HNP DISCUSSION PAPER

Water, Sanitation and Hygiene: Interventions and Diarrhoea

A Systematic Review and Meta-analysis

Lorna Fewtrell and John M. Colford, Jr.

July 2004

Water Supply & Sanitation Sector Board

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WATER, SANITATION AND HYGIENE: Interventions and Diarrhoea
A Systematic Review and Meta-analysis

Lorna Fewtrell[a] and John M. Colford, Jr.[b,c]

[a] Senior Research Fellow, Centre for Research into Environment and Health, University of Wales, Aberystwyth, UK
[b] Associate Professor of Epidemiology, School of Public Health, University of California, Berkeley, CA, USA
[c] Visiting Scientist, Water, Sanitation, and Health Programme, World Health Organization, Geneva, Switzerland

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Abstract: Many individual studies have reported results of interventions intended to reduce illness through improvements in drinking water, sanitation facilities and hygiene practices. This paper provides a formal systematic review and meta-analysis examining the evidence of the effectiveness of these interventions.

Through a comprehensive literature search and bibliographic review, 2120 titles published prior to June 26th, 2003 were screened, 336 papers were obtained for a more thorough examination, and 64 of these papers (representing 60 distinct studies) were identified which detailed water supply, water quality, sanitation, hygiene or multifactorial interventions and examined diarrhoea morbidity as a health outcome in non-outbreak conditions. Data were extracted from these papers and pooled through meta-analysis to provide summary estimates of the effectiveness of each type of intervention.

All interventions reduced diarrhoea morbidity, with pooled risk ratios ranging from 0.98 to 0.51 (where a risk ratio of 1.0 indicates no effect and lower risk ratios indicate stronger effects). The removal of poor quality studies from the analyses improved the strength of the intervention impact in most cases. The 95% confidence intervals (CIs) for the pooled risk ratios of various interventions overlapped, indicating their effects were not statistically significantly different from each other.

In developing countries, water quality interventions, specifically point-of-use treatment, reduced diarrhoeal illness levels. Water supply interventions reduced diarrhoea, but this effect was mainly seen with the provision of household connections and use of water without household storage. Hygiene interventions, especially those promoting hand-washing, were effective. Only limited data were available for sanitation interventions, but these suggested effectiveness in reducing diarrhoea. Multifactorial interventions consisting of water supply, sanitation and hygiene education acted to reduce diarrhoea but were not more effective than individual interventions.

Relatively few studies examined interventions in established market economies. Those that did supported the effectiveness of hygiene interventions, sanitation, and water supply.

Keywords: water, sanitation, hygiene, health, diarrhoea

Disclaimer: The findings, interpretations and conclusions expressed in the paper are entirely those of the authors, and do not represent the views of the World Bank, its Executive Directors, or the countries they represent.

Correspondence Details: Lorna Fewtrell, Centre for Research into Environment and Health (CREH), University of Wales, 5 Quakers Coppice, Crewe Gates Farm, Crewe, Cheshire, CW1 6FA United Kingdom; Tel: 44 1270 250583; Fax: 44 1270 589761; Email: lorna@creh.demon.co.uk
John M. Colford, Jr., Department of Epidemiology, University of California, Berkeley, 140 Warren Hall, MC 7360, Berkeley, CA 94720; Tel: (510) 642-3997; Fax: (413) 228-5931; Email: jcolford@socrates.berkeley.edu

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FOREWORD

Increasingly, we realize that success in reaching the Millennium Development Goals (MDGs) will depend on our ability to work cooperatively within and across sectors. This is especially clear in the case of the MDGs related to child mortality and water supply and sanitation services. Diarrheal disease related to inadequate water supply and sanitation is among the leading causes of death among young children in the developing world, and stemming the tide means that we must look critically at what does, and does not, work in decreasing morbidity and mortality.

This comprehensive review represents the first of its kind in more than a decade. It looks critically at all of the available published data on the effectiveness of interventions in water supply, sanitation, and hygiene promotion, and synthesizes the findings in a meta-analytic framework that allows meaningful comparisons to be made.

The results have some important lessons for us. First and foremost, the review confirmed that all the interventions that were reviewed - whether related to water supply, water quality, sanitation, or hygiene promotion - are effective in reducing diarrheal diseases. And interestingly, hygiene promotion and water treatment in the home are among the most effective interventions. These latter programs depend upon the expertise of health education experts for consumer education and motivation, yet will be most effective when basic water and sanitation needs are met. Thus, these findings perfectly illustrate the need for health and water sector experts to work closely together.

Another result will be surprising to many. This is that multiple interventions - those that combine water supply, sanitation, and hygiene promotion into a single package - have not been shown to be more effective than individual interventions. This suggests that we need further research into how and why the components of such interventions do or do not work to decrease disease risk, so that we may ultimately design evidence-based projects that will maximize effectiveness.

As part of the effort to increase effectiveness, we are committed to fostering joint sector work to increase knowledge, develop tools, and support collaborative intervention programs. This study represents one important knowledge tool along the path to greater effectiveness. We encourage managers and operations staff in the health and water sectors to incorporate the lessons in this report into their work.

Jacques Baudouy
Sector Director
Health, Nutrition, and Population Team

Jamal Saghir
Director
Energy, Water, and Sanitation Team

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EXECUTIVE SUMMARY

Many individual studies have reported results of interventions intended to reduce illness through improvements in drinking water, sanitation facilities and hygiene practices. There has, however, been no formal systematic review and meta-analysis examining the evidence of the effectiveness of these interventions.

Through a comprehensive literature search using key words and review bibliographies, 2120 titles published prior to June 26th, 2003 and their available abstracts were screened. As a result of this, 336 papers were obtained for a more thorough examination, and 64 of these papers (which due to multiple publications represented 60 distinct studies) were identified which detailed water, sanitation and/or hygiene interventions examining diarrhoea morbidity as a health outcome in non-outbreak conditions. Data were extracted from these papers and, where possible, pooled through meta-analysis to provide summary estimates of the effectiveness of each type of intervention.

Studies from all regions of the world were identified. The South East Asia region was the most frequently identified site for the conduct of intervention studies; Europe was the least frequently identified. The most commonly performed intervention addressed water quality.

The principal results from the meta-analyses are shown in the Table and Figure below. More detailed results are given throughout the text. The findings lead to the following observations.

In established market economies the published evidence suggests that:

- Hygiene interventions, such as hand-washing and hygiene education in child care centres significantly contribute to reducing diarrhoeal disease (pooled risk ratio estimate of 0.582; 95% confidence interval [CI] 0.476 – 0.712).

- Only one study was found to examine the impact of improved sanitation on health at the household level. (Wider impacts, such as the effect of waste water disposal on drinking water, recreational water and shellfish growing water were beyond the scope of this review.)

- Two studies suggested that water supply interventions at household level are effective in reducing diarrhoeal illness. Clearly, however, this intervention is not widely applicable in developed countries as household connection is widespread.

- In non-outbreak conditions, the weight of evidence does not suggest that water quality interventions effectively reduce levels of diarrhoeal illness in the study population. These interventions, however, represented additional treatment to water supplies that were already of reasonable quality, in populations where diarrhoeal prevalence was low.

In developing countries the published evidence suggests that:

- Water quality interventions, specifically point-of-use treatment, reduced diarrhoeal illness levels. This evidence is consistent with the idea that water quality interventions may be more important than previously thought (previous studies have suggested that such interventions are only effective where good sanitary conditions already exist).

Meta-analysis results summary

Intervention	Number of studies	Pooled estimate	95% CI
Established Market Economies			
Hygiene	4	0.582	0.476 – 0.712*
Excluding poor quality studies	3	0.640	0.455 – 0.899*
Sanitation	1	0.51†	0.32 – 0.83*
Water supply	2	0.509	0.471 – 0.551*
Water quality	5	0.984	0.878 – 1.103
Point of use	4	0.967	0.851 – 1.097
Developing countries			
Multiple	5	0.670	0.592 – 0.757*
Hygiene	11	0.633	0.524 – 0.765
Excluding poor quality studies	8	0.547	0.400 – 0.749
Hand-washing	5	0.556	0.334 – 0.925
Education	6	0.722	0.628 – 0.831
Sanitation	2	0.678	0.529 – 0.868*
Water supply	6	0.749	0.618 – 0.907*
HH connection and diarrhoea	2	0.904	0.425 – 1.925
Standpipe and diarrhoea	3	0.935	0.648 – 1.348
Water quality	15	0.687	0.534 – 0.885*
Source treatment only	3	0.891	0.418 – 1.899
HH treatment only	12	0.645	0.475 – 0.875*
HH treatment – excluding poor quality studies	8	0.607	0.457 – 0.807*

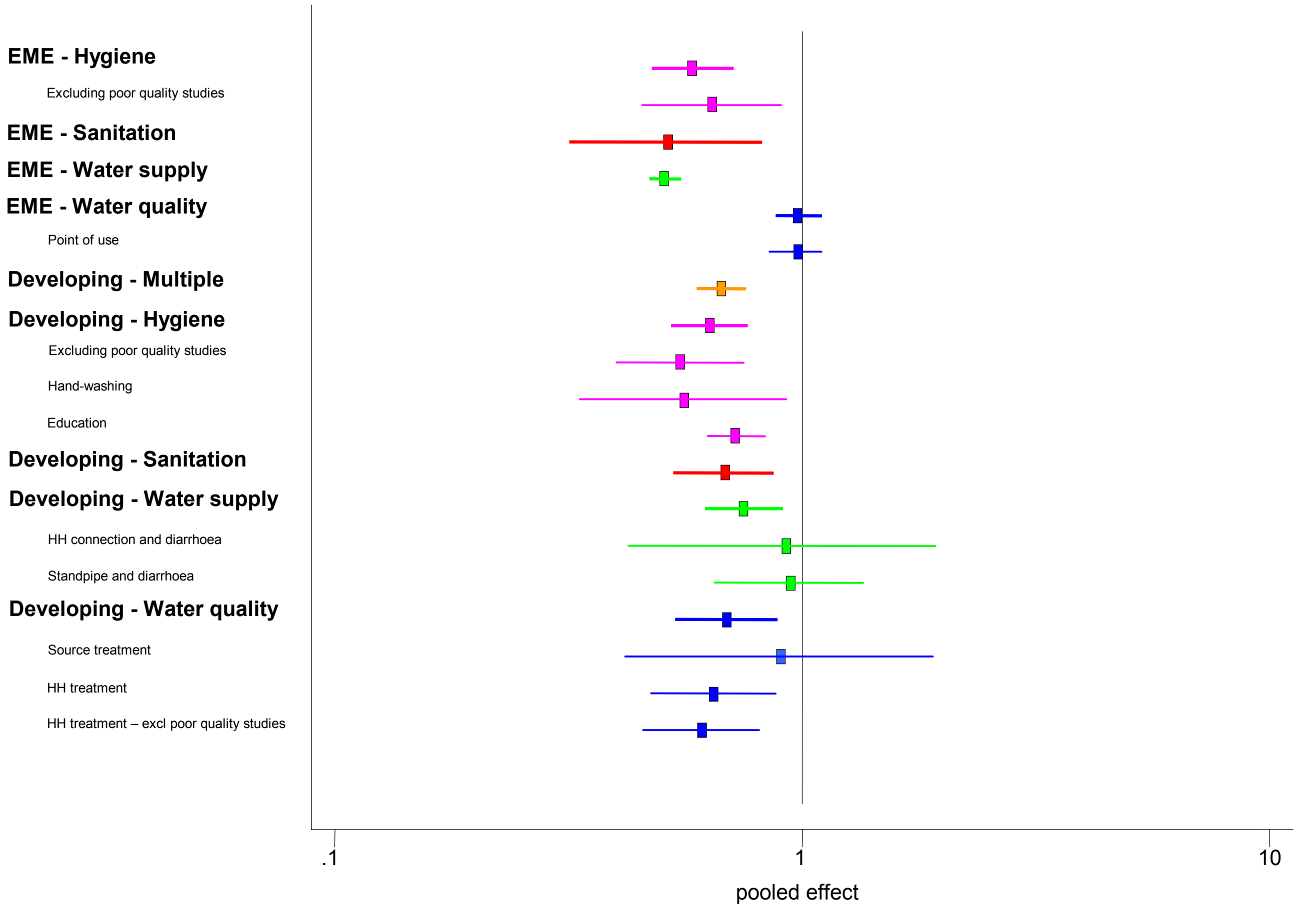
HH – household * significant at $p < 0.05$
† this does not represent the results of a meta-analysis

- Water supply interventions reduced diarrhoeal illness levels, but this effect was mainly seen with the provision of household connection and use of the water without household storage. Water source improvements also decrease the level of diarrhoeal illness (pooled estimate 0.935; 95% CI 0.648 – 1.348), but this was not statistically significant. It is currently not possible to distinguish between health benefits resulting from water quality or water quantity. Indeed, in many cases water consumption levels are not documented and although water access is improved it is not clear that this translates to an increased use of water.

- Hygiene interventions are effective in reducing diarrhoeal illness levels, and have mainly centred on hand-washing and other ‘good’ behaviours in the home. Many of the hygiene intervention studies have been conducted in areas which already have improved drinking water and sanitation, although these interventions are also effective in areas with poorer water and/or sanitation. Focussed hand-washing interventions may be more effective than hygiene education measures (pooled estimates of 0.556 and 0.722, respectively).

- There were four studies that examined sanitation interventions. Examination of the existing data suggests that sanitation is effective in reducing diarrhoeal illness levels, the meta-analysis, however, was based on the results of only two of the studies, one of which was considered to be of poor quality. It is suggested, therefore, that further research is needed in this area.

Forest plot of meta-analysis results



- Multiple interventions consisting of water supply, sanitation provision and hygiene education act to reduce diarrhoeal illness levels (pooled estimate of 0.670; 95% CI 0.592 – 0.757) but were not more effective than individual interventions. None of these interventions assessed the water quality at the point of consumption and it is, therefore, possible that their effectiveness could be improved by ensuring water safety in the household.

The removal from the analyses of studies judged to be poor quality by criteria defined prior to analysis (specifically those with inadequate or inadequately described control groups; no measurement of confounders; those without a specific definition of diarrhoea; or a health indicator recall period of greater than two weeks), improved the strength of the intervention impact in most cases.

This review suggests that there is a need for guidance about the standard design and reporting of future water, sanitation and health interventions.

Given the similarities in the impacts on health of the different interventions, there would seem to be little to choose between them. Improved water supplies, adequate sanitation facilities and hygienic behaviour are all important and intertwined elements. The main thrust of future research should not be ‘how do we choose between different interventions?’ but ‘which package of specific measures combining all the main intervention areas will maximise the health benefits to each individual community?’

SECTION 1. INTRODUCTION

Diarrhoeal disease is one of the leading causes of morbidity and mortality in developing countries, especially among children under the age of five (Kosak *et al*., 2003; Prüss *et al*., 2002). In the developed world, too, it would appear from estimates of the Global Burden of Disease that complacency should be avoided, with 139,000 Disability Adjusted Life Years (DALYs) attributed to water, sanitation and hygiene in established market economies (Prüss *et al*., 2002).

Since the seminal reviews of Steve Esrey and colleagues in 1985, 1986 and 1991, additional literature has been published on various water, hygiene and sanitation-related interventions aimed at population health improvements. The publication of the original reviews (Esrey *et al*., 1985, 1991; Esrey and Habicht, 1986), together with a paper by Blum and Feachem (1983), has led to a better understanding of methodological issues in this area. The Esrey reviews examined studies that quantified differences in health outcomes between groups that had different water and/or sanitation conditions. This current paper focuses on literature documenting interventions (planned or occurring as natural experiments) directed at water quality, water supply, hygiene and sanitation and their impact on diarrhoeal disease in non-outbreak conditions. This report presents a systematic review and, where appropriate, meta-analyses of related groups of interventions as part of an attempt to critically evaluate the evidence of the effectiveness of these interventions. The report also suggests possible directions for future research.

SECTION 2. BACKGROUND

The important role of sanitation and safe water in maintaining health has been recognised for centuries, with the 'sanitary revolution' in the 19^{th} and early 20^{th} century considered to play a vital role in reducing illness and death from infectious diseases in industrialised countries (McKeown and Record, 1962; Preston and van de Walle, 1978).

In 1977, the UN Water Conference in Mar del Plata (Argentina) recommended that the 1980s should be proclaimed the 'International Drinking Water Supply and Sanitation Decade' (IDWSSD). The aim of the decade was for all countries to achieve 100% coverage in water supply and sanitation by 1990. Although generally the provision of services did increase, in many countries the increase in sanitation facilities could not keep pace with the rising population, meaning that the number of people unserved continued to rise (DFID, 1998).

The current situation with regard to water supply and sanitation provision is shown in Table 1. It can be seen that there are notable differences between the urban and rural situations in many cases.

Table 1: Regional coverage (%) of improved* water supply and sanitation facilities in 2000[a]

	Urban		Rural	
Region	**% water supply**	**% sanitation**	**% water supply**	**% sanitation**
Africa	85	85	47	45
Asia	93	78	74	31
Latin America and the Caribbean	93	87	62	49
Oceania	98	99	63	81
Europe	100	98	87	74
North America	100	100	100	100

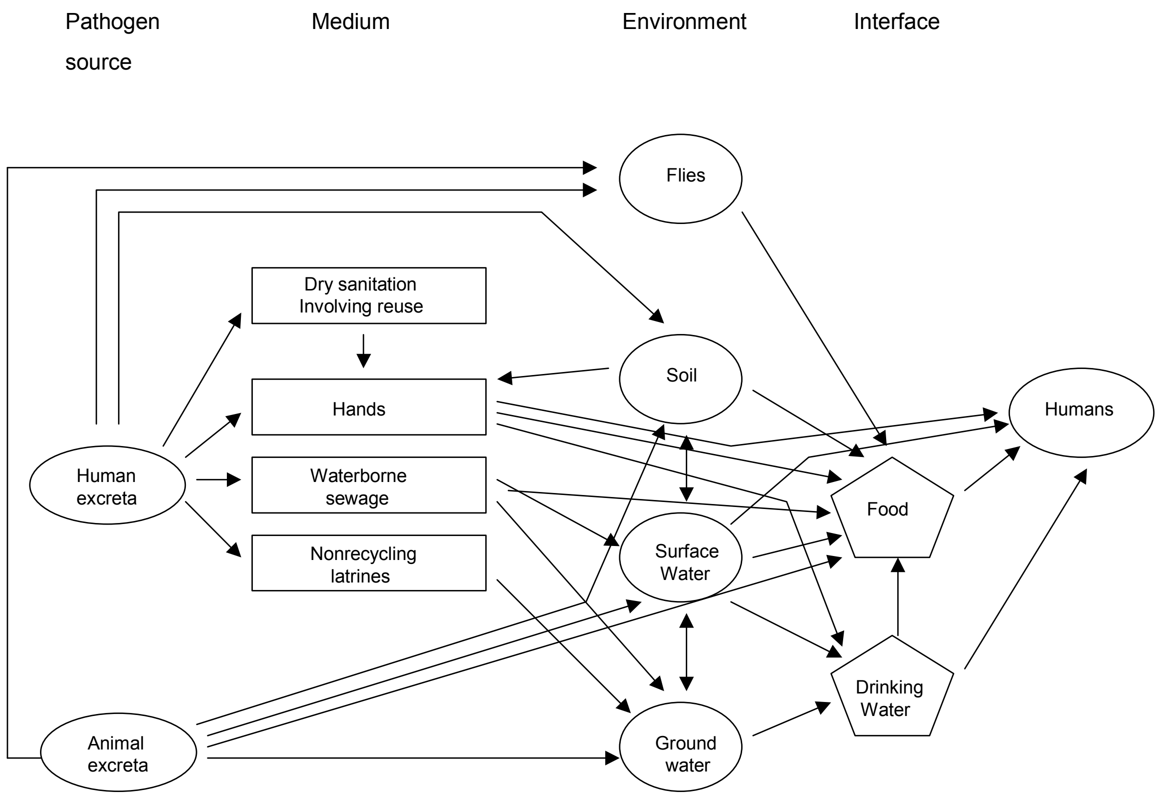
[a] Adapted from WHO/UNICEF (2000)
* Defined in Table 4

The various transmission routes by which faecal-oral pathogens can cause infection and illness (Figure 1) have been described previously (Curtis *et al*., 2003; Prüss *et al*., 2002; Curtis and Kanki, 1998; Kolsky and Blumenthal, 1995). These are complex and often inter-related.

