MILLENNIUM DEVELOPMENT GOAL 7.C – ACCESS TO WATER: AN EXPLORATORY LOOK AT SIX COUNTRIES

by

Christina Marie Gerstel

Bachelor of Arts, International Relations, Boston University, 2005

Submitted to the Graduate Faculty of

Graduate School of Public Health in partial fulfillment

of the requirements for the degree of

Master of Public Health

University of Pittsburgh

2012

UNIVERSITY OF PITTSBURGH

Graduate School of Public Health

This thesis was presented

by

Christina Marie Gerstel

It was defended on

July 19, 2012

and approved by

Thesis Director: Martha Ann Terry, Ph.D., Assistant Professor,
Department of Behavioral and Community Health Sciences
Graduate School of Public Health
University of Pittsburgh

Aaron Barchowsky, Ph.D., Professor, Department of Environmental and Occupational Health
Graduate School of Public Health
University of Pittsburgh

Nicholas Chakos, Adjunct Professor, Division of International Development
Graduate School of Public and International Affairs
University of Pittsburgh

MILLENNIUM DEVELOPMENT GOAL 7.C – ACCESS TO WATER: AN EXPLORATORY LOOK AT SIX COUNTRIES

Christina Marie Gerstel, MPH

University of Pittsburgh, 2012

At the beginning of 1980, it was estimated that 1.8 billion people, or 40 percent of the world's population, lacked access to a safe drinking water supply. In 2000, the United Nations established the Millennium Development Goals, and among these goals is MDG 7.C, which aims to reduce by half the proportion of people without sustainable access to safe drinking water. In March of 2012, the WHO and UNICEF announced that the drinking water target for MDG 7.C had been met ahead of the 2015 deadline. However, 30 years after access to safe drinking water became a global priority, millions of people around the world still lack this basic necessity.

Water has many important health and developmental applications and consequences. Lack of water or access to poor quality water contributes to inadequate hygienic practices and is closely linked to diseases. High mortality and morbidity rates that result from the inaccessibility of safe water come with significant social and economic costs. With a primary emphasis on the consequences to health, the public health significance of this paper focuses on access to safe drinking water as a means to improve hygiene practices and reduce water-borne diseases.

This paper explores six developing countries that have experienced different levels of success in achieving the drinking water target of MDG 7.C. As this analysis reveals, one of the biggest contributing factors that seem to have led to the success of Malawi and Burkina Faso is each country's ability to absorb the rapid urban population growth each has experienced while still increasing the proportion of the population's access to improved drinking water sources. Additionally, both countries have made water a specific development priority and backed this up

with funding, sound policies and seemingly strong water sector authorities with clearly defined roles.

There remain 780 million people without access to safe drinking water who are in constant danger of illness, disability and death. As Malawi and Burkina Faso have demonstrated, MDG 7.C can be achieved. With the right support and planning, many of the world's poorest countries can achieve the same successes as these two countries.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

1.0 INTRODUCTION

Access to safe drinking water has been at the forefront of both global health and global development agendas for the past 30 years. In 1980, 40 percent of the world's population did not have access to a safe drinking water supply. This left an estimated 1.8 billion people susceptible to numerous water-borne diseases that contribute to loss of health, loss of productivity and loss of life while ultimately contributing to the slow progress some of the world's poorest countries have experienced in their attempts to develop.

Over the course of the past 30 years, the world has acknowledged that access to safe drinking water is a human right. In 2000, the United Nations established the Millennium Development Goals (MDGs). These goals are aimed at tackling some of the world's greatest development challenges by 2015. Among these goals is MDG 7.C, which aims to reduce by half the proportion of people without sustainable access to safe drinking water.

In 2012, the announcement was made that the drinking water target of MDG 7.C. had been reached at the global level ahead of the of the 2015 deadline. However, even though this goal has been reached on a global scale, that does not mean that all developing countries have reached this goal; in fact, many have not.

The following analysis explores six different developing countries that have experienced different levels of success in achieving the drinking water target of MDG 7.C. The countries included in this analysis are grouped by twos into three different categories. The first category includes two countries that have successfully reduced by half the proportion of their population lacking access to a safe drinking water source. The countries in this category are Malawi and Burkina Faso. The second category includes two countries that have experienced some gains towards achieving the drinking water goal but progress has stalled or the countries have not been able to reach the benchmark. These two countries are Nigeria and Bangladesh. The last category includes two countries that have actually regressed and the proportion of their population without access to an improved drinking water source has increased. These two countries are Lesotho and Tanzania.

For each country, the same set of factors is explored in order to identify key influences that may have contributed to the successes and failures of these countries in reaching the established benchmark. The main factors include country population changes, water access throughout the country, each country's recent water management practices and policies, sanitation access in each country and a set of economic indicators. To help add depth to the analysis, narratives are included to highlight how water has impacted health in each country and examples of small scale water interventions are also included when available. All of these elements are looked at for the period of 1990 to 2010.

The second section of this analysis begins with the background on the importance of water to health and development. The third section includes both the country sample selection methodology and the research methodology for the analysis. The fourth section includes the results of the research and explains the findings for each of the six countries. The fifth section includes a discussion of the findings while the last section includes the analysis conclusions.

2.0 BACKGROUND

The International Drinking Water and Sanitation Decade, which spanned from 1981 to 1990, came with the slogan "Water and Sanitation for All." At the beginning of 1980, it was estimated that 1.8 billion people, or 40 percent of the world's population, lacked access to a safe drinking water supply (Black, 1998). By the end of the Water and Sanitation Decade, an estimated 76 percent of the world's population had access to improved water sources, an increase of 36 percent (World Health Organization [WHO] and United Nations Children Fund [UNICEF] Joint Monitoring Programme [JMP], 2012).

In September of 2000, ten years after the end of the Water and Sanitation Decade, the members of the United Nations General Assembly established the world's Millennium Development Goals (MDGs) under the United Nations Millennium Declaration (United Nations [UN], 2000). The intention of establishing the MDGs was to reaffirm the UN's commitment to global development while also drawing the world's attention to some of the most pressing issues that many living throughout the world faced. Among the MDGs is MDG 7.C. Found under the broader environmental sustainability goal, MDG 7.C aims to halve by 2015 the proportion of people without sustainable access to safe drinking water and basic sanitation. Further highlighting the importance of access to safe drinking water, in 2003 the UN declared 2005-2015 the World Water Decade with a slogan of "Water for Life."

In 2002, the UN Committee on Economic, Cultural and Social Rights "took the unprecedented step of agreeing on a 'General Comment'[1] on water as a human right" (WHO, 2002). The comment stated that "the human right to water entitles everyone to sufficient, affordable, physically accessible, safe and acceptable water for personal and domestic uses" (WHO, 2002). Yet it was not until 2010 that the UN General Assembly formally recognized access to water and sanitation as a human right.

In March of this year, 2012, the WHO and UNICEF announced that the drinking water target for MDG 7.C had been met ahead of the 2015 deadline. However, 30 years after access to safe drinking water became a global priority, millions of people around the world still lack this basic necessity. Even though two billion people have gained access to improved drinking water sources since 1990, reports estimate that more than 780 million people still lack access and if current trends continue, by 2015 605 million people will still not have access to safe drinking water sources (WHO & UNICEF, 2012).

2.1 IMPORTANCE OF WATER

Water has many important health and developmental applications and consequences. To start, water is important and necessary to sustain life. The recommended minimum daily amount of water necessary to meet basic needs and to minimize risks to health is 50 to 100 liters of water per person per day (UN Water, nd). Yet, many do not have this level of access. Lack of water or

[1] A General Comment is an interpretation of the provisions of the International Covenant on Economic, Social and Cultural Rights which typically compels countries to take action based on the General Comment.

access to poor quality water contributes to inadequate hygienic practices and is closely linked to diseases such as cholera, dysentery and scabies (Mulwafu & Msosa, 2005).

High mortality and morbidity rates that result from the inaccessibility of safe water come with significant social and economic costs. People who are sick and incapacitated due to water-related diseases are unable to contribute to economic and social growth (Arvai & Post, 2011). Additionally, for many around the world, the closest water source may be kilometers away from their homes and once reached, more time may be spent waiting in long lines. In many developing countries, this burden of water collection typically falls on women and children who may spend as much as 25 percent of their time collecting water (Sullivan et al., 2002). This is time spent on non-income generating activities that take women and children away from work and educational opportunities, of which there are direct developmental consequences. It has been well documented that water-related diseases disproportionately impact poor people in developing countries as extreme poverty is linked to poor health and poor health further exacerbates impoverishment (Arvai & Post, 2011).

Water is also necessary in agricultural and food production processes as well as many industrial and manufacturing endeavors. Furthermore, water is crucial for the natural environment. Insufficient water can negatively impact biomass growth while also contributing to increased rates of desertification and wind-induced soil erosion (Sullivan et al., 2003).

It is argued that water plays a critical role in countries' abilities to achieve any and all of the targeted Millennium Development Goals. Overall, WHO notes that

> investment to improve drinking water, sanitation, hygiene and water resource management systems makes strong economic sense: every dollar invested leads to up to eight dollars in benefits. US $84 billion a year could be regained from the yearly investment of US $11.3 billion needed to meet the water and sanitation targets under the Millennium Development Goals (WHO, 2009, June).

Mulwafu and Msosa highlight the various roles that water plays in the other Millennium Development Goals. For example, for poverty and hunger, they emphasize that access to safe water improves health which positively impacts an individual's productivity while also reducing the burden on those who care for the sick. Additionally, healthy people, in contrast to those suffering from water-borne diseases, are better able to absorb nutrients from food. Looking at universal primary education, school attendance improves when children are healthier and when there is a decrease in water-carrying burdens, especially for girls. Gender equality is impacted when there is a reduction in time spent on health and care-giving burdens which give women more time to spend on productive efforts and education. Also, having water sources closer to the home reduces the risk of women and girls being physically and sexually assaulted while collecting water. Furthermore, an improvement in the quality and quantity of water can reduce the main morbidities and mortalities of children. When looking at maternal health, improved health and nutrition as a result of safe drinking water can reduce susceptibility to anemia while access to water for washing before and after birth can reduce life threatening infections (Mulwafu and Msosa, 2005). Lastly, for the global partnership goal, aid and affordable technologies geared towards improving access to safe water and improved sanitation benefit producers and consumers.

With a primary emphasis on the consequences to health, this paper focuses on access to safe drinking water as a means to improve hygiene practices and reduce water-borne diseases. As such, drinking water should be of acceptable quality physically, chemically, and bacteriologically so that it can be safely used for drinking, cooking and for hygienic purposes while not posing any significant health risk to a person through life long consumption (WHO, 2012a; WHO, 2011b).

2.2 WATER AND HEALTH

The WHO states that nearly one tenth of the global disease burden could be prevented by "increasing access to safe drinking water, improving sanitation and hygiene and improving water management to reduce risks of water-borne infectious diseases, and accidental drowning during recreation" (WHO, 2009, June). Additionally, WHO notes that improvements to water conditions could prevent the death of 1.8 million people who die from diarrheal disease, 90 percent of whom are children. Another five million people could be saved from disabilities due to trachoma (WHO 2004, November; WHO, 2009, June). Cairncross and Feachem note that

> health impacts of water are related to both the quality of water and its availability within a reasonable distance; studies indicate that clean water within a distance of not more than 1 km from the house tends to lead to improved health status, since people start to use substantially more water for cleaning and washing (as cited in Sullivan et al., 2003, p. 190).

Turning specifically to water for drinking and hygiene applications, the primary concerns of water contamination come in two forms, microbial and chemical.

2.2.1 Microbial Issues

The primary microbial risks of water consumption result from ingestion of water that is contaminated with human or animal feces. As a pathogenic source, feces contaminated water may contain bacteria, viruses, protozoa and helminthes (WHO, 2011b). In testing water, the identification of bacteria coliforms is widely used as an indication of water contamination. Different studies may use different measures of coliforms. For instance, some studies may look at total coliforms counts which can include coliforms found in the soil. However, the WHO notes that total coliform count is not a good indicator of the safety of water as there are a number of bacteria that can be present in untreated waters that pose no significant health risk (New York State [NY], 2011; WHO, 2011b). Other studies may look specifically for fecal coliforms, or coliforms that are typically present in the gut or feces of humans and animals. The most common fecal indicator coliform is *Escherichia coli* (*E. coli*) which is generally not found in the environment (NY, 2011). Thermotolerant coliforms, which are capable of withstanding elevated temperatures, can also be used to test for *E. coli*. Water meant for human consumption should contain zero fecal indicator organisms (WHO, 2011b).

Six primary diseases are associated with unsafe water supplies. These are diarrhea, *Ascariasis*, *Dracunculiasis*, hookworm, *Schistosomiasis*, and Trachoma.

Diarrhea, defined as the passage of three or more loose or liquid stools per day, is the second leading cause of death in low income countries and the leading cause of morbidity and mortality in children (WHO, 2011, June; WHO, 2009, August). If untreated, diarrhea can lead to severe dehydration and death. According to WHO, 88 percent of diarrheal disease is due to unsafe water supplies and inadequate sanitation and hygiene (WHO, 2004, November). The three most common diarrheal diseases directly attributable to unsafe water consumption are cholera, bacillary dysentery and typhoid (WaterAid, nd).

An infection of the small intestine, *Ascariasis* is caused by a large roundworm. *Ascariasis* infection is caused by ingesting the eggs of the roundworm. Ingestion usually occurs due to contaminated food sources and soil that have been irrigated with unsafe water. The larvae hatch and penetrate the walls of the host's intestines and have the ability to cause intestinal blockage, which can lead to death. As one of the most common human parasitic infections, *Ascariasis* leads to approximately 60,000 global deaths annually (WHO, 2001b).

Dracunculiasis, or guinea-worm disease, is a crippling parasitic disease caused by a long thread-like worm (WHO, 2012, January). Caused by consuming the infected water flea vector found in contaminated water sources, guinea-worm disease can leave its victims nonfunctional for months. Typically found in rural isolated communities of sub-Saharan Africa that rely on open water sources, prevalence of the disease has dropped dramatically to fewer than 1,100 reported cases in 2011 as a result of a global eradication campaign (WHO, 2012, January).

Hookworm is mostly a soil-transmitted helminth and enters the body through skin contact. An infective third-stage larvae is capable of penetrating the skin and typically enters the body through the hands, feet, arms and legs. One form of hookworm can be ingested primarily due to the use of untreated wastewater in agricultural practices. According to WHO, chronic hookworm infections in children have been shown to have profound effects on child physical and intellectual development. Reduced attendance and school performance as a result of hookworm infections have been shown to adversely impact future productivity and as a result, wage-earning potential (WHO, Parasitic Disease, nd).

Schistosomiasis is a water-borne parasitic helminth that is transmitted by snails. It is estimated that *Schistosomiasis* leads to 20,000 deaths annually due to the severe consequences of infection. Infection can lead to bladder cancer, renal failure, liver fibrosis and portal hypertension. According to the WHO, "environmental changes linked to water resource development, population movements and population growth have led to the spread of the disease to previously low or non-endemic areas, particularly in sub-Saharan Africa" (WHO, Parasitic Disease, nd).

Lastly, trachoma, which occurs in overcrowded conditions where people have limited water and health care access, is the leading cause of preventable blindness (WHO, 2001b).

Transmitted from person to person, blinding trachoma is prevalent in in the Middle East, North and Sub-Sahara Africa, parts of the Indian subcontinent, Southern Asia and China. Interventions focused on improving access to water, properly disposing of fecal material and promoting face washing have been shown effective in decreasing the number of trachoma infections in communities (WHO, 2001b).

Overall, WHO notes that diarrhea morbidity could be reduced by six to 25 percent with improved water supplies and that the implementation of household water treatment could reduce the number of diarrhea episodes by 35-39 percent (WHO, 2004, November). In addition, trachoma morbidity could be reduced by 27 percent with improved access to safe water sources coupled with better hygiene practices (WHO, 2004, November). Lastly, the combination of improved access to safe water and sanitation along with better hygiene practices could reduce morbidity from intestinal helminths such as *Ascariasis* and hookworm by 29 percent and 4 percent respectively (WHO, 2004, November).

2.2.2 Chemical Issues

While microbial contamination may have immediate impacts on population health, chemical contamination usually requires prolonged exposure. In some instances, this makes contamination identification difficult as symptoms may take years to develop. According to the WHO, only a few chemicals have been shown to have widespread negative health effects in humans exposed at certain levels to them through drinking-water (WHO, 2011b). These chemicals are fluoride, nitrate and arsenic.

Fluoride is a common element found in the earth's crust. Although found in many water sources, higher concentrations of fluoride are typically found in ground water. Artificially added to drinking water in small concentrations (0.5-1 mg/l), fluoride has been adopted as a cost-effective public health tool to help combat dental caries. However, elevated fluoride intake, typically due to consumption of groundwater rich in fluoride, has been known to cause dental and skeletal fluorosis. Crippling skeletal fluorosis, which can result in osteosclerosis, tendon and ligament calcification and bone deformities, is known to occur when 14 mg of fluoride are consumed per day. The maximum WHO guideline values for fluoride consumption is 1,500 µg/l (or 1.5 mg/liter) (WHO, 2011b).

Naturally occurring in the environment, nitrate is important to plant functioning. Nitrite, also present in the environment, is not as prevalent. WHO notes that as a result of agricultural activity, waste water disposal and oxidation of waste products from humans and animals, nitrate is able to reach both surface and ground waters (WHO, 2011b). Excess consumption of nitrate primarily from drinking water sources has been linked to incidences of methaemoglobinaemina, a condition where oxygen transport throughout the bloodstream is inhibited. The most prevalent cases of methaemoglobinaemina are found in bottle-fed infants and lead to what is known as "blue baby syndrome." The maximum WHO guideline values for nitrate and nitrite consumption is 15 mg/liter and 3 mg/liter respectively (WHO, 2011b).

Again, similar to fluoride and nitrate, arsenic is found within the earth's crust. In many waters, typical concentrations are less than 1-2 µg/l, but in ground waters where sulfide mineral deposits and volcanic sedimentary rocks are found, concentrations can be considerably higher (WHO, 2011b). The result of consuming drinking-water with high concentrations of arsenic is known as arsenicism. Depending on the level of exposure, nutritional status and immune response, arsenicism can take as long as eight to 14 years to develop (Alam et al., 2007). Signs of arsenicism include dermal lesions, peripheral neuropathy, skin cancer, bladder and lung cancers and peripheral vascular disease (WHO, 2011b). In addition, during pregnancy, studies have shown that arsenicism can result in higher rates of fetal loss, infant death and low birth weight (Gardner et al., 2011). The maximum WHO guideline values for arsenic consumption is 10 µg/l (or 0.01 mg/liter) (WHO, 2011b).

2.3 IMPROVED AND UNIMPROVED WATER SOURCES

One of the targets of MDG 7.C is to halve the proportion of the population without sustainable access to safe drinking water. As the JMP explains, the term 'access' can have different meanings in different settings, making country comparisons challenging. Since the JMP is mandated to report on a global level across time, it created a set of categories for 'improved' and 'unimproved' facilities that it uses to analyze and report on country data and trends (JMP, 2012b). The following is a list and description of each type of water source as defined by JMP.

Improved sources of drinking water:

- Piped water into dwelling, also called a household connection, is defined as a water service pipe connected with in-house plumbing to one or more taps (e.g. in the kitchen and bathroom).
- Piped water to yard/plot, also called a yard connection, is defined as a piped water connection to a tap placed in the yard or plot outside the house.
- Public tap or standpipe is a public water point from which people can collect water. A standpipe is also known as a public fountain or public tap. Public standpipes can have one or more taps and are typically made of brickwork, masonry or concrete.
- Tube well or borehole is a deep hole that has been driven, bored or drilled, with the purpose of reaching groundwater supplies. Boreholes/tube wells are constructed with casing, or pipes, which prevent the small diameter hole from caving in and protects the water source from infiltration by run-off water. Water is delivered from a tube well or borehole through a pump, which may be powered by human, animal, wind, electric, diesel or solar means. Boreholes/tube wells are usually protected by a platform around the well, which leads spilled water away from the borehole and prevents infiltration of run-off water at the well head.

- Protected dug well is a dug well that is protected from runoff water by a well lining or casing that is raised above ground level and a platform that diverts spilled water away from the well. A protected dug well is also covered, so that bird droppings and animals cannot fall into the well.
- Protected spring. The spring is typically protected from runoff, bird droppings and animals by a "spring box", which is constructed of brick, masonry, or concrete and is built around the spring so that water flows directly out of the box into a pipe or cistern, without being exposed to outside pollution.
- Rainwater refers to rain that is collected or harvested from surfaces (by roof or ground catchment) and stored in a container, tank or cistern until used (JMP, 2012b).

Unimproved sources of drinking water:

- Unprotected spring. This is a spring that is subject to runoff, bird droppings, or the entry of animals. Unprotected springs typically do not have a "spring box".
- Unprotected dug well. This is a dug well for which one of the following conditions is true: 1) the well is not protected from runoff water; or 2) the well is not protected from bird droppings and animals. If at least one of these conditions is true, the well is unprotected.
- Cart with small tank/drum. This refers to water sold by a provider who transports water into a community. The types of transportation used include donkey carts, motorized vehicles and other means.
- Tanker-truck. The water is trucked into a community and sold from the water truck.
- Surface water is water located above ground and includes rivers, dams, lakes, ponds, streams, canals, and irrigation channels.
- Bottled water is considered to be improved only when the household uses drinking water from an improved source for cooking and personal hygiene; where this information is not available, bottled water is classified on a case-by-case basis (JMP, 2012b).

2.4 TYPES OF WATER INTERVENTIONS

Three general types of water interventions can enable people to improve their access and the quality of their drinking water. First, there are point-of-use (POU) and household water treatments (HWTs). These types of applications are conducted at an individual or household level. POUs and HWTs are geared towards small volume applications and typically consist of household filters or mixtures intended to clean and remove hazards from water. The second type of intervention includes those found at a community level. Community level interventions target many households at once and usually consist of the installation of water wells and/or pumps. Lastly, there are interventions that are scaled to a regional level. These interventions, usually established by the government, are aimed at improving water access for large numbers of people and typically take the form of piped water.

2.4.1 Point-of-Use and Household Water Treatment

Although the delivery of safe water through in-house piping is ideal, this goal is typically cost-prohibitive and often out of reach for many in developing countries. As a result, the WHO has been promoting HWTs as a means of achieving the health benefits that result from regular access to safe drinking water (Clasen et al., 2007).

Considering that the JMP monitoring indicators for MDG 7.C focus exclusively on community and regional level interventions, it is important to briefly describe POU and HWT options that may be available to individuals to treat poor quality water. With such a high prevalence of water-borne diseases, POU technologies have empowered people and communities, typically with limited or no access to safe water, to improve water quality through at-home treatments (Sobsy, Stauber, Casanova, Brown & Elliott, 2008). The WHO describes HWT applications as the technologies, devices and methods used to treat poor quality water at the household level or at any point-of-use setting such as schools and health-care facilities. These technologies and methods include chemical disinfection, membrane filtration, granular media filtration, solar disinfection, ultra-violet light, thermal applications, sedimentation and a combination of methods that are used simultaneously or sequentially. To be most effective and protective, HWT should aim to meet the WHO recommended level of risk of 10^{-6} disability adjusted life years (DALYs) per person per year (WHO, 2011a).

2.4.1.1 Chemical Disinfection

Chemical disinfection includes chlorine or iodine based technologies. In developing countries, free chlorine is the typical mode of chemical disinfection as it is typically considered to be effective, available, inexpensive and easy to dose properly when compared to iodine. Free chlorine, if dosed correctly, is effective against bacteria and viruses but not *Cryptosporidium* (WHO, 2011a).

2.4.1.2 Membrane and Porous Media Filtration

Filtration technologies typically include the use of cloth, membranes, porous ceramic, carbon blocks and composite filters. These filters reduce the presence of microbes through straining, sedimentation and absorption. Cloth filters have been an important component of *Dracunculiasis* eradication programs and the reduction of cholera. Small-scale and low-cost applications of these types of POU technologies are becoming more prominent in developing countries (WHO, 2011a).

2.4.1.3 Granular Media Filtration

Granular media filtration technologies use sand or other media that is compacted or layered so that water may pass through. Again with the aid of straining, sedimentation and absorption, these methods collect microbes and other contaminates from the water passing through (WHO, 2011a).

2.4.1.4 Solar and UV Disinfection

Solar technologies use solar irradiation to disinfect water. A number of technologies use dark or opaque containers that allow heat from sunlight to disinfect water. One of the more recent technologies, specifically called SODIS, uses clear PET water bottles that allow UV radiation in combination with oxidative activities to disinfect water. Other applications include the use of UV lamps. Specifically for household small-scale applications, low-pressure mercury arc lamps can be employed (WHO, 2011a).

2.4.1.5 Thermal Technologies

Thermal technologies rely on heat from burning fuel to disinfect water. Boiling water remains the most common HWT application in developing countries (WHO, 2011a).

Overall, the WHO notes that

> in some regions, it has been shown that investments in water supply and sanitation can yield a net economic benefit, as the reductions in adverse health effects and health-care costs outweigh the costs of undertaking the intervention....[and] experience has also shown that interventions in improving access to safe water favour the poor in particular whether in rural or urban areas, and can be an effective part of poverty alleviation strategies (WHO, 2011b).

2.5 BARRIERS TO ACCESS

A number of reasons exist that help to explain why access to safe drinking water has yet to be achieved globally. Within a country, lack of financial resources and low prioritization of water issues constrain maintenance and expansion efforts necessary to increase access to safe drinking water (Montgomery & Elimelech, 2007). Furthermore, corruption, poor management, and lack of accountability often stand in the way of improvement efforts (Montgomery & Elimelech, 2007). Inadequate and hard to enforce water quality standards also make it challenging to improve health outcomes related to drinking water (Montgomery & Elimelech, 2007).

2.6 OTHER CONSIDERATIONS

Other factors can greatly impact the quality of drinking water. First and foremost the availability and quality of proper sanitation methods and technologies can have a large effect on the quality of water available to a community. Typical standards indicate that sanitation facilities should be 100 meters downstream from water sources while studies indicate this is not regularly adhered to in many developing countries.

Additionally, it is often observed that microbiological contamination of water is higher at home than when gathered at the source. This suggests that contamination is occurring during collection, transport, storage and drawing of water (Wright, Gundry, & Conroy, 2004). Household storage containers that utilize a closed or narrow neck are a critical component to household water management in order to prevent contact with contaminated sources such as people's hands or utensils used to ladle water (WHO, 2011).

Furthermore, sources of contamination frequently come from human activity around the source itself. Poor hygiene practices such as open defecation and trash disposal have been noted in and around water sources. It has been suggested that a lack of knowledge about sanitary principles, unaffordable water costs, inadequate water sources and long distances to safe water sources results in these poor hygiene practices (Masangwi, 2009).

In general, regardless of the source, regular monitoring should occur. Even improved sources need to be routinely inspected and regular maintenance needs to occur in order to ensure integrity of the source (Kavitz, Nyaphisi, Mandel & Petersen, 1999).

3.0 METHODOLOGY

3.1 SAMPLE SELECTION METHODOLOGY

In order to draw general conclusions as to why some of the least developed countries are succeeding in meeting the drinking water target of MDG 7.C while others are struggling to halve the proportion of the population with access to safe drinking water, the author decided to analyze varying levels of success and failure. Wanting to assess the potential explanations for successes and failures across the spectrum while also looking at the individual successes and failures on a case-by-case basis, the author employed the following methodology.

Data from the WHO/UNICEF Joint Monitoring Programme (JMP) for Water Supply and Sanitation were aggregated using the JMP data and estimates tool (JMP, 2012a). The author initially looked at total population data for all of the countries for which data existed from 1990, the baseline for MDG 7, to 2010, the most recent year for which data are available. In order to note changes over time, the author looked at data in five-year increments beginning with 1990 and ending with 2010. The author looked at the percent of the population that had access to an improved drinking water source for each year. This proxy measure, as determined by WHO, is the "proportion of people using improved drinking water sources: household connection; public standpipe; borehole; protected dug well; protected spring; and rainwater collection" (WHO, 2012a) and by JMP as “those that by the nature of their construction, are protected from outside contamination, particularly faecal material” (UNICEF, 2012, p.4).

The author further analyzed the data in order to identify countries that demonstrated large improvements in access versus those that either stagnated or demonstrated decreases in access. The author designated three categories for country coding. The first category included countries that have reached the MDG goal to reduce by half the proportion of the population without access to safe drinking water. The second category included countries that have either stagnated in access or have made advances in access to improved water sources but as of 2010 have not been able to reach the “halved” benchmark. The third category included countries that have experienced reductions in access to safe drinking water. During this stage of country selection, countries that experienced war or prolonged internal conflict within the past ten years, are considered to be failed states, or experienced massive disasters were excluded as such characteristics result in extremely complicated situations with numerous compounding factors that would make analyzing a country’s access to water nearly impossible.

In addition to briefly referencing country histories, the author also reviewed the World Bank’s *Harmonized List of Fragile Situations FY2010* to identify additional countries that would be particularly challenging to assess due to internal qualities that make a country increasingly vulnerable to internal or external threats (World Bank, 2010). Lastly, the author removed countries that had incomplete data or that were already at the world’s 2015 “halved” mark of 88 percent in 1990, the baseline year. Starting with data on 224 countries, applying the first round of inclusion and exclusion criteria narrowed the scope down to 47 countries.

Table 1: Round 1 Inclusion/Exclusion Results

Description of 224 Countries	Results
Excluded: War, failed states, incomplete data, already at 88 percent access at 1990 baseline	175
Included: Reached MDG benchmark	23
Included: Stagnated or have not reached MDG benchmark	22
Included: Regressed	2
Remaining Countries	**47**

The author then cross-referenced the remaining 47 countries with the Human Development Index (HDI), which is a single statistic used as a frame of reference for social and economic development that is widely used by development practitioners as a basic snapshot of each country's level of human development (United Nations Development Programme [UNDP], 2011). The author used both the 1990 and 2011 HDI reports as a basic frame of reference by which to generally categorize countries. The HDI cannot be used to make specific comparisons across time due to the changes in how the HDI is calculated and the number of countries included over the years. Yet, this should not preclude its use as a basic inclusion and exclusion metric for the purposes of this paper. Using the HDI rankings, the author eliminated countries that were not ranked in the 1990 report and countries that were ranked as having "very high" or "high" levels of human development in the 2011 report. Ultimately wanting to focus on the outcomes among the least developed countries, the author further eliminated countries that were ranked as having a "medium" level of human development in the 2011 HDI report. This resulted in the exclusion of an additional 31 countries. Altogether, this reduced the number of countries from 47 to 16 countries.

Table 2: Round 2 Inclusion/Exclusion Results

Description of 47 Countries	Results
Excluded: not included in 1990 HDI ranking; ranked "very high", "high" or "medium" in 2011 HDI rankings	31
Included: Reached halved benchmark	4
Included: Plateaued or have not reached MDG benchmark	10
Included: Regressed	2
Remaining Countries	**16**

Of the remaining 16 countries, the author selected those that displayed the most dramatic characteristics of each of the three categories (i.e. showed the most gains in access, stagnated the most or showed the most decline) and that were also ranked as having "low" levels of human development in the 2011 *Human Development Report*. This resulted in the selection of Malawi and Burkina Faso as the countries that have succeeded in reducing by half the proportion of the population without access to an improved water source. For countries that have stagnated or have made minimal improvements to their populations' access to an improved drinking water source, Bangladesh has shown the least amount of improvement. In selecting a second country for this category, three countries showed the same level of improvement (Mozambique, Nigeria and Senegal). Nigeria was selected for inclusion due to its large population and as a result the country's slow progress in achieving access to improved water sources impacts the greatest number of people. Lastly, Tanzania and Lesotho were the two examples of countries that have seen reductions in the proportion of each population's access to an improved water source.

Table 3: Selected Countries for Inclusion

Inclusion	Results
Included: Reached MDG benchmark	Malawi Burkina Faso
Included: Stagnated or have not reached MDG benchmark	Nigeria Bangladesh
Included: Regressed	Lesotho Tanzania

3.2 RESEARCH METHODOLOGY

For each of the selected six countries, the author used Scopus to conduct key word searches to identify sources that would help establish a better understanding of each country's history, to determine what types of water-borne diseases have been issues for the country and to explore different water projects or policies that have been developed. All of this was done to help explain the differences in each country's access to improved drinking water sources over the past 20 years. Each search was limited to articles in English that ranged from 1990 to 2012 and pertained to relevant country information for the years of 1990 to 2010. Below, Table 5 summarizes each key word search. Titles and abstracts of returned articles from each set of key word searches were reviewed for relevance. Articles that pertained to water projects, water interventions, water treatments, water contamination (both microbial and chemical), access to water, drinking water, water quality, water policies, water management, hygiene and sanitation and programs or curricula that were aimed at reducing particular water-borne illnesses were reviewed. Bibliographies from reviewed articles and reports were examined for additional references.

