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Water, Sanitation, Hygiene and Diarrheal Diseases in Children: A Global Perspective of Effective Interventions and Barriers to Achieving the Millennium Development Goals.

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Abstract

The following study examines the effectiveness of drinking water, sanitation and hygiene related interventions in decreasing diarrheal prevalence in developing countries. The studies examined in this paper have been implemented in both urban and rural locations, but ultimately target a child population. Five basic types of interventions were found – drinking water supply, drinking water quality, sanitation, hygiene and multiple interventions. It was concluded that all interventions successfully reduce diarrheal prevalence to some degree. Drinking water quality interventions were found to be the most common, and have received the largest amount of financial prioritization. Likewise, access to safe drinking water has increased significantly over the past 25 years, and coverage far exceeds that of sanitation and hygiene. It is suggested that more attention be given to sanitation interventions, as they have the potential for the broadest and most enduring health benefits. However, barriers to increasing access in the developing world are hard to overcome. Rapid urbanization, increasing slum population, urban and rural disparities and the necessity for behavioral changes are slowing forward progress. Sustainability is difficult to measure, yet needs to be ensured in all types of interventions in order to effectively reduce the under-five diarrheal mortality rate. Limitations in this study include a short time frame of research, and a lack of expert insight; the information was obtained solely through meta-analyses and case studies.

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Introduction

Millennium Development Goals & Progress

Diarrhea is one of the most easily treatable and preventable diseases burdening the world's population; yet, it is the second leading cause of child mortality, behind only pneumonia (UNICEF/WHO 2009). Diarrhea alone is responsible for more child deaths each year than AIDS, malaria and measles combined (UNICEF/WHO 2009). Of the 9.7 million children that die before the age of five, 1.6 million of these children die due to diarrheal diseases (UNICEF/WHO 2009; Water Aid 2008).About 88%of diarrheal deaths in children can be attributed to a combination of poor sanitation, unsafe drinking water and a lack of personal hygiene, which are three unfortunate trends that permeate the developing and underdeveloped world (Water Aid 2008).Together, Africa and South Asia, bear the heaviest burden of both water-related diseases as well as the highest rates of child mortalities; these two regions account for more than half of diarrheal cases annually, and over 80% of child deaths due to diarrhea (UNICEF 2009).

These shocking trends are not going unnoticed. The Millennium Development Goals (MDGs) were established after the Millennium Summit of the United Nations as a blueprint for the world's countries to abide by. Their tasks, wide as they are, ultimately aim to meet the most basic needs of the world's poorest people (UN Department 2013). Many of the MDGs overlap with one another, targeting the same populations from different areas of focus. Children in developing countries constitute one population in great need of help, and are the heart of the fourth Millennium Development Goal. The target of MDG 4 is to, "reduce by two thirds, between 1990 and 2015, the under-five child mortality rate" (UN Department 2013). With so many children dying due to diarrheal diseases, it is fitting that making improvements in water, sanitation and hygienic circumstances worldwide would reduce this diarrheal burden on children, and decrease the under-five mortality rate. Thus, the seventh Millennium Development Goal closely overlaps with MDG 4 - MDG 7 (Target 7c) hopes to, "halve, by 2015, the proportion of people without sustainable access to safe drinking-water and basic sanitation" (WHO 1, 2012). As some of the target populations for these two specific MDGs overlap, many interventions directed at one MDG often contribute to fulfilling the other; for example, improving water and sanitation may indirectly affect the number of child deaths, and vice versa.

The establishment of the Millennium Development Goals promoted significant progress in many countries, and gains have been made in both of the aforementioned areas of Millennium Development Goal focus. The under-five mortality rate has, in fact, decreased by 47%percent since 1990; however, 9 million children-under-five died in the year 2012 (UN Department 2013), and 1.5 million of these deaths were due to diarrhea. Improvements in drinking water quality and accessibility have also been made, as the target for drinking water coverage was reached in 2010 when the proportion of people with access to safe drinking water was *more* than halved from

24% to 11% (WHO 1, 2012). While this means that 89% of the population has access to safe drinking water, it still leaves 700 million people relying on unimproved sources of water (WHO 1, 2012). Sanitation, though targeted in the same MDG as drinking water, lags far behind. Only 64% of the world's population has access to an improved sanitation facility, which means that2.5 billion people are lacking adequate sanitation (WHO 1, 2012; WHO 2, 2012).

Despite the large achievements that have been made, these statistics demonstrate that there is still much work to be done. Developing countries are faced with various barriers preventing access to safe drinking water, sanitary systems, and proper hygienic behaviors; therefore, further interventions with more sustainable strategies are still needed. Diarrhea-causing pathogens spread more easily in environments where drinking water is easily contaminated with fecal matter, where sanitation is inadequate, and where lack of hygienic practices makes food and water highly susceptible to contamination (UNICEF/WHO 2009). In developing countries at least one, if not all three, of these unfortunate circumstances are likely, and increase the likelihood of the spread of diarrheal diseases. While some countries may need improvements in water-quality, others could better utilize the installation of sanitation facilities. Both of these interventions relate to the transmission of diarrheal diseases through the medium of water, though one may be more relevant to some countries than others. Proper attention needs to be given to barriers that developing countries are facing, and interventions should be targeted at the appropriate areas of focus. As 2015 approaches, it is becoming a reality that some of the Millennium Development Goals will not be achieved; therefore, evaluations should be made to determine the effectiveness of previous interventions and to discover the most difficult barriers that must be overcome in order to allow future implementations to be more successful.