A number of studies assessing the health impact of various water, sanitation and hygiene conditions had been conducted prior to the 1980s and the start of the IDWSSD. These included the impact of planned interventions as well as observational studies, describing the health of groups with different water and sanitation provision. These were reviewed for their methodological flaws (Blum and Feachem, 1983) and also their overall impact (Esrey *et al*., 1985; Esrey and Habicht, 1986). In 1991, Esrey *et al*. updated their review and included a wider range of health impacts and health indicators.

Blum and Feachem (1983) noted a number of methodological flaws in identified water, sanitation and hygiene studies, namely: lack of adequate control, one to one comparison, inadequate control for confounders, extended health indicator recall, lack of health indicator definition, failure to analyse by age, failure to record usage of the intervention and lack of consideration of seasonal impact on the health indicator. Esrey and colleagues also noted a number of methodological flaws (outlined in Esrey and Habicht, 1986). They analysed all of the identified studies, but also conducted a separate analysis considering only those judged to be of better quality (Esrey *et al*., 1991). The percentage reductions in diarrhoea expected to result from improvements to water supply, excreta disposal or hygiene behaviours are outlined in Table 2 (Esrey *et al*., 1991). This Table includes those studies reviewed in the earlier papers (Esrey *et al*., 1985; Esrey and Habicht, 1986).

Figure 1: Transmission pathways of faecal-oral diseases[a]



[a] Adapted from Prüss *et al*. (2002)

Table 2: Expected reduction in diarrhoeal disease morbidity from improvements in one or more components of water and sanitation[a]

		All studies		Rigorous studies	
	Intervention	**N**	**% reduction in diarrhoeal disease**	**N**	**% reduction in diarrhoeal disease**
1	Water and sanitation	7[b]/11[c]	20	2[b]/3[c]	30
2	Sanitation	11/30	22	5/18	36
3	Water quality and quantity	22/43	16	2/22	17
4	Water quality	7/16	17	4/7	15
5	Water quantity	7/15	27	5/10	20
6	Hygiene	6/6	33	6/6	33

[a] Adapted from Esrey *et al*. (1991)
[b] The number of studies for which morbidity reduction calculations could be made
[c] The total number of studies that related the type of facility to diarrhoeal morbidity, nutrition and mortality studies.

It can be seen from Table 2 that all the interventions reduced diarrhoea levels, with the effect varying between 15 to 36%, depending upon the intervention and the perceived quality of the study.

SECTION 3. OBJECTIVE

The objective of this review is to update the previous reviews conducted in this area, with a view to informing interested parties on the relative effectiveness of possible interventions addressing water, sanitation and hygiene.

SECTION 4. METHODOLOGY

4.1 SEARCH STRATEGY

The PubMed database searches were made with key word searches pairing aspects of water, sanitation and hygiene ('sanitation', 'water quality', 'water quantity' and 'hygiene') against 'diarrhoea' (which was unaffected by the USA or UK spelling). An additional series of searches paired 'sanitation', 'drinking-water', and 'hygiene' against 'intervention'. The searches were limited to papers relating to humans published between January 1, 1986 and June 26, 2003 (when the search was conducted). The Esrey reviews were used to identify studies conducted prior to 1985. Similar searches were conducted using Embase, Pascal Biomed, LILACs and the Cochrane Library, again limited to papers relating to humans published before June 26, 2003.

The abstracts (where available) were examined from each of the searches and papers which appeared to be relevant were obtained for review. As references were obtained they were examined for further possible relevant studies. No restrictions were put on study location, design or language of publication.

4.2 INITIAL SELECTION CRITERIA

There were two key selection criteria for articles:

- The article reported diarrhoea morbidity as the health outcome, measured under endemic (i.e. non-outbreak) conditions (no specific definition of diarrhoea was required);
- The article reported specific water, sanitation and/or hygiene intervention(s), or some combination of such interventions.

These criteria led to the exclusion of studies that solely examined water quality measures as an outcome (e.g. Quick *et al*., 1996), studies reporting nutritional or other health measures (e.g. Abate *et al*., 2000) without reporting diarrhoea frequency following an intervention, studies that quantified differences in health outcomes between groups that had different water, sanitation and/or hygiene conditions (e.g. Velema *et al*., 1997) and studies that looked at health differences in groups with pre-existing interventions (e.g. Young and Briscoe, 1987).

Data from studies meeting these selection criteria were extracted, tabulated and, where appropriate, pooled using meta-analysis. Where multiple papers reported the same study, details were derived from both papers, but the results only considered once (where there was a choice of results the latest publication was used).

4.2.1 Interventions

Water, sanitation and hygiene interventions were not pre-specified. The following classification was used:

- *Hygiene interventions* were those that included hygiene and health education and the encouragement of specific behaviours, such as hand-washing. Hygiene interventions could include measures as diverse as keeping animals out of the kitchen to advice on the correct disposal of human faeces.
- *Sanitation interventions* were those which provided some means of excreta disposal, usually latrines (either public or household).
- *Water supply interventions* included the provision of a new or improved water supply and/or improved distribution (such as the installation of a hand pump or household connection). This could be at the public or household level.

- *Water quality interventions* were related to the provision of water treatment for the removal of microbial contaminants, either at the source or at the household level.
- *Multiple interventions* were those which introduced water, sanitation and hygiene (or health education) elements to the study population.

4.3 DATA EXTRACTION

Data were extracted, where possible, from each reference selected for review inclusion. Data included the following:

- Study location (country and urban/rural population);
- Study type;
- Study length;
- Study period;
- Sample size;
- Data collection method;
- Participant age band;
- Confounders examined;
- Illness definition;
- Frequency of illness observation;
- Recall period;
- Type and level of water supply (prior to intervention);
- Type and level of sanitation provision (prior to intervention);
- Water source;
- Intervention;
- Relative risk values and confidence bounds.

Where relative risk values (or similar) were not reported, data were abstracted (where possible) to allow the calculation of a relative risk and confidence interval. Where there was a choice between adjusted and unadjusted measures, the most adjusted estimate was always chosen. In all cases the relative risk values (or other summary measure reported) and the 95% confidence interval are expressed such that a relative risk value of less than unity means that the intervention has reduced the frequency of diarrhoea in comparison to the control group.

4.3.1 Pre-intervention water and sanitation situation

The descriptions of the pre-intervention water supply and the pre-intervention sanitation provision for each study (from developing countries) were combined to provide a single measure for comparison between different studies (as outlined in Table 3) in sub-group meta-analysis. Based on data provided by WHO/UNICEF (2000), a series of mutually exclusive exposure scenarios have been described (Prüss *et al*., 2002) which relate to improved and basic sanitation and drinking water and also the likely environmental faecal-oral pathogen load.

Table 3: Water and sanitation exposure scenarios for developing countries

Level	Description	Environmental faecal-oral pathogen load
F	Basic water supply and basic sanitation.	Very high
Eb*	Improved water supply but basic sanitation.	Very high
Ea*	Basic water supply and improved sanitation.	High
D	Improved water supply and improved sanitation.	High

[a] Adapted from Prüss *et al*. (2002)

In order to ascribe one of these scenarios as the baseline situation for each study, a number of techniques was employed. Using the definitions of improved and unimproved water supply and sanitation (Table 4) provided in WHO/UNICEF (2000), these were compared with data provided by the individual studies. Where limited information was available in terms of the baseline conditions, the intervention was examined to determine if it was possible to establish what the pre-intervention conditions were most likely to have been.

Table 4: Definitions of improved and basic water supply and sanitation[a]

Status	Water supply	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	

[a] Adapted from WHO/UNICEF (2000)

Where no data were available, the scenario applying to the majority of the population (according to WHO/UNICEF, 2000) in each relevant country was assumed to apply (see Appendix 1), with the exception that no such assumption was made for studies published before 1985 because the figures are unlikely to be appropriate for earlier studies. This was done to examine the possible impact of the study starting point on the subsequent effect of the intervention.

4.4 QUALITY ISSUES

In brief, the quality of each study was examined by considering the following:

- **Adequate control/ comparison group**. The importance of an adequate control group is outlined by Blum and Feachem (1983), and principally helps to ensure that changes in health outcome can be attributed to the intervention and not to other factors.
- **Control for confounders**. A confounder is a variable that is associated with the exposure and, independent of that exposure, is a risk factor for the disease. For example, if two groups being compared had markedly different age distributions and age was itself associated with diarrhoea, an estimate of the relative frequency of diarrhoea in the two groups is confounded by age. Properly conducted randomization, in a sufficiently large study, should minimise the effect of confounding by equally balancing the distribution of confounding factors. Where randomization is not possible, investigators may have selected groups so that they are comparable (in terms of confounding variables) in a process called matching; alternatively, suspected confounding variables can be measured and controlled (adjusted) for during data analysis (Blum and Feachem, 1983). The possible confounding factors were recorded from the reviewed papers; these are outlined in Appendix 2. No attempts were made to assess the most appropriate confounders needing control (nor could this be done without access to the primary data from each study).

- **Randomization**. The process by which participants or groups involved are randomly allocated to different treatment (or control) arms of the study. As discussed above, when possible this is the best method for controlling confounding.
- **Health indicator definition**. It is important that the chosen health indicator is defined, especially where reliance is placed on self-reported or mother-reported data. The most commonly used definition was 'three or more loose bowel movements in 24 hours'. As the health indicator definition was found to vary, study results were divided into three categories, those with no definition (which included 'mother's perception'), those with a standard definition (which was considered to be '2 or more', '3 or more' or '4 or more' loose bowel movements in a 24 hour period) and those with a non-standard definition (such as highly credible gastrointestinal illness [HCGI][1], severe diarrhoea, dysentery or cholera).
- **Health indicator recall**. Ideally, the maximum recall should be limited to two weeks. Blum and Feachem (1983) considered recall periods exceeding 48 hours to be a methodological problem, however, Black (1984) suggested that recall periods of up to two weeks provide illness data with adequate accuracy.
- **Analysis by age** (if a large age range considered). Susceptibility to infection and illness is known to vary by age. Many studies examine young children (generally under the age of five years) as this is typically the group that suffers the highest incidence of diarrhoea. Where studies examined diarrhoea in all age groups it is important to analyse the results by age as this may reveal different associations between the health outcome and the intervention.
- **Intervention/compliance assessed**. Although a group may receive an intervention, receiving it is not synonymous with using it, whether it is a latrine, new water supply or hygiene education. Any efforts reported by individual study authors to assess compliance or use of the intervention were noted. These ranged from study participant-reported information to extensive observation by researchers and/or assessment of environmental microbiological contamination, although clearly some are likely to be better at ascertaining the true situation than others.
- **Blinding**. Bias can be limited by blinding subjects and researchers to the specific intervention received. For most water, sanitation and hygiene interventions this is nearly impossible in terms of the subjects and often the researchers on the ground (although there are exceptions where blinding has successfully been carried out – see Colford *et al*., 2002; Hellard *et al*., 2001). In most cases, however, it should be possible to blind those performing the analysis. Blinding of any of the groups (subjects or researchers) has been recorded.
- **Placebo intervention**. Observation and measurement of individuals can affect their behaviours, leading to an impact that is not related to the intervention (known as the Hawthorne effect – see Grufferman, 1999). A placebo intervention can help to minimise this by equalising the contact time and type of contact between the control and intervention groups.
- **Adequate study size**. Where no statistically significant effect is seen between the intervention and non-intervention groups, it is important to ask whether this is due to an inability to detect a meaningful effect due to limited sample size. This was addressed in the process of the meta-analysis, which weighted studies partly based on sample sizes (inverse variance weighting).

No study was excluded from the systematic review or meta-analysis on the presence or absence of the above criteria, but quality issues were examined in the meta-analysis as a possible source of heterogeneity accounting for differences in the observed study results. Poor quality studies, for the purposes of this review, were considered to be those that had any of the following flaws: inadequate or inadequately described control groups; no clear measurement of possible confounders (see Appendix 2);

[1] HCGI is generally defined as symptoms involving at least one of the following combinations: a) vomiting and liquid diarrhoea with or without confinement to bed, consultation with a doctor or hospitalisation, or b) nausea or soft diarrhoea combined with abdominal cramps with or without absence from school/work, confinement to bed, consultation with a doctor or hospitalization (Payment *et al*., 1991).

undefined health indicator; or a health indicator recall period of greater than two weeks. Quality issues for each study are summarised in tables in the Results section. Those considered to result in the study being of poor quality appear as shaded entries.

4.5 META-ANALYSIS

A introduction to meta-analysis is given in Appendix 3 (based on Pai *et al*., 2004). (Other good introductions are provided by LaValley, 1997 and Egger *et al.*, 2001). Relative risk estimates from the selected studies were pooled using STATA software (STATA Corporation, College Station, TX, USA, version 8). STATA commands for meta-analysis are not an integral part of the original software but are additional, user-written, add-on programs that can be freely downloaded from the www.stata.com website and added to the STATA 'ado' file list.

Studies were stratified, prior to data analysis, into groups of related interventions. Studies were divided according the level of country development (i.e. established market economies and developing countries) and then analyzed by intervention type (multiple interventions, hygiene, sanitation, water supply and water quality). For the main intervention analysis only a single result from each study was used. Thus, for example, where multiple age group analyses were given in the original paper only a combined estimate was used, or where multiple health outcomes were given, these were either combined, or (if that was not possible or was inappropriate) the standard definition of diarrhoea was used (Section 4.4).

Where sufficient studies were available within each intervention they were further examined in sub-group analyses defined by:

- health outcome ('standard' diarrhoea definition versus non standard definition(s));
- age groups;
- pre-intervention water and sanitation situation;
- design (intervention versus other – see Appendix 4);
- location (urban versus rural); and
- study quality

Forest plots and pooled estimates of risk were generated. Both fixed and random effects estimates were prepared for all analyses. Where evidence suggesting the presence of heterogeneity was strong ($p < 0.20$), the random effects model was used, otherwise the fixed effects model was used. Publication bias was explored through the use of Begg's test (results with $p < 0.2$ was defined, *a priori*, to indicate the possible presence of publication bias).

SECTION 5. RESULTS

A total of 2120 papers were identified as potentially relevant as a result of the database keyword searches (PubMed, Embase, Pascal Biomed, LILACS and Cochrane Library). Table 5 shows the number of references identified through the PubMed search. Few additional papers were identified from Embase and no additional papers were identified from the other databases.

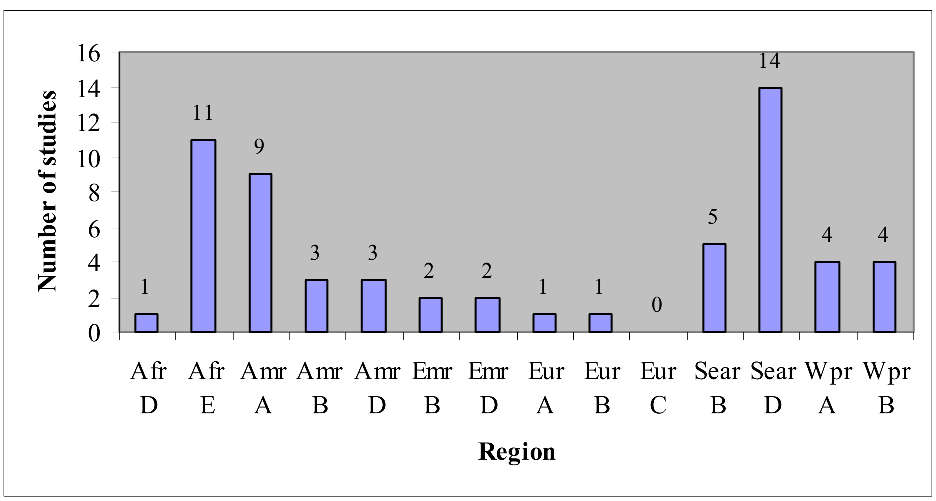
Table 5: PubMed key word search
(references relating to humans published between January 01, 1985 and June 26, 2003)

Key word search	Initial number of references
Diarrhoea AND sanitation	636
Diarrhoea AND water quality	128
Diarrhoea AND water quantity	26
Diarrhoea AND hygiene	423
Drinking water AND intervention	111
Sanitation AND intervention	263
Hygiene AND intervention	459

The majority of these references proved, after review of titles and, where necessary, abstracts, not to be relevant and were excluded (e.g. 'Burden of chronic severe anaemia in obstetric patients in rural north India'). A total of 336 papers were obtained for further examination, either as a result of the database or review bibliography searches. A total of 64 papers were retained for full review. As a result of multiple publication, the 64 papers outlined 60 different studies and 62 interventions (two studies detailed the results of two interventions separately).

The studies encompass most regions of the world (Figure 2), deriving from 28 countries, although, not surprisingly, there is a preponderance of studies from developing countries.

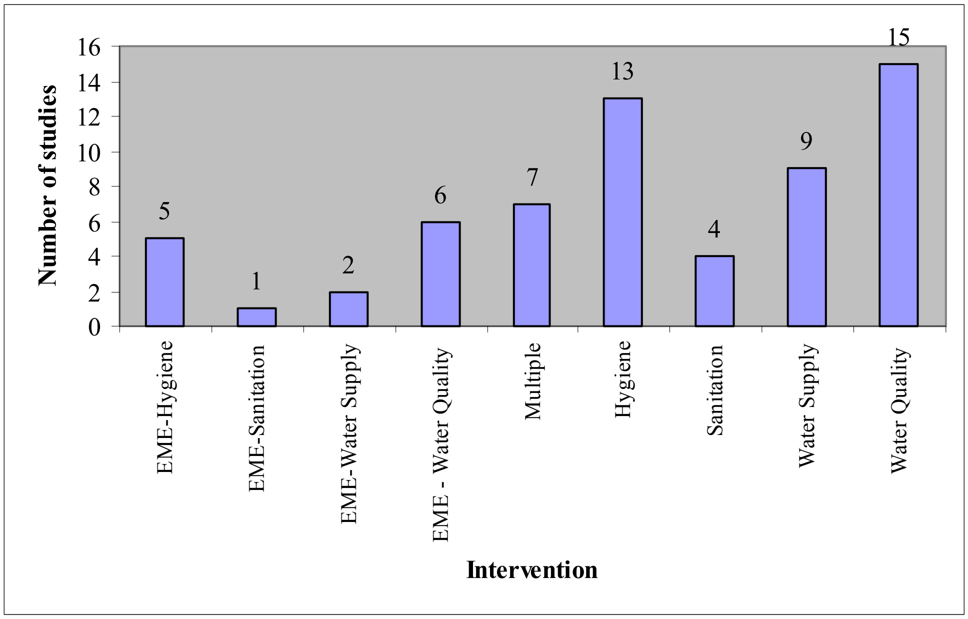
Figure 2: Graph of selected studies by region*



* Regions based on WHO Comparative Risk Assessment regions (see Appendix 5 for more details)

These have been divided according to the intervention employed in each study, illustrated in Figure 3.

