	Pipe-line, survey	All ages	3,124	30	W: improved S: improved	Low: recall more than two weeks; comparability of treatment and control groups not sufficiently clear	Yes

Study	Study location	Intervention	Study design	Age of participants	Sample size	Length (months)	Baseline water and sanitation	Study quality	Included in meta-analysis?
Water quality interventions									
Blanton et al. (2008)	Ghana, urban	POU NaDCC tablet	RCT with placebo control; control received water tablet	0-59 months	682	3	W: improved S: basic	Abstract only: N/A	No (abstract only; effect size not estimable)
Brown et al. (2007)	Cambodia, rural and peri-urban	POU filtration	Non-RCT	0-59 months	163	48	W: basic S: improved	Low: definition of diarrhoea unclear; comparability of treatment and control groups not sufficiently clear	Yes
Brown et al. (2008)	Cambodia, rural	POU filtration ceramic/ non-ceramic filters (average calculated)	RCT	0-59 months	249	4	W: basic S: improved	High	Yes
Chiller et al. (2006)	Guatemala, rural	POU flocculation, safe storage	Cluster-RCT	0-59 months	328	3	W: basic S: basic	High	Yes
Clasen et al. (2004)	Bolivia, rural	POU filtration	RCT	0-59 months	32	6		High	Yes
Clasen et al. (2005)	Colombia, rural and urban	POU filtration	RCT	0-59 months	142	5	W: improved S: improved	High	Yes
Clasen et al. (2006)	Bolivia, rural	POU filtration	RCT	0-59 months	60	5	W: basic S: basic	High	Yes

Study	Study location	Intervention	Study design	Age of participants	Sample size	Length (months)	Baseline water and sanitation	Study quality	Included in meta-analysis?
Conroy et al. (1996)	Kenya, rural	POU UV disinfection	RCT with placebo control; control instructed to place bottles inside	5-15 years	206	3	W: improved S: basic	High	Yes
Conroy et al. (1999)	Kenya, rural	POU UV disinfection	RCT with placebo control; control instructed to place bottles inside	0-71 months	349	12	W: basic S: basic	High	Yes
Crump et al. (2005)	Kenya, rural	POU flocculation/ chlorination (average calculated)	RCT	0-23 months	715	5	W: basic S: improved	High	Yes
Doocy and Burnham (2006)	Liberia, urban	POU flocculation	Cluster-RCT	All ages	2,191	3	W: basic S: basic	High	
Du Preez et al. (2008)	South Africa and Zimbabwe, rural	POU filtration	RCT	24-36 months	114	8	W: improved S: basic	Low: recall more than two weeks; definition of diarrhoea unclear; comparability of treatment and control groups not sufficiently clear	Yes

Study	Study location	Intervention	Study design	Age of participants	Sample size	Length (months)	Baseline water and sanitation	Study quality	Included in meta-analysis?
Gasana et al. (2002)	Rwanda, rural	Source water quality (filtration)	Non-RCT	0-59 months	170	15	W: basic S: basic	Low: recall more than two weeks, definition of diarrhoea unclear; comparability of treatment and control groups not sufficiently clear	Yes
Iijima et al. (2001)	Kenya, rural	POU filtration	Non-RCT	All ages	300	4	W: basic S: basic	Low: recall more than two weeks; no comparison of treatment and control groups	Yes
Jensen et al. (2003)	Pakistan, rural	Source chlorination	Non-RCT	0-59 months	226	6	W: basic S: basic	High	Yes
Kirchhoff et al. (1985)	Brazil, rural	POU chlorination	Blinded cross-over trial, placebo group received distilled water	0-59 months	38	5	W: basic S: basic	High	Yes
Kremer et al. (2008)	Kenya, rural	POU chlorination	RCT	0-47 months	2,121	5	W: improved S: improved	High	Yes
Kremer et al. (2009)	Kenya, rural	Source water quality (spring protection)	RCT	0-47 months	2,042	20	W: basic S: improved	High	Yes

Study	Study location	Intervention	Study design	Age of participants	Sample size	Length (months)	Baseline water and sanitation	Study quality	Included in meta-analysis?
Luby et al. (2004)	Pakistan, urban	POU bleach, safe storage (average calculated of imported/local vessel)	Non-RCT with placebo control; control children received books and pens	0-15 years	630	18	W: basic S: basic	Low: treatment and control groups comparability confounded by water supply and sanitation source	Yes
Luby et al. (2006)	Pakistan, urban	POU bleach/ flocculation + safe storage (average calculated)	Cluster-RCT with placebo control; control children received books and pens	0-59 months	575	9	W: improved S: improved	High	Yes
Lule et al. (2005)	Uganda, rural	POU chlorination, safe storage	RCT	0-35 months	255	19	W: basic S: improved	High	Yes
Mahfouz et al. (1995)	Saudi Arabia, rural	POU chlorination	Cluster-RCT	0-59 months	311	6	W: basic S: improved	High	Yes
Quick et al. (2002)	Zambia, peri-urban	POU chlorination, safe storage	RCT	All ages	1,581	2	W: basic S: basic	High	Yes
Quick et al. (1999)	Bolivia, peri-urban	POU chlorination, safe storage	RCT	0-59 months	161	4	W: basic S: basic	High	Yes

Study	Study location	Intervention	Study design	Age of participants	Sample size	Length (months)	Baseline water and sanitation	Study quality	Included in meta-analysis?
Reller et al. (2003)	Guatemala, rural	POU flocculation/bleach, safe storage (average calculated)	RCT	0-11 months	208	12	W: basic S: basic	High	Yes
Roberts et al. (2001)	Malawi, peri-urban	Safe storage	RCT	0-59 months	208	4	W: basic S: basic	High	Yes
Rose et al. (2006)	India, urban	POU UV disinfection	RCT	6-59 months	200	6	W: improved S: basic	High	Yes
Semenza et al. (1998)	Uzbekistan, urban	POU chlorination, safe storage	RCT	0-59 months	344	2	W: improved S: improved	High	Yes
Sobsey et al. (2003)	Bangladesh urban	POU chlorination, safe storage	RCT	0-59 months	275	8	W: improved S: basic	High	Yes
Stauber et al. (2009)	Dominican Republic, urban, peri-urban	POU filtration	RCT	0-59 months	243	10	W: improved S: improved	High	Yes
Tiwari et al. (2009)	Kenya, rural	POU filtration	RCT	0-59 months	222	6	W: basic S: basic	High	Yes
Universidad Rafael Landivar (1995)	Guatemala, rural, urban, peri-urban	POU filtration	RCT	0-59 months	558	11	W: basic S: improved	High	Yes

Study	Study location	Intervention	Study design	Age of participants	Sample size	Length (months)	Baseline water and sanitation	Study quality	Included in meta-analysis?
Sanitation interventions									
Bose (2009)	Nepal, national	Latrine	PSM, survey	0-59 months	5,447	12	W: improved S: basic	High	Yes
Kolahi et al. (2008)	Iran, urban	Sewer connection	Non-RCT	6-59 months	2,096	24	W: improved S: improved	High	Yes
Moraes et al. (2003)	Brazil, urban	Drainage/drainage + sewer connection (average calculated)	Non-RCT	0-59 months	1,275	24	W: improved S: improved	High	Yes
Pradhan & Rawlings (2002)	Nicaragua, national	Sewer connection	PSM, survey	0-71 months	68	48	W: improved S: improved	Low: recall more than two weeks	Yes
Pradhan and Rawlings (2002)	Nicaragua, national	Latrine	PSM, survey	0-71 months	677	48	W: improved S: improved	Low: recall more than two weeks	Yes
Root (2001)	Zimbabwe, rural	Latrine	Survey	0-59 months	272	24	W: improved S: basic	Low: comparability of treatment and control groups not sufficiently clear	Yes
Walker et al. (1999)	Honduras, national	Sewer connection	Pipe-line, survey	All ages	1,853	30	W: improved S: improved	Low: recall more than two weeks; comparability of treatment and control groups not sufficiently clear	Yes

