8-7-2012

Consumption of Rainwater and Diarrheal Disease in Children Under Five in the Dominican Republic from 2002 to 2007

Andrea Mpogui

ABSTRACT

ANDREA C. MPOGUI
Consumption of Rainwater and Diarrheal Disease in Children Under Five in the Dominican Republic from 2002 to 2007
(Under the direction of Dr. Christine Stauber, Faculty Member)

Background: With the MDG 7 target deadline approaching to halve the global population lacking access to improved water and sanitation by 2015, many nations, developing nations in particular, find the need to explore alternative water sources. Rainwater has been consumed by people all over the world for centuries and today millions of people around the world depend on rainwater for drinking and domestic use. However, there have been concerns raised in recent decades as to the quality of rainwater harvested for potable use.

Methods: Data from the Demographic and Health Surveys database were examined for this study. The data included 50,579 household surveys between 2002 and 2007 from the Dominican Republic. STATA version 8 was used for data analysis. Descriptive statistics were computed, and logistic regression analysis was used to compare toilet type, water source, and type of place of residence with prevalence of diarrheal disease in children under five.

Results: This study found that rainwater presents less risk for diarrheal disease when compared to all other water sources (excluding bottled water). In 2002, people who consumed all other sources of water (excluding bottled) were 1.28 times more likely to have diarrhea in children under 5 (95% CI 1.05-1.57) compared to those who consumed rainwater. In 2007, people who consumed all other sources of water (excluding bottled water) were 1.33 times more likely to have diarrhea in children under 5 (95% CI 1.08-1.65) compared to those who consumed rainwater and 1.31 times more likely in both years (95% CI 1.13-1.51) to have diarrhea in children under 5 in those who consumed all other sources of water (excluding bottled water) compared to those who consumed rainwater.

Discussion: This study concluded that consuming rainwater presents a decreased risk for diarrheal disease compared to all other sources (excluding bottled water). These results are consistent with existing studies that have attempted to quantify the health risks of rainwater consumption which also found no increased health risks associated with consumption of rainwater though the designs are vastly different. More studies are needed to add more evidence to the existing literature regarding health risks associated with rainwater consumption.

CONSUMPTION OF RAINWATER AND DIARRHEAL DISEASE IN CHILDREN UNDER FIVE IN THE DOMINICAN REPUBLIC FROM 2002 TO 2007

By

ANDREA C. MPOGUI

B.S., UNIVERSITY OF GEORGIA

A Thesis Submitted to the Graduate Faculty
of Georgia State University in Partial Fulfillment
of the Requirements for the Degree

MASTER OF PUBLIC HEALTH

ATLANTA, GEORGIA

2012

CONSUMPTION OF RAINWATER AND DIARRHEAL DISEASE IN CHILDREN UNDER FIVE IN THE DOMINICAN REPUBLIC FROM 2002 TO 2007

By

ANDREA C. MPOGUI

Approved:

Christine Stauber, PhD, MS
Committee Chair

Lisa Casanova, PhD
Committee Member

July 20, 2012
Date

Acknowledgements

I would first like to thank my thesis committee, Dr. Christine Stauber and Dr. Lisa Casanova. I am beyond grateful for your guidance and patience during this process.

I am eternally grateful to the loving family and supportive friends who kept me lifted during this journey. I appreciate your words of encouragement, prayers, and moments of truth.

Lastly, it is my faith in God that has always sustained me. I recite daily Philippians 4:6-- Do not be anxious about anything, but in every situation, by prayer and petition, with thanksgiving, present your requests to God.

AUTHOR'S STATEMENT

In presenting this thesis as a partial fulfillment of the requirements for an advanced degree from Georgia State University, I agree that the Library of the University shall make it available for inspection and circulation in accordance with its regulations governing materials of this type. I agree that permission to quote from, to copy from, or to publish this thesis may be granted by the author or, in her absence, by the professor under whose direction it was written, or in his absence, by the Associate Dean, College of Health and Human Sciences. Such quoting, copying, or publishing must be solely for scholarly purposes and will not involve any potential financial gain. It is understood that any copying from or publication of this dissertation which involves potential financial gain will not be allowed without written permission of the author.

Andrea C. Mpogui

Signature of the Author

NOTICE TO BORROWERS

All theses deposited in the Georgia State University Library must be used in accordance with the stipulations prescribed by the author in the preceding statement.

The author of this thesis is:

Andrea C. Mpogui
C/o Institute of Public Health
Georgia State University
P.O. Box 3995
Atlanta, GA 30302-3995

The Chair of the committee for this thesis is:

Christine Stauber, Ph.D., M.S.
Institute of Public Health
Georgia State University
P.O. Box 3995
Atlanta, Georgia 30302-3995

Users of this thesis who not regularly enrolled as students at Georgia State University are required to attest acceptance of the preceding stipulation by signing below. Libraries borrowing this thesis for the use of their patrons are required to see that each user records here the information requested.

NAME OF USER	ADDRESS	DATE	TYPE OF USE (EXAMINATION ONLY OR COPYING)

CURRICULUM VITAE

Andrea C. Mpogui
C/o Institute of Public Health, Georgia State University
P.O. Box 3995
Atlanta, GA 30302-3995
acheevers@gmail.com

EDUCATION

Georgia State University, Atlanta, GA **2009 - 2012**
Master of Public Health; Prevention Sciences track

University of Georgia, Athens, GA **2001 - 2005**
Bachelor of Science, Environmental Health

PROFESSIONAL EXPERIENCE

Dekalb County Board of Health **2006 - Present**
Environmental Health Specialist

PROFESSIONAL CERTIFICATIONS

- Certified Food Safety Professional (National Registry)
- Standardized Food Retail Inspection/Training Officer (Georgia Department of Human Resources)
- Registered Environmental Health Specialist (Georgia Board of Registered Professionals)

SKILLS

Microsoft Excel, Microsoft Word, Microsoft PowerPoint, and STATA 8

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER I:

INTRODUCTION

1.1 Background

According to the World Health Organization (WHO), 1.9 million people died from diarrheal disease in 2004 and 88% of deaths from diarrheal disease are water, sanitation or hygiene related (2012). Diarrheal disease is especially a concern in children under five as it accounts for the deaths of 1.5 million children per year worldwide and is the second leading cause of death in children under five (WHO, 2009). Access to improved water and sanitation play a key role in reducing morbidity and mortality of diarrheal disease. WHO estimates that advances in access to improved water and sanitation as well as improvements in hygiene and water resource management could result in the reduction of almost 10% of the total burden of disease worldwide (2012).

The United Nations signed a declaration in September of 2000 to combat poverty, hunger, disease, illiteracy, environmental degradation, and discrimination against women. Out of this declaration the Millennium Development Goals (MDGs) were born with targets set to be achieved by the year 2015 (WHO 2012). The MDG to increase access to improved water sources has been met, but in order to achieve universal access and to maintain sustainable water sources, nations around the world will have to tap into alternative resources.

Rainwater has been consumed by people all over the world for centuries and today millions of people around the world depend on rainwater for drinking and domestic use. However, there have been concerns raised in recent decades as to the quality of rainwater harvested for potable use (Gould 1999). There are few studies in the literature examining the health risks associated with rainwater consumption and the findings have varied in the past (Lye, 2002 and Dean & Hunter, 2012). A recent review of the literature found no evidence that there is increased risk of gastrointestinal illness associated with rainwater consumption (Dean & Hunter, 2012), while a previous review of the literature found that consumers of rainwater may be at "considerable risk to a variety of infectious disease" (Lye, 2002). Clearly, there is a need for more studies to provide evidence as to the health risks associated with rainwater consumption.

1.2 Purpose of the Study

Access to improved water and sanitation play an important role in reducing the global childhood burden of diarrheal disease. Though access to improved water sources has significantly improved since the Millennium Development Goal target was set in 2000, there are still over 780 million people still using unsafe drinking water sources. Furthermore, it is important to determine if sources we now consider to be improved, such as rainwater, are safe.

The purpose of this study was to examine the association between consumption of rainwater as the main drinking water source and reported diarrhea in children under five in a cross-sectional survey of respondents from the Dominican Republic. More information is needed in order to fully determine the effect of implementation of rainwater harvesting systems on access to safe water sources and prevalence of gastrointestinal illness.

1.3 Research Questions

To further assess the association of rainwater consumption and diarrheal disease the following questions were examined:

1. Who in the study population is using rainwater and how has that changed over time?
2. Is consumption of rainwater associated with decreased risk of diarrheal disease as compared to other sources of drinking water?

CHAPTER II:

REVIEW OF THE LITERATURE

The purpose of this study was to examine the association between rainwater consumption and diarrheal disease in children under five. To support the need for this study, a review of existing literature illustrated the issue of access to improved water sources and focused on what is currently known about the microbial quality of rainwater and risk for gastrointestinal illnesses with consumption of rainwater. There is still more evidence needed to determine the health risks associated with consumption of rainwater.