Diarrhea as A Disease

As defined by the WHO, diarrhea is the "passage of loose or watery stools at least three times in a 24 hours period" (WHO3 2013). Increases in volume, fluidity, frequency and changes in consistency of stools are indicators of the onset of diarrhea (Thapar & Sanderson 2004), and are easily detectable. Symptoms such as these are ultimately the result of gastrointestinal infections, caused by pathogens such as bacteria, viruses, or protozoa. Diarrheal infections manifest themselves with observable symptoms and can be classified in three main groups: acute watery diarrhea, bloody diarrhea, and chronic or persistent diarrhea (UNICEF/WHO 2009; Thapar & Sanderson 2004).Acute diarrhea is most prevalent, and is characterized by rapid dehydration significant fluid loss and duration of several hours to a few days (Buttenheim, A 2008). Rotavirus is the most common causes of acute diarrhea, and accounts for 60% of all diarrheal episodes in developing countries, and an estimated 870,000 child deaths annually (Thapar & Sanderson 2004).*V. cholerae,* and *E. coli* are other common causes of acute diarrhea(UNICEF/WHO 2009). Although more regularly referred to as dysentery, bloody diarrhea is a sign of severe intestinal damage and significant nutrient loss due to bacterial infections from *Shigella*. Finally

chronic or persistent diarrhea is the most severe type condition, which can last up to 14 days in infected individuals (Thapar & Sanderson 2004). Chronic diarrhea presents the most long-term dangers because it can result in an inability to absorb nutrients and therefore compromise a child's growth and development (Buttenheim, A 2008).

The main route of transmission of diarrheal diseases is from the stool of an infected individual or animal to the mouth of another person; this is known as a fecal-oral pathway (UNICEF/WHO 2009). Excreta that contains harmful pathogens can follow this fecal-oral pathway by contaminating drinking water sources via unsanitary fecal disposal, by indirectly contacting humans, or by contaminating food sources (Pruss, Kay, Fewtrell & Bartram 2002).An individual is then infected with these same pathogens by ingesting them through the water or food sources. While diarrheal infections cannot solely be attributed to a lack of water, sanitation and hygiene, these factors are ultimately the largest contributors to the disease burden (Pruss, Kay, Fewtrell & Bartram 2002).Water is the key element that these bacteria, viruses and protozoa use to migrate from stools to drinking water, sewage systems and food sources (WHO 3, 2012); therefore, water sources, levels of sanitation, and personal hygiene practices directly affect the prevalence, incidence and proliferation of diarrheal diseases.

Focus of My Research

Even though the Millennium Development Goals state, specifically, what they hope to achieve, not all countries have been able to fulfill these goals. What then, is prohibiting most developing and underdeveloped countries from providing access to water and sanitation, and how can we prevent so many children from dying due to diarrhea before they reach the age of five? In this paper, I ultimately hope to examine the relationships between water, sanitation and child deaths due to diarrhea. My research process examines the effectiveness of water, sanitation, hygiene and multiple-interventions throughout the developing world in reducing diarrheal diseases in children. With this information, I aim to answer the questions, "What effective and sustainable interventions have been implemented to address child mortalities due to lack of safe water, adequate sanitation and poor hygiene?" and "What barriers are preventing improvements in water and sanitation in developing countries, thus contributing to the under-five death rates?"

In order to combat diarrheal diseases, interventions can be targeted at improving water quality, sanitation levels, personal hygiene practices, or all of the above. Though not the most frequently addressed issue, sanitation interventions act as a primary barrier to diarrheal diseases, by preventing the initial contamination of fluids (Padilla 2012). In contrast, clean drinking water is a "secondary barrier" to infections and disease when sanitation fails; it prevents the direct ingestion of fluids that have already been contaminated (Padilla 2012). As stated by the UN Secretary General, Kofi Annan, in October of 2010, "access to safe water is a fundamental human need and…a basic human right. Contaminated water jeopardizes both the

physical and social health of all people" (Rabia 2010). It is fitting, then, that drinking water quality and quantity are the most frequently addressed and issues, and have therefore made the most significant improvements worldwide (Padilla 2012). Related interventions include filtering, chemically treating, and removing of microbial contaminants from water at its source to increase the quality, or improving and expanding water pipes to increase water quantity (Padilla 2012; Fewtrell et al. 2005). Hygiene interventions, though sometimes overlooked, ultimately encourage changes in behaviors, which would prevent contamination of surfaces, food, and indirect contact with fecal material. Much like Secretary General Annan, I, too, agree that water is a basic human right, and hope to understand what is preventing universal access to this essential element. Likewise, I hope to discover areas of improvement for sanitation and hygiene interventions as well.

Methods

The initial focus of my research was directed towards food safety, food security and their respective relationships to health in developing and underdeveloped countries. However, after obtaining an internship position at the Global Institute for Water, Environment and Health (GIWEH), my interest shifted to the impact of water, sanitation, hygiene – or a lack thereof – has on human health. Thus, my research process changed to familiarizing myself with global trends of access and availability of safe drinking water, adequate sanitation and general hygiene practices.

As my research progressed, I began to focus on the Millennium Development Goals, specifically MDG 7. The global data on the Millennium Development Goals demonstrated that diarrheal diseases are some of the most common consequences of unsafe drinking water, lack of sanitation and poor hygiene in developing countries. The data also suggested that children in these countries ultimately bear the heaviest burden of these diarrheal diseases and deaths. Children, therefore, became my main area of focus, and a second Millennium Development Goal, MDG 4, became more relevant to my studies.

Primarily using the World Health Organization and UNICEF, I examined the global progress, thus far, towards MDGs 4a and 7c. The year 1990 was used as the baseline from which to measure global progress, because data for the Millennium Development Goals was first collected during this year. Statistics for the year 2013 cannot be collected (as the year is not over yet), thus the year 2012 was used to represent the most up-to-date progress. The years 1990 and 2012 were used for a general guideline; I searched for empirical, intervention specific research papers within this window of time. However, studies conducted outside of this window were not discounted, as they still provided relevant information to the progress before the establishment of Millennium Development Goals. One country specific, hygiene intervention was used from the year 1988 because it was one of few hygiene

interventions available, and the meta-analyses I reviewed took older studies into consideration as well. Using various online databases, such as PubMed, World Health Organization Reserves, LibGuides.sit, and Santa Clara University Reserves, I searched for research papers with various combinations of the following keywords: water, drinking-water, sanitation, hygiene, hygiene-practices, diarrhea, diarrheal disease, children, children under-five, child mortality, prevention, intervention, sustainability, effectiveness.