Table 4: Literature Searches

Search Engine/Database	Search Terms	Results Returned	Relevant Articles
Scopus	Water intervention Malawi AND health	15	7
Scopus	Water intervention Burkina Faso AND health	9	2
Scopus	Water intervention Nigeria AND health	48	23
Scopus	Water intervention Bangladesh AND health	73	26
Scopus	Water intervention Lesotho AND health	4	1
Scopus	Water intervention Tanzania AND health	43	9
Scopus	Drinking water Malawi AND health	13	8*
Scopus	Drinking water Burkina Faso AND health	8	4*
Scopus	Drinking water Nigeria AND health	142	73*
Scopus	Drinking water Bangladesh AND health	350	127*
Scopus	Drinking water Lesotho AND health	2	2*
Scopus	Drinking water Tanzania AND health	24	9*
Scopus	Safe water Malawi AND health	10	5*
Scopus	Safe water Burkina Faso AND health	4	4*
Scopus	Safe water Nigeria AND health	73	27*
Scopus	Safe water Bangladesh AND health	123	39*
Scopus	Safe water Lesotho AND health	3	1*
Scopus	Safe water Tanzania AND health	16	7*
** indicates multiple counting as some articles appeared in multiple searches*			

Beyond policies and specific water interventions, the author was also interested in exploring if other indicators would help to explain the differences in the six sampled countries. As a result, the author looked at additional data from the JMP, Transparency International and a range of indicators provided in the World Bank database. Specifically, the author looked at data about each country's access to improved sanitation, each country's perceived level of corruption as well as gross domestic product (GDP), GDP per capita, net official development assistance received and national health expenditure data.

Sanitation data were explored due to the close relationship between clean water and sanitation. Corruption, an important component to development, was included as there have been indications that a negative relationship exists between corruption and access to improved drinking water (Anbarci, Escleras & Reister, 2009). Transparency International develops an annual corruption perception index that scores countries on a scale from zero to 10 where zero indicates that a country is "highly corrupt" and a score of 10 means that the country is "very clean."

Gross domestic product indicators were selected to assess if there were improvements to general standards of living and to evaluate if changes in access to water could be related to changes in basic living standards. Net official development assistance was explored to see if changes in water access were related to international aid and therefore external interest in a country's development. And health expenditures were explored to see if changes in access to water could be related to government changes in expenditures. Although the health expenditure indicators do not include water or sanitation, health expenditures could be viewed as a proxy indication of a government's commitment to improving health. Table 5 provides definitions, as provided by the World Bank, for the economic indicators used throughout this paper.

Table 5: Definitions for World Bank Indicators (World Bank, 2012)

World Bank Indicator	Definition
GDP (constant 2000 US$)	GDP at purchaser's prices is the sum of gross value added by all resident producers in the economy plus any product taxes and minus any subsidies not included in the value of the products. It is calculated without making deductions for depreciation of fabricated assets or for depletion and degradation of natural resources. Data are in constant 2000 U.S. dollars. Dollar figures for GDP are converted from domestic currencies using 2000 official exchange rates.
GDP per capita (constant 2000 US$)	GDP per capita is gross domestic product divided by midyear population. GDP is the sum of gross value added by all resident producers in the economy plus any product taxes and minus any subsidies not included in the value of the products. It is calculated without making deductions for depreciation of fabricated assets or for depletion and degradation of natural resources. Data are in constant U.S. dollars.
Net official development assistance received (constant 2009 US$)	Net official development assistance (ODA) consists of disbursements of loans made on concessional terms (net of repayments of principal) and grants by official agencies of the members of the Development Assistance Committee (DAC), by multilateral institutions, and by non-DAC countries to promote economic development and welfare in countries and territories in the DAC list of ODA recipients. It includes loans with a grant element of at least 25 percent (calculated at a rate of discount of 10 percent). Data are in constant 2009 U.S. dollars.

Table 5 (continued)

Health expenditure, public (% of GDP)	Public health expenditure consists of recurrent and capital spending from government (central and local) budgets, external borrowings and grants (including donations from international agencies and nongovernmental organizations), and social (or compulsory) health insurance funds.
Health expenditure, public (% of total health expenditure)	Public health expenditure consists of recurrent and capital spending from government (central and local) budgets, external borrowings and grants (including donations from international agencies and nongovernmental organizations), and social (or compulsory) health insurance funds. Total health expenditure is the sum of public and private health expenditure. It covers the provision of health services (preventive and curative), family planning activities, nutrition activities, and emergency aid designated for health but does not include provision of water and sanitation.
External resources for health (% of total expenditure on health)	Funds or services in kind that are provided by entities not part of the country in question. The resources may come from international organizations, other countries through bilateral arrangements, or foreign nongovernmental organizations. These resources are part of total health expenditure.

4.0 RESULTS

The following describes the situation for each of the selected six countries from 1990, the baseline of MDG 7.C, to 2010, the most recent year for which MDG 7.C data are available. For each country, changes to national access to improved water sources and rural versus urban access over time were explored. As MDG 7 also includes the target to halve the proportion of people without sustainable access to basic sanitation and there is a strong relationship between basic sanitation and safe drinking water, information on each country's sanitation status is also included. Additionally, changes in different economic indicators such as GDP, international aid and health expenditures were identified. When possible, reports and studies on microbial and chemical contaminations are noted. Lastly, information from reviewed literature that focused on different types of water interventions, projects and policies are also included for each country.

4.1 MALAWI

4.1.1 Malawi at a Glance

A multiparty democracy comprised of 28 districts, Malawi, located in sub-Saharan Africa, is a landlocked country slightly smaller than Pennsylvania that shares borders with Tanzania, Zambia and Mozambique (CIA, 2012). Life expectancy at birth has increased from 47.1 years in 1990 to

53.5 years in 2010 (World Bank, 2012). And in 2003, 62.7 percent of the population over age 15 was considered to be literate (CIA, 2012). For 2000, 2005 and 2010, Malawi's corruption scores were 4.1, 2.8 and 3.4 respectively (Transparency International [TI], 2012).

Based on the HDI created by the UNDP, Malawi was considered of "low human development" in 1990. In 2011, Malawi ranked 171 out of the 187 countries included in the HDI, leaving Malawi securely within the classification of "low human development" (UNDP, 1990 & 2011). Poverty in Malawi is widespread and found in both urban and rural settings with rural inhabitants accounting for the largest share of the poor. In 2004, Malawians were poorer than they had been in 1994 and many lacked access to basic social services (Mulwafu & Msosa, 2005). In 2002, it was estimated that 40 percent of Malawians were considered to be suffering from extreme poverty with two-thirds living on an income of less than US $40 per capita per year (Pritchard, Mkandawire & O'Neil, 2007).

The Malawi climate is tropical. With annual rainfall ranging between 700 and 2,400 mm, average annual rainfall is approximately 1,800 mm (FAO, 2006). In terms of water, Malawi has sufficient water resources to meet the domestic needs of most of its population. Both ground and surface waters are prevalent in the country. Surface water extraction is done primarily through mechanical pumps while ground water is drawn primarily from wells, bore holes or gravity fed systems (Mulwafu & Msosa, 2005). However, the country's average water consumption per person per day is only 29.7 liters, more than 20 liters below the WHO recommend minimum daily requirement (Kumambala & Ervine, 2009).

4.1.2 Population Changes

Malawi has experienced rapid national population growth, most notably in its urban centers. Malawi's population has increased by nearly 59 percent over 20 years. Its rural population has increased by 44 percent while its urban population has increased more than two-fold with nearly a 172 percent increase (see Figure 1) (JMP 2012a**)**. Although on the decline, Malawi still maintains a high fertility rate. In 1990, Malawi registered 6.2 births per woman and in 2010, 5.5 births per woman (World Bank, 2012).

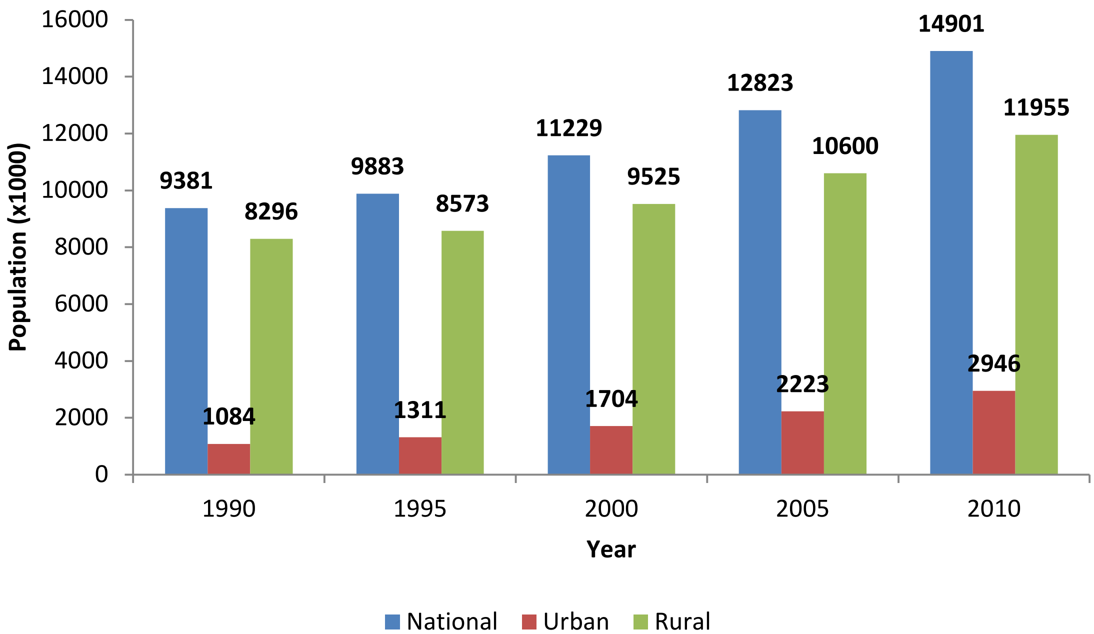

Figure 1: Malawi Population Changes (data from JMP 2012a)

4.1.3 Water Access Over Time

In 1990, of the more than nine million inhabitants of Malawi, only 41 percent had access to an improved drinking water source. However, in Malawi's urban settings where 12 percent of the population lived, 91 percent had access to an improved drinking water source. During the same time, only 35 percent Malawi's eight million rural population had access to an improved drinking water source (JMP, 2012a).

By 2010, Malawi had reached its MDG 7.C by providing 83 percent of its total population with access to an improved source of water. With a population reaching almost 15 million, both rural and urban access was improved with the greatest gains seen in rural settings. With nearly 12 million of the population still residing in the rural parts of Malawi, 80 percent of those had access to an improved source. Ninety-five percent of the nearly three million urban inhabitants also had access to an improved source (see Table 6) (JMP, 2012a).

Nationally, piped water coverage has remained steady but low with only seven percent of the population able to access piped sources. Urban dwellers have experienced a decrease in piped access but an increase in other improved sources while surface water is no longer accessed and only five percent of the urban population is using an unimproved source. Rural inhabitants have experienced a huge increase in improved source accessibility, up from 33 percent in 1990 to 78 percent in 2010. At the same time, there has been a reduction from 45 percent unimproved source usage down to 16 percent usage (JMP, 2012a).

Table 6: Change in Water Access Over Time, Urban vs. Rural, Malawi (data from JMP 2012a)

	Population Using Improved Drinking Water Sources (x 1000)					
Year	*National*	*Improved (%)*	*Urban*	*Improved (%)*	*Rural*	*Improved (%)*
1990	9381	3891 (41%)	1084	987 (91%)	8296	2904 (35%)
1995	9883	5149 (52%)	1311	1206 (92%)	8573	3943 (46%)
2000	11229	7014 (62%)	1704	1585 (93%)	9525	5429 (57%)
2005	12823	9297 (73%)	2223	2090 (94%)	10600	7208 (68%)
2010	14901	12363 (83%)	2946	2798 (95%)	11955	9564 (80%)

Figure 2 graphically depicts the upward trend in national, urban and rural access to improved drinking water sources in Malawi.

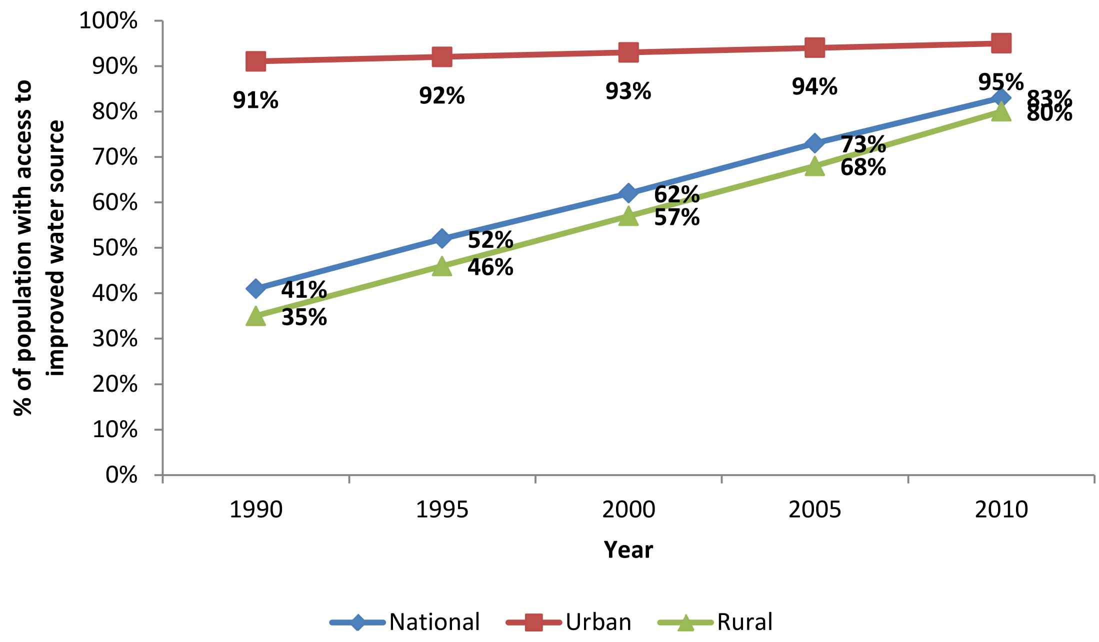

Figure 2: Change in Water Access Over Time, Urban vs. Rural, Malawi

4.1.4 Water and Health

It is estimated that nearly 50 percent of all illnesses in Malawi are related to water-borne disease while the Ministry of Health estimates that 80 percent of school children lack clean and safe drinking water (Pritchard et al., 2007). In 2002, 19,500 deaths resulted from diarrheal disease, the fourth leading cause of mortality accounting for 9.1 percent of years of life lost (YLL). At the same time, unsafe water and sanitation ranked as the third most important risk factor for cause of death and was linked to 6.7 percent of all deaths (Bowie, 2006; WHO, 2004, December). In 2004, 20,700 lives were lost to diarrheal diseases and in 2008 another 15,100 people died (WHO, 2009, February; WHO, 2011, April).

Estimates indicate that *Ascariasis* and hookworm each accounted for 5,000 DALYs in 2002 while trachoma represented 34,000 DALYs. In 2004, *Ascariasis* accounted for 5,000

DALYs while hookworm increased to 7,000 DALYs. At the same time, trachoma related DALYs dropped to 2,000 (WHO, 2004, December; WHO, 2009, February).

A number of studies looking specifically at the quality of Malawi's drinking water have noted contamination issues over the years. For example, a study carried out in 2005 and 2006 in the cities of Blantyre, Chiradzulu and Mulanje noted that water supplies tested from shallow wells failed to meet the water quality guidelines established by the Ministry of Water Development. In this study, 80 percent of wells during the dry season and 100 percent of wells during the rainy season had excessive total coliforms (>50 TC/100mL) while 50 percent of wells during the dry season and 94 percent of wells during the rainy season had excessive fecal coliforms (>50 FC/100mL). Although the study demonstrated that chemical results were within the drinking water guidelines, the study did find that some of the tested shallow wells were located less than 100 meters from pit latrines and waste dumps, which goes against sanitation recommendations (Pritchard et al., 2007).

4.1.5 Water Management and Policies

In 2000, Malawi endorsed the Millennium Development Goals and in 2002 developed the Malawi Poverty Reduction Strategy Paper, which stated that "the provision of and equitable access to potable water supplies and reasonable sanitation facilities are central to poverty reduction as they have a direct impact on health status and therefore productivity" (Government of Malawi [GOM], 2002). In 2005 Malawi established its formal National Water Policy which proclaimed "water and sanitation for all, always" (GOM, 2005). The 2007 Malawi Growth and Development Strategy specifically included measures to address Malawian's limited access to safe drinking water and efforts to control pollution of ground water while also advocating for greater authority in enforcing pollution efforts and establishing a water quality database (International Monetary Fund [IMF], 2007).

As one of the five countries that received funding from the Canadian International Development Agency under the Partnership for African Water Development (PAWD), Malawi developed its own Integrated Water Resource Management Plan (IWRM). The development of IWRM plans came about as a result of the 2002 World Summit on Sustainable Development at which countries committed to take steps towards more sustainable and coordinated approaches to water resource management (Mulwafu & Msosa, 2005).

Additionally, through the support of the PAWD, between 2006 and 2008, water development became the country's second priority in overall national development planning with a 40 percent increase in resource allocation for water development efforts (Cox & Patterson, 2008). The main goal of the government's water policies is to reduce the incidence of water-borne diseases through the provision of clean potable water to all its people. Additionally, for rural populations, the government aims to provide clean, untreated borehole water supplied no more than 500 meters (Mulwafu & Msosa, 2005). To aid in these goals, the Ministry of Health distributes free chlorine through local health clinics for people to treat their drinking water (Wood, Foster & Kols, 2011).

A separate water sector for Malawi is relatively new and has evolved over time. Currently, the Ministry of Irrigation and Water Development (MoIWD) has authority over the development and management of Malawi's water resources. MoIWD is comprised of three departments, Water Resources, Irrigation, and Water Supply and Sanitation. One of the responsibilities of the Water Resources Department is to monitor and assess the physical, biological and chemical qualities of water while the Water Supply and Sanitation Department is responsible for providing water to the rural communities (Chipofya, Kainja & Bota, 2009).

4.1.6 Sanitation Over Time

Although access to improved water sources has seen tremendous improvement in Malawi, the same cannot be said about access to improved sanitation. In 1990, only 39 percent of the population had access to improved sanitation. Twenty years later this had increased to 51 percent. The greatest improvements were notably seen in the rural areas of Malawi where the proportion of people with access to improved sanitation had increased from 38 percent in 1990 to 51 percent in 2010 (see Table 7) (JMP, 2012a).

Table 7: Change in Sanitation Access Over Time, Urban vs. Rural, Malawi (data from JMP 2012a)

	Population Using Improved Sanitation (x 1000)					
Year	*National*	*Improved (%)*	*Urban*	*Improved (%)*	*Rural*	*Improved (%)*
1990	9381	3673 (39%)	1084	521 (48%)	8296	3153 (38%)
1995	9883	4144 (42%)	1311	629 (48%)	8573	3515 (41%)
2000	11229	5121 (46%)	1704	835 (49%)	9525	4286 (45%)
2005	12823	6177 (48%)	2223	1089 (49%)	10600	5088 (48%)
2010	14901	7541 (51%)	2946	1443 (49%)	11955	6097 (51%)

Figure 3 graphically displays sanitation access in Malawi between 1990 and 2010.

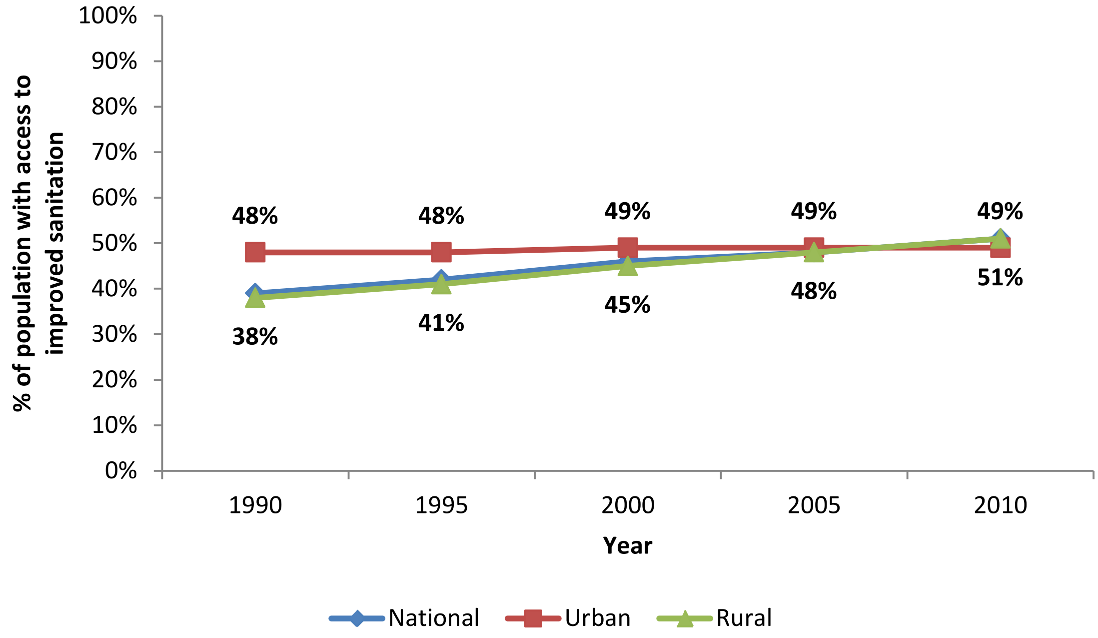

Figure 3: Change in Sanitation Over Time, Urban vs. Rural, Malawi

4.1.7 Economic Indicators

Malawi's GDP has increased over the past 20 years from US $1.24 billion to US $2.74 billion. Per capita GDP has also risen but only slightly from US $132 to US $184. At the same time, net official development assistance has fluctuated over the past 20 years and most recently reached more than US$ 1 billion (World Bank, 2012).

In general Malawi's health expenditure indicators have been on the rise. Public health expenditures as a percent of GDP increased from 1.87 percent to 6.07 between 1995 and 2005. However, in 2010, both public expenditures as a percent of total health expenditures and external resources as a percent of total health expenditures declined (see Appendix A for more details) (World Bank, 2012).

4.1.8 Water Interventions

The literature discussed a number of noted water interventions in Malawi. For example, a HWT project carried out in Blantyre and Salima targeted pregnant women and new moms by providing women with hygiene kits that included water storage containers, soap, two sachets of oral rehydration salts and free samples and free refills (up to three based on antenatal visits) of a well-known HWT known as WaterGuard. WaterGuard is a form of HWT chlorination. In 2005, seven percent of mothers reported using WaterGuard. In 2007, the baseline for the study, 73 percent of respondents reported treating their drinking water by using WaterGuard, boiling water or by using the government provided chlorine. At follow-up, 99 percent of respondents reported treating their water with 61 percent having confirmed WaterGuard use (Sheth et al., 2010). A follow-up study conducted in 2010 noted that 28 percent of respondents were still maintaining WaterGuard usage. Although maintenance had dropped, respondents reported switching back and forth between the free chlorination provided by the government and the WaterGuard, which they had to purchase (Wood et al., 2011).

4.2 BURKINA FASO

4.2.1 Burkina Faso at a Glance

Burkina Faso is a parliamentary republic comprised of 13 regions. This country, which is slightly larger than Colorado, is located in sub-Saharan Africa, is a landlocked country and is bordered by Niger, Mali, Togo, Ghana, Benin and Cote d'Ivoire (CIA, 2012). Life expectancy at birth has increased from 48.5 years in 1990 to 54.9 years in 2010 (World Bank, 2012). And in 2003, only 21.8 percent of the population over age 15 was considered to be literate (CIA, 2012). For 2000, 2005 and 2010, Burkina Faso's corruption scores were 3, 3.4 and 3.1 respectively (TI, 2012).

In 1990 Burkina Faso was classified as a country of "low human development" and in 2011 had the lowest rank of the six countries included in this assessment. The 2011 HDI rankings put Burkina Faso at 181 out of 187 countries (UNDP, 1990 & 2011). As one of the poorest countries in the world with an estimated 46 percent living below the poverty line, GDP per capita in 2007 amounted to US $268 (Petit & Baron, 2009).

In Burkina Faso, ground water accounts for 85 percent of the country's drinking water. The climate of the country is considered continental as there are wide variations in temperature and rainfall (Petit & Baron, 2009). Rainfall varies across the country as well with 900-1200 mm a year in the south compared to 600-900 mm a year in the north, with the entire country averaging 748 mm annually (FAO, 2005a).

In the urban centers of the Burkinabe part of the Volta River Basin, both ground and surface waters are used in equal parts to serve residents. In these same urban centers, it is estimated that water consumption is only 31 liters per person per day, almost 20 liters below the minimum WHO standard. In much of the rest of the country, daily consumption ranges between less than five liters up to 20 liters per person per day (Martin & van de Giesen, 2005).

4.2.2 Population Changes

Burkina Faso, like Malawi, has experienced rapid national population growth with nearly a 77 percent increase from 1990 to 2010. As Figure 4 shows, the largest relative increase is seen in

Burkina Faso's urban regions which saw a 228 percent increase over 20 years compared to the 52 percent increase in rural areas (JMP 2012a**)**. Similar to Malawi, Burkina Faso still maintains a high fertility rate. In 1990, Burkina Faso registered 6.8 births per woman and in 2010, 5.9 births per woman (World Bank, 2012).

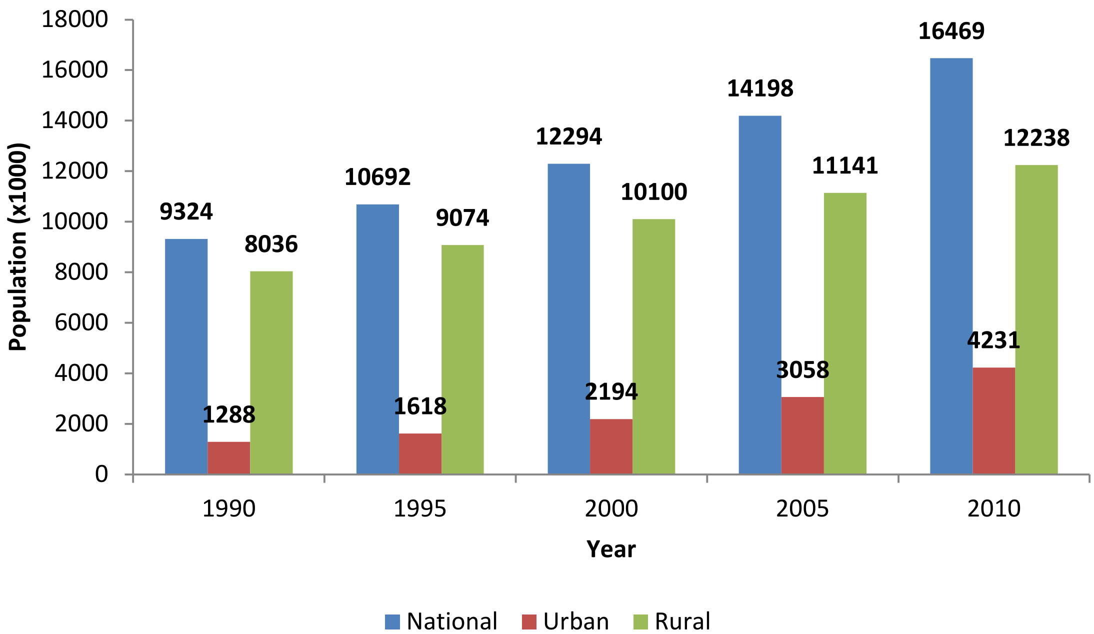

Figure 4: Burkina Faso Population Changes (data from JMP 2012a)

4.2.3 Water Access Over Time

Forty-three percent of Burkina Faso's nine million people had access to an improved drinking water source in 1990. Of the nine million inhabitants, 14 percent were located in urban settings with 75 percent having access to an improved water source. Only 38 percent of the eight million rural dwellers had similar access (JMP, 2012a).

Like Malawi, Burkina Faso was also able to halve the proportion of its population between 1990 and 2010 that did not have access to an improved drinking water source. In 2010, with a population of almost 16.5 million, 26 and 74 percent of the population lived in urban and rural settings respectively. Of the more than four million urban inhabitants, 95 percent had access to an improved source while 73 percent of the more than 12 million rural inhabitants had access (see Table 8) (JMP, 2012a)..

In urban areas, there was a marked increase from 13 percent to 28 percent of inhabitants with access to piped water while the use of surface water was eliminated altogether. Although piped water has yet to emerge in rural area, access to other improved sources has risen while surface water use has decreased from 10 to five percent, and other unimproved sources have decreased from 52 to 22 percent over 20 years (JMP, 2012a).

Table 8: Change in Water Access Over Time, Urban vs. Rural, Burkina Faso (data from JMP 2012a)

	Population Using Improved Drinking Water Sources (x 1000)					
Year	*National*	*Improved (%)*	*Urban*	*Improved (%)*	*Rural*	*Improved (%)*
1990	9324	4020 (43%)	1288	966 (75%)	8036	3054 (38%)
1995	10692	5452 (51%)	1618	1278 (79%)	9074	4174 (46%)
2000	12294	7420 (60%)	2194	1865 (85%)	10100	5555 (55%)
2005	14198	9882 (70%)	3058	2752 (90%)	11141	7130 (64%)
2010	16469	12953 (79%)	4231	4019 (95%)	12238	8934 (73%)

Figure 5 graphically illustrates the upward trend in national, urban and rural access to improved drinking water sources in Burkina Faso.

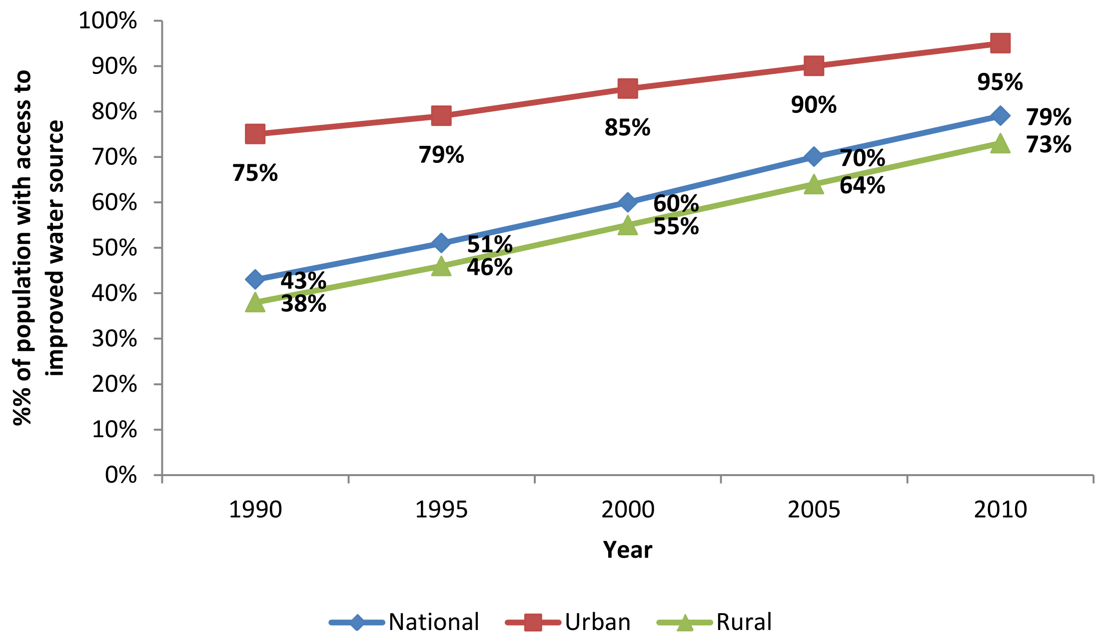

Figure 5: Change in Water Access Over Time, Urban vs. Rural, Burkina Faso

4.2.4 Water and Health

In 2002, WHO estimated that nearly 22,000 people from Burkina Faso died as a result of diarrheal diseases. In 2004 and 2008, 26,800 and 23,100 people died from diarrhea respectively (WHO, 2004, December; WHO, 2009, February; WHO, 2011, April). In 2002 and 2004, trachoma resulted in an estimated 21,000 and 5,000 DALYs respectively. *Ascariasis* resulted in an estimated 32,000 DALYs for both years while hookworm accounted for 5,000 and 6,000 DALYs respectively (WHO, 2004, December; WHO, 2009, February).