2.1 Water Access

The United Nations (UN) created the Millennium Development Goals (MDG) in 2000 after creating and signing a declaration to "free people from extreme poverty and multiple deprivations" (UNDP 2012). As part of Goal 7 to ensure environmental sustainability, the UN proposed to halve the proportion of people without sustainable access to safe drinking water and basic sanitation by 2015 (WHO 2012 & UNDP 2012).

As the 21st Century began, one in five people living in the developing world (1.1 billion people) lacked access to clean water (UNDP 2006) and according to the WHO/UNICEF Joint Monitoring Programme for Water Supply and Sanitation (JMP), today, over 780 million people still use unsafe drinking water sources (2012).

The UNDP's 2006 Human Development Report states that average water use ranges from 200–300 liters per person per day in most countries in Europe to 575 in the

United States while the average use in countries such as Mozambique is less than 10 liters. The World Health Organization (WHO) and the United Nations Children's Fund (UNICEF) suggest a minimum requirement of 20 liters per day from a source within 1 kilometer of the household; however, UNDP suggest that this is only sufficient for drinking and basic personal hygiene and that if bathing and laundry needs are considered this would raise the personal threshold to about 50 liters per day (2006).

Improved vs. Unimproved Water Source

In order to make global comparison of estimates of water source, JMP classified water sources into two groups—improved and unimproved (2010). JMP defines an improved drinking-water source as "one that, by nature of its construction or through active intervention, is protected from outside contamination, in particular, from contamination with fecal matter (2010). Figure 1 displays the different types of water sources categorized into improved and unimproved sources.

Figure 1. Types of sources of drinking water. Source: WHO/UNICEF JMP

"Improved" sources of drinking water

- Piped water into dwelling
- Piped water to yard/plot
- Public tap or standpipe
- Tubewell or borehole
- Protected dug well
- Protected spring
- Rainwater

"Unimproved" sources of drinking water

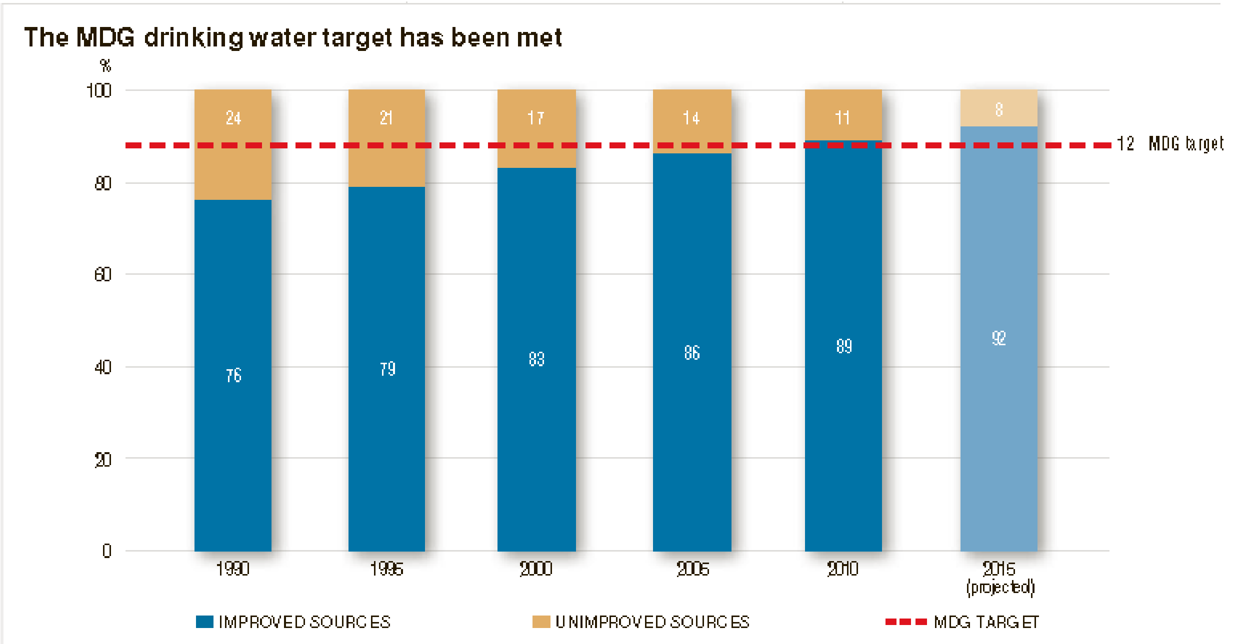
- Unprotected spring
- Unprotected dug well
- Cart with small tank/drum
- Tanker-truck
- Surface water
- Bottled water

MDG Update

WHO reports that the MDG drinking water target has been reached (2012). Over 2 billion people gained access to improved water sources from 1990 to 2010, and the proportion of the global population still using unimproved sources is estimated at 11%. Therefore, 89% of the world's population was using an improved water source in 2010 (WHO 2012).

Figure 2. Trends in global drinking water coverage, 1990-2010, projected to 2015.

Source: UNICEF/WHO 2012



While this is a great accomplishment, WHO cautions that a great deal of work still remains. They cite the lack of complete information about drinking water safety for global monitoring as an issue that needs to be addressed moving forward. Because lab testing at the national level in all countries is expensive and complicated, the JMP created a proxy indicator for water quality as mentioned above by defining "improved" and "unimproved" water sources. However, some of these improved sources may not be adequately maintained, and therefore may not actually provide "safe" drinking water

(WHO 2012). Consequently, it is important moving forward to measure the risk of disease associated with various water sources.

2.2 Burden of Diarrheal and Concern for Children Under Five

WHO states that in 2004, water, sanitation and hygiene were responsible for 1.9 million deaths from diarrhea, and 4.2% of the global burden of disease. WHO also estimates that 88% of the world's diarrheal deaths are caused by unsafe water, sanitation, or hygiene (2012). Diarrheal disease is the second most common contributor to the disease burden in developing countries (Prüss & Havelaar, 2001). Diarrheal disease mainly affects children under two years old, and it is a leading cause of mortality and malnutrition in children under five years (WHO,2009). According to UNDP, of the 60 million deaths in the world in 2004, 10.6 million (nearly 20%) were children under the age of five (2006). There are 5 billion cases of diarrhea in children each year in developing countries which claim the lives of 1.8 million children under the age of five each year (UNDP, 2006). Clean water and sanitation play a big role in reducing child mortality. WHO lists them among the key measures to prevent diarrhea (WHO, 2009).

2.3 Rainwater

There have been various approaches to addressing the global water crisis. Rainwater harvesting has gained attention as a community-based and environmentally sustainable method to increasing water access. Gould states that rainwater harvesting is of particular interest in rural areas of developing countries where community systems fail to provide adequate water supplies (1999).

Economic Benefits and Considerations

The benefit is not just in having increased access to water, but household rainwater collection can also save time, energy, and money. By not having to haul water from a communal source or purchase it from a vendor, households can have more time, energy, and money for other purposes, which, in turn can provide an economic boost (Cain 2010). Lehmann and Tsukada examined how rainwater harvesting might reduce poverty (2011). They also found that rainwater harvesting allows for savings in time devoted to household collection which may mean more time spent engaging in other productive activities which, in turn may have an economic benefit. Specifically, the authors found that households would be able to dedicate more time and resources to agriculture and livestock production (Lehmann and Tsukada 2011).Though rainwater harvesting overall can be viewed as cost-effective, the initial cost of rainwater harvesting system could be an issue for some households. Cain points out that poorer families may not be able to afford the initial installation of a basic system. A basic system can cost around $60.00 which, while relatively inexpensive in developed nations, can add up to several months' income for a poorer family in a developing nation (2010). Implementation of more rainwater harvesting systems in lower income communities will require assistance from governments and non-governmental organizations (Cain 2010). Nijhof and Strestha examined the use of micro-credit (small loans) in Nepal to promote rainwater harvesting (2010). The researchers found that issuing micro-credit for rainwater harvesting systems can greatly contribute to the promotion of rainwater harvesting technology in Nepal (Nijhof and Strestha, 2010).

Climate Considerations

When considering the success of a rainwater harvesting system, climate is of chief concern. How can climate affect the success of a rainwater harvesting system? In his review of the literature, Gould found that a semi-humid climate with an average rainfall of 1,000 mm in a year, a roof sized at $50m^2$ can yield $40m^3$ of water per year which is equivalent to 100 liters per day. He also found that in a semi-arid climate, with average yearly rainfall of 500 mm, a roof sized $50m^2$ can potentially yield $20m^3$ of water which, with sufficient storage, could supply more than 50 litres of water per day to the household (1999). In Cain's survey of rainwater use in India, he stated that field testing has demonstrated the usefulness of rainwater harvesting in variety of environments in India (2010). Pandey, Gupta, and Anderson examined rainwater use in arid climates. The authors hypothesized that as water resources are affected by climate changes, people will resort to rainwater harvesting rather than migration (2003). They found that historically in India as the aridity increased, rainwater harvesting practices increased (Pandey et al, 2003).