Study	Study location	Intervention	Study design	Age of participants	Sample size	Length (months)	Baseline water and sanitation	Study quality	Included in meta-analysis?
Walker et al. (1999)	Honduras, national	Latrine	Pipe-line, survey	All ages	1,694	30	W: improved S: improved	Low: recall more than two weeks; comparability of treatment and control groups not sufficiently clear	Yes
Hygiene interventions									
Ahmed et al. (1993)	Bangladesh rural	Hygiene education	Non-RCT	0-18 months	350	7	W: improved S: improved	High	Yes
Bateman et al. (1995)	Bangladesh rural	Hygiene education	Non-RCT	0-59 months	590	0.5	W: improved S: improved	Low: definition of diarrhoea unclear; comparability of treatment and control groups unclear	Yes
Haggerty et al. (1994)	Zaire, rural	Hygiene education	Cluster-RCT with placebo control; control received education on reducing diarrhoea duration	3-35 months	1,764	3	W: basic S: basic	High	Yes

Study	Study location	Intervention	Study design	Age of participants	Sample size	Length (months)	Baseline water and sanitation	Study quality	Included in meta-analysis?
Han & Hlaing (1989)	Burma, urban	Hygiene, soap	RCT	6-59 months	482	5	W: improved S: improved	High	Yes
Khan (1982)	Bangladesh	Hygiene, soap	Non-RCT	All ages	30	0.3	W: improved S: basic	Low: comparability of treatment and control groups unclear	Yes
Lee et al. (1991)	Thailand, rural	Hygiene education	Non-RCT	0-59 months	904	6	W: improved S: improved	High	Yes
Luby et al. (2004)	Pakistan, urban	Hygiene, soap	Non-RCT with placebo control; control children received books and pens	0-15 years	834	18	W: basic S: basic	Low: comparability of treatment and control groups confounded by water supply and sanitation source	Yes
Luby et al. (2005)	Pakistan, urban	Hygiene, soap (average calculated of plain/antibacterial soap)	Cluster-RCT with placebo control; control children received books and pens	0-59 months	249	12	W: basic S: basic	High	Yes

Study	Study location	Intervention	Study design	Age of participants	Sample size	Length (months)	Baseline water and sanitation	Study quality	Included in meta-analysis?
Luby et al. (2006)	Pakistan, urban	Hygiene, soap	Cluster-RCT with placebo control; control children received books and pens	0-59 months	575	9	W: improved S: improved	High	Yes
Luby et al. (2008)	Pakistan, urban	Hygiene education	Non-RCT	0-59 months	1,000	8	W: improved S: basic	Low: definition of diarrhoea unclear; comparability of treatment and control groups not sufficiently clear	Yes
Odio et al. (2004)	Mexico	Hygiene education, anti-bacterial soap	RCT	0-59 months	718	4	W: improved S: improved	Abstract only: N/A	No (abstract only; effect size not estimable)
Pattanayak et al. (2007)	India, rural	Latrine, hygiene education	Cluster-RCT	0-59 months	2,991	12	W: improved S: basic	High	Yes
Pinfold & Horan (1996)	Thailand, rural	Hygiene education, soap	Non-RCT	0-59 months	2,219	3	W: improved S: improved	High	Yes
Shahid et al. (1996)	Bangladesh peri-urban	Hygiene education, soap	Non-RCT	0-59 months	270	12	W: basic S: basic	High	Yes

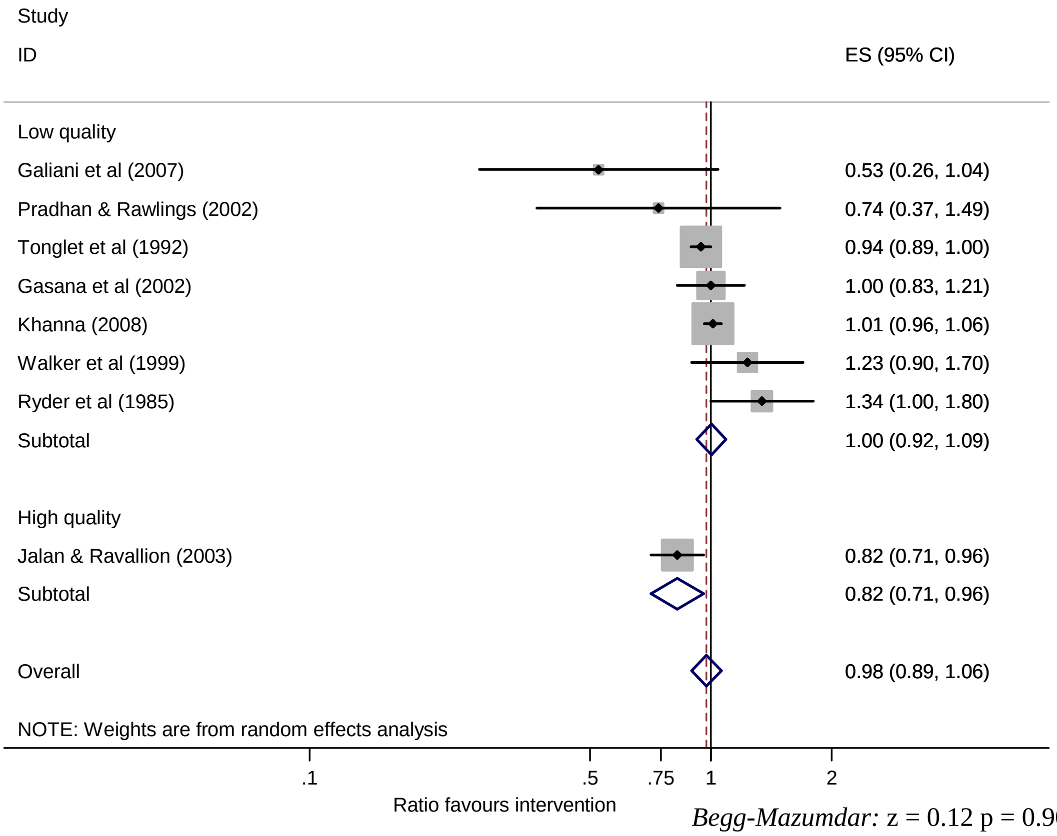
Study	Study location	Intervention	Study design	Age of participants	Sample size	Length (months)	Baseline water and sanitation	Study quality	Included in meta-analysis?
Sircar et al. (1987)	India, urban	Hygiene education, soap	Non-RCT	0-59 months	90	12	W: improved S: basic	High	Yes
Stanton et al. (1988)	Bangladesh, urban	Hygiene education	Non-RCT	0-71 months	2,119	12	W: basic S: basic	High	Yes
Torun (1982)	Guatemala, rural	Hygiene education	Non-RCT	0-71 months	2,914	12	W: basic S: basic	Low: definition of diarrhoea unclear; insufficiently comparable treatment and control groups	Yes
Wilson et al. (1991)	Indonesia, peri-urban	Hygiene education, soap	Non-RCT	0-11 years	315	4	W: improved S: basic	High	Yes
Multiple interventions									
Alam et al. (1989)	Bangladesh rural	Source water supply, hygiene education	Non-RCT	6-23 months	623	34	W: improved S: basic	High	Yes
Aziz et al. (1990)	Bangladesh rural	Source water supply, latrine, hygiene education	Non-RCT	0-59 months	1,391	46	W: basic S: basic	High	Yes
Garrett et al. (2008)	Kenya, rural	POU water quality (chlorination) latrine, hygiene education	Cluster-RCT	0-59 months	960	3	W: basic S: basic	High	Yes

Study	Study location	Intervention	Study design	Age of participants	Sample size	Length (months)	Baseline water and sanitation	Study quality	Included in meta-analysis?
Huttly et al. (1990)	Nigeria, rural	Source water supply, latrine, hygiene education	Non-RCT	0-71 months	9,377	24	W: basic S: basic	Low: confidence interval not provided.	No (confidence interval not estimable)
Khanna (2008)	India, national	Source water supply (average calculated of piped/ pump/ well), sanitation	PSM, survey	12-47 months	8,680	12	W: improved S: basic	Low: comparability of treatment and control groups not sufficiently clear	Yes
Lou et al. (1990)	China, peri-urban	Source water supply, latrine	Non-RCT	0-59 months	382	24	W: basic S: improved	Low: recall more than two weeks; comparability of treatment and control groups not sufficiently clear; confidence interval not provided.	No (confidence interval not estimable)
Luby et al. (2006)	Pakistan, urban	POU water treatment (flocculant), soap	Cluster-RCT with placebo control; control children received books and pens	0-59 months	575	9	W: improved S: improved	High	Yes

