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Overview and Meta-Analysis of Global Water, Sanitation, and Hygiene (WASH) Impact Evaluations

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Abstract

This paper presents an overview and meta-analysis of the effects of water, sanitation, and hygiene interventions around the world. It is based on 136 impact evaluations (randomized and quasi-experimental studies) that explore the effects of water, sanitation, and hygiene interventions on health and non-health outcomes, ranging from behavior change—such as the adoption of water treatment—to school attendance rates, to a reduction in diarrhea. The selected impact evaluations were divided into five groups, and meta-regressions with fixed effects (at the regional level) and random effects were performed, controlling for each study's characteristics (implementing organization, sample sizes, type of publication, number of publication views, and so forth). All results are reported as changes in odds ratios, with respect to the standard deviation of reported effects. Water, sanitation, and hygiene interventions were found to increase the likelihood of behavior changes and the adoption of new hygiene practices by 17 percent. The smallest effects were observed from water, sanitation, and hygiene interventions aimed at reducing the rates of child mortality and non-diarrheal disease. Water, sanitation, and hygiene interventions implemented in schools showed statistically significant results in reducing school absenteeism and dropouts. Similarly, the results showed a statistically significant aggregate likelihood of increased access to safe water and improved water quality, as well as increased water treatment options—a difference of one-fifth with respect to the standard deviation of the average effect size reported. Finally, the results showed that water, sanitation, and hygiene interventions reduced the likelihood of the incidence of diarrheal and enteric disease by 13 percent, which is consistent with findings in other meta-analyses of the same subject.

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Produced by the Research Support Team

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1. Introduction and Objectives

Access to safe drinking water, sanitation, and hygiene (WASH) is an important determinant of human health and socioeconomic well-being. Increased access aims to reduce rates of malnutrition, morbidity, and mortality, particularly of children. Economic benefits of WASH interventions are realized through a decreased dependency on health care services and an increased accumulation of human capital (Piper *et al*. 2017). Hence, improved health boosts productivity. Indeed, a lack of access to WASH services is estimated to be responsible for 20 percent of total deaths and disability-adjusted life years (DALYs) in children under 14 (Pruss-Ustun *et al.* 2008). Despite global efforts to ensure equitable access to these critical services, the 2017 Joint Monitoring Program for Water, Sanitation and Hygiene[2] estimates that 30 percent of all people lack access to safely managed drinking water services and 60 percent lack access to safely managed sanitation services (JMP 2015).

While the effects of WASH interventions on the reduction of diarrheal disease have been thoroughly documented (see, for example, Waddington *et al*. 2009), a comparable body of evidence on other outcomes of health and well-being, such as school attendance and children's growth, remains conspicuously absent. Moreover, WASH interventions, and consequently the studies designed to evaluate their effectiveness, have historically focused on water quality, while little is known about the effectiveness of other interventions. For example, despite the importance of behavior change to sanitation and hygiene, there is little evidence supporting its effectiveness in WASH interventions. Additionally, while the link between diarrheal disease and WASH services is undisputed, in their synthetic review evaluating the effectiveness of WASH interventions in reducing diarrhea in children, Waddington *et al.* (2009) identified methodological weaknesses that challenged the effectiveness of water treatment interventions. Furthermore, while most studies evaluated the effects of WASH interventions on diarrheal morbidity and others evaluated their effects on cholera, few evaluated their effects on mortality.

More recently, an exhaustive review of existing WASH knowledge concluded that more evidence is needed to optimize resources and better understand the social impacts arising from improved health outcomes (Hutton and Chase 2017). This is especially relevant given that the benefits of WASH interventions vary according to context (Waddington *et al*. 2009; Cumming *et al.* 2014), a phenomenon that has been understudied to date. Finally, given the magnitude of people impacted globally, and time and resource constraints, policy makers often face challenging ethical decisions when tasked with allocating resources to WASH programs. Consequently, understanding the evidence supporting the effectiveness of WASH interventions on outcomes of health and well-being is imperative to optimize results and improve the performance and sustainability of WASH programs in the long run.

An impact evaluation is an assessment tool used to determine the efficacy of an intervention while also assessing its design. Properly conducted impact evaluations provide high-quality evidence that help orient investment decisions, improve design policies, adjust ongoing interventions, and increase transparency and accountability. Since Waddington *et al.* undertook their synthetic review in 2009; a proliferation of impact evaluations of WASH interventions has been published. However, there are no dedicated research repositories and no known research endeavors that have sought to review and collectively analyze this additional evidence. Furthermore, as noted, the vast majority of impact evaluations conducted to date have focused on the effects of WASH interventions—notably, to

[2] A collaborative effort of the World Health Organization (WHO) and the United Nations Children's Fund (UNICEF).

improve water quality—on diarrheal morbidity. There is a clear need for a wider body of evidence on a broader range of WASH interventions and outcomes.

Therefore, the purpose of this study is twofold: (i) to collate new and existing evidence from impact evaluations of global WASH interventions into a single, publicly available repository; and (ii) to quantify the effects of a broad range of WASH interventions on an array of different outcomes, by performing a quantitative meta-analysis of available evidence.

Conducting a systematic review and meta-analysis of a single WASH-related outcome is a time-consuming endeavor. Expanding efforts to include the panoply of studies evaluating a diverse set of WASH outcomes around the globe is exponentially more laborious, as illustrated by the time lag between the commencement of this study and the publication of its results. Although a number of other, reputable impact evaluations and meta-analyses evaluating the effects of WASH interventions on single outcomes have been published since this study began in 2013, this study remains the first of its kind to compare and contrast the effects of WASH interventions on diverse health and nonhealth outcomes through a combined meta-analysis. As such, this study represents a critical, historical review of the effects of global WASH interventions that could be a valuable starting point for any future evaluation.

2. Selection of Impact Evaluations

2.1 Inclusion Criteria

To ensure the integrity of this review, only evidence-based studies were included, that is, studies that rigorously measured impacts attributed to WASH interventions. Studies falling into this category include evaluations that identify causality between interventions and outcomes of interest by estimating the true effect (or impact) of an intervention on particular outcomes and applying counterfactual analyses (comparing intervention outcomes with what would have occurred in the absence of the intervention). Thus, all studies included in this review reported impact estimates along with their standard error, as is customary when conducting a meta-analysis.

In terms of research methods, randomized controlled trials (RCTs) are considered the gold standard for establishing a causal attribution between interventions and outcomes. However, the choice to conduct an RCT may be limited by ethical considerations or study design, in which case experimental or quasi-experimental methods are instead applied. This review incorporates studies where RCTs, experimental design, and quasi-experimental evaluation methods were applied.

In summary, only studies meeting the following criteria were included in this review: (i) they were completed before 2014 (ongoing evaluations or baseline findings not included); (ii) their results have been fully disclosed; (iii) they included quantitative evaluations with discernible comparison groups or an estimation of counterfactuals; and (iv) they included a clear, acceptable description of the impact identification strategy, as well as a description of the formal method used for comparison.

2.2 Search Methods

As this review focuses exclusively on evidence-based impact evaluations, an extensive yet targeted search of published and unpublished material was conducted. The primary source of published material was the Register of Impact Evaluation Published Studies (RIEPS) database, a comprehensive digital warehouse of impact evaluations with registered protocols in PubMed managed by the International Initiative for

Impact Evaluation (3ie). Additionally, given that the effectiveness of WASH interventions is often measured by the health outcomes of the target population, published material from the Cochrane Library (as well as the Database of Abstracts of Reviews of Effects [DARE], accessed via the Cochrane Library) was also included. Finally, published and unpublished materials were sourced from various research institutions including the World Bank, regional development banks (such as the Inter-American Development Bank, IDB), research centers, universities, nongovernmental organizations (NGOs), and other organizations (see Appendix B for a full list of databases searched).

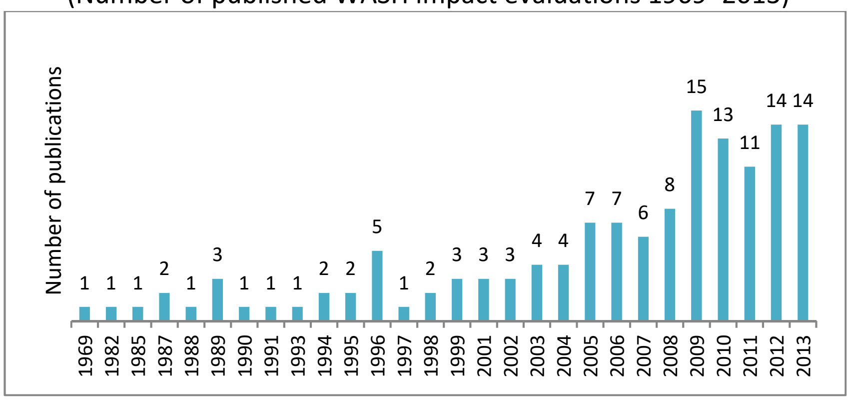
The initial search gave rise to approximately 850,000 studies. A keyword search was then conducted using the following terms and combinations of terms: "water and sanitation," "water sanitation," "water supply," "sanitation," "handwashing," "water + hygiene," and "water + sanitation + hygiene." Study designs were restricted to RCTs, and experimental and quasi-experimental evaluation methods. This refined search resulted in 136 studies[3] used to construct the data set for this meta-analysis.

2.3 Data Collection and Coding

WASH-related impact evaluations have been published at a steadily accelerating rate over the past decade. Almost 50 percent of the evaluations included in this review were published after 2008 (Figure 1). Of those, almost half were evaluations of WASH programs that combined more than one intervention, reflecting their increased popularity in recent years.

Figure 1. Big Uptick in WASH Impact Evaluations since 2009

(Number of published WASH impact evaluations 1969–2013)



Source: World Bank GWSP-SIEF WASH Impact Evaluation Database.

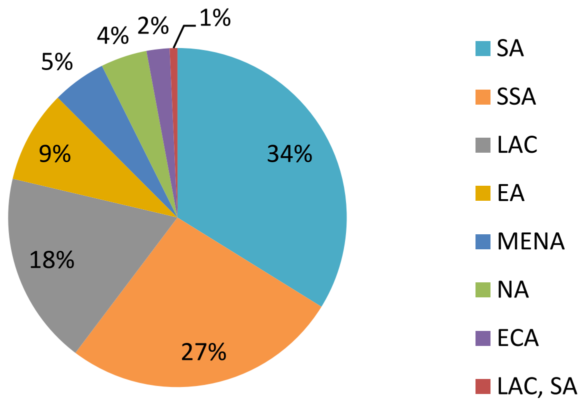
Geography

Studies appear to be geographically biased; 80 percent are concentrated in just three regions: South Asia (34 percent), Sub-Saharan Africa (27 percent), and Latin America and the Caribbean (18 percent) (Figure 2). This finding is not particularly surprising given the significant lack of basic services in these areas. However, the scant attention paid to other regions, notably East Asia and the Pacific, the Middle East and North Africa, and Europe and Central Asia, points to a gap that future research could fill. In addition, only five publications examined multicounty or multiregional interventions. The country with the largest number of studies was India (18), followed closely by Bangladesh (16) and Kenya (12). Approximately 67

[3] The 136 impact evaluations reviewed in this study were used to create an updated database of research papers, systematic reviews, and meta-analyses of the sector publicly available at: http://www.wsp.org/library.

percent of all studies were conducted in rural environments, while 29 percent analyzed urban and peri-urban populations, and 5 percent analyzed interventions in both rural and urban settings.

Figure 2. Regional Distribution of Studies



Source: World Bank GWSP-SIEF WASH Impact Evaluation Database.
Note: SA = South Asia, SSA = Sub-Saharan Africa, LAC = Latin America and the Caribbean, EA = East Asia and Pacific, MENA = Middle East and North Africa, NA = North America, and ECA = Europe and Central Asia. The LAC, SA category (1 percent) represents studies done jointly in both regions.

Interventions

Studies were classified into one of five conventional subgroups by type of WASH intervention: *hygiene, sanitation, water quality, water supply,* and *multiple* (Table 1).