Environmental Considerations

Environmental sustainability is the overarching in issue in the goal for improving water access. Pandey et al point out that more than half of the accessible freshwater runoff globally is already appropriated for human use and that per capita availability of freshwater will decrease in the coming century because the human population will grow faster than increases in the amount of accessible freshwater (2003). With depletion of our natural resources being a constant concern, success with increasing access to improved water sources is hinged upon ensuring that these sources are sustainable. Positive effects of implementing rainwater harvesting systems can include reduced pressure on ecosystems (by reducing the need to pump groundwater or divert ecological flows), reduced demand on current water infrastructure, and reduction of storm water and wastewater flows which can carry pollution into area waters (Cain 2010).

Water Quality and Human Health Considerations

According to Thomas and Greene (as cited by Gould 1999), rainwater is generally considered unsafe to drink in most industrialized urban areas where there is a high degree of atmospheric pollution. Atmospheric pollution is generally of less concern in rural areas, and Waller states (as cited by Gould 1999) that most contamination occurs after the rainwater comes into contact with the catchment system. A rainwater tank can be contaminated when material from the roof and gutters are washed into it. Pathogens may be present from fecal matter of birds, lizards, and other animals which may access the roof (Ahmed, Vieritz, Goonetilleke, & Gardner, 2010). There are a number of contaminants that could affect the quality of rainwater, but as mentioned earlier, review of the existing literature for this study will focus on microbial contamination.

Ahmed, Gardner, and Toze examined the literature for health risks associated with the use of roof-harvested rainwater (RHRW) and found that published data suggest that the microbial quality of RHRW should be considered less than that expected for potable water (2011). In a study of the quality of roof-collected rainwater in Auckland, New Zealand, researchers found a high prevalence of bacterial indicator organisms. They were also able to detect *Salmonella* and *Cryptosporidium*. They suggest that their findings indicate that roof-collected rainwater supplies are a potential source for human illness, even stating that roof-collected rainwater systems appear to be of poor microbiological quality (Simmons, Hope, Lewis, Whitmore, & Gao, 2001). It should be noted however that the eligible samples for testing were small in number and the prevalence of *Salmonella* and *Crypstosporidium* was small, 0.9% and 4% respectively. Also, there was no indication as to what health risks may be presented from the pathogens at the levels at which they were detected.

Ahmed et al used quantitative microbial risk assessment to determine the health risks associated with roof-harvest rainwater in Queensland, Australia. They found that in their study that the pathogens detected in the potable and nonpotable rainwater supplies did not present health risks at the level at which they were detected (2010).

In an assessment of rainwater quality in Greece, researchers were able to detect total coliforms in 80.3% of collected rainwater samples and *E.coli* and enterococci at 40.9% and 28.8% respectively. Though found in high percentages of sample, the indicators were found at low concentrations and the researchers concluded that the rainwater assessed during their 3-year for chemical and microbial quality was unpolluted. They also suggest regular cleaning of catchments, using first flush to discard the first portion of each rainfall, and disinfection of tanker trucks use to transport the rainwater in order to maintain a safe supply (Sazakli, Alexopoulos & Leotsinidis, 2007).

Fry et al (2010) used engineering analysis methodology to estimate potential public health improvement from increased water supply. Specifically, they estimated potential reduction in diarrhea disability adjusted life years (DALYs) per month from enhancements in the water supply from domestic rainwater harvesting (DRWH). The study focused on West Africa and showed that the effectiveness of DRWH for reducing diarrheal disease burden varied throughout the region with up to a 25% reduction in diarrhea DALYs.

Heyworth, Glonek, Maynard, Baghurst, and Finlay-Jones conducted a study which was published in 2006 of 4 to 6 year old children who drank tank rainwater (untreated rainwater) or treated public mains water in rural South Australia. They concluded that in this study, children who regularly consumed tank rainwater were at no greater odds of gastroenteritis than those who drank treated public mains water (Heyworth et al 2006).Abdulla and Al-Shareef found in their study of roof-harvested rainwater in Jordan that the presence of fecal coliforms and total coliforms in the rainwater samples they tested did not meet WHO standards. They suggested chlorination of the collected rainwater at least once every rainy season and cleaning of the catchment area before the start of the rainy season. Further they found that when the "first flush" method is used, (collecting the first flush of water and disposing of it, minimizing the amount of material present in the collected water that will be consumed) the collected rainwater is usually safe to consume (2009).

Garrett et al, in their examination of household water treatment, latrines, shallow wells, and rainwater harvesting on diarrhea incidence in children in rural Kenya, found that chlorination of stored water, latrine presence, rainwater use, and living in an intervention village were all independently associated with lower risk of diarrhea (2008).

Dean and Hunter in their recent systematic review of the literature aimed to improve estimates of the health risk (particularly gastrointestinal) associated with consumption of harvested rainwater. The authors cited a previous review (Lye 2002) which concluded that consumption of rainwater may pose considerable risk to various infectious diseases. Dean and Hunter, however, criticized this review as not being systematic with no attempt to quantify said risks. Dean and Hunter's review examined eight studies about the health risks associated with rainwater consumption. The authors found that when compared with unimproved sources, there is evidence that rainwater consumption is associated with fewer episodes of diarrheal disease. They also found that while overall, there was no evidence that rainwater consumption carries increased risk compared to other improved source, there may be evidence for increased risk of specific infections when consuming rainwater, particularly campylobacteriosis. However, the authors acknowledge and discussed the limitations to the study in which that association was found. The review concluded that there is currently no evidence that rainwater carries increased risk when compared to other improved sources (Dean and Hunter 2012).

2.4 Dominican Republic

Water Access and Diarrheal Disease in the Dominican Republic

WHO data from 2010 shows that 3.7% of all deaths in the Dominican Republic were water, sanitation and hygiene related. The most recent JMP estimates show access to water in the Dominican Republic overall to be high. According to JMP, from the 1990 to 2010 the proportion of urban residents using water piped onto premises for drinking water decreased by 14% and increased by 9% in rural areas with an overall drop of 1%. During this time, the proportion of urban residents using other improved sources increased by 3% while the number of rural residents using other improved sources decreased by 1% with an over decrease in Dominican Republic residents using drinking water from other improved sources by 1%. The proportion of urban residents using unimproved sources (other than surface water) increased by 11% and increased by 13% for rural residents while overall increasing by 11%. So, in 2010 86% of the country had access to improved drinking water sources. This number is down from 88% in 1990. As of 2010, 14% of the country still in need of access to an improved drinking water source (JMP 2012).

WHO estimates the burden of diarrheal disease in the Dominican Republic, based on 2004 data, at 1300 deaths/yr.--5.0 DALYs (Daily adjusted life years) per 1000 capita per year 2009). The overall under five mortality rate is 29/1000 live births (WHO, 2009).

2.5 Summary

Improving global access to improved water, has long been on the UN agenda. Great strides have been made to increase access to improved water sources all of the world and the latest WHO/UNICEF reports indicate that the MDG 2015 target for access to improved water has been met. Still, there is more work to do as there are still some 780 million people who use unsafe drinking water sources, and in order to ensure that the "improved" water sources are safe, more research is needed to quantify health risks associated with specific water sources.

Interest in harvesting rainwater has been well documented throughout history and continues to increase around the world, in developing areas of the world in particular. Rainwater harvesting systems are fairly inexpensive and their use provides some economic benefits as well as environmental benefits. However, the benefits and/or risk of rainwater consumption are not well defined. One most recent review of the literature suggests that despite the findings of an earlier review, there is no evidence of an increased risk for gastrointestinal illness when consuming rainwater. Still, more studies are needed.

CHAPTER III:

METHODOLOGY

3.1 Data Source

The data used in this study were obtained from the Demographic and Health Surveys (DHS). The MEASURE DHS project was initiated in 1984 by U.S. Agency for International Development (USAID) to provide data and analysis on the population, health, and nutrition of women and children in developing countries. The project provides technical assistance to more than 240 surveys in over 85 countries. The surveys are nationally-representative household surveys that provide data for a wide range of monitoring and impact evaluation indicators in the areas of population, health, and nutrition (MEASURE DHS, 2007).

There are two types of surveys—standard and interim. These surveys have large sample sizes (between 5,000 and 30,000 households) and are usually conducted every 5 years. DHS surveys take on average 18-20 months to complete. The process is completed in four stages: survey preparation and questionnaire design; training and fieldwork; data processing; and final report, data preparation and dissemination. A special software package named CSPro (previously ISSA) is used to process all the survey data. All steps are completed with CSPro which include data entry, production of statistics (including sampling errors) and creating tables which are published in DHS final reports. CSPro also provides a mechanism to export data to the statistical software programs SPSS, SAS and STATA.