Study	Study location	Intervention	Study design	Age of participants	Sample size	Length (months)	Baseline water and sanitation	Study quality	Included in meta-analysis?
Messou et al. (1997)	Cote d'Ivoire, rural	Source water supply, latrines, hygiene education	Non-RCT	0-59 months	880	24	W: basic S: basic	Low: definition of diarrhoea unclear; comparability of treatment and control groups not sufficiently clear	Yes
Xiao et al. (1997)	China, rural	Source water supply, POU water treatment (boiling), hygiene education	Non-RCT	All ages	480	36	W: basic S: basic	Low: no information on recall period; definition of diarrhoea unclear; comparability of treatment and control groups not sufficiently clear	Yes

ANNEX 4: FOREST PLOTS

Figure 9 - Water supply: study quality



Begg-Mazumdar: z = 0.12 p = 0.90

Figure 10 - Water supply sub-groups

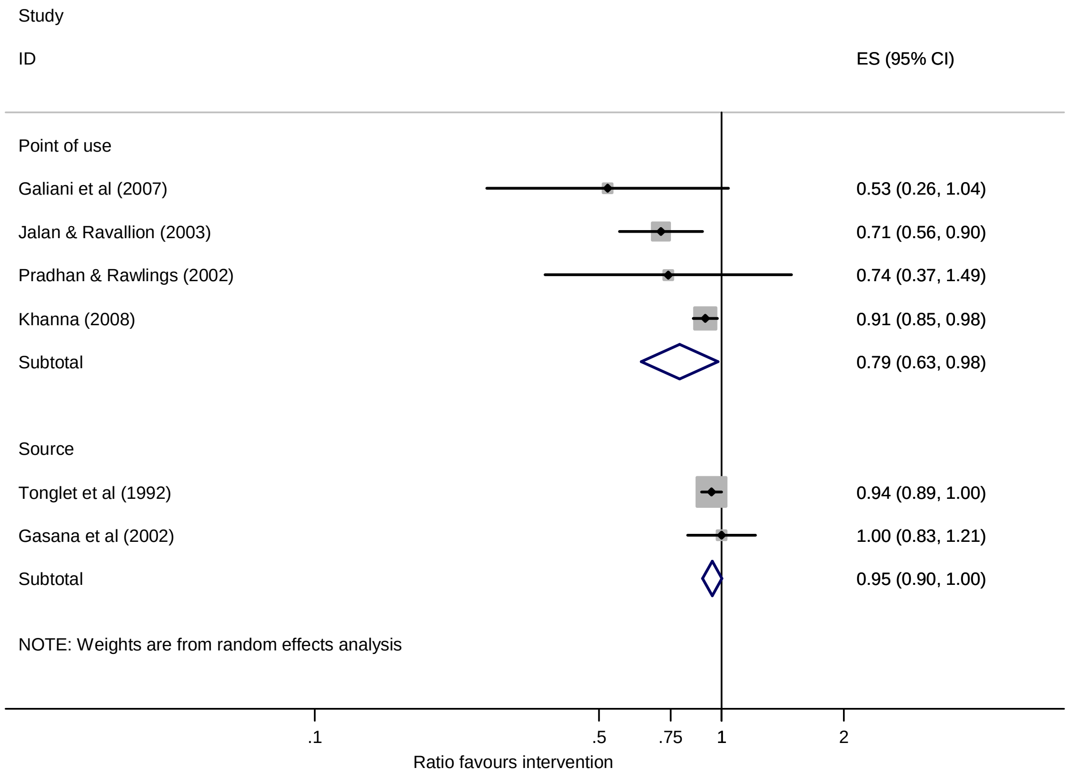
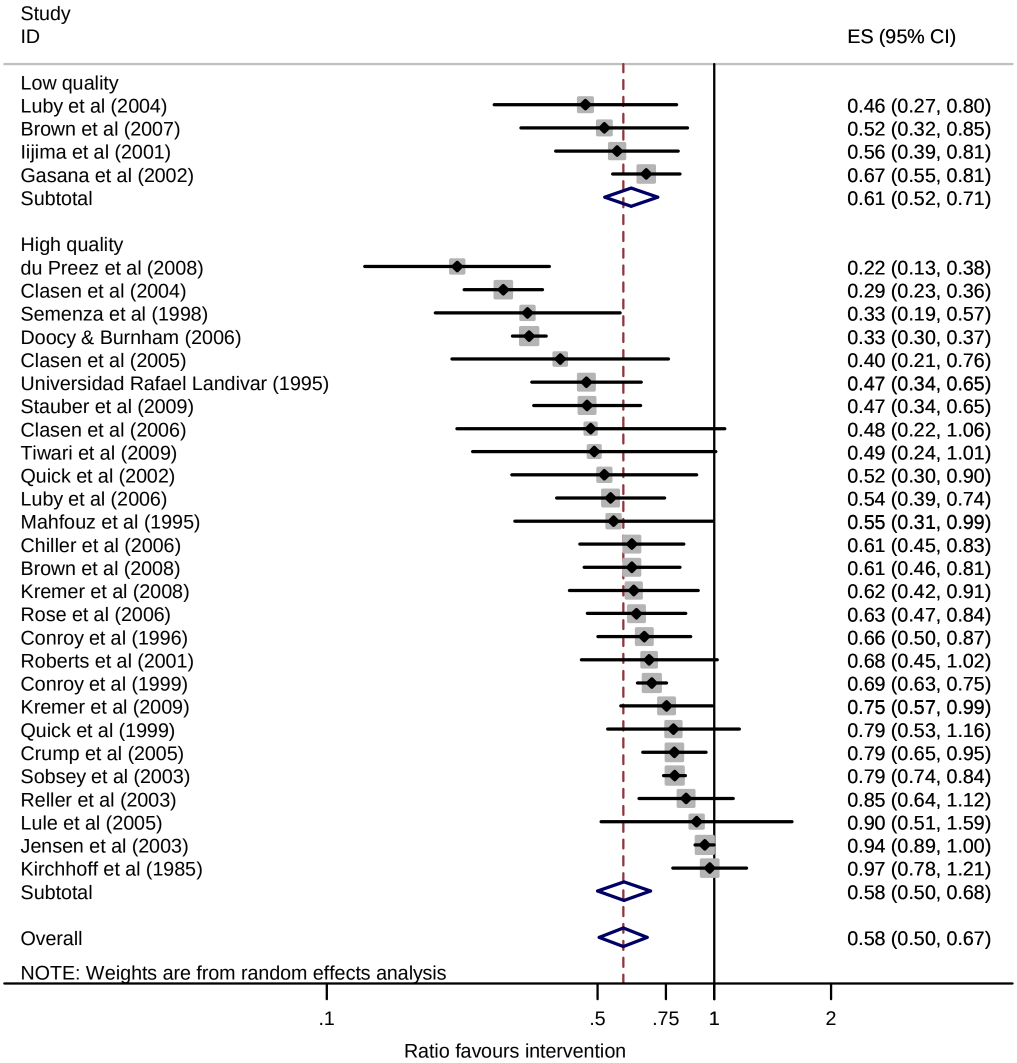