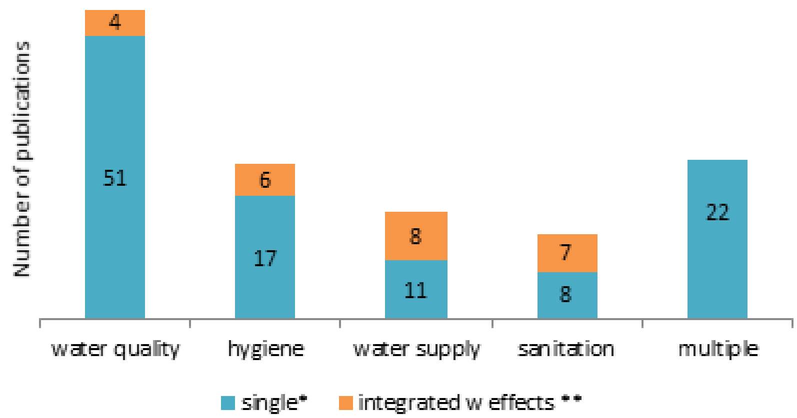
Table 1. Description of WASH Intervention Subgroups

Intervention	Description
Hygiene	Sought to prevent the oral transmission of pathogens through proper handwashing after defecation, before and after handling food, and cleaning infants. Often combined with handwashing infrastructure, water storage and management, training in household waste management, and strong educational components designed to drive behavioral change.
Sanitation	Aimed to prevent the transmission of disease by correctly separating feces, especially in rural areas, by: (i) improving waste disposal facilities; (ii) building simple sanitation facilities (e.g. latrines, toilets, etc.); and (iii) building complex infrastructure (e.g., sewage systems). Although some of the interventions were innovative, such as subsidized training in the adoption of new technologies, most relied on information campaigns to reduce open defecation, promote utilization of facilities, and adopt healthy behaviors.
Water quality	Interventions that tested affordable point-of-use treatments, such as flocculation, chlorination, solar treatment, and ceramic filters, to remove pathogens or prevent them from entering water collected for drinking or food preparation. Most such efforts took place in remote and vulnerable environments, were implemented by nongovernmental organizations, and were small-scale and thus involved small sample sizes.
Water supply	Designed to ensure access to sufficient water for basic hygiene through: (i) new sources (wells, springs, etc.); (ii) reconstructing and maintaining current infrastructure (network rehabilitation, piped water, etc.); and (iii) introducing management and financial support innovations to spur access (such as credit, private-public partnerships, and community participation).
Multiple	Efforts that included two or more interventions in combination.

Source: World Bank GWSP-SIEF WASH Impact Evaluation Database.

In the case of studies evaluating multiple interventions, any specific effects reported were included in the relevant intervention subgroup and accounted for as integrated with effects. For example, a study of water supply and sanitation interventions in Pakistan (Rauniyar 2009) reported separate impacts for water supply, which was included in the water supply intervention subgroup (Figure 3).

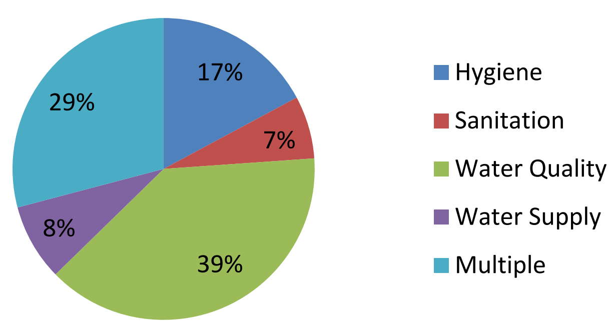
Figure 3. Water Quality Interventions Dominate WASH Impact Evaluations
(by type of intervention)



Source: World Bank GWSP-SIEF WASH Impact Evaluation Database.
Note: Interventions are counted in all publications.

Studies assessing the effectiveness of interventions aimed at improving water quality are the most common, accounting for 39 percent of the 136 studies (Figure 4), followed by interventions related to hygiene (17 percent), water supply (8 percent), and, finally, sanitation (7 percent). Multiple or combined WASH interventions were reported in 29 percent of all studies evaluated.

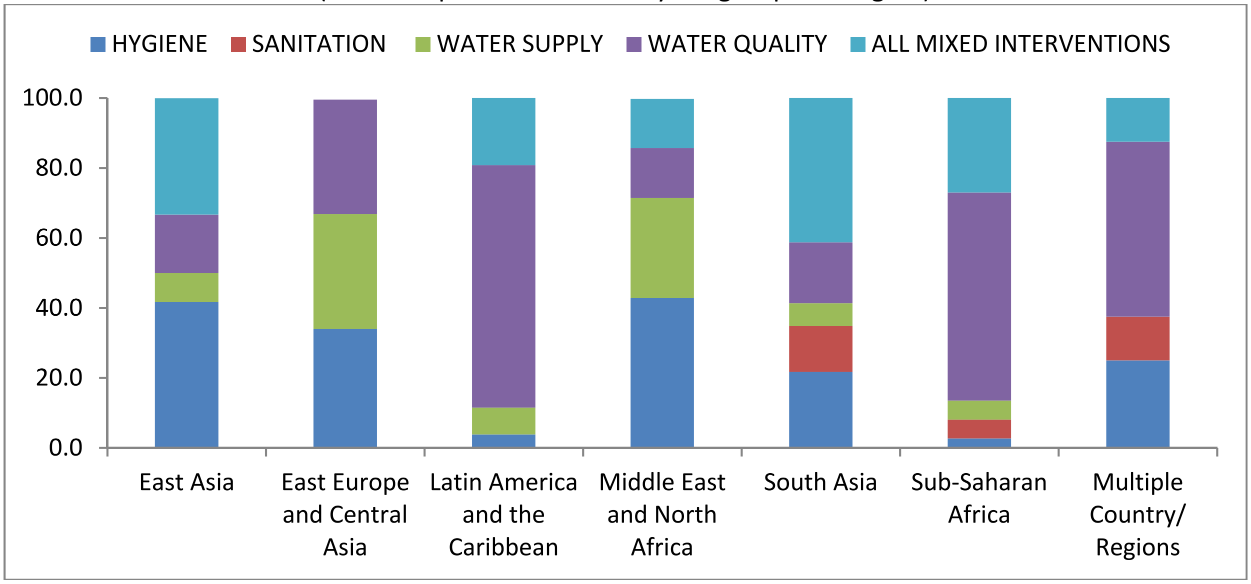
Figure 4. Distribution of Interventions by Subtheme



Source: World Bank GWSP-SIEF WASH Impact Evaluation Database.

The prevalence of WASH interventions evaluated varies greatly by region (Figure 5). Hygiene interventions were most common in East Asia and the Pacific and the Middle East and North Africa. Water quality interventions dominated in Latin America and the Caribbean and Sub-Saharan Africa, accounting for 80 percent and 60 percent of all studies, respectively. In Eastern Europe and Central Asia, studies were split evenly between water quality, water supply, and hygiene interventions. In South Asia, the region with the most studies targeting combined interventions (41 percent), the focus was split relatively evenly between hygiene, water quality, and sanitation. Overall, sanitation interventions were the focus of studies in only three regions: North America, South Asia, and Sub-Saharan Africa. Finally, at the country level the most common intervention in India was sanitation, whereas in Bangladesh, handwashing evaluations prevailed, along with trials of point-of-use devices for water treatment.

Figure 5. Different Regions Focus on Different Types of Interventions
(WASH impact evaluations by subgroup and region)

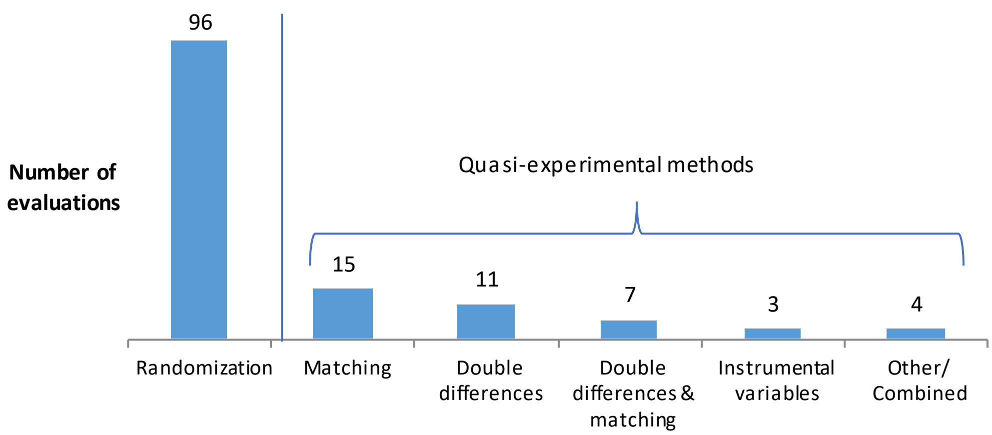


Source: World Bank GWSP-SIEF WASH Impact Evaluation Database.

Research Methods

Most studies included in this review (71 percent) were experimental, mainly RCTs (Figure 6). In such a design, the intervention is offered randomly to a subset of the eligible population (the treatment group), while assigning the rest of that population to the control group.

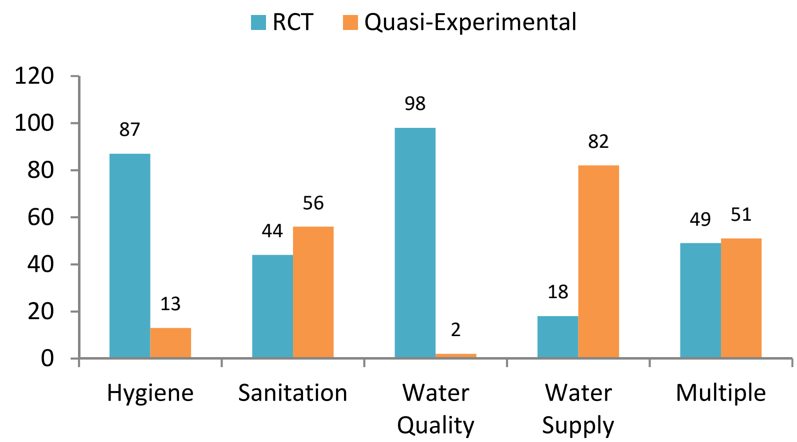
Figure 6. Randomization Far Exceeds Quasi-Experimental Approaches
(Identification strategy for WASH impact evaluations)



Source: World Bank GWSP-SIEF WASH Impact Evaluation Database.

Where RCTs could not be used, quasi-experimental research methods were applied, in this case, typically for studies involving multiple interventions and sanitation programs. Of these, 45 percent used matching methods to build a counterfactual and nine studies used matching to pair subsamples. Likewise, matching and double-differences methods were applied for large-scale programs pertaining to infrastructure construction or rehabilitation, and water access uptake. Instrumental variables were applied in only three studies in Asia, while regression discontinuity studies were thoroughly absent. Figure 7 presents the distribution of study research methods by intervention.

Figure 7. Distribution of Research Methods by Intervention Subgroup (%)



Source: World Bank GWSP-SIEF WASH Impact Evaluation Database.

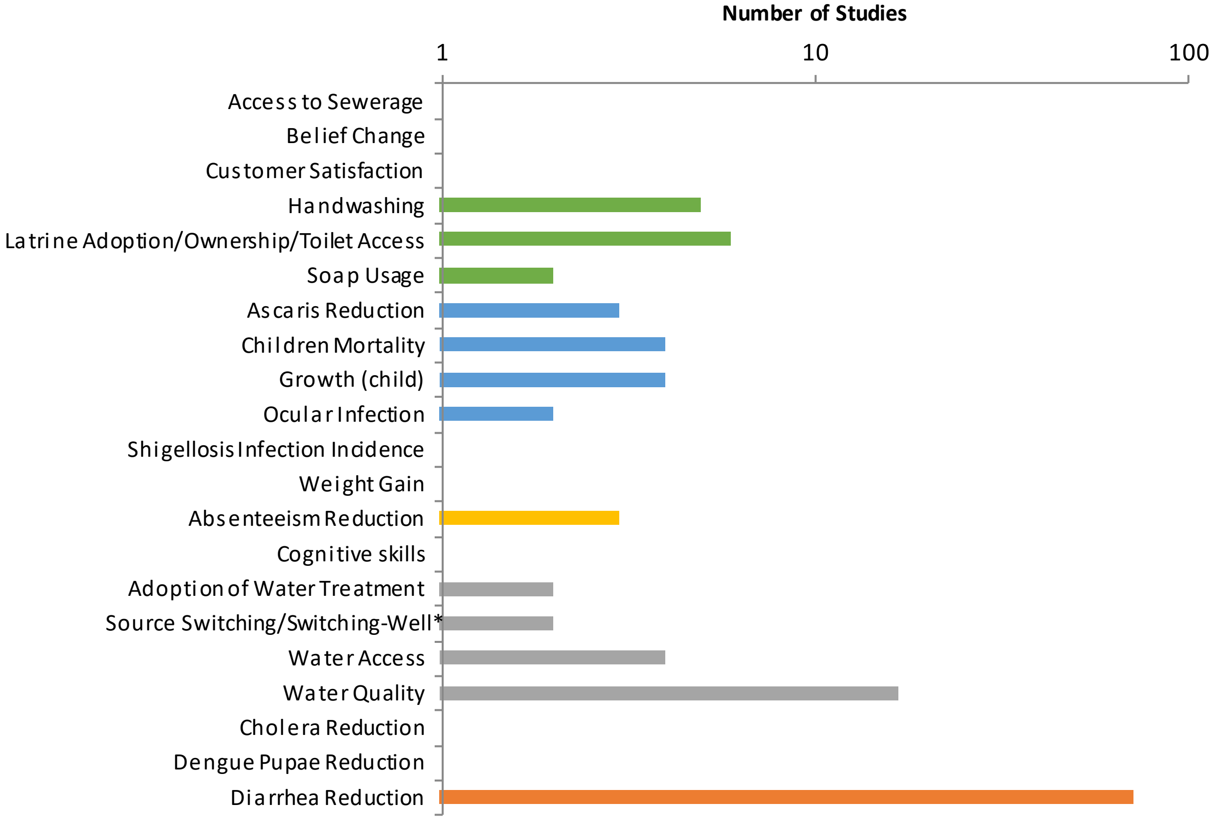
Note: The total number of papers listed here is greater than 136, given that some papers included more than one intervention.