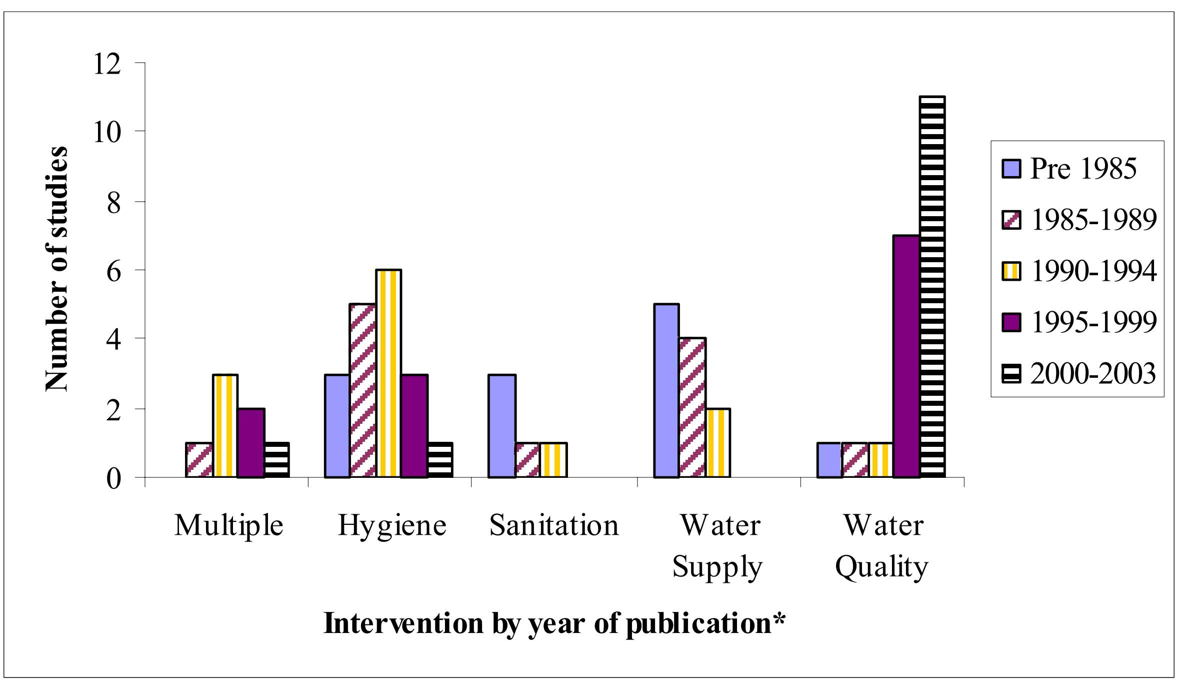
Figure 3: Graph of selected studies by intervention



EME – Established Market Economies

It can be seen from Figure 4 that the main area of interest in recent years has been water quality interventions. These interventions have been mainly introduced at the point of use. In contrast to the increase in water quality studies, projects examining other interventions seem to be declining in popularity.

Figure 4: Intervention by the year of study publication



* If studies were reported by more than one paper, only the earliest is shown

5.1 ESTABLISHED MARKET ECONOMIES (EME) STUDIES

Fourteen of the studies identified were conducted in developed countries (defined here by being 'A' regions, i.e. Amr A, Eur A and Wpr A, which correspond to 'established market economies' – see Appendix 5), namely the United States of America, Canada, Australia and the United Kingdom. Five of the studies examined hygiene interventions, one examined a sanitation intervention, two examined water supply interventions and six examined water quality interventions.

5.1.1 Hygiene interventions

The five hygiene intervention studies were all undertaken in child care centres, and are summarised in Table 6. With the exception of the study by Bartlett *et al*. (1988), each study had a summary risk measure of less than 1, suggesting that the intervention reduced the levels of diarrhoea in the study population. In two cases (Black *et al*., 1981; Roberts *et al*., 2000) the results were statistically significant. Details of the specific interventions for each study are outlined in Appendix 6; in all cases, however, hand-washing was a major part of the intervention. In most cases the hand-washing included both children and caregivers (it is not clear from the paper by Carabin *et al*., 1999 whether caregivers were included, or whether they were simply asked to wash the children's hands).

Table 6: Studies conducted in EME countries examining hygiene interventions

Ref	Intervention	Design	Country	Region	Location	Health outcome	Age group	Measure	Result	95% CI
Black *et al.*, 1981	Hand-washing with soap	Interv.	USA	Amr A	Suburban (child care centres)	Diarrhoea	0 – 36 months	RR*	**0.52**	**0.36-0.76**
							6 – 17 months	RR*	0.45	0.27-0.75
							18 – 19 months	RR*	0.66	0.38-1.17
Bartlett *et al*., 1988	Hygiene education	Interv.	USA	Amr A	Urban (child care centres)	Diarrhoea	0 – 35 months	RR*	1.09	Information not available
Kotch *et al*., 1994	Hand-washing + hygiene education	Interv.	USA	Amr A	Urban (child care centres)	Diarrhoea	0 – 36 months	RR*	**0.84**	**0.50-2.08**
Carabin *et al*., 1999	Hygiene education	Interv.	Canada	Amr A	Unstated (child care centres)	Diarrhoea	18 – 36 months	IRR	**0.77**	**0.51-1.18**
Roberts *et al*., 2000	Hand-washing	Interv.	Australia	Wpr A	Urban (child care centres)	Diarrhoea	0 – 36 months	RR	**0.5**	**0.36-0.68**
							0 – 24 months	RR	0.9	0.67-1.19
							> 24 months	RR	0.48	0.29-0.78

* - Calculated Interv. – Intervention IRR – Incidence Rate Ratio RR – Relative Risk
Results in bold are those used in the overall meta-analysis

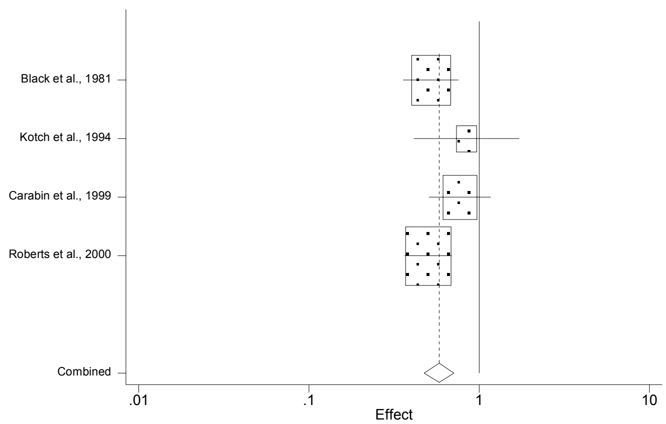
Quality issues are shown in Table 7. It can be seen from this Table that the more recent studies are of good quality (using the pre-defined criteria outlined in Section 4.4); highlighting indicates flags for poor quality. Although Carabin *et al*. (1999) did not analyse by age, they only examined children aged between 18 and 36 months.

Table 7: Quality of EME country hygiene intervention studies

Ref	Adequate control group	Measurement of confounders	Randomization	Health indicator definition	Health indicator recall	Analysis by age	Intervention /compliance assessed	Blinding	Placebo
Black *et al.*, 1981	Yes	Not clear	Yes	Non-standard	Daily	Yes	Yes	No	No
Bartlett *et al.*, 1988	Yes	Not clear	Yes	Non-standard	Daily or twice weekly	NA	No	Some	Some
Kotch *et al.*, 1994	Yes	Yes	Yes	Non-standard	2 weeks	Yes	Yes	No	No
Carabin *et al.*, 1999	Yes	Yes	Yes	Non-standard	Daily	NA	Yes	Not clear	No
Roberts *et al.*, 2000	Yes	Yes	Yes	Standard	2 weeks	Yes	Yes	Some	No

The results in bold shown in Table 6 (and similar tables throughout this report) indicate the risk measures used in the meta-analysis. The results of the meta-analysis (based on the four studies which had useable data) shown in Figure 5 suggest that overall the intervention reduces the level of diarrhoeal illness, with no evidence of publication bias. The bolding of the fixed effects result indicates the preferred summary measure (based on the test for heterogeneity).

Figure 5: Fixed effects forest plot of hygiene intervention study results



Random 0.592 (0.467 – 0.752)
Fixed 0.582 (0.476 – 0.712)
Heterogeneity p = 0.266
Begg's test p = 0.308

It is important to note, however, that one of the studies, which specifically examined the 'Hawthorne effect', where subjects alter their behaviour when they are being observed, (Carabin *et al*., 1999) found an equal effect for monitoring alone. The level of faecal contamination on the children's and educator's hands was also found to decrease markedly in both the intervention group and the monitoring only group. Bartlett *et al*. (1988), also found that continuous surveillance was associated with a significant decrease in diarrhoea (although it is not clear whether this represents a true decrease, or a change in perception (over time) of what constitutes diarrhoea).

Re-analysing the results, excluding the study considered to be of poor quality, suggests a slightly weaker effect, although the confidence intervals overlap (random effects model pooled estimate = 0.640; 95% CI 0.455–0.899). No other subgroup analyses were conducted due to the limited number of available studies.

5.1.2 Sanitation interventions

A single sanitation intervention conducted in a developed country was identified. This was conducted in the USA in 1952 and related to the disposal of excreta in simple pits. The impact of the intervention on diarrhoea (RR: 0.51, 95% CI: 0.32 – 0.83) and shigella (RR: 0.59, 95% CI: 0.35 – 0.99) in all age groups was examined (McCabe and Haines, 1957). The study is classed as poor quality, as the health indicator recall was a month and neither of the health indicators was defined.

5.1.3 Water supply interventions

Two studies examined water supply interventions (outlined in Tables 8 and 9). One of these was a natural experiment in drought conditions that resulted in an extremely restricted water supply. The intervention was considered to have occurred when the supplies were returned to normal (Burr *et al.*, 1978). Meta-analysis of the two studies resulted in a pooled estimate (random effects model) of 0.509 (95% CI: 0.471 – 0.551).

Table 8: Studies conducted in EME countries examining water supply interventions

Ref	Intervention	Design	Country	Region	Location	Health outcome	Age group	Measure	Result	95% CI
Rubenstein *et al.*, 1969	Household water supply	Interv.	USA	Amr A	Rural	Diarrhoea	0 – 12 months	RR*	**0.43**	**0.19-1.00**
Burr *et al.*, 1978	Lifting of water restrictions	Interv.	UK	Eur A	Unstated	Diarrhoea	< 11 years	RR*	**0.51**	**0.47-0.55**

* - Calculated Interv. – Intervention RR – Relative Risk
Results in bold are those used in the overall meta-analysis

Table 9: Quality of EME country water supply intervention studies

Ref	Adequate control group	Measurement of confounders	Randomization	Health indicator definition	Health indicator recall	Analysis by age	Intervention /compliance assessed	Blinding	Placebo
Rubenstein *et al.*, 1969	No	Yes	No	Non-standard	NA	NA	No	Not clear	No
Burr *et al.*, 1978	Yes	Yes	No	No	Weekly	No	NA	No	No

5.1.4 Water quality interventions

The water quality interventions included both point-of-use treatment and source treatment. Studies examining changes to the treatment of source water were ecological in nature. Study details are outlined in Table 10, and their quality is summarised in Table 11.

Table 10: Studies conducted in EME countries examining water quality interventions

Ref	Intervention	Design	Country	Region	Location	Health outcome	Age group	Measure	Result	95% CI
Payment *et al*., 1991b	Point of use water treatment (reverse osmosis)	Interv.	Canada	Amr A	Suburban	HCGI	All	RR*	**0.74**	**0.50-0.98**
							0 – 5 years	RR*	0.71	0.36-1.06
Payment *et al*., 1997	Purified bottled water versus tap water	Interv.	Canada	Amr A	Suburban	HCGI	All	RR*	**1.02**	**0.64-1.41**
							2 – 5 years	RR*	0.86	0.30-1.41
Hellard *et al*., 2001	Point of use water treatment (filtration + UV)	Interv.	Australia	Wpr A	Urban	HCGI	All	Rate ratio	**0.99**	**0.85-1.15**
McConnell *et al*., 2001	Source water treatment	Eco.	Australia	Wpr A	Rural	Diarrhoeal specimen requests	All	Information not available		
Colford *et al*., 2002	Point of use water treatment (filtration + UV)	Interv.	USA	Amr A	Urban	HCGI	All	IRR	**1.32**	**0.75-2.33**
Hellard *et al*., 2002	Source water treatment (chlorination)	Eco.	Australia	Wpr A	Urban	Severe diarrhoea	Children	OR	**1.06**	**0.72-1.21**

* Calculated Interv. – Intervention Eco. – Ecological HCGI – Highly credible gastrointestinal symptoms
RR – Relative Risk IRR – Incidence Rate Ratio OR – Odds Ratio
Results in bold are those used in the overall meta-analysis

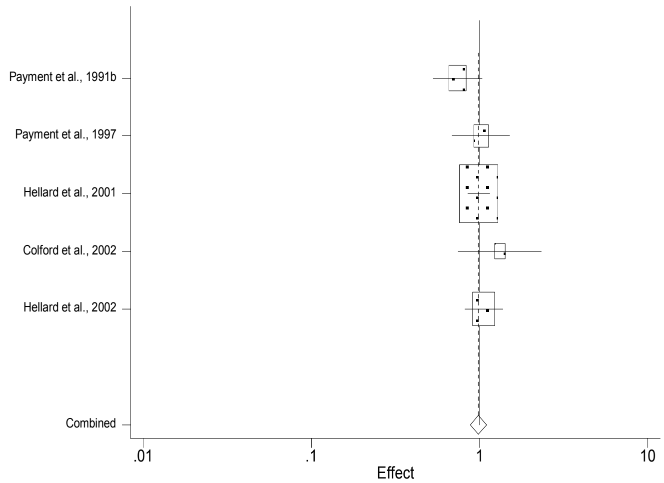
Table 11: Quality of EME country water quality intervention studies

Ref	Adequate control group	Measurement of confounders	Randomization	Health indicator definition	Health indicator recall	Analysis by age	Intervention /compliance assessed	Blinding	Placebo
Payment et al., 1991	Yes	Limited	Yes	Non-standard	Diary sheet	Yes	Yes	No	No
Payment *et al*., 1997	Yes	Limited	Yes	Non-standard	Diary sheet	Yes	Yes	No	No
Hellard *et al*., 2001	Yes	Yes	Yes	Non-standard	Diary sheet	Yes	Yes	Yes	Yes
McConnell *et al*., 2001	Yes	Yes	No	Non-standard	NA	No	Yes	No	No
Colford *et al*., 2002	Yes	Yes	Yes	Non-standard	Daily	No	Yes	Yes	Yes
Hellard *et al*., 2002	NA	NA	NA	Non-standard	NA	Yes	No	NA	NA

NA – Not applicable

Of the six studies identified that examined the effects of water quality interventions, five could be used in the meta-analysis. Where there was a choice of data points the most inclusive age group was used (“all”).

Figure 6: Fixed effects forest plot of water quality interventions



Random 0.984 (0.874 – 1.108)
Fixed 0.984 (0.878 – 1.103)
Heterogeneity p = 0.387
Begg's test p = 0.462

The results of the meta-analysis, shown in Figure 6, suggest that overall water quality interventions in developed countries are not effective in reducing diarrhoea levels, with no evidence of publication bias.

This result is in line with those from the two most rigorously conducted studies (Hellard *et al*., 2001; Colford *et al*., 2002). Although the study reported in Colford *et al*. (2002) was small and was not designed to test the effect of the intervention on health, a more recent study by the same group with 1296 participants suggested no reduction in gastrointestinal illness from an in-home drinking water intervention despite a microbiologically challenged source water receiving conventional water treatment; this study was not included in the meta-analysis because it is not fully published (Colford *et al*., 2003). Excluding the one source water treatment study (Hellard *et al*., 2002) and conducting the meta-analysis only on point-of-use water treatment does not markedly affect the result (fixed model pooled estimate 0.967, 95% CI 0.851 – 1.097).

5.2 DEVELOPING COUNTRIES STUDIES

Forty-eight paper were identified representing forty-six studies in developing countries (regions Afr D, Afr E, Amr B, Amr D, Emr B, Emr D, Eur B, Sear B, Sear D and Wpr B – see Appendix 5), two of which examined two separate interventions. The studies were from 24 countries and included three foreign language papers (Xiao *et al*., 1997; Messou *et al.*, 1997; Lou *et al.*, 1990). Seven of the studies examined multiple-type interventions, 13 examined hygiene interventions, four examined sanitation interventions, nine examined water supply interventions and 15 examined water quality interventions.

5.2.1 Developing countries - multiple interventions

Nine papers outlined studies that examined interventions with at least three components, namely the introduction of water, sanitation and hygiene or health education measures. In such cases it is neither possible nor appropriate to separate out individual components. Only seven distinct studies were identified (sometimes the same study is reported in several publications, usually presenting methodology and results separately). The seven studies are summarised in Table 12.

Table 12: Water, sanitation and hygiene-related interventions

Ref	Intervention	Design	Country	Base	Location	Health outcome	Age group	Measure	Result	95% CI
Rahaman *et al.*, 1986#	Water supply, latrines, health education	Interv.	Bangladesh	Not clear	Unstated	Diarrhoea	0 – 60 months	Information not available		
Aziz *et al.*, 1990	Hand pump and latrine installation, hygiene education	Interv.	Bangladesh	F	Rural	Diarrhoea	0 – 60 months	IDR	**0.75**	**0.70-0.80**
						Persistent diarrhoea	0 – 60 months	IDR	0.58	0.52-0.65
						Dysentery	0 – 60 months	IDR	0.73	0.61-0.88
Blum *et al.*, 1990/ Huttly *et al.*, 1990	Boreholes, hand pumps, VIP latrines, hygiene education	Interv.	Nigeria	F	Rural	Diarrhoea	0 – 72 months	RR*	1.9	Informa-tion not available
Mertens *et al.*, 1990 a,b	Tube well construction, traditional well rehabilitation, latrine construction, health education	Case-control	Sri Lanka	F	Rural	Severe diarrhoea	0 – 60 months	RR	**0.65**	**0.58-0.72**
Hoque *et al.*, 1996	Hand pump and latrine installation, hygiene education	Interv.†	Bangladesh	F	Rural	Diarrhoea	0 – 60 months	RR	0.64	0.37-1.09
							> 60 months	RR	0.45	0.31-0.64
							All	RR*	**0.50**	**0.37-0.67**
Messou *et al.*, 1997‡	Water supply, pit latrines and health education	Interv.	Ivory Coast	F	Rural	Diarrhoea	0 – 60 months	RR*	**0.63**	**0.50-0.81**
Nanan *et al.*, 2003	Improve potable supply at village + household levels, sanitation , hygiene education	Case-control	Pakistan	Eb	Rural	Severe diarrhoea	4 – 71 months	OR	**0.75**	**0.56-0.99**

* - Calculated Base – Baseline water and sanitation scenario Interv. – Intervention IDR – Incidence Density Ratio
OR – Odds Ratio RR – Relative Risk † - Follow-up, six years after the original intervention reported by Aziz *et al.*, 1990
- abstract only ‡ - paper in French
Results in bold are those used in the overall meta-analysis

Table 13 summarises the quality issues relating to each of the studies. Where there was sufficient information to judge the paper quality, each of the studies had reasonable control groups and they all measured confounding factors, although it was not always clear how these were accounted for in the results.

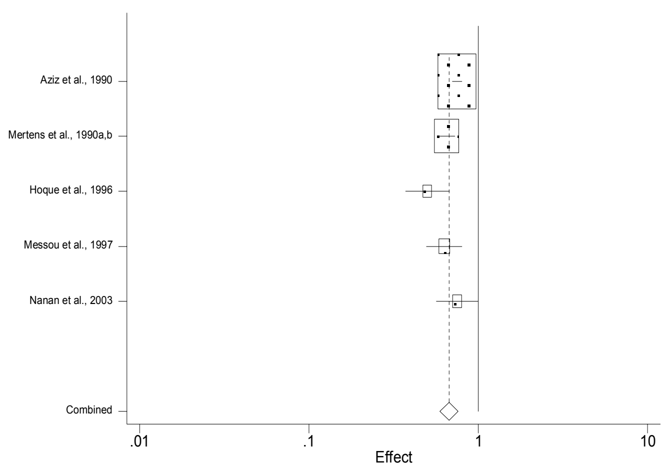
Table 13: Quality of developing country multiple intervention studies

Ref	Adequate control group	Measurement of confounders	Randomization	Health indicator definition	Health indicator recall	Analysis by age	Intervention /compliance assessed	Blinding	Placebo
Rahaman *et al.*, 1986#	Insufficient data to judge quality – abstract only								
Aziz *et al.*, 1990	Moderate	Limited	No	Standard	1 week	Yes	Yes	No	No
Blum *et al.*, 1990 / Huttly *et al.*, 1990	Yes	Yes	No	Standard	8 days – 2 weeks	Yes	Yes	No	No
Mertens *et al.*, 1990a,b	Yes	Measured	NA	Non-standard	NA	No (children < 5)	No	No	NA
Hoque *et al.*, 1996	Yes	Limited	No	Standard	24 hour point prev	Yes	Some	No	No
Messou *et al.*, 1997‡	Yes	Not clear	No	No	2 weeks	No (children < 4)	Not clear	No	No
Nanan *et al.*, 2003	Yes	Yes	NA	Standard	NA	Yes	Not stated	Some	No

NA – Not applicable prev. - prevalence
- abstract only ‡ - paper in French

Five of the six studies, with summary estimates reported risk estimates of less than 1. Unfortunately it was not possible to include the study which reported a risk estimate of greater than 1 (Blum *et* al., 1990; Huttly *et* al., 1990) in the meta-analysis (Figure 7) as insufficient data were presented to permit calculation of confidence intervals.