Figure 11 - Water quality: study quality



Begg-Mazumdar: z = 1.72 p = 0.09

Figure 12 - Water quality sub-groups: POU and source

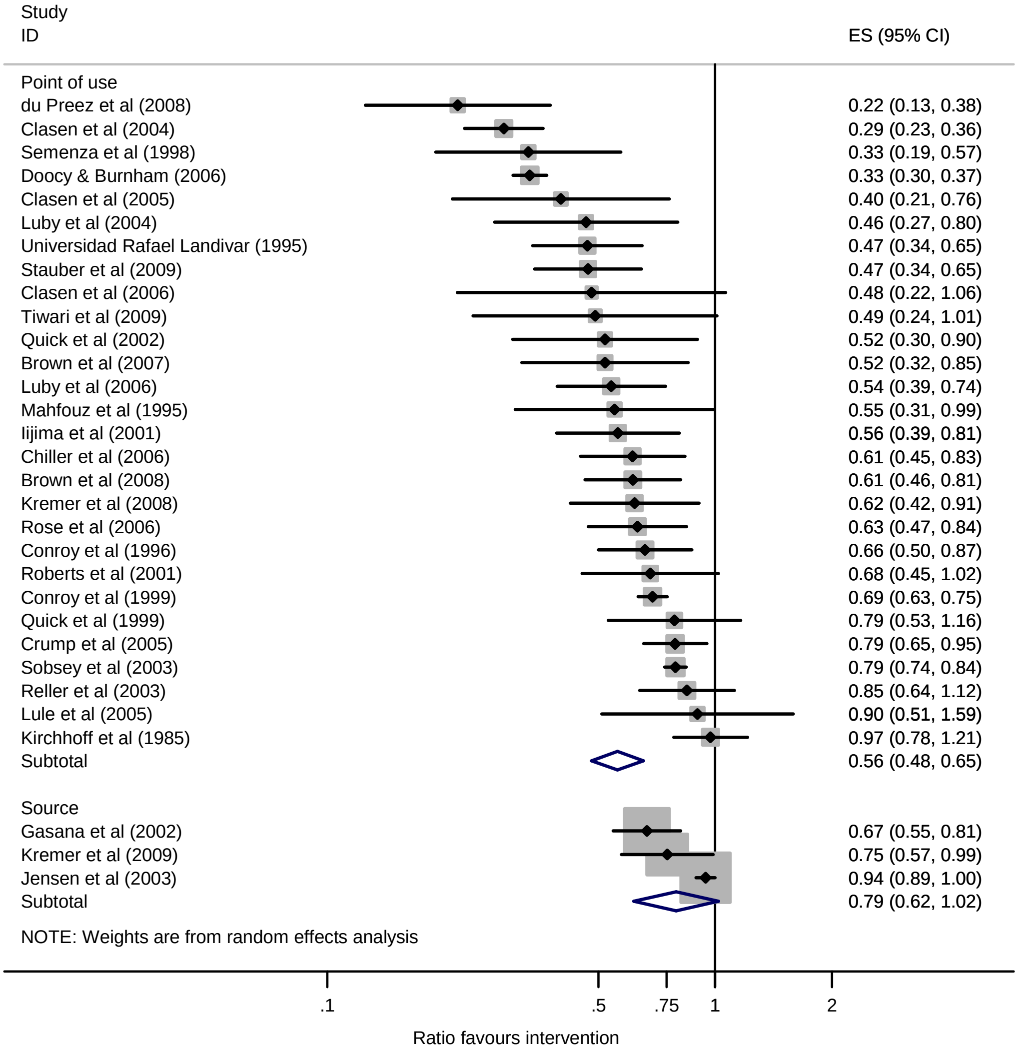


Figure 13 - Water quality sub-groups: storage device