Nitrate concentrations greater than 100 mg/l have been found in groundwater in the western part of the country. More troubling, arsenic contamination has recently been discovered in some of the country’s water sources. One study from a community where members of the population had visible skin lesions reported ground water samples from boreholes had arsenic concentrations ranging from less than 0.5 µg/l up to 1630 µg/l (Smedley, Knudsen & Maiga, 2007). In another study, 52 percent of water samples from 31 tube wells exceeded WHOs recommended level of 10 µg/l. Residents whose drinking water had the highest levels of arsenic contamination were observed with melanosis (hyperpigmentation) and keratosis (skin lesions) (Some et al., 2012).

In Burkina Faso, improved hygiene practices and health related behaviors have been proven to improve with greater access to safe water sources. For instance, a 1995 study noted that mothers who had access to a tap in the yard reported using safe hygiene practices three times more often than mothers utilizing wells outside of their home. They were also two times more likely to exhibit better hygiene practices than mothers who used public standpipes or wells within the yard. Mothers were observed washing their hands more frequently after wiping a child's bottom when they lived in a compound that had a tap compared to those who lacked a tap (Curtis et al., 1995). This study supported the argument that improved hygiene, and as a result improved health benefits, can occur as a result of access to improved domestic water supplies (Cairnoss as cited in Curtis et al., 1995).

4.2.5 Water Management and Policies

Reform of Burkina Faso's water policies began in the wake of the first World Water Forum held in 1997. In 1998, Burkina Faso adopted its first set of water policies and strategies. In 2001, a Water Framework Law was approved that formalized the water policies and strategies of 1998 and led to the creation of a National Water Council which is responsible for all non-agriculture related water issues. An action plan for an Integrated Management of Water Resources Plan followed in 2003. And in 2008, Burkina Faso adopted an acceleration strategy for reaching the MDGs, with water named as one of its top priorities (Petit & Baron, 2009).

The General Directorate of Water Supply and Drinking Water is responsible for the development, coordination and implementation of water supply and sanitation initiatives in urban and rural regions while also acting as the water supply and sanitation provider for towns under 10,000 people. At the same time, the National Office for Water and Sanitation is charged with being the water and sanitation service provider for all urban and peri-urban areas with over 10,000 people (US Agency for Int'l Development [USAID], nd).

The government has also established national water quality standards. For instance, the national limit for arsenic levels in drinking water was set at 10 µg/l, consistent with WHO recommendations (Smedley et al., 2007). In regions where arsenic has been detected in groundwater serving as drinking water, the government has already closed contaminated boreholes and earmarked them for replacement as part of the government's planned drilling campaign (Smedley et al., 2007).

In addition, the government has sought out solutions before problems become insurmountable. For example, the government reached out to the International Development Association arm of the World Bank in 2001 as Burkina Faso's capital, Ouagadougou, was on the verge of a drinking water shortage. Between 1985 and 2000, the city's population had doubled and was outpacing the ability of public water provision. At the beginning of the project in 2000, only 30 percent of city residents had access to the water system. By the end of the project in 2007, household piped connections increased from 300,000 to 1,040,000, accounting for 94 percent of the city's population (World Bank, 2009).

4.2.6 Sanitation Over Time

Similar to Malawi, Burkina Faso has made great strides in advancing its population's access to improved water sources while improvements in sanitation have lagged behind. In 1990, only eight percent of Burkina Faso's population was utilizing improved sanitation. By 2010, this had increased to only 17 percent. Notably, in the rural parts of Burkina Faso where a majority of the country's inhabitants reside, utilization of improved sanitation is minimal with only five percent of the rural population using improved sanitation in 2010, up from two percent in 1990 (see Table 9) (JMP, 2012a).

Table 9: Change in Sanitation Access Over Time, Urban vs. Rural, Burkina Faso (data from JMP 2012a)

	Population Using Improved Sanitation (x 1000)					
Year	*National*	*Improved (%)*	*Urban*	*Improved (%)*	*Rural*	*Improved (%)*
1990	9324	715 (8%)	1288	554 (43%)	8036	161 (2%)
1995	10692	1000 (9%)	1618	728 (45%)	9074	272 (3%)
2000	12294	1413 (11%)	2194	1009 (46%)	10100	404 (4%)
2005	14198	2025 (14%)	3058	1468 (48%)	11141	557 (5%)
2010	16469	2850 (17%)	4231	2115 (50%)	12238	734 (6%)

Figure 6 depicts the urban, rural and nation changes to sanitation access in Burkina Faso.

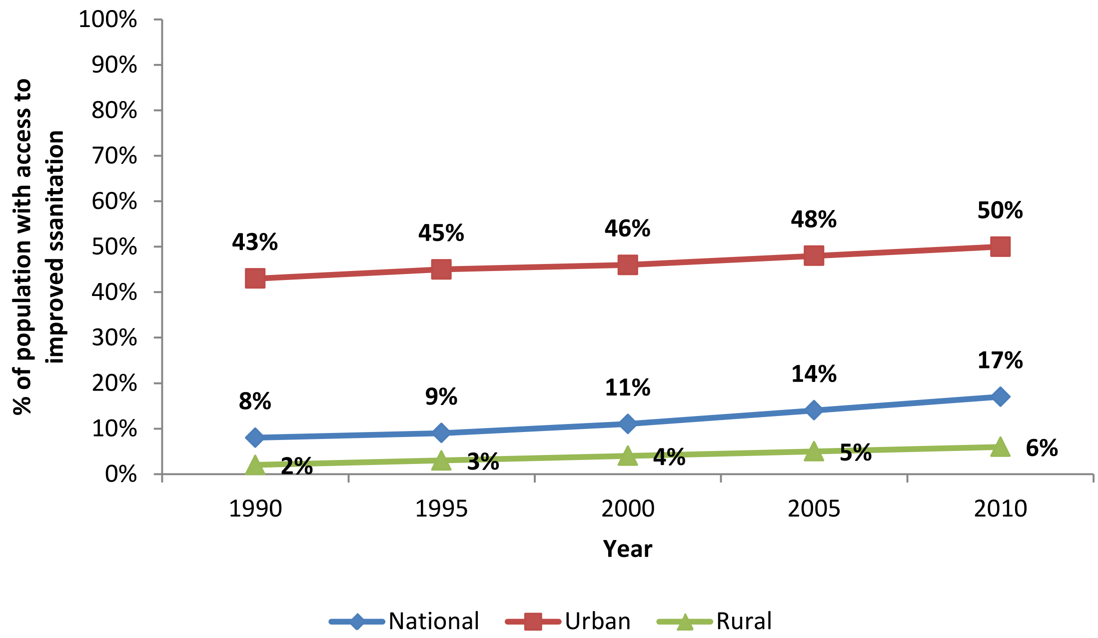

Figure 6: Change in Sanitation Over Time, Urban vs. Rural, Burkina Faso

4.2.7 Economic Indicators

Over the past 20 years, Burkina Faso's GDP has increased from US $1.55 billion to US $4.55 billion. Per capita GDP has also risen from US $166 to US $276. Net official development assistance reached more than US $1 billion in 2010 after dipping from US $636 million in 1995 to a little more than US $333 million in 2000 (World Bank, 2012).

Similar to Malawi, health expenditure indicators have generally been on the rise with the exception of public expenditures as a percent of total health expenditures and external resources as a percent of total health expenditures which both declined in 2010. Health expenditures as a percent of GDP rose from 1.67 percent to 3.98 percent between 1995 and 2005 (see Appendix B for more details) (World Bank, 2012).

4.2.8 Water Interventions

The author struggled to find peer-reviewed literature that pertained to any specific water interventions in Burkina Faso. The one study that was returned in searches was from 1990 and analyzed water quality after the use of earthenware filtration that included alternating layers of sand, gravel and charcoal. The study concluded that although the earthenware filtration provided aesthetically pleasing water (improved taste and smell), the filters were ineffective in completely eliminating fecal coliforms (Monjour et al. 1990).

4.3 NIGERIA

4.3.1 Nigeria at a Glance

A federal republic comprised of 36 states and one territory, Nigeria, which is more than double the size of California, is located in sub-Saharan Africa. Sharing borders with Niger, Benin, Cameroon and Chad, it also has a coastline on the South Pacific (CIA, 2012). Life expectancy at birth has increased from 45.6 years in 1990 to 51.4 years in 2010 (World Bank, 2012). And in 2003, 68 percent of the population over age 15 was considered to be literate (CIA, 2012). For 2000, 2005 and 2010, Nigeria's corruption scores were 1.2, 1.9 and 2.4 respectively (TI, 2012).

Nigeria was yet another country considered to be of "low human development" in 1990. In 2011, Nigeria remained at that status with a ranking of 156 of the 187 assessed countries (UNDP, 1990 & 2011). Based on a 2005 report, real income and consumption were at levels as low as 40 years ago, and rural Nigeria suffers from widespread poverty with 40 percent of inhabitants living below the poverty line (FAO, 2005c)

The northern part of the country is semi-arid while the south is humid (FAO, 2005c). There are large differences in water availability between the north and the south. In the north, annual precipitation averages about 500 mm per year while in the south precipitation reaches 3,000 mm per year, but overall Nigeria is considered to have abundant water resources (Government of Nigeria, 2000; Akpor & Muchie, 2011). However, even with an abundant quantity of water, it is estimated that only 32 liters of water per person per day are delivered to urban inhabitants while only 10 liters are delivered to rural areas (Akpor & Muchie, 2011).

In the Niger Delta region, most urban and rural settings receive water for drinking and domestic purposes from rivers, creeks, streams, ponds, hand-dug wells or harvested rain water (Rim-Rukeh, Ikhifa & Okokoyo, 2007). In a majority of the rest of Nigeria, sachet-packaged drinking water (water in bags) and bottled water are extremely common and typically sold on the streets, in market places and by food vendors (Olaoye & Onilude, 2009). There has been a notable increase in demand for these products largely due to inadequate, unavailable or unreliable safe municipal waters in urban settings (Oyedeji, Olutiola & Moninuola, p. 96).

4.3.2 Population Changes

Nigeria is the most populous country in Africa and has experienced a 62 percent increase in its population over the past 20 years. As Figure 7 highlights, Nigeria has also experienced a leveling out of the proportion of rural versus urban inhabitants with urban population growth outpacing rural growth (JMP 2012a**)**. Like the other sub-Saharan countries included in this analysis to this point, Nigeria still has a high fertility rate of 5.5 births per woman in 2010 compared to 6.4 in 1990 (World Bank, 2012).

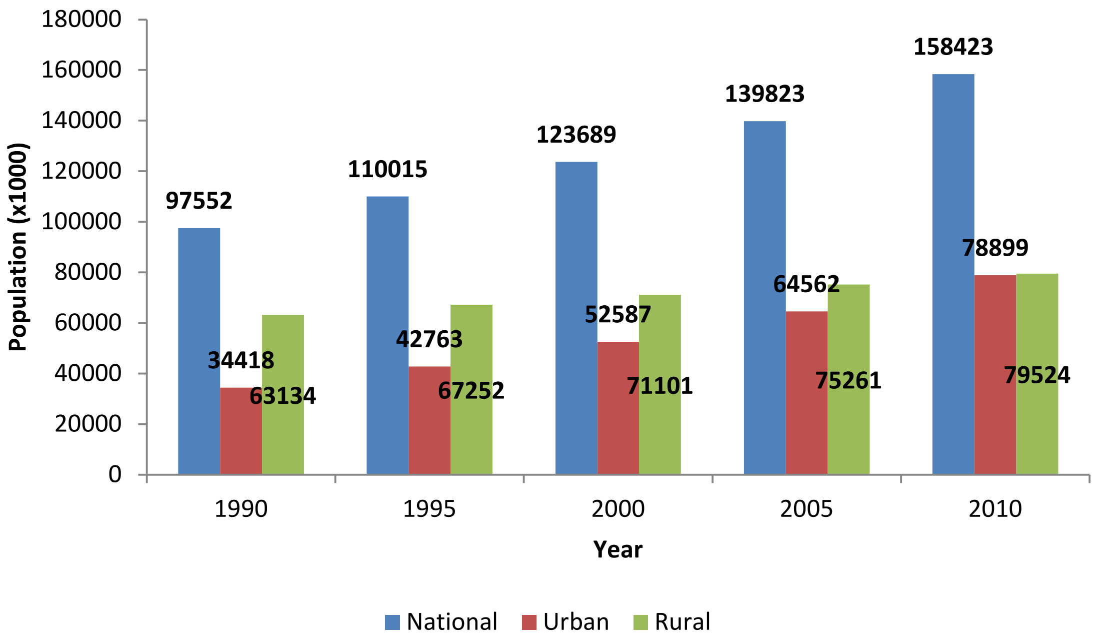

Figure 7: Nigeria Population Changes (data from JMP 2012a)

4.3.3 Water Access Over Time

Nigeria, which has been able to decrease the proportion of people that did not have access to an improved drinking water source in 1990, has so far been unable to reach the MDG 7.C target. In 1990, 47 percent of the 97.5 million residents had access to an improved drinking water source. As of 2010, 58 percent of the increased 158.4 million residents had access to an improved source (JMP, 2012a).

In 1990, 35 percent of the population resided in urban settings, of which 79 percent had access to an improved drinking water source. By 2010, 50 percent of Nigeria's population was urban dwelling, yet only 74 percent of those residents had access to an improved source. In contrast, 65 percent of the population lived rurally in 1990 with 30 percent having access to an improved source. By 2010, only 50 percent of the population remained in rural settings and 43 percent had access to an improved source (see Table 10) (JMP, 2012a).

Nigeria's national access to piped water has dropped from 14 percent of the country having access in 1990 to only four percent having access in 2010. The drop in urban piped water from 32 percent coverage to eight percent is the leading contributor to the national change. Access to other improved sources has increased nationally but so has the utilization of unimproved sources (JMP, 2012a).

Table 10: Change in Water Access Over Time, Urban vs. Rural, Nigeria (data from JMP 2012a)

	Population Using Improved Drinking Water Sources (x 1000)					
Year	*National*	*Improved (%)*	*Urban*	*Improved (%)*	*Rural*	*Improved (%)*
1990	97552	46131 (47%)	34418	27190 (79%)	63134	18940 (30%)
1995	110015	55548 (50%)	42763	33355 (78%)	67252	22193 (33%)
2000	123689	66089 (53%)	52587	40492 (77%)	71101	25596 (36%)
2005	139823	79172 (57%)	64562	49067 (76%)	75261	30105 (40%)
2010	158423	92581 (58%)	78899	58386 (74%)	79524	34195 (43%)

Figure 8 graphically represents the increases to rural and national water access in Nigeria while highlighting the decrease in urban access.

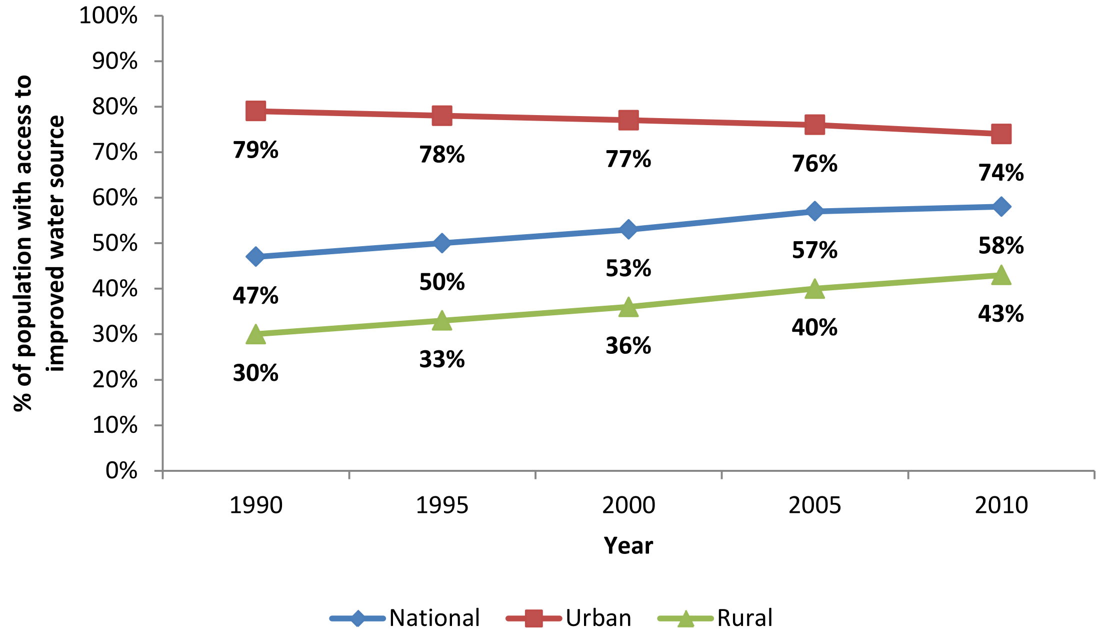

Figure 8: Change in Water Access Over Time, Urban vs. Rural, Nigeria

4.3.4 Water and Health

Looking at WHO statistics, in 2002 diarrheal diseases claimed the lives of 134,500 Nigerians. In 2004, such diseases led to 199,700 deaths while in 2008 173,900 people died due to diarrhea (WHO, 2004, December; WHO, 2009, February; WHO, 2011, April). For 2002, trachoma accounted for 233,000 DALYs, while *Ascariasis* accounted for 282,000 DALYs and hookworm accounted for another 39,000 DALYs. In 2004, trachoma DALYs dropped to 100,000 while *Ascariasis* and hookworm both increased to contribute 322,000 and 62,000 DALYs respectively (WHO, 2004, December; WHO, 2009, February).

Poor manufacturing standards and unhygienic practices by water handlers have been cited as contributing to water-borne infectious disease in Nigeria. Unpublished reports indicate that epidemic outbreaks have been caused by the consumption of sachet-packaged drinking water

(Olaoye & Onilude, 2009). One study conducted on the physio-chemical characteristics of water sources frequently used for drinking water in the Niger Delta region of the country noted that nitrate levels were above WHO permissible limits for drinking water (Rim-Rukeh et al., 2007).

4.3.5 Water Management and Policies

Overall, Nigeria's national water supply policy goals include ensuring for all citizens access to adequate, affordable and sustainable safe drinking water (Akpor & Muchie, 2011) and a goal of providing potable water to all of its citizens by 2020. In Nigeria, numerous entities have a role in water management. All 36 states and the federal capital territory each has Water Corporation/Boards or Public Utility Boards managing public water supply efforts. These entities are often times supported by local governments that are responsible for distributing water within the jurisdiction (Akpor & Muchie, 2011). The overarching national water management body is the Federal Ministry of Water Resources, and the secondary body is the River Basin Development Authority. However, a number of other agencies and departments play a role in Nigeria's water sector. These agencies include the Federal Ministry of Agriculture, Water Resource and Rural Development, National Council on Water Resources and state water agencies (Akpor & Muchie, 2011).

The National Agency for Food and Drug Administration Control (NAFDAC) is the authority empowered to enforce compliance with drinking water standards for packaged water (Dada, 2009). Some sources have noted inefficiencies and ineffectiveness within the agency citing favoritism over technical expertise in recruitment, promotion primarily based on seniority, weak and ineffective on-the-job training and rare dismissals due to inefficiencies (Dada, 2009, p. 926). Additionally, staffing shortages and limited government support have resulted in ineffective surveillance and a passive and reactive system (Dada, 2009; Olaoye & Onilude, 2009). In general, it has been noted that neither the Federal Ministry of Water Resources nor the River Basin Development Authority has been given the power to develop management plans, generate data for planning or building a department with the capacity to effectively manage water resources and as a result there has been a lack of effective water resources management resulting in confusion within the sector (Akpor & Muchie, 2011).

4.3.6 Sanitation Over Time

Nigeria's utilization of improved sanitation methods decreased from 36 percent coverage in 1990 to 31 percent in 2010. This decline has been noted in both the urban and rural locales within the country. Urban dwellers have experienced a reduction from 39 percent coverage to 35 percent coverage while rural residents have experienced a greater decline, from 36 percent to 27 percent coverage (see Table 11) (JMP, 2012a).

Table 11: Change in Sanitation Access Over Time, Urban vs. Rural, Nigeria (data from JMP 2012a)

	Population Using Improved Sanitation (x 1000)					
Year	*National*	*Improved (%)*	*Urban*	*Improved (%)*	*Rural*	*Improved (%)*
1990	97552	36151 (37%)	34418	13423 (39%)	63134	22728 (36%)
1995	110015	39116 (36%)	42763	16250 (38%)	67252	22866 (34%)
2000	123689	42210 (34%)	52587	19457 (37%)	71101	22752 (32%)
2005	139823	45068 (32%)	64562	23242 (36%)	75261	21826 (29%)
2010	158423	49086 (31%)	78899	27615 (35%)	79524	21471 (27%)

Figure 9 graphically illustrates the decline in Nigeria's sanitation access.

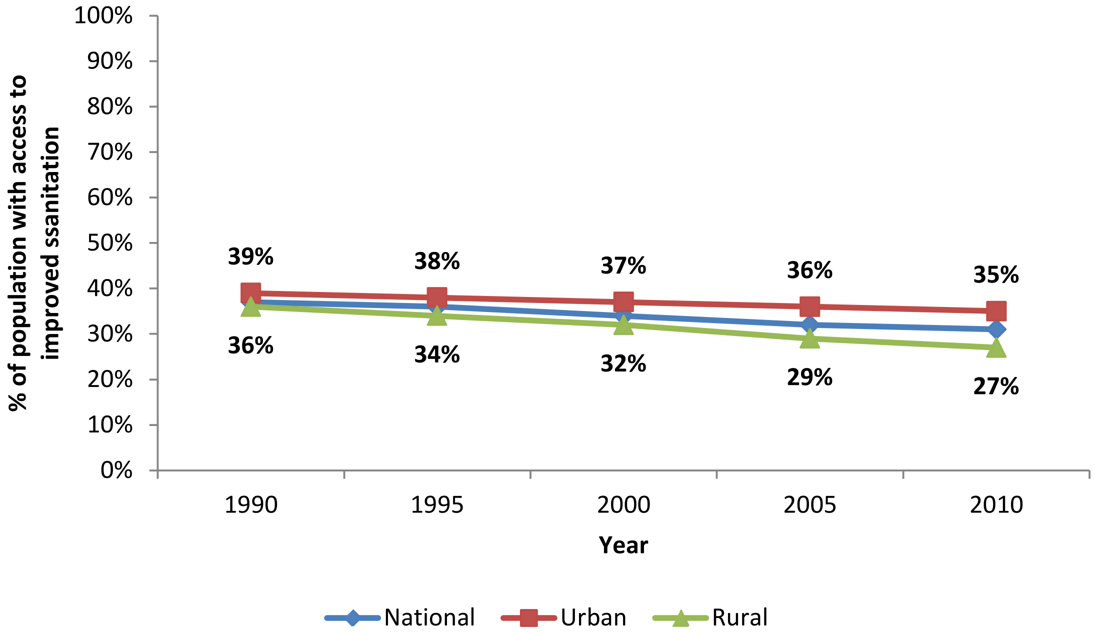

Figure 9: Change in Sanitation Over Time, Urban vs. Rural, Nigeria

4.3.7 Economic Indicators

Nigeria's GDP increased from close to US $34.98 billion in 1990 to nearly US $86.28 billion in 2010. Nigeria's per capita GDP has also risen from US $358 to US $544. Net official development assistance sky rocketed from US $380 million in 1990 to over US $7.1 billion in 2005 before dropping to US $2 billion in 2010 (World Bank, 2012).

Public health expenditure as a percent of GDP rose from 1.13 percent in 1995 to 1.93 percent in 2005, and public health expenditure as a percent of total health expenditure has fluctuated from 25.5 percent in 1990 to 33.46 percent in 1995 to 29.17 percent in 2005 then up again to 37.89 percent in 2010. Similarly, external resources for health have fluctuated from 0.47 percent of total health expenditure in 1995 to 16.22 percent in 2000 down to 3.07 percent in

2005 and up again to 9.16 percent in 2010 (see Appendix C for more details) (World Bank, 2012).

4.3.8 Water Interventions

A study conducted by the Katsian State Rural Water and Sanitation Agency included three objectives to: 1) assess regional capacity to monitory water quality, 2) sample water quality at the household level, and 3) determine linkages between knowledge, attitudes and behaviors leading to contamination between the water source and household consumption. The results of the study concluded that most of the water samples collected at the source were safe but that contamination occurred in the home. Furthermore, only half of the participants reported employing any form of HWTs (Onabolu et al., 2011).

Additionally, a study focused on assessing diarrhea prevention in HIV patients through chlorine POU was carried out in Lagos. The results noted that diarrhea rates dropped by 36 percent in all participants and rates dropped by 46 percent in participants whose water samples showed residual chlorine in 85 percent of their water tests over the course of the 30-week intervention (Barzilay et al., 2011).

4.4 BANGLADESH

4.4.1 Bangladesh at a Glance

In southern Asia, Bangladesh, slightly smaller than the state of Iowa, borders Burma and India and has a coast line along the Indian Ocean. Bangladesh is a parliamentary republic comprised of seven regions which are further divided into 64 districts (CIA, 2012). Life expectancy at birth in 2010 reached 68.6 years, up from 59.5 years in 1990 (World Bank, 2012). In 2003, only 48 percent of the population over age 15 was considered to be literate (CIA, 2012). For 2005 and 2010, Bangladesh's corruption scores were 1.7 and 2.4 respectively (TI, 2012).

Bangladesh, like the others to this point, was a country of "low human development" in 1990. In 2011, Bangladesh ranked 146 out of 187 countries. Although this ranking still leaves Bangladesh in the "low human development" classification, it has the highest rank of the six countries included in this assessment (UNDP, 1990 & 2011).

The only country for this analysis located outside of sub-Saharan Africa, Bangladesh is one of the most densely populated countries in the world while also being one of the poorest (Alam, Allinson, Stagnitti, Tanaka & Westbrooke, 2002). In the 1990s, the poverty incidence of Bangladesh was around 57 percent. In 2000 this had declined to 50 percent and in 2005, poverty incidence dropped to 40 percent (World Bank, 2008).

Bangladesh, with large variations in rainfall and temperature, is considered to have a tropical monsoon climate. With 80 percent of annual precipitation occurring during the monsoon season, annual precipitation is approximately 2,320 mm, with as little as 1,110 mm in the northwest and 5,690 mm in the north east. Bangladesh is susceptible to both droughts and floods. Located in the floodplains of the Ganges, Brahmaputra and Meghna, 79 percent of the country's estimated 35.87 km^3 annual water withdrawal comes from ground water while the remaining 21 percent is derived from surface water (FAO, 2010).

4.4.2 Population Changes

Bangladesh's population has increased by a little more than 40 percent in past 20 years. The urban population has double over the same span while the rural population has seen slightly more than a 25 percent increase to its population (see Figure 10) (JMP 2012a**)**. At the same time, Bangladesh's fertility rate has declined from 4.5 births per woman in 1990 to 2.2 births per woman in 2010 (World Bank, 2012).

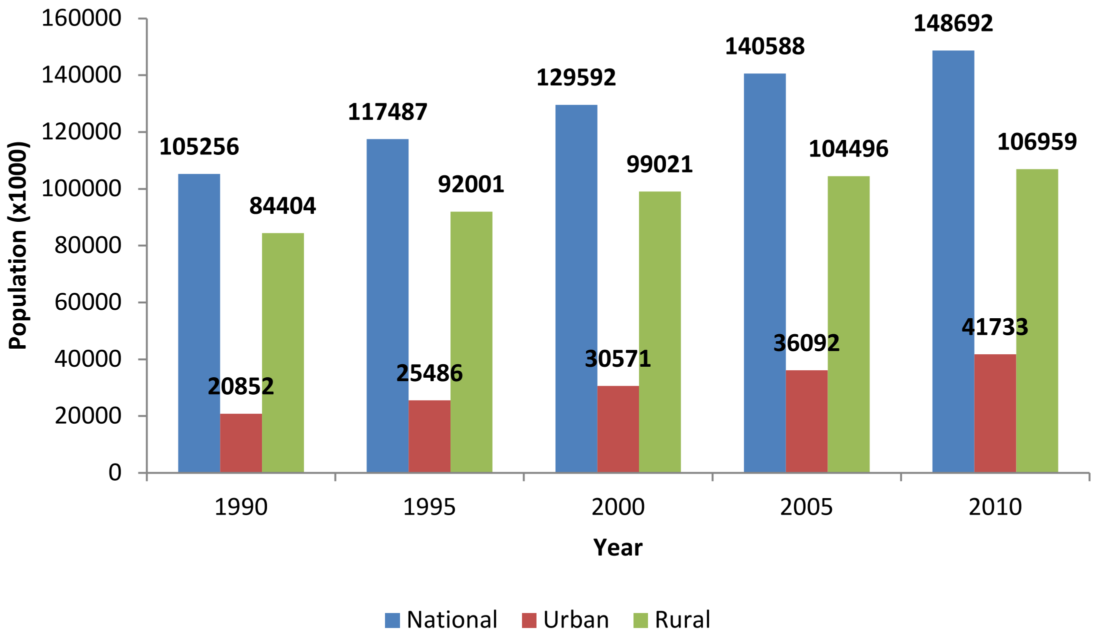

Figure 10: Bangladesh Population Changes (data from JMP 2012a)

4.4.3 Water Access Over Time

Bangladesh is another example of a country that has yet to reach the drinking water target of MDG 7.C. Bangladesh was providing 77 percent of its more than 105 million people with access to an improved drinking water source in 1990. In terms of urban versus rural access, 87 percent of urban residents and 75 percent of rural residents had access to improved sources. In 1990, 20.8 million people, or 20 percent of the population, lived in urban settings whereas 84.4 million or 75 percent of Bangladeshis lived in rural settings (JMP, 2012a).

With an increase in population of more than forty-three million, in 2010 Bangladesh was providing only 81 percent of its inhabitants with access to an improved water source. Eighty percent of the rural population, accounting for 72 percent of the total population, had access to improved sources while 85 percent or urban dwellers also had access to an improved source (see Table 12) (JMP, 2012a).

Nationally, there have been negligible changes to the types of water sources Bangladeshis have been able to access. In urban regions, there has been a small decrease in piped water access, a small increase in other improved source utilization and a small increase in unimproved source utilization. Rural areas have fared somewhat better with a small increase in access to other improved sources and small decreases in surface water and other unimproved sources (JMP, 2012a).

Table 12: Change in Water Access Over Time, Urban vs. Rural, Bangladesh (data from JMP 2012a)

	Population Using Improved Drinking Water Sources (x 1000)					
Year	*National*	*Improved (%)*	*Urban*	*Improved (%)*	*Rural*	*Improved (%)*
1990	105256	81444 (77%)	20852	18141 (87%)	84404	63303 (75%)
1995	117487	91174 (78%)	25486	22173 (87%)	92001	69000 (75%)
2000	129592	102537 (79%)	30571	26291 (86%)	99021	76247 (77%)
2005	140588	113230 (80%)	36092	30678 (85%)	104496	82552 (79%)
2010	148692	121040 (81%)	41733	35473 (85%)	106959	85567 (80%)

Figure 11 depicts in graph form the small increases in rural and national water access while simultaneously highlighting the small decrease in Bangladesh's urban access.

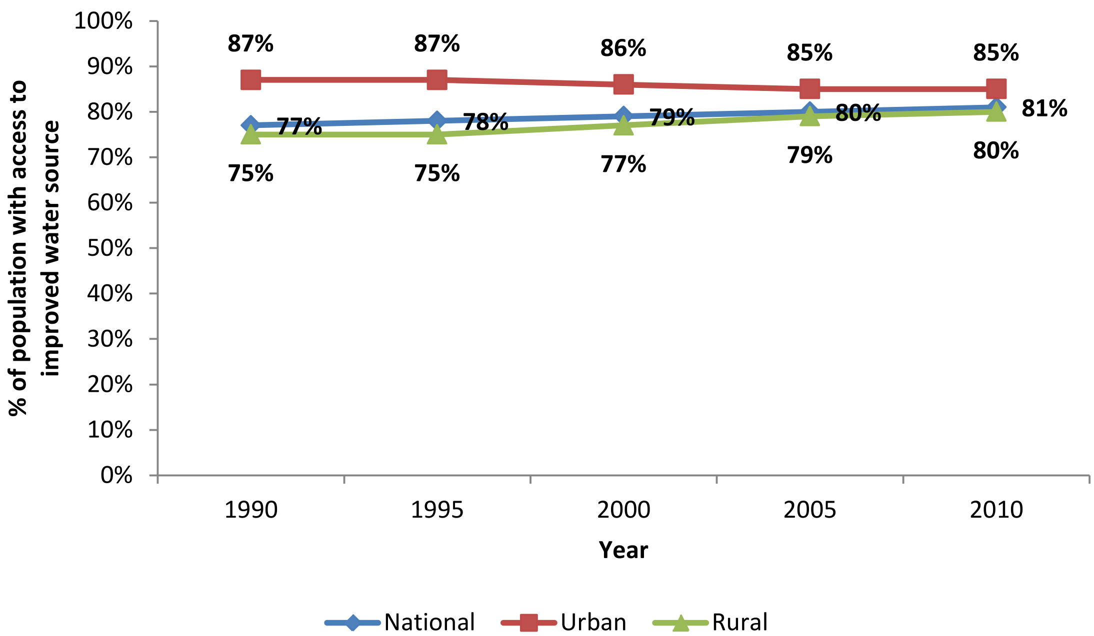

Figure 11: Change in Water Access Over Time, Urban vs. Rural, Bangladesh

4.4.4 Water and Health

Through the 1970s in Bangladesh, surface waters, largely used for domestic purposes, were contaminated with microorganisms, resulting in a significant burden of disease and mortality (Smith, Lingas & Rahman, 2000). As a result, Bangladesh's Department of Public Health Engineering, through the financial and programmatic support of UNICEF, began installing millions of tube wells throughout the country. Typically 5 cm in diameter and capped with a hand pump, these tube wells were sunk to depths no greater than 200 meters as a means to provide seemingly safe water to residents. Bangladesh received world-wide acclaim for its ability and initiative in providing more than 80 percent of its population with a tube well with safe water within 100 meters (Alam et al., 2002).