Intervention specific studies were found in four main categories: drinking water interventions (including both water supply and water quality studies), sanitation interventions, hygiene promotion projects, and multiple interventions (which include projects targeting two or more of these factors in the same study). Two meta-analyses were obtained: one analyzed the effectiveness of 47 different interventions (Padilla, D 2012), and the other examined 46 interventions (Fewtrell & Colford 2004). Both meta-analyses examined all types of interventions – water, sanitation, hygiene and multiple interventions. These meta-analyses were used to determine the general effectiveness of a large range of interventions. The case specific studies that were found were used to analyze the individual processes used when implementing an intervention. They also outlined what indicators were used to measure improvements in water, sanitation and hygiene in addition to how declines in diarrheal diseases were measured.

While some articles did not explicitly state, a majority of papers measured their results in children ages zero to six or seven. For those studies that did not state the age-range that was being examined, the results were taken into consideration for a global perspective, but not necessarily included for children related statistics. Most studies measured their results with diarrhea as the outcome, unless otherwise stated.

Limitations in Methods

The methods in this paper are mainly limited to empirical research that has already been conducted. Although I was able to obtain the contact information fora handful of professionals, their responses were minimal. None of these professionals and experts followed through, and I was unable to schedule with meetings during my research period (one became available after the process, but was able to be included in my work). Another limitation is the ability to compare the outcomes between different countries. The primary reason for this is the differing characteristics between countries. These characteristics include the time of the study (in years, and the seasons during which research was conducted), country population sizes, urban versus rural data and results, and duration of outside help during interventions. Additionally, there are limitations in regards to evaluations of sustainability, which was in fact acknowledged in some of the studies I examined (Waddington&Snilstevelt2009). Sustainability is hard to measure when intervening persons leave the intervention site.

Results

The two meta-analysis papers proved to be most useful in determining the overall effectiveness of water, sanitation, and hygiene related interventions, respectively. These meta-analyses established five main types of interventions: sanitation, water supply, water quality, hygiene and multiple interventions (Fewtrell& Colford 2004; Padilla 2012; Waddington &Snilstevelt 2009). Figure 1 shows the five types of interventions and their main focuses. From these meta-analyses, I found that all interventions, water, sanitation, hygiene and multiple-interventions alike, were successful to some degree in preventing diarrheal disease in children (Padilla 2012, Fewtrell 2005).Each intervention was found to intrude at one or more places in the fecal-oral pathway to prevent diarrheal disease transmission. Figure 2 demonstrates the various intervening points for the respective interventions.

Individual, country-specific interventions were examined to determine the intervention processes and their respective measurements of progress. The types of interventions that each country benefitted most from varied, and the sustainability of the projects was not always measured. This posed somewhat of a problem when trying to determine the most sustainable methods that can be implemented for future water, sanitation and hygiene interventions. The setting of the intervention, both its geographical location and urban versus rural placement, resulted in different barriers. These barriers were discovered in country-specific, case studies and through World Health Organization and UNICEF reports.

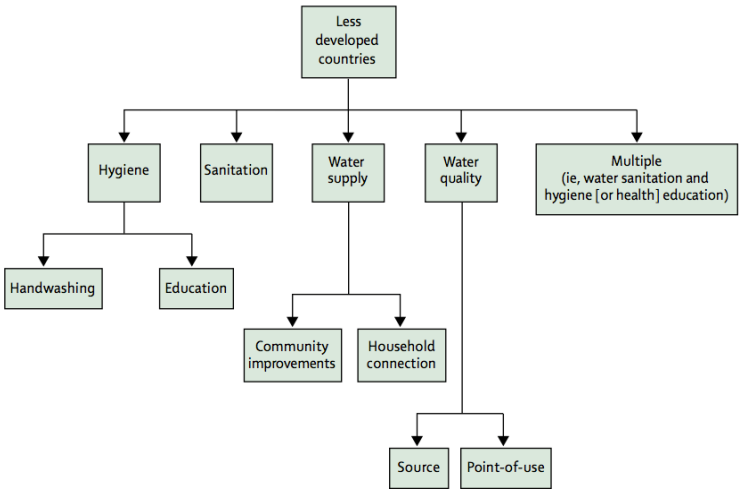

Figure 1. This stratification shows the five types of interventions used to prevent diarrheal disease, and the multiple focuses that each intervention may have. (Fewtrell 2004)

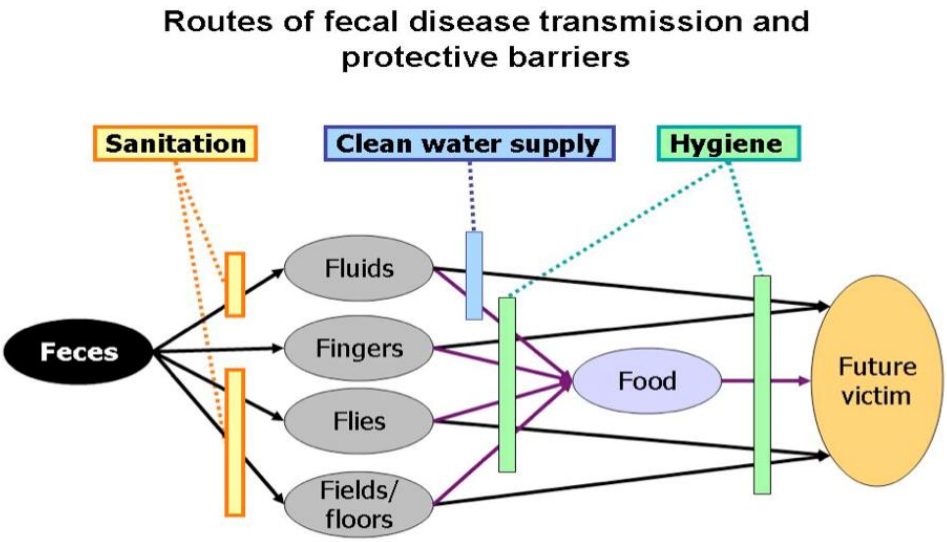

Figure 2. The diagram above shows the pathways through which an individual ingests fecal matter, and highlights where the main interventions (sanitation, water, and hygiene) occur throughout the fecal-oral pathway. (Padilla, 2012)