Outcome Indicators

Twenty-two unique outcomes were identified.[4] When an evaluation presented more than one outcome for each intervention, the outcome with the most significant effect was used in the meta-analysis. The prevalent unit of analysis (and unit of sampling) was children or households with children. Not surprisingly, the most frequently measured outcome was diarrhea (prevalence or incidence). This was used in more than half of all evaluations (Table 3), either as a single outcome or in combination with another indicator. The second-most frequently measured outcome was water quality (accounting for 13 percent of the total), which was classified as a direct output of water purification (or disinfection) interventions. Most of these studies used chemical tests at the household level as a proxy for water quality, for example, particle suspension.

[4] Studies evaluating the effects on enteric disease reduction (5) were classified separately from studies evaluating the effects on diarrhea reduction (72), giving rise to 22 unique outcomes. However, for the purposes of the meta-analysis, both outcomes were combined into a single group.

Figure 8. Distribution of Outcomes



Source: World Bank GWSP-SIEF WASH Impact Evaluation Database.

Note: In this figure, diarrhea reduction includes five studies on enteric disease reduction. ** Source Switching/Switching-Well refers to any WASH intervention that, directly or indirectly, induced a change in water source from basic or unimproved to improved.*

Effect Sizes

A number of systematic reviews have been conducted to assess the impacts of WASH interventions on the prevalence and incidence of diarrhea (Esrey, Feachem, and Hughes 1985; Esrey *et al.* 1991; Fewtrell *et al.* 2005; Clasen *et al.* 2006, 2010; Arnold and Colford 2007; Ejemot *et al.* 2008; Waddington *et al.* 2009; Norman, Pedley, and Takkouche 2010). However, these reviews were not limited to studies that identified a causal attribution between interventions and outcomes.[5] Other, more recent, meta-analyses of WASH interventions frequently focused on only one outcome of interest.

A recent trend in WASH meta-analyses includes limiting the number of studies to those with experimental designs that identify the causal attribution between the intervention and a given outcome of interest.

[5] In an experimental evaluation (RCT), the treatment and comparison groups are selected from the target population by a random process. Therefore, comparison between control and treatment groups to explore causal attribution between the intervention and outcomes of interest is statistically valid. Quasi-experimental designs estimate the counterfactual by conducting measurements of a nonrandomly selected comparison group. In many cases, intervention participants are selected based on certain characteristics, whether it is the level of need, location, social or political factors, or other factors. In such conditions, quasi-experimental designs estimate a valid counterfactual through statistical and econometric methods.

For instance, Freeman *et al*. (2017) conducted a meta-analysis to estimate pooled measures of the effects of different levels of sanitation services on infectious diseases and nutritional outcomes, primarily using studies with an experimental design. Stocks *et al*. (2014) suggested sanitation services protect against diarrhea, active trachoma, some soil-transmitted helminth (STH) infections, schistosomiasis, and height-for-age reductions, and have no protective effect against other anthropometric outcomes. However, their meta-analysis also highlighted the poor quality of the estimation methods used in the papers selected for study.

Garn *et al*. (2017) conducted a meta-analysis of 24 studies to examine the association between structural design characteristics of sanitation facilities and facility use, and found that most sanitation interventions had only a modest impact on increasing latrine coverage and use.[6] The authors combined the effects of sanitation interventions into a single outcome: latrine adoption and usage.

Studies that assessed health outcomes using RCTs[7] generally showed significant effects on the prevalence of diarrhea and waterborne diseases such as cholera (Taylor *et al*. 2015). In contrast, differences in the incidence of diarrhea across groups were not significant in four quasi-experimental studies. Evidence on other health-related variables (e.g. child mortality, stunting, height, and weight) was scarce and limited to single studies, except for small-scale studies evaluating combined interventions, which reported significant effects on mortality and stunting.

The evidence related to water quality was relatively solid, given that 75 percent of the trials that tested reductions in bacterial contamination reported strong effects. These studies were typically RCTs, implemented in rural zones, with in-situ collection of water samples. Many of these were not explicitly labeled as water quality interventions, yet included a purification/filtration component as a complementary add-on (frequently flocculants, chlorination, and ceramic filters) to strengthen the expected effect. In these combined interventions, the positive relationship was less evident and in 57 percent of the studies the effects were mixed.

Access to WASH was generally considered an intermediate outcome, since access is a direct result of water supply and sanitation interventions, especially those focused on improving infrastructure. Increases in access were well documented for water supply interventions and in seven out of eight studies effects were statistically verified. For on-site water access, rigorous RCTs showed that outcome effects were half those of studies that relied on other methods to identify effects, which is consistent with what is reported by Ercumen, Gruber, and Colford (2014). In combined interventions the results were not strong, especially for outcomes difficult to measure (such as collecting time and distance).

WASH interventions are increasingly adding multiple components to achieve greater impacts on access, health, behavior change, and other socioeconomic indicators. Historically, WASH interventions have been skewed toward targeting particular health outcomes (such as reducing the incidence of diarrhea), negating other important outcomes. However, recent trends in WASH impact evaluations suggest more complex interventions can deliver results in multiple areas of development and well-being.

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[6] A recent meta-analysis of hygiene interventions found an average risk ratio for diarrhea of 0.60 for the promotion of handwashing with soap (95 percent CI: 0.53–0.68) and an average risk ratio of 0.76 for general hygiene education alone (95 percent CI: 0.67–0.86) (Hutton and Chase 2016; Freeman *et al*. 2014). Other systematic reviews found a relative risk for respiratory infection of 0.84 (0.79–0.89) compared with no handwashing (Rabi and Curtis, 2006).

[7] Including other research design methods such as quasi-RCTs, non-randomized controlled trials, controlled before-and-after studies, and cross-sectional and uncontrolled before-and-after studies.

A large set of studies strongly supported the effectiveness of water treatment (i) on-site,[8] (ii) across the supply, and (iii) at the source in reducing children's exposure to diarrhea. Other studies indicated the effectiveness of combining water quality and hygiene interventions (including the provision of soap for handwashing and hygiene information campaigns) in reducing several diarrhea-related indicators (e.g. rates of incidence, episodes per person, and prevalence).

In general, impact evaluations that included a large number of studies as well as those that applied more rigorous research methods had less ambiguous results. Specifically, individual RCTs reported significant reductions in dysentery, influenza, shigellosis, conjunctivitis, respiratory diseases, parasite infections, and impetigo. Water supply interventions also produced strong reductions in enteric and other health-related diseases. Conversely, impact evaluations that included only a small number of studies and studies that focused on respiratory illnesses, child growth, ocular infection, and mortality had mixed results.

Effects on widespread waterborne diseases (such as gastroenteritis, cholera, hepatitis, amoebiasis, and adenovirus) were scarcely analyzed in the studies included in this overview. Yet diarrhea, ultimately a symptom, reported in most cases as a dependent variable, may be related to the diagnosis of those diseases whose incidence is not typically measured as an outcome. Other outcomes, such as the adoption of healthy practices, take-up rates, and behavior changes, did not show a definitive causal relationship to WASH interventions and require further empirical exploration.

Evaluations of combined interventions tended to consider behavioral outcomes. Such evaluations are important to understand if a combination of behaviors and the provision of physical infrastructure are driving impact results. However, at this point, 70 percent of behavior outcomes come from single-intervention evaluations of either hygiene or water quality trials (Figures A1 and A2).

4. Meta-Analysis

Different WASH interventions produce different results for the same outcome. For instance, water quality studies using a relatively common measurement of water treatment and health outcomes (e.g. incidence of diarrhea) varied widely in their estimates of the magnitude of outcome effects, depending on the approach or technology used. Thus, meta-analysis is required to aggregate the point estimates and generalize the results. Ideally, all study designs are expected to have an adequate sample size; however, historically most WASH impact evaluations have been underpowered and have included small-scale interventions. To counteract this problem, meta-analysis is a powerful statistical tool that estimates the overall effects of different programs by pooling data that on their own would be too small to draw confident conclusions. The conclusions of a meta-analysis are nonetheless based on the quality of the studies identified to estimate the pooled effect.[9]

4.1 Heterogeneity

To assess heterogeneity, papers were categorized by geographical region and intervention subtheme and plotted against the standard error and precision of estimates. Figure A3 (see Appendix A) illustrates high

[8] Neither chlorine treatment nor solar disinfection had significant impacts on diarrhea after a meta-analysis adjusted for the nonblinding of the intervention, although an earlier systematic review and meta-analysis of water quality interventions found household-level treatment was more effective than source treatment (Hunter *et al*. 2009).
[9] The quality of randomized impact evaluations was evaluated and included with regard to the randomization, adequate assignment, and explanation of dropouts and withdrawals; this addresses the issues of both internal validity (minimization of bias) and external validity (ability to generalize results).

variation (or heterogeneity) in standard errors for the entire sample of impact evaluations. This is not surprising given that 90 percent of the impact evaluations were RCTs. To the contrary, the variation in correlations of outcome effects (pcorr) is generally low (or homogenous) across subgroups and especially so for sanitation and water supply.

Smaller sample sizes may overestimate effects while larger sample sizes increase sensitivity; thus, meta-analysis generally improves statistical power by increasing sample size. There is no correlation between sample size and outcome effects in the publications included in this review (Figure A4 in Appendix A), suggesting that studies with smaller sample sizes are not exerting undue influence on overall effects, and that the minimum requirements for internal and external validity have been met.

4.2 Bias

Evidence of potential regional bias was detected in two areas, North America and South Asia (Table 2). South Asia represented the largest subset of studies; however, the estimate was imprecise and the standard error relatively high and therefore unlikely to have exerted significant bias on the pooled outcomes. On the contrary, the subset of studies from North America was limited to six well-designed evaluations that estimated the effects of WASH interventions on diarrhea, and these may have disproportionately influenced the pooled outcomes (Table 2).

Table 2. Heterogeneity Estimates by Region

	East Asia and Pacific	Europe and Central Asia	Latin America and the Caribbean	Middle East and North Africa	North America	South Asia	Sub-Saharan Africa
Slope (Precision)	2.986***	0.660	2.904***	1.796**	1.487***	0.975	3.053***
	(0.966)	(0.472)	(0.935)	(0.882)	(0.312)	(2.068)	(0.992)
Bias	-0.245	-0.149	-0.0111	-0.171	-0.256***	1.222**	0.134
	(0.190)	(0.0899)	(0.222)	(0.159)	(0.0598)	(0.536)	(0.265)

Source: World Bank GWSP-SIEF WASH Impact Evaluation Database.
Note: Standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1.

Finally, Figure A5 (in Appendix A) illustrates evidence of comparability between publications given the number of views per publication and limited outliers. The size of the circles indicates the number of views and the closer and more overlapped the circles, the higher their comparability.

4.3 Effects Trends

At least two different studies per outcome are needed to perform a meta-analysis. Thus, only the results for 13 of the 21 outcome indicators were included in the meta-analysis. Table 3 lists the estimated effects and types of interventions for the remaining eight outcomes. In terms of risk differences, studies assessing access to sewerage and incidence of shigellosis infection showed the highest effects, +0.20 and -0.22, respectively. Among risk ratios, behavior change and child weight gain were the only statistically significant outcome effects with a reported mean higher than 1. One study measuring cholera reduction showed the third-highest risk ratio coefficient of 0.48, which was statistically significant.

Table 3. Effects of Outcomes with Single-Impact Evaluations

Outcome	Intervention	Effect Measure	Effect	Significance
Access to sewerage	Multiple	Risk difference	0.20	*
Behavior change	Hygiene	Risk ratio	1.11	*
Cholera reduction	Water quality	Risk ratio	0.48	**
Cognitive skills	Sanitation	% variation	0.30	**
Satisfaction	Water supply	Risk difference	0.13	*
Dengue pupae reduction	Multiple	Risk ratio	0.34	**
Shigellosis infection incidence	Hygiene	Risk difference	-0.22	**
Child weight gain	Water quality	Risk ratio	1.27	*

Source: World Bank GWSP-SIEF WASH Impact Evaluation Database.
Note: * p-value<0%, ** p-value<5%.