Unfortunately, it was not until 1993 that it was discovered that Bangladesh's ground water extracted from depths between 70-200 meters was contaminated with arsenic. When the tubes were initially installed, arsenic contaminated waters were not recognized as a problem and as a result, water testing did not include tests for arsenic (Smith et al., 2000). In 2000, it was estimated that 20 million Bangladeshis were possibly consuming arsenic-contaminated water (Smith et al., 2000). It was later discovered that a layer of silt clay rich in arsenic ran 450km long between 70-200 meters below ground, indicating that the arsenic contamination was geologic in nature (Alam et al., 2002). The consumption of arsenic-contaminated groundwater throughout Bangladesh has been cited as the largest mass poisoning of a population in history (Smith et al., 2000; Anstiss & Ahmed, 2006).

In 1996, a WHO country situation report gathered results from over 400 water testing measurements and discovered that more than half of the samples contained arsenic in excess of 50µg/l, concentrations above Bangladesh's established threshold of 50µg/l and well above the WHOs recommended levels of 10µg/l (Smith et al., 2000). A screening program undertaken by the Bangladesh Arsenic Mitigation Water Supply Project (BAMWSP) with the help of a number of NGOs and with US $44.4 million in funding, discovered that 29.12 percent of the 4.9 million tested tube wells were contaminated with the district of Chandpur having a contamination rate of 93 percent. Other reports have indicated that 50 percent of the population living in 61 of the 64 districts is at risk of arsenic poisoning. The regions impacted the most by arsenic contamination are those in the southern coastal areas and northeastern parts of the country (Khan et al., 2007).

Additionally, by the end of 2004, the 4.9 million tested tube wells accounted for only half of the country's wells.

Estimates of the burden of disease that have resulted from Bangladeshi consumption of arsenic contaminated water conservatively indicate that 290,000 cancer cases will result in the present generation (Khan et al., 2007). Another report indicates that 38,380 people had been officially diagnosed with arsenicosis by 2004 (Atkins, Hassan & Dunn, 2007). While yet another study revealed that disease induced by arsenic poisoning have resulted in the annual death of 9,136 people with an additional 174,174 DALYs lost in those exposed to arsenic in concentrations exceeding 50 µg/l (Khan et al., 2007).

Beyond the physical health consequences of arsenic poisoning, low literacy rates and a lack of information result in additional social implications. Skin lesions that can from as a result of arsenic poisoning are often confused with leprosy and ultimately lead to ostracism. In addition, it is poor women and children who are the worst affected. Affected women are often abandoned by their spouse while affected school-aged children are not permitted to attend school. In general, severe arsenicosis leaves people incapacitated and impacts productivity (Alam et al., 2007).

Looking at diarrhea, the WHO estimated that in 2002 68,200 Bangladeshi deaths were caused by diarrheal disease. In 2004 and 2008, Bangladesh experienced 73,500 and 31,700 diarrhea related deaths respectively (WHO, 2004, December; WHO, 2009, February; WHO, 2011, April). Trachoma accounted for 17,000 DALYs in 2002 and zero DALYs in 2004. *Ascariasis* and hookworm accounted for 33,000 and 14,000 DALYs respectively in 2002. In 2004, *Ascariasis* related DALYs decreased to 32,000 while hookworm related DALYs increased to 15,000 (WHO, 2004, December; WHO, 2009, February).

4.4.5 Water Management and Policies

In Bangladesh, the Ministry of Water Resources (MoWR) is the overarching body responsible for water management. The Water Resources Planning Organization (WARPO) is the planning arm of the Ministry while the Bangladesh Water Development Board (BWDB) is the implementing arm of the Ministry. However, when reviewing the mandate of the MoWR, the primary focus of the Ministry seems to be aimed at irrigation and flood control and there is no mention of drinking water oversight (Ministry of Water Resources, 2005). As other sources have noted, “on the demand side, irrigation has received higher priority than the safe supply of drinking water” (Chowdhury, 2010, p.40).

Due to the complexities of poverty, environmental vulnerability and weak administrative capacity, Bangladesh had long faltered in establishing or implementing a national water policy (Atkins et al. 2007). But in 1999, the MoWR published its first attempt at a National Water Policy. Yet again, very little is noted about drinking water management and nothing is mentioned about how to deal with the widespread arsenic contamination. In 2004, WARPO approved the Bangladesh’s National Water Management Plan. Although the author was unable to locate the document and it has not been made publically available through the WARPO website, it is said to include plans aimed at arsenic mitigation (WARPO, 2004).

Upon further exploration, it was discovered that the Department of Public Health Engineering (DPHE), which falls under the Ministry of Local Government, Rural Development and Cooperatives, is the lead agency tasked with the provision of drinking water and waste management. Initially charged with arsenic mitigation efforts, reports claim that DPHE has failed to invest in the necessary technical and managerial skills necessary to tackle the problem (Atkins et al., 2007).

In 2004, Bangladesh created a National Policy for Arsenic Mitigation along with an Implementation Plan for Arsenic Mitigation. Well-switching has been the main mitigation strategy proposed by the plan. In addition, instead of sinking deeper wells beyond the depths of the arsenic silt line, residents have been encouraged to return to surface and very shallow groundwater (Ahmed et al., 2006).

To help with arsenic mitigation efforts, in 2007 more than 257 registered NGOs were working to tackle the problem. However, it has been noted that when also factoring in the more generally health focused NGOs, only half of the country's communities were being reached (Atkins et al., 2007). Mitigation efforts between 2002 and 2009 cost hundreds of millions of US dollars, but follow-up and evaluation of these efforts were often short and focused on reported behaviors (Gardner et al. 2010).

4.4.6 Sanitation Over Time

Bangladesh has increased national sanitation access. Improved sanitation was available to 39 percent of the population in 1990 and 56 percent of the population by 2010. However, urban sanitation has seen a slight decrease from 58 percent to 57 percent. Meanwhile, rural residents have seen access increase from 34 to 55 percent (see Table 13) (JMP, 2012a).

Table 13: Change in Sanitation Access Over Time, Urban vs. Rural, Bangladesh (data from JMP 2012a)

	Population Using Improved Sanitation (x 1000)					
Year	*National*	*Improved (%)*	*Urban*	*Improved (%)*	*Rural*	*Improved (%)*
1990	105256	40792 (39%)	20852	12094 (58%)	84404	28697 (34%)
1995	117487	48822 (42%)	25486	14782 (58%)	92001	34040 (37%)
2000	129592	60310 (47%)	30571	17731 (58%)	99021	42579 (43%)
2005	140588	71775 (51%)	36092	20572 (57%)	104496	51203 (49%)
2010	148692	82615 (56%)	41733	23788 (57%)	106959	58827 (55%)

Figure 12 graphically highlights the increase in sanitation coverage both rurally and nationally while also highlighting the slight decrease in Bangladesh's urban coverage.

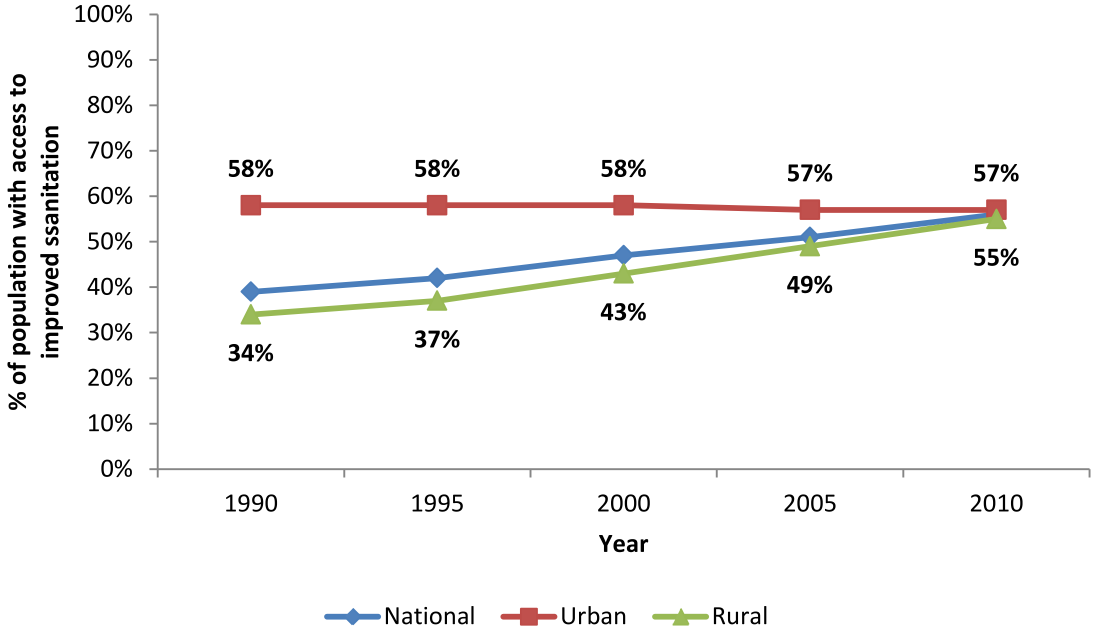

Figure 12: Change in Sanitation Over Time, Urban vs. Rural, Bangladesh

4.4.7 Economic Indicators

In 2010, Bangladesh's GDP reached almost US $82.98 billion, up from US $29.49 billion in 1990. GDP per capita has increased from US $280 in 1990 to US $558 in 2010. Bangladesh is the only country that has seen a large decrease in net official development assistance which dropped from close to US $3.18 billion in 1990 to US $1.39 billion in 2010 (World Bank, 2012).

Public health expenditure as a percent of GDP has decreased minimally over 15 years. At the same time public health expenditure as a percent of total health expenditure and external health resources as a percent of GDP have both fluctuated minimally over 15 years (see Appendix D for more details) (World Bank, 2012).

4.4.8 Water Interventions

The WHO notes that in general, arsenic exposure can be mitigated in rather straightforward ways but in Bangladesh, which suffers from a relatively weak economy and is regularly dependent on external aid to help address public health problems, the situation is more complicated (Smith et al., 2000). Many NGOs have proposed various options to overcome Bangladesh's contaminated waters. Such options have included piping in safe water, filtering surface water through clay pots, harvesting rain water or chemically treating arsenic contaminated ground water (Opar et al., 2007). After seven years of intensive arsenic mitigation efforts, one study found that children are still being exposed to unacceptably high levels of arsenic (Gardner et al., 2011).

One of the other mitigation strategies taken on by the government was the use of color coding the wells. Of the wells that were tested, those that returned results with contamination levels beyond Bangladesh's 50 µg/l parameters were painted red while those that were below this threshold were painted green. Red wells were to be avoided in favor of green wells. However, a number of studies reported various conflicts with this process. For instance, one study found that well switching dropped off dramatically if a safe well was located more than 100 meters away (Chen et al., 2007) while another study noted that at a two-year follow up, long-term well switching compliance was low (Gardner et al., 2011). At the same time, yet another study found that 4.2 percent of the wells included in the study that had been painted green were in fact contaminated above acceptable levels while 50.2 percent of red wells were in fact free of arsenic (Khan et al., 2007).

Beyond well color coding, another randomized study focused on assessing the effectiveness of dug wells and three-pitcher filters as arsenic mitigation strategies. The study implemented self-reporting in addition to urinalysis to test arsenic levels being expelled from the body. The study found low levels of compliance among all participants. Those who were noncompliant noted distance as a barrier to using the dug wells while bad smells, tastes and small yield were barriers to compliance with the three-pitcher filters (Milton et al., 2007).

Finally, a study that implemented flocculant-disinfectant POU for reducing arsenic exposure noted a reduction in median tube well water arsenic concentrations from 136 µg/l at baseline compared to 16 µg/l at post-intervention. However, the study also noted a marked increase in the amount of thermotolerant coliforms found in stored drinking water. At baseline, 14 percent of tube well samples were contaminated with coliforms while treated water at two and six weeks showed 30 percent of samples were contaminated, and at 12 weeks, 83 percent of samples were contaminated with coliforms (Norton et al., 2009).

4.5 LESOTHO

4.5.1 Lesotho at a Glance

Returning to sub-Saharan Africa, Lesotho, slightly smaller than Maryland, is the smallest country in this analysis and is one of only three enclaved countries in the world, being completely surrounded by South Africa (CIA, 2012). In 1990, life expectancy was at 59.3 years. Hit hard by the AIDS pandemic, by 2005 life expectancy had dropped to 44.2 years. Seeming to be slowly on the rise again, life expectancy reached 47.4 years in 2010 (World Bank, 2012). And in 2003, nearly 85 percent of Lesotho's inhabitants were considered literate, the highest in this analysis (CIA, 2012). For 2005 and 2010, Lesotho's corruption scores were 3.4 and 3.5 respectively (TI, 2012).

Lesotho is the only country in this analysis that was ranked in 1990 as a country of "medium human development" but by 2011 was ranked 160 out of the 187 assessed countries. This ranking dropped Lesotho into "low human development classification" (UNDP, 1990 & 2011). In addition, 49 percent of the population is considered to be poor (FAO 2005b).

Lesotho's climate consists of cool to cold winters and hot rainy summers. Average annual rainfall country wide is approximately 788 mm with a range of 300 mm in the western lowlands up to 1,600 mm in the northeastern highlands. Droughts reportedly occur three years out of every ten (FAO, 2005b). Traditional drinking water sources in rural Lesotho have included open reservoirs, springs and open wells (Gwimbi, 2011).

4.5.2 Population Changes

Of the six countries included in this analysis, Lesotho had the smallest percent increase in its population from 1990 to 2010. Over 20 years, Lesotho's population increased by 32.5 percent. As Figure 13 helps to illustrate, the urban populations saw the largest percentage increase of nearly 155 percent between 1990 and 2010 compared to only a 12.5 percent increase to the rural population (JMP 2012a**)**. Lesotho's fertility rate has been on the decline over the same period with 4.9 births per woman in 1990 down to 3.2 births per woman in 2010 (World Bank, 2012).

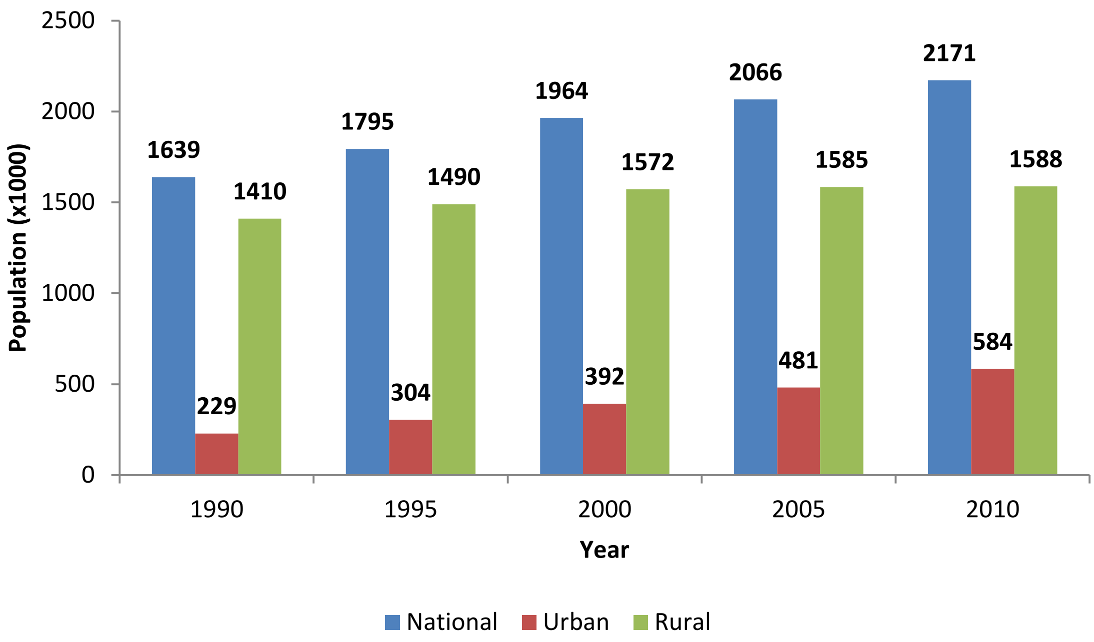

Figure 13: Lesotho Population Changes (data from JMP 2012a)

4.5.3 Water Access Over Time

Lesotho is one of the two countries in this analysis that has yet to meet its MDG 7.C drinking water target while also experiencing a reduction in the proportion of its population that has access to an improved drinking water source. In 1990, 80 percent of the population had access to an improved source. By 2010, that number had dropped to 78 percent. Additionally, in 1990 only 14 percent of Lesotho's population was located in urban settings, and 95 percent of those 229 thousand urban inhabitants had access to an improved source. By 2010, the urban population had more than doubled, reaching 584 thousand and accounting for 27 percent of the country's population. In 2010, 91 percent of urban inhabitants had access to improved drinking water sources (JMP, 2012a).

At the same time, in 1990 78 percent of the 1.4 million rural inhabitants had access to an improved drinking water source. By 2010, with almost 1.6 million inhabitants, rural access had dropped to 73 percent (see Table 14) (JMP, 2012a).

In Lesotho, national access to piped water has increased from five percent to 20 percent. However, access to other improved sources has decreased from 75 percent to 58 percent while utilization of unimproved sources has risen slightly from 18 percent to 21 percent. The most notable changes occurred in the urban centers where piped water access increased from 25 percent to 63 percent while access to other improved sources decreased from 70 percent to 28 percent. In rural regions, piped water has improved minimally while access to other improved sources has decreased and utilization of unimproved sources has increased (JMP, 2012a).

Table 14: Change in Water Access Over Time, Urban vs. Rural, Lesotho (data from JMP 2012a)

	Population Using Improved Drinking Water Sources (x 1000)					
Year	*National*	*Improved (%)*	*Urban*	*Improved (%)*	*Rural*	*Improved (%)*
1990	1639	1317 (80%)	229	217 (95%)	1410	1100 (78%)
1995	1795	1437 (80%)	304	289 (95%)	1490	1148 (77%)
2000	1964	1563 (80%)	392	369 (94%)	1572	1194 (76%)
2005	2066	1615 (78%)	481	442 (92%)	1585	1173 (74%)
2010	2171	1690 (78%)	584	531 (91%)	1588	1159 (73%)

Figure 14 graphically portrays the small decreases in access to safe water sources that Lesotho residents have experienced.

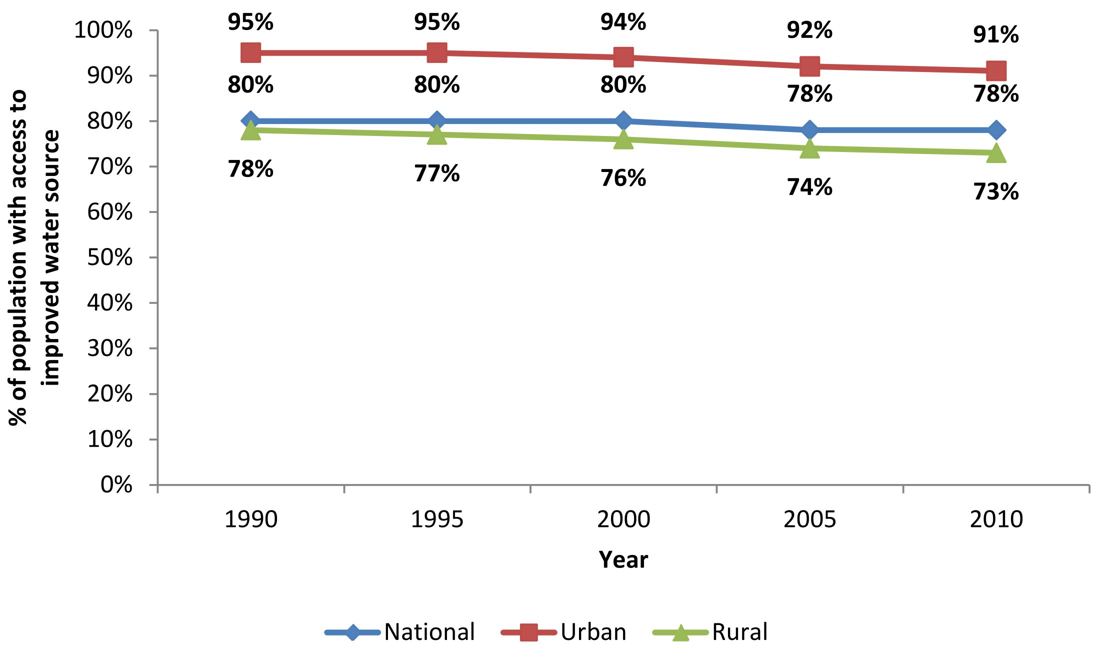

Figure 14: Change in Water Access Over Time, Urban vs. Rural, Lesotho

4.5.4 Water and Health

In 2002, 1,500 people in Lesotho died from diarrheal disease. In 2004, 400 people died and in 2008, 900 people died due to diarrheal disease (WHO, 2004, December; WHO, 2009, February; WHO, 2011, April). For 2002 and 2004, this equated to an estimated 59,000 DALYs. For the same years, *Ascariasis* and hookworm each accounted for 1,000 DALYs in 2002 and 2004 (WHO, 2004, December; WHO, 2009, February).

4.5.5 Water Management and Policies

1n 1999, Lesotho adopted its Water Resource Management Policy. In 2006, as one of the countries that subscribed to the call to develop an Integrated Water Resource Management Plan, the Global Water Partnership identified Lesotho as one of the countries that had failed to meet the 2005 deadline to have a fully developed an IWRWP. As a result and through various partnerships, in 2007 the Ministry of Natural Resources developed Lesotho's Water and Sanitation Policy. This policy included the initial steps of devising Lesotho's IWRMP (Government of Lesotho [GOL], 2007, April; UN Water, 2008).

Overall, it is the Office of the Commissioner of Water that is tasked with the coordination of programs and activities within the water sector. The government itself has noted the challenges the country has faced in trying to achieve effective water resource coordination and management (GOL, 2007, February).

Additionally, corruption within the water sector has been an issue for Lesotho. In 1999, the chief executive of Lesotho's Highlands Development Agency received an 18 year sentence for accepting bribes of more than $6 million from multinational firms in exchange for the firms receiving contracts to work on water projects in the country (Anbarci, Escaleras & Register, 2009).

4.5.6 Sanitation Over Time

Lesotho's utilization of improved sanitation methods has made little progress over the past 15 years (data for 1990 were not available). Nationally, improved sanitation has increased from 24 percent to only 26 percent. Urban residents have seen a decrease in coverage from 38 percent down to 32 percent while rural residents have seen a small increase from 21 percent to 24 percent (see Table 15) (JMP, 2012a).

Table 15: Change in Sanitation Over Time, Urban vs. Rural, Lesotho (data from JMP 2012a)

	Population Using Improved Sanitation (x 1000)					
Year	*National*	*Improved (%)*	*Urban*	*Improved (%)*	*Rural*	*Improved (%)*
1990	1639	no data	229	no data	1410	no data
1995	1795	429 (24%)	304	116 (38%)	1490	313 (21%)
2000	1964	491 (25%)	392	145 (37%)	1572	346 (22%)
2005	2066	533 (26%)	481	168 (35%)	1585	365 (23%)
2010	2171	568 (26%)	584	187 (32%)	1588	381 (24%)

Figure 15 graphically displays the sanitation coverage changes of Lesotho.

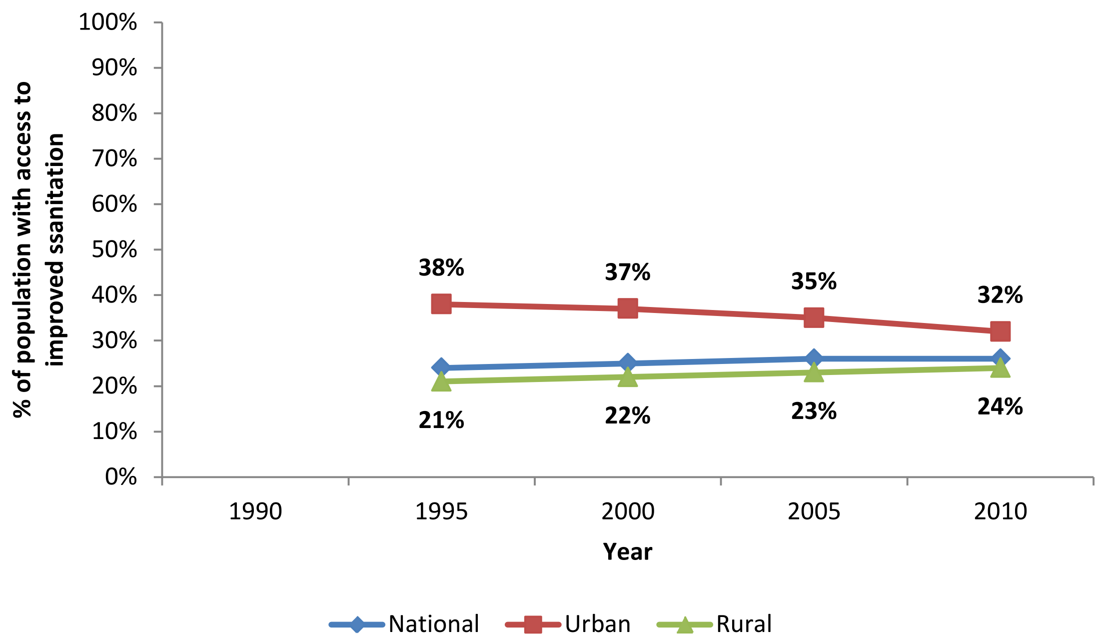

Figure 15: Change in Sanitation Over Time, Urban vs. Rural, Lesotho

4.5.7 Economic Indicators

Over 20 years, Lesotho's GDP rose from US $504 million to nearly US $1.07 billion while GDP per capita rose from US $307 to US $495 between 1990 and 2010. Net official development assistance fluctuated a lot over 20 years starting at US $214 million in 1990, dropping to US $60 million in 2000 and back up to US $ 250 million in 2010 (World Bank, 2012).

Public health expenditure as a percent of GDP dropped negligibly while public health expenditure as a percent of total health expenditure rose from 45.87 percent in 1995 to 76.24 percent in 2010. At the same time, external resources for health fluctuated a bit over 15 years starting at 5.74 percent in 1995, down to 3.05 percent in 200 and up again to 19.47 percent in 2010 (see Appendix D for more details) (World Bank, 2012).

4.5.8 Water Interventions

The author was unable to locate any peer-reviewed literature on water interventions previously or currently carried out in Lesotho.

4.6 TANZANIA

4.6.1 Tanzania at a Glance

Tanzania, located in sub-Saharan Africa, is roughly the same size as Nigeria and is a little more than double the size of California. Bordered by Burundi, Democratic Republic of Congo, Kenya, Malawi, Mozambique, Rwanda, Uganda and Zambia, Tanzania also has a coast along the Indian Ocean (CIA, 2012). Life expectancy at birth increased from 50.6 years to 57.4 years between 1990 and 2010 (World Bank, 2012). Based on 2003 estimates, nearly 69 percent of Tanzanians were literate (CIA, 2012). For 2000, 2005 and 2010, Tanzania's corruption scores were 2.5, 2.7 and 2.9 respectively (TI, 2012).

In1990, Tanzania was considered a country with “low human development.” Based on the 2011 HDI rankings, Tanzania remains a country of “low human development” at a rank of 152 out of 187 countries (UNDP, 1990 & 2011). In addition, poverty is concentrated in the rural areas but due to rapid urbanization, urban poverty has been increasing. Thirty-six percent of the country is reportedly living in poverty (FAO, 2005d).

The climate of Tanzania is considered tropical along the coast and temperate in the highlands. Annual rainfall for most of the country fluctuates between 500 mm to 1000 mm (FAO, 2005d). For much of the rural population, extreme water shortages are typical (Arvai & Post, 2011). A study that focused on communities with improved but non-networked water supplies determined that participants, on average, were collecting 48 liters of water per person per day, two liters under the minimum WHO guidelines (Pickering et al., 2010). At the same time, 70 percent of people included in a study in Itumba village noted that the number of liters available to their household each day had decreased from 180 liters to 60 liters primarily due to high water prices (Kibassa, 2011).

4.6.2 Population Changes

Tanzania is another country that has experienced a huge population growth with a 76 percent increase between 1990 and 2010 and after Nigeria, is the second most populous African country. Similar to the other countries in this analysis, the urban population grew the most with nearly a 146 percent increase compared to an almost 60 percent increase in the rural population (see Figure 16) (JMP 2012a**)**. Tanzania has seen only a minor reduction in its fertility rate over 20 years with a decrease from 6.2 births per woman to 5.5 births between 1990 and 2010 (World Bank, 2012).

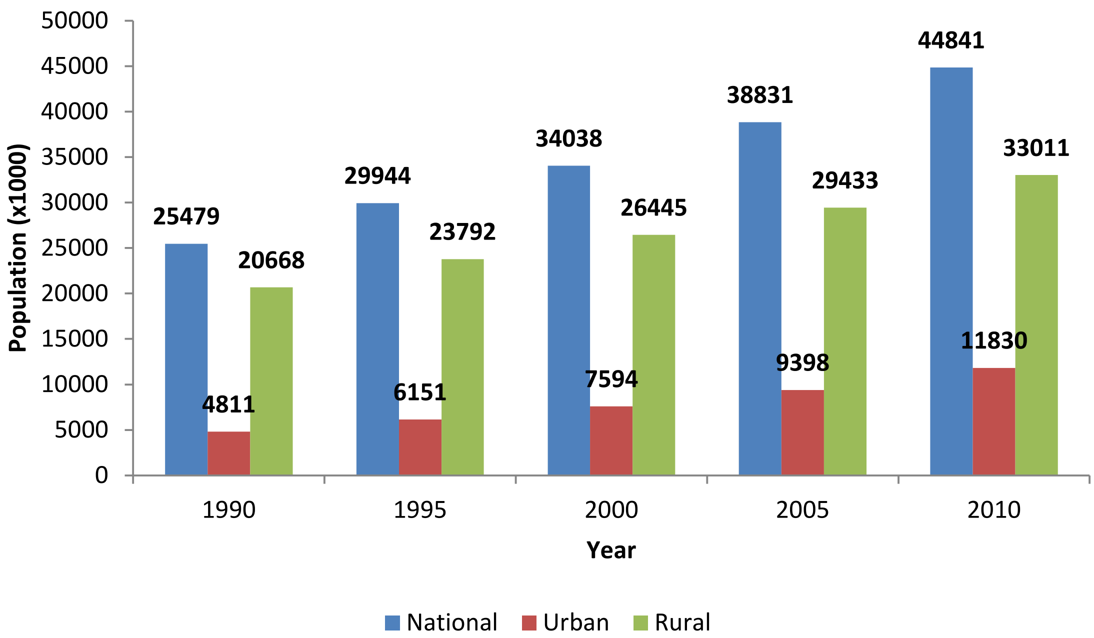

Figure 16: Tanzania Population Changes (data from JMP 2012a)

4.6.3 Water Access Over Time

As of 2010, Tanzania, like Lesotho, had yet to meet its MDG 7.C drinking water target. Also similar to Lesotho, Tanzania has seen a reduction in the proportion of its population that has access to an improved-drinking water source. With a 19 to 81 percent split in urban versus rural inhabitants, in 1990 only 55 percent of the nearly 25.5 million Tanzanians had access to an improved drinking water source. By 2010, 53 percent of Tanzania's 44.8 million inhabitants had access to an improved source (JMP, 2012a).

In 1990, 46 percent of rural residents had access to an improved source and by 2010, this had been reduced to 44 percent. At the same time, 94 percent of urban residents in 1990 had access while only 79 percent did in 2010 (see Table 16) (JMP, 2012a).