Sanitation

Sanitation interventions served as a primary barrier to transmission of diarrheal disease; they were the first possible step when intervening into the fecal oral pathway (Figure 2, yellow box). Throughout all of the reviewed literature, the definition of an improved sanitation system was widely agreed upon. Improved facilities are any that hygienically separate human excreta from human contact, thus creating the aforementioned 'primary barrier' (WHO 2013; Cairncross et al. 2010; Waddington et al. 2009). Sanitation interventions either provided or encouraged basic means of excreta disposal at the household or individual levels. This could include installing new sewage systems, improving existing systems, providing new latrines, or updating current latrines(Padilla 2012; Fewtrell & Colford 2005). From the sanitation interventions examined, a variety of improved excreta disposal systems were found. They include: connection to a public sewer or septic system, a pour-flush latrine, a simple pit latrine, a ventilated improved latrine, and a composting toilet(UNICEF/WHO 2009; Waddington&Snilstevelt2009). The intent of sanitation interventions was to prohibit or limit the amount of *initial* fecal contamination (Padilla 2012).

In her meta-analysis, Dianna Padilla found that sanitation interventions were successful in decreasing the prevalence of diarrhea, diarrheal incidences, and overall reductions diarrheal diseases (2012). **Table 1** outlines the sanitation interventions examined in both meta-analyses considered for this report. The target of each sanitation intervention was found to have different results. For example, making improvements to existing sewer systems decreased diarrheal prevalence, installing

completely new sewer systems decreased incidence, and revising existing latrines resulted in an overall decline in diarrhea (Padilla 2012). The sanitation studies examined in Table 1 were all implemented in an urban setting, and they were all effective. Although all three studies measured diarrheal outcomes in children, the ages ranged from zero to three years, six months to five years, and zero to eleven years in the respective studies. In the second meta-analysis, Lorna Fewtrell and John Colford found that, after discarding poor quality studies from their analysis, the two evaluated sanitation interventions were effective in reducing diarrheal disease (2004). Both of these studies measure the outcome of diarrhea in children under-five years of age in developing countries, although one takes place in an urban setting, and the other in a rural setting (Fewtrell & Colford 2004).While some studies measure latrine usage, others found associations between latrine ownership and diarrheal outcome. Additionally it was found that having improved sanitation systems often coincided with improved water sources and better hygiene practices, although these would be measured in multiple interventions (Daniels, Cousens, Makoae, Feachem 1990).

Reference	Intervention	Country	Setting	Outcome & Measurement (if available)	Age	Effective ?	Results
Baretto, ML 2007	Improved Sewer System	Brazil	Urban	Diarrhea	0 – 3 years	Yes	Decrease in Diarrheal Prevalence
Kolahi AA 2009	New Sewer System	Iran	Urban	Diarrhea	6 months – 5 years	Yes	Decrease in Diarrheal Incidence
Meddings DR 2004	Revised Latrine	Afghanistan	Urban	Diarrhea	0 – 11 years	Yes	Decrease in Diarrheal Diseases
Daniels 1990	New Latrines	Lesotho	Rural	Diarrhea	0 – 5 years	Yes	Decrease in Diarrhea

Table 1: *Sanitation Interventions*: The table below includes a combination of the sanitation interventions examined in two meta-analyses and their effectiveness (Fewtrell 2004; Padilla 2012).

Drinking Water

Inadequate drinking water was found to be the most commonly addressed issue; therefore, it has received the most attention and made the most significant progress. Two different types of drinking water interventions were found: water supply or source interventions and water quality interventions. Definitions for improved drinking water supplies or sources were consistently agreed to be any source that protect water from outside contamination either by the construction or through active intervention (UNICEF/WHO 2009). Some examples of such improved water sources include piped water into a plot or yard, public tap or standpipe, a tube

well, a protected dug well, protected spring water, or rainwater (UNICEF/WHO 2009; Fewtrell & Colford 2004). Water quality interventions were generally categorized as those that improved the drinking water itself prior to ingestion, usually at the point of use. Water quality treatments that accomplish this include: filtering, disinfecting, boiling and point of source chlorination (Padilla 2012; Fewtrell & Colford 2004).

The meta-analyses revealed that both water supply/source interventions and water quality interventions were successful in reducing rates of diarrhea (Padilla 2012; Fewtrell & Colford 2004). One study suggested, however, that, while making improvements to water supplies or sources can be beneficial, there is still the possibility of later contamination of the water due to inadequate household storage (Fewtrell & Colford 2004). Therefore, while water supply or source interventions provide some benefits, water quality interventions are ultimately the most effective because they make direct improvements in the microbial safety of water *immediately* before consumption (Fewtrell & Colford 2004; Waddington &Snilstevelt 2009). Dianna Padilla also supports this finding in her meta-analysis, where she, too, found water quality interventions to be more effective than water source interventions (2012). Padilla noted that seventy-two percent of the water quality interventions she examined effectively reduced the diarrheal rates (Padilla 2012).

Table 2 outlines the evaluations of water source interventions, and **Table 3** outlines water quality interventions.