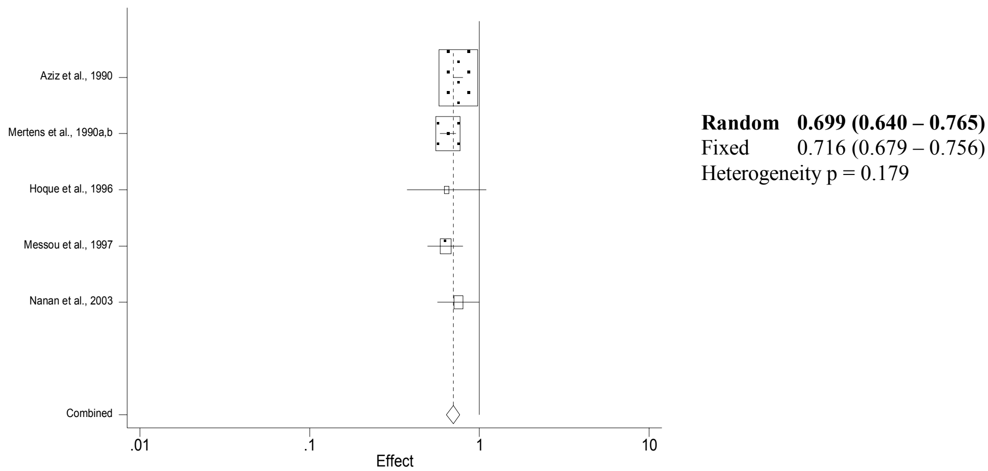
Figure 7: Random effects forest plot of multiple interventions (developing countries)



Random 0.670 (0.592 – 0.757)
Fixed 0.709 (0.672 – 0.748)
Heterogeneity p = 0.02
Begg's test p = 0.462

The largest effect on diarrhoea reduction was seen in the study reported by Hoque *et al.*, 1996. This reflects the large effect seen in children over the age of five years. Meta-analysis of the data (Figure 8), excluding this older age group (in line with the other studies, which only include children up to the age of 5 or 6 years) reveals that the results using the random effects model are still statistically significant.

Figure 8: Random effects forest plot of multiple interventions looking at diarrhoea in children up to the age of five or six years



The studies used a variety of health outcome measures ('diarrhoea', 'severe diarrhoea' and 'dysentery'). A slightly greater impact of the intervention was seen in children under the age of six when looking at 'severe diarrhoea' or 'dysentery' as the health outcome compared to 'diarrhoea' (fixed effects model). All the studies were conducted in rural locations. It was, therefore, not possible to determine if different levels of impact are seen in rural and urban locations.

Severe diarrhoea/dysentery:	random effects	0.677 (0.620 – 0.740)
	fixed effects	**0.677 (0.620 – 0.740)**
	heterogeneity	p = 0.426
Diarrhoea:	random effects	0.733 (0.674 – 0.797)
	fixed effects	**0.739 (0.693 – 0.788)**
	heterogeneity	p = 0.343

Aziz *et al*. (1990) also examined data on a within-intervention area basis (data not shown) and noted that higher diarrhoeal incidence rates were seen in children in households which were located further from the hand pump. Diarrhoea was found to be lower in households where a latrine was used for the disposal of children's faeces. As part of the same intervention project, Henry *et al*. (1990) examined the impact of the interventions on food and water contamination, but did not find a consistent pattern between contamination and diarrhoea.

The study by Hoque *et al*. (1996) represents a follow up of the interventions originally reported by Aziz *et al*. (1990). Despite the fact that fewer hand pumps and latrines were functional in the follow-up, Hoque *et al*. (1996) reported a greater impact of the intervention than in the original study (although this difference is not statistically significant). This may be related to the methodology adopted by Hoque (as the health impact was based on a 24 hour point prevalence of illness) or it may represent an increase in the usage of the intervention facilities over time (as they noted that 84% of adults were using the latrines). Re-analysis of the data, excluding the Hoque study from the meta-analysis, does not markedly affect the results (random effects pooled estimate = 0.699; 95% CI: 0.633 – 0.733).

5.2.2 Developing countries - hygiene interventions

Fifteen papers, detailing thirteen studies, were identified that examined hygiene interventions. These are summarised in Table 14 and quality issues are outlined in Table 15.

Table 14: Studies examining hygiene interventions

Ref	Intervention	Design	Country	Base	Location	Health outcome	Age group	Measure	Result	95% CI
Khan, 1982	Hand-washing with soap	Interv.	Bangladesh	Not clear	Unstated	Diarrhoea	All	RR*	**0.62**	**0.35-1.12**
Torún, 1982	Hygiene education	Interv.	Guatemala	F	Rural	Diarrhoea	0 – 72 months	RR*	**0.81**	**0.75-0.87**
Sircar *et al*., 1987	Hand-washing with soap	Interv.	India	D	Urban	Watery diarrhoea	0 – 60 months	RR*	1.13	0.79-1.62
						Watery diarrhoea	> 5 years	RR*	1.08	0.86-1.37
						Dysentery	0–60mths	RR*	0.67	0.42-1.09
						Dysentery	> 5 years	RR*	0.59	0.37-0.93
						Comb. outcome	Comb. ages	RR*	**0.97**	**0.82-1.16**
Stanton *et al*., 1988/ Stanton + Clemens, 1987	Hygiene education	Interv.	Bangladesh	D	Urban	Diarrhoea	0 – 72 months	IDR	**0.78**	**0.74-0.83**
Alam *et al*., 1989	Hygiene ed. (and increased water supply)	Interv.	Bangladesh	Eb	Rural	Diarrhoea	6 – 23 months	OR	**0.27**	**0.11-0.66**
Han + Hlaing, 1989	Hand-washing with soap	Interv.	Myanmar	D	Urban	Diarrhoea	0 – 60 months	RR	0.70	0.54-0.92
						Diarrhoea	0–24mths	RR	0.69	0.48-1.01
						Diarrhoea	25–60mth	RR	0.67	0.45-0.98
						Dysentery	0–60mths	RR	0.93	0.39-2.23
						Dysentery	0–24mths	RR	0.59	0.22-1.55
						Dysentery	25–60mth	RR	1.21	0.52-2.80
						Comb. Outcome	0–60 months	RR*	**0.75**	**0.60-0.94**
Lee *et al*., 1991	Hygiene education	Interv.	Thailand	D	Rural	Diarrhoea	0 – 60 months	RR*	**0.43**	**0.32-0.56**
Wilson *et al*., 1991	Hand-washing with soap	Interv.	Indonesia	D	Rural	Diarrhoea	< 11 years	RR*	**0.21**	**0.08-0.53**
Ahmed *et al*., 1993	Hygiene education	Interv.	Bangladesh	D	Rural	Diarrhoea	0 – 18 months	RR*	0.66	Info not available
Wilson + Chandler, 1993	Hand-washing with soap	Interv.†	Indonesia	D	Rural	Diarrhoea	< 11 years	RR*	0.33	Information not available
Haggerty *et al*., 1994a/b	Hygiene education	Interv.	Zaire	F	Rural	Diarrhoea	3 – 35 months	RR*	**0.89**	**0.80-0.98**
Pinfold + Horan, 1996	Hygiene education	Interv.	Thailand	D	Rural	Diarrhoea	0 – 60 months	RR*	**0.61**	**0.37-1.00**
Shahid *et al*., 1996	Hand-washing with soap	Interv.	Bangladesh	F	Periurban	Diarrhoea	All	IDR	**0.38**	**0.33-0.43**
							0–11mths	IDR	0.39	0.29-0.54
							12– 23m	IDR	0.53	0.37-0.77
							24–59mth	IDR	0.44	0.34-0.59
							5–9 yrs	IDR	0.27	0.19-0.37
							10–14 yrs	IDR	0.28	0.16-0.49
							≥15 years	IDR	0.38	0.30-0.49

* - Calculated   Base – Baseline water and sanitation scenario   Interv. – Intervention
IDR – Incidence Density Ratio   IRR – Incidence Rate Ratio   RR – Relative Risk
† - Follow-up two years after the original intervention reported by Wilson *et al*., 1991, in comparison with the pre-intervention data for the intervention group
Results in bold are those used in the overall meta-analysis

The paper by Stanton *et al*. (1988) represents an extension of the study reported by Stanton and Clemens (1987) from a six-month to a 12-month period. The results are extracted from the full-scale study (Stanton *et al*., 1988). Both papers by Wilson are included (Wilson *et al*., 1991; Wilson and Chandler, 1993), as the second paper reassesses the situation two years after the original intervention, when soap was no longer being supplied (although due to lack of data it was not possible to include the follow up study in the meta-analysis).

One of the studies outlined in Table 14 (Alam *et al*., 1989) examined improved water supply and hygiene education. It has been classified as a hygiene intervention because the results used here are for the effect of the uptake of the hygiene messages in the group with the improved water supply. The four hygiene messages related to the source of water, the presence of faeces in the yard, hand-washing before serving food and hand-washing after defecation.

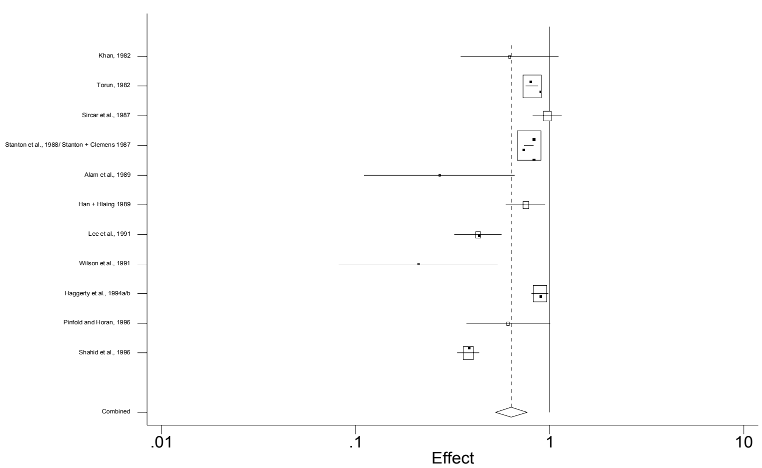
All of the studies (except for Torún, 1982) had reasonable control groups, although the subsequent control for confounding factors varied. Three studies employed at least some randomization, although it is not always clear how this was done (Han and Hlaing, 1989). With the exception of the studies conducted in Indonesia (Wilson *et al*., 1991; Wilson and Chandler, 1993), the results were either analysed by age or included such a narrow age range that age stratification was unnecessary. Placebo interventions consisting of education on the prevention of dehydration during diarrhoeal episodes were used by two studies (Haggerty *et al*., 1994; Wilson *et al*., 1991). Compliance with the intervention was assessed in most studies. In some cases this took the form of observation, raising the possibility of the Hawthorne effect.

Table 15: Quality of developing country hygiene intervention studies

Ref	Adequate control group	Measurement of confounders	Randomization	Health indicator definition	Health indicator recall	Analysis by age	Intervention /compliance assessed	Blinding	Placebo
Khan, 1982	Moderate	Limited	No	Standard	Daily	Yes	Yes	No	No
Torún, 1982	No	Limited	No	No	Twice weekly	Yes	Yes	No	No
Sircar *et al.*, 1987	Yes	Limited	No	Standard	1 week	Yes	Yes	No	No
Stanton *et al.*, 1988 / Stanton + Clemens, 1987	Yes	Measured	Yes	Standard	2 weeks	Yes	Yes	No	No
Alam *et al.*, 1989	Moderate	Limited	No	Standard	1 week	No (children 6-23 months)	Yes	No	No
Han + Hlaing, 1989	Yes	Yes	Yes	Standard	Daily	Yes	Yes	No	No
Lee *et al.*, 1991	Yes	Measured	No	Standard	2 weeks	Yes	Yes	No	No
Wilson *et al.*, 1991	Yes	Limited	No	Non-standard	2 weeks	No	Not clear	No	Yes
Ahmed *et al.*, 1993	Moderate	Limited	No	Non-standard	1 week	No (children 0-18 months)	Yes	No	No
Wilson + Chandler, 1993	Yes	Limited	No	Non-standard	2 weeks	No	Yes	No	No
Haggerty *et al.*, 1994	Moderate	Limited	Some	No	1 week	Yes	Not clear	No	Yes
Pinfold + Horan, 1996	Yes	Not clear	No	Standard	Diary sheet	No (children < 5)	Yes	No	No
Shahid *et al.*, 1996	Yes	Yes	No	Standard	48 hours	Yes	Yes	No	No

Overall, the meta-analysis suggests that hygiene interventions act to reduce diarrhoeal illness levels. Figure 9 shows the results using the random effects model. Although there is a much narrower confidence interval from the fixed effect model, the heterogeneity p value of < 0.2 indicates that the random effect model is the most appropriate to use. There is some evidence of publication bias.

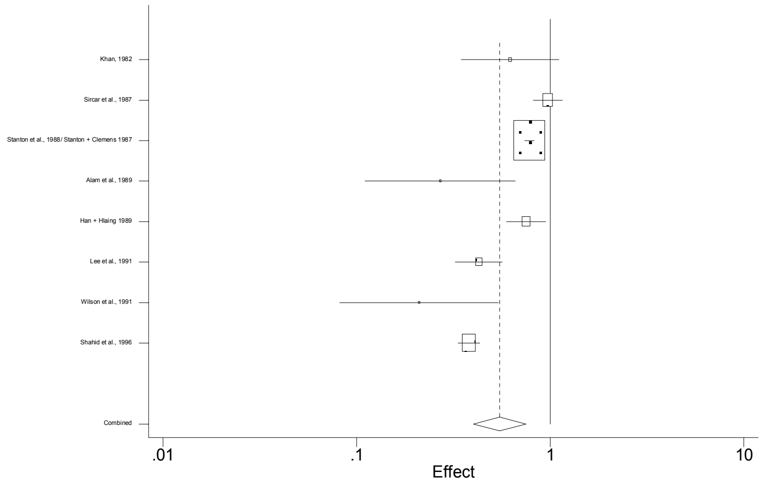
Figure 9: Random effects forest plot of hygiene interventions (developing countries)



Random 0.633 (0.524 – 0.765)
Fixed 0.751 (0.723 – 0.780)
Heterogeneity p = 0.000
Begg's test p = 0.199

Re-analysis of the data, following exclusion of the studies considered to be of poor quality resulted in an apparently greater effect of the intervention on reducing diarrhoea levels, as shown in Figure 10.

Figure 10: Random effects forest plot of hygiene interventions (developing countries), excluding studies of poor quality



Random 0.547 (0.400 – 0.749)
Fixed 0.701 (0.668 – 0.736)
Heterogeneity p = 0.000

It is not possible to produce a meaningful meta-analysis examining the effect of age on the effectiveness of hygiene interventions, but the data in Table 14 suggest that the impact is not restricted to a certain age group.

Hygiene interventions were typically of two types, those concentrating on health and hygiene education and those that actively promoted hand-washing (usually alongside education messages). The number of messages, content of those messages and the way in which they were delivered varied between studies (see Appendix 6 for further details). Performing separate meta-analyses for studies examining each component suggests that hand-washing may be more effective than education, although education measures have a smaller 95% confidence interval:

Hand-washing:	**random effects**	**0.556 (0.334 – 0.925)**
	fixed effects	0.564 (0.513 – 0.619)
	heterogeneity	p = 0.000
Education:	**random effects**	**0.722 (0.628 – 0.831)**
	fixed effects	0.793 (0.761 – 0.826)
	heterogeneity	p = 0.000

Examination of the study results according to the baseline water and sanitation scenario (Section 4.3.1) suggests that hygiene interventions are effective irrespective of the starting conditions. The following data compare results from studies with improved water and improved sanitation (scenario D) to those with poorer water supplies and/or poorer sanitation (i.e. scenarios E and F):

Scenario D:	**random effects**	**0.663 (0.525 – 0.837)**
	fixed effects	0.772 (0.733 – 0.813)
	heterogeneity	p = 0.000

Scenarios E & F:	**random effects**	**0.583 (0.385 – 0.884)**
	fixed effects	0.729 (0.691 – 0.770)
	heterogeneity	p = 0.000

5.2.3 Developing countries - sanitation interventions

Four studies examining the effect of sanitation interventions on diarrhoea were identified. These are summarised in Table 16. Quality factors are shown in Table 17. The study by Azurin and Alvero (1974) examined the provision of latrines and improved water supply both independently and in combination (see Section 5.2.4.1). The study by Gross *et al*. (1989) also looked at the effect of piped water on health, but although the results were presented separately for each aspect (see Table 18), the effect of each component on the other was not taken into account; further, the lack of 95% CIs did not allow inclusion of the result in the meta-analysis.

Table 16: Studies examining sanitation interventions

Ref	Intervention	Design	Country	Base	Location	Health outcome	Age group	Measure	Result	95% CI
Kumar *et al.*, 1970	Excreta disposal in simple pits	Interv.	India	F	Rural	Diarrhoea	0 – 60 months	Information not available		
Azurin & Alvero, 1974	Provision of communal latrines†	Interv.	Philippines	F	Urban	Cholera	All	RR*	**0.32**	**0.24-0.42**
							0 -48 months	RR*	0.59	0.43-0.81
Gross *et al.*, 1989	Piped water and connection to the public sanitation system	Interv.	Brazil	D	Urban	Diarrhoea	0 - 72 months	RR*	0.55	Information not available
Daniels *et al.*, 1990	VIP latrine installation (and hygiene education)	Case-control	Lesotho	F	Rural	Diarrhoea	0 – 60 months	OR	**0.76**	**0.58-1.01**

* Calculated   Base – Baseline water and sanitation scenario   Interv. – Intervention   OR – Odds Ratio
RR – Relative Risk   † - Also provided improved water supply
Results in bold are those used in the overall meta-analysis

Only two of the studies could be included in the meta-analysis, as it was not possible to extract data from the paper by Kumar *et al*. (1970) and confidence intervals could not be calculated for Gross *et al*.(1989). Using the data for young children (i.e. ≤ 60 months) a random effects pooled estimate of 0.678 (95% CI: 0.529 – 0.868) was calculated. Given the paucity of results for this intervention and the fact that only a single study was considered to be of good quality, it may be useful to look at studies that have examined groups of people with different sanitation provision or to conduct additional studies in this area.

Table 17: Quality of developing country sanitation intervention studies

Ref	Adequate control group	Measurement of confounders	Randomization	Health indicator definition	Health indicator recall	Analysis by age	Intervention /compliance assessed	Blinding	Placebo
Kumar *et al.*, 1970	No	Yes	Not stated	Non-standard	Weekly	NA	Not stated	Not stated	No
Azurin & Alvero, 1974	Yes	Not clear	No	Non-standard	Daily	Yes	Not clear	Not stated	Yes
Gross *et al.*, 1989	Not clear	Measured	No	Standard	2 weeks (pt prev.)	No (children < 6)	Yes	No	NA
Daniels *et al.*, 1990	Yes	Limited	NA	Non-standard	NA	Yes	NA	NA	NA

NA – not applicable   pt prev. – point prevalence

5.2.4 Developing countries - water supply interventions

It is often not possible, when improvements to a water supply system have been made, to determine whether this has improved quality, quantity or both. For this reason, interventions have simply been categorised as being 'water supply' interventions (where a new source may have been introduced, or piped supply provided, for example). Where a clear quality intervention has been made, it has been classified separately as a water quality intervention (section 5.2.5).

Nine of the studies have been categorised as being 'water supply' interventions, and are summarised in Table 18. One study examined the effects of increased water supply and hygiene education. However, as the results are related to the effects of hygiene within the group which received increased water supply it has been classified as a 'hygiene' intervention (Alam *et al*., 1989 – see Table 14); it should be noted, however, that it was found that if the use of hand pump water was the only hygienic measure adopted then diarrhoea incidence was the same as if none of the practices were adopted.