National access to different water sources has been relatively stagnant over the past 20 years with piped water increasing from seven to eight percent, access to other improved sources dropping from 48 to 45 percent, surface water usage dropping from 21 to 16 percent and utilization of unimproved sources increasing from 24 to 31 percent. Both urban and rural residents have experienced decreased access to other improved sources and increases in utilization of unimproved sources. At the same time, urban piped coverage dropped from 35 percent to 22 percent (JMP, 2012a).

Table 16: Change in Water Access Over Time, Urban vs. Rural, Tanzania (data from JMP 2012a)

	Population Using Improved Drinking Water Sources (x 1000)					
Year	*National*	*Improved (%)*	*Urban*	*Improved (%)*	*Rural*	*Improved (%)*
1990	25479	14030 (55%)	4811	4523 (94%)	20668	9507 (46%)
1995	29944	16481 (55%)	6151	5536 (90%)	23792	10945 (46%)
2000	34038	18431 (54%)	7594	6530 (86%)	26445	11900 (45%)
2005	38831	21045 (54%)	9398	7800 (83%)	29433	13245 (45%)
2010	44841	23871 (53%)	11830	9346 (79%)	33011	14525 (44%)

Figure 17 highlights the decreases in urban, rural and national access to water in Tanzania.

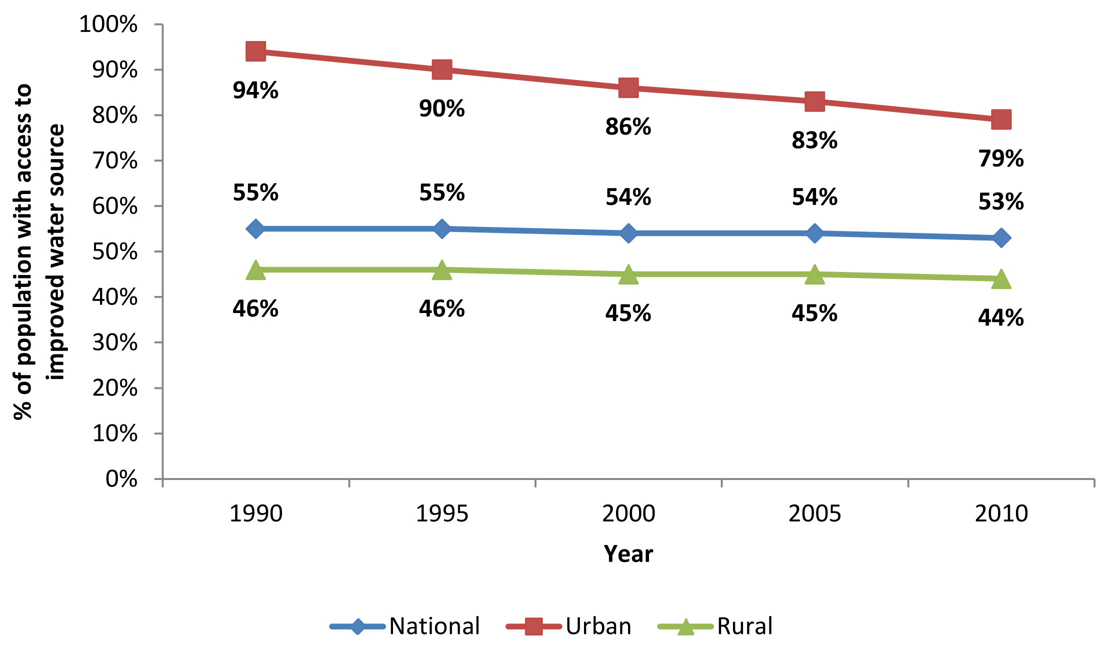

Figure 17: Change in Water Access Over Time, Urban vs. Rural, Tanzania

4.6.4 Water and Health

According to WHO estimates, 31,900 Tanzanians died in 2002 due to diarrheal disease. In 2004, 36,900 people died while in 2008 Tanzania experienced another 35,500 deaths (WHO, 2004, December; WHO, 2009, February; WHO, 2011, April). Additionally, 17 percent of Tanzania's under-five mortality can be attributed to diarrheal disease (Arvai & Post, 2011) while trachoma still plays a debilitating role, causing blindness in regions throughout Tanzania (Lewallen et al., 2008). In 2002, trachoma contributed to 111,000 DALYs and in 2004, another 84,000 DALYs. Also, in 2002, *Ascariasis* contributed to 14,000 DALYs while hookworm contributed to another 15,000. In 2004, hookwork related DALYs increased to 21,000 while *Ascariasis* related DALYs decreased to 13,000 DALYs (WHO, 2004, December; WHO, 2009, February).

One Tanzanian study noted that after hygiene education, an inadequate quantity of water was related to 15.6-22.5 percent of disease incidence while water quality contributed another 3-8 percent to disease incidence (Mayo, 2007). The same study also ranked water quality and water quantity in terms of their relative importance to disease reduction. Quality was rated as having medium importance while quantity was rated as having high importance as they relate to diarrhea. For eye infections, such as trachoma, water quality was considered to be negligible while water quantity was considered to be of high importance. Looking at worms, quality was also negligible while quantity was considered of low importance. In the case of *Schistosomiasis* both quality and quantity were considered of low importance. Typhoid and dysentery have the same rankings with water quality being ranked as having medium importance while water quantity was of low importance. At the same time, water quality was considered highly important for cholera while quantity was of relatively low importance (Mayo, 2007).

Another study focused on households using non-networked water sources and the level of fecal contamination in household drinking water in Dar es Salaam, the most populous city in Tanzania. The study found a positive correlation between fecal contamination on hands and fecal contamination of stored drinking water. Similarly, there was a positive association between fecal contamination of hands and the prevalence of gastrointestinal and respiratory symptoms found within a household (Pickering et. al., 2010).

4.6.5 Water Management and Policies

In Tanzania, the Ministry of Water is the overarching governing body for the water sector. There are then separate divisions tasked with different aspects of Tanzania's water management. The Urban Water and Sanitation Supply Division is responsible for policies and strategies that pertain to urban water and sewerage. However, the majority of the functions listed under the division revolve around commercial use and nothing is mentioned about domestic water use. The Rural Water Supply Division is responsible for rural policies and strategies. The functions listed under the Rural Division do make reference to the supply of community water but make no reference to the quality of water. It is the Water Quality Services Division that is tasked with analyzing the chemical and bacteriological quality of fresh water sources (United Republic of Tanzania, 2011).

Tanzania bases its service provision on a cost recovery plan, so in order to help offset costs, people form Water User Associations. Water User Associations are "small associations or cooperatives of water users cover areas commanded by a single furrow, one domestic water supply scheme (group or single) or various furrows in a given village or ward" (Sokile, Mwaruvand & van Koppen, 2005, p. 28-7).

In 1995, Tanzania, with the assistance of the World Bank, underwent a comprehensive review of its water policies and in 2002 created a formal National Water Policy. The policy states that access to water supply and sanitation is a right for all Tanzanians (Kibassa, 2011). Yet, similar to Bangladesh, very little is mentioned about drinking water management. A 2006 survey based study carried out by UN Water indicated that Tanzania was in the planning stages of developing an IWRM framework; however, the author was unable to locate a formal plan which seems to indicate that a formal IWRM plan may not yet exist for Tanzania (UN Water, nd).

4.6.6 Sanitation Over Time

Tanzania has made minimal improvements to sanitation access over 20 years. National access to improved sanitation has only increased from seven to 10 percent between 1990 and 2010. Urban coverage has doubled from 10 to 20 percent while rural coverage has only increased from six to seven percent (see Table 17) (JMP, 2012a).

Table 17: Change in Sanitation Over Time, Urban vs. Rural, Tanzania (data from JMP 2012a)

	Population Using Improved Sanitation (x 1000)					
Year	*National*	*Improved (%)*	*Urban*	*Improved (%)*	*Rural*	*Improved (%)*
1990	25479	1721 (7%)	4811	481 (10%)	20668	1240 (6%)
1995	29944	2465 (8%)	6151	800 (13%)	23792	1665 (7%)
2000	34038	2990 (9%)	7594	1139 (15%)	26445	1851 (7%)
2005	38831	3752 (10%)	9398	1692 (18%)	29433	2060 (7%)
2010	44841	4677 (10%)	11830	2366 (20%)	33011	2311 (7%)

Figure 18 graphically highlights the increase in urban sanitation coverage while also illustrating the stagnated rural and national sanitation coverage in Tanzania.

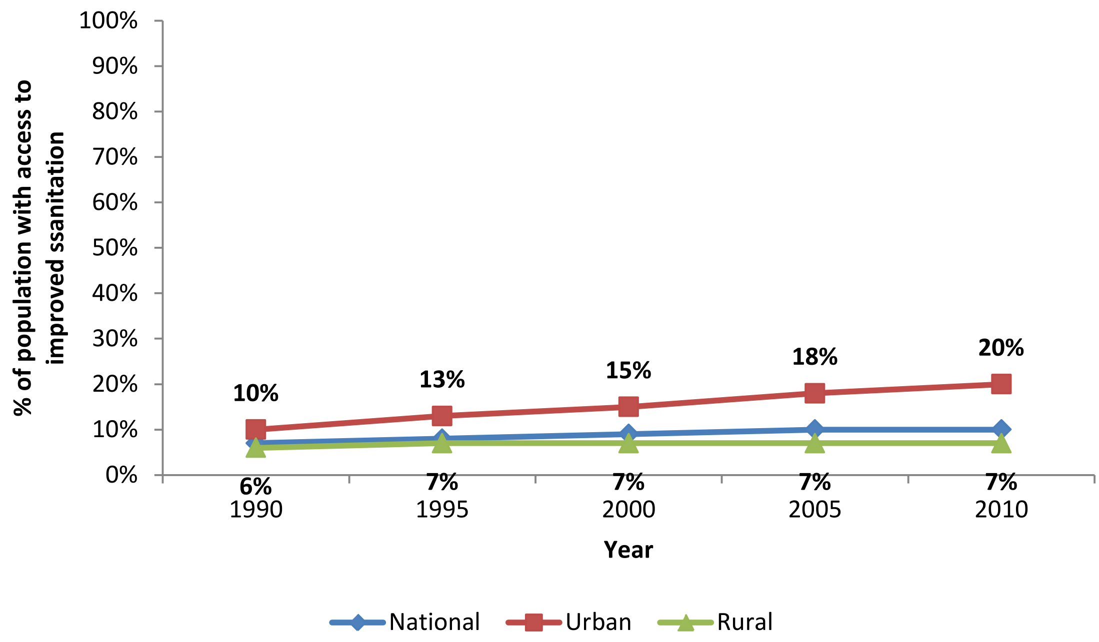

Figure 18: Change in Sanitation Over Time, Urban vs. Rural, Tanzania

4.6.7 Economic Indicators

Tanzania's GDP increased in 2010 to nearly US $19.67 billion from a GDP of nearly US $7.55 billion in 1990. Per capita income rose from US $305 in 1990 to US $456. Net official development assistance fluctuated from US $1.78 billion in 1990, dropping in 1995 before increasing again in 2000 and ending close to US $2.93 billion in 2010 (World Bank, 2012).

Public health expenditure as a percent of GDP rose minimally between 1995 and 2010. Public health expenditure as a percent of total health expenditure increased from 40.10 percent in 1995 to 67.32 percent in 2010 while external resources for health also increased from 9.29 percent in 1990 to 48.83 percent in 2010 (see Appendix F for more details) (World Bank, 2012).

4.6.8 Water Interventions

As trachoma is still a problem in Tanzania, one study focused on behavior change and the effects of a school-based trachoma curriculum on participants. Although the study noted some differences in ocular discharge, nasal discharge and dirty faces, many of the teachers interviewed for the study referenced how the lack of water at the schools made the application of health education messaging problematic (Lewallen et al., 2006).

Additionally, another study undertaken in Tanzania implemented a comprehensive assessment of household preferences for five POU interventions. The interventions included boiling water, SODIS solar disinfection, sodium hypochlorite solution (bleach branded as WaterGuard), sachet and flocculation disinfectant (branded as PUR) and clay filters locally manufactured. The study had participants in two villages rank water and treatment attributes such as taste, odor, time of application and ease of use. Efficacy was tested by study conductors. Water quality was tested both before and after treatment and was analyzed for the presence of *E. coli* and other coliforms. Both villages opted to select WaterGuard treatments as the treatment most preferred and the one that would be recommended throughout the village. Even though it was one of the least effective methods in removing coliforms, residents preferred its ease of use over the others (Arvai & Post, 2011).

5.0 DISCUSSION

Although the drinking water target of MDG 7.C has been met on a global scale, understanding more about the factors that can impact a country's ability to achieve the drinking water target of MDG 7.C is critical in order to assist those countries that are currently faltering at halving the proportion of their population without access to an improved drinking water source.

5.1 POPULATION CHANGES

Population growth and trends are important aspects when planning for community and country development. How and where a population is growing can have dramatic effects on the provision of services and can tax already limited resources. All six of the countries included in this analysis experienced national population increases above the global average of 30 percent for the time period of 1990-2010. Lesotho and Bangladesh experienced the smallest increases in population at 32.46 percent and 41.27 percent respectively while Tanzania and Burkina Faso experienced the highest percent change in population at 75.99 percent and 76.63 percent increases respectively.

Looking specifically at urban population changes, all of the countries experienced more than a doubling of the population. Malawi and Burkina Faso saw the largest increases to their populations with Malawi experiencing a 171.64 percent increase and Burkina Faso experiencing a 228.44 percent increase over the 20 year span of data used for this analysis.

All of the countries, with the exception of Nigeria, had similar ratios of urban to rural inhabitants. In 1990, the countries ranged from 12:88 percent to 20:80 percent ratios of urban versus rural inhabitants and ended in 2010 with ratios that ranged from 20:80 percent to 28:72 percent of urban versus rural inhabitants. Nigeria, however, began 1990 with a 35:65 percent split and leveled off in 2010 with a 50:50 percent split between urban and rural inhabitants.

Looking at the results of the population changes to each of the six countries, it is clear that all of the countries have experienced huge increases to their total population. More importantly, all of the countries have experienced high rates of urbanization, above the global 54 percent increase in urban areas. All of the countries in this analysis have experienced more than a doubling of their populations over the course of 20 years. Given the high fertility rates in all of the countries except Bangladesh and Lesotho, population growth could have serious detrimental effects on urban areas and strain already fragile water sources in many of these countries.

5.2 WATER ACCESS

Access to safe drinking water for internal consumption, cooking and hygienic practices is a critical component to country development as water can greatly impact the health of residents and ultimately have a bearing on their productivity. For the purposes of this analysis, six countries were selected that have experienced varying successes in achieving the drinking water target of MDG 7.C. From the six countries sampled, the actual regional (urban versus rural) levels of success seem to be the dividing line between the countries that have successfully halved the proportion of their population without access to an improved drinking water source and those that have not yet achieved this benchmark.

Malawi saw national access improve by 42 percentage points over the 20 year span this analysis covered. This equated to a 45 percentage point gain in rural regions and a 4 percentage point gain in urban centers. Similarly, Burkina Faso saw a national gain of 36 percentage points with a rural gain of 35 percentage points and an urban gain of 20 percentage points. At the opposite end of the spectrum, Tanzania saw a national reduction of 2 percentage points, a rural reduction of 2 percentage points and an urban reduction of 15 percentage points.

Although a small sample size, essentially Malawi and Burkina Faso were able to make progress in improving population access to improved water sources in both urban and rural parts of their countries while Nigeria and Bangladesh lost ground in their urban centers and made only small gains in rural areas. Lesotho and Tanzania saw declines in both their urban and rural access to an improved drinking water source. From these six countries, it was Malawi's and Burkina Faso's ability to accommodate large increases to urban populations while simultaneously improving urban water access that set them apart from the other four countries and have allowed them to successfully achieve the drinking water target of MDG 7.C.

5.3 WATER AND HEALTH

The six countries in this analysis all displayed some burden of disease that could be related to unsafe drinking water. All countries have experienced some level of death related to diarrhea over the course of 1990-2010, although it is important to note that not all incidences of diarrhea are due to unsafe drinking water; food contamination can also cause diarrhea. However, as the

WHO notes, 88 percent of diarrheal disease is attributable to unsafe drinking water, inadequate sanitation and hygiene (WHO, 2004, November). Additionally, all countries had some level of noted *Ascariasis* and hookworm incidence. All countries, with the exception of Lesotho, still had reported cases of trachoma although based on 2004 numbers, Bangladesh seems to have eliminated most cases.

Looking at chemical contaminations, arsenic has severely and negatively impacted Bangladesh (see below for additional comments). Burkina Faso has also begun to report arsenic contamination in parts of the country and some reports have indicated that elevated levels of nitrate exist in the western part of the country.

5.3.1 Bangladesh

Bangladesh was an interesting yet tragic case to investigate and a country that seems to have found itself firmly stuck between two equally poor options at the moment. Bangladesh had made tremendous improvements to increasing its population's access to improved drinking water sources. Unfortunately, without the inclusion of arsenic testing in the millions of tube wells that were sunk, many in the country have already been exposed to or run the risk of regularly consuming arsenic contaminated water. It is likely due to this groundwater contamination that Bangladesh has been unable to make further advances in improving people's access to safe drinking water. Many Bangladeshis have been forced to make the decision of consuming what may be arsenic contaminated groundwater or reverting back to using surface water that may have microbial contaminations.

Two of the keys to mitigating the health impacts of water-borne diseases include first, taking steps to recognizing their existence (e.g. testing water) and second, taking accurate and definitive steps towards remediation. Although Bangladesh's arsenic contamination is arguably more pervasive than what has been noted so far in Burkina Faso, Burkina Faso has implemented plans to close down contaminated wells and redrill new, arsenic free wells. Although Bangladesh made attempts at mitigation through the use of red and green color coding, reports demonstrated that the wells were perhaps not accurately tested and only half of the nearly nine million wells received any sort of testing. In addition, even through the implementation of the red and green color coding, alternative options to red wells were apparently never provided.

5.4 WATER MANAGEMENT AND POLICIES

Water policies and water management, as would be expected, seem to play a large role in the level of success that a country has achieved towards the drinking water target of MDG 7.C.

To start, both Malawi and Burkina Faso have made safe drinking water a top priority. Both countries have backed this up with money, documented policies and action. Compared to the other countries, Malawi and Burkina Faso both seem to have coherently stated policies and clearly defined roles of authority. Additionally, both countries have been proactive in addressing drinking water issues. For instance, Malawi's government provides free chlorine to disinfect water at the household level while Burkina Faso's government sought out assistance when it began to realize that urban population growth was getting dangerously close to outpacing urban water provision. Lastly, Malawi and Burkina Faso are the only two countries that have fully developed and implemented Integrated Water Resource Management strategies.

All of the other countries seem to have struggled with successful water policy formation and overall water management. This seems to have occurred for a number of reasons. First, some countries simply have other priorities that supersede the importance of safe drinking water. For instance, Lesotho's primary focus has been on combating HIV/AIDS. Second, unforeseen circumstances have impeded the way towards progress. Bangladesh, for example, has struggled since the mid-90s to overcome its country's arsenic poisoning and to provide viable safe water solutions to its contaminated tube wells. Third, even when policies have been developed for water resource management, drinking water has frequently been neglected. Fourth, there seem to be too many administrative divisions in each country's water sector. This can negatively impact water management effectiveness if divisions do not communicate with one another and if division policies are not compatible with one another. Lastly, at least one, if not more of the following have been noted for the four countries that have so far been unsuccessful in meeting the drinking water target of MDG 7.C: ineffective administrative capacity, weak authoritative powers and corruption within the water sector.

5.5 SANITATION

Sanitation and safe drinking water are grouped together as part of MDG 7.C. Even though globally the drinking water target has been met, the sanitation target still has a long way to go. With the exception of Nigeria, all of the countries have made national progress towards increasing access to improved sanitation but none have yet reached the halved benchmark. Bangladesh, Malawi and Burkina Faso have demonstrated the greatest gains between 1990 and 2010 with 17, 12 and nine percentage point gains. Looking at rural progress, again Bangladesh and Malawi have demonstrated the most gains with 21 and 13 percentage point increases while Burkina Faso still ranked third with only a four percentage point increase. When looking at urban sanitation, Tanzania has demonstrated the greatest gains with a 10 percentage point gain followed by Burkina Faso with a seven percentage point gain. In general, Malawi, Burkina Faso and Tanzania are the three countries that show gains in urban, rural and national sanitation measures. Most likely, these results are due to country prioritization. For instance, Malawi and Burkina Faso have formally articulated that access to improved drinking water sources has been their main priority. Perhaps with their success in reaching the halved benchmark, resources will start to funnel towards improved sanitation. Although the sample is too small to be conclusive, this is an interesting finding that could benefit from further research exploring the direct linkages between access to improved sanitation and access to improved drinking water sources.

5.6 ECONOMIC INDICATORS

The economic indicators included in this analysis gave no real indications as to why some of the countries in this analysis have succeeded in reaching the drinking water targets of MDG 7.C and others have failed. All of the countries demonstrated relative increases in GDP with Lesotho and Malawi displaying the smallest relative changes of 113 percent and 121 percent increases respectively while Burkina Faso and Bangladesh demonstrated 192 percent and 181 percent increases respectively.

Turning to GDP per capita, Malawi and Tanzania demonstrated the smallest relative changes with 39 percent and 55 percent increases respectively. This is an interesting observation considering Malawi has made the greatest improvements to water access while Tanzania has struggled the most. Similarly, it is interesting to note that in absolute terms, Malawi and Burkina Faso had the smallest absolute gains to GDP per capita over the 20 years this analysis explored.

Malawi experienced only a US $51.64 per capita gain in GDP while Burkina Faso experienced a US $109.36 gain between 1990 and 2010.

Due to the yearly fluctuations noted, net official development assistance received also did not reveal anything of value to help explain successes in drinking water improvements. Even when the author did crude per capita calculations, nothing of note materialized. One small point to note is that all of the countries showed the highest amount of assistance in 2010. This seems to indicate that donor countries are beginning to answer the call of MDG 8.B, which asks donor countries to increase official assistance to 0.7 percent of each donor country's gross national product. Even with this increase, it is important to remember that development assistance granted to developing countries is often considered fungible, meaning that instead of development assistance being added on top of what a country's government has already earmarked for a developmental purpose, the government might decide to reallocate its money elsewhere which has the potential of limiting the intended benefit of the development assistance dollars.

Lastly, the health expenditure indicators also did not aid in drawing any meaningful conclusions. The only thing to note is that out of the six countries included, Malawi and Burkina Faso spent the largest percent of GDP on health in 2005 at 6.07 percent and 3.98 percent respectively. Lesotho was relatively consistent over the course of the 15 years for which data was available but seems to be trending downward. In 1995, Lesotho spent 3.44 percent of GDP on health and 3.29 percent in 2010.

5.7 WATER INTERVENTIONS

The inclusion of water intervention descriptions and findings in this analysis was used to highlight alternative methods of improving drinking water. The JMP parameters of "improved" drinking water sources limits estimates and findings to just community and governmental level interventions. It fails to take into account the applicability and effectiveness of interventions that can occur at the household level. For instance, a conducted meta-analysis linked 35-44 percent reductions in diarrheal diseases to HWTs (Fewtell et al., 2005).

Looking specifically at some of the noted projects, in Malawi, the free provision of chlorine from the government is an excellent and inexpensive way to provide additional protection for citizens. The HWTs interventions employed in Nigeria, Bangladesh and Tanzania all showed favorable results which indicate that more sophisticated HWTs (i.e. above and beyond boiling) have the potential of being more widely beneficial in these countries.

The author initially thought that the lack of literature on water projects for Malawi and specifically for Burkina Faso may be due to the notable reductions in the populations' use of unimproved drinking water sources and surface water implying that HWTs would be less relevant. However, this is contrary to what UNICEF and WHO have reported. In their 2011 JMP thematic report, it was noted that households with access to an improved drinking water source were more likely to treat their water than households accessing an unimproved source (JMP, 2011). The report also noted, that although there is variability between individual countries, sub-Saharan Africa has a low prevalence of HWTs.

Although far from representative, the existence of literature pertaining to HWTs and POUs indicates a number of things. First, in countries where water projects were noted, this demonstrates a level of acceptance to the notion of alternative means to obtain safe water. In countries where information was limited or nonexistent, this illustrates areas that can be further explored as a means to improve drinking water quality.

Lastly, it is important to note small scale water projects and interventions are frequently conducted at the discretion of those interested in studying the results and those who have the financial resources to implement them. This typically means that NGOs or academics with project funding are setting up short term interventions in locations of their choosing. In other words, small scale projects are usually supply driven and not demand driven. Additionally, intervention results likely suffer from publication bias where unfavorable results are less likely to be published than favorable results.

5.8 LESOTHO

Lesotho was a bit of an outlier through this entire analysis. It was very challenging to find any literature relevant to Lesotho and MDG 7.C, water contamination or any connection between access to water and negative health outcomes. This may have occurred for a few reasons. First, HIV has had a devastating impact on Lesotho and as a result the government has decided that MDG 6, which is focused on combating HIV/AIDS, should be the country's first priority (UN Lesotho, nd). Second, in 1990, Lesotho was already demonstrating a relatively high level of access to improved drinking water sources. As such, its two percentage point reduction in improved water source access has likely gone unnoticed by many in the global community. However, if Lesotho's downward trend in people's access to improved drinking water sources continues, there could be serious consequences.

5.9 ADDITIONAL POINTS OF DISCUSSION

A few additional points warrant further discussion. First, all of the countries had scores below 4.5 on the corruption perception index, which does not instill a lot of confidence in each country's public administration capabilities.

Second, considering the prominent role that water plays in the success of the many of the MDGs, it is unfortunate that it is buried within the overarching environmental sustainability goal.

Lastly, the evidence from the small selection of countries does not clearly highlight that improved access to water improves country development. Both Malawi and Burkina Faso, the two countries that have successfully halved the proportion of their populations without access to an improved drinking water source, are still two of the poorest countries in the world and are both still considered to be of "low human development." As such, it is important to consider that although water is related to a country's ability to develop and is inextricably linked to the other MDGs, improving access to water alone is not sufficient in fostering a country's development. Development requires a multi-faceted approach that is not limited to just one aspect or sector of development. Perhaps given more time and resources, Malawi and Burkina Faso can continue to work on tackling other MDGs and will eventually begin their ascent into the classification of "medium human development."

6.0 CONCLUSION

In conclusion, it is important to identify and understand the factors that may contribute to a country's success in achieving the global Millennium Development Goals. This analysis focused on exploring the possible factors that contributed to the varying levels of success that six countries have experienced on the way towards halving the proportion of their populations who do not have access to a safe drinking water source. While a six country sample is extremely limited, the results are still informative.

This analysis began by emphasizing the importance of safe drinking water for health and development outcomes. Following the sample and research methodologies, the analysis explored different country factors such as population changes, changes in water access, water management and policies, sanitation access and economic indicators. Additionally, the analysis included details on how water has impacted health for each of the countries and also included information, when available, about water interventions that have been undertaken in each country.

Two of the countries included in this analysis have successfully reached the drinking water target of MDG 7.C while four countries have not. Additionally, two countries have actually experienced increases in the proportion of people who currently do not have access to an improved drinking water source. The two countries that have successfully met the drinking water target of MDG 7.C are Malawi and Burkina Faso. Nigeria, Bangladesh, Lesotho and

Tanzania have not yet been able to meet this target and Lesotho and Tanzania have actually lost ground in halving the proportion of people without access to safe drinking water. However, this does not mean that this goal is out of reach for these countries. As this analysis reveals, one of the biggest contributing factors that seems to have impacted the success of Malawi and Burkina Faso deal with each country's ability to absorb the rapid urban population growth each has experienced while still increasing the proportion of the population's access to improved drinking water sources. Additionally, both countries have made water a specific development priority and backed this up with funding, sound policies and seemingly strong water sector authorities with clearly defined roles.

At a global level, an emphasis has been made on improving rural access to safe water. Although certainly critical, with rapidly growing urban populations, countries need to make sure they are equipped to adequately maintain pace between water service provision in urban areas and the increasing demand. If not, countries may risk back sliding in their accomplishments, much like Lesotho and Tanzania.

Furthermore, POU/HWTs are viable solutions to improving drinking water quality, especially in regions where access to improved drinking water sources are deficient. As such, promotion and education efforts for POU/HWTs should be increased specifically in these areas. As POU/HWTs technologies become more prevalent, effective health messaging will need to be included as part of the long term strategy. In order for households to achieve the full benefits and protective qualities of POU/HWTs the importance of compliance and long term maintenance will need to be conveyed. Also, proper hygiene education will also be a necessary component in order for POU/HWTs to be successful. As a common theme that emerged throughout the studies and as the literature highlighted, higher levels of water contamination were frequently noted in homes compared to at the water collection source. This contamination indicates that hygiene practices also need to be improved in the home to avoid further contaminating or recontaminating already treated water.

In addition, steps should be taken to create affordable, simple ways for people to accurately test their own water for contamination. This will empower people to take action in treating their own water if community and regional services have failed.

Overall, not all approaches to safe drinking water will be applicable to every setting. It is crucial that each country thoroughly review its needs, capacities and priorities.

There were a number of limitations with this analysis. First, no original data were collected for this analysis. Second, only articles that were accessible through the University of Pittsburgh Library system free of charge and in English were used. Third, using the MDG benchmark of "halving" as an initial criterion resulted in the exclusion of some countries that have made great strides in improving access to water.

There were a number of limitations in using the JMP's indicators. The biggest limitation is that the "proportion of population using an improved drinking water source" does not actually infer any sort of quality or quantity standards for the drinking water. There seems to be an assumption made on the part of the JMP that "improved" necessarily means contaminant free and of sufficient quantity. As a result, it seems likely that the JMP estimates are overestimates. Furthermore, the JMP indicator fails to account for household level interventions. However, the JMP data still includes people who are using an unimproved source where a household level intervention could and may very well have been applied.

It has been a long road for the world to get where it is now, but in looking back, great strides have been made in giving two billion people access to safe drinking water. However, the work is not done yet. There remain another 780 million people that lack this vital life source. Without access to safe drinking water they are in constant danger of illness, disability and death and as a result their families and communities suffer too. As Malawi and Burkina Faso have demonstrated, MDG 7.C can be achieved. With the right support and planning, many of the world's poorest countries can achieve the same successes as these two countries.