3.2 Study Population

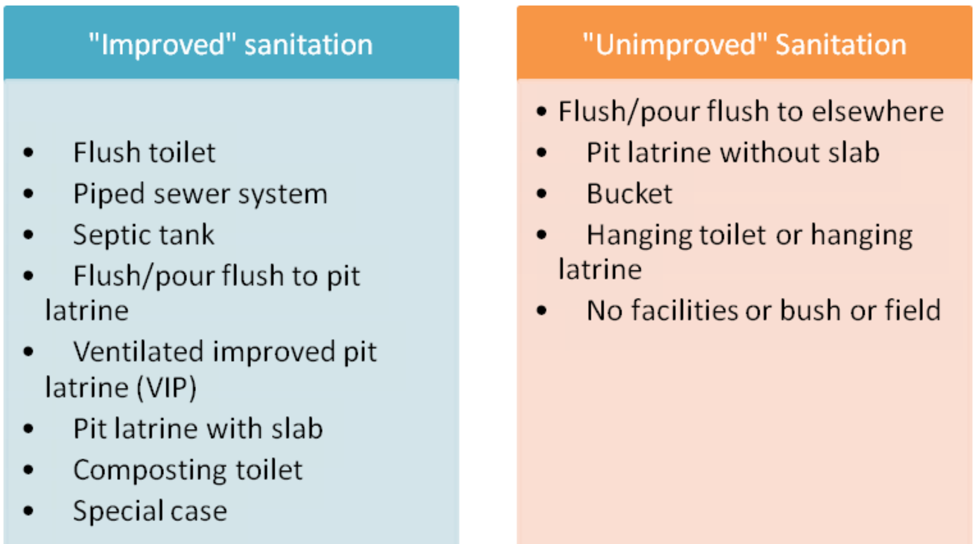
The data for this study were obtained from standard DHS surveys for the years 2002 and 2007 for the Dominican Republic. There are three core questionnaires in DHS surveys-- Household, Women, and Male. In all households, women age 15-49 are eligible to participate and in many surveys men age 15-59 from a sub-sample are also eligible to participate. Data from household surveys were used in this study. In 2002, the sample size included 27,135 households, 23,384 women, and 2,833 men. In 2007, the sample size included 32,431 households, 27,195 women, and 27,975 men. As stated earlier, the data for this study were taken from the household survey data for which all of the respondents were women.

3.3 Study measures

The dependent variable examined in this study is reported diarrhea in children under five in the two weeks preceding the survey. In the household survey, respondents were asked for each child under five years of age if that child had presented with diarrhea within the last two weeks. The response were either yes, no, or don't know with individual responses for up to 6 children in the household under 5 five years of age. A new variable was generated which categorized "don't know" responses with "no" responses.

The independent variables were drinking water source, sanitation (toilet facility type), and type of place of residence (urban or rural). A new variable for drinking water source was created, decreasing the number of categories to 3: rainwater, bottled water, and all other sources. Sanitation was originally coded as toilet type, listing 6 different types of toilet facilities along with options for no facility and other. A new sanitation variable was created to make it a dichotomous variable by categorizing toilet facilities as either improved or unimproved as described by JMP. Figure 3 illustrates the categories for sanitation.

Figure 3. Sanitation Categories. Source: WHO/UNICEF JMP



Other variables examined were age of respondents in five-year groups, highest education level achieved, month of interview, province, and year of survey.

3.4 Data Analysis

Statistical analysis was conducted using STATA 8. Descriptive statistics were generated to describe the study population. Distribution of water source was examined across province and stratified by urban or rural type of place of residence. Proportion of reported diarrhea in children under five was examined by water source, and the proportion of toilet type in the overall cohort was examined.

Binary logistic regression analysis was performed to test the association between reported diarrhea in children under five and water source. Odds ratios, 95% confidence intervals, and p-values were calculated using this analysis. A p-value of less than 0.05 was considered statistically significant.

A multivariate logistic regression analysis was performed to control for potential confounding and examine the association between reported diarrhea in children under five, water source, sanitation, and type of place of residence. Again, odds ratios, 95% confidence intervals, and p-values were calculated with a p-value of less than 0.05 considered as statistically significant.

CHAPTER IV:

RESULTS

4.1 Descriptive Statistics

Socio-demographic Characteristics

The respondents in this study are all women because data from household surveys was used, and only women were interviewed for household surveys. Their ages ranged from 15 to 49. The largest proportion of respondents in a particular age group was in the 15-19 group. The average age of the respondents in 2002 and 2007 was between 29 and 30 (29.58; 29.49 in 2002 and 29.66 in 2007). The majority of respondents have at least a primary level education. Also the majority of the respondents lived in urban areas. In the Dominican Republic, urban is defined as population residing in communal and municipal district capitals and rural is defined as population residing in areas other than communal or municipal district capitals (UN, 1999).

Table 1. Socio-demographic Characteristics of Study Respondents			
	2002	2007	Total
Variable			
	N (%)	N (%)	N (%)
Age in 5 year groups			
15-19	**4,808 (20.56)**	**5,847 (21.50)**	**10,655 (21.07)**
20-24	4,043 (17.29)	4,357 (16.02)	8,400 (16.61)
25-29	3,530 (15.10)	3,919 (14.41)	7,449 (14.73)
30-34	3,279 (14.02)	3,725 (13.70)	7,004 (13.85)
35-39	3,120 (13.34)	3,568 (13.12)	6,688 (13.22)
40-44	2,466 (10.55)	3,170 (11.66)	5,636 (11.14)
45-49	2,138 (9.14)	2,609 (9.59)	4,747 (9.39)
Total	23,384 (100)	27,195 (100)	50,579 (100)
Highest Education Level			
No Education	1,197 (5.12)	1,313 (4.83)	2,510 (4.96)
Primary	**11,557 (49.42)**	**11,129 (40.92)**	**22,686 (44.85)**
Secondary	7,395 (31.62)	10,148 (37.32)	17,543 (34.68)
Higher	3,235 (13.83)	4,605 (16.93)	7,840 (15.50)
Total	23,384 (100)	27,195 (100)	50,579 (100)
Type of Place of Residence			
Urban	**14,633 (62.58)**	**16,376 (60.22)**	**31,009 (61.31)**
Rural	8,751 (37.42)	10,819 (39.78)	19,570 (38.69)
Total	23,384 (100)	27,195 (100)	50,579 (100)

Month of Interview

The month of interview varied from 2002 to 2007 with January and February being the only months in both years when no interviews were conducted. In 2002, interviews took place from July to December. In 2007, interviews took place from March to August.

Table 2. Month of Interview			
Month of Interview	2002	2007	Total
	N (%)	N (%)	N (%)
March	--	4,044 (14.87)	4,044 (8.00)
April	--	4,912 (18.06)	4,912 (9.71)
May	--	6,520 (23.97)	6,520 (12.89)
June	--	6,119 (22.50)	6,119 (12.10)
July	4,168 (17.82)	5,438 (20.00)	9,606 (18.99)
August	5,148 (22.02)	162 (0.60)	5,310 (10.50)
September	4,021 (17.20)	--	4,021 (7.95)
October	5,540 (23.69)	--	5,540 (10.95)
November	4,368 (18.68)	--	4,368 (8.64)
December	139 (0.59)	--	139 (0.27)
Total	23,384 (100.00)	27,195 (100.00)	50,579 (100.00)

Drinking Water Source and Place of Residence

Drinking water source was categorized into three groups, rainwater, bottled water, and all other sources. Other sources included in the "all other sources" category included piped into dwelling, piped into yard/lot, water from well, surface water, spring, river, stream, tanker truck, and other for 2002. In 2007, sources included in the "all other sources" category included piped into dwelling, piped into yard/plot, tube well or borehole, river, dam, lakes, ponds, stream, canal, irrigation, tanker truck, cart with small tank, and other. Table 3 shows proportion of drinking water sources. Rainwater was used by fewer people over all, and the proportion of people using rainwater also decreased from 9.88% in 2002 to 8.45% in 2007. In both years, bottled water is the single most used source, and the proportion of people using bottled water increased from 44.92% in 2002 to 50.91% in 2007. The changes between 2002 and 2007 were shown to be statistically significant using a chi square test.

Table 3. Proportion of Drinking Water Source			
	2002	2007	Total
	N (%)	N (%)	N (%)
Rainwater	2,319 (9.88)	2,296 (8.45)	4,606 (9.11)
Bottled Water	10,502 (44.92)	13,839 (50.91)	24,341 (48.14)
All other Sources	10,566 (45.20)	11,048 (40.64)	21,614 (42.75)
Total	23,378 (100.00)	27, 183 (100.00)	50,561 (100.00)

The majority of households which were using rainwater for drinking water were located in rural areas as shown in table 4. Also, most households in urban areas used bottled water for drinking water. As previously mentioned, the proportion of households that reported using rainwater for drinking water decreased from 2002 to 2007. While Table 4 displays the distribution of water source stratified by urban and rural, Appendix A gives a more in depth view by specific province. The largest proportion of rainwater use in a single province was in the Salcedo Province.