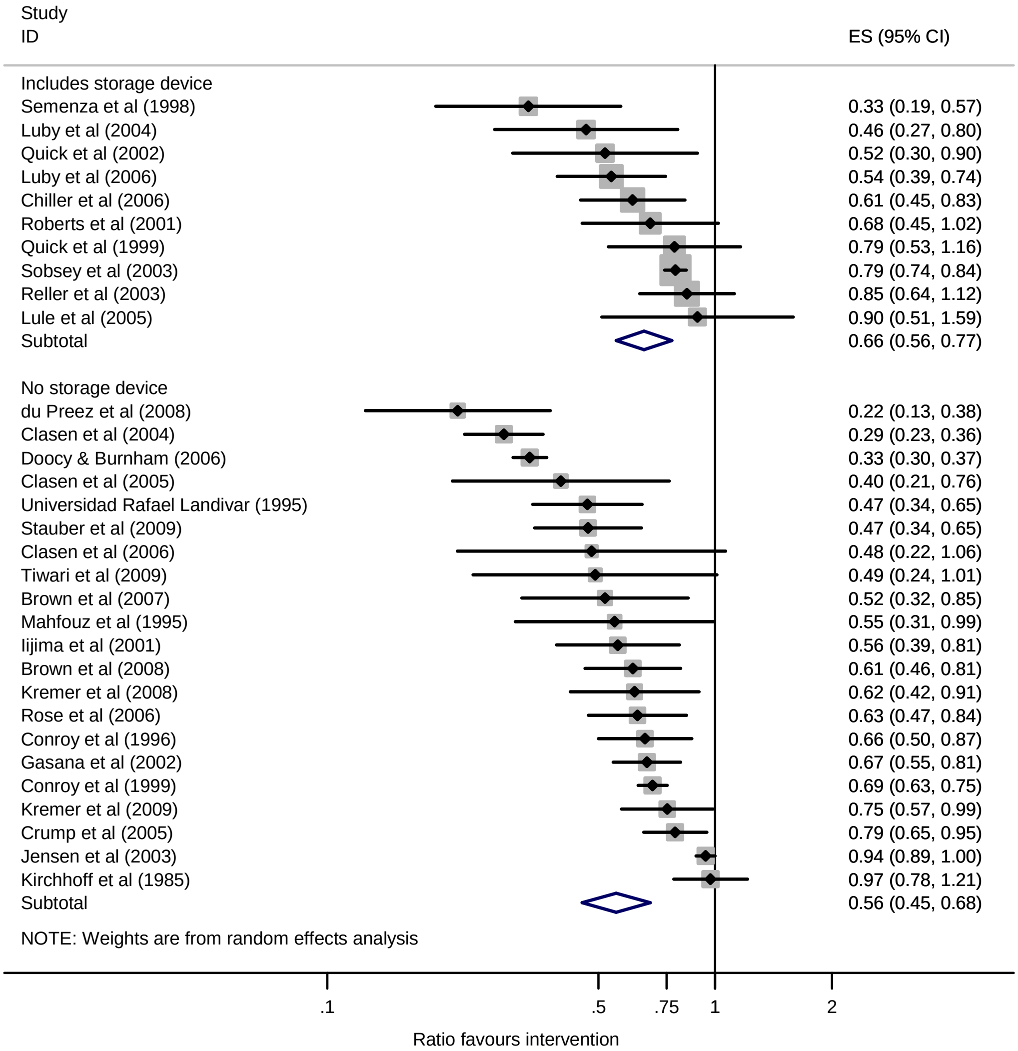


Figure 14 - Water quality: placebo-control

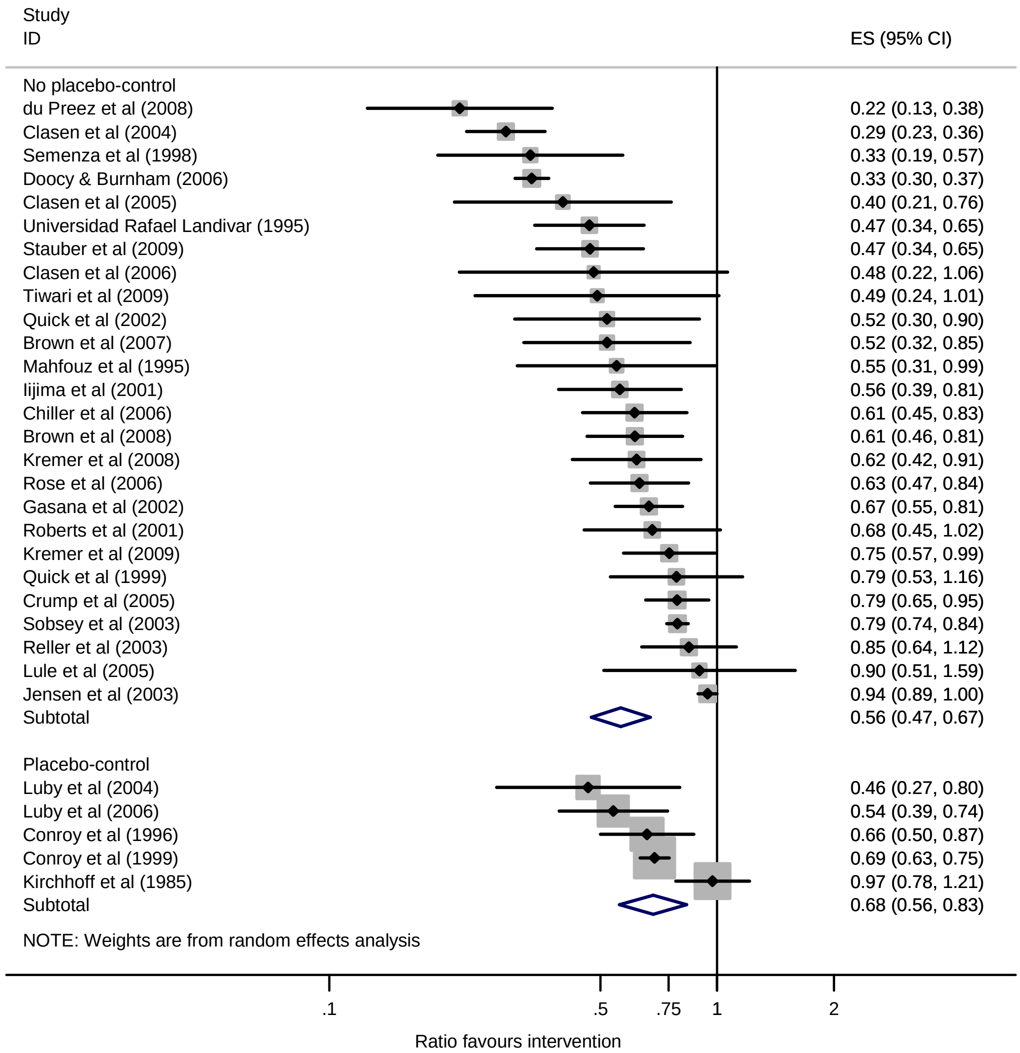


Figure 15 - Water quality: conflict of interest

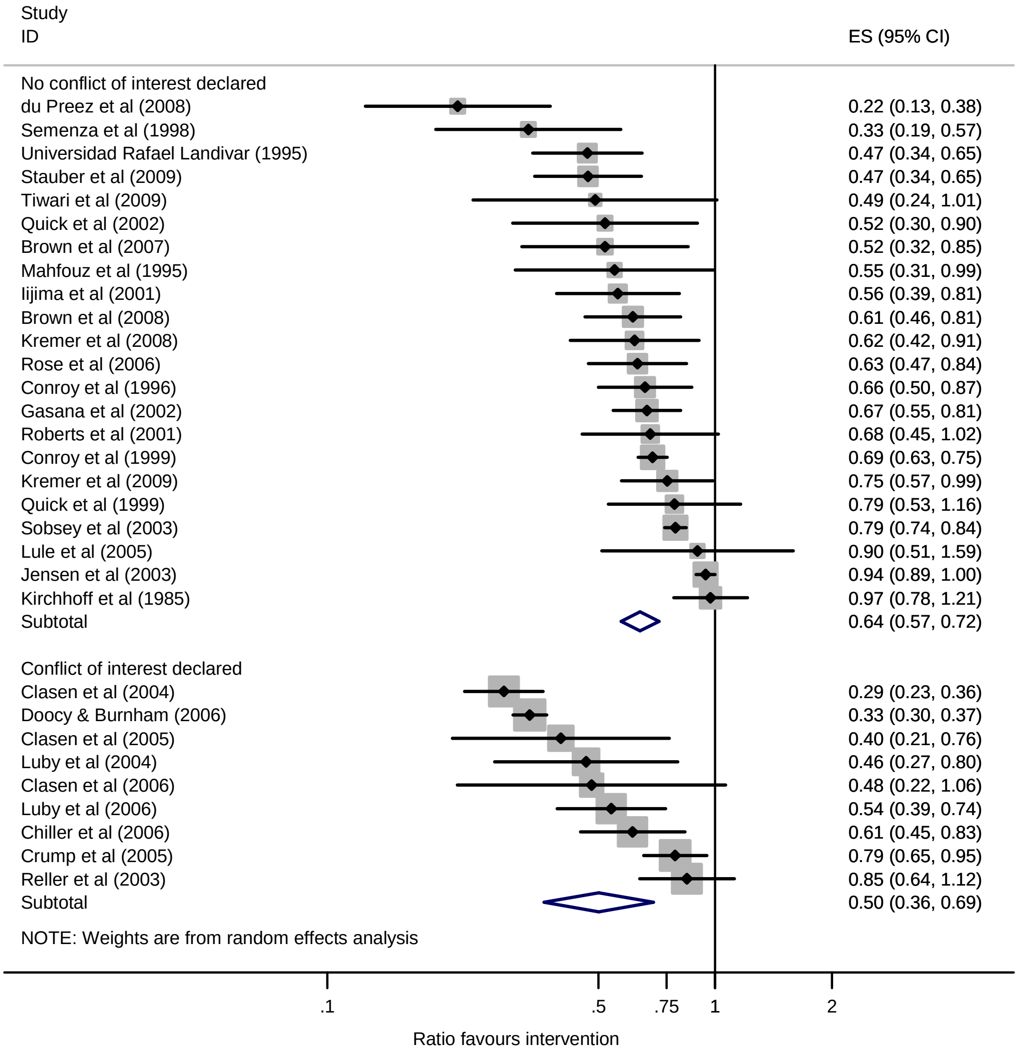
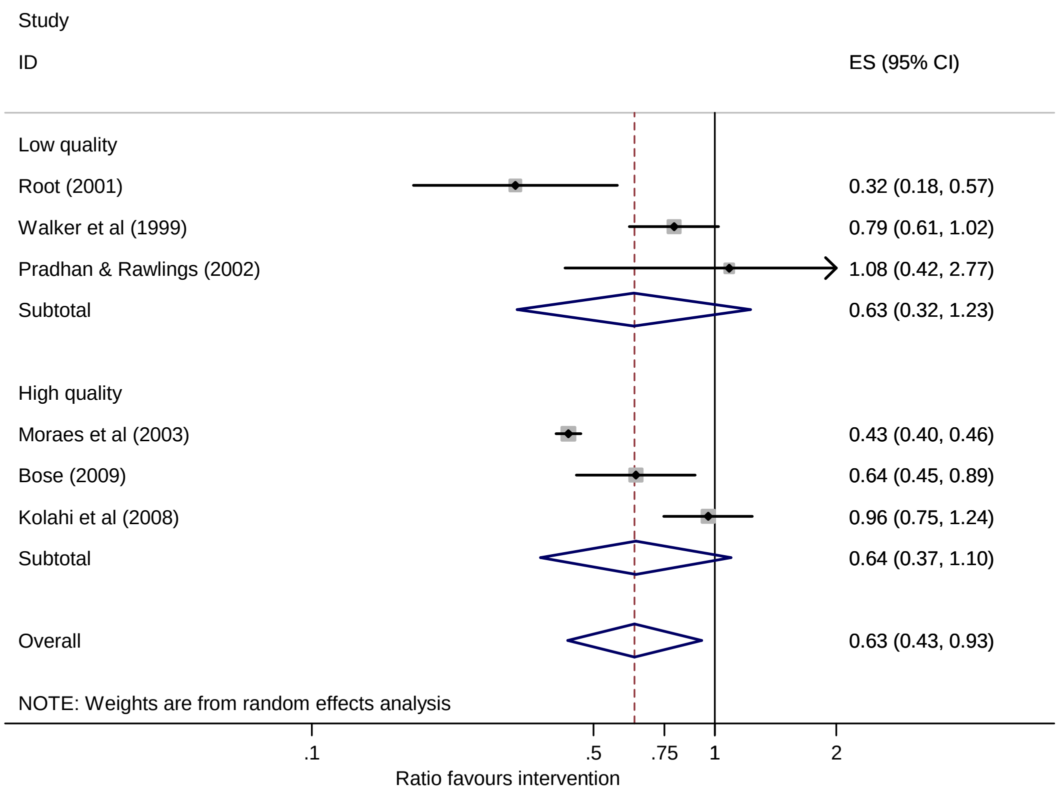