Table 4 summarizes the results of the meta-analysis for the remaining outcomes. Overall, there are three outcomes (adoption of water treatment, incidence of ocular infection, and source switching) for which the heterogeneity of effects, combined with the heterogeneity effects of small sample sizes, led to statistically insignificant aggregate results. The pooled effects of WASH interventions on the remaining 10 outcomes were statistically significant. In particular, the odds of missing school were reduced by a factor of 0.69 for students who had benefited from a WASH intervention. Similarly, children who received a WASH intervention were 1.44 times as likely to use soap, 0.5 times as likely to develop *Ascaris* infections, 0.65 times as likely to develop diarrhea (however, this particular result may be inflated due to the potential bias of the six studies from North America), and 0.91 times as likely to die than children not receiving one. Finally, child growth, handwashing, and latrine adoption increased by 26, 8, and 22 percent, respectively, and water quality improved by 20 percent.

Table 4. Pooled Effects of Outcomes with Multiple Impact Evaluations

Outcome	Effect Measure	Effect	Significance
Adoption of water treatment	Risk ratio	1.35	-
Ocular infection	Odds ratio	0.91	-
Soap usage	Risk ratio	1.44	**
Source switching	Risk difference	0.04	-
School absenteeism	Odds ratio	0.69	**
Ascaris reduction	Risk ratio	0.47	**
Child mortality	Risk ratio	0.91	**
Child growth	Risk difference	0.26	**
Water access	Risk difference	0.09	**
Handwashing	Risk difference	0.08	**
Latrine adoption/ Toilet access	Risk difference	0.22	**
Water quality	Risk difference	0.21	**
Diarrhea reduction	Risk ratio	0.65	**

Source: World Bank GWSP-SIEF WASH Impact Evaluation Database.
Note: * p-value<10%, ** p-value<5%.

4.4 Meta-Regression

Table 5 presents the results of the meta-regressions of the correlation of study outcomes against study characteristics hypothesized to be associated with the studies' effects (variables) for the entire meta-analysis data set. Overall, three study characteristics appeared to be significantly correlated with outcomes, namely, the type of WASH intervention, which showed a slight positive correlation, and reporting metric (risk difference) and implementing entity (government), which showed slight negative correlations.

The number of publication views is also slightly, but significantly, correlated to outcomes, which is intuitive and may be indicative of studies seeking to build upon the evidence of their predecessors. Moreover, the direction of the relationship is negative, which could suggest well-known studies are eventually refuted over time, indicative of good practice and conducive to the well-being of the sector as a whole. Overall, very few variables were significantly correlated and standard errors were robust. Thus, the regression model was correctly specified, and 57 to 65 percent of the variation in correlations can be explained by the selected study characteristics.

Table 5. Correlation of Outcomes against Study Characteristics for the Entire Meta-Analysis Data Set

Variables	Model (1) Study Correlation (pooled effects)	Model (2) Study Correlation (group dummies)	Model (3) Study Correlation (group dummies)
Region fixed effects	No	No	Yes
Number of views	-0.0113***	-0.0113***	-0.0110**
	(0.00413)	(0.00360)	(0.00444)
Journal, dummy	-0.00501	-0.00501	-0.00823
	(0.00908)	(0.00792)	(0.0109)
Report/chapter, dummy	-0.0213	-0.0213*	-0.0194
	(0.0133)	(0.0116)	(0.0178)
Single intervention, dummy	-0.00726	-0.00726	-0.00589
	(0.0116)	(0.0101)	(0.0118)
Randomized assignment, dummy	-0.00142	-0.00142	0.00184
	(0.00804)	(0.00701)	(0.00994)
Child health, growth outcomes group	-0.00409	-0.00409	-0.00317
	(0.0117)	(0.0102)	(0.0146)
Risk difference (RD) effect, dummy	-0.0389***	-0.0389***	-0.0433***
	(0.0140)	(0.0122)	(0.0109)
Subtheme groups, categorical	0.0319***	0.0319***	0.0337***
	(0.00715)	(0.00623)	(0.00548)
Years of implementation, cont.	-1.153	-1.153	-0.220
	(1.494)	(1.301)	(1.630)
Government implemented, dummy	-0.0219**	-0.0219***	-0.0259**
	(0.00870)	(0.00758)	(0.0120)
Sample size, continuous	-0.00227	-0.00227	-0.00167
	(0.00389)	(0.00339)	(0.00370)
Urban interventions, categorical	-0.0141	-0.0141*	-0.0175
	(0.00925)	(0.00806)	(0.0110)
Constant	8.906	8.906	9.821
	(11.36)	(9.895)	(12.39)
Observations	136	135	104
R-squared	0.621	0.573	0.650

Source: World Bank GWSP-SIEF WASH Impact Evaluation Database.
Note: Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

5. Meta-Analysis of Subgroups

To facilitate the meta-analysis,[10] and analyze the association between outcome effects and study characteristics in detail, outcomes were classified into five thematic subgroups based on expert review and according to conventional WASH themes. When the regression model for the entire meta-analysis data set was controlled for these outcome subgroups there was no statistical difference (Table 5), and the meta-analysis was therefore repeated at the group level without compromising the integrity of the results.

5.1 Heterogeneity of Subgroups

Forest plots show differences in the results, methodology, or study populations used in the studies included in a meta-analysis. The pooled results of a forest plot show the overall combined result derived from combining (pooling) the individual studies. A forest plot was constructed to illustrate these elements for each of the five subgroups (see Figure A8 in Appendix A). The forest plots showed that the pooled effects are not within the area of "no effect" for: water quality, treatment, and access; diarrhea reduction; and hygiene, soap usage, handwashing, and latrine adoption. The pooled effects on school absenteeism were large and significant but based on too few studies to draw statistical conclusions. The pooled effects corresponding to other health outcomes including child mortality, growth, nutrition, ocular infection, and *Ascaris* reduction showed ambiguous results (and for some papers were in the "no effect" area[11]).

Group 1, which primarily included outcomes related to behavior change and sanitation, comprised 16 studies across all intervention subgroups, except water supply, and were concentrated in the South Asia region. There was limited correlation between estimated effects, and the standard error was fairly homogenous across studies with the exception of the multiple interventions subgroup in Sub-Saharan Africa (Figure A6 in Appendix A).

Group 2 comprised 15 studies related to growth and mortality in children combined with infectious diseases (namely water-washed diseases), across three intervention subgroups concentrated in the Sub-Saharan Africa region. The variation in correlation between estimated effects across studies was clearly low, while the variation in standard errors was high (Figure A6).

Group 3 included four papers related to cognitive skills and school absenteeism, across two intervention subgroups and only three regions. The correlation between estimated effects was effectively zero yet there was some variation in standard errors (Figure A6).

Group 4 included 25 studies related to water supply and water quality outcomes across all intervention subgroups except sanitation, although water quality and multiple interventions dominated. The studies were primarily concentrated in Latin America and the Caribbean, South Asia, and Sub-Saharan Africa. There was limited variation between correlations of estimated effects across studies. To the contrary,

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[10] Aggregating outcomes ensured there was sufficient variation in sample sizes, effects, and standard errors to conduct the meta-analysis, while increasing the statistical power.

[11] The null effect of 1 corresponds to a statistic similar to an odds ratio (OR) or a relative risk (RR). Alternatively, the statistic being used might be "absolute" such as absolute risk reduction (ARR) or standardized mean difference (SMD). Knowing the difference between relative and absolute statistics is important because it affects which number sits at the vertical line. For absolute statistics such as absolute risk or ARR or SMD, the null difference value is 0. However, this was not used in this analysis.

there was a high variation of standard errors across all studies owing to the high variability in water quality studies in Latin America and the Caribbean and multiple interventions in South Asia (Figure A6).

Finally, Group 5, which pertained to diarrhea and enteric disease, comprised 79 studies, the highest number of all groups, distributed comparatively evenly across subgroups and regions. The variation in correlations of estimated effects was relatively low across subgroups except for water supply, especially in Sub-Saharan Africa. The variation in standard errors across all papers was high, especially for water quality in Latin America and the Caribbean (Figure A6).

In summary, all the groups showed low variations in correlations between outcome effects, making them highly suitable for pooling. However, slight heterogeneity was detected in Groups 4 and 5 because of the high variability in standard errors.

5.2 Bias of Subgroups

Funnel plots were constructed for each subgroup (Figure A7 in Appendix A) to assess potential bias. There is no evidence of asymmetry for Groups 1 through 4, and bias is unlikely. In the case of Group 5, while the outcome effects are relatively evenly distributed when considering all studies, the distribution of larger, more precise studies is skewed, suggesting an absence of studies. However, since most of the missing studies fall within an area of high significance, asymmetry is unlikely to have resulted from reporting bias. Group 5 includes the six highly influential studies from North America, and thus aligns with the findings from the full data set and may be the source of asymmetry.

5.3 Meta-Regression

Table A1 (see Appendix A) presents the results of a meta-regression of the correlation of study outcomes to study characteristics (variables) for each group; Table A2 presents the results of a meta-regression of study characteristics on the pooled effects by group.

In the case of Group 1, studies conducted in Latin America and the Caribbean and South Asia were slightly correlated, indicating similar evidence bases in those regions. Sample size produced a slight, but significantly inverse, effect, which is somewhat counterintuitive given that larger sample sizes often lead to greater representation. Effectively, the number of studies is positively correlated with outcome effects, suggesting more studies may lead to improved results. Quasi-experimental (or nonrandomized program assignment) designs are negatively correlated with outcome effects, suggesting experimental designs (RCTs) are more likely to produce reliable results. Similarly, studies undertaken in urban areas are positively correlated with outcome effects, suggesting urban studies may produce better results than their rural counterparts. This is not surprising, given that all four evaluations conducted in urban areas used randomized methods, and studies in rural areas predominantly used quasi-experimental methods.

There was less evidence of correlation between papers in Group 2 than in all other groups except Group 3, which may indicate a lack of relationship between the different studies. Further, it may suggest that individual outcome effects are not easily explained by study characteristics. Indeed, none of the study characteristics evaluated was significantly correlated with outcomes in Group 2, which indicates a diverse set of studies that, when compared with Group 1, for example, exerts less influence on overall effects.

The ability to draw significant conclusions regarding Group 3 was limited by its small size. Nonetheless, there does not appear to be a relationship between study characteristics and outcomes here. Similarly, studies conducted in the same region were not correlated.

Studies within Group 4 were more homogenous than those of any other group, although most correlations were weak. This may be due to studies testing complementary interventions or impact evaluations being replicated in different locations. Experimental research methods (RCTs) and the implementing agency were both factors that contributed to the correlation between papers. The number of studies was significantly correlated to outcome effects and explained 78 percent of the variation, suggesting larger data sets produce more reliable results.

Finally, while certain aspects of papers within Group 5 were also significantly correlated, these papers had the widest variation in outcomes of all groups, making them especially suitable for aggregation. Two study characteristics were significantly and highly correlated with outcomes: i.e., study locale and implementing agency. Studies implemented by government agencies had a significant, negative impact on outcome effects, suggesting interventions implemented by NGOs produce more reliable results. Studies conducted in urban areas (64 percent of all studies) had a significant, negative impact on outcome effects even though all but one of those studies were implemented by NGOs.

6. Discussion

Overall, there has been a large increase in WASH-related impact evaluations over the past decade. Studies have been concentrated in the most underserved areas, while the East Asia and Pacific, Europe and Central Asia, and Middle East and North Africa regions remain underrepresented. Despite a large increase in studies evaluating combined WASH interventions, few evaluations target multicountry or multiregional interventions. Water quality interventions dominate impact evaluations, especially in Sub-Saharan Africa and Latin America and the Caribbean. This finding is not surprising, given that the more quantitative nature of water quality interventions makes them suitable for experimental methods. Although sanitation interventions were very common in India and behavior change interventions dominated in Bangladesh, these interventions were generally underrepresented in impact evaluations, making it difficult to assess regional effectiveness.

Despite a relatively high number of unique outcomes, more than half of all evaluations focused on diarrhea. This review corroborates the earlier findings of Hutton and Chase (2017) and Esteves Mills and Cumming (2016) that the positive effects on diarrhea reduction are well established and thoroughly documented, particularly for handwashing with soap and water quality trials. However, while experimental designs resulted in significant effects, quasi-experimental designs did not produce the same results.[12]

Evidence from the nonpooled studies on behavior change and other health-related outcomes (e.g. child mortality, stunting, height, and weight) is scarce, and predominantly limited to single studies, although small-scale studies evaluating combined interventions did report weak yet significant results for child mortality and stunting. Moreover, while a range of WASH interventions was frequently employed to control cholera outbreaks, few programs have been evaluated using rigorous impact evaluation

[12] For instance, these studies reported that a recent meta-analysis of five randomized controlled trials found a mean difference of 0.08 in height-for-age z-scores of children under age five (95 percent CI: 0.00–0.16) for solar disinfection of water, provision of soap, and improvements in water quality (Dangour *et al*. 2013).

techniques, limiting researchers' ability to draw evidence-based conclusions. Further, there is a clear distinction between program effects from stand-alone WASH interventions versus programs that are designed to target multiple WASH themes. For example, the evidence for water quality in single interventions using experimental designs is solid, but less so in combined interventions.