Table 18: Studies examining water supply-related interventions

Ref	Intervention	Design	Country	Base	Location	Health outcome	Age group	Measure	Result	95% CI
Azurin & Alvero, 1974	Municipal water (< 50% with hh connection)	Interv.	Philippines	F	Urban	Cholera	All	RR*	**0.27**	**0.20-0.36**
							0 – 48 months	RR*	0.39	0.27-0.57
Bahl, 1976	Piped water and standpipes	Ecolog	Zambia	Ea	Urban	Diarrhoea	All	RR*	**0.63**	**0.62-0.63**
						Typhoid	All	RR*	0.15	0.05-0.43
Shiffman *et al.*, 1978	Protected source, treatment & hh connection	Interv.	Guatemala	Not clear	Rural	Diarrhoea	All	Information not available		
Ryder *et al.*, 1985	Improved quality + hh connection	Interv.	Panama	Ea	Rural	Diarrhoea	0 – 60 months	RR*	**1.34**	**1.05-1.63**
Esrey *et al.*, 1988	Continually functioning tap/hand pump serving less than 100 hh	Interv.	Lesotho	F	Rural	Diarrhoea	1 – 60 months	RR*	**1.86**	**1.11-3.14**
							1 - 12 months	RR*	1.70	0.84-3.43
							13 – 60 months	RR*	1.80	0.88-3.67
Gross *et al.*, 1989	Piped water + hh connection	Interv.	Brazil	D	Urban	Diarrhoea	0 – 72 months	RR*	0.55	Information not available
Wang *et al.*, 1989	Well with household or nearby connection	Interv.	China	F	Rural	Diarrhoea	All	RR*	**0.62**	**0.59-0.65**
Lou *et al.*, 1990†	Household connection	Interv.	China	Eb	Rural	Diarrhoea	All	Information not available		
Tonglet *et al.*, 1992	Piped water (standpipes)	Interv.	Zaire	F	Rural	Diarrhoea	0 – 48 months	RR*	**0.95**	**0.88-1.00**

* - Calculated Base – Baseline water and sanitation scenario Interv. – Intervention OR – Odds Ratio
RR – Relative Risk † - Paper in Chinese
Results in bold are those used in the overall meta-analysis

Table 19 summarises the quality issues for each of the studies. Six studies are considered to be of poor quality: Esrey *et al*., 1988 because there is no health indicator definition (other than that determined by the mother); the others because it is unclear whether there were adequate control groups and/or account taken of confounding factors.

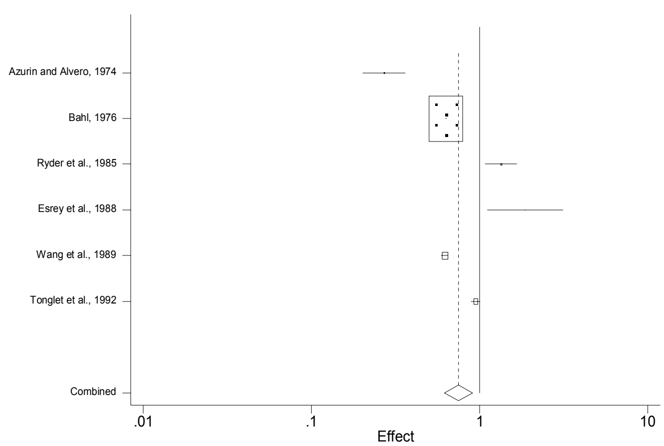
Table 19: Quality of developing country water supply intervention studies

Ref	Adequate control group	Measurement of confounders	Randomization	Health indicator definition	Health indicator recall	Analysis by age	Intervention /compliance assessed	Blinding	Placebo
Azurin & Alvero, 1974	Yes	Not clear	No	Non-standard	Daily	Yes	Not clear	Not clear	Yes
Bahl, 1976	No	Yes	No	Non-standard	NA	No	No	No	No
Shiffman *et al*., 1978	Yes	Not clear	No	None	2-4 weeks	No	Yes	Not stated	No
Ryder *et al*., 1985	Not clear	No	No	Standard	Daily	No (children < 5)	Yes	No	No
Esrey *et al*., 1988	Yes	Yes	NA	None	24 hour pt prev.	Yes	Yes	NA	NA
Gross *et al*., 1989	Not clear	Measured	No	Standard	2 weeks (pt prev.)	No (children < 6)	Yes	No	NA
Wang *et al*., 1989	Yes	Yes	No	Standard	NA	No	Yes	No	No
Lou *et al*., 1990†	Yes	Not stated	No	Standard	Not stated	Yes	Not stated	No	No
Tonglet *et al*., 1992	Moderate	Yes	No	Standard	2 weeks	Yes	Yes	No	No

NA – Not applicable pt prev. – point prevalence † - Paper in Chinese

Only six of the studies had data which could be used for meta-analysis. Combining the studies suggests that the intervention does reduce diarrhoea (Figure 11), although this includes results from an ecological study, one examining cholera as the health outcome and a range of water supply interventions (ranging from standpipe provision of water to household connection).

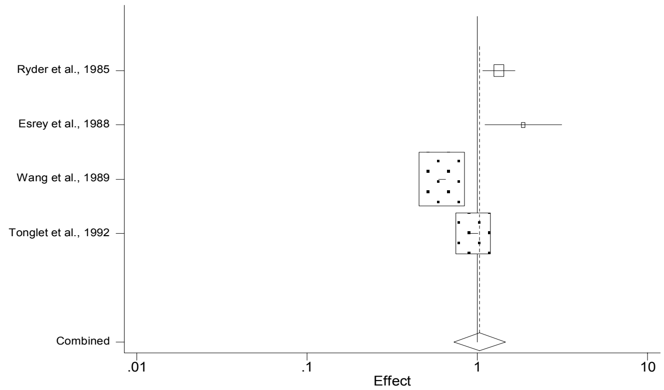
Figure 11: Random effects forest plot of water supply interventions (developing countries)



Random 0.749 (0.618 – 0.907)
Fixed 0.634 (0.629 – 0.639)
Heterogeneity p = 0.000
Begg's test p = 0.707

Restricting the analysis to intervention studies examining diarrhoea produces a rather different picture, as shown in Figure 12; these studies showed no overall impact.

Figure 12: Random effects forest plot of water supply interventions (restricting analysis to diarrhoea and intervention studies)



Random 1.031 (0.730 – 1.457)
Fixed 0.740 (0.713 – 0.769)
Heterogeneity p = 0.000

Further examining the effect of the intervention subtype (i.e. household connection versus communal connection) on the level of diarrhoea produces the following results:

Household connection:	**random effects**	**0.904 (0.425 – 1.925)**
	fixed effects	0.643 (0.613 – 0.674)
	heterogeneity	p = 0.000
Standpipe/communal:	**random effects**	**0.935 (0.648 – 1.348)**
	fixed effects	0.634 (0.629 – 0.639)
	heterogeneity	p = 0.000

This suggests that both interventions have similar and statistically non-significant effects. Only two of these studies, however, were classified as being of good quality (Table 19), and although one of the household connection studies did provide taps at household level, residents still stored water in the traditional manner. Comparing the two good quality studies suggests that household connection is a more effective means of reducing diarrhoea than standpipe provision:

Household connection (Wang *et al*., 1989)	0.62 (0.59 – 0.65)
Standpipe connection (Tonglet *et al*., 1992)	0.95 (0.88 – 1.00)

5.2.4.1 Water supply and sanitation interventions

Azurin and Alvero (1974) report the impact of a water supply and sanitation intervention on cholera levels in the Philippines. The intervention was found to be very effective, with a relative risk of 0.28 (0.20 – 0.39) in all ages; the intervention seemed to have slightly less impact in children under the age of four years (RR 0.36; 95% CI 0.25 – 0.51). There was no information on how the intervention affected rates of diarrhoea.

5.2.5 Developing countries - water quality interventions

The water quality intervention studies are outlined in Table 20. The majority of the interventions were some sort of water treatment at the point of use, i.e. within the household (including chemical treatment, boiling, pasteurisation and solar disinfection).

Table 20: Studies examining water quality interventions

Ref	Intervention	Design	Country	Base	Location	Health outcome	Age group	Measure	Result	95% CI
Ghannoum *et al.*, 1981	Reservoirs & chlorination	Eco	Libya	Not clear	Unstated	Dysentery	All	RR*	**0.41**	**0.39-0.44**
						Giardia	All	RR*	1.43	0.98-2.08
Kirchhoff *et al.*, 1985	Point-of-use water treatment (hypochlorite)	Interv.	Brazil	F	Rural	Diarrhoea	< 2 years	RR*	**1.07**	**0.88-1.30**
							2 – 4 yrs	RR*	1.16	0.90-1.51
							5 – 9 yrs	RR*	0.71	0.48-1.07
							10+ years	RR*	1.8	1.02-3.16
Mahfouz *et al.*, 1995	Point-of-use water treatment (chlorination)	Interv	Saudi Arabia	D	Rural	Diarrhoea	0 – 60 months	RR*	**0.54**	**0.30-0.99**
Conroy *et al.*, 1996	Point-of-use water treatment (solar disinfection)	Interv	Kenya	Ea	Rural	Diarrhoea	5 – 16 years	OR	**0.66**	**0.50-0.87**
						Severe diarrhoea	5 – 16 years	OR	0.65	0.50-0.86
Sathe *et al.*, 1996	Point-of-use water treatment (boiling†)	Eco	India	D	Urban	Diarrhoea	All	RR*	**2.15**	**1.57-2.73**
Xiao *et al.*, 1997‡	Point-of-use water treatment (boiling) (+ source improvements)	Interv.	China	Not clear	Rural	Diarrhoea	All	RR*	**0.38**	**0.35-0.40**
Semenza *et al.*, 1998	Point-of-use water treatment (disinfection + safe storage)	Interv	Uzbekistan	D		Diarrhoea	All	RR	**0.15**	**0.07-0.31**
							< 5 years	RR	0.33	0.19-0.57
Quick *et al.*, 1999/ Sobsey *et al.*, 2003	Point-of-use water treatment (disinfection + safe storage)	Interv	Bolivia	F	Periurban	Diarrhoea	All	OR	**0.57**	**0.39-0.84**
Iijima *et al.*, 2001	Point-of-use water treatment (pasteurisation)	Cohort	Kenya	F	Rural	Severe diarrhoea	All	RR*	**0.56**	**0.39-0.81**
Roberts *et al.*, 2001	Safe household storage	Interv	Malawi	F	Refugee camp	Diarrhoea	All	RR*	**0.79**	**0.62-1.03**
							< 5 years	RR*	0.68	0.45-1.01
Gasana *et al.*, 2002	Source protection and source treatment	Interv.	Rwanda	F		Diarrhoea	0 – 60 months	RR*	**1.0**	**0.9-1.12**
Quick *et al.*, 2002	Point-of-use treatment (disinfection + safe storage)	Interv	Zambia	Ea	Peri-urban	Diarrhoea	All	RR	**0.53**	**0.3-0.93**
Colwell *et al.*, 2003	Point-of-use treatment (simple filtration)	Interv	Bangladesh	F	Rural	Cholera	0 – 60 Months	RR*	**0.62**	**0.46-0.83**
Jensen *et al.*, 2003	Source water treatment (chlorination)	Interv	Pakistan	F	Rural	Diarrhoea	0 – 60 months	OR	**1.99**	**1.10-3.61**
Sobsey *et al.*, 2003	Point-of-use water treatment (disinfection + safe storage)	Interv	Bangladesh	Eb	Urban	Diarrhoea	0 – 60 months	IDR	**0.78**	**0.73-0.83**

† Various treatment types studied, boiling chosen to compare against no treatment ‡ - Paper in Chinese
* Calculated Interv – Intervention Eco – Ecological HCGI – Highly credible gastrointestinal symptoms
RR – Relative Risk IDR – Incidence Density Ratio OR – Odds Ratio
Results in bold are those used in the overall meta-analysis

In five cases (Gasana *et al.*, 2002; Ghannoum *et al*., 1981; Iijima *et al.*, 2001; Sathe *et al.*, 1996; Sobsey *et al.*, 2003), it is not clear from the paper that an adequate control group was used, and in three of these studies it is also unclear whether any effort to determine confounding factors was made (Table 21). Three of these studies raise additional quality issues, namely the absence of a health indicator definition, or an extended or unstated health indicator recall period. Five of the studies employed randomization. Only one of the studies, not classified as poor quality, did not either analyse the results by age group or restrict the study group to children under the age of five or six. Compliance with the intervention was assessed in most cases, although this ranged from observation and microbiological testing to participant-reported compliance. Only one study attempted blinding (Kirchhoff *et al*., 1985); this was achieved by using hypochlorite at a level which did not impart a detectable smell or taste alongside the use of a distilled water additive as a placebo intervention. Conroy *et al.* (1996) also used a placebo intervention in the form of water stored in the dark (as opposed to sunlight). Sathe *et al.* (1996) looked at the incidence of diarrhoea in relation to a number different water treatment types (filtration, alum precipitation, boiling and various commercial domestic water purifiers) versus no treatment, and found a lower mean incidence of diarrhoea in the no treatment group in each case. Because only one result from the study could be included in the meta-analysis, boiling was chosen as the included treatment.

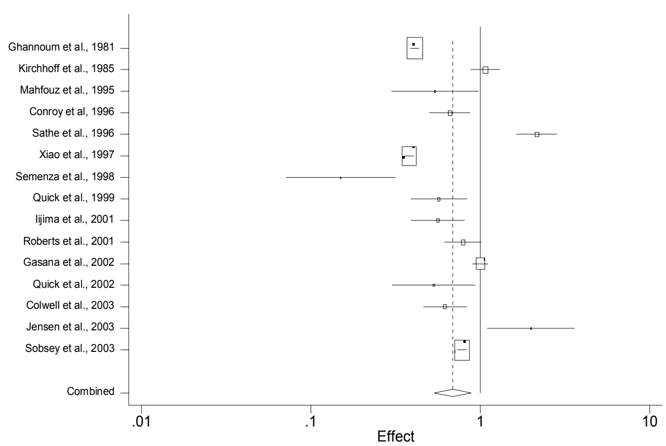
Table 21: Quality of developing country water quality intervention studies

Ref	Adequate control group	Measurement of confounders	Randomization	Health indicator definition	Health indicator recall	Analysis by age	Intervention /compliance assessed	Blinding	Placebo
Ghannoum *et al.*, 1981	No	Yes	No	Non-standard	NA	No	No	Not stated	No
Kirchhoff *et al.*, 1985	Yes	Yes	Not stated	Non-standard	3 times a week	Yes	Yes	Yes	Yes
Mahfouz *et al.*, 1995	Yes	Measured	Yes	Standard	NA	No (children < 5)	Yes	No	No
Conroy *et al.*, 1996	Yes	Yes	No	Standard	2 weeks	Yes	Yes	No	Yes
Sathe *et al.*, 1996	Not clear	Limited	No	None	Not stated	No	Not stated	No	No
Xiao *et al.*, 1997‡	Yes	Not stated	No	No	Not stated	No	Not stated	Not stated	No
Semenza *et al*,1998	Yes	Yes	Yes	Standard	2 times a week	Yes	Yes	No	No
Quick *et al.*, 1999 / Sobsey *et al.*, 2003	Yes	Yes	Yes	Standard	1 week	Yes	Yes	No	No
Iijima *et al.*, 2001	Not clear	Not clear	No	Non-standard	2-3 weeks	No	Not considered in results	No	No
Roberts *et al.*, 2001	Yes	Yes	Yes	Standard	2 times a week	Yes	Yes	No	No
Gasana *et al.*, 2002	Not clear	Not stated	No	None	NA	No (children < 5)	Some	No	No
Quick *et al.*, 2002	Yes	Yes	Yes	Standard	1 week	No	Yes	No	No
Colwell *et al.*, 2003	Yes	Yes	No	Non-standard	NA	No (children < 6)	Yes	No	No
Jensen *et al.*, 2003	Moderate	Yes	No	Standard	1 week	No (children < 5)	Yes	No	No
Sobsey *et al.*, 2003	Not clear	Not stated	No	Standard	1 week	No (children < 5)	Yes	No	No

‡ - Paper in Chinese

A total of 15 water quality intervention studies were identified, all of which had results that could be used in the meta-analysis (Figure 13).

Figure 13: Random effects forest plot of water quality interventions

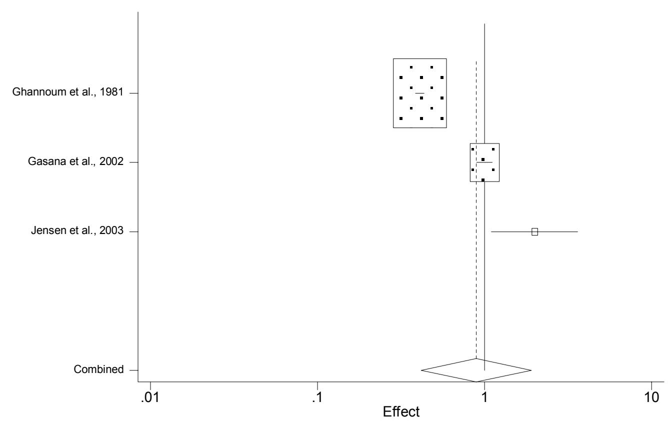


Random 0.687 (0.534 – 0.885)
Fixed 0.560 (0.542 – 0.579)
Heterogeneity p = 0.000
Begg's test p = 0.092

The pooled results show that water quality interventions seem to reduce the risk of diarrhoea. Conroy *et al*. (1999) also found that families continued to use the disinfection technique after the cessation of field work.

These studies can be divided into source treatment and household treatment. Figure 14 shows the meta-analysis results examining the three source treatment studies, with the pooled CI showing no overall impact.

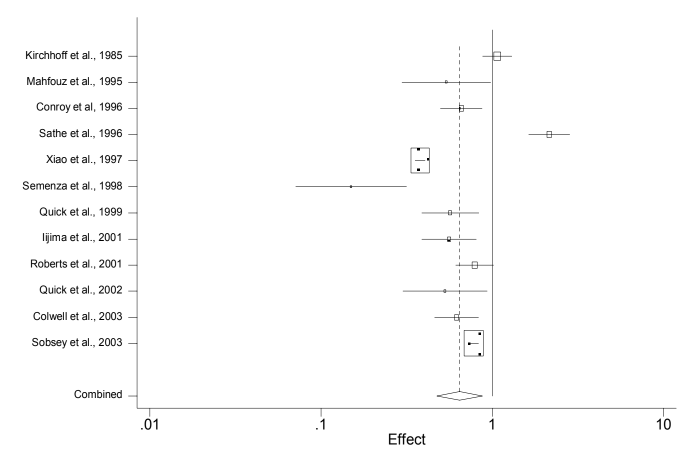
Figure 14: Random effects forest plot of source water treatment interventions



Random 0.891 (0.418 – 1.899)
Fixed 0.510 (0.484 – 0.538)
Heterogeneity p = 0.000

The majority of the interventions were household (point of use) treatments of various sorts, and these show a statistically significant impact on diarrhoea levels (Figure 15).

Figure 15: Random effects forest plot of household treatment interventions



Random 0.645 (0.475 – 0.875)
Fixed 0.595 (0.570 – 0.620)
Heterogeneity p = 0.000

Excluding the study reporting the greatest impact (i.e., Semenza *et al*., 1998) in a sensitivity analysis does not significantly change the outcome of the meta-analysis, with the random effects model providing a pooled estimate of 0.709 (95% CI: 0.519 – 0.967).

Examining the effect of the intervention on diarrhoea levels by the type of household treatment suggests that chemical treatment is more effective than non-chemical treatment:

Chemical:	**random effects**	**0.605 (0.443 – 0.828)**
	fixed effects	0.783 (0.738 – 0.831)
	heterogeneity	p = 0.000
Non chemical:	**random effects**	**0.713 (0.378 – 1.344)**
	fixed effects	0.438 (0.412 – 0.466)
	heterogeneity	p = 0.000

This result, however, is largely driven by Sathe *et al*. (1996); removing this study from the meta-analysis results in a reduced pooled estimate.