Reference	Intervention	Country	Setting	Outcome/ Measurement (if available)	Age	Effective	Results
Corella-Barud 2009	UV Disinfection	Mexico	Urban	Diarrhea	All	No	Similar Diarrheal Prevalence before and after
Colford 2005	UV Light Disinfection	U.S.	Rural	Diarrhea	All	No	No reduction in diarrheal Prevalence
Frost et al. 2009	Filtration and Ozonation	U.S.	Urban	Diarrhea	All	No	No difference found. Some rates increased
Bahl 1976	Piped Water and Standpipes	Zambia	Urban	Diarrhea	All	Yes	Slight reduction in Diarrhea
Ryder 1985	Improved quality and household connection	Panama	Rural	Diarrhea	0 – 5 years	Yes	Reduced diarrheal rates
Gross 1989	Piped water and household	Brazil	Urban	Diarrhea	0- 6 years	Yes	Reduction in Diarrhea

	connection						
Wang 1989	Well with household connection	China	Rural	Diarrhea	All	Yes	Reduced Risk of diarrhea
Tonglet 1992	Piped water (standpipes)	Zaire	Rural	Diarrhea	0 – 4 years	Yes	Reduced Diarrhea

Table 2: *Water Source Interventions*: Below, the table outlines the effectiveness and results of various drinking water source interventions, in both urban and rural locations. Not all interventions were effective in reducing diarrheal rates in the respective countries. (Padilla 2012; Fewtrell 2004).

Table 3: *Water Quality Interventions*: The table below shows the outcomes of drinking-water quality interventions at the point of use. All water quality interventions effectively reduced diarrheal rates. (Padilla 2012; Fewtrell 2004).

Reference	Intervention	Country	Setting	Outcome/ Measurement (if available)	Age	Effective	Results
Ghannoum 1981	Reservoirs & Chlorination	Libya	Unstated	Dystentery	All	Yes	Reduced Dysente
Kirchhoff 1985	Hypochlorite Treatment at point-of-use	Brazil	Rural	Diarrhea	All	Yes	Most effective in age-groups 0 – 2 years and 2 – 4 years
Mahfouz 1995	Chlorination at point-of-use	Saudi Arabia	Rural	Diarrhea	0 – 5 years	Yes	Reduction in Diarrhea
Conroy 1996	Solar Disinfection at point-of-use	Kenya	Rural	Diarrhea& Severe Diarrhea	5 – 16 years	Yes	Decrease in diarrhea and Severe diarrhea
Sathe 1996	Boiling at point of use	India	Urban	Diarrhea	All	Yes	Large decrease in risk of Diarrhea
Xiao 1997	Boiling at point of use	China	Rural	Diarrhea	All	Yes	Slight reduction in Diarrhea
Semenza 1998	Disinfection and safe water storage	Uzbekistan	Not stated	Diarrhea	All	Yes	Most effective in children under 5 years
Quick 1999	Disinfection and safe water storage	Bolivia	Peri-urban	Diarrhea	All	Yes	Decreased Diarrhea
Iijima 2001	Pasteurization at point of use	Kenya	Rural	Severe Diarrhea	All	Yes	Decreased Diarrhea

Roberts 2001	Safe household storage	Malawi	Refugee camp	Diarrhea	All	Yes	Reduced risk of diarrhea
Gasana 2002	Secure protection and source treatment	Rwanda	Not stated	Diarrhea	0 – 5 years	Yes	Reduction of diarrhea prevalence
Quick 2002	Disinfection and safe storage	Zambia	Peri-urban	Diarrhea	All	Yes	Reduced risk of diarrhea
Jensen 2003	Chlorination	Pakistan	Rural	Diarrhea	0 – 5 years	Yes	Large decrease in diarrhea
Sobsey 2003	Disinfection and safe storage	Bangladesh	Urban	Diarrhea	0 – 5 years	Yes	Decrease in diarrhea

Hygiene

Much like drinking water interventions, hygiene interventions came in two forms: those that concentrated on providing education on health and hygiene, and those that actively promoted hand washing (with or without soap) (Fewtrell 2004). The reviewed literature did not often distinguish between the two focuses of hygiene, as they often coincide with one another. Therefore, in my review, hygiene education and hand washing promotion interventions are grouped into the same category. My research showed that hygiene education was primarily aimed at mothers, yet they measured the outcomes of diarrheal diseases and changes in hygienic behavior in children (Fewtrell 2004). It was found that hygiene interventions required the most behavioral changes, and that the most effective motivators for change were not always health related incentives; rather, promoting soap as a product for consumers that will make children smell and feel clean is more effective (Fewtrell 2004). Data was obtained on hygiene interventions from both urban and rural areas (Padilla 2012; Fewtrell 2004). **Table 4:** outlines the hygiene interventions considered in the two meta-analyses.

One intervention conducted in urban Bangladesh developed an educational intervention emphasizing changes in behaviors in order to reduce diarrheal incidence (Stanton, Clemens, Khair 1988). Maternal hand washing before food preparation, defecation away from living areas, and proper disposal of waste and feces were the target behaviors. Results showed that one year after the sanitation intervention, there were significant differences in the number of diarrheal episodes between the intervention communities versus the control communities. The intervention communities experienced a 22% reduction in diarrheal episodes when re-evaluated one year after the initiation of the study (Stanton, Clemens, Khair 1988). Children around the age of two years were found to be impacted the most by this intervention.

Table 4: *Hygiene Interventions*: The table below is the combination of various hygiene interventions examined in two meta-analyses (Fewtrell 2004; Padilla 2012).