Finally, impact evaluations specifically focused on child health outcomes were heterogeneous. Several studies included multiple sources of potential bias and all the studies failed to mask the WASH intervention of participants. Child health as a primary outcome (Fink, Gunther and Hill, 2011)—measured, for example, by weight-for-age, linear growth, weight-for-height, and height-for-age ratios—was reported in only 5 of the 136 studies, a fact that may have influenced this review. Notwithstanding, the combined data set showed little variation in estimated effects and high variation in standard errors, suggesting the studies were suitable for pooling. Further, there was no correlation between sample size and effects, that is, small samples did not exert a disproportionate influence on the pooled results.

The relationship between WASH interventions and outcomes is complex. Some interventions were combined without information reported on individual effects from interventions, which may have impacted the meta-analysis and the ability to draw concrete conclusions. Although there was evidence of regional bias stemming from the subset of studies conducted in North America, the inclusion of these studies was deemed reasonable given that the interventions included in them were large-scale with strong methodological designs for causal attribution between the intervention and outcomes.

The pooled effects of WASH interventions on school absenteeism were significant: the odds of missing school were reduced by a factor of 0.69 among students who had received a WASH intervention. Similarly, children receiving a WASH intervention were 1.44 times as likely to use soap, only 0.5 times as likely to develop *Ascaris* infections, 0.65 times as likely to develop diarrhea, and 0.91 times as likely to die as children not receiving a WASH intervention—and all results were significant. Finally, child growth, handwashing, and latrine adoption increased by 26, 8, and 22 percent, respectively, and water quality improved by 20 percent. These findings illustrate the importance of increased statistical power facilitated by meta-analysis to improve evidence.

Applying meta-analysis at the subgroup level enabled a more detailed evaluation of results. There was no evidence of bias in Groups 1 through 4. Group 5, which focused on diarrhea and enteric-disease-related outcomes, presented evidence of bias in larger, more precise studies; however, reporting bias was ruled out as the likely cause. Group 5 included the subset of studies from North America, which had similarly presented evidence of bias on the full data set of evaluations.

In certain circumstances, research methods can significantly influence outcome effects. In particular, RCTs tend to estimate larger and more precise effects. In some cases, study locale (e.g. urban versus rural) was found to affect the reliability of results; however, this varied by outcome and could not always be explained by other study characteristics. For example, though WASH interventions targeting behavior change and sanitation produced more robust effects in urban areas, this was also a function of study design, given that the studies conducted in urban areas applied experimental methods, which have been shown to improve results. On the contrary, WASH interventions targeting the reduced incidence of diarrhea and enteric-related diseases and conducted in rural areas produced more precise results than interventions in urban areas. This is even though most interventions in urban areas had been implemented by NGOs, which are shown to improve the accuracy of results when compared to government agencies. This could be explained by reinfection rates, which are typically higher and/or impact more people in densely populated, urban areas. However, given the potential bias in this group, results should be interpreted with caution.

7. Conclusions

In general, evaluations that encompass large numbers of studies with rigorous research methods produce more precise results. This was the case for studies evaluating WASH interventions' effects on behavior and sanitation outcomes. Improving study design specifically in rural areas for these outcomes might be one area for future research. Indeed, there is a wide range of qualitative approaches that can be employed in combination with quantitative methods to strengthen effects. However, there is a trade-off[13] between the internal and external validity of WASH impact evaluations that should be taken into account when designing studies.

Similarly, although the effects of WASH interventions on some health-related outcomes were unambiguous—for example, water quality on the incidence of diarrhea—other health-related outcomes such as child mortality, stunting, weight, and height showed mixed results. This would also appear to be a result of study size, and ambiguities in these other health-related outcomes would likely decrease if more studies were undertaken in those areas. Likewise, more research needs to be undertaken on hygiene and sanitation interventions overall, and greater geographical representation is needed. Finally, additional research is needed to better understand the impacts of study locale on the results of WASH interventions targeting reduced diarrhea and enteric diseases.

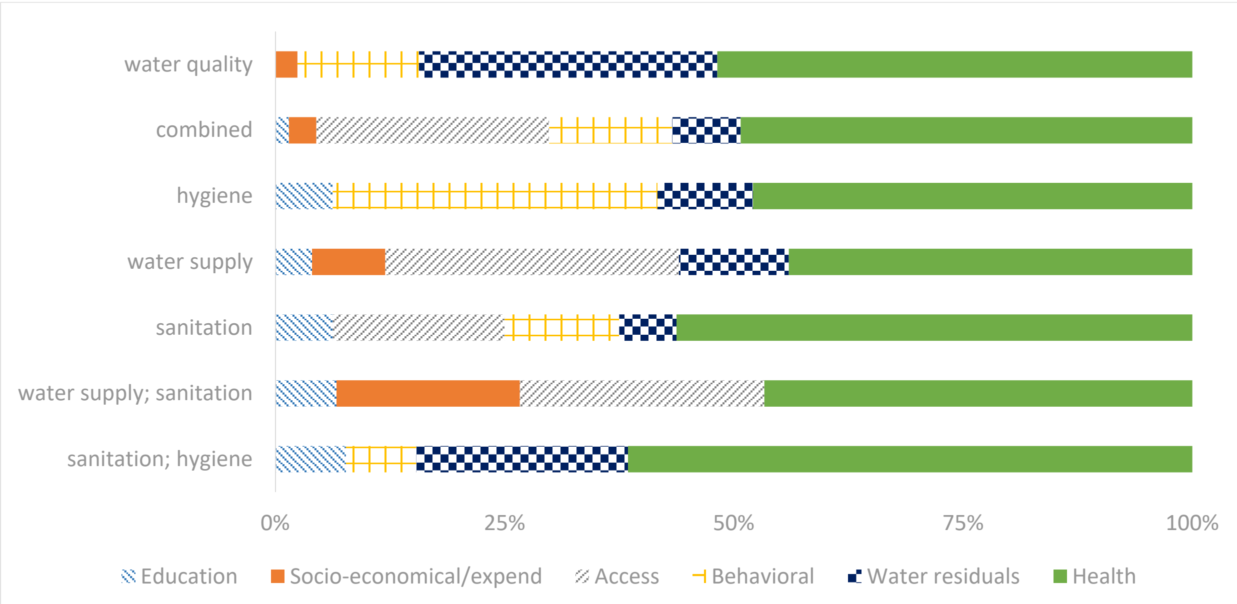
The effects of multiple interventions, especially in combination with initiatives to promote behavior change, would also benefit from additional research. Specifically, there is a need to ensure a consistent approach to undertaking impact evaluations. For example, outcome effects—and not just the combined effect—should be reported for each intervention. There are grounds to suggest capacity-building efforts in government implementing agencies would lead to more reliable results, which also supports the argument for a better, more cohesive approach to conducting impact evaluations. Clearly, more evidence is needed to support the emerging understanding of the wider health and social effects of WASH interventions. In summary, all findings seem to point to the need for larger studies, with broader geographical representation and rigorous research methods, in addition to well-trained implementing agencies.

[13] See, for instance, Prichett and Sandefur (2014), who state the trade-off with nonexperimental estimates of treatment effects comprise a causal treatment effect and a bias term due to selectivity. When nonexperimental designs and estimates vary across contexts, any claim of external validity must make the assumptions that (i) treatment effects are not the same across contexts, and (ii) selection processes vary according to contexts. Therefore, parameter heterogeneity will not come from economic or institutional factors that make external validity implausible.

Appendix A. Additional Figures

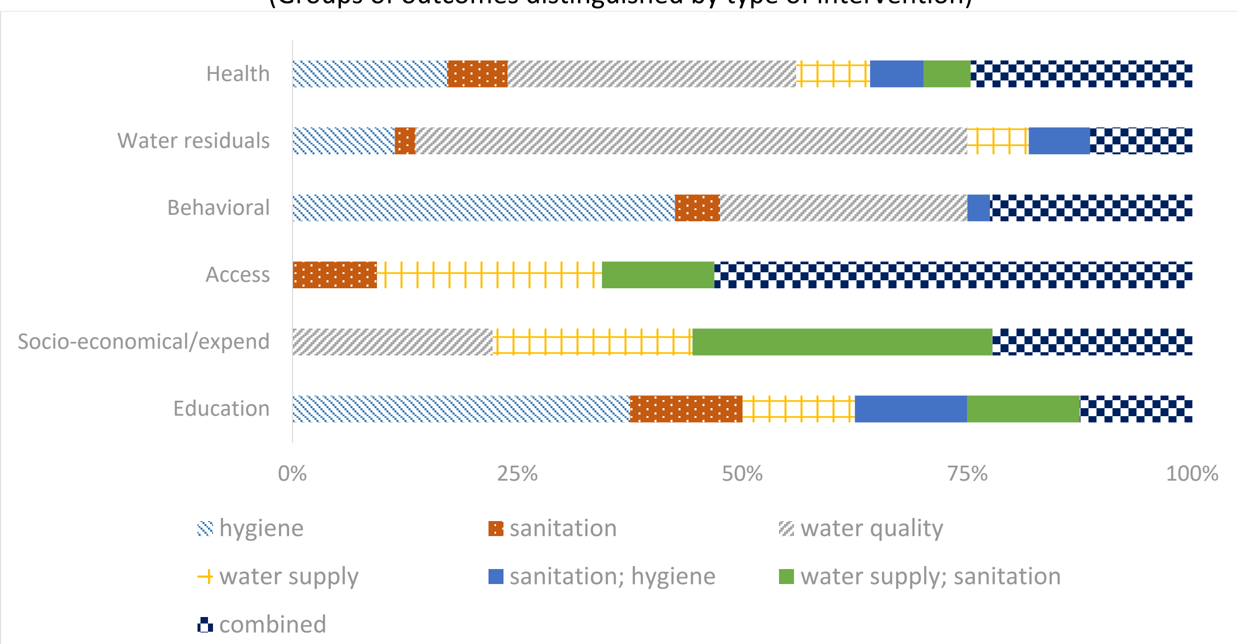
Distribution of Main Outcome Groups

Figure A1. Most Interventions Focus on Health and Water Residuals
(Classification of interventions and outcomes analyzed)



Source: World Bank GWSP-SIEF WASH Impact Evaluation Database.

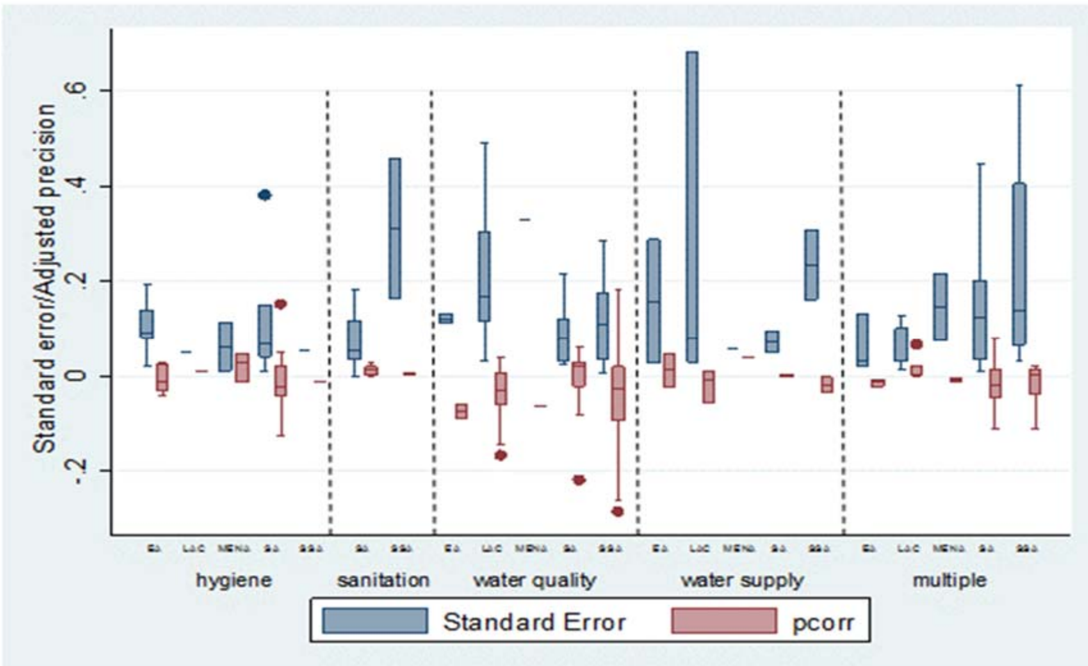
Figure A2. Water Quality Interventions Dominate
(Groups of outcomes distinguished by type of intervention)



Source: World Bank GWSP-SIEF WASH Impact Evaluation Database.