Table 4. Proportion of Drinking Water Source Stratified by Type of Place of Residence						
	2002		2007		Total	
	Urban	Rural	Urban	Rural	Urban	Rural
	N (%)	N (%)	N (%)	N (%)	N (%)	N (%)
Rainwater	649 (4.44)	1661 (18.99)	469 (2.86)	1,827 (16.90)	1,118 (3.60)	3,488 (17.83)
Bottled Water	8,397 (57.39)	2,105 (24.06)	10,266 (62.70)	3,573 (33.05)	18,663 (60.20)	5,678 (29.03)
All other sources	5,584 (38.17)	4,982 (56.95)	5,638 (34.44)	5,410 (50.05)	11,222 (36.20)	10,392 (53.14)
Total	14,630 (100.00)	8,748 (100.00)	16,373 (100.00)	10,810 (100.00)	31,003 (100.00)	19,558 (100.00)

Diarrhea in Children Under Five

Fifty-three percent (53%) of respondents reported no children in the household under 5 years of age. The number of children under the age of 5, ranged from 0 to 7 for a single household. The average number of children under 5 per household was 1.50 in

2002, 1.42 in 2007, and 1.46 in both years combined. The proportion of households having children under 5 years of age that reported diarrhea in children under 5 was nearly 13% in both years combined as shown in table 5. The proportion of reported diarrhea in children under 5 is very similar in 2002 and 2007 with proportion slightly decreasing from 2002 to 2007. A chi square test showed this change to be statistically insignificant.

Table 5. Proportion of households with children under 5 reporting recent diarrhea in children under 5

Recent Diarrhea in children under 5	2002	2007	Combined
	N (%)	N (%)	N (%)
No	9,988 (87.00)	10,720 (87.15)	20,708 (87.08)
Yes	1,492 (13.00)	1,580 (12.85)	3,072 (12.92)
Total Responses	11,480 (100.000	12,300 (100.00)	23,780 (100.00)

As illustrated in table 6, among the three drinking water source categories, households that reported rainwater use had the smallest proportion of reported diarrhea in children under 5. The proportion of reported diarrhea in children under 5 among households using rainwater decreased from 2002 to 2007.

Table 6. Proportion of Households with recent diarrhea in children under 5 by water source

	Recent Diarrhea Reported		
	2002	2007	Both Years
Water Source	N (%)	N (%)	N (%)
Rainwater	131 (8.79)	114 (7.23)	245 (7.99)
Bottled Water	494 (33.13)	682 (43.25)	1,176 (38.33)
All other Sources	866 (58.08)	781 (49.52)	1,647 (53.68)
Total	1491 (100.00)	1,577 (100.00)	3,068 (100.00)

Sanitation

Tables 7 and 8 illustrate the distribution of types of sanitation facilities. The majority of households had access to improved sanitation. The proportion of unimproved toilets decreased from about 23% in 2002 to just under 19% in 2007. A chi square test showed that this change is statistically significant. A larger proportion of people had access to improved sanitation facilities in urban areas than in rural areas. Conversely, the proportion of unimproved sanitation facilities was greater in rural areas than in urban areas.

Table 7. Proportion of sanitation facilities by type

Sanitation	2002	2007	Both Years
	N (%)	N (%)	N (%)
Unimproved	5,366 (22.96)	5,052 (18.60)	10,418 (20.62)
Improved	18,004 (77.04)	22,104 (81.40)	40, 108 (79.38)
Total	23,370 (100.00)	27,156 (100.00)	50,526 (100.00)

Table 8. Sanitation facilities stratified by urban rural for 2002, 2007, and both years combined

	2002		2007		Both Years	
	Urban	Rural	Urban	Rural	Urban	Rural
Sanitation	N (%)	N (%)	N (%)	N (%)	N (%)	N (%)
Unimproved	2,969 (20.30)	2,397 (27.41)	2,524 (15.44)	2,528 (23.39)	5,493 (17.73)	4,925 (25.19)
Improved	11,655 (79.70)	6,349 (72.59)	13,826 (84.56)	8,278 (76.61)	25,481 (82.27)	14,627 (74.81)
Total	14,624 (100.00)	8,746 100.00)	16,350 (100.00)	10,806 (100.00)	30,974 (100.00)	19,552 (100.00)

4.2 Logistic Regression Analyses

Logistic regression analyses were performed in STATA 8. A binary logistic regression analysis was performed to examine the relationship between water source and reported diarrhea in children under five in this cohort, and the results are displayed in table 9. People who reported consuming bottled water in 2002 reported 0.81 times the odds of diarrhea in children under 5 (95% CI 0.66-0.99) compared to rainwater with a p-value of 0.044. This indicates a statistically significant decrease in odds of diarrhea in children under 5 when bottled water was consumed as the drinking water source compared to rainwater. However, people who reported using other sources (other than bottled) were 1.35 times more likely to have reported diarrhea in children under 5 (95% CI 1.11-1.164) compared to those who reported consuming rainwater in 2002. When compared in 2007, a similar result was found. Those using other sources (other than bottled) were 1.34 times more like to have reported diarrhea in children under 5 in 2007 (95% CI 1.08-1.65) compared to those using rainwater. This was also similar when both years were compared together as shown in Table 9.

Table 9. Binary logistic regression analysis: reported diarrhea in children under 5 and water source; rainwater is referent

	2002		2007		Combined	
	OR (CI 95%)	P-Value	OR (CI 95%)	P-Value	OR (CI 95%)	P-Value
Rainwater	Referent	Referent	Referent	Referent	Referent	Referent
Bottled Water	**0.81 (0.66-0.99)**	**0.044**	1.02 (0.83-1.26)	0.820	0.92 (0.79-1.06)	0.250
All other Sources	**1.35 (1.11-1.64)**	**0.003**	**1.34 (1.08-1.65)**	**0.007**	**1.34 (1.16-1.55)**	**0.000**

As shown in table 10, when bottled water is used as the referent group, the results are similar to the previous analysis. People who consumed rainwater were 1.23 times more likely to have diarrhea in children under 5 (95% CI 1.01-1.52) compared to bottled water. This result is statistically significant. People who consumed all other sources of water (except rainwater) in comparison to bottled water had increased risk for diarrhea in children under 5 with 1.66 times the risk in 2002 (95% CI 1.48-1.87), 1.30 times the risk in 2007 (95% CI 1.17-1.45), and 1.46 times the risk in both years (95% CI 1.35-1.58). All of these results are statistically significant.

Table 10. Binary logistic regression analysis: reported diarrhea in children under 5 and water source; bottled water is referent						
	2002		2007		Both Years	
	OR (CI 95%)	P-value	OR (CI 95%)	P-value	OR (CI 95%)	P-value
Bottled Water	Referent	Referent	Referent	Referent	Referent	Referent
Rainwater	**1.23 (1.01-1.52)**	**0.044**	0.98 (0.79-1.20)	0.820	1.09 (0.94-1.26)	0.250
All other sources	**1.66 (1.48-1.87)**	**0.000**	**1.30 (1.17-1.45)**	**0.000**	**1.46 (1.35-1.58)**	**0.000**

Stratifying this analysis across urban and rural residences, as shown in table 11, demonstrated a statistically significant result only in comparison of all other sources (except bottled water) with rainwater. As previously indicated all other sources (except bottled water) present an increased risk for diarrhea in children under 5 when compared to rainwater.

In urban areas in 2002, people who consumed all other sources of water (excluding bottled water) were 1.57 times more likely to have diarrhea in children under 5 (95% CI 1.06-2.32) compared to people who consumed rainwater. In urban for both years combined, people who consumed all other sources of water (excluding bottled water) were 1.48 times more like to have diarrhea in children under 5 (95% CI 1.09-2.01).

In rural areas in 2007, people who consumed all other sources of water (excluding bottled water) were 1.37 times more likely to have diarrhea in children under 5 (95% CI 1.08-1.74) compared to people who consumed rainwater. In rural areas in both years combined, people who consumed all other sources of water (excluding bottled water) were 1.31 times more likely to have diarrhea in children under 5 (95% CI 1.11-1.54) than people who consumed rainwater.