Figure 16 - Sanitation: study quality



Begg-Mazumdar: z = 0.19 p = 0.85

Figure 17 - Sanitation sub-groups

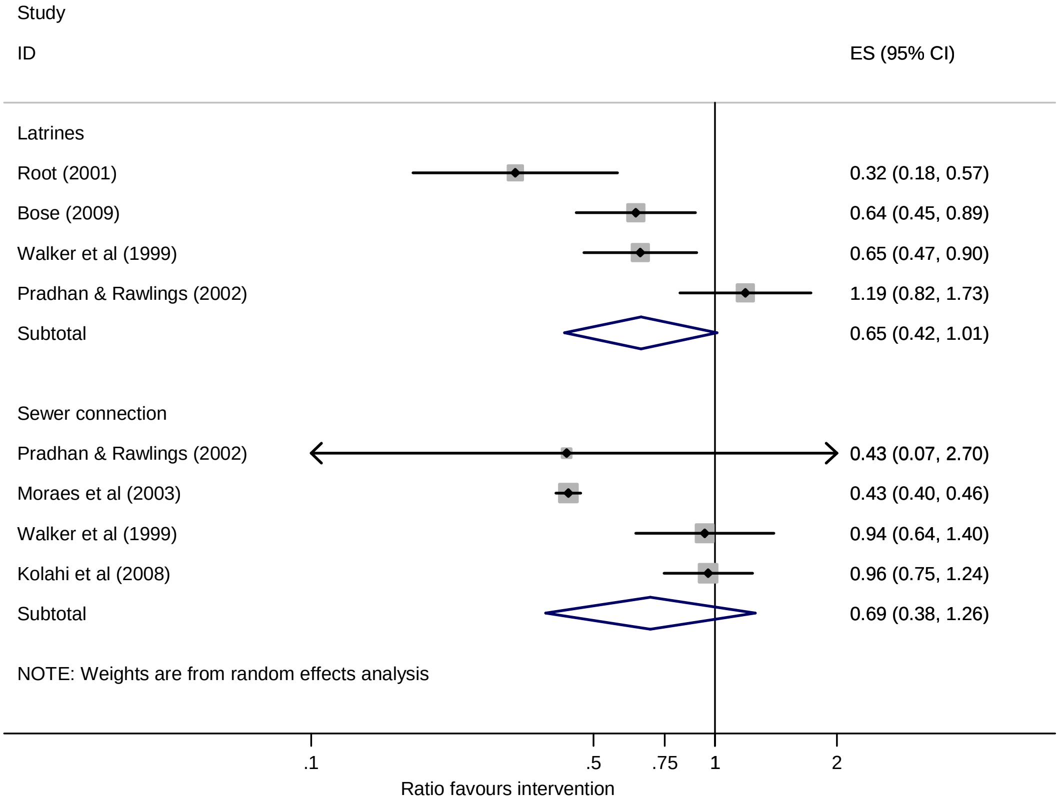
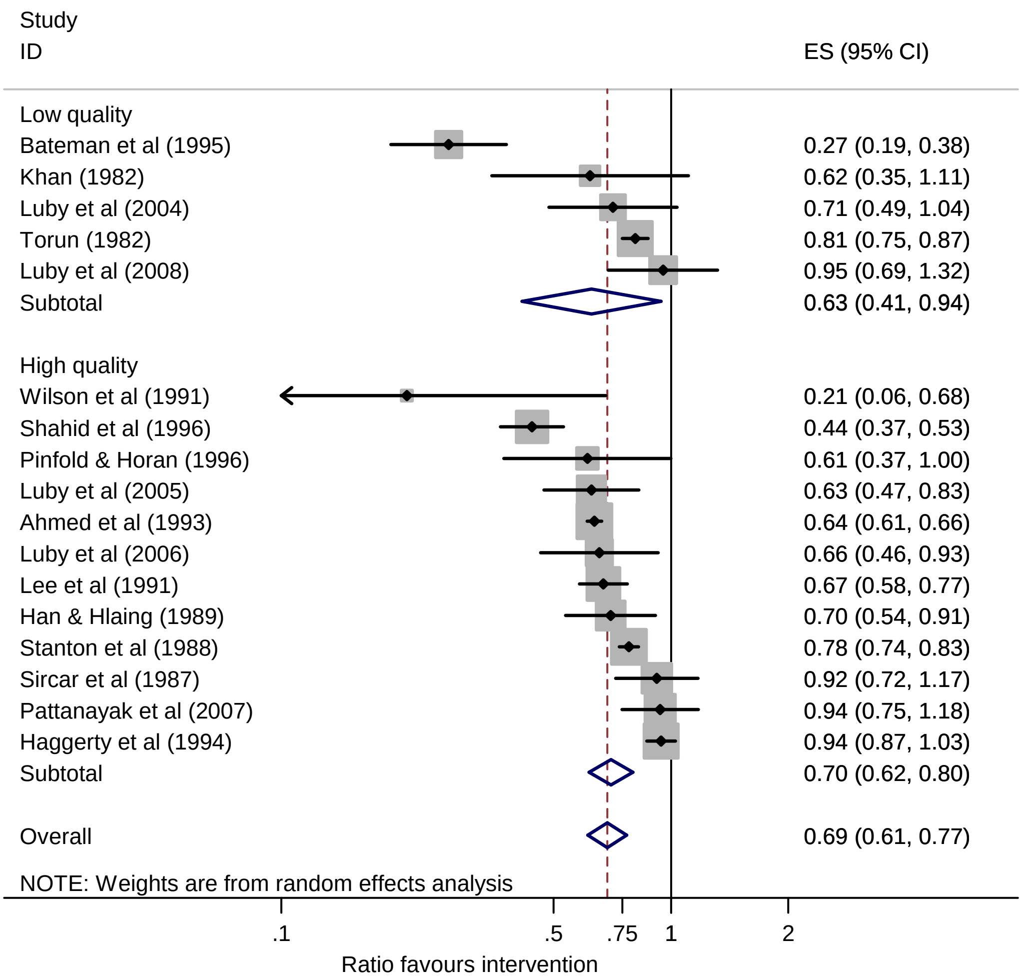