Meta-Analysis Graphical Representation of Publications

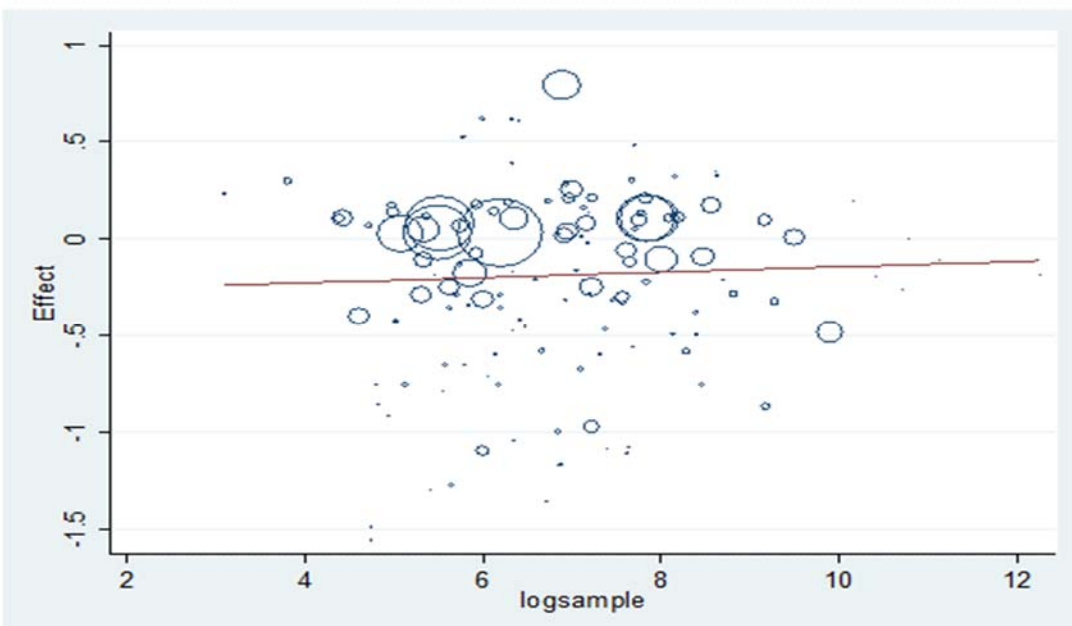
Figure A3. Variability in Standard Errors and Correlations of Outcome Effects (between publications) by Region and Intervention Type (entire data set)



Source: World Bank GWSP-SIEF WASH Impact Evaluation Database.

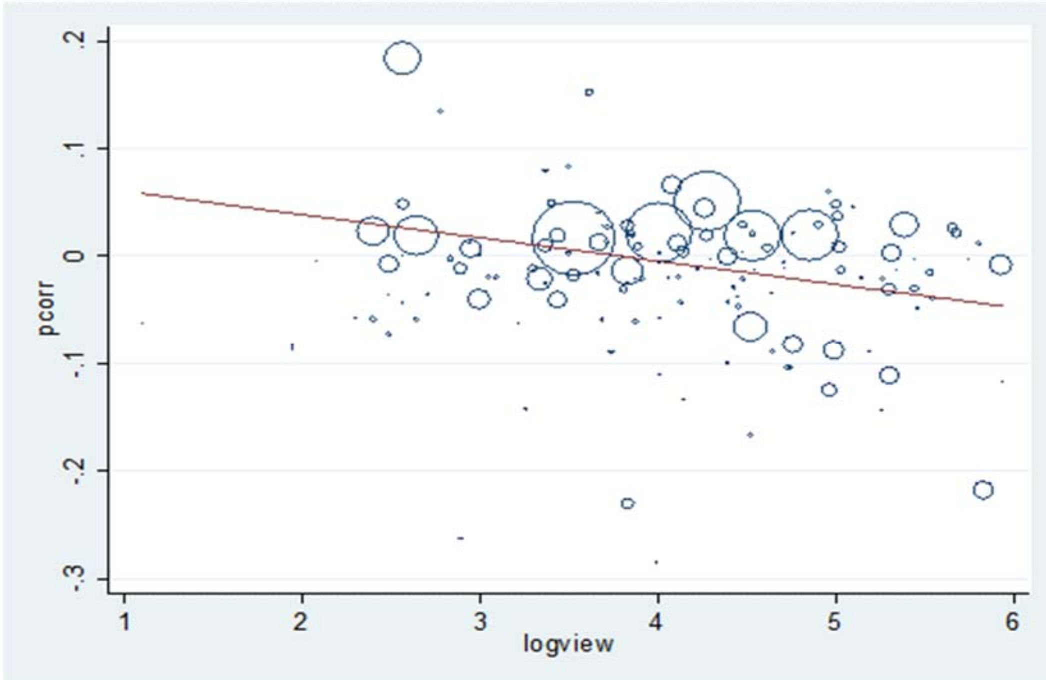
Note: EA = East Asia and Pacific, LAC = Latin America and the Caribbean, MENA = Middle East and North Africa, NA = North America, SA = South Asia, SSA = Sub-Saharan Africa.

Figure A4. Relationship between Publication's Sample Size and Estimated Effects (entire sample)



Source: World Bank GWSP-SIEF WASH Impact Evaluation Database.

Figure A5. Paper Views and Publication Correlation

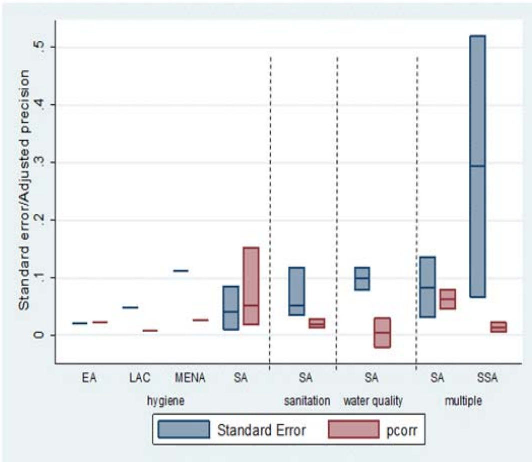


Source: World Bank GWSP-SIEF WASH Impact Evaluation Database.

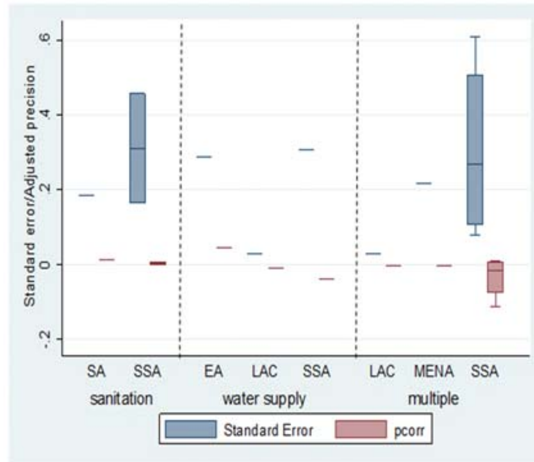
Group Meta-Analysis: Effect Trend, Bias, and Heterogeneity

Figure A6. Box Plots per Outcome Subgroup

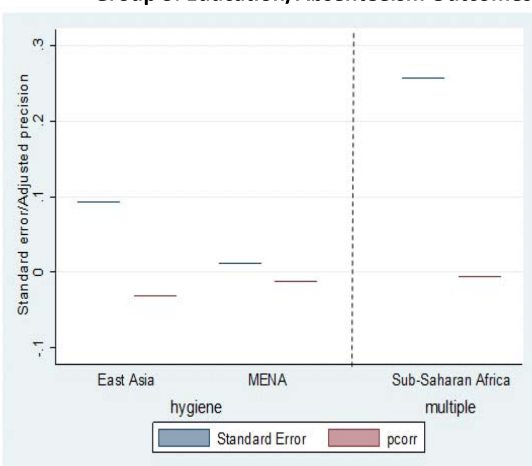
Group 1: Behaviors, Hygiene, Sanitation (outcomes)



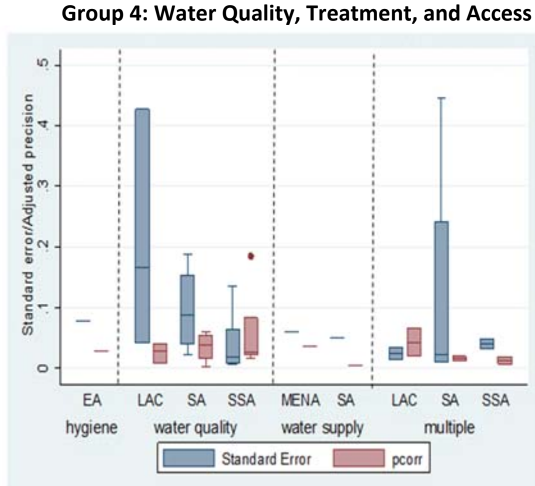
Group 2: Child Mortality, Growth, Other Health Outcomes



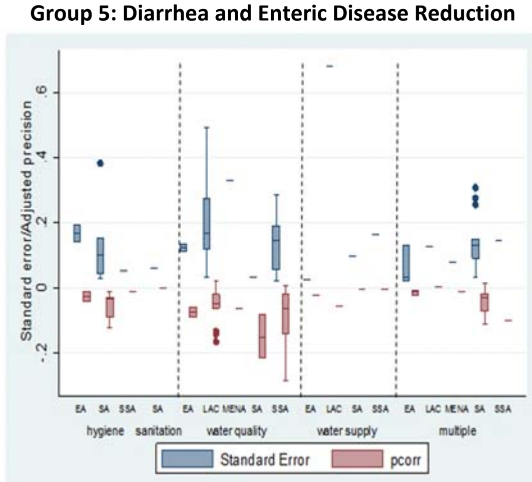
Group 3: Education/Absenteeism Outcomes



Group 4: Water Quality, Treatment, and Access



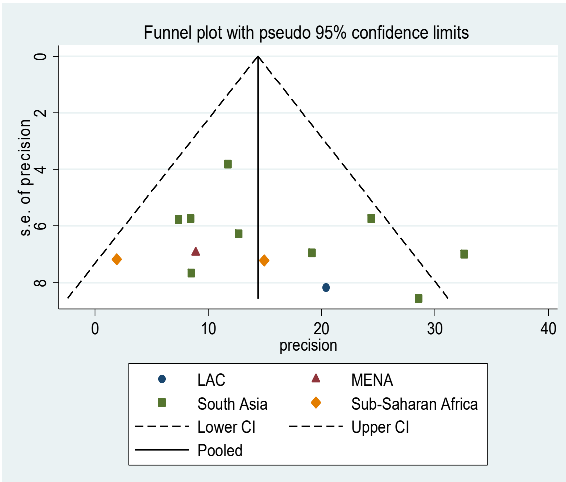
Group 5: Diarrhea and Enteric Disease Reduction



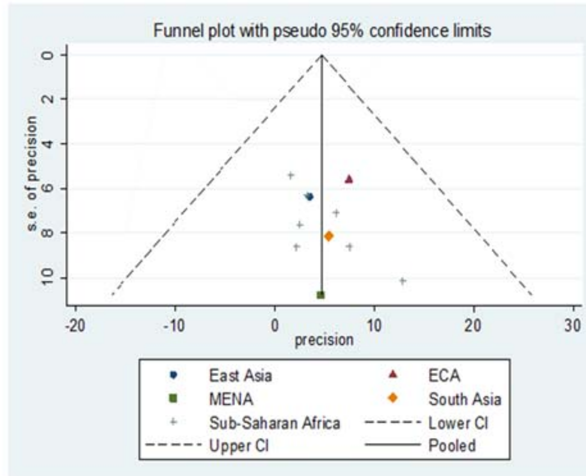
Source: World Bank GWSP-SIEF WASH Impact Evaluation Database.
Note: EA = East Asia and Pacific, LAC = Latin America and the Caribbean, MENA = Middle East and North Africa, SA = South Asia, SSA = Sub-Saharan Africa.