APPENDIX A: MALAWI ECONOMIC GRAPHS

Data from World Bank, 2012

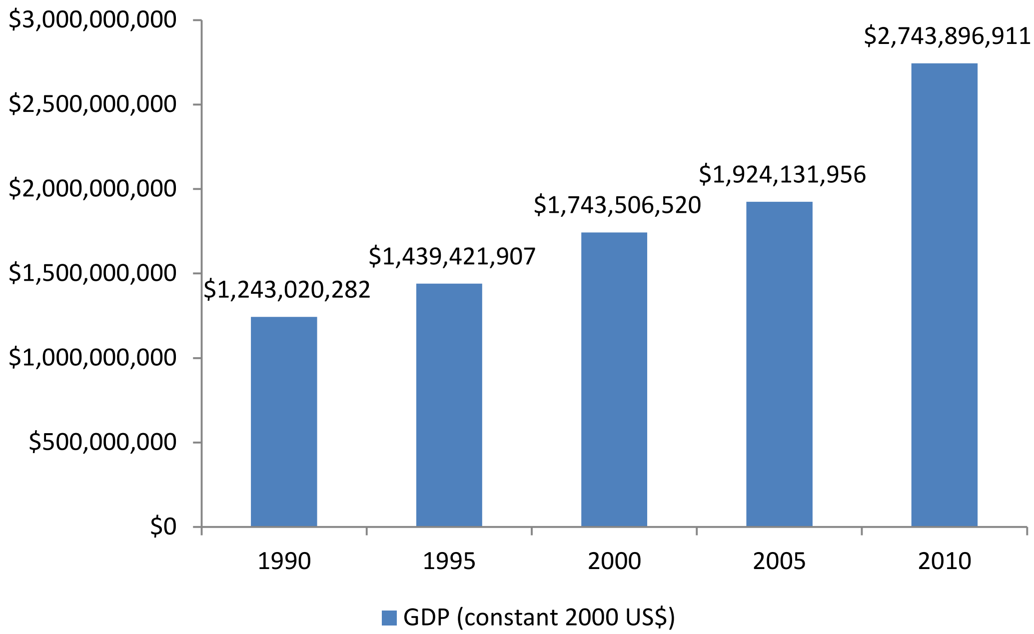

Figure 19: GDP, Malawi

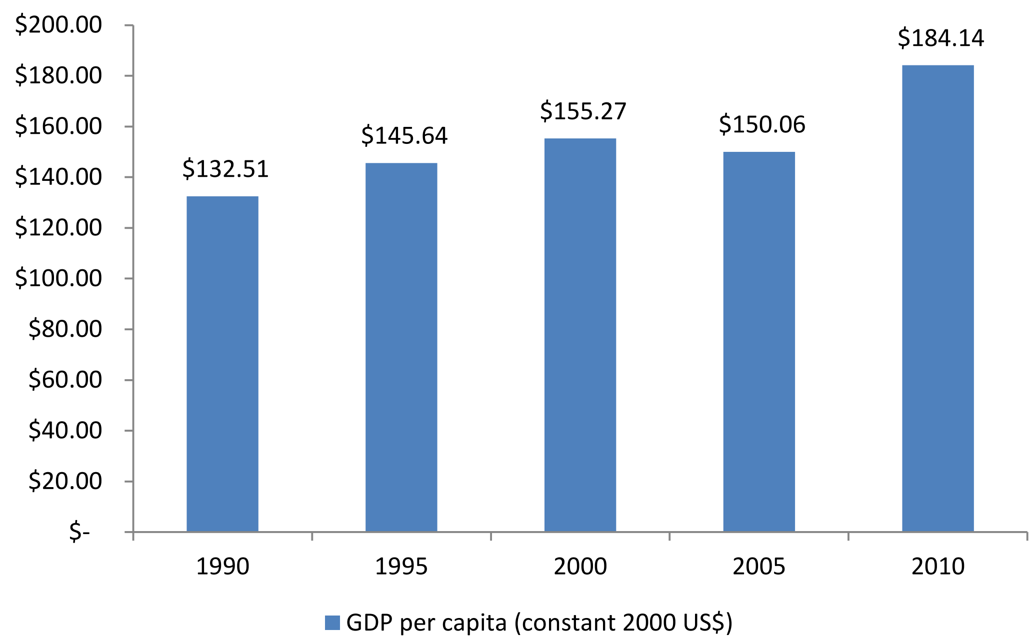

Figure 20: GDP per capita, Malawi

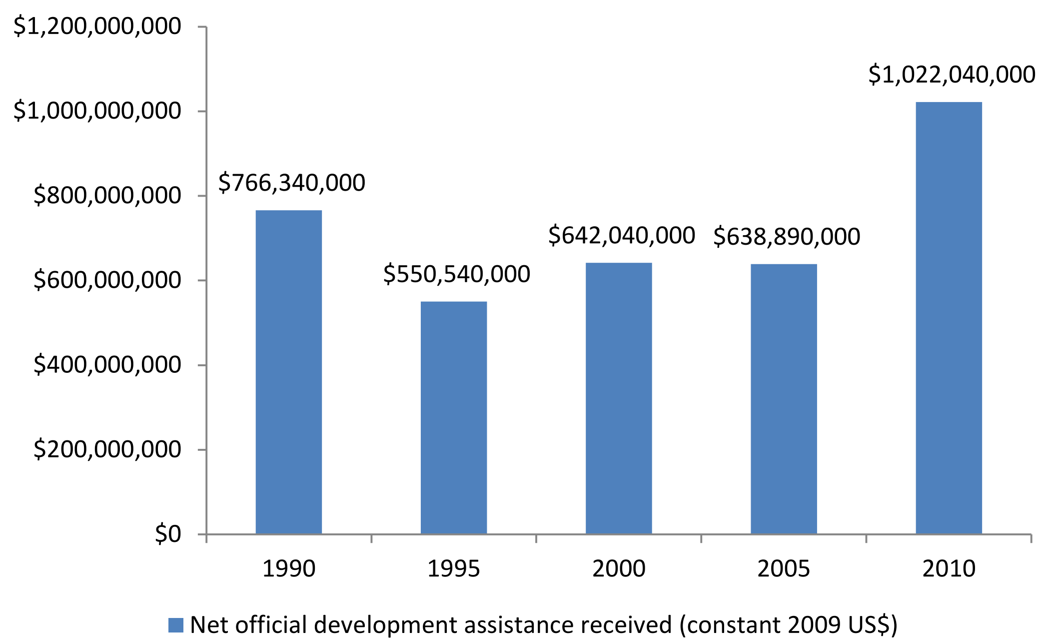

Figure 21: Net Official Development Assistance, Malawi

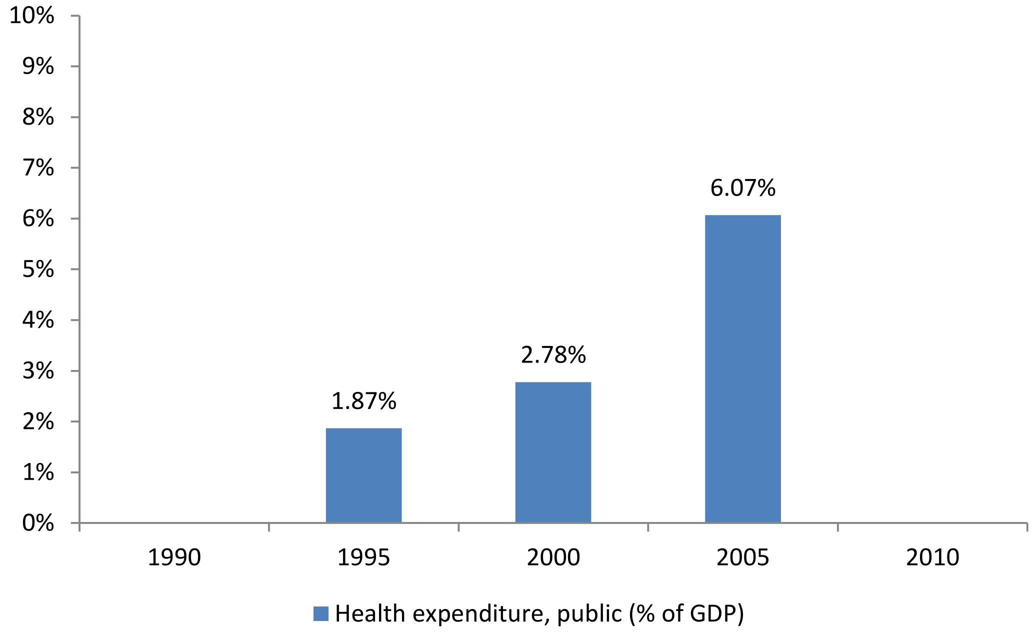

Figure 22: Health Expenditure, public (% of GDP), Malawi

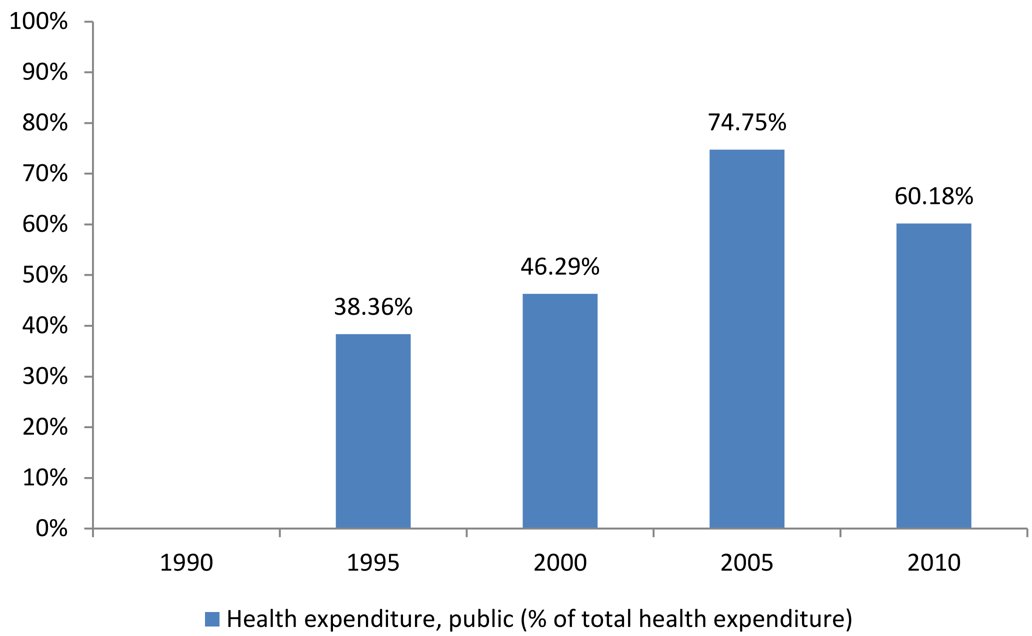

Figure 23: Health Expenditure, public (% of total), Malawi

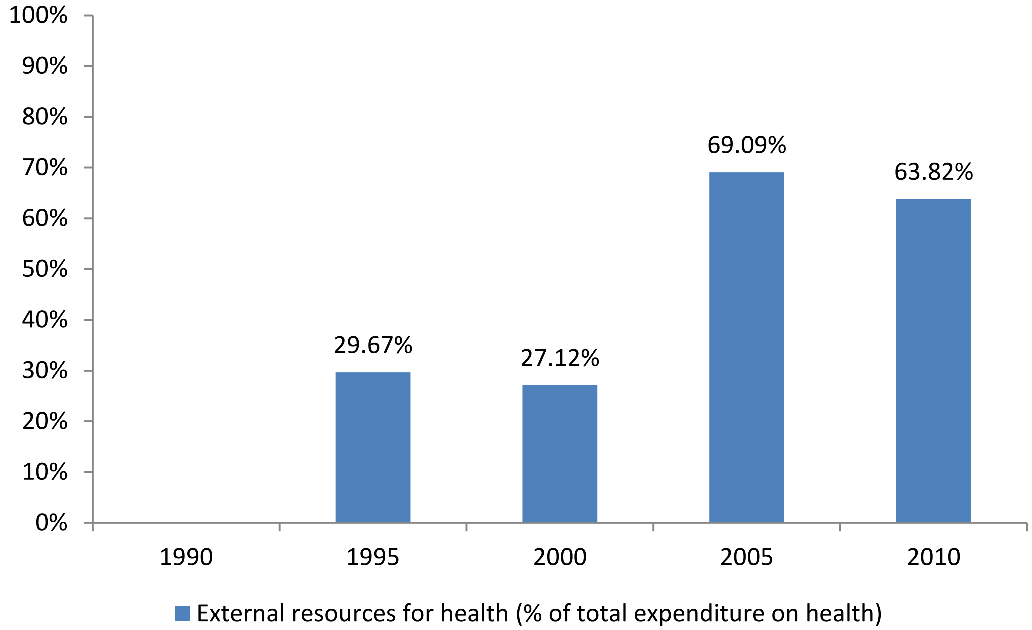

Figure 24: External Resources for Health (% of total health expenditure), Malawi

APPENDIX B: BURKINA FASO ECONOMIC GRAPHS

Data from World Bank, 2012

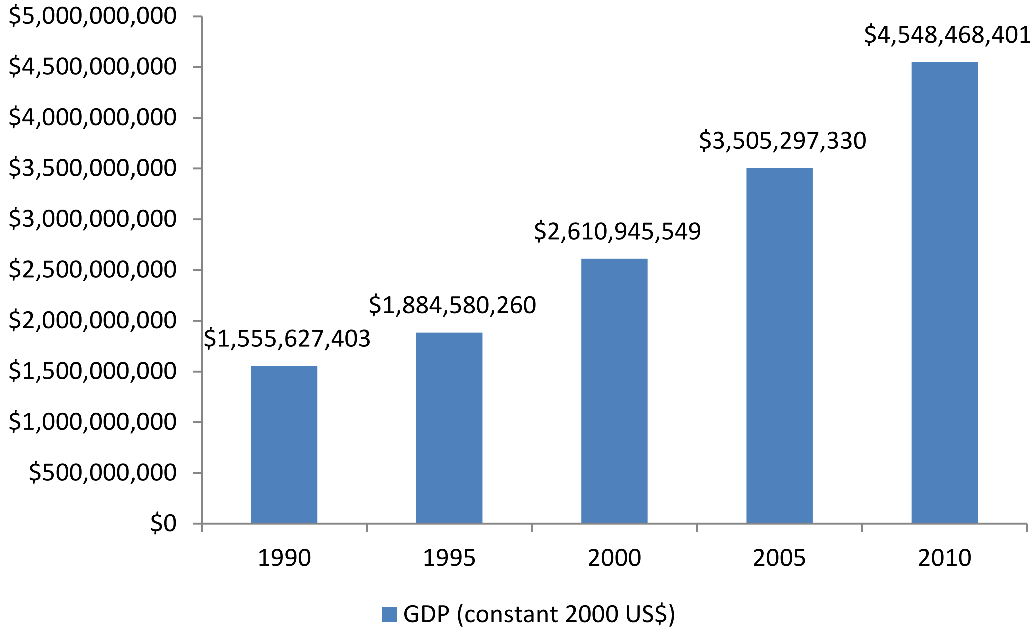

Figure 25: GDP, Burkina Faso

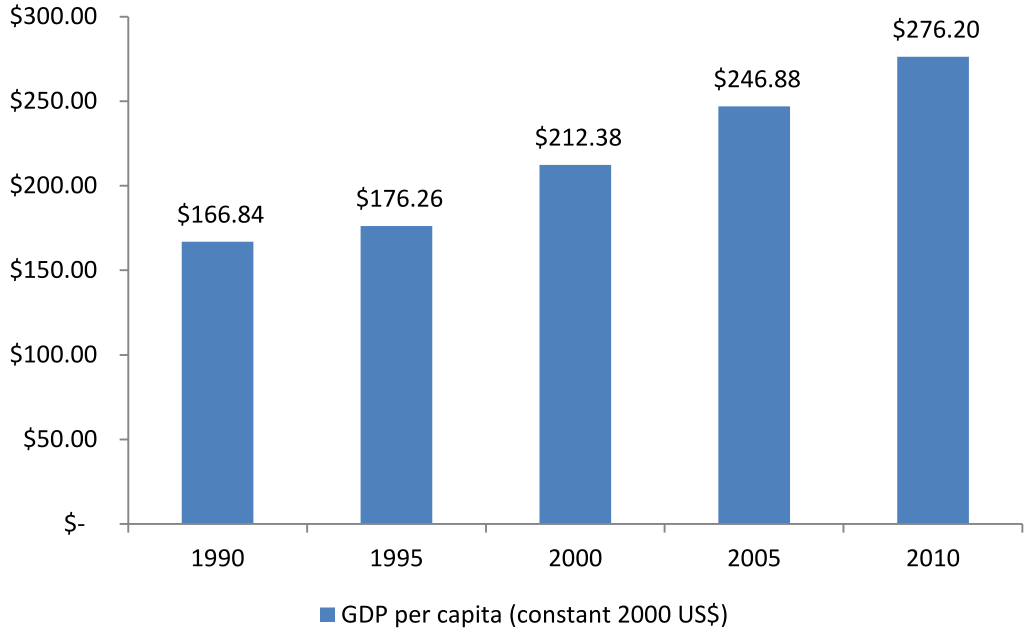

Figure 26: GDP per capita, Burkina Faso

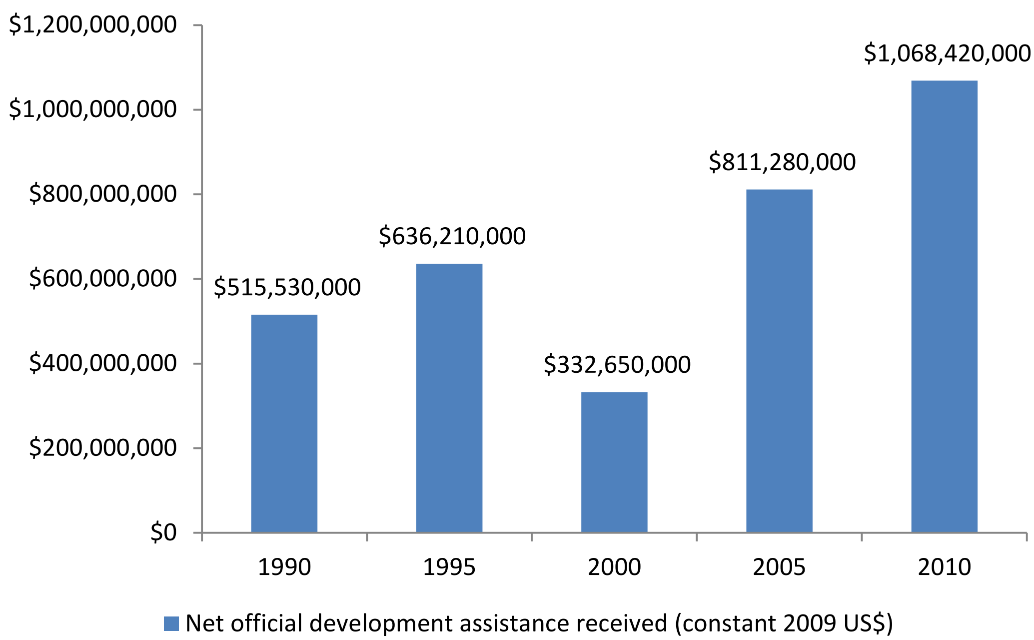

Figure 27: Net Official Development Assistance, Burkina Faso

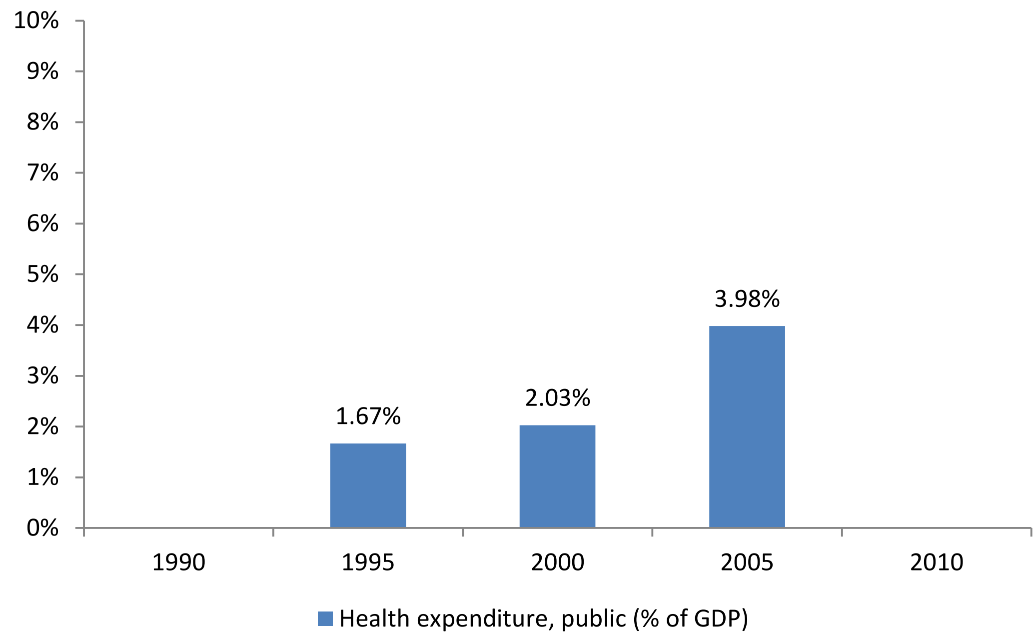

Figure 28: Health Expenditure, public (% of GDP), Burkina Faso

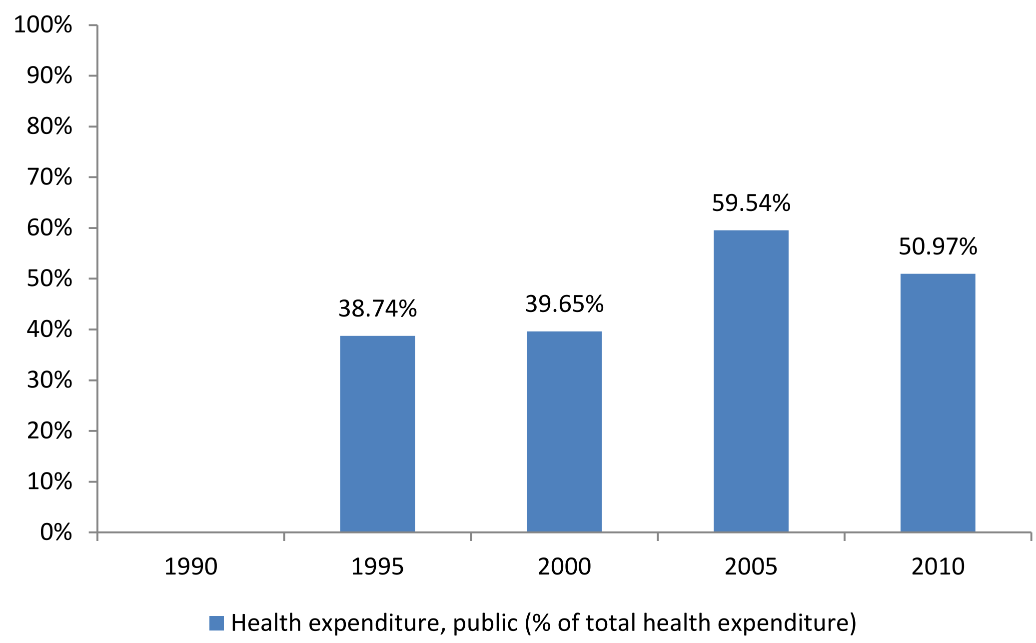

Figure 29: Health Expenditure, public (% of total), Burkina Faso

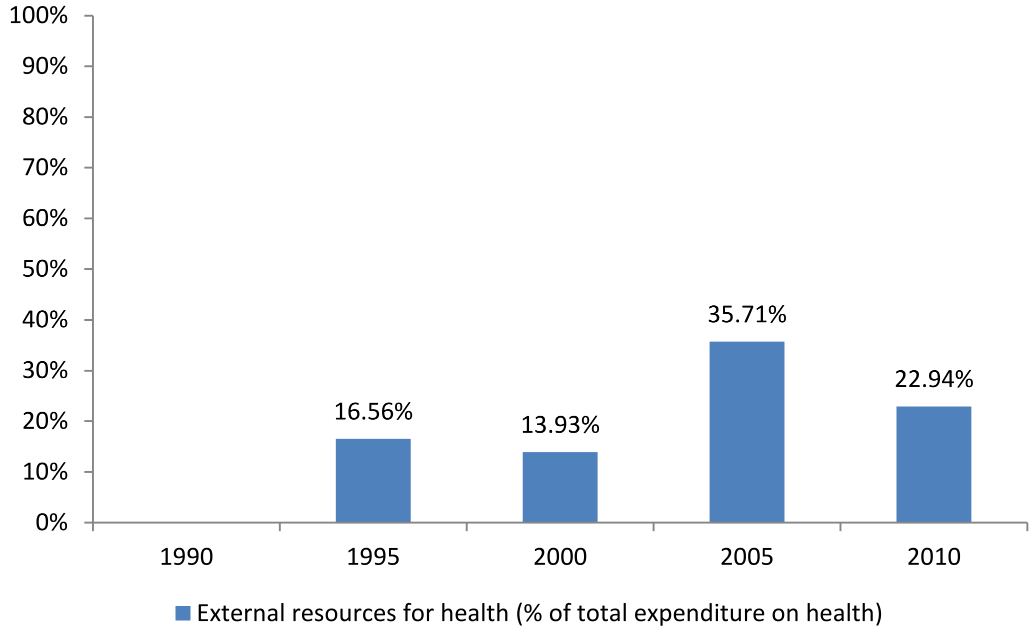

Figure 30: External Resources for Health (% of total health expenditure), Burkina Faso

APPENDIX C: NIGERIA ECONOMIC GRAPHS

Data from World Bank, 2012

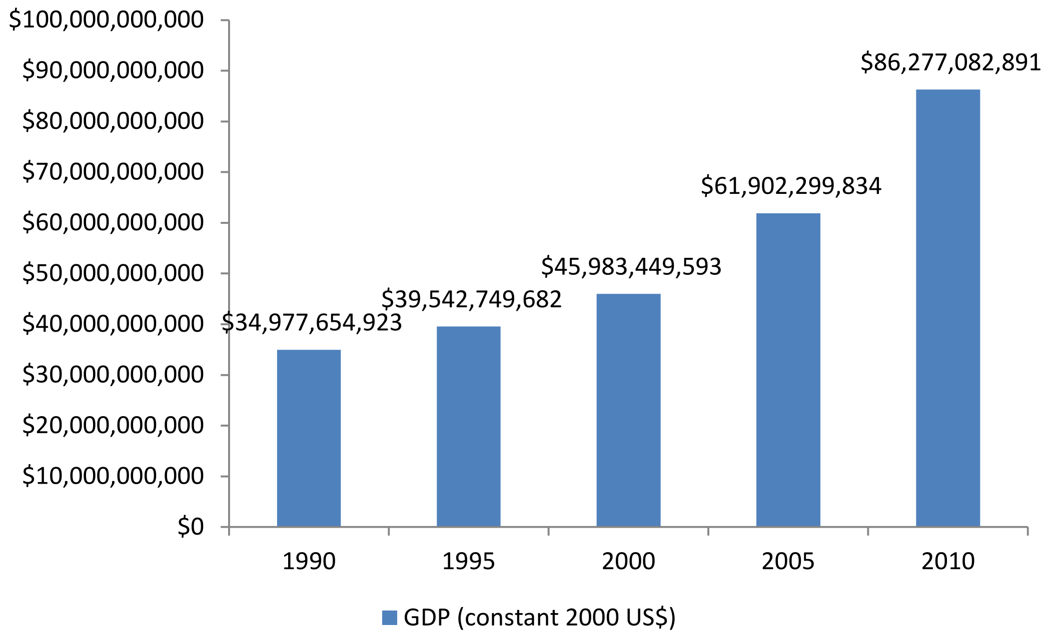

Figure 31: GDP, Nigeria

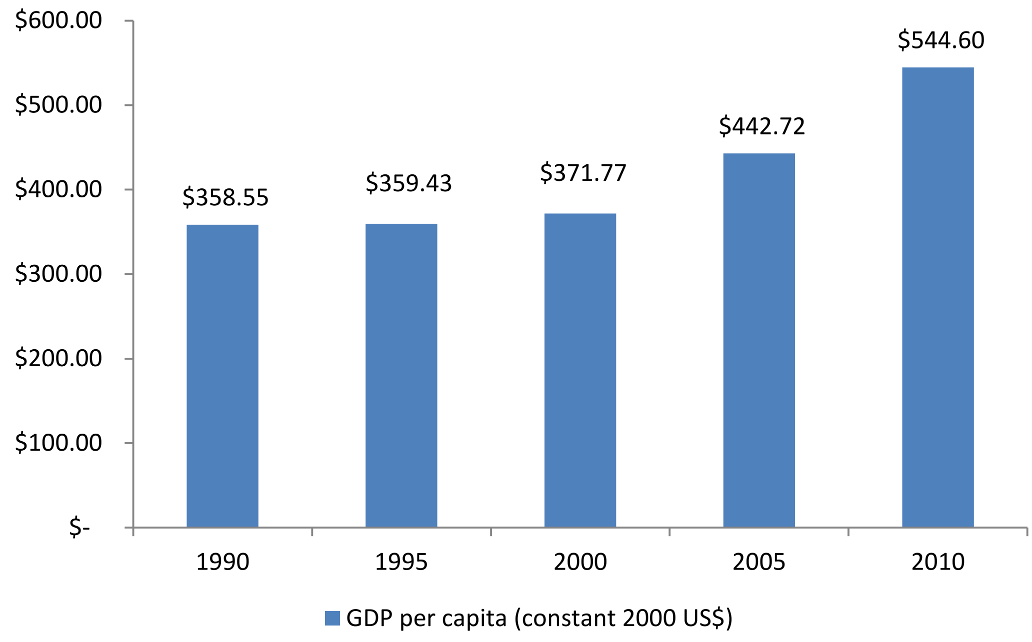

Figure 32: GDP per capita, Nigeria

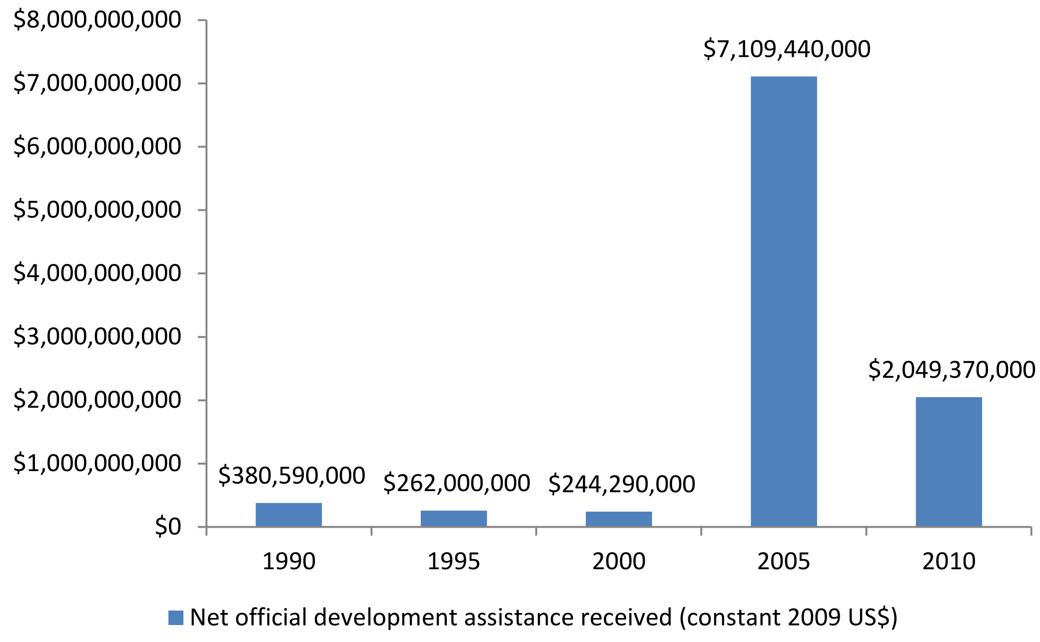

Figure 33: Net Official Development Assistance, Nigeria

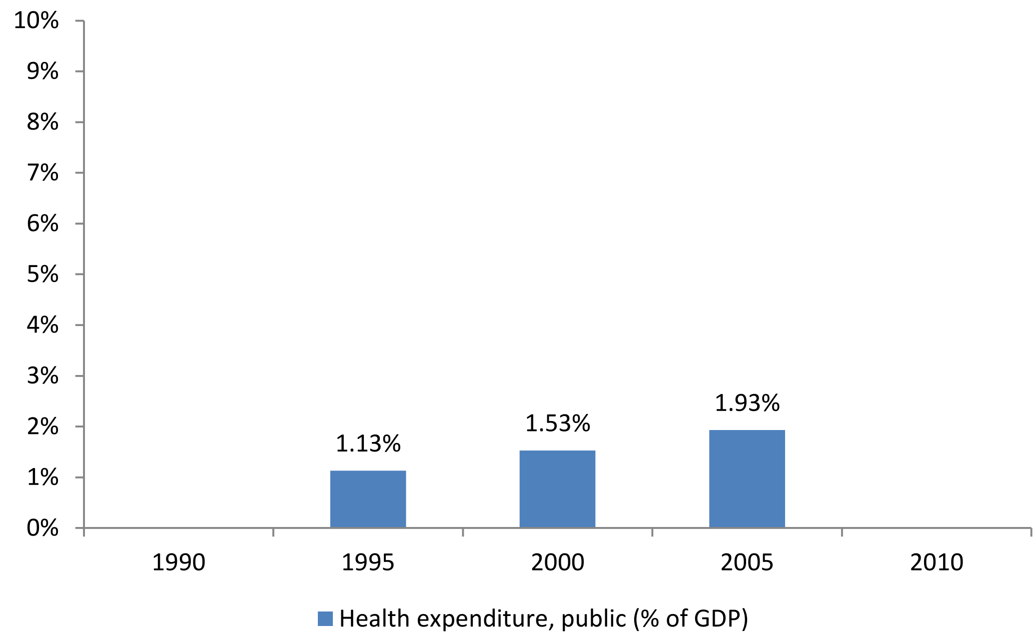

Figure 34: Health Expenditure, public (% of GDP), Nigeria

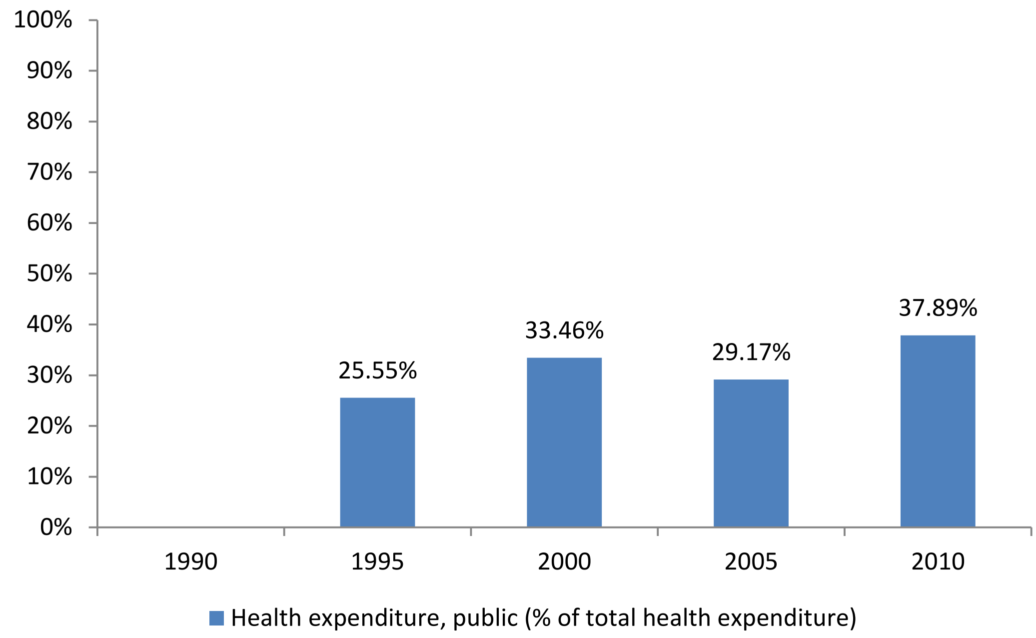

Figure 35: Health Expenditure, public (% of total), Nigeria

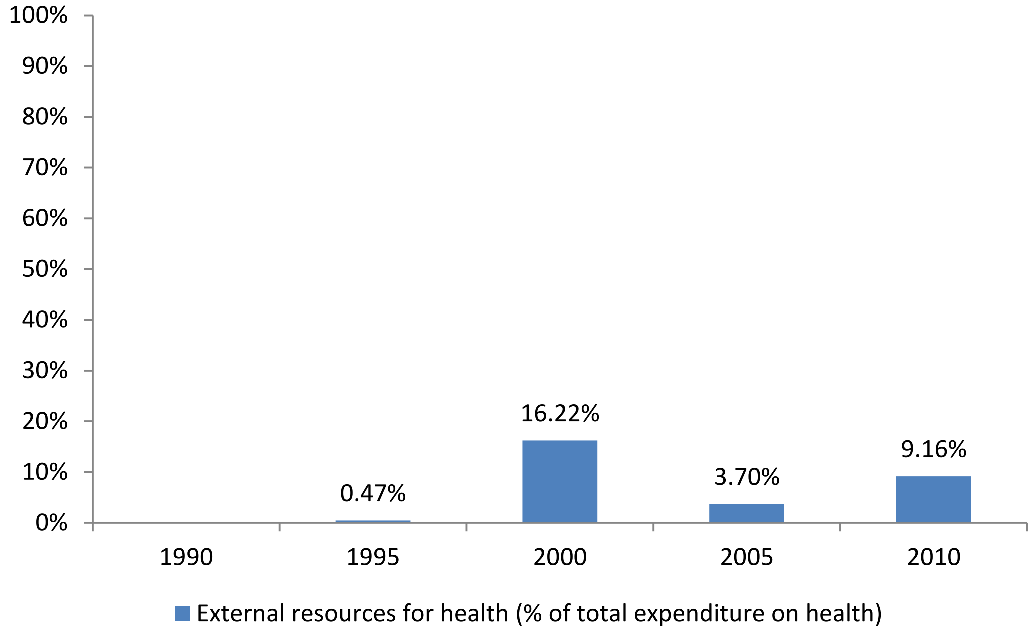

Figure 36: External Resources for Health (% of total health expenditure), Nigeria