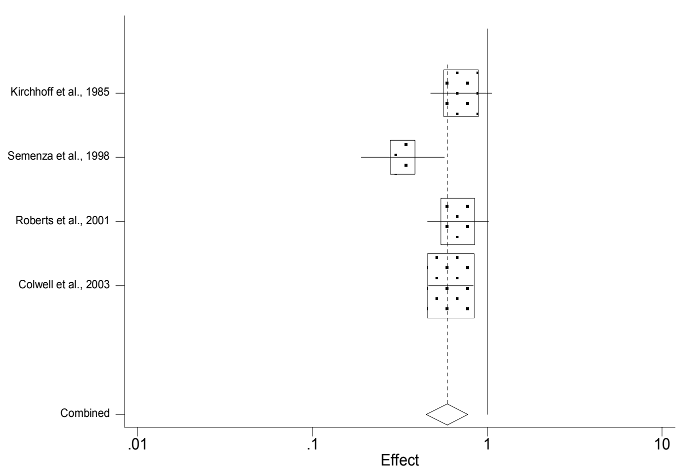
Non chemical:	**random effects**	**0.534 (0.379 – 0.752)**
(excluding Sathe)	fixed effects	0.404 (0.380 – 0.430)
	heterogeneity	p = 0.000

Household treatment seems to be more effective in rural communities than in urban/ periurban communities (even when excluding the Sathe *et al*., 1996 study from the urban analysis) as follows:

Rural:	**random effects**	**0.534 (0.392 – 0.727)**
	fixed effects	0.405 (0.381 – 0.431)
	heterogeneity	p = 0.000
Urban/periurban:	random effects	0.740 (0.645 – 0.849)
(excluding Sathe)	**fixed effects**	**0.771 (0.725 – 0.819)**
	heterogeneity	p = 0.238

Examining the four studies that report the impact of household treatment on children under the age of 5 or 6 years suggests an even greater effect, as shown in Figure 16.

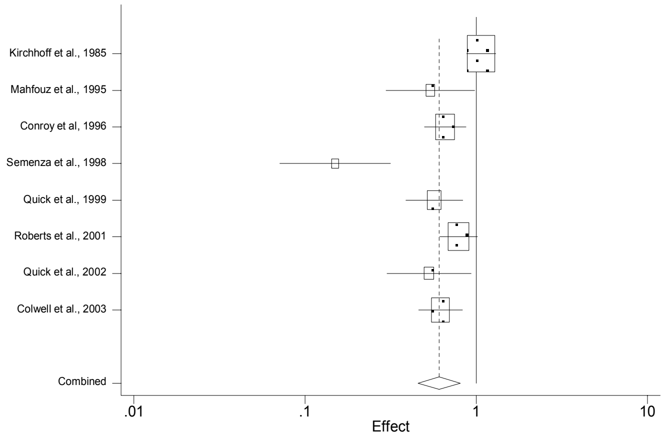
Figure 16: Random effects forest plot of household treatment impacts on children aged less than 5 or 6



Random 0.590 (0.448 – 0.775)
Fixed 0.605 (0.499 – 0.733)
Heterogeneity p = 0.131

Excluding four household treatment studies which were considered to be of poor quality (Table 21) produces a pooled estimate of 0.607 (0.457 – 0.807) as shown in Figure 17.

Figure 17: Random effects forest plot of household treatment excluding studies of poor quality



Random 0.607 (0.457 – 0.807)
Fixed 0.745 (0.667 – 0.833)
Heterogeneity p = 0.000

5.3 RESULTS SUMMARY

A summary of the meta-analysis results is shown in Table 22.

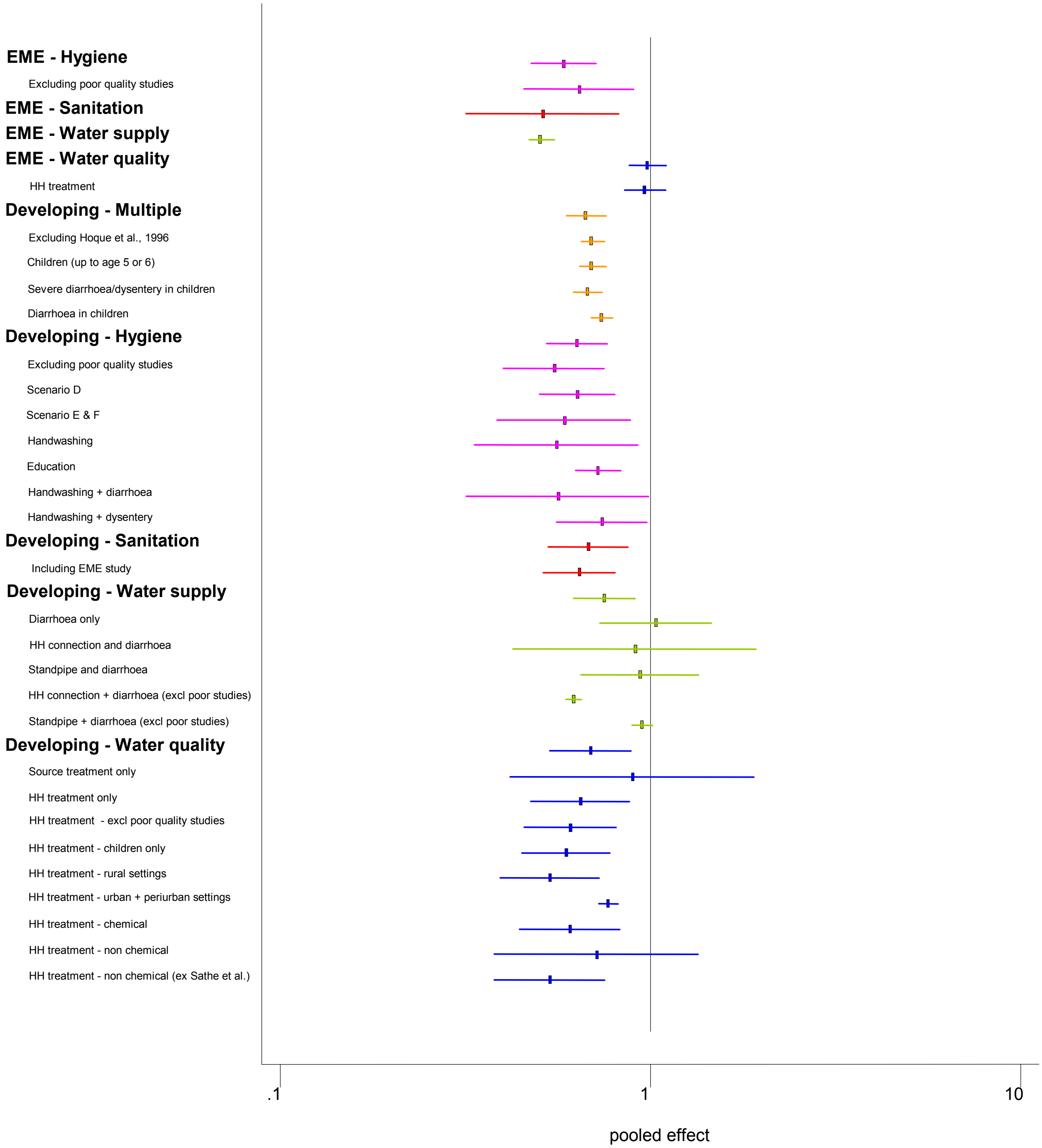
Table 22: Meta-analysis results summary

Intervention	Number of studies	Pooled estimate	95% CI
Established Market Economies			
Hygiene	4	0.582	0.476 – 0.712*
Excluding poor quality studies	3	0.640	0.455 – 0.899*
Sanitation	1	0.51†	0.32 – 0.83*
Water supply	2	0.509	0.471 – 0.551*
Water quality	5	0.984	0.878 – 1.103
Point of use	4	0.967	0.851 – 1.097
Developing countries			
Multiple	5	0.670	0.592 – 0.757*
Excluding study by Hoque *et al.*, 1996	4	0.699	0.633 – 0.733*
Children aged up to five or six only	5	0.699	0.640 – 0.756*
Severe diarrhoea/dysentery in children	3	0.677	0.620 – 0.740*
Diarrhoea in children	3	0.739	0.693 – 0.788*
Hygiene	11	0.633	0.524 – 0.765
Excluding poor quality studies	8	0.547	0.400 – 0.749
Baseline scenario D	6	0.633	0.525 – 0.837
Baseline scenarios E & F	4	0.583	0.385 – 0.884
Hand-washing	5	0.556	0.334 – 0.925
Education	6	0.722	0.628 – 0.831
Hand-washing + diarrhoea	5	0.560	0.318 – 0.984
Hand-washing + dysentery	2	0.738	0.558 – 0.977
Sanitation	2	0.678	0.529 – 0.868*
Water supply	6	0.749	0.618 – 0.907*
Diarrhoea only	4	1.031	0.730 – 1.457
HH connection and diarrhoea	2	0.904	0.425 – 1.925
Standpipe and diarrhoea	3	0.935	0.648 – 1.348
HH connection + diarrhoea (excl. poor studies)	1	0.62†	0.59 – 0.65*
Standpipe + diarrhoea (excluding poor studies)	1	0.95†	0.88 – 1.00
Water quality	15	0.687	0.534 – 0.885*
Source treatment only	3	0.891	0.418 – 1.899
HH treatment only	12	0.645	0.475 – 0.875*
HH treatment – excl poor quality studies	8	0.607	0.457 – 0.807*
HH treatment – children only	4	0.590	0.448 – 0.775*
HH treatment – rural settings	6	0.534	0.392 – 0.727*
HH treatment – urban and periurban settings	5	0.771	0.725 – 0.819*
HH treatment – chemical	6	0.605	0.443 – 0.828*
HH treatment – non chemical	5	0.713	0.378 – 1.344
HH treatment – non chemical (excl Sathe *et al.*)	4	0.534	0.379 – 0.752*

R – Random effects model; F – Fixed effects model HH - household
* significant at $p < 0.05$ † this does not represent the results of a meta-analysis
scenario D - improved water and improved sanitation
scenarios E & F – poorer water and/or poorer sanitation

It can be seen from this table that most of the interventions reduce the level of diarrhoeal illness, and the majority of these are statistically significant. Where poor quality studies have been excluded from the analysis the magnitude of the effect, in most instances, seems to be greater. The pooled estimates are also shown in Figure 18, as this gives a visual representation of the magnitude of each intervention's effect and its statistical significance.

Figure 18: Forest plot of meta-analysis results



SECTION 6. DISCUSSION

The following sections discuss each intervention and then examine some general points that have arisen from the systematic review process and the meta-analyses.

6.1 EME – HYGIENE INTERVENTIONS

The hygiene intervention studies which were conducted in EME countries were all targeted at child care centres and all emphasised the importance of hand-washing. The actual hygiene messages, the way in which they were delivered and the level of reinforcement varied between studies. Health information was determined either from the parents or the day care staff. The age at which the intervention was found to be most effective varied, and Carabin *et al*. (1999) found that simply observing and recording illness seemed to be at least, if not more, effective at reducing diarrhoea and hand contamination than a one-day training programme. Despite the differences between the studies, the meta-analysis produced a statistically significant pooled estimate (0.582; 95% CI 0.476 – 0.712) suggesting that hand-washing is effective in reducing diarrhoeal illness in this setting. With the small number of studies, however, it is not possible to determine which intervention format produces the greatest illness reduction.

6.2 EME – SANITATION INTERVENTIONS

A single sanitation intervention study was identified. This provided an adaptation of a bored-hole latrine for the disposal of excreta, consisting of a hole 8 feet deep and 16 inches in diameter, covered with a concrete slab, with an aluminium riser, seat and lid. A statistically significant reduction in the incidence of diarrhoea (0.51; 95% CI 0.32 – 0.83) and shigella was observed (0.59; 95% CI 0.35 – 0.99), as was a decrease in the number of houseflies.

6.3 EME – WATER SUPPLY INTERVENTIONS

Two water supply interventions were identified. These were very different in nature, with one being the provision of a household water supply to a Native American village in the United States, while the other examined diarrhoea levels in school children subjected to very limited water supplies (with no water for up to 17 hours a day) during drought conditions in the United Kingdom, with the intervention being considered to take place when the supplies were returned to normal (i.e. 24-hour functioning). These studies suggest that household supply of water is an effective intervention for reducing diarrhoea (0.509; 95% CI 0.471 – 0.551).

6.4 EME – WATER QUALITY INTERVENTIONS

The evidence from the meta-analysis did not support the hypothesis that water quality interventions are effective at reducing diarrhoeal illness in developed countries. Each of the studies outlined in Table 10 added additional treatment to water which was already of good, if not ideal, quality. In the case of the studies which examined point-of-use treatment (Colford *et al*., 2002; Hellard *et al*., 2001; Payment *et al*., 1991), each of the sources received conventional treatment prior to distribution. The first study of this nature was conducted by Payment *et al*. (1991), who found that the addition of reverse osmosis prior to drinking water consumption markedly reduced the level of highly credible gastrointestinal illness in those drinking the additionally treated water, suggesting that publicly supplied water meeting current quality standards was responsible for a significant level of illness. This study was subject to some criticism and was repeated, with modification, by Hellard *et al*. (2001). Hellard and colleagues did not see a decrease in diarrhoea levels in those drinking additionally treated water; however, the source water was derived from a pristine catchment, as opposed to a microbiologically challenged riverine source of that used by the Payment *et al*. (1991) study. Colford *et al*. (2002), however, also found no effect from additional household treatment on a riverine source.

6.5 DEVELOPING COUNTRIES – MULTIPLE INTERVENTIONS

The studies examining multiple interventions are complex. All of the studies included water supply, sanitation and hygiene intervention components, although the levels of provision varied. The health outcome examined was either 'diarrhoea', 'persistent diarrhoea', 'severe diarrhoea' or 'dysentery', although this did not affect the overall result. All of the studies targeted young children, with the exception of Hoque *et al*. (1996), who also examined older children (over the age of 5). Overall, the interventions seemed to be effective in reducing diarrhoea (pooled estimate 0.670; 95% CI 0.592 – 0.757). Although it might have been expected that multiple interventions would be somewhat more effective than individual interventions, this effect was not seen as a rule. The studies reported varying degrees of community involvement, which, along with differences in the specific interventions, may explain some of the variability between the studies. None of the studies report on the final water quality (i.e., after household storage) and none employ household treatment. It is possible, therefore that including a water quality intervention may further improve the effectiveness of the multiple interventions. The problems of ensuring the success (in terms of illness reduction) of a multiple intervention are illustrated by Blum *et al*. (1990) who noted that water became heavily contaminated during collection and storage and that there was no significant change in consumption of water per person. Only 46% of adults were using the latrines by the end of the study period and use by children was low. Household drinking water treatment (boiling or adding alum) decreased once boreholes were introduced and hand-washing was already appreciated by the population. Such issues may easily explain why a greater impact is not seen from multiple interventions in comparison with single interventions, where more effort can be focussed on encouraging compliance.

6.6 DEVELOPING COUNTRIES – HYGIENE INTERVENTIONS

The majority of developing country hygiene interventions were conducted in areas that already had improved water and sanitation facilities (i.e. the baseline scenarios were categorised as D) and although the intervention was effective in these areas (pooled estimate 0.633; 95% CI 0.525 – 0.837), an impact on illness was also seen in areas with poorer water and/or sanitation (pooled estimate 0.583; 95% CI 0.385 – 0.884). The hygiene measures implemented varied widely, although most emphasised the importance of hand-washing and the safe disposal of faeces. The diarrhoea reduction was strengthened by the removal of poor quality studies (pooled estimate 0.547; 95% CI 0.400 – 0.749). Splitting the intervention according to whether it focussed on actual hand-washing or hygiene education showed that the studies directed at hand-washing showed a greater impact on illness (pooled estimate of 0.556 (95% CI 0.334 – 0.925) compared to 0.722 (95% CI 0.628 – 0.831) for the education studies).

6.7 DEVELOPING COUNTRIES – SANITATION INTERVENTIONS

A total of four studies examining sanitation interventions in developing countries were identified, three of which were classed as being of poor quality and two of which could not be used in the meta-analysis. The low number of studies may reflect people's preference for water over sanitation (DFID, 1998). It may also reflect the tendency for projects to provide multiple interventions over sanitation alone, as indicated by lower levels of sanitation provision, especially in rural areas (see Table 1). Despite the low number of studies, there is an indication that sanitation interventions are effective in reducing diarrhoea levels (pooled estimate 0.678; 95% CI 0.529 – 0.868).

6.8 DEVELOPING COUNTRIES – WATER SUPPLY INTERVENTIONS

An initial examination of the results from the meta-analysis suggests that water supply interventions in developing countries are effective in reducing illness levels (pooled estimate 0.749; 95% CI 0.618 – 0.907). Much of this reduction, however, is driven by large impacts related to cholera and an ecological study. Removing these from the meta-analysis and examining the impact on diarrhoea from intervention studies suggests a different picture, where no health benefit is seen. Dividing the studies further and examining them by level of service provision (i.e. household connection or standpipe connection), suggests that the interventions may result in a small decrease in diarrhoea level but that neither impact is statistically significant. Although the majority of the water supply intervention studies assessed compliance, this generally amounted to establishing that people were actually using the new supply/standpipe. In most cases, water was still stored in the household prior to use. Few studies explicitly investigated the impact that household storage had on contamination levels. Household contamination is likely to act against seeing an improvement in diarrhoea levels. Additionally, most studies did not clearly record whether the provision of an improved supply significantly changed usage levels or how the water was used, meaning that no conclusions can be drawn about the possible beneficial effects of increased water quantity. One good quality study did suggest that household connection is an effective intervention against diarrhoea, with a relative risk of 0.62 (0.59 – 0.65).

6.9 DEVELOPING COUNTRIES – WATER QUALITY INTERVENTIONS

Maximising the likelihood that water is microbiologically safe immediately prior to its consumption appears to be a very effective intervention in terms of reducing diarrhoeal disease in developing countries. Of the 12 studies that examined some form of household treatment (or safe storage), nine (75%) found statistically significant reductions in diarrhoeal illness. Meta-analysis showed a strong effect of the intervention (pooled estimate 0.645; 95% CI 0.475 – 0.875), especially when the three studies considered to be of poor quality were removed (pooled estimate 0.607; 95% CI 0.457 – 0.807). The treatment methods employed ranged from relatively simple measures such as cloth filtration, solar disinfection and safe storage methods to pasteurisation, boiling and disinfection (principally chlorination). Chemical treatment was initially found to be more effective at reducing diarrhoeal illness levels than non-chemical treatment, which could be a function of the residual protection provided by chemical disinfection; however, re-analysis after removing one poor-quality paper suggested that there was little difference between the treatment types.

The apparent effectiveness of water quality treatment is in contrast with other studies, which have suggested that improved source water quality reduces diarrhoea only in families living in good sanitary conditions (VanDerslice and Briscoe, 1995; Esrey, 1996; van der Hoek *et al*., 2001), as half of the studies in this systematic review (6/12) had no improved sanitation (i.e. baseline scenario F or Eb).

Three studies examined the impact of *source* treatment or protection on diarrhoea levels. The uncontrolled ecological study by Ghannoum *et al*. (1981) examined the incidence of water-related diseases before and after the installation of water treatment plants in an area where boiling water prior to drinking was standard practice. Perhaps surprisingly, bacillary dysentery dropped quite markedly, although poor maintenance of the treatment plants and pipework saw disease starting to increase again. Gasana *et al*. (2002) looked at four water sources. All of the sources were contaminated to some degree and, in all cases, additional contamination occurred as a result of water transportation and household storage. The 'control' site was the most highly contaminated, and this, coupled with the differences between the sites in terms of diet and socio-economic status, makes evaluation of the intervention effect problematic. Jensen *et al*. (2003) tried to compare villages using chlorinated and unchlorinated water supplied from the same irrigation channel. They were hampered, however, by not determining pre-intervention diarrhoea levels and the presence and frequent use of alternative sources of water, the microbiological quality of which was not ascertained. None of these three studies is convincing and it is suggested that the evidence is too poor to assume that the intervention is ineffective. This issue would benefit from some well-conducted studies that consider quality of water stored in the household as well as source water quality.