Figure A7. Funnel Plots (precision) per Outcome Subgroup

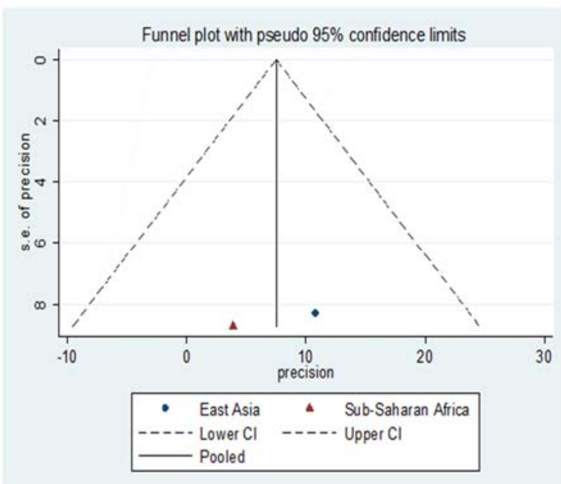
Group 1: Behaviors, Hygiene, Sanitation (outcomes)



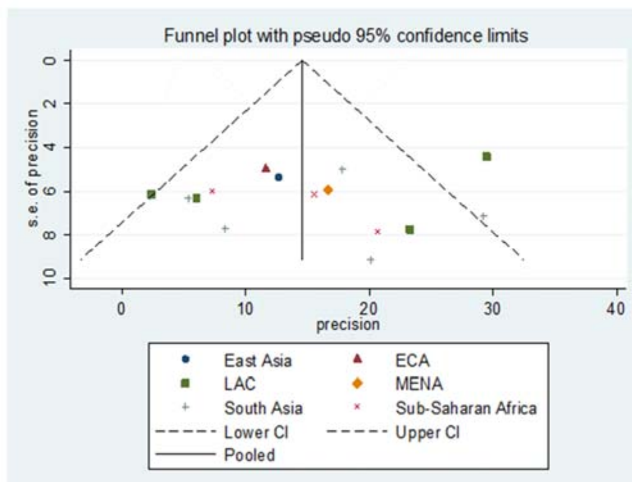
Group 2: Child Mortality, Growth, Other Health Outcomes



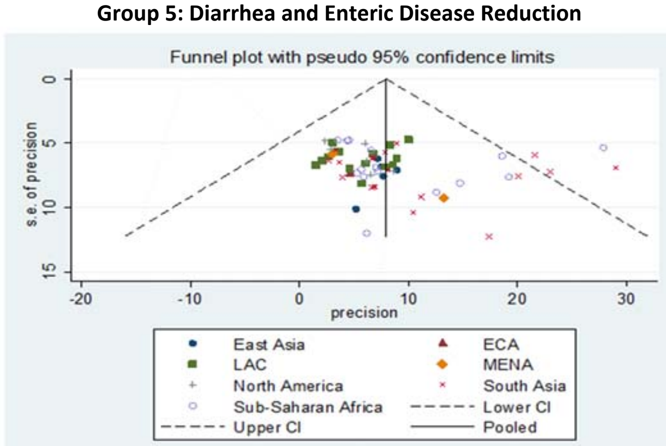
Group 3: Education/Absenteeism Outcomes



Group 4: Water Quality, Treatment, and Access



Group 5: Diarrhea and Enteric Disease Reduction



Source: World Bank GWSP-SIEF WASH Impact Evaluation Database.

Note: CI = confidence interval; ECA = Europe and Central Asia, LAC = Latin America and the Caribbean, MENA = Middle East and North Africa.

Group Regressions

Table A1. Meta Regressions by Outcome Group (between publication corr.)

Independent Variables	Group 1 Paper Corr	Group 2 Paper Corr	Group 3 Paper Corr	Group 4 Paper Corr	Group 5 Paper Corr
Effect size (ES)	0.166**	0.0599***	0.0970**	0.198***	0.130***
	(0.0674)	(0.0132)	(0.0433)	(0.0133)	(0.0118)
Standard error of study	0.0305	-0.0235	-0.0428	-0.423***	0.193***
	(0.0848)	(0.0547)	(0.125)	(0.0633)	(0.0410)
Journal=1, 0=Otherwise	0.0231	0.0182**	0.00797	0.000547	0.0107
	(0.0193)	(0.00751)	(0.0159)	(0.00470)	(0.00753)
Number of studies	0.0352	-0.0285**	0.0339	-0.0536***	-0.00566*
	(0.0267)	(0.0124)	(0.0426)	(0.0106)	(0.00326)
Sample size	-0.0514***	-0.00338	-0.0180**	-0.00697**	0.0155***
	(0.0177)	(0.00385)	(0.00755)	(0.00295)	(0.00295)
Urban dummy	0.00187	0.00173	0.0248	-0.00241	0.000599
	(0.0313)	(0.00998)	(0.0279)	(0.00770)	(0.00776)
Government implementation dummy	0.0414	0.0159	0.0641	0.0664***	-0.0183
	(0.0318)	(0.0211)	(0.0503)	(0.0170)	(0.0133)
Quasi-experimental dummy	-0.0457	-0.00377	0.00299	-0.149***	-0.000528
	(0.0327)	(0.0139)	(0.0548)	(0.0343)	(0.0131)
LAC region dummy	0.120*	-0.0274	-0.0576	-0.00376	-0.0197
	(0.0618)	(0.0395)	(0.0855)	(0.0121)	(0.0156)
MENA region dummy	0.129	0.0225	-0.0223	0.143***	0.000652
	(0.0850)	(0.0471)	(0.0628)	(0.0361)	(0.0232)
SA region dummy	0.116*	-0.0312	-0.0298	0.00241	-0.0287**
	(0.0643)	(0.0490)	(0.0591)	(0.0117)	(0.0142)
SSA region dummy	0.0663	0.0142	-0.0103	-0.0110	-0.0234
	(0.0454)	(0.0564)	(0.0539)	(0.0122)	(0.0145)
Constant	0.0761	0.0123	0.0202	0.166***	-0.0771**
	(0.0977)	(0.0806)	(0.0999)	(0.0384)	(0.0343)
R-squared	0.43	0.21	0.07	0.58	0.72

Source World Bank GWSP-SIEF WASH Impact Evaluation Database.

Note: Standard errors in parentheses.*** p<0.01, ** p<0.05, * p<0.1. LAC = Latin America and the Caribbean, MENA = Middle East and North Africa, SA = South Asia, SSA = Sub-Saharan Africa.

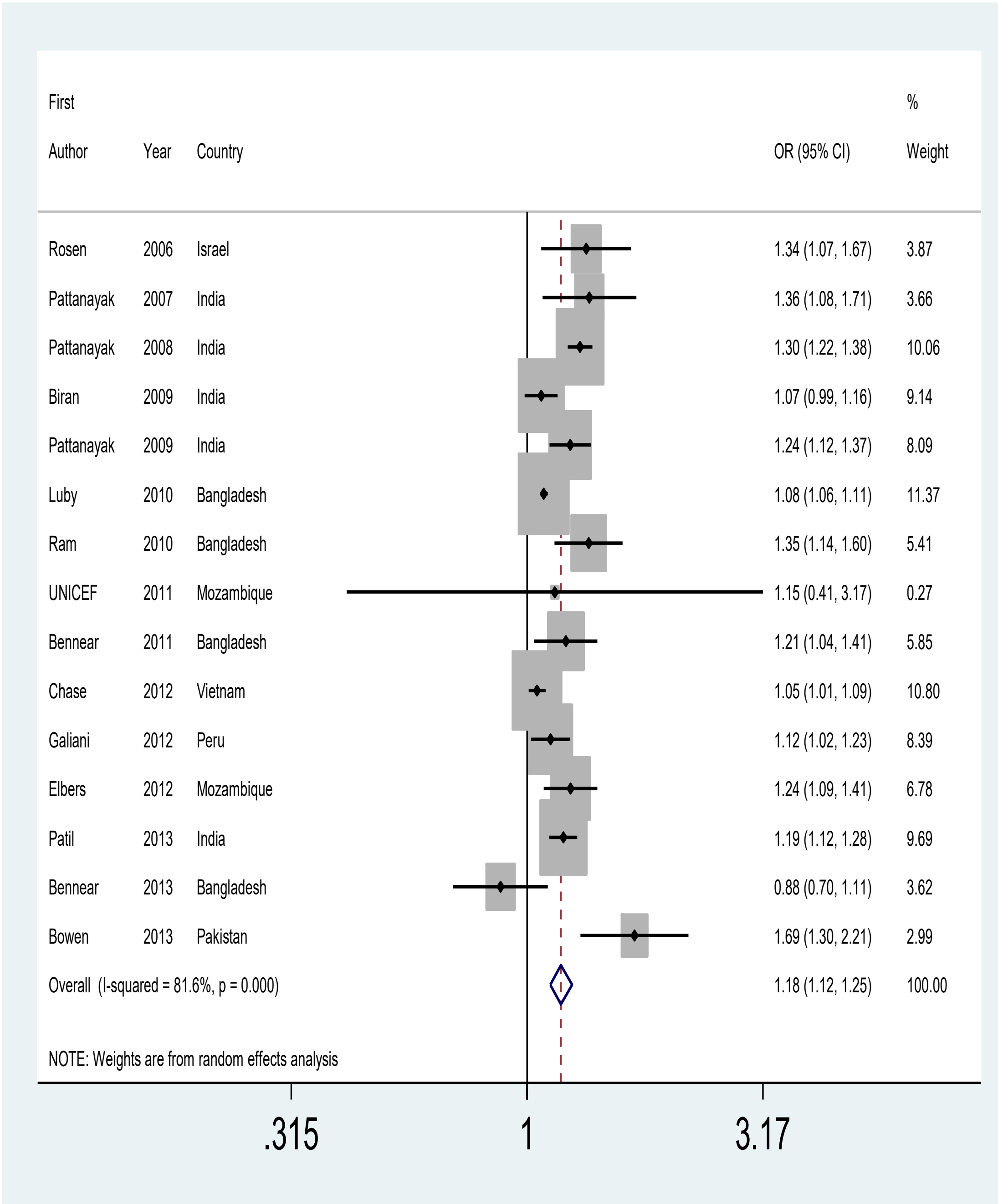
Table A2. Meta Regressions by Outcome Group (effects)

Independent Variables	Group 1 Effect	Group 2 Effect	Group 3 Effect	Group 4 Effect	Group 5 Effect
Number of studies	0.569*	0.443	0.0112	0.382**	-0.0966
	(0.288)	(0.431)	(0.683)	(0.170)	(0.0498)
Sample size	0.0840	-0.0705	0.131	-0.0262	0.0799
	(0.0797)	(0.151)	(0.159)	(0.0873)	(0.0522)
Urban dummy	0.626**	-0.378	-0.364	-0.175	-0.651**
	(0.193)	(0.566)	(0.454)	(0.266)	(0.165)
Government implementation dummy	-0.0701	0.183	0.0931	-0.0708	-1.208***
	(0.164)	(0.434)	(0.124)	(0.266)	(0.211)
Quasi-experimental dummy	-0.589*	-0.324	-0.887	-0.397	0.128
	(0.241)	(0.596)	(0.782)	(0.396)	(0.242)
Precision	-0.0206***	-0.00539**	-0.00615***	-0.0243***	-0.00567***
	(0.00455)	(0.00149)	(0.00131)	(0.00316)	(0.000394)
Mean diff. within group	0.566**	0.898**	0.890***	0.891***	1.089***
	(0.157)	(0.246)	(0.219)	(0.114)	(0.137)
Constant	-3.058***	-1.076	-1.782	-0.402	0.252
	(0.571)	(1.935)	(1.345)	(1.004)	(0.471)
R-squared	0.67	0.34	0.10	0.78	0.85

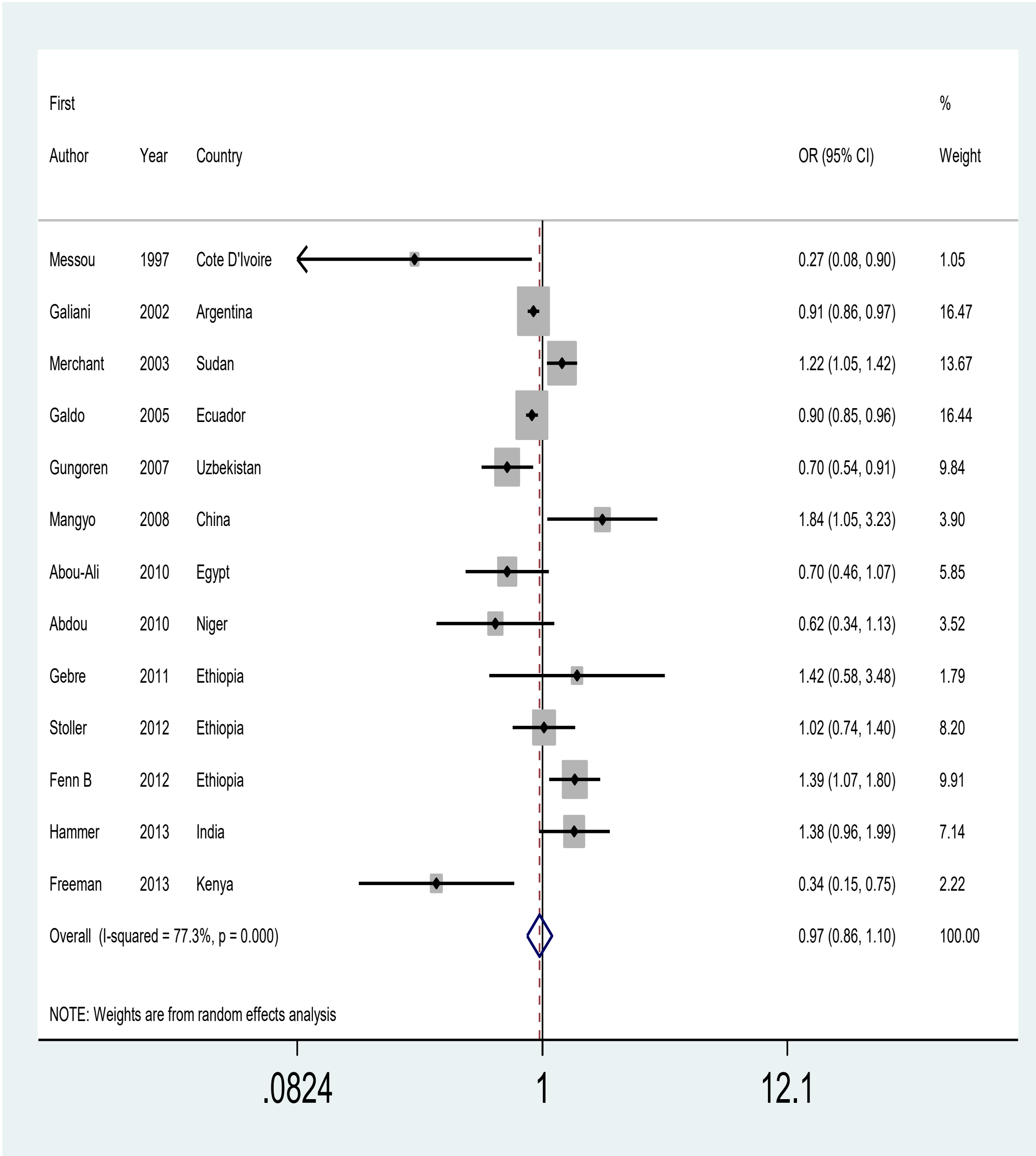
Source: World Bank GWSP-SIEF WASH Impact Evaluation Database.
Note: Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Figure A8. Forest Plots per Outcome Group