APPENDIX D: BANGLADESH ECONOMIC GRAPHS

Data from World Bank, 2012

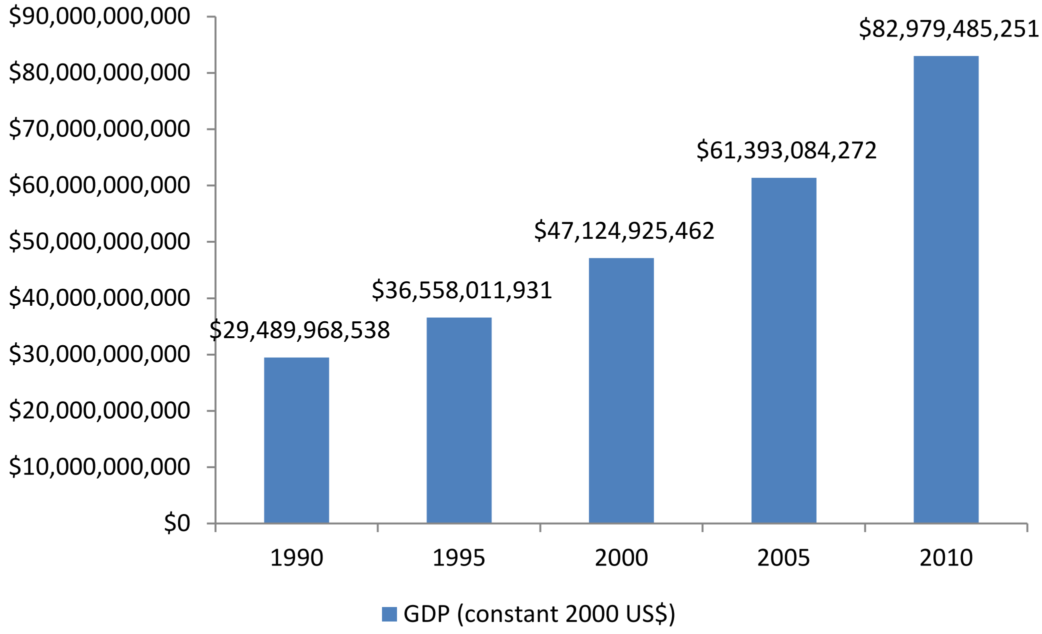

Figure 37: GDP, Bangladesh

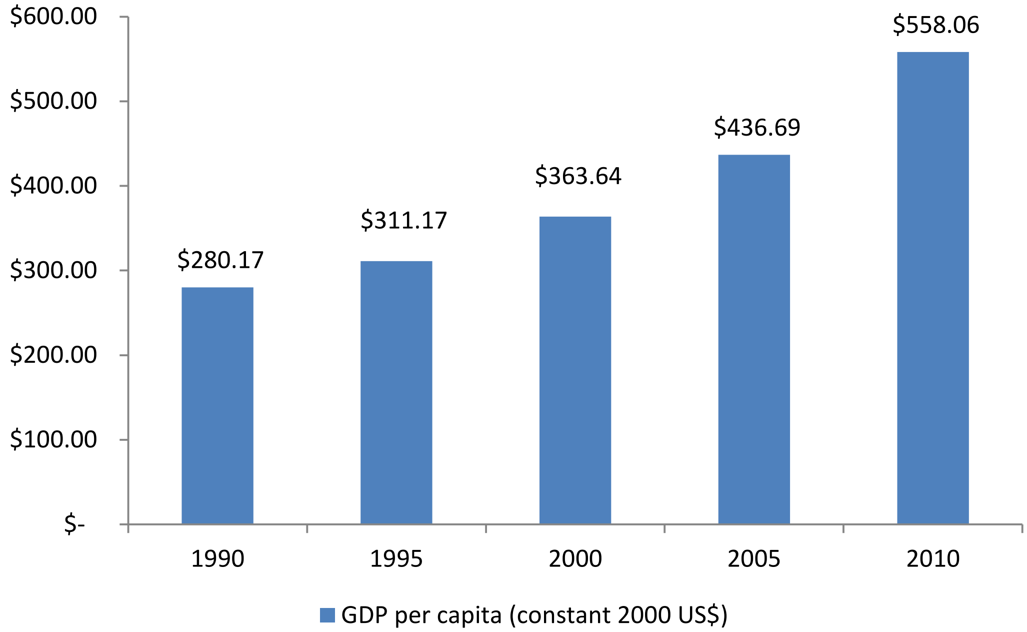

Figure 38: GDP per capita, Bangladesh

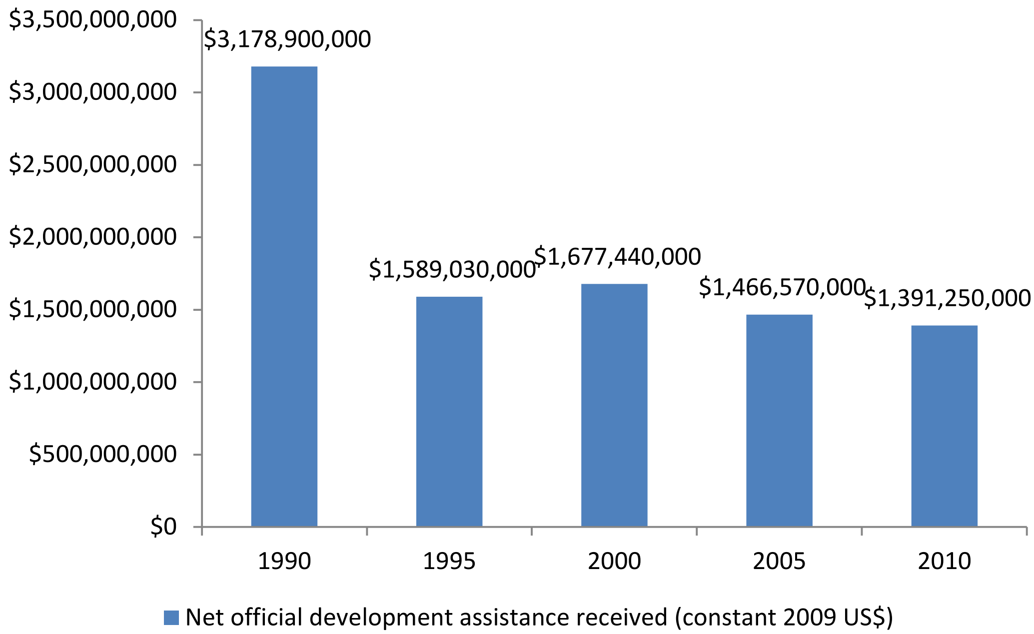

Figure 39: Net Official Development Assistance, Bangladesh

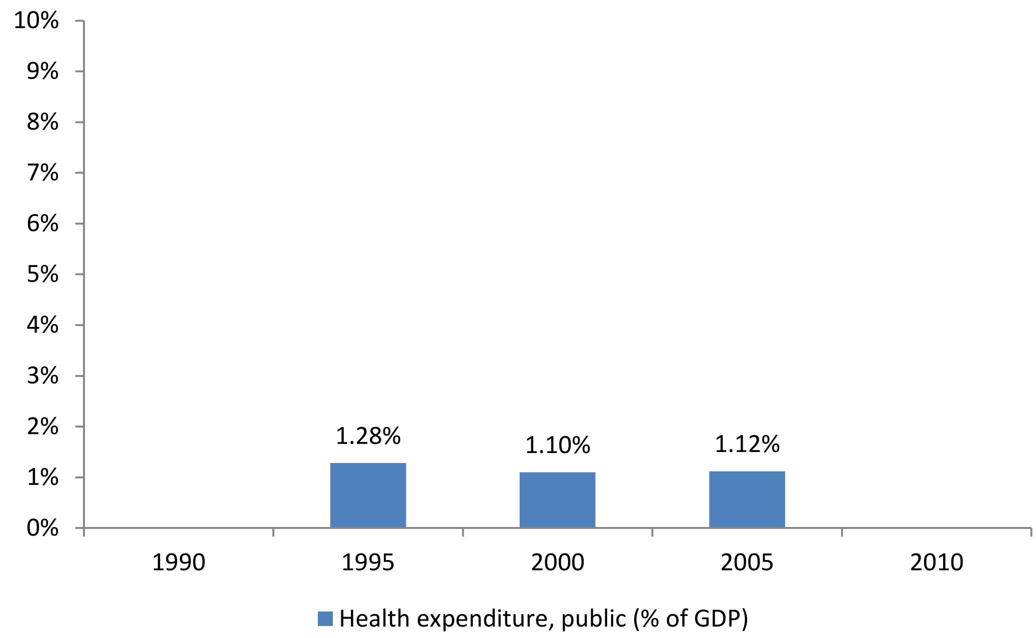

Figure 40: Health Expenditure, public (% of GDP), Bangladesh

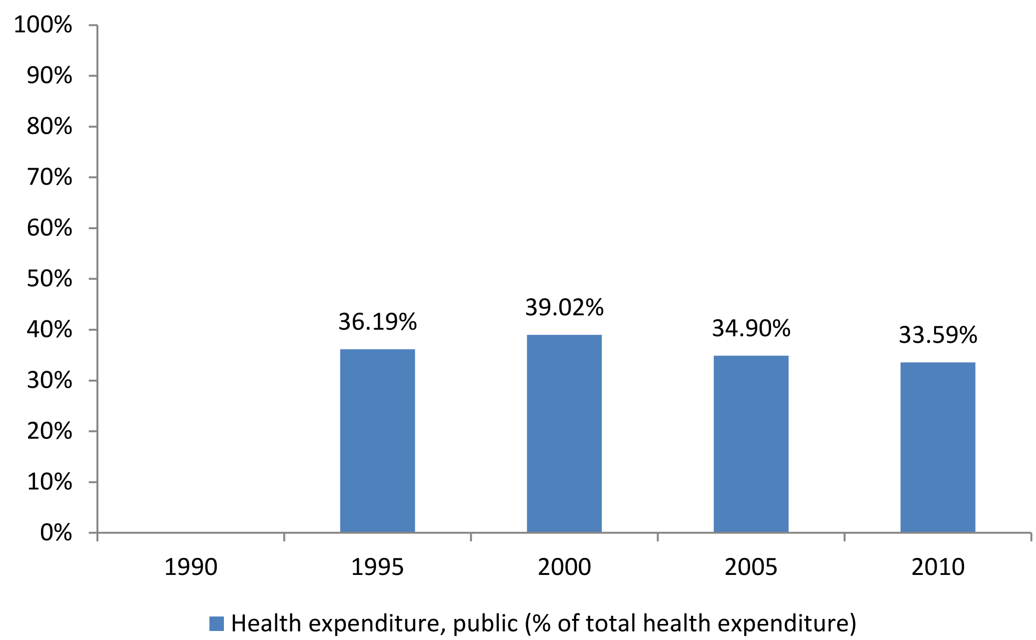

Figure 41: Health Expenditure, public (% of total), Bangladesh

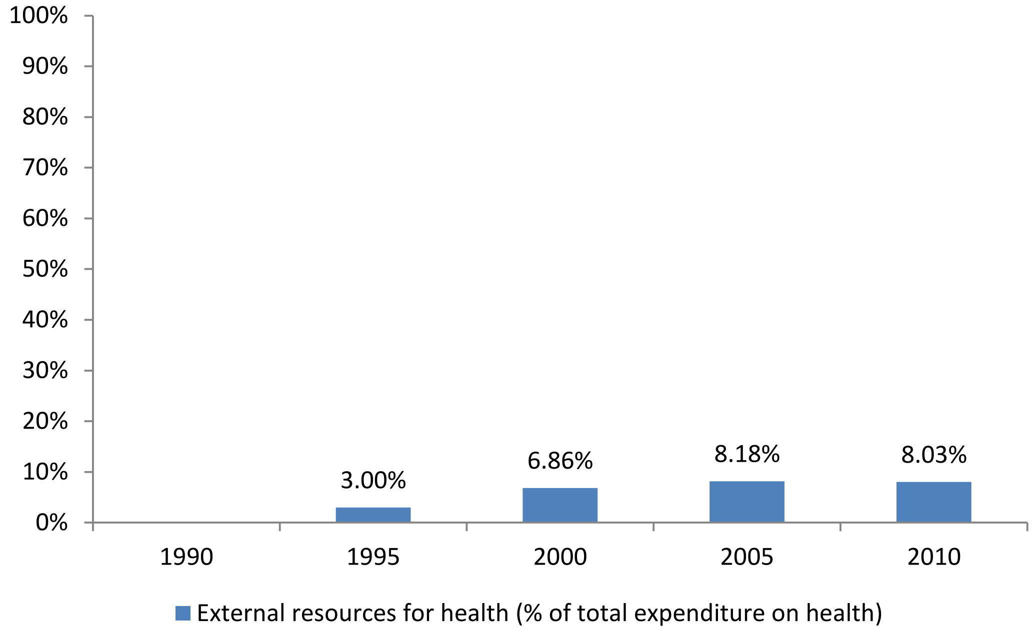

Figure 42: External Resources for Health (% of total health expenditure), Bangladesh

APPPENDIX E: LESOTHO ECONOMIC GRAPHS

Data from World Bank, 2012

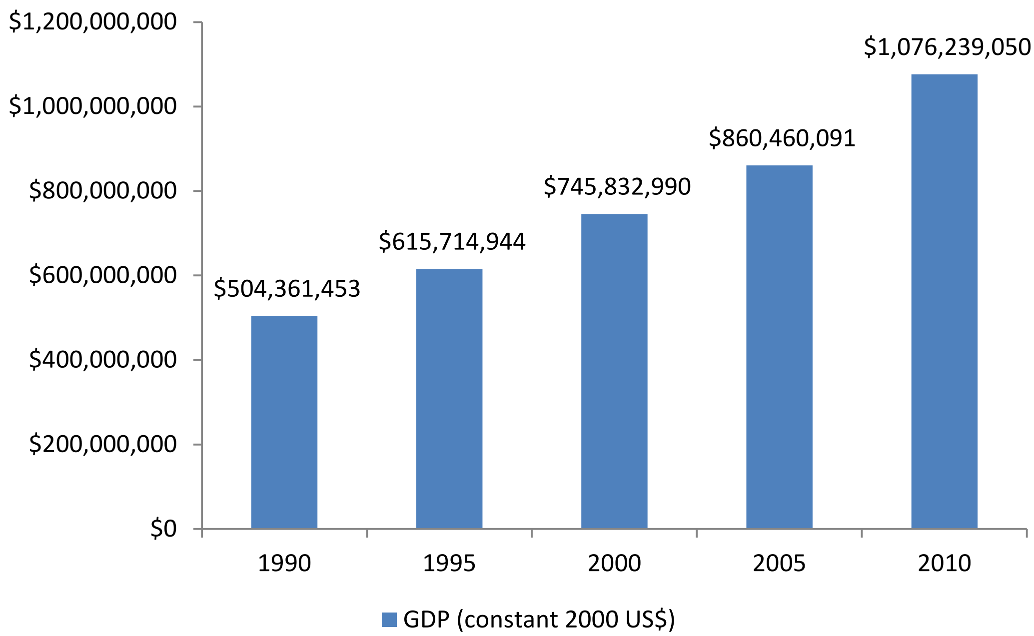

Figure 43: GDP, Lesotho

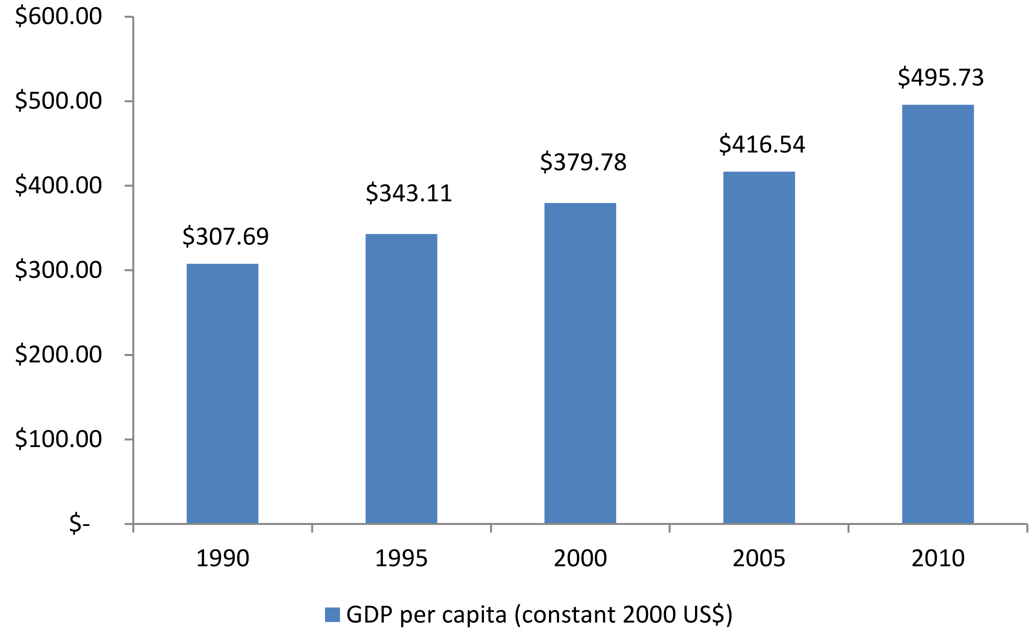

Figure 44: GDP per capita, Lesotho

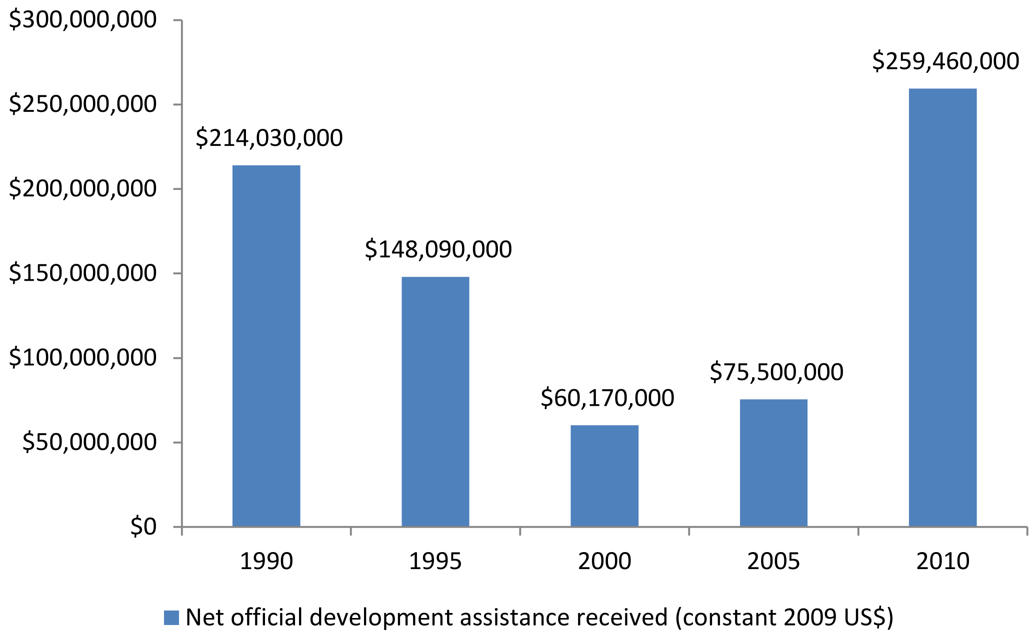

Figure 45: Net Official Development Assistance, Lesotho

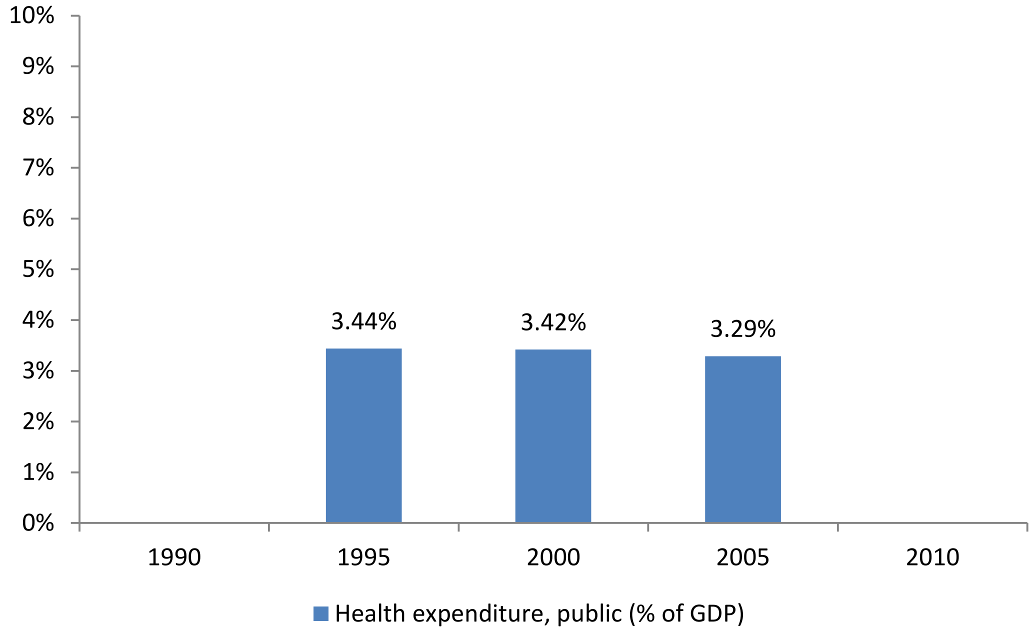

Figure 46: Health Expenditure, public (% of GDP), Lesotho

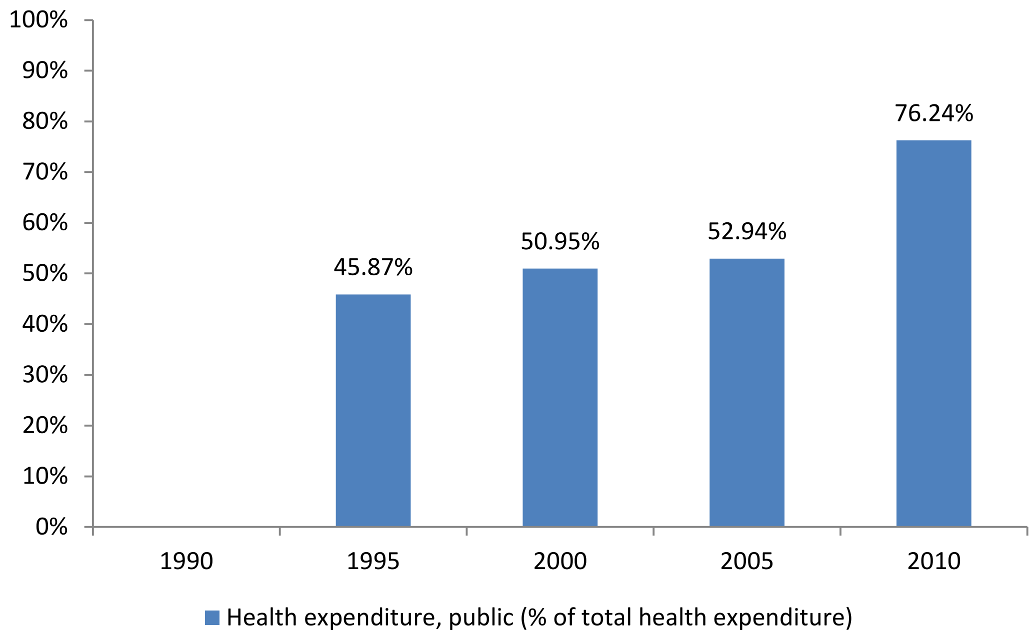

Figure 47: Health Expenditure, public (% of total), Lesotho

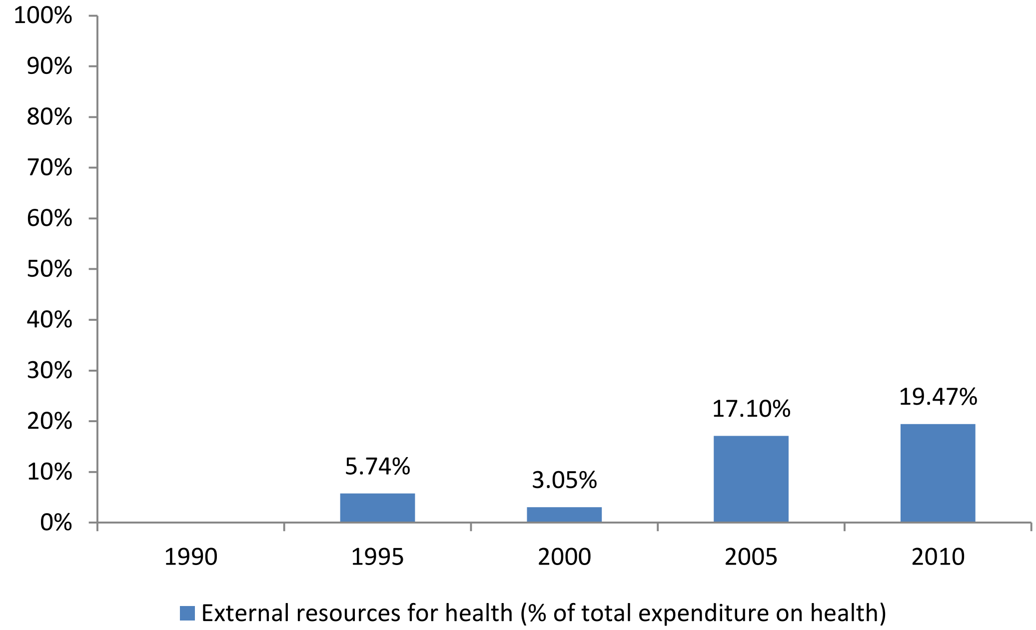

Figure 48: External Resources for Health (% of total health expenditure), Lesotho