6.10 STUDY QUALITY

Studies defined as being of poor quality were those having any of the following flaws:

- Lack of an adequate control group;
- No measurement of confounding factors (in non-randomized studies), see Appendix 2;
- Undefined health indicator;
- Health indicator recall of greater than two weeks.

Overall, 32% of the studies were classified as poor (19 from 60). Where possible, the impact of the various interventions were examined with and without the contribution of the poor-quality studies. In most cases, this resulted in the intervention apparently being more effective (i.e. greater reductions in the level of diarrhoeal illness was seen).

6.11 BASELINE SCENARIO

Generally, there were too few studies within each category of intervention to enable a meaningful stratification by the baseline scenario, although intuitively it might be expected that the starting point may have an impact on the apparent effectiveness of the intervention. For example, an intervention that provides safe water might appear less effective in settings where substantial disease transmission is occurring via contaminated food – or, indeed, in settings where water was already essentially safe at baseline. In addition, the same percentage disease reduction could translate to differing absolute reductions across settings. For example, if an intervention reduces diarrhoea levels by 20% in the USA and in rural Africa, in terms of disease burden the area in Africa will realise the greater health benefit because the baseline rate is higher. In the developing countries, the majority of studies were conducted in areas classified as F (21/46), i.e. those with basic water and basic sanitation. Only when examining hygiene interventions was there dominance by one of the other categories. In this instance, 62% of the studies were category D (accounting for two thirds of all category D studies), i.e. improved water and improved sanitation (and hygiene interventions remained effective in these settings).

6.12 PRE-INTERVENTION DIARRHOEA AND BEHAVIOURS

Many studies do not ascertain pre-intervention diarrhoea level or water, sanitation and hygiene behaviour. It is well-established that rates of diarrhoea in the population fluctuate. There may be a regular seasonal pattern, but rates may also vary on a yearly basis for no apparent reason. If pre-intervention baseline diarrhoea levels are not determined in both intervention and suitable comparison groups, it may be difficult to attribute changes to the intervention, or changes in the natural levels may mask the impact of the intervention. It is also important to determine baseline behaviours prior to an intervention study. This may help to maximise the benefit of hygiene education messages by targeting those areas that need most attention and also explain subsequent health impacts as a result of the intervention. For example, if the intervention consists of providing latrines, but the local custom is already to bury faeces it would not be surprising to find that the intervention had no effect (Almedom, 1996).

6.13 HOUSEHOLD STORAGE

In developing countries, household storage of water prior to consumption is commonplace. In the five possible interventions types examined in this review, the quality of stored water may potentially play a role in three of them, namely, multiple interventions, water supply interventions and water quality interventions. Additionally, some hygiene interventions are expected to improve stored water quality. With the exception of interventions specifically aimed at point-of-use treatment, household storage was generally not considered. Possible sources of household contamination include unclean water containers, unhygienic domestic water handling practices, natural contamination from the ambient domestic environment as a result of uncovered containers and biofilm occurrence in plastic containers (Jagals *et al*., 2003). Clasen and Bastable (2003) examined faecal contamination of drinking water during collection and household storage and reported that even water from safe sources was subject to frequent and extensive faecal contamination (with over 90% of samples containing thermotolerant coliforms after collection). In a meta-analysis of studies examining microbiological contamination at source and point-of-use, Wright *et al.* (2004) reported in a systematic review that the bacteriological quality of drinking-water significantly declined after collection in many settings. This potentially undermines the benefits of any source improvement interventions if it is simply assumed that diarrhoea level relates to source water quality. Although it has been argued (VanDerslice and Briscoe, 1993) that a contaminated water source poses a greater risk to health as it may introduce new pathogens into a household, the effect of the household treatment intervention seen in this review suggests that protection should be provided at the point of use.

6.14 UNUSABLE DATA

A total of ten studies did not present data in a way that allowed the extraction or calculation of a relative risk value and 95% confidence interval; this amounted to almost a sixth of all the studies identified for the review. Given the cost of conducting such projects it is unfortunate that such a large proportion can not be used in the meta-analyses.

6.15 TRENDS IN INTERVENTION STUDIES

Analysis of the identified studies by the year of publication (Figure 4) reveals that, with the exception of water quality intervention studies (principally point of use treatment), most water, sanitation and hygiene intervention studies are decreasing in frequency. This may simply reflect the interest in different interventions, or researchers may have felt previous evidence was compelling and therefore turned their attention elsewhere.

6.16 COMPARISON WITH OTHER REVIEWS

It is possible to compare the results from this review with those from the previous review of Esrey *et al*. (1991), after re-categorising some of Esrey's groups (in Table 2). The intervention 'water and sanitation' (1) is considered equivalent to 'multiple' interventions; while 'water quality and water quantity' (3) and 'water quantity' (4) have been averaged and considered equivalent to 'water supply' (figures in brackets refer to rows in Table 2). The percentage diarrhoeal reduction has been converted to a relative risk, to allow the comparison between reviews, using the following formula:

$$RR = 1 - (\%\ \text{disease reduction}/100)$$

This comparison is outlined in Table 23 and Figure 19. Percentage diarrhoeal disease reduction figures have not been calculated based on the results of the current review as the use of studies which reported odds ratios in the meta-analyses does not allow an accurate estimation to be made.

Table 23: Comparison of the effectiveness of interventions in reducing diarrhoea between the current review and Esrey *et al.*, 1991

	Esrey *et al.*, 1991						Current review			
	All studies			Rigorous studies			All studies		More rigorous studies	
Intervention	N	% DDR	Calc. RR	N	% DDR	Calc. RR	N	Pooled estimate	N	Pooled estimate
Multiple (developing countries)	7[a]/11[b]	20	0.800	2[a]/3[b]	30	0.700	5[c]/6[d]	0.670	5/6	0.670
Hygiene (EME and developing countries)	6/6	33	0.670	6/6	33	0.670	15/18	0.628	11/18	0.577
Sanitation (developing countries)	11/30	22	0.780	5/18	36	0.640	2/4	0.678		
Water supply (developing countries)	29/58	22	0.780	7/32	19	0.810	6/9	0.749	2/9	0.765
Water quality (developing countries)	7/16	17	0.830	4/7	15	0.850	15/15	0.687	8/12	0.607[e]

DDR – Diarrhoeal disease reduction RR – relative risk

[a] The number of studies for which morbidity reduction calculations could be made

[b] The total number of studies that related the type of facility to diarrhoeal morbidity, nutrition and mortality studies

[c] The number of studies included in the meta-analysis

[d] Total number of studies identified

[e] Household treatment only

Seventeen of the studies included here were also reviewed by Esrey (Esrey *et al*., 1991; Esrey and Habicht, 1986). Seven of these related to hygiene interventions (Alam *et al*., 1989; Black *et al.*, 1981; Han and Hlaing, 1989; Khan, 1982; Stanton and Clemens, 1987; Stanton *et al*., 1988; Torun, 1982), seven to water supply interventions (Azurin and Alvero, 1974; Bahl, 1976; Burr *et al*., 1978; Esrey *et al*., 1988; Rubenstein *et al.*, 1969; Ryder *et al*., 1985; Shiffman *et al.*, 1978), one to water quality (Ghannoum *et al.*, 1981) and two to sanitation (Kumar *et al.*, 1970; McCabe and Haines, 1957).

It can be seen that all of the interventions are effective and at a greater level than reported by Esrey. In contrast to Esrey *et al*. (1991), who found that water quality was the least effective intervention, this review finds it to be one of the most effective (developing countries only), particularly when examining the better-quality studies which investigated household treatment. This difference is probably related to the treatment location. Those cited by Esrey tended to be improvements to the source water and it was possible that in a number of cases, the benefits to health were not fully realised due to subsequent contamination prior to consumption. It can be seen from Figure 4 that studies on water quality interventions have increased rapidly with 11 studies being published between 2000 and the middle of 2003. Household treatment interventions have the advantage of being relatively inexpensive to perform and study, with compliance easy to test. The situation in developing countries is in marked contrast to that in established market economies where water quality interventions are extremely expensive to study and also do not seem to give any significant added health benefit to that achieved by well run conventional water treatment (Table 22).

Figure 19a: Comparison of 'all' studies (Esrey *et al*., 1991 and the current review)

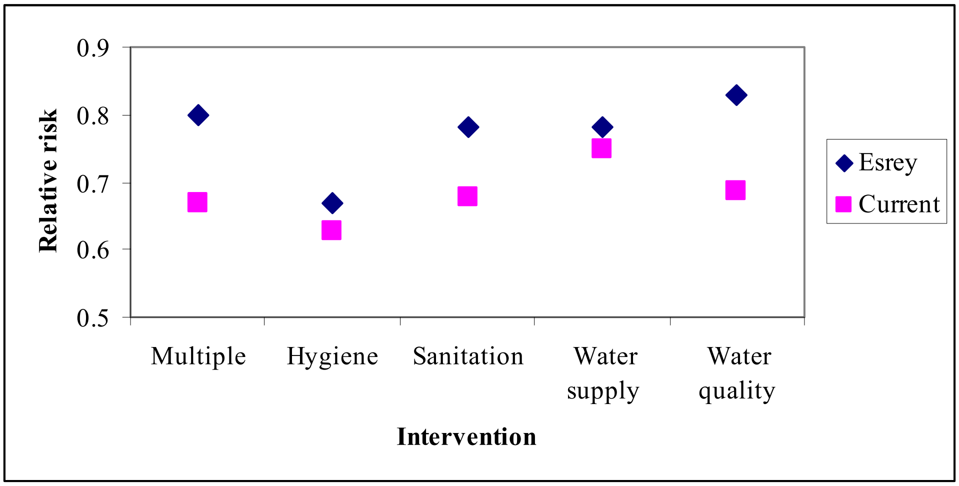
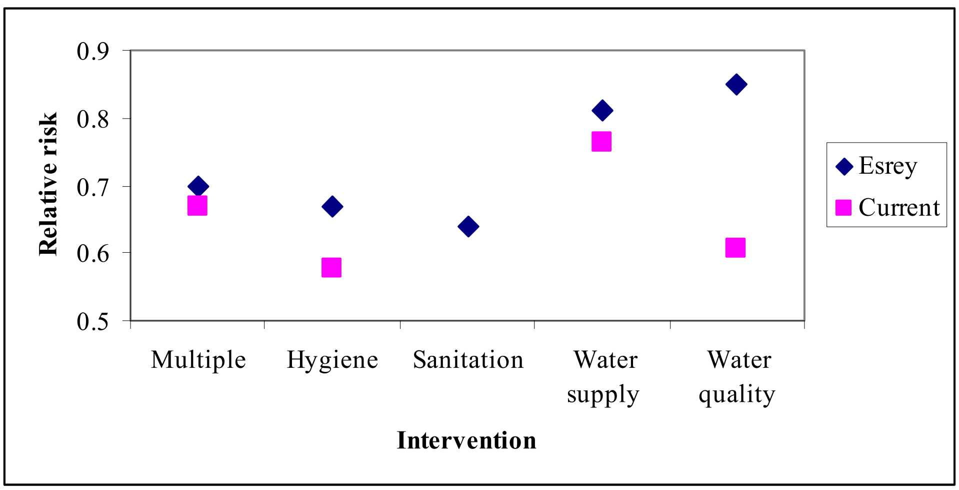


Figure 19b: Comparison of 'rigorous' studies (Esrey *et al*., 1991 and current review)



Water supply interventions were also found to be more effective than reported by Esrey *et al*. (1991), although this was mainly due to large reduction in cholera levels in one study and the contribution of an ecological study. As described above, excluding these studies and examining only the impact on diarrhoea suggests that the intervention is not effective in reducing illness levels (pooled estimate 1.031; 95% CI 0.730 – 1.457).

In a meta-analysis of the effect of hand-washing on diarrhoea, Curtis and Cairncross (2003a) found a relative risk of 0.57 (95% CI 0.46 – 0.72) from the 17 studies that they included in their review. Seven of these studies examined specific interventions (as opposed to reporting cross-sectional observations) and were therefore included in the current review. Overall, hygiene interventions in this review (including health and hygiene education) were found to result in a relative risk of 0.63 (95% CI 0.53 – 0.74), a finding similar to that of Curtis and Cairncross (2003a).

SECTION 7. DIRECTIONS FOR FUTURE RESEARCH

There are a number of areas within the field of water, sanitation and hygiene that would benefit from additional, high quality, research.

There is currently very little information available on the effectiveness of sanitation interventions. The meta-analysis of this intervention was based on only two studies from developing countries. It is suggested that, in the first instance, it may be appropriate to return to the literature and examine cross-sectional, non-intervention studies that report on risk factors and the difference in diarrhoeal levels as a result of different levels/types of sanitation provision. Such an examination may help to establish which measures are most likely to be effective. Given that in many rural areas, sanitation provision often lags behind improved drinking water provision (Table 1), it may be possible to target a location where the sole intervention is sanitation (or sanitation and hygiene education) and perform a well-conducted study to examine the impact of this intervention.

There is scant information on water quality interventions in developing countries aimed at treating the source water (rather than water at household level). It is important that such studies as well as water supply studies explicitly examine both water quality improvements at the source and water quality at the point of consumption.

Where water supply interventions have been conducted, it is difficult to disentangle health impacts due to water quantity and water quality. Many studies do not detail water usage levels and whether these change as access is improved. It is suggested that future projects explicitly examine these issues.

Hygiene interventions seem to be effective in both developing and developed countries. Future research, however, could be aimed at establishing the best way to ensure that hygiene messages are taken on board and implemented, as short-term research projects may not lead to lasting behavioural change and reductions in diarrhoeal illness in a 'real world' situation. After all, hand-washing has been found to be effective even in established market economies and knowledge about 'good' hygiene practices and actual behaviour is often very different, a situation well illustrated by the finding of Carabin *et al*. (1999) that the investigators' observations had a noticeable impact on hygiene behaviour. Curtis (Curtis and Cairncross, 2003b; Curtis 2001) has suggested that hand-washing with soap (and other hygiene messages) could be promoted as a consumer product, with the emphasis being on making the hands look, feel and smell good rather than as a sickness prevention method. This potential effectiveness of this approach is currently being field-tested.

There are few studies that examine the longevity of intervention-related health impacts, i.e. the sustainability of the effect and the persistence of the behaviours required to achieve it. Research examining this question may allow specific measures to be identified which are readily accepted by participants and consequently have long-lasting effects. It may also help to determine the type of follow-up support that may be required to ensure that hardware interventions can be effectively maintained by the community.

The level of community participation is thought to be important in the success of water, sanitation and hygiene interventions (DFID, 1998). However, the level of community participation is infrequently documented. Explicit examination of this and the form which it takes, in all future studies, may provide a useful point of comparison and, indeed, act as a possible predictor of how effective an intervention may be.

The sole health outcome studied in this review was diarrhoeal morbidity. Clearly, water, sanitation and hygiene interventions are likely to have an impact on other illnesses, such as schistosomiasis, ascariasis and respiratory outcomes. It would be useful to expand the systematic review and meta-analysis approach to examine the impact these interventions have on other health outcomes.

The study population used by the majority of studies identified in this review is confined to young children, generally under the age of five or six years. Traditionally, this group has been targeted because of its relatively high incidence of diarrhoeal disease. However, the impact of interventions may not be generalisable to other groups, and it may also be important to examine the effect on other vulnerable groups, such as older people and those who are HIV positive.

Finally, the finding that multifactorial interventions were not more effective than individual interventions raises the question of why, as a greater-than-individual effect would be intuitively expected. Future studies could help to answer this question by measuring individual inputs and outputs of such interventions along with intermediate risk factors along the relevant causal pathways to disease. This approach could help determine which components of the multifactorial interventions are effective and which are not, as well as provide some insights into the reasons for these outcomes.

SECTION 8. CONCLUSIONS

This review identified and analysed five broad types of intervention, specifically those targeted towards hygiene, sanitation, water supply, water quality or a combination of these measures. The majority of studies examined the situation in developing countries, although hygiene, sanitation, water supply and water quality intervention studies conducted in established market economies were also identified.

In established market economies:

- Hygiene interventions, comprising hand-washing and hygiene education in child care centres, can significantly contribute to reducing diarrhoeal disease.
- Only a single study was identified that examined the impact of improved sanitation on health at the household level. Wider impacts, such as the effect of waste water disposal on drinking water, recreational water and shellfish growing water were beyond the scope of this review.
- Based on the two studies identified, interventions targeting water supply at the household level were effective at reducing diarrhoea levels. Clearly, however, this intervention is not widely applicable in developed countries as household connections are widespread.
- In non-outbreak conditions, water quality interventions do not generally reduce levels of diarrhoeal illness in the study population, although the majority of these have comprised additional treatment to water of already good quality, in a population where diarrhoeal prevalence is low.

In developing countries:

- Multiple interventions consisting of water supply, sanitation provision and hygiene education in developing countries act to reduce diarrhoeal illness levels. It is possible that their effectiveness could be improved by ensuring water safety in the household.
- Hygiene interventions, mainly centred on hand-washing and other 'good' behaviours in the home, are effective both in areas which already have improved drinking water and sanitation and areas with poorer water and/or sanitation. Focussed hand-washing interventions may be more effective than hygiene education interventions.
- There are few studies examining sanitation interventions and, although examination of the existing data suggests that sanitation is effective in reducing diarrhoeal illness levels, further research is needed in this area.
- Water supply interventions seem to reduce diarrhoeal illness levels, but this result mainly relates to the provision of household connection and use of the water without household storage. There is a suggestion that water source improvements may also slightly decrease the level of diarrhoeal illness, but this was not statistically significant. It is currently not possible to distinguish between health benefits resulting from water quality and those from water quantity. Indeed, in many cases, water consumption levels are not documented and although water access is improved, it is not clear that this translates to an increased use of water.
- Water quality interventions, in terms of household (point-of-use) treatment seem to reduce diarrhoeal illness levels. This review suggests that water quality interventions may be more

important than previously thought, as previous studies have suggested that such interventions are only effective where good sanitary conditions already exist.

Overall:

- Despite a comprehensive search that identified 64 relevant papers, the number of studies providing usable data within each category of interest was relatively small.

- Many issues related to research quality were raised by the process of this systematic review, including concerns about study design, field methods and the analysis or the subsequent reporting. In most cases, when studies rated as being of poor quality were removed from the meta-analysis, a greater effect due to the intervention of interest was seen.

- It is clear that the water supply, sanitation and hygiene field would benefit from further guidance in terms of issues to be examined (such as the baseline diarrhoea levels and underlying trends, pre-intervention hygiene behaviour and environmental conditions), reiteration of some quality considerations (such as the need for a good control group and explicit examination and control for confounders) and guidelines in terms of reporting and results presentation. These measures would go towards improving the quality of future research, enhancing the possibilities of comparisons between studies and allowing future meta-analyses.

- The results are broadly similar to those reported in other reviews, although all the interventions seem to be more effective those reported by Esrey *et al.* (1991). Water quality interventions show the greatest increase in effectiveness, probably reflecting the more recent emphasis on point-of-use treatment rather than source treatment. In terms of relative effectiveness there is little to guide the choice between the different interventions in developing countries with the relative risk values being similar for all intervention types.

The figures derived from this review give a broad indication of the possible effectiveness of each intervention only in terms of their reduction in levels of diarrhoeal morbidity. These interventions may affect other health outcomes differently, and although diarrhoea is a major cause of illness in developing countries, the significance of locally important illnesses should not be ignored.

Additionally, many of these interventions may have long term impacts which no study attempts to quantify, namely general improvement in the quality of life including a reduction in time taken to collect water. The latter, in some settings, may free female children to attend school, with the possible distal consequence that improved education of girls may lead to a decrease in diarrhoea levels (effectively establishing a virtuous circle).

As noted by VanDerslice and Briscoe (1995), "we know that people in developing countries will not be healthy until they are able to use reasonable amounts of safe, reliable water and until they have adequate excreta disposal facilities". One of the Millennium Development Goals is to halve the proportion of people without sustainable access to safe drinking water and basic sanitation by the year 2015, with the ideal situation being water and sanitation for all (Mara, 2003).