Table 11. Binary logistic regression analysis						
	2002		2007		Combined	
Urban						
	OR (CI 95%)	P-value	OR (CI 95%)	P-value	OR (CI 95%)	P-value
Rainwater	Referent	Referent	Referent	Referent	Referent	Referent
Bottled Water	0.86 (0.58-1.27)	0.441	1.07 (0.66-1.73)	0.793	0.96 (0.71-1.30)	0.778
All Other Sources	**1.57 (1.06-2.32)**	**0.024**	1.39 (0.85-2.27)	0.184	**1.48 (1.09-2.01)**	**0.012**
Rural						
	OR (CI 95%)	p-value	OR (CI 95%)	p-value	OR (CI 95%)	p-value
Rainwater	Referent	Referent	Referent	Referent	Referent	Referent
Bottled Water	0.97 (0.74-1.29)	0.857	1.13 (0.88-1.47)	0.340	1.06 (0.88-1.28)	0.563
All Other Sources	1.25 (0.99-1.58)	0.063	**1.37 (1.08-1.74)**	**0.010**	**1.31 (1.11-1.54)**	**0.002**

Shown in Table 12 are the results of a multivariate logistic regression which tests the relationship between water source and diarrhea in children under five while controlling for place of residence (urban/rural) and sanitation. In this model the consumption of rainwater presents decreased odds of diarrheal disease when compared to all other water sources (excluding bottled water). In 2002, people who consumed all other sources of water (excluding bottled) were 1.28 times more likely to have diarrhea in children under 5 (95% CI 1.05-1.57) compared to those who consumed rainwater. In 2007, people who consumed all other sources of water (excluding bottled water) were 1.33 times more likely to have diarrhea in children under 5 (95% CI 1.08-1.65) compared to those who consumed rainwater and 1.31 times more likely in both years (95% CI 1.13-1.51) to have diarrhea in children under 5 in those who consumed all other sources of water (excluding bottled water) compared to those who consumed rainwater.

For sanitation facilities, people with improved sanitation facilities in 2002 were 0.49 times less likely to have diarrhea in children under 5 compared to those who had unimproved sanitation facilities (95% CI 0.43-0.54). In 2007, people who were using improved sanitation facilities were 0.64 times less likely to have diarrhea in children under 5 than those who used unimproved sanitation facilities (95% CI 0.57-0.72). In both years combined, people who used improved sanitation facilities were 0.56 less like to have diarrhea in children under 5 than (95% CI 0.51-0.61).

Table 12. Multivariate logistic regression analysis

	2002		2007		Combined	
	OR (CI 95%)	p-value	OR (CI 95%)	p-value	OR (CI 95%)	p-value
Rainwater	Referent	Referent	Referent	Referent	Referent	Referent
Bottle Water	0.87 (0.70-1.07)	0.190	1.14 (0.911-1.41)	0.257	1.01 (0.86-1.17)	0.950
All Other Sources	**1.28 (1.05-1.57)**	**0.015**	**1.33 (1.08 1.65)**	**0.009**	**1.31 (1.13-1.51)**	**0.000**
Urban/Rural	1.00 (0.89-1.13)	0.972	1.09 (0.98-1.23)	0.116	1.05 (0.97-1.14)	0.230
Unimproved/Improved Toilet	**0.49 (0.43-0.54)**	**0.000**	**0.64 (0.57-0.72)**	**0.000**	**0.56 (0.51-0.61)**	**0.000**

CHAPTER V:

DISCUSSION AND CONCLUSION

5.1 Discussion

There are few studies in the existing literature examining health risks associated with rainwater consumption, but the results of this study were consistent with previous studies which have attempted to quantify health risks associated with rainwater consumption and found decreased risk or no increased risk with consumption of rainwater. However, the study designs vary, and there are many differences in the design of this study and the studies reviewed in the existing literature.

Garret et al (2008) in their examination of diarrhea prevention in a high-risk rural Kenyan population evaluated a program that included the implementation of a strategy called Safe Water Systems (SWS)and promoted for latrine building, rainwater collection, and shallow well construction. The SWS had 3 components: point-of-use water disinfection with sodium hypochlorite, safe water storage, and behavior change techniques. In their study, Garret et al conducted weekly diarrheal surveillance for an 8 week period from March to May in their study population. The results of the study showed that chlorinating stored water, latrine use, and consumption of rainwater all decreased risk of diarrhea. Garret et al study was very different from our study. First, no primary data was collected in this study. Second, we did not include information about how respondents are treating and storing drinking water in our study. Lastly, it is unclear if and what other improved water sources were in use other than rainwater collection and shallow wells.

The study by Fry et al (2010) showed that rainwater harvesting could potentially reduce diarrhea disease in West Africa. This study was very different from our study. The study by Fry et al used engineering analysis (modeling) to make estimates of potential reduction in diarrhea resulting from domestic rainwater harvesting. The study only considered the quantity of water that would potentially be added to the region and not the quality and assumed improved sanitation and hygiene with increased quantity of water. While the study results showed promise of potentially reducing diarrheal disease burden in West Africa by implementing more DRWH systems, it is difficult to compare these study results with our study because of the design and the assumptions that were made regarding diarrheal disease, sanitation, and hygiene.

Ahmed et al (2010) examined the health risk from use of roof-harvested rainwater in Southeast Queensland, Australia. The study found that the pathogens they detected in roof-harvested drinking water posed not health threats at the levels at which they were detected. They also found that the pathogens detected in the roof-harvested rainwater for nonpotable use also posed no health risks. This study by Ahmed et al was very different from our study. The Ahmed et al study focused on the microbial quaility of the rainwater samples and estimating risk from analysis of those samples. The researchers sampled rainwater from 82 residences and tested it for 5 pathogens which may cause diarrheal disease. They used QMRA to estimate health risk associated with exposure to those pathogens. There were no measurements of actual levels of diarrheal disease occurring in the study population and sanitation facilities were not considered.

In their examination of consumption of untreated tank rainwater and gastroenteritis in among young children in South Australia, Heyworth et al (2006) found no increase in odds of gastroenteritis among children who drank rainwater compared with treated mains water. This study was based on survey data which is one similarity between their study and our study, but there are still many difference. The researchers followed 1016 4 to 6 year old children who drank rainwater or treated mains water. The children's parents kept daily diaries of their gastrointestinal symptoms and water consumption for 6 weeks. The first difference is that we did not collect primary data in our study as previously mentioned. While the Heyworth et al study did observe diarrheal illness in young children, the age group was between 4 and 6 and not children under the age of 5. The study also only compared rainwater consumption with public treated mains water, and there was no information regarding sanitation facilities.

Access to improved drinking water sources in the Dominican Republic is high (JMP 2012). Bottled water accounts for the highest proportion of a specific water source with 48% of respondents (in both years combined) in this study using bottled water as their drinking water source. Considering the large proportion of the population using bottled water, it may be necessary to develop more sustainable water resources in order to maintain a high level of access in the future. Rainwater may be a viable alternative source.

Studies in the existing literally found rainwater to be a viable option for an alternative improved water source even in arid climates (Pandey et al 2003 & Cain 2010). The climate in the Dominican Republic is humid. The rainy season occurs from May to November, during which most regions receive 100-200mm per month (UNDP 2012).

Temperature and wet seasons can vary from year to year due to El Niño and La Niña episodes. Rainwater harvesting may be seasonal due to variation in rainfall at different times of the year (UNDP 2012). In this study, the respondents from 2002 were interviewed during the months July to December and in 2007 they were interviewed during the months March to August. If rainwater harvesting is seasonal, it is difficult to tell what affect that may have on this data set due to the distribution of month of interview across both years. Also, seasonal rainwater harvesting could result in changing main drinking water source in months where rainwater is scarce which may not give an accurate estimate when a population is sampled and surveyed about who is using rainwater. This could be a concern as recent estimates indicate that precipitation in the Dominican Republic has decreased since 1960 at a rate of 5.0mm per month per decade (UNDP 2012). Therefore, considerations must be made for rainfall variability when harvested rainwater is the main drinking water source. These include providing large catchment system, insuring proper storage and protection of harvested rainwater, and promoting water conservation.

The majority of respondents in this cohort lived in urban areas, but the proportion of rural dwelling respondents was still large. In 2002, the proportion of respondents who lived in rural areas was 37% and increased to nearly 40% in 2007. For both 2002 and 2007 combined, 9.11% of people consumed rainwater as their main drinking water source in this study population, and the majority of respondents who consumed rainwater lived in rural areas. Access to water in developing nations is of particular concern in rural areas because the access to improved water sources and basic sanitation tends to be lower than in urban areas (Gould 1999). Recent JMP (2012) estimates show that this is generally true of the Dominican Republic. However, these estimates also show that as access to improved water is increasing in rural areas, it is decreasing in urban areas. The decline in improved water access appears to be mainly an issue for urban areas. 2012 JMP estimates show that access to improved drinking water in urban areas of the Dominican Republic in 1990 was 98%, but dropped to 95% in 1995, 92% in 2000, 89% in 2005, and 87% in 2010. JMP estimates also show that from 2002 to 2007 the proportion of the urban population increased from 63% to 67% (2012). The UN previously identified keeping up with the growing demand for water as one challenge for water access in the future. It is possible that as urban areas are growing in the Dominican Republic the country may be experiencing difficulty in keeping up with the demand for improved water sources. This further highlights the importance of exploring alternative resources that are more sustainable on a long term basis. Perhaps urban areas could benefit more from rainwater harvesting in the future, but previously stated, the majority of rainwater consumers in this study lived in rural areas. More than half of the respondents who lived in the Salcedo province (now Hermanas Mirabal) consumed rainwater as their main drinking water source. Salcedo is the smallest province in the Dominican Republic. It is part of the Cibao region in the northeast of the country and is largely rural (CTO, 2008).