Reference	Intervention	Country	Setting	Outcome & Measurement (if available)	Age	Effective	Results
Khan 1982	Hand washing with Soap	Bangladesh	Unstated	Diarrhea (RR)	All	Yes	Reduction in Diarrhea
Sircar et al. 1987	Hand washing with Soap	India	Urban	Watery Diarrhea. Dysentery. Combined Outcome. (RR)	0 – 5 years	Yes	Decreased Prevalence
Stanton et al. 1988	Hygiene Education	Bangladesh	Urban	Diarrhea (OR)	0 – 6 years	Yes	Decrease in Diarrhea
Han & Hlang 1989	Hand washing with Soap	Burma	Urban	Diarrhea. Dysentery. Combined Outcome (RR)	0 – 5 years	Yes	Decrease in Diarrhea
Lee et al. 1991	Hygiene Education	Thailand	Unstated	Diarrhea	0 – 5 years	Yes	Reduction in Diarrhea
Wilson et al. 1991	Hand washing with soap	Indonesia	Rural	Diarrhea	0 – 11 years	Slightly	Small decrease in Diarrheal Prevalence
Shahid et al. 1996	Hand washing with Soap	Bangladesh	Peri-urban	Diarrhea	All	Yes	Decrease in Diarrhea for all age groups
Apisarnthana et al. 2009	Hygiene Education	Thailand	Urban	Diarrhea, hand/foot/mouth infections	0 – 5 years	No	No observable reduction in Diarrheal Diseases
Ashley et al. 2004	Food Safety Program	Jamaica	Urban	Traveler's diarrhea	16 + years	Yes	Decrease in Diarrheal Disease
Fisher et al. 2011	BRAC Program and Hand washing	Bangladesh	Rural	Diarrhea	All	Yes	Reduced diarrheal disease
Kotch et al. 2007	Hygiene Education	U. S.	Urban	Diarrhea	0 – 6 years	Yes	Decreased Illness in centers with sanitation
Larson et al. 2004	Hand washing and home cleaning	U. S.	Urban	Diarrhea, Fever, Runny Nose	All	No	Not effective
Luby et al. 2004	Hand washing with Soap	Pakistan	Urban	Diarrhea	0 – 15 years	Yes	Lower Diarrheal Incidence

Ponka et al. 2004	Hygiene Education	Finland	Urban	Diarrhea, Respiratory Tract Infections	0 – 3 years; 3 + years	Yes and No	Reduction in illness for children 0 – 3 years; no difference in children 3 + years
Sheth et al. 2004	Food Safety Education and Hand washing	India	Unstated	Diarrhea	All	Yes	Reduction in Diarrheal Disease by 52%
Alam et al. 1989	Hygiene education	Bangladesh	Rural	Diarrhea (OR)	0 – 2 years	Slightly	Decrease in Diarrhea, but with large C.I.

Sanitation

Sanitation interventions repeatedly produced results showing their positive impact on combating diarrheal morbidity (Daniels et al. 1990; Fewtrell 2004; Padilla 2012). However, these interventions pose a few problems in their evaluations. Firstly, a problem arises in the measurements of sanitation interventions. Some studies measured sanitation by the direct *usage* of improved facilities (Hoque, et al. 1996); however, other studies acknowledged the difficulties in obtaining information on usage and chose instead to measure installation, ownership or the mere presence of improved sanitation facilities (Daniels et al 1990). Although it was not strictly mentioned in any studies, measuring the presence of improved facilities may overestimate the actual progress that is being made, as households that posses these facilities might not actually use or maintain the quality of them. Secondly, the two meta-analyses examined interventions that were conducted only in urban areas, and acknowledged that thisdid not allow thegeneralization oftheir finding across rural locations (Fewtrell 2004; Padilla 2012). However, separate studies conducted by Daniels et al., and Hoque et al.in rural Lesotho and rural Bangladesh, respectively, obtained similar findings to all of the urban intervention sites. This suggests that the benefits of improved sanitation facilities may actually be consistent across rural and urban locations, but further evaluationsare still needed.

Additionally, sustainability of interventions was not always measured. Indicators of improvements in sanitation were noted throughout the intervention processes; yet, few studies examined these same indicators in subsequent years to noteany enduring benefits of the interventions. One study in particular, located in rural Bangladesh, did, in fact, conduct a follow-up evaluation six years after the initial intervention (Hoque et al. 1996). Although the project was a multiple intervention, targeting drinking water, sanitation and hygiene, the researchers were able to evaluate the three components individually in order to determine the effectiveness of each aspect. They found that sanitation practices were ultimately maintained throughout

the six years, and the intervention communities showedsimilar rates of latrine usage both during and after the intervention (1996). This study concluded that the lasting impacts of the intervention were primarily due to the community involvement throughout the entire process, relying especially on the participation of women in the community to sustain the practices and maintain the quality of the new sanitation facilities (Hoque et al. 1996). Ultimately, sanitation interventions required both a change in defecation practices and an investment in the installation and upkeep of sanitation facilities, two large behavioral and lifestyle modifications expected of intervention communities (Hoque et al. 1996). Additional studies touched on the idea of sustainability, and proposed that it depends on both the behavioral mechanisms that need changing and the context in which the intervention takes place (Waddington &Snilstevelt 2009). In order for interventions to be accepted, effective and enduring in a community, the behavioral changes must align with the context in which they are proposed (Waddington &Snilstevelt. 2009). From this idea, it may be assumed that the sustainability of the Bangladesh sanitation project can be attributed to the proper aligning of the intervention with the context of the target community.

Drinking Water

Much like the slight difference in measurements used for various sanitation interventions, similar measurement discrepancies were encountered in drinking-water quality interventions. It is not always clear the extent to which individuals actively consume improved drinking water (i.e. after filtration, boiling, chlorination, etc.) nor is it clear how strictly the target communities avoided consuming unsafe drinking water (Waddington &Snilstevelt 2009). This often means that the presence of mechanisms to improve drinking-water quality is measured instead of assessingthe actual consumption of improved drinking water. Using this type of measurement, however, does not discount the effectiveness of improved drinking-water methods at the point of use, as they were more effective in reducing the prevalence of diarrhea among children consuming the improved water. It was commonly agreed that point of use interventions were significantly more effective than point of source treatments, mainly because of the potential for later contamination or improper storage of water after point of source treatments (Fewtrell 2004; Waddington &Snilstevelt2009; Padilla 2012). Improper storage and subsequent contamination basically eliminates any improvements that had been made to the quality of the water, and reverts the source back to its original state, if not adding even more contaminants to the water.