Improved water supplies, adequate sanitation facilities and hygienic behaviour are all important and intertwined elements. The main thrust of future research should be not 'how do we choose between different interventions?' but 'which package of specific measures combining all the main intervention areas will maximise the health benefits to each individual community?'

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APPENDIX 1 - WATER AND SANITATION SCENARIO BY STUDY COUNTRY

Table A1.1: Improved water and sanitation provision (rural areas)

Country	Year	Improved water (%)*	Improved sanitation (%)*	F	Eb	Ea	D
Democratic Republic of Congo	1990						
	2000	26	6	74	20	0	6
Kenya	1990	25	81	19	0	56	25
	2000	31	81	19	0	50	31
Lesotho	1990						
	2000	88	92	8	0	4	88
Malawi	1990	43	70	30	0	27	43
	2000	44	70	30	0	26	44
Nigeria	1990	33	51	49	0	18	33
	2000	39	45	55	0	6	39
Zambia	1990	28	48	52	0	20	28
	2000	48	64	36	0	16	18
Bangladesh	1990	89	27	11	62	0	27
	2000	97	44	3	53	0	44
China	1990	60	18	40	42	0	18
	2000	66	24	34	42	0	24
India	1990	73	8	27	65	0	8
	2000	86	14	14	72	0	14
Indonesia	1990	60	44	40	16	0	44
	2000	65	52	35	13	0	52
Myanmar	1990	56	38	44	18	0	38
	2000	60	39	40	21	0	39
Pakistan	1990	79	13	21	66	0	13
	2000	84	42	16	42	0	42
Saudi Arabia	1990						
	2000	64	100	0	0	36	64
Sri Lanka	1990	59	79	21	0	20	59
	2000	80	80	20	0	0	80
Thailand	1990	68	83	17	0	15	68
	2000	77	96	4	0	19	77
Uzbekistan	1990						
	2000	78	100	0	0	22	78
Bolivia	1990	52	28	48	24	0	28
	2000	55	38	45	17	0	38
Brazil	1990	58	23	42	35	0	23
	2000	58	32	42	26	0	32
Guatemala	1990	72	66	28	6	0	66
	2000	88	76	12	12	0	76
Panama	1990						
	2000	86	87	13	0	1	86

* Data from WHO/UNICEF, 2000
Levels D-F calculated by assuming that improved sanitation is associated with improved water. Definitions of improved water and sanitation are given in Table 4 in the main text.

Table A1.2: Improved water and sanitation provision (urban areas)

Country	Year	Improved water (%)*	Improved sanitation (%)*	F	Eb	Ea	D
Democratic Republic of Congo	1990						
	2000	89	53	11	36	0	53
Kenya	1990	89	94	6	0	5	89
	2000	87	96	4	0	9	87
Lesotho	1990						
	2000	98	93	2	5	0	93
Malawi	1990	90	96	4	0	6	90
	2000	95	96	4	0	1	95
Nigeria	1990	78	77	22	1	0	77
	2000	81	85	15	0	4	81
Zambia	1990	88	86	12	2	0	86
	2000	88	99	1	0	11	88
Bangladesh	1990	98	78	2	20	0	78
	2000	99	82	1	17	0	82
China	1990	99	57	1	42	0	57
	2000	94	68	6	26	0	68
India	1990	92	58	8	34	0	58
	2000	92	73	8	19	0	73
Indonesia	1990	90	76	10	14	0	76
	2000	91	87	9	4	0	87
Myanmar	1990	88	65	12	23	0	65
	2000	88	65	12	23	0	65
Pakistan	1990	96	78	4	18	0	78
	2000	96	94	4	2	0	94
Saudi Arabia	1990						
	2000	100	100	0	0	0	100
Sri Lanka	1990	90	93	7	0	3	90
	2000	91	91	9	0	0	91
Thailand	1990	83	97	3	0	14	83
	2000	89	97	3	0	8	89
Uzbekistan	1990						
	2000	96	100	0	0	4	96
Bolivia	1990	92	77	8	15	0	77
	2000	93	82	7	11	0	82
Brazil	1990	91	76	9	15	0	76
	2000	89	81	11	8	0	81
Guatemala	1990	88	94	6	0	6	88
	2000	97	98	2	0	1	97
Panama	1990						
	2000	88	99	1	0	11	88

* Data from WHO/UNICEF, 2000
Levels D-F calculated by assuming that improved sanitation is associated with improved water. Definitions of improved water and sanitation are given in Table 9 in the main text.

In many cases it was not possible to determine the baseline water and sanitation provision from the published data. Where this was the case, scenarios were assumed from Tables A1.1 and A1.2. If improved sanitation of water supply affects less than 50% of the population, the situation is assumed to be equivalent to unimproved provision. For example, Colwell *et al*. (2003) note that the water was from unimproved (i.e. basic) sources, but do not comment on sanitation provision. Data from Table A1.1 for rural Bangladesh in the year 2000 indicate that none of the population is served by basic water and improved sanitation. Therefore it is assumed that the study population is exposed to basic water and basic sanitation (scenario F).

APPENDIX 2 – COVARIATES

As part of the data extraction and quality assessment procedures, information was gathered on the measurement and control of covariates that might represent possible confounding factors. This appendix is a complete listing of the confounding factors that were measured by the different authors.

GENERAL

Parental age
Occupation
Household size
Socio-economic status
Religion
Time of residence

HYGIENE

Source of water
Water supplies
Water quantity or distance to supply
Number of hours without a water supply
Water storage
Drinking water treatment/ drinking boiled water
Sanitation facilities
Frequency of maternal bathing
Refuse removal
Pets

EDUCATION

Educational indicators
Mother's education
Father's education

CHILD/SIBLING CHARACTERISTICS

Day care centre attendance
Length enrolled in care
Sibling child care
Child's sex
Birth interval
Birth order
Weight at birth
Breastfeeding
Nutritional status
Single parent family
Siblings
Siblings < 5 years

APPENDIX 3 - A BRIEF INTRODUCTION TO META-ANALYSIS

This text is based on Pai *et al*. (2004) and is reproduced with permission. An excellent introduction is also provided by LaValley (1997).

Meta-analysis is a two-stage process. Most reviewers begin analysis with tabulation of study characteristics, such as year, setting, study design, and results in the form of summary statistics (which are usually risk ratios, odds ratios, risk differences and so on). In the second stage the overall treatment or intervention effect is calculated as a weighted average of the summary statistics. Forest plots display effect estimates from each study with their confidence intervals (CI) and provide a visual summary of the data. The results of each component study are shown as boxes centered on the point estimate, with the horizontal line representing the CI. The pooled estimate is shown, at the bottom of the plot, by the middle of a diamond, where the left and right extremes represent the corresponding confidence interval. (Figure A3.1).

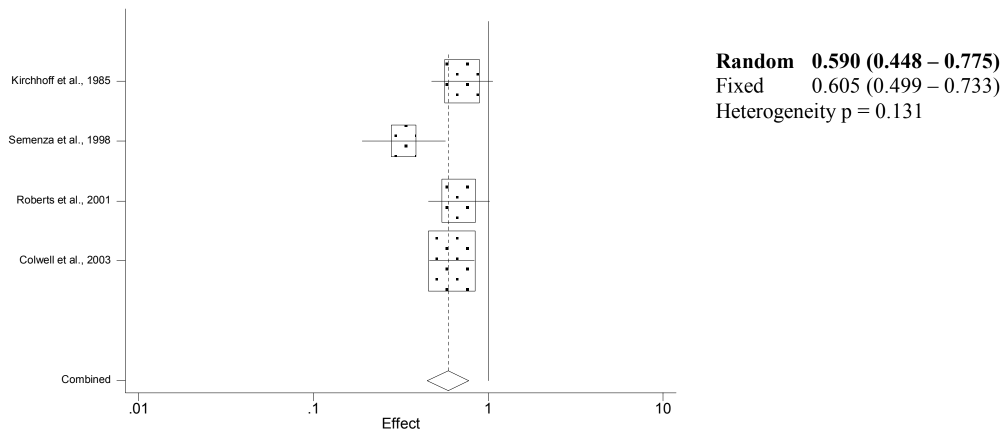

Figure A3.1: Random effects forest plot of household treatment impacts on children aged less than 5 or 6

The size of the boxes, in the plot, reflect the amount of information that each study contains, usually the inverse of the variance (the square of the standard error) of the treatment/intervention effect, which relates closely to sample size. The 'meta' command (used in STATA) uses inverse-variance weighting.

Pooling is accomplished using two statistical models: the random effects model or the fixed effects model. Both can be used to pool a variety of effect measures (discrete and continuous): odds ratios, risk ratios, risk differences, p-values, differences in means etc. The fixed effects model assumes that the studies included in the meta-analysis estimate the same underlying 'true' effect that is 'fixed', and that the observed differences across studies are due to random error. The random effects model assumes that the studies included in the meta-analysis are only a random sample of a theoretical universe of all possible studies on a given research question and that the effects for the individual studies vary around some overall average effect. Random effects models incorporate two sources of variability: random error and between-study variability. Thus, the random effects model is preferred when the data are heterogeneous, since it allows for between-study and within-study variability and provides a more conservative estimate with a wider confidence interval. In the absence of heterogeneity, both models produce similar results. In the presence of heterogeneity (indicated by the results of the test for heterogeneity and an examination of the forest plot) it is appropriate to investigate potential sources of variability in effect estimates. This may be accomplished by methods such as subgroup analyses, meta-regression and graphical methods.

Evaluation of publication bias is an important element in meta-analysis. Publication bias is just one type of a family of biases called 'reporting biases'. Reporting biases tend to occur when statistically significant ('positive') studies are more likely to be submitted and accepted for publication (publication bias), more likely to be published in English (language bias), more likely to be published rapidly (time-lag bias) and cited more often (citation bias). Also, studies that are easily accessible as electronic, full-text reports may be identified more often that those that are not. If a meta-analysis summarizes only published studies prone to these biases, the overall summary effect might be spuriously exaggerated. Since it is very hard to identify unpublished studies, there is no easy method to overcome this problem. The presence of publication bias can be assessed, however, using graphical methods and statistical tests (Begg and Mazumdar, 1994; Egger *et al.*, 1997).

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APPENDIX 4 - STUDY DESIGN

This is a brief introduction to the epidemiological designs employed in the studies identified in this review. There is a range of epidemiological study designs that can be applied to study the impact of improvements to water, sanitation and hygiene, although because of the selection criteria employed in this review, the majority here are classified as intervention studies.

INTERVENTION STUDIES

In an randomized intervention study, subjects have their health status is observed at baseline and then are randomly assigned to either receive, or not receive, a given intervention. Their health status is measured again after the intervention is put in place, so that the degree of change can be compared across groups. Such assignment of the intervention should minimise the potential sources of bias that could occur with self-selection into groups, and also helps to avoid the pitfalls in cross-sectional observational studies where only associations – not causality – can be observed.

The randomized *double-blinded* trial is considered to be the strongest epidemiological design that can be applied to the study of human disease (Robertson *et al*., 2003). However, double-blinding requires that neither the participant nor the researcher is aware of any individual's intervention status until after the completion of the trial. Clearly, in the context of most water, sanitation and hygiene interventions, it is difficult to achieve either full blinding or randomization. The use of a placebo intervention can be useful, especially to minimise the impact of the Hawthorne effect (where people modify their behaviour simply as a result of being observed or investigated). But, as noted by Cairncross, "there is no placebo for a pit latrine". Thus, double-blinded studies are relatively uncommon in environmental epidemiology but have been undertaken successfully in examining the impact of improved water quality on gastrointestinal illness in developed countries (Hellard *et al*., 2001; Colford *et al*., 2002).

CASE-CONTROL STUDIES

These differ from intervention studies in that the groups of participants are selected on the basis of whether they have a particular illness (e.g. diarrhoea) or not (controls). Often the control group will be made up of people reporting to the same clinic as the cases, but with illnesses considered to be unrelated to water, sanitation and hygiene. The proportions of cases and controls exposed to the intervention are then compared.

ECOLOGICAL STUDIES

These describe the prevalence of disease in entire populations and generally use routinely collected health data such as might be available from national surveys or health care facilities. While relatively easy to perform, and a reasonable first step in investigating new disease hypotheses, ecological studies are considered weak because they cannot control for self-selection, confounding, or localized secular trends unrelated to the intervention of interest. In addition, ecological studies can be misleading because it is possible to observe an intervention-effect relationship across populations that is not borne out within the individuals in the given populations.

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APPENDIX 5 - WORLD HEALTH ORGANIZATION (WHO) COMPARATIVE RISK ASSESSMENT (CRA) REGIONS

For the purposes of the WHO CRA countries have been categorised according to their geographical location and the level of adult and child mortality. There are 14 regions in total;
2 African regions (Afr D; Afr E)
3 American regions (Amr A; Amr B; Amr D)
2 Eastern Mediterranean regions (Emr B; Emr D)
3 European regions (Eur A; Eur B; Eur C)
2 South East Asian regions (Sear B; Sear D)
2 Western Pacific Regions (Wpr A; Wpr B)

Mortality levels are indicated as follows:
A: very low child mortality and very low adult mortality
B: low child mortality and low adult mortality
C: low child mortality and high adult mortality
D: high child mortality and high adult mortality
E: high child mortality and very high adult mortality.

Countries within each region are listed in Table A5.1.

Table A5.1: Countries by WHO CRA Region

Region	Mortality stratum	Countries
AFR	**D**	Algeria, Angola, Benin, Burkina Faso, Cameroon, Cape Verde, Chad, Comoros, Equatorial Guinea, Gabon, Gambia, Ghana, Guinea, Guinea-Bissau, Liberia, Madagascar, Mali, Mauritania, Mauritius, Niger, Nigeria, Sao Tome And Principe, Senegal, Seychelles, Sierra Leone, Togo
AFR	**E**	Botswana, Burundi, Central African Republic, Congo, Côte d'Ivoire, Democratic Republic Of The Congo, Eritrea, Ethiopia, Kenya, Lesotho, Malawi, Mozambique, Namibia, Rwanda, South Africa, Swaziland, Uganda, United Republic of Tanzania, Zambia, Zimbabwe
AMR	**A**	Canada, Cuba, United States of America
AMR	**B**	Antigua and Barbuda, Argentina, Bahamas, Barbados, Belize, Brazil, Chile, Colombia, Costa Rica, Dominica, Dominican Republic, El Salvador, Grenada, Guyana, Honduras, Jamaica, Mexico, Panama, Paraguay, Saint Kitts and Nevis, Saint Lucia, Saint Vincent and The Grenadines, Suriname, Trinidad and Tobago, Uruguay, Venezuela
AMR	**D**	Bolivia, Ecuador, Guatemala, Haiti, Nicaragua, Peru
EMR	**B**	Bahrain, Cyprus, Iran (Islamic Republic of), Jordan, Kuwait, Lebanon, Libyan Arab Jamahiriya, Oman, Qatar, Saudi Arabia, Syrian Arab Republic, Tunisia, United Arab Emirates
EMR	**D**	Afghanistan, Djibouti, Egypt, Iraq, Morocco, Pakistan, Somalia, Sudan, Yemen
EUR	**A**	Andorra, Austria, Belgium, Croatia, Czech Republic, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Israel, Italy, Luxembourg, Malta, Monaco, Netherlands, Norway, Portugal, San Marino, Slovenia, Spain, Sweden, Switzerland, United Kingdom

Region	Mortality stratum	Countries
EUR	**B**	Albania, Armenia, Azerbaijan, Bosnia And Herzegovina, Bulgaria, Georgia, Kyrgyzstan, Poland, Romania, Slovakia, Tajikistan, The Former Yugoslav Republic Of Macedonia, Turkey, Turkmenistan, Uzbekistan, Yugoslavia
EUR	**C**	Belarus, Estonia, Hungary, Kazakhstan, Latvia, Lithuania, Republic of Moldova, Russian Federation, Ukraine
SEAR	**B**	Indonesia, Sri Lanka, Thailand
SEAR	**D**	Bangladesh, Bhutan, Democratic People's Republic Of Korea, India, Maldives, Myanmar, Nepal
WPR	**A**	Australia, Brunei Darussalem, Japan, New Zealand, Singapore
WPR	**B**	Cambodia, China, Cook Islands, Fiji, Kiribati, Lao People's Democratic Republic, Malaysia, Marshall Islands, Micronesia (Federated States Of), Mongolia, Nauru, Niue, Palau, Papua New Guinea, Philippines, Republic Of Korea, Samoa, Solomon Islands, Tonga, Tuvalu, Vanuatu, Viet Nam

APPENDIX 6 - HYGIENE INTERVENTIONS

The following Tables (A6.1 and A6.2) describe the specific hygiene interventions employed in each study outlined in Sections 5.1.1 and 5.2.2. References are all within the main text.

Table A6.1: Hygiene interventions conducted in EME countries

Reference	Intervention
Black *et al*., 1981	Staff hand-washing: before handling food, after arriving at the centre, after helping a child to use the toilet, after using the toilet. Child hand-washing: children had their hands washed when they arrived, after they used the toilet or were diapered, before they ate.
Bartlett *et al*., 1988	Centre directors were taught management procedures for disease control (including separation of child groups, physical organization of diapering and toilet areas, requirements for environmental cleaning, management of sick children) and the hygiene-related tasks that the classroom staff were taught. Hygiene tasks included staff and child hand-washing, diapering, food handling and environmental cleaning.
Kotch *et al*., 1994	Staff were taught skills in hand-washing (of children and staff) and diapering, disinfection of the toilet and diapering areas, physical separation of the diapering areas from food preparation and serving areas, hygienic diaper disposal, the importance of the ready availability of soap, running water and disposable towels, schedule for toy cleaning.
Carabin *et al*., 1999	Hand-washing after arrival at the day care centre, after playing outside, after going to the bathroom and before lunch. Cleaning of toys and sand, opening windows.
Roberts *et al*., 2000	Staff were encouraged to teach hand-washing techniques to children and perform handwashes for infants. The recommended circumstances for hand-washing for staff and children were on arrival at the centre, after toileting or diapering, before eating. Toys were washed daily and staff who changed diapers were discouraged from preparing food.

Table A6.2: Hygiene interventions conducted in developing countries

Reference	Intervention
Khan, 1982	Hand-washing. Intervention groups were supplied with soap and water, just soap or just water. The control group was provided with neither soap nor water.
Torun, 1982	The educational programme was related to faecal contamination and diarrhoea.
Sircar *et al*., 1987	Hand-washing with soap, the subjects were provided with 2 cakes of soap and advised to use one cake after defecation and the other before handling/eating food.
Stanton *et al*., 1988	The education intervention was designed to improve 3 behaviours that had been shown to be associated with high rates of childhood diarrhoea: lack of hand-washing before preparing food, open defecation by children in the family compound and inattention to the proper disposal of garbage and faeces.
Alam *et al*., 1989	The danger of illness and the role of clean water and hygiene was explained. The following practices were encouraged: consistent and exclusive use of hand pump water and safe water handling and storage practices; disposal of faeces after defecation; washing hands after defecation and before handling food.
Han + Hlaing, 1989	Hand-washing with soap (provided) after defecation and before preparing/eating meals.
Lee *et al*., 1991	Education involving general health care and hygiene, symptoms and causes of diarrhoea and preventative health behaviour.
Wilson *et al*., 1991	Given soap and an explanation of the faecal-oral route of transmission and encouraged to wash hands before preparing food/eating and after defecation.
Ahmed *et al*., 1993	Hygiene education along three themes: ground sanitation (keeping babies from touching and eating disease-causing matter); personal hygiene (reducing the transmission of germs from defecation and other personal hygiene behaviours) and food hygiene (reducing the transmission of germs during supplementary and bottle feeding).
Wilson + Chandler, 1993	Follow up to the study by Wilson *et al*., 1991 – two years after the free soap supply stopped.
Haggerty *et al*., 1994a/b	Education encouraging: disposal of animal faeces from the yard; hand-washing after defecation and before meal preparation/eating; disposal of children's faeces.
Pinfold + Horan, 1996	Promotion of hand-washing, especially before feeding a baby, cooking, eating and after defecation or cleaning a baby's bottom. Dish washing immediately after eating also encouraged.
Shahid *et al*., 1996	Hand-washing with soap (provided).

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