5.2 Limitations of the Study

First, this study is limited by the data source itself. Cross-sectional data gives a snap shot. We don’t know what the relationship between rainwater consumption and diarrhea was prior to the snap shot and therefore while the change between 2002 and 2007 is statistically significant, there are limitations to the conclusions we can make about changes over time.

The data is also a secondary source, and because we did not collect it, the process was not tailored to the needs of our study. This means that there may be information that was not collected in the surveys which may have been pertinent in our examination. There is no indication as to how the rainwater was being harvest. Different methods could carry different risk. Not all consumers who harvest rainwater use roof collection systems. Also it may be helpful to know if the rainwater was collected using a household system or if there is perhaps a small community collection site. The purpose of seeking to assess the risk of rainwater consumption is to encourage this practice if indeed harvest rainwater is considered safe to consume. Having more detailed information as to the type of catchment systems or collection practices that may be associated with more or less risks may be helpful to researchers, in particular those seeking to develop and design rainwater harvesting programs and systems.

While diarrhea is primarily a concern in children under 5 because of its high morbidity and mortality in this age group, it may have been helpful to get an overall picture of the burden of diarrheal disease. There were no questions that asked about diarrhea in household members other than children under 5.

5.3 Recommendations

My first recommendations are to include questions about rainwater collection and diarrhea in all household members. Perhaps there are more health risks associated with different catchment systems or practices. Different methods of storage and transport of water could also present risk for contamination, and could, therefore, present health risks as well.

Perhaps future studies could address hygiene practices as water, sanitation, and hygiene are integral in prevention of diarrheal disease. More studies are needed linking rainwater quality with specific health risks. More studies are need in rainwater treatment practices. Generally, more studies are needed to provide more evidence regarding the health risks associated with rainwater consumption to the existing literature.

5.4 Conclusion

Although the MDG drinking water target has been met, there was still more than one tenth of the global population relying on unimproved drinking water sources in 2010 (UNICEF and WHO 2012). Interest in rainwater harvesting has grown, particularly in developing nations where cost effective and sustainable alternatives for water source are needed. With gastrointestinal illness being an ever-present concern in areas where access to improved water and sanitation facilities is limited, it is important to examine the potential risk of illness from the various water sources. This will allow us to continue to make strides towards providing safe drinking water and basic sanitation for all people. This study found that rainwater consumption posed less risk of diarrheal disease in children under five in the Dominican Republic in 2002 and 2007 than alternative water sources with the exception of bottled water. Still, more studies are needed to provide more evidence of specific health risks of rainwater consumption.

Appendix A

Distribution of Water Source by Province

	2002				2007				Combined			
	Water Source				Water Source				Water Source			
Province	Rainwater	Bottled Water	All Other Sources	Total	Rainwater	Bottled Water	All Other Sources	Total	Rainwater	Bottled Water	All Other Sources	Total
	N (%)	N (%)	N (%)	N (%)	N (%)	N (%)	N (%)	N (%)	N (%)	N (%)	N (%)	N (%)
Distrito Nacional	2	792	270	1,064	0	873	313	1,186	2	1665	583	2250
	0.19%	74.44%	25.37%	100.00%	0.00%	73.61%	26.39%	100.00%	0.09%	74.00%	25.91%	100.00%
Azua	1	221	531	753	0	314	455	769	1	535	986	1522
	0.13%	29.35%	70.52%	100.00%	0.00%	40.83%	59.17%	100.00%	0.07%	35.15%	64.78%	100.00%
Bahoruco	7	65	490	562	1	200	594	795	8	265	1084	1357
	1.25%	11.56%	87.19%	100.00%	0.12%	25.16%	74.72%	100.00%	0.59%	19.53%	79.88%	100.00%
Barahona	14	150	518	682	6	212	561	779	20	362	1079	1461
	2.05%	22.00%	75.95%	100.00%	0.77%	27.21%	72.02%	100.00%	1.37%	24.78%	73.85%	100.00%
Dajabón	11	130	458	599	6	225	490	721	17	355	948	1320
	1.84%	21.70%	76.46%	100.00%	0.83%	31.21%	67.96%	100.00%	1.29%	26.89%	71.82%	100.00%
Duarte	242	445	227	914	255	521	204	980	497	966	431	1894
	26.48%	48.69%	24.83%	100.00%	26.02%	53.16%	20.82%	100.00%	26.24%	51.00%	22.76%	100.00%
El Seibo	79	194	259	532	99	332	249	680	178	526	508	1212
	14.85%	36.47%	48.68%	100.00%	14.56%	48.82%	36.62%	100.00%	14.69%	43.40%	41.91%	100.00%
Elías Piña	1	70	440	511	3	154	460	617	4	224	900	1128
	0.20%	13.70%	86.10%	100.00%	0.49%	24.96%	74.55%	100.00%	0.35%	19.86%	79.79%	100.00%
Espaillat	141	264	324	729	142	415	260	817	283	679	584	1546
	19.34%	36.21%	44.45%	100.00%	17.38%	50.80%	31.82%	100.00%	18.31%	43.92%	37.77%	100.00%
Hato Mayor	240	224	105	569	149	418	186	753	389	642	291	1322
	42.18%	39.37%	18.45%	100.00%	19.79%	55.51%	24.70%	100.00%	29.43%	48.56%	22.01%	100.00%

Independencia	4	126	460	590	0	232	542	774	4	358	1002	1364
	0.68%	21.35%	77.97%	100.00%	0.00%	29.97%	70.03%	100.00%	0.29%	26.25%	73.46%	100.00%
La Altagracia	55	456	109	620	48	551	77	676	103	1007	186	1296
	8.87%	73.55%	17.58%	100.00%	7.10%	81.51%	11.39%	100.00%	7.95%	77.70%	14.35%	100.00%
La Romana	15	824	115	954	11	748	192	951	26	1572	307	1905
	1.57%	86.37%	12.06%	100.00%	1.16%	78.65%	20.19%	100.00%	1.36%	82.52%	16.12%	100.00%
La Vega	187	307	410	904	196	478	368	1,042	383	785	778	1946
	20.69%	33.96%	45.35%	100.00%	18.81%	45.87%	35.32%	100.00%	19.68%	40.34%	39.98%	100.00%
Maria Trinidad Sánche	230	261	100	591	280	328	154	762	510	589	254	1353
	38.92%	44.16%	16.92%	100.00%	36.75%	43.04%	20.21%	100.00%	37.70%	43.53%	18.77%	100.00%
Monseñol Nouel	5	177	551	733	7	324	460	791	12	501	1011	1524
	0.68%	24.15%	75.17%	100.00%	0.89%	40.96%	58.15%	100.00%	0.79%	32.87%	66.34%	100.00%
Monte Cristi	71	323	142	536	53	441	171	665	124	764	313	1201
	13.25%	60.26%	26.49%	100.00%	7.97%	66.32%	25.71%	100.00%	10.32%	63.62%	26.06%	100.00%
Monte Plata	134	162	362	658	124	205	387	716	258	367	749	1374
	20.36%	24.62%	55.02%	100.00%	17.32%	28.63%	54.05%	100.00%	18.78%	26.71%	54.51%	100.00%
Pedernales	4	117	437	558	17	225	428	670	21	342	865	1228
	0.72%	20.97%	78.31%	100.00%	2.54%	33.58%	63.88%	100.00%	1.71%	27.85%	70.44%	100.00%
Peravia	8	355	432	795	3	435	338	776	11	790	770	1571
	1.01%	44.65%	54.34%	100.00%	0.39%	56.06%	43.55%	100.00%	0.70%	50.29%	49.01%	100.00%
Puerto Plata	45	408	332	785	31	674	252	957	76	1082	584	1742
	5.73%	51.97%	42.30%	100.00%	3.24%	70.43%	26.33%	100.00%	4.36%	62.12%	33.52%	100.00%
Salcedo	**372**	187	110	669	**445**	295	90	830	**817**	482	200	1499
	55.61%	27.95%	16.44%	100.00%	**53.62%**	35.54%	10.84%	100.00%	**54.50%**	32.16%	13.34%	100.00%
Samaná	137	250	253	640	125	418	233	776	262	668	486	1416
	21.41%	39.06%	39.53%	100.00%	16.11%	53.87%	30.02%	100.00%	18.50%	47.18%	34.32%	100.00%
San Cristóbal	81	600	442	1,123	59	592	586	1,237	140	1192	1028	2360
	7.21%	53.43%	39.36%	100.00%	4.77%	47.86%	47.37%	100.00%	5.93%	50.51%	43.56%	100.00%