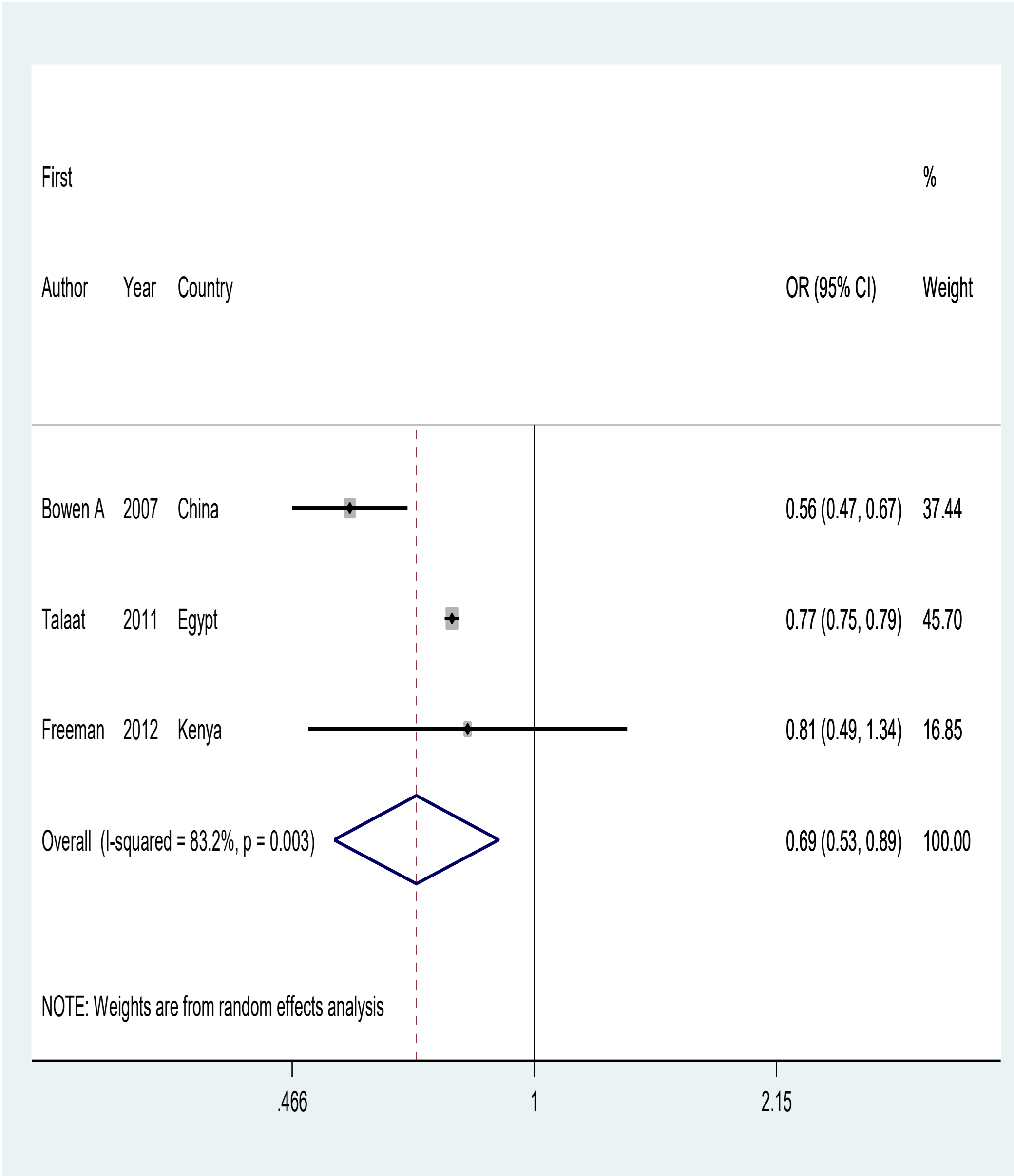
Group 1: Behaviors, Hygiene, Sanitation (outcomes)



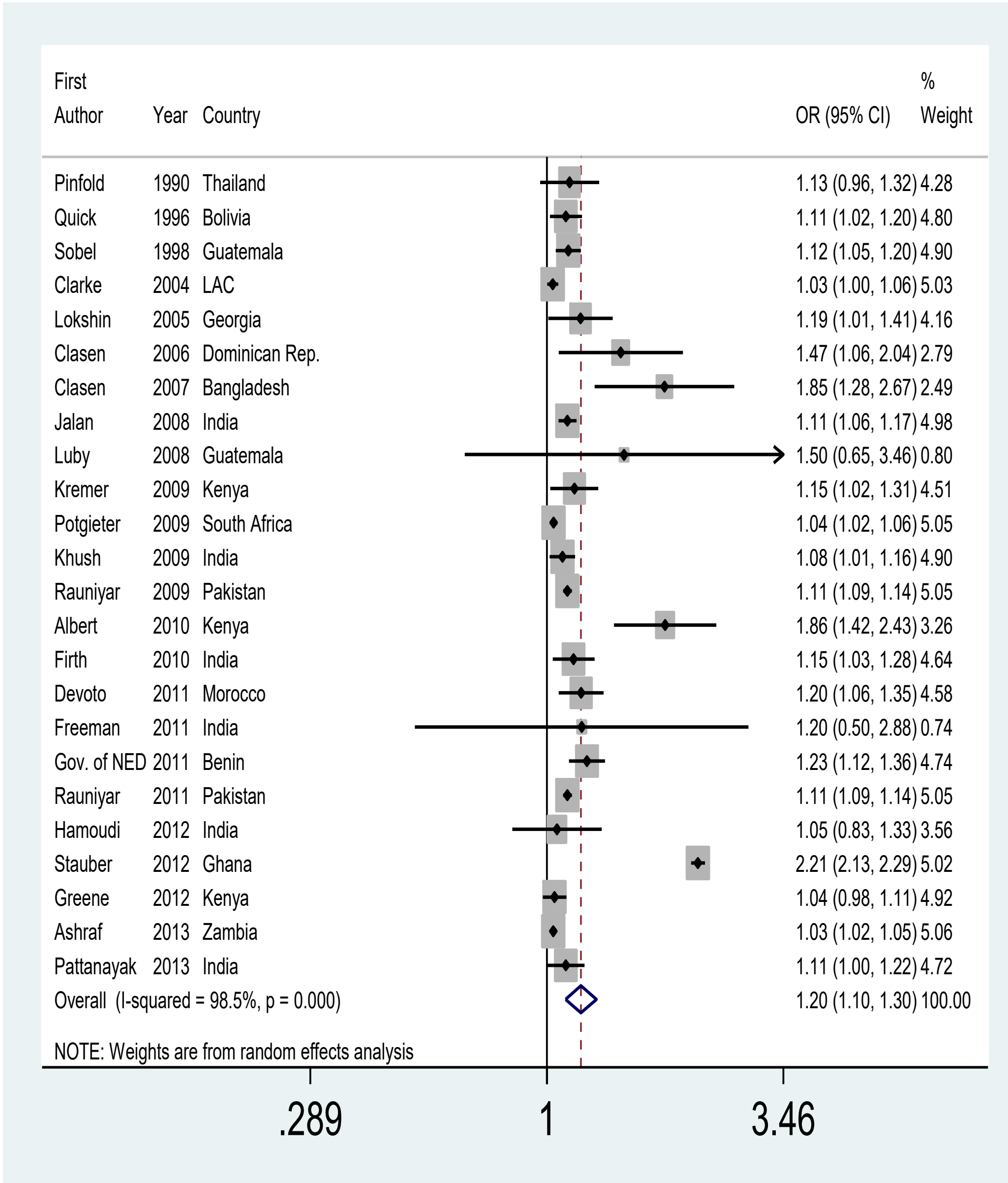
Group 2: Child Mortality, Growth, other Health Outcomes



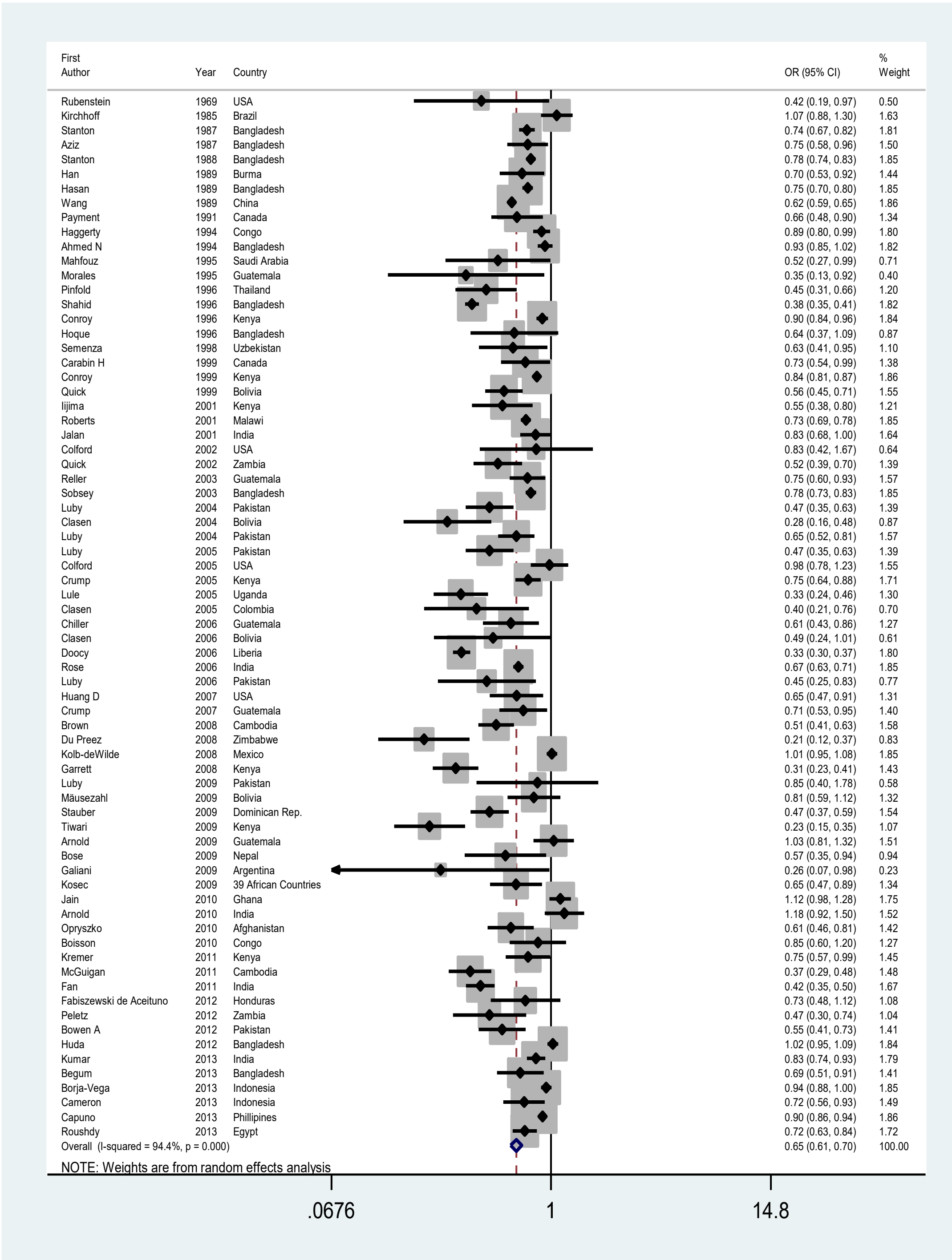
Group 3: Education/Absenteeism Outcomes



Group 4: Water Quality, Treatment, and Access



Group 5: Diarrhea and Enteric Disease Reduction



Source: World Bank GWSP-SIEF WASH Impact Evaluation Database.

Appendix B. List of WASH Studies Included in the Final Data Set

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