APPENDIX F: TANZANIA ECONOMIC GRAPHS

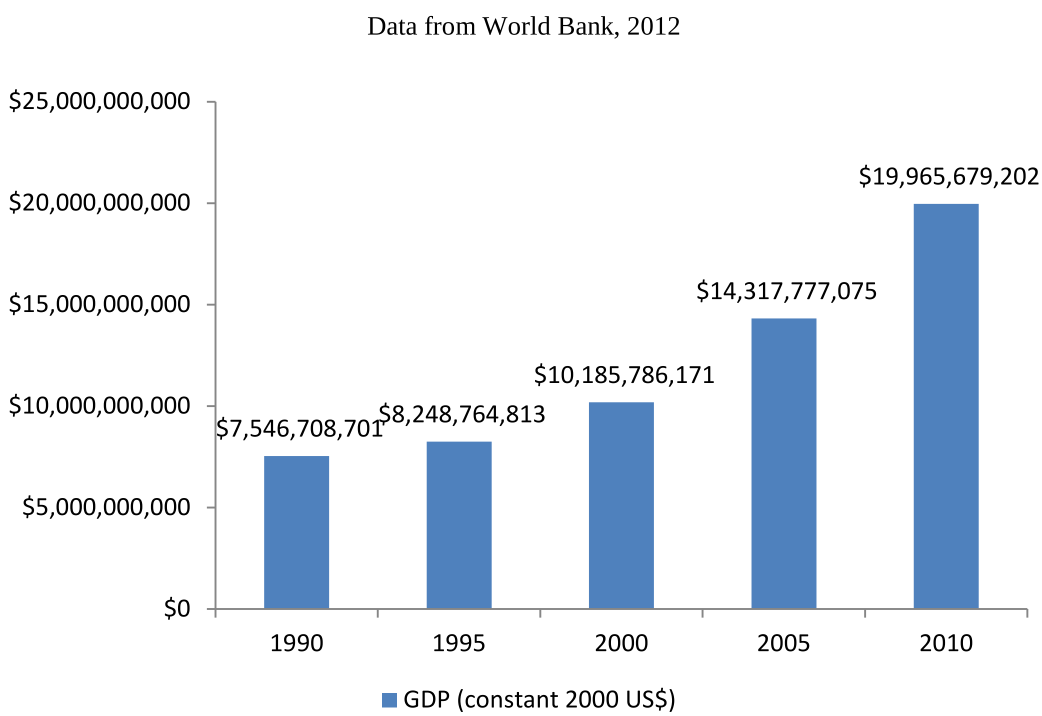

Figure 49: GDP, Tanzania

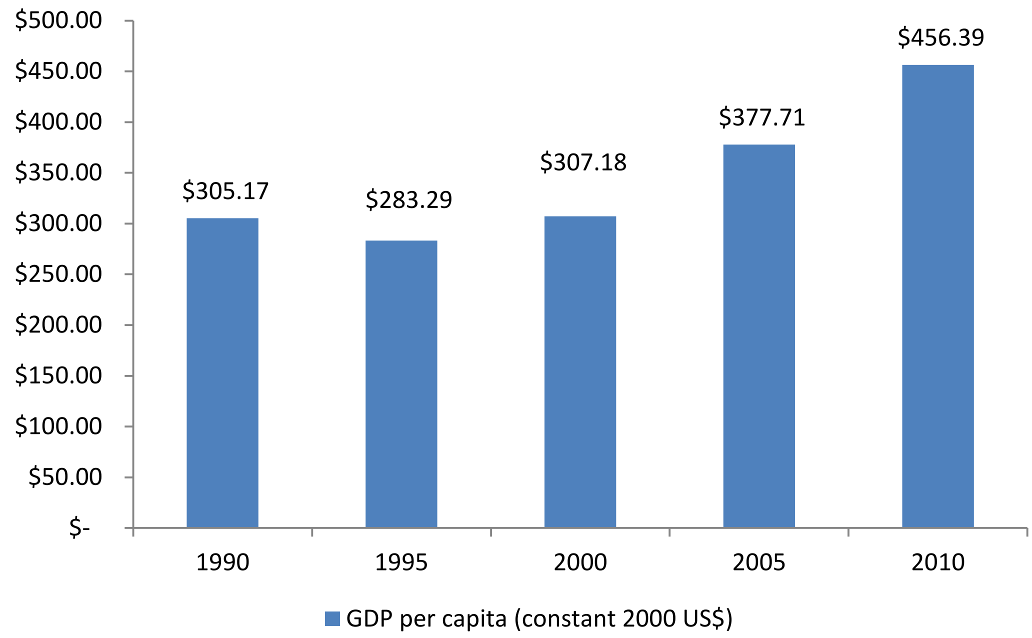

Figure 50: GDP per capita, Tanzania

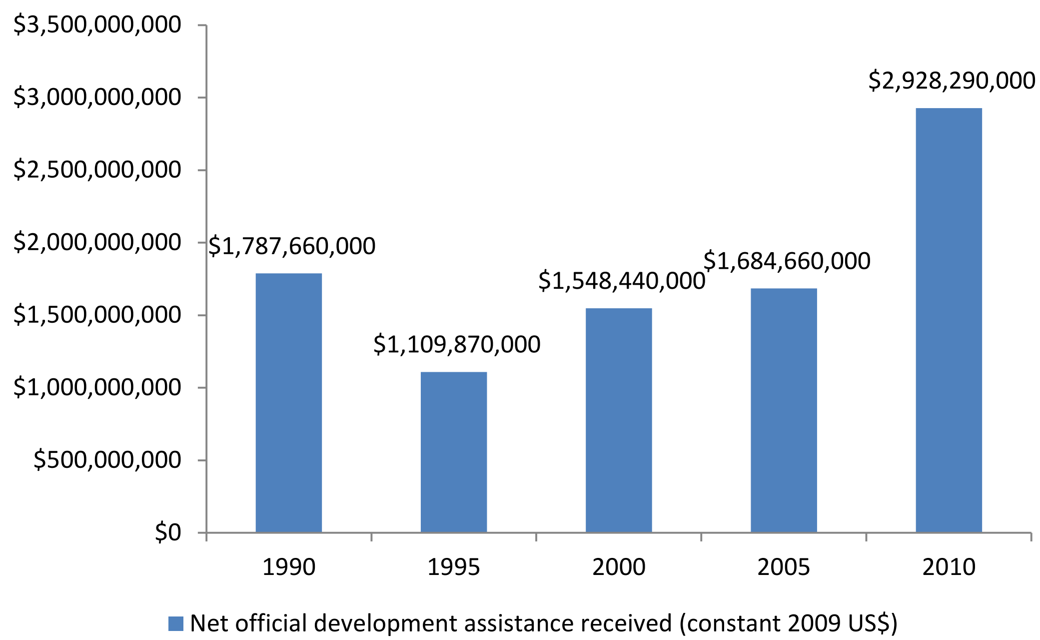

Figure 51: Net Official Development Assistance, Tanzania

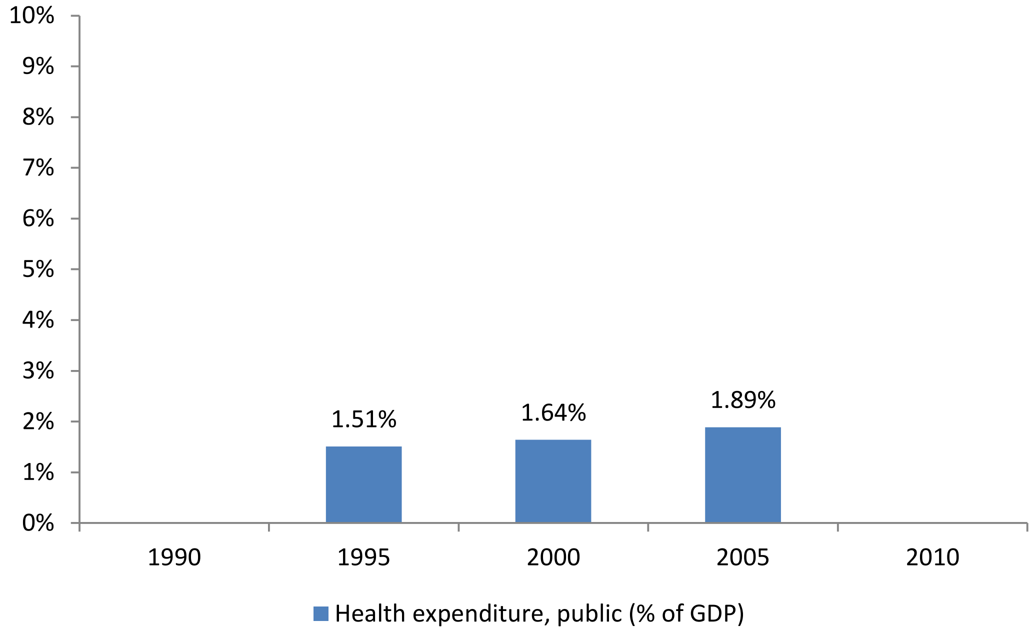

Figure 52: Health Expenditure, public (% of GDP), Tanzania

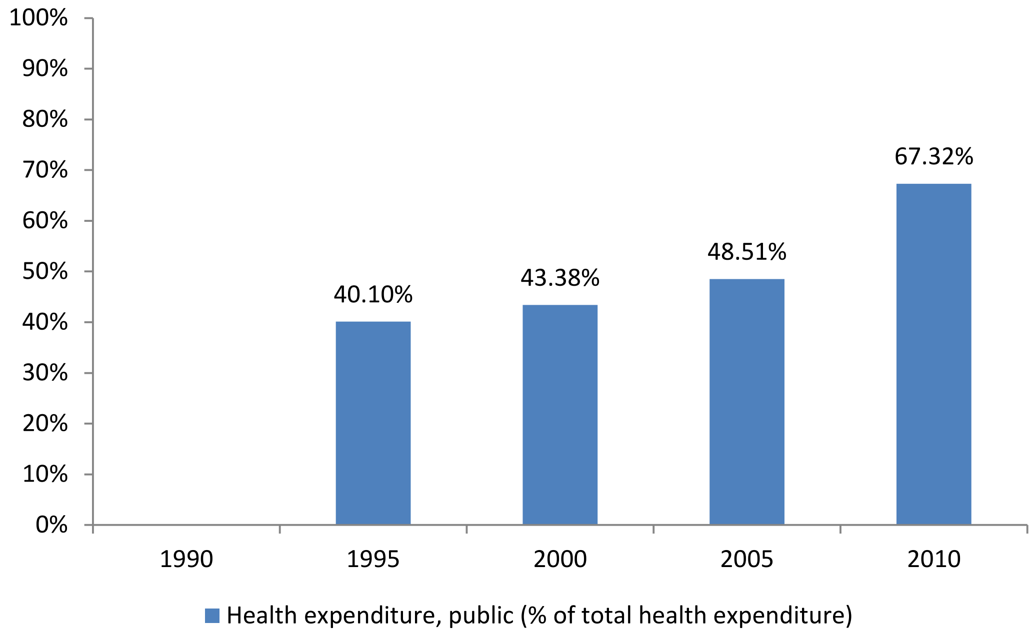

Figure 53: Health Expenditure, public (% of total), Tanzania

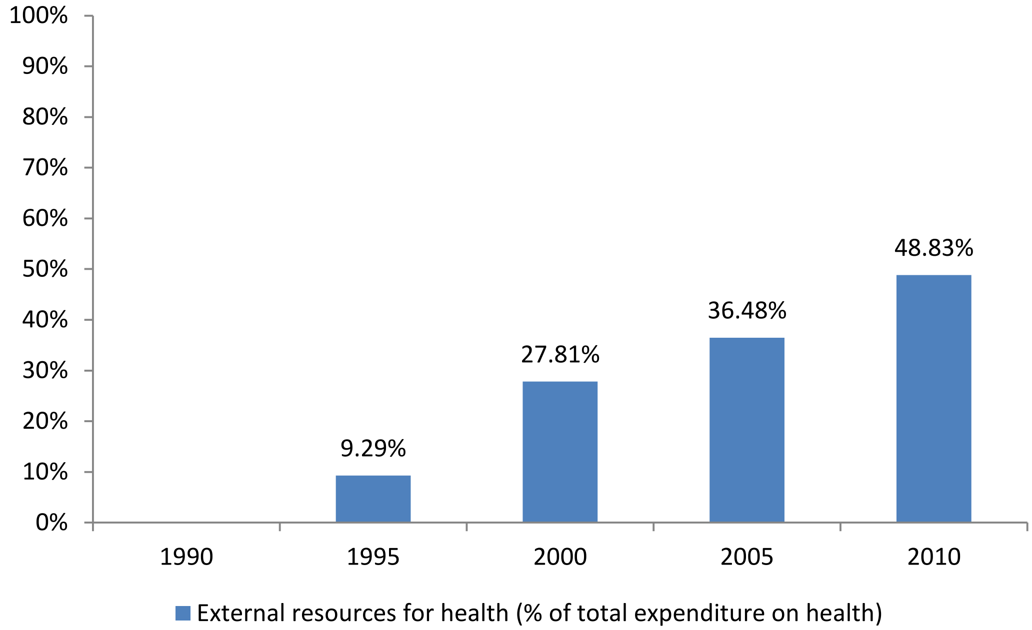

Figure 54: External Resources for Health (% of total health expenditure), Tanzania

BIBLIOGRAPHY

Ahmed, M.F., Ahuja, S., Alauddin, M., Hug, S.J., Lloyd, J.R., Pfaff, A.,...van Green, A. (2006, December 15). Ensuring Safe Drinking Water in Bangladesh. *Science, 314*, 1687-88.

Akpor, O.B. & Muchie, M. (2011). Challenges in Meeting the MDGs: The Nigerian Drinking Water Supply and Distribution Sector. Journal of Environmental Science and Technology, 4 (5), 480-9.

Alam, M.G.M., Allinson, G., Stagnitti, F., Tanaka,A.& Westbrooke, M. (2002). Arsenic contamination in Bangladesh groundwater: a major environmental and social disaster. *International Journal of Environmental Health Research, 12*, 236-53.

Anbarci, N., Escaleras, M., & Register. C.A. (2009, May). The Ill Effects of Public Sector Corruption in the Water and Sanitation Sector. Land Economics, 85 (2), 363-77.

Anstiss, R.G & Ahmed, M. (2006, September). A Conceptual Model to be Used for Community-based Drinking-water Improvements. *Journal of Health and Population Nutrition, 24* (3), 262-66.

Arvail, J. & Post, K. (2012). Risk Management in a Developing Country Context: Improving Decisions About Point-of-Use water Treatment Among the Rural Poor in Africa. Risk Analysis, 32 (1), 67-80. doi: 10.1111/j.1539-6924.2011.01675.

Atkins, P., Hassan, M. & Dunn, C. (2007). Poisons, pragmatic governance and deliberative democracy: The arsenic crisis in Bangladesh. *Geoforum, 38*, 155-70.

Barzilay, E.J., Aghoghovbia, T.S., Blanton, E.M., Akinpelumi, A.A., Coldiron, M.E., Akinfolayan, O.,...Quick, R. (2011, March 23). Diarrhea prevention in people living with HIV: an evaluation of a point-of-use water quality intervention in Lagos, Nigeria. *AIDS Care, 3*, 330-39.

Black, M. (1998). 1978-1998 Learning What Works: A 20 Year Retrospective View on International Water and Sanitation Cooperation. UNDP-World Bank Water and Sanitation Program. Retrieved from http://www.un.org/esa/sustdev/sdissues/water/InternationalWaterDecade1981-1990_review.pdf.

Bowie, C. (2006, September). The Burden of Disease in Malawi. *Malawi Medical Journal, 18* (3), 103-110.

Carter, R.C., Tyrrel, S.F., & Howsam, P. (1999, August 13). The Impact and Sustainability of Community Water Supply and Sanitation Programmes in Developing Countries. *Journal of the Chartered Institution of Water and Environmental Management, 13* (4), 292-296.

Central Intelligence Agency, The. (2012). The World Fact Book. Retrieved from https://www.cia.gov/library/publications/the-world-factbook/.

Chen, Y., van Green A., Graziano, J.H., Pfaff, A., MadajewiczParvez, F.,...Ahsan, H. (2007, June). Reduction in Urinary Arsenic Levels in Response to Arsenic Mitigation Efforts in Arailhazar, Bangladesh. *Environmental Health Perspectives, 115* (6), 917-923.

Chipofya, V., Kainja, S. & Bota, S. Policy harmonization and collaboration amongst institutions – A strategy towards sustainable development, management and utilization of water resources: Case of Malawi, *Desalination, 248*, 678-683.

Chowdhury, N.T. (2010). Water management in Bangladesh: an analytical review. Water Policy, 12, 32-51.

Clasen, T. Saeed, T.F., Boisson, S., Edmondson, P. & Shipin, O. (2007). Household Water Treatment Using Sodium Dichloroisocyanurate (NaDCC) Tablets: A Randomized, Controlled Trial to Assess Microbiological Effectiveness in Bangladesh. *American Journal of Tropical Medicine and Hygiene, 76* (1), 187-92.

Clasen, T., Schmidt, W.P., Rabie, T., Roberts, I. & Cairncross, S. (2007, March 12). Intervention to improve water quality for preventing diarrhoea: systematic review and meta-analysis. *BMJ, 34*, 1-10. doi: 10.1136/bmj.39118.489931.BE.

Coussens, C., *rapporteur*. (2009). Global Environmental Health: Research Gaps and Barriers Providing Sustainable Water, Sanitation, and Hygiene Services, Workshop Summary. Retrieved from http://www.nap.edu/catalog/12597.html.

Cox, P & Patterson, H. (2008, July 7). Program Evaluation of Partnership for Africa's Water Development Program (PAWD), Global Water Partnership, Final Report. Retrieved from http://www.gwp.org/Global/The%20Challenge/Resource%20material/final_evalrep_pawd.pdf.

Curtis, C., Kanki, B., Mertens, T, Traore, E., Diallo, I., Tall, F & Cousens, S. (1995). Potties, Pits and Pipes: Explaining Hygiene Behaviour in Burkina Faso. *Social Science & Medicine, 41* (3), 383-93.

Dada, C.A. (2009). Towards a successful packaged water regulation in Nigeria. *Scientific Research and Essay, 4* (9), 921-8.

Fewtrell, L., Kaufmann, R.B., Kay, D., Enanoria, W., Haller, L. & Colford Jr., J.M. (2005, January). Water, sanitation, and hygiene interventions to reduce diarrhea in less developed countries: a systematic review and meta-analysis. *Lancet Infectious Disease, 5*, 42-52.

Food and Agricultural Organization of the United Nations. (2005a). Aquastat: Burkina Faso. Retrieved from http://www.fao.org/nr/water/aquastat/countries_regions/burkina_faso/indexfra.stm.

Food and Agricultural Organization of the United Nations. (2005b). Aquastat: Lesotho. Retrieved from http://www.fao.org/nr/water/aquastat/countries_regions/lesotho/index.stm.

Food and Agricultural Organization of the United Nations. (2005c). Aquastat: Nigeria. Retrieved from http://www.fao.org/nr/water/aquastat/countries_regions/nigeria/index.stm.

Food and Agricultural Organization of the United Nations. (2005d). Aquastat: United Republic of Tanzania. Retrieved from http://www.fao.org/nr/water/aquastat/countries_regions/tanzania/index.stm.

Food and Agricultural Organization of the United Nations. (2006, May). Aquastat: Malawi. Retrieved from http://www.fao.org/nr/water/aquastat/countries_regions/malawi/index.stm.

Food and Agricultural Organization of the United Nations. (2010). Aquastat: Bangladesh. Retrieved from http://www.fao.org/nr/water/aquastat/countries_regions/bangladesh/index.stm.

Gardner, R., Hamadani, J., Grander, M., Tofail, F., Nermell, B., Palm, B.,…Vahter, M. (2011). Persistent Exposure to Arsenic via Drinking Water in Rural Bangladesh Despite Major Mitigation Efforts. *American Journal of Public Health, 101* (1), S333-38.

Government of Bangladesh, Ministry of Water Resources. (2005). Ministry of Water Resources: Mandate. Retrieved from http://www.mowr.gov.bd/.

Government of Bangladesh, Water Resources Planning Organization. (2004, September). National Water Management Plan Approved. *WARPO Newsletter,* 7. Retrieved from http://www.warpo.gov.bd/pdf/newsletter7.pdf.

Government of Lesotho, Ministry of Natural Resources, (2007, February). Lesotho Water and Sanitation Policy. Retrieved from http://trc.org.ls/wp-content/uploads/2011/05/Lesotho-Water-and-Sanitation-Policy.pdf.

Government of Lesotho, Ministry of Natural Resources, (2007, April). Road map to Completing Integrated Water Resources Management and Water Efficiency Planning in Lesotho. Retrieved from http://www.lwsims.gov.ls/Documents/Roadmap%20Lesotho.pdf.

Government of Malawi. (2002, April). Final Draft: Malawi Poverty Reduction Strategy Paper. Retrieved from http://www.imf.org/external/np/prsp/2002/mwi/01/043002.pdf.

Government of Malawi, Ministry of Irrigation and Water Development (2005). National Water Policy. Retrieved from http://www.moafsmw.org/ocean/docs/Policy%20Documents/National%20Water%20Policy%20FINAL.pdf.

Government of Nigeria, Federal Ministry of Water Resources. (2000, January). National Water Supply and Sanitation Policy. Retrieved from http://www.nwri.gov.ng/userfiles/file/National_Water_Supply_and_Sanitation_Policy.pdf.

Gwimbi, P. (2011, September 3). The microbial quality of drinking water in Manonyane community: Maseru District (Lesotho). *African Health Sciences, 11* (3), 474-80.

International Monetary Fund. (2007, February). Malawi: Poverty Reduction Strategy Paper – Growth and Development Strategy. Retrieved from http://www.imf.org/external/pubs/ft/scr/2007/cr0755.pdf.

Khan, M.M.H., Aklimunnessa, K., Kabir, M. & mori, M. (2007). Determinants of drinking arsenic-contaminated tubewell water in Bangladesh. *Health Policy and Planning, 22*, 335-43.

Kibassa, D. (2011). The impact of cost recovery and sharing system on water policy implementation and human right to water: a case of Ileje, Tanzania. Water Science and Technology, 63 (11), 2520-26. doi: 10.2166/wst.2011.482.

Kumambala, P.G & Ervine, A. Site selection for combine hydro, irrigation and water supply in Malawi: Assessment of water resource availability. *Desalination, 248,* 537-545.

Lewallen, S., Massae, P., Tharaney, M, Somba, M., Geneau, R., MacArthur, C. & Courtright, P. (2008). Evaluating a school-based trachoma curriculum in Tanzania. *Health Education Research, 23* (6), 1068-1073.

Martin, N. & van De Giesen, N. (2005, June). Spatial Distribution of Groundwater Production and Development Potential in the Volta River basin of Ghana and Burkina Faso. *Water International*, 30 (2), 239-49.

Masangwi, S.J., Morse, T.D., Ferguson, N.S., Zawdie, G., Grimason, A.M. & Namangale, J.J. Behavioural and environmental determinants or childhood diarrhea in Chikwawa, Malawi. *Desalination*, *248,* 684-691.

May, A.W. Prioirtization of intervention methods for preventions of communicable diseases in Tanzania. *Physics and Chemistry of the Earth, 32,* 1204-11.

Milton, A., Smith, W., Dear, K., NG, J., Malcolm, S., Ranmuthugala, G.,...Shahidullah, S.M. (2007). A Randomized intervention trial to assess two arsenic mitigation options in Bangladesh. *Journal of Environmental Science and Health*, *42*, 1897-1908.

Monjour, L., Volta, C., Uwechue, N. & De Lorenzi, G. Evaluation of Traditional Filters for Water Purification in Burkina Faso. *Annales Société Belge Médecine Tropicale, 70*, 311-15.

Montgomery, M.A. & Elimelech, M. (2007, January 1). Water and Sanitation in Developing Countries: Including Health in the Equation. *Environmental Science & Technology, 41* (1), 17-24.

Mulwafu, W.O. & Msosa, H.K. (2005). IWRM and poverty reduction in Malawi: A socio-economic analysis. *Physics and Chemistry of the Earth, 30*, 961-7.

New York State, Department of Health. (2011, June.) Coliform Bacteria in Drinking Water Supplies. Retrieved from http://www.health.ny.gov/environmental/water/drinking/coliform_bacteria.htm.

Norton, D.M., Rahman, M., Shane, A.L., Hossain, Z., Kulick, R.M., Bhuiyan, M.I.,...Luby, S.P. (2009, February). Flocculant-disinfectant point-of-use water treatment for reducing arsenic exposure in rural Bangladesh. *International Journal of Environmental Health Research, 19* (1), 17-29.

Olaoye, O.A. & Onilude, A.A. Assessment of microbiological quality of sachet-packaged drinking water in Western Nigeria and it public health significance. Public Health, 123, 729-34. doi: 10.1016/j.puhe.2009.09.015.

Onabolu, B., Jimoh, O.D., Igboro,S.B., Sridhar, M.K.C., Onyilo, G., Gege, A. & Ilya, R. (2011). Source to point of use drinking water changes and knowledge, attitude and practices in Katsina State, Northern Nigeria. *Physics and Chemistry of the Earth, 36*, 1189-1196.

Opar, A., Pfaff, A., Seddique, A.A., Ahmed, K.M. Graziano, J.H & van Green, A. (2007). Response of 6500 households to arsenic mitigation in Araihazar, Bangladesh. *Health & Place, 13*, 164-72.

Oyedeji, P., Olutiola, P.O. & Moninuola, M.A. (2010, January). Microbiological quality of packaged drinking water brands marketed in Ibadan metropolis and Ile-Ife city in South Western Nigeria. *African Journal of Microbiology Research, 41* (1), 96-102.

Petit, O & Baron, O. (2009). Integrated Water Resources Management: From general principles to its implementation by the state. The case of Burkina Faso. *Natural Resources Forum, 33*, 49-59.

Pickering, A.J., Davis, J., Walters, S.P, Horak, H.M., Keymen, D.P., Mushi, D.,…(2010). Hands, Water, and Health: Fecal Contamination in Tanzanian Communities with Improved, Non-Networked Water Supplies. *Environmental Science and Technology*, *44*, 3261-72. doi: 10.1021/es903524m.

Pritchard, M., Mkandawire, T & O'Neill, J.G. (2007). Biological, chemical and physical drinking water quality from shallow wells in Malawi: Case study of Blantyre, Chiradzulu and Mulanje. *Physics and Chemistry of the Earth, 32*, 1167-1177.

Rim-Rukeh, A., Ikhifa, G.O., & Okokoyo, P.A. Physcio-Chemical Characteristics of Some Water Used for Drinking and Domestics Purposes in the Niger Delta, Nigeria. Environmental Monitoring and Assessment, 128, 475-82. doi: 10.1007/s10661-006-9340-4.

Sansom, K. (2006). Governemtn Engagement with Non-state Providers of Water and Sanitation Services. Public Administration and Development, 26, 207-217. doi: 10.1002/pad.419.

Sheth, A.N., Russo, E.T., Menon, M., Wannemuehler, K., Weinger, M. Amose, C.K.,… Tauzie, B. (2010). Impact of the Integration of Water Treatment and Handwashing Incentives with Antenatal Services on Hygiene Practices of Pregnant Women in Malawi. *American Journal of Tropical Medicine and Hygiene, 83* (6), 1315-21.

Smedley, P.L., Knudsen, J. & Maiga, D. (2007). Arsenic in groundwater from mineralized Proterozoic basement rocks of Burkina Faso. *Applied Geochemistry, 22*, 1074-92.

Smith, A.H., Lingas, E.O. & Rahman, M. (2000). Contamination of drinking-water by arsenic in Bangladesh: a public health emergency. *Bulleting of the World Health Organization, 78* (9), 1093-1103.

Sobsy, M.D., Stauber, C.E., Casanova, L.M., Brown, J.M. & Elliott, M.A. (2008). Point of Use Household Drinking Water Filtration: A Practical, Effective Solution for Providing Sustained Access to Safe Drinking Water in the Developing World. *Environmental Science & Technology, 42* (12), 4261-67.

Sokile, C.S., Mwaruvanda, W. & van Koppen, B. (2005, January). Integrated Water Resource Management in Tanzania: interface between formal and informal institutions, *International workshop on 'African Water Laws: Plural Legislative Frameworks for Rural Water Management in Africa*, 26-28 January 2005, Johannesburg, South Africa. Retrieved from http://www.nri.org/projects/waterlaw/AWLworkshop/SOKILE-C.pdf.

Some, I.T., Sakira, A.K, Ouedraogo, M, Ouedraogo, T.A., Traore, A, Sondo, B. & Guissou, P.I. (2012). Arsenic level in tube-wells water, food, residents' urine and the prevalence of skin lesions in Yatenga province, Burkina Faso. *Interdisciplinary Toxicology, 5* (1), 38-41.

Sullivan, C. (2002). Calculating a Water Poverty Index. *World Development*, 30 (7), 1195-1210.

Sullivan, C.A., Meigh, J.R., Giacomello, A.M., Fediw, T., Lawrence, P., Samad, M., Mlote, S…Steyl, I. (2003). The Water Poverty Index: Development and application at the community left. *Natural Resources Forum, 27*, 189-99.

Transparency International. (2012). Corruption Perception Indices. Retrieved from http://cpi.transparency.org/cpi2011/results/.

United Nations Children Fund & World Health Organization (March, 2012). Progress on Drinking water and Sanitation: 2012 Updated. Retrieved from http://www.wssinfo.org/fileadmin/user_upload/resources/JMP-report-2012-en.pdf.

United Nations Development Programme (1990). Human Development Report. http://hdr.undp.org/en/reports/global/hdr1990/.

United Nations Development Programme (2011). Human Development Report. Retrieved from http://hdr.undp.org/en/statistics/hdi/.

United Nations General Assembly (September 6-8, 2000). Resolution Adopted by the General Assembly 55/2. *Universal Nations Millennium Declaration*. Retrieved from http://www.un.org/millennium/declaration/ares552e.htm.

United Nations Lesotho. (no date). MDGs in Lesotho. Retrieved from http://www.un.org.ls/mdgs/mdgs_lesotho.php#hiv.

United Nations Water, Task Force on IWRM Monitoring and Reporting. (2008, May). Status Report on Integrated Water Resources Management and Water Efficiency Plans. Retrieved from http://www.unwater.org/downloads/UNW_Status_Report_IWRM.pdf.

United Nations Water. (no date). Statistics: Graphs & Maps, Drinking Water and Sanitation. Retrieved from http://www.unwater.org/statistics_san.html.

United Republic of Tanzania. (2011). Ministry of Water. Retrieved from http://www.maji.go.tz/divisions/index.php.

United States Agency for International Development. (no date). Burkina Faso Water and Sanitation Profile. Retrieved from http://pdf.usaid.gov/pdf_docs/PNADO927.pdf.

Water Aid. (no date). Diarrhoeal Disease. Retrieved from http://www.wateraid.org/uk/what_we_do/the_need/disease/684.asp.

Wood, S., Foster, J., & Kols, Adrienne. Understanding why women adopt and sustain home water treatment: Insights from the Malawi antenatal care program. (2011). Social Science & Medicine, 1-9. doi:10.1016/j.socscimed.2011.09.018.

World Bank, Poverty Reduction, Economic Management, Finance and Private Sector Development Sector Unit South Asia Region. (2008, October 21). Bangladesh Poverty Assessment for Bangladesh: Creating Opportunities and Bridging the East-West Divide. Retrieved from http://www-wds.worldbank.org/external/default/WDSContentServer/WDSP/IB/2008/12/10/000333037_20081210001004/Rendered/PDF/443210ESW0P09910Box334107801PUBLIC1.pdf.

World Bank. (2010). Harmonized List of Fragile Situations FY 2010. Retrieved from http://siteresources.worldbank.org/EXTLICUS/Resources/511777-1269623894864/Fragile_Situations_List_FY10_Mar_26_2010_EXT.pdf.

World Bank. (2012). World DataBank [Data Set]. Retrieved from http://databank.worldbank.org/data/home.aspx.

World Bank, International Development Association. (2009, August). IDA at Work: Turning the Water on in Burkina Faso's Capital City. Retrieved from http://go.worldbank.org/2546IA2IE0.

World Health Organization. (2009, August). Diarrhoeal Disease, fact sheet. Retrieved from http://www.who.int/mediacentre/factsheets/fs330/en/index.html.

World Health Organization. (2012, January). Dracunculiasis, fact sheet. Retrieved from http://www.who.int/mediacentre/factsheets/fs359/en/.

World Health Organization. (2011a). Evaluating Household Water Treatment Options: Health-based targets and microbiological performance specifications. Retrieved from http://www.who.int/water_sanitation_health/publications/2011/evaluating_water_treatment.pdf.

World Health Organization. (2011b). Guidelines for Drinking water Quality, 4th ed. Retrieved from http://whqlibdoc.who.int/publications/2011/9789241548151_eng.pdf.

World Health Organization. (2009, June). How does safe water impact global health? Retrieved from http://www.who.int/features/qa/70/en/index.html.

World Health Organization. (2010). Preventing Disease Through Healthy Environment, Inadequate or Excess Fluoride: A Major Public Health Concern. Retrieved from http://www.who.int/ipcs/features/fluoride.pdf.

World Health Organization. (no date). Initiative for Vaccine Research, Parasitic Diseases. Retrieved from http://www.who.int/vaccine_research/diseases/soa_parasitic/en/index2.html.

World Health Organization. (2011, June). The Top 10 Cause of Death, fact sheet. Retrieved from http://www.who.int/mediacentre/factsheets/fs310/en/index.html.

World Health Organization. (2002, November). Water for health enshrined as a human right. Retrieved from http://www.who.int/mediacentre/news/releases/pr91/en/.

World Health Organization. (2012a). Water Sanitation and Hygiene links to health. Retrieved from http://www.who.int/water_sanitation_health/monitoring/jmp2012/key_terms/en/index.html.

World Health Organization. (2004, November). Water Sanitation Health, facts and figures. Retrieved from http://www.who.int/water_sanitation_health/publications/facts2004/en/index.html

World Health Organization. (2001a). Water Sanitation Health, Water related diseases, Ascariasis. Retrieved from http://www.who.int/water_sanitation_health/diseases/ascariasis/en/

World Health Organization. (2001b). Water Sanitation Health, Water related diseases, Trachoma. Retrieved from http://www.who.int/water_sanitation_health/diseases/trachoma/en/index.html

World Health Organization, Department of Measurement and Health Information. (2004, December). Estimated Total Deaths by Cause and WHO Member State, 2002 [Data Set]. Retrieved from http://www.who.int/healthinfo/global_burden_disease/estimates_2000_2002/en/index.html.

World Health Organization, Department of Measurement and Health Information. (2009, February). Estimated Total Deaths by Cause and WHO Member State, 2004 [Data Set]. Retrieved from http://www.who.int/healthinfo/global_burden_disease/estimates_country/en/index.html.

World Health Organization, Department of Measurement and Health Information. (2011, April). Estimated Total Deaths by Cause, Sex and WHO Member State, 2008 [Data Set]. Retrieved from http://www.who.int/healthinfo/global_burden_disease/estimates_country/en/index.html.

World Health Organization & United Nations Children Fund Joint Monitoring Programme [JMP] for Water Supply and Sanitation. (2011). Drinking Water, Equity, Safety and Sustainability: JMP Thematic Report on Drinking Water, 2011. Retrieved from http://www.wssinfo.org/fileadmin/user_upload/resources/report_wash_low.pdf.

World Health Organization & United Nations Children Fund Joint Monitoring Programme [JMP] for Water Supply and Sanitation. (2012a). Data & Estimates. Retrieved from http://www.wssinfo.org/data-estimates/table/.

World Health Organization & United Nations Children Fund Joint Monitoring Programme for Water Supply and Sanitation (2012b). Types of Drinking water and Sources. Retrieved from http://www.wssinfo.org/definitions-methods/watsan-categories/.

Wright, J., Gundry, S. & Conroy, R. (2004, January). Household drinking water in developing countries: a systematic review of microbiological contamination between source and point-of-use. *Tropical Medicine and International Health, 9* (1), 106-117.