Figure 18 - Hygiene: study quality



Begg-Mazumdar: z = 1.19 p = 0.23

Figure 19 - Hygiene sub-groups

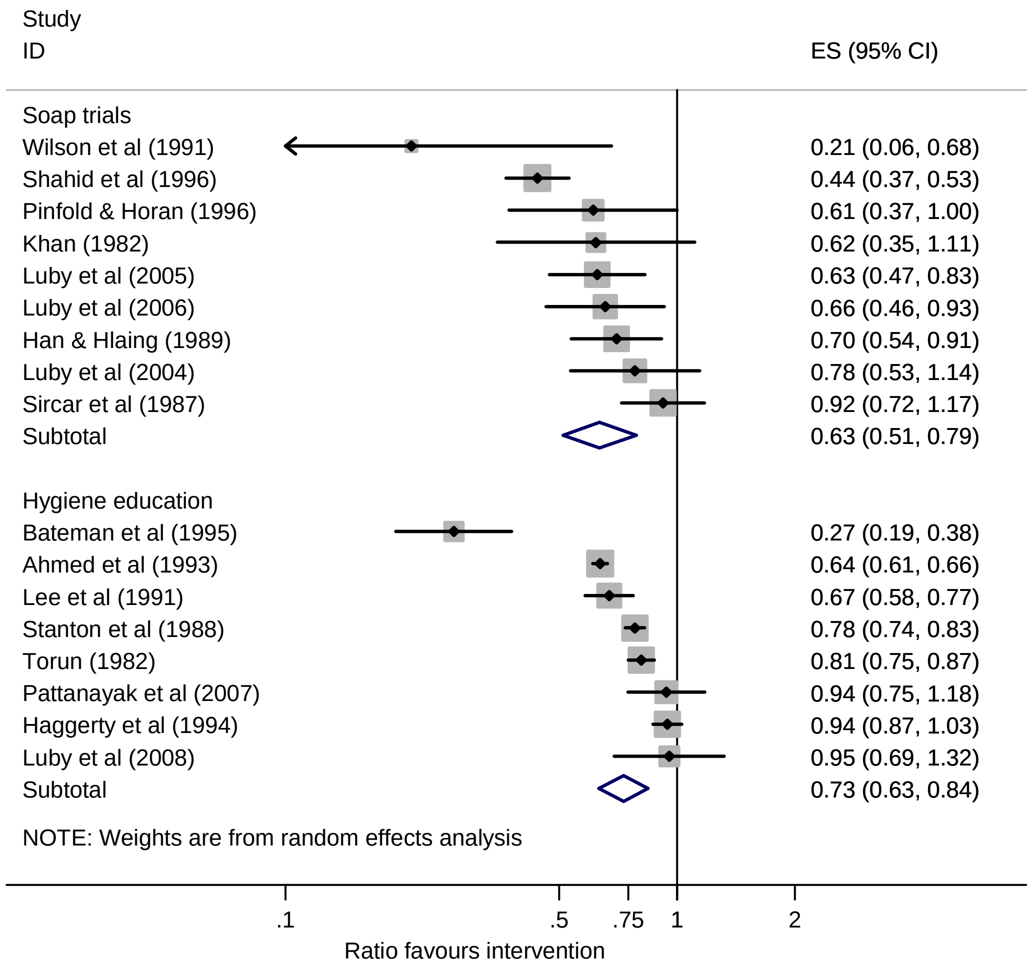


Figure 20 - Hygiene: placebo-control

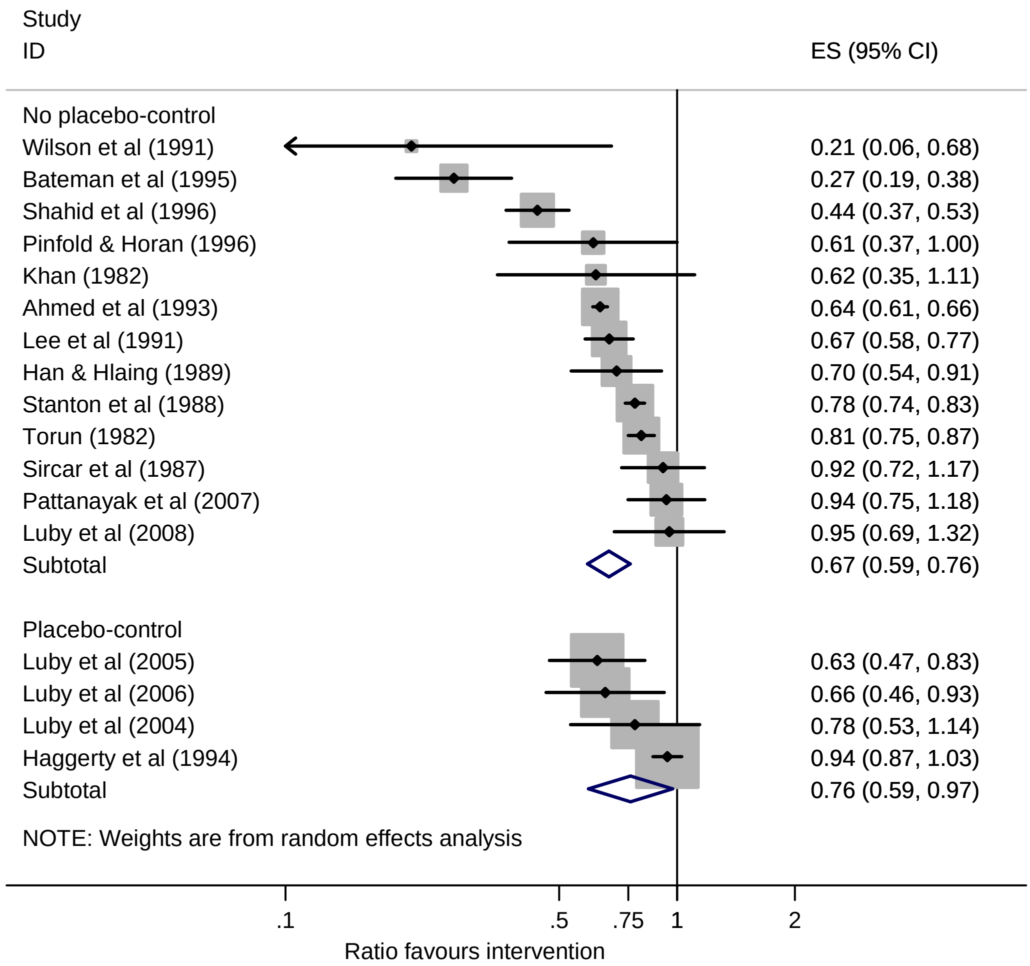


Figure 21 - Hygiene: conflict-of-interest

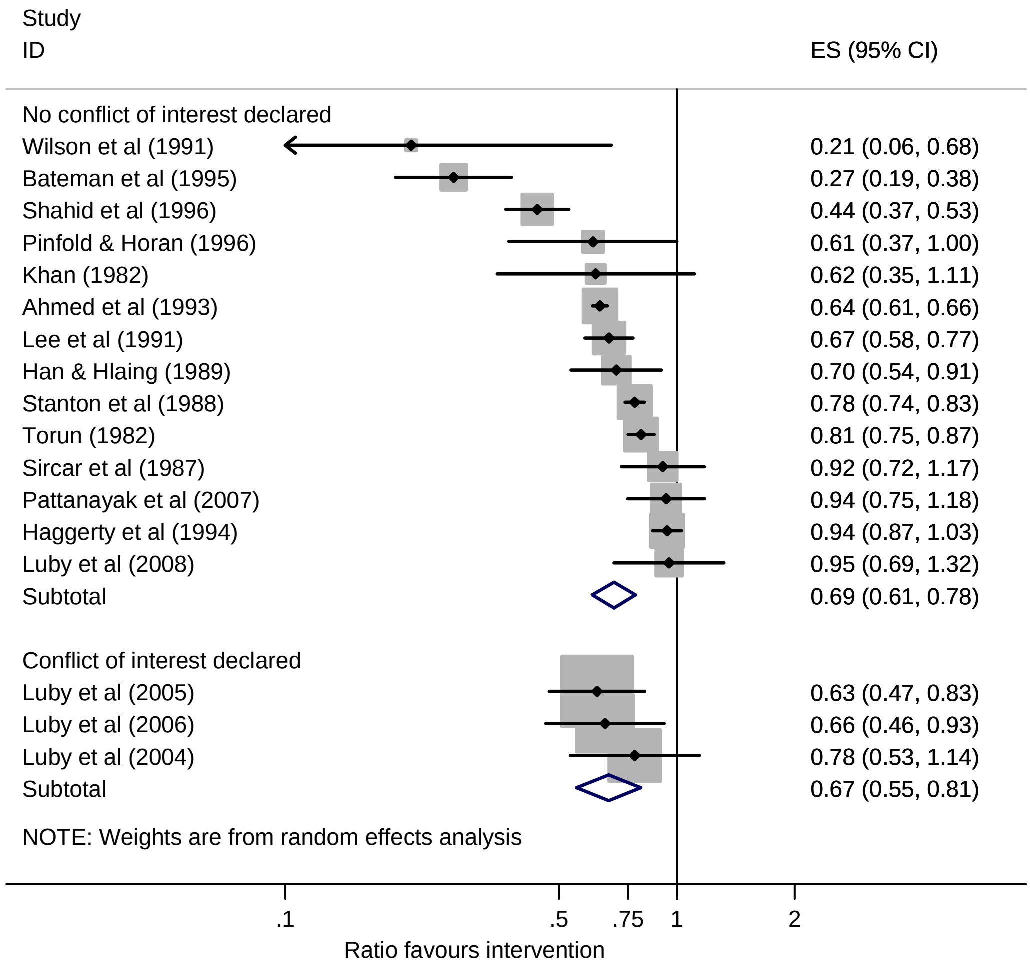
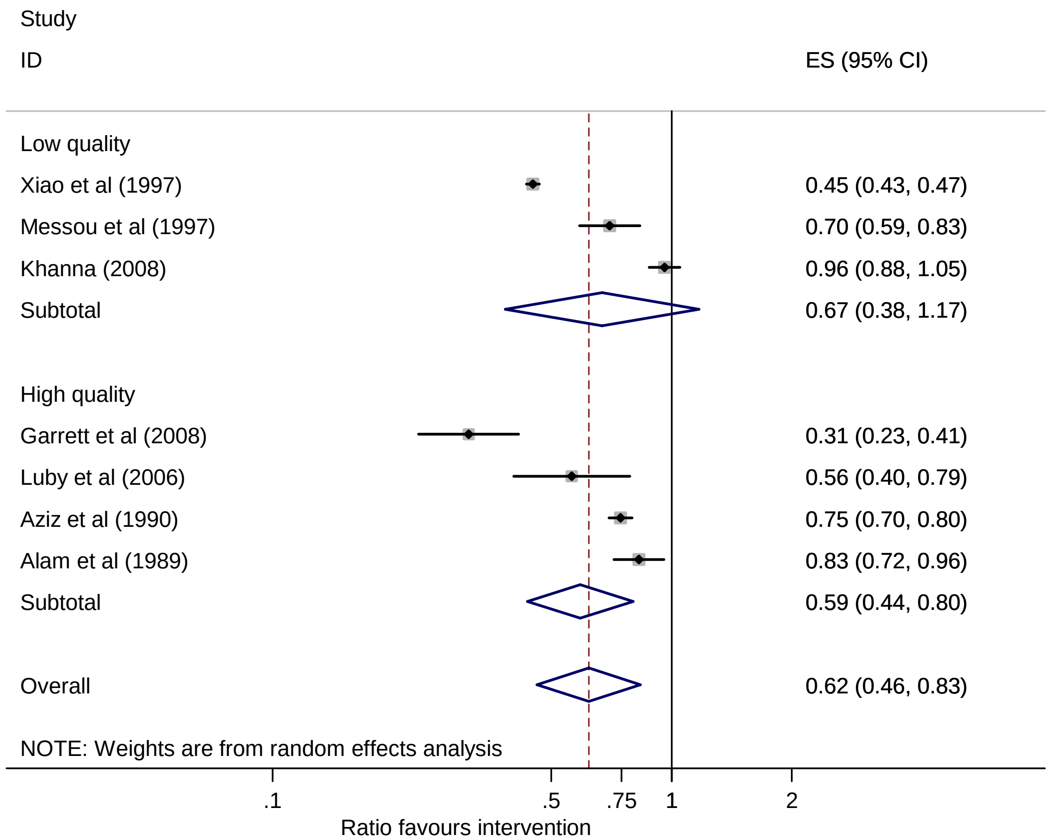