As far as sustainability of drinking water interventions is concerned, there was found to be a large lack of data. Drinking water interventions, much like sanitation interventions, require large behavioral modifications. The techniques and methods required to improve drinking water quality must be understandable for the potential beneficiaries – the process must be clear, effective and replicable in the implementation setting (Waddington &Snilstevelt 2009). In reference to the above

mentioned multiple intervention in rural Bangladesh, the sustainability of water improvements was actually measured. This study ultimately conducted a water source intervention, by providing or improving tube wells and hand pumps for the population. Upon evaluation six years after the intervention, the researchers concluded that drinking water improvements were enduring in this intervention area because the products used for maintenance and upkeep of the pumps were easily available and accessible to the population (Hoque et al. 1996). This implies that the beneficiaries understood how the pumps worked, knew the components necessary to maintain their function, and adapted their lifestyles and resource allocations to include these drinking water facilities in their daily prioritization (Hoque et al. 1996).

Hygiene

Although the two types of hygiene interventions were grouped together in this analysis, many sources suggested that projects promoting handwashing with soap were more successful than hygiene education programs (Waddington &Snilstevelt 2009). The hygienic outcomes were most often measured within a child population; however, the practices and behaviors that were targeted for change were usually those of mothers or adult women in the intervention population. In order to evaluate sustainability of hygiene interventions, assessments were made both before and after the interventions. Knowledge of disease transmission, risk factors diarrhea, hygienic practices and opinions on sanitary defecation practices were assessed before, during and after interventions. This allowed researchers to determine their initial understanding of hygiene and to monitor their progress.

Most Common Interventions & Their Barriers

Of the different types of interventions, those directed at drinking water sources and qualities were most common and those targeting sanitation were found to be the least common. From the research gathered, it was concluded that a majority of financial contributions to diarrheal prevention methods are aimed specifically at large-scale, drinking-water interventions, rather than sanitation interventions, in major urban areas (Uwejamomere 2008). My findings that sanitation interventions were, in fact, the least common, ultimately supports this claim. Just as urban areas are the most targeted locations for drinking water interventions, 75% of sanitation interventions were implemented in urban areas as well. It is unfortunate that sanitation interventions are not as highly prioritized; one study suggested their prioritization should be changed due to the fact that safe excreta disposal is even more important than drinking water quality, if the most broad range of health impacts are desired (Waddington &Snilstevelt 2009). While drinking water interventions did obtain successful results in their urban target population, they may not have affected a large

enough number of people to make significant gains in the total sanitation coverage, or make any progress towards reaching the Millennium Development Goals. Rapid urbanization is an increasing trend in developing countries, and it is expected that 80% of the world's entire population will reside in developing countries within the next 30 years (Uwejamomere 2008); thus, there are increasingly more people at risk for inadequate sanitation, poor drinking water and improper hygienic practices in rapidly urbanizing areas. Interventions need to be addressed according to the exponentially growing populations and their geographical locations (Uwejamomere 2008).

In order to see the most successful results, many of the interventions required major behavioral changes within the intervention communities. Sanitation, water quality, and hygiene interventions can all potentially encounterproblems regarding behavioral modifications. Open defecation practices in developing countries were one factor found to prevent progress in decreasing the diarrheal rates in all types of interventions. Open defecation interfered with drinking water quality, meant that sanitation was heavily lacking, and increased the likelihood of poor hygiene practices.

Multiple Interventions

All literature that was reviewed commonly agreed that separating the individual components of multiple interventions was not possible, nor appropriate. Therefore the data collected from multiple interventions analyze some combination of water quality or source, sanitation and hygiene interventions together. The majority of multiple interventions were found to be effective (Fewtrell 2004; Padilla 2012); however, it is unclear which components of the interventions had the most significant impact on the decreases in diarrheal prevalence. A multiple intervention study conducted in rural areas of Malawi (Young & Briscoe 1987) found that improvements in water and sanitation conditions reduced the odds of contracting diarrhea. This study focused on children under the age of five years measured water quality and sanitation by the fecal coliform count and latrine usage in the home, respectively. ; both of these factors contributed to the reduction of diarrhea. Similarly, a combined water, sanitation and hygiene education intervention in Bangladesh found that latrine usage in rural Bangladesh was much higher in the intervened population than in the control population (Hoque, Juncker, Sack, Ali, Aziz 1996). Table 5 outlines the effectiveness of multiple-interventions.

Table 5: *Multiple Interventions*: The table below shows the various components of multiple interventions, and their respective effectiveness.