San José De Ocoa	1	79	445	525	0	296	339	635	1	375	784	1160
	0.19%	15.05%	84.76%	100.00%	0.00%	46.61%	53.39%	100.00%	0.09%	32.33%	67.58%	100.00%
San Juan	2	120	492	614	6	208	541	755	8	328	1033	1369
	0.33%	19.54%	80.13%	100.00%	0.79%	27.55%	71.66%	100.00%	0.58%	23.96%	75.46%	100.00%
San Pedro De Macorís	36	663	115	814	11	565	303	879	47	1228	418	1693
	4.42%	81.45%	14.13%	100.00%	1.25%	64.28%	34.47%	100.00%	2.78%	72.53%	24.69%	100.00%
Sanchéz Ramírez	61	288	354	703	135	479	236	850	196	767	590	1553
	8.68%	40.97%	50.35%	100.00%	15.88%	56.35%	27.77%	100.00%	12.62%	49.39%	37.99%	100.00%
Santiago	54	657	556	1,267	47	983	441	1,471	101	1640	997	2738
	4.26%	51.86%	43.88%	100.00%	3.20%	66.83%	29.97%	100.00%	3.69%	59.90%	36.41%	100.00%
Santiago Rodríguez	24	1,032	156	1,212	4	338	363	705	28	1370	519	1917
	1.98%	85.15%	12.87%	100.00%	0.57%	47.94%	51.49%	100.00%	1.46%	71.47%	27.07%	100.00%
Santo Domingo	12	222	315	549	19	928	451	1,398	31	1150	766	1947
	2.19%	40.44%	57.37%	100.00%	1.36%	66.38%	32.26%	100.00%	1.59%	59.07%	39.34%	100.00%
Valverde	34	333	256	623	14	432	324	770	48	765	580	1393
	5.46%	53.45%	41.09%	100.00%	1.82%	56.10%	42.08%	100.00%	3.45%	54.92%	41.63%	100.00%

REFERENCES

Abdulla, F.A. & Al-Shareef, A.W. (2009). Roof Rainwater Harvesting Systems for Household Water Supply in Jordan. *Desalination, 243,* 195-2007

Ahmed, W., Gardner, T. & Toze, S. (2011). Microbiological Quality of Roof-Harvested Rainwater and Health Risks: A Review. *Journal of Environmental Quality, 40,* 1-9

Ahmed, W., Vieritz, A., Goonetilleke, A., & Gardner, T. (2010). Health Risk from the Use of Roof-harvested Rainwater in Southeast Queensland, Australia, as Potable or Nonpotable Water, Determined Using Quantitative Microbial Risk Asssessment. *Applied Environmental Microbiology, 76* (22), 7382-7391.

Cain, N. (2010). A Different Path: The Global Water Crisis and Rainwater Harvesting. *Consilience: The Journal of Sustainable Development, 3 (1),* 187-196

Cairncross S, Valdmanis V (2006). Water Supply, Sanitation and Hygiene Promotion. Ch.41 in Jamison et al. (eds.) Disease Control Priorities in Developing Countries. Washington, DC, World Bank. Available at: www.dcp2.org/pubs/DCP

children in South Australia. *International Journal of Epidemiology,35,* 1051-1058.

CTO (2008). Competing with the Best: Good Practices in Community Based Tourism in the Caribbean. Available at: http://www.onecaribbean.org/goodpractices/manualsreports.aspx

Dean, J. & Hunter, P.R. (2012). Risk of Gastrointestinal Illness Associated with the Consumption of Rainwater: A systematic Review. *Environmental Science Technology, 46,* 2501-2507

Fry, L.M., Cowden, J.R., Watkins, D.W., Clasen, T., & Mihelcic, J.R. (2010). Quantifying Health Improvements from Water Quanity Enhancement: an Engineering Perspective Applied to Rainwater Harvesting in West Africa. *Environmental Science and Technology, 44* (24), 9535-9541

Garrett, V., Ogutu, P., Mabonga, S., Ombeki, Mwaki, A., Aluoc, G., Phelan, M., & Quick, R.E. (2008). Diarrheoa Prevention in a High Risk Rural Kenyan Population Through Point-of-use Chlorination, Safe Water Storage, Sanitation, and Rainwater Harvesting. *Epidemiology and Infection, 136,* 1463-1471.

Gould, J. (1999). Contributions Relating to Rainwater Harvesting. World Commison on Dams. Available at: http://oldwww.wii.gov.in/eianew/eia/dams%20and%20development/kbase/contrib/opt163.pdf

Gould, J. (1999). Is rainwater safe to drink ? A review of recent findings. Proceedings of the 9th International Rainwater Catchment Systems Conference, 1999. Available at: http://www.cpatsa.embrapa.br/catalogo/doc/quality/7_4_John_Gould.doc

Heyworth, J.S., Glonek, G., Maynard, E.J., Baghurst, P.A. & Finlay-Jones, J. (2006). Consumption of Untreated Tank Rainwater and Gastroenteritis among young

JMP (2010). Types of Drinking Water Sources and Sanitation. Available at: http://www.wssinfo.org/definitions-methods/watsan-categories/

JMP (2012). Estimates for the use of Improved Drinking Water Sources. Retrieved from: http://www.wssinfo.org/fileadmin/user_upload/resources/DOM_wat.pdf

Lehmann, C. & Tsukada, R. (2011). The Effect of Rainwater Harvesting on Reducing Poverty. Available at: http://www.inesad.edu.bo/bcde2011/Dc2011/40%20Lehmann%20Christian.pdf

Lye, D.J. (2002). Health Risks Associated With Consumption of Untreated Water from Household Roof Catchment Systems. *Journal of American Water Resources Association, 38* (5), 1301-1306.

MEASURE DHS (2007). MEASURE DHS Demographic and Health Surveys. Available at: http://legacy.measuredhs.com/aboutdhs/

Nijhof, S. & Strestha, B.R. (2010). Micro-credit and Rainwater Harvesting. IRC Symposium 2010: Pumps, Pipes, and Promises. Available at: http://www.rainfoundation.org/fileadmin/PublicSite/publications/IRC_symposium_nov.2010_Micro-credit_RainwaterHarvesting-Nepal.pdf

Onda, K., LoBuglio, J. & Bartram, J. (2012). Global Access to Safe Water: Accounting for Water Quality and the Resulting Impact of MDG Progress. International Journal of Environmental Research and Public Health, 9, 880-894.

Pandey, D.N., Gupta, A.K., & Anderson, D.M. (2003). Rainwater Harvesting as an Adaptation to Climate Change. *Current Science, 85 (1),* 46-59

Prüss A, Havelaar A (2001) The Global Burden of Disease study and applications in water, sanitation and hygiene. In: Bartram J, Fewtrell L, editors. Water Quality: Guidelines, Standards and Health. Risk assessment and management for water-related infectious disease. London: IWA Publishing.

Sazakli, E., Alexopoulos, A., Leotsinidis, M. (2007). Rainwater Harvesting, Quality Assessment and Utilization in Kefalonia Island, Greece. *Water Research, 41*, 2039-2047.

Simmons, G., Hope, V., Lewis, G., Whitmore, J., & Gao, W. (2001). Contamination of Potable Roof-collected Rainwater in Auckland, New Zealand. *Water Research, 35* (6), 1518-1524.

UN (1999). Latin America: Projection of Urban-Rural Population. Available at: http://www.eclac.org/publicaciones/xml/7/5337/BD63def00i.html

UNDP (2006). Human Development Report 2006: Beyond Scarcity Power, Povert and Global Water Crisis. Retrieved from: http://hdr.undp.org/en/reports/global/hdr2006/

UNDP (2012). The Millennium Development Goals. Available at: http://www.undp.org/content/undp/en/home/mdgoverview.html

UNDP (2012). The UNDP Climate Change Country Profiles. Available at: http://ncsp.undp.org/news/undp-country-profiles

UNICEF (2012). Water, Sanitation, and Hygiene. Available at: http://www.unicef.org/wash/

UNICEF and WHO (2012). Progress on Drinking Water and Sanitation: 2012 Update. Available at: http://whqlibdoc.who.int/publications/2012/9789280646320_eng.pdf

WHO (2009). Country profile of environmental burden of disease. Available at: http://www.who.int/quantifying_ehimpacts/national/countryprofile/dominicanrepublic.pdf

WHO (2009). Diarrhoeal Disease. Available at: http://www.who.int/mediacentre/factsheets/fs330/en/index.html

WHO (2011). Valuing Water, Valuing Livelihoods: Guidance on Social Cost-benefit Analysis of Drinking-water Interventions, with special reference to Small Community Water Supplies. London: IWA Publishing. Available at: http://whqlibdoc.who.int/publications/2011/9781843393108_eng.pdf

WHO (2012) Global Health Observatory: Mortality and Burden of Disease from Water and Sanitation. Retrieved from: http://www.who.int/gho/phe/water_sanitation/burden/en/index.html

WHO (2012). MDG 7: Ensure Environmental Sustainability. Available at: http://www.who.int/topics/millennium_development_goals/mdg7/en/

WHO (2012). Millennium Development Goals. Available at: http://www.who.int/topics/millennium_development_goals/en/