Figure 22 - Multiple interventions: study quality



Begg-Mazumdar: z = 0.60 p = 0.55

Figure 23 - Multiple interventions: sub-groups

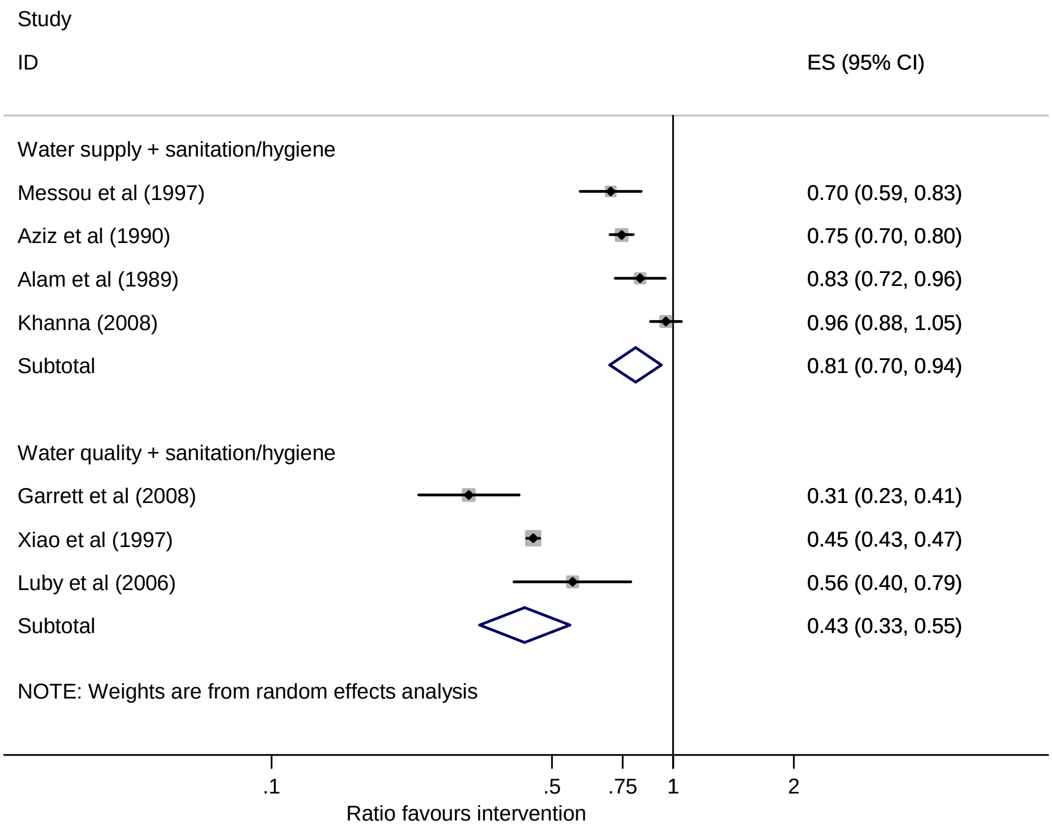
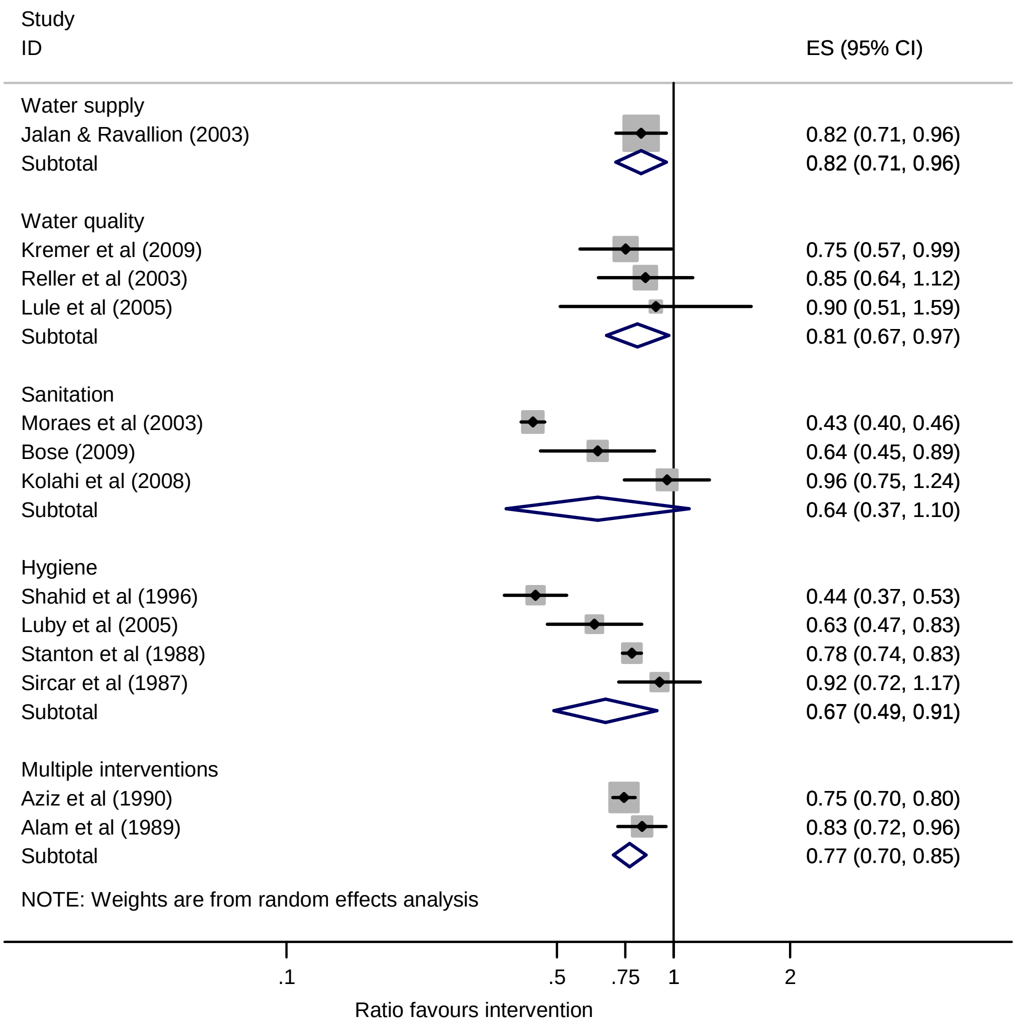


Figure 24 - High quality interventions conducted for 12 months or longer



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