Reference	Intervention	Country	Setting	Outcome/ Measurement (if available)	Age	Effective	Result
Aziz 1990	Hand pump and latrine installation, hygiene education	Bangladesh	Rural	Diarrhea, Persistent Diarrhea, Dysentery	0 – 5 years	Yes	Overall reduction in diarrhea
Mertens 1990	Tube well construction, rehab of traditional well, latrine construction, health education	Sri Lanka	Rural	Severe Diarrhea	0 – 5 years	Yes	Decrease Diarrhea
Hoque 1996	Hand pump and latrine installation, hygiene education	Bangladesh	Rural	Diarrhea	0 – 5 years; 5 + years	Yes	Greater reduction in 0 – 5 year age group
Messou 1997	Water supply, pit latrines and health education	Ivory Coast	Rural	Diarrhea	0 – 5 years	Yes	Decrease diarrhea
Nanan 2003	Improve potable supply (village and households), sanitation, hygiene education	Pakistan	Rural	Severe Diarrhea	0 – 6 years	Yes	Decrease Diarrhea
Arnold 2009	Hand washing with soap, household water treatment	Guatemala	Rural	Diarrhea	0 – 5 years	No	No difference found
Garrett 2008	Latrines, household chlorination, rainwater use, shallow wells	Kenya	Rural	Diarrhea	0 – 5 years	Yes	Reduced Diarrheal rates. Shallow wells were lease effective
Hosain 2003	Hygiene education, latrine utilization	Bangladesh	Urban	Intestinal Parasites	5 – 12 years	Yes	Lower infections in intervention groups
Luby 2004	Hand washing with soap, food safety education, water disinfection	Pakistan	Urban	Diarrhea	All	Yes	Decreased diarrheal incidence
Migele 2007	Hand washing, water quality	Kenya	Rural	Diarrhea	5 – 18 years	Yes	Decreased diarrheal incidence

Moll 2007	Hygiene education, new water tank/source, new or improved latrines	Honduras, Nicaragua, El Salvador, Guatemala	Not stated	Diarrhea	0 – 3 years	Yes	Decreased rates of diarrhea
Opryszko 2010	Hygiene promotion, chlorination, new tubewells	Afghanistan	Rural	Diarrhea	All	Yes	Reduced Diarrhea
Shrestha 2006	Hygiene education, point of use treatment, safe water storage	Uganda	Rural	Diarrhea	All	Yes	Averted diarrhea
Xue 2010	Hygiene package provided, water disinfection	Malawi	Urban	Diarrhea	Infants	Yes	Lower rates of diarrhea

Discussion

From the data collected, it is apparent that any type of interventions related to water, sanitation, hygiene or a combination of any of the above, effectively combat the proliferation of diarrhea in children. Though a few of the studies that were examined throughout this analysis measured the outcome of diarrhea in entire populations, the majority of the studies looked specifically into a population of children, anywhere from the ages of zero to six or seven years old. The positive results obtained in this specifically young population emphasizes the importance that such interventions can have in reducing a child's risk of developing a diarrheal disease.

Conclusion

After ample research, I am able to conclude that water, sanitation and hygiene interventions collaboratively work to reduce the burden of diarrheal diseases in children in developing countries. Global trends reveal that the same regions throughout the developing world face unsafe drinking water conditions, posses poor or non-existent sanitation facilities, lack hygienic practices and report the highest rates of child mortalities due to diarrhea. While the Millennium Development Goals acknowledged these trends and ignited a wave of interventions aimed at addressing these issues, there is still much work to be done. Individually, drinking water, sanitation, and hygiene interventions actively contribute to the reduction of diarrheal morbidity and mortality rates for children; my research showed a general decrease in diarrheal provenance rates following all interventions. Additionally, multiple interventions show similar results.

However, there are apparent barriers that developing countries face when trying to increase the access to sustainable drinking water, sanitation and hygienic methods. Rapid urbanization, growing slum populations, open defecation practices, inadequate allocation of financial resources, and necessity for major behavioral modifications make achieving the Millennium Development Goals much more difficult. These barriers are hard to overcome, and in many cases require large behavioral modifications within the beneficiary population, a daunting task involving time, dedication and observable benefits to encourage new behaviors. Future interventions should take into consideration the context in which they are being implemented, and strive to facilitate a cohesive transition from current behaviors and practices to the desired and improved behaviors. Sanitation interventions, specifically, should be more prioritized than they are at the moment, if any type of progress towards reducing the child death rate due to diarrhea is going to be made.

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ISP Journal

Wednesday 4 September 2013

- Met with Nezha for the first time to discuss my ISP project ideas
- She approved of my desire to look into food security and food safety and encouraged me to do further research

Friday 13 September 2013

- Sent in my research justification for verification, which included my reasoning for choosing my topic

Tuesday 24 September 2013

- First lunch meeting with Dr. Nidal Salim at the Global Institute for Water, Environment and Health (GIWEH), organized by Christian Viladent
- Decided to intern at GIWEH, and followed up with Dr. Salim via email after our in-person meeting

Friday 27 September 2013

- Literature Review essay sent in to SIT for approval

Wednesday 16 October 2013

- Second meeting with Dr. Nidal Salim at GIWEH (Geneva)
- Determined my work schedule and expected duties for the month long internship

Monday 21 October 2013

- First official day of work at GIWEH
- Assigned task of researching water, sanitation, hygiene and related diseases
- Decided to change my ISP topic from food security to global water and sanitation disparities

Thursday 24 October 2013

- Given 2 contacts at the World Health Organization from Dr. Salim, and sent emails to both of them regarding possibility of meetings/interviews
- Given another contact at CEWAS, would contact later once I had a better understanding of the organization and what information they could offer

Monday 28 October 2013

- Needed revising/consolidation of my question for ISP, so asked Mrs. Drissi for advice via email
- Narrowed my focus to diarrheal diseases as opposed to all water-related diseases, specifically focusing on children
- Tentative outline for ISP drafted

Monday 4 November 2013

- Contacted Didier Allely at WHO again via email – still waiting for response

Wednesday 13 November 2013

- Met with Dr. Salim to go over my research progress
- Was given another contact at the Embassy for Bangladesh to try and arrange a meeting or interview via email

Thursday 14 November 2013

- Heard back form Preeti Rahman (Bangladesh contact) – she will direct me to another person to contact with more specific information

Wednesday 20 November 2013

- Talked to Nezha to check my progress on my paper
- Received another contact at Swiss Water. Will email them ASAP

Thursday 21 November 2014

- Emailed contact at Swiss Fresh Water (which was provided by Nezha) and still waiting to hear back about potential meeting

Friday 22 November

- Altered the methods section of my ISP paper to include the limitation in research: did not receive responses in time from any of contacts, which ended up being a major limitation in research