

UNCOVERING INFECTIOUS DISEASE BURDEN AND SOCIO-CULTURAL  
DETERMINANTS OF WATER USE AND HEALTH  
IN A PERI-URBAN COMMUNITY IN THE DOMINICAN REPUBLIC

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## ABSTRACT

The Dominican Republic is a low-middle income country located in the Caribbean that has been selected to be one of the seven pilot countries for the UN's Millennium Development Project. Despite the economic growth experienced by this country within recent years, improvements in basic indicators of growth and development, such as water quality, have not been achieved. Given the critical importance of quality of water for community health and economic development, this study aims to describe the burden of infectious diseases associated with water quality, particularly diarrheal disease, in the municipality of Constanza in the Dominican Republic. A convenience sample of 88 households throughout the Constanza municipality was selected. Interviews with heads of households and ethnographic observations were conducted to obtain information about access to safe and clean water and to observe cultural practices surrounding water. A household survey was administered to examine self-reported diarrheal morbidity, water handling practices, and healthcare-seeking behavior. Survey questions were modeled after the Dominican Republic Demographic and Health Survey, and communities were GPS tagged. Water samples were collected from households and selected environmental sources (e.g. aqueducts) were analyzed for *E. coli* and coliform bacteria. Despite governmental potable water treatment recommendations, the majority (60.2%) of households reported not taking any measures to sanitize their water, which accounted for the majority of individuals self-reporting diarrheal disease (59.8%). Logistic regression analysis indicates that adults aged 65+ are at highest risk for diarrheal disease. Although aqueducts carrying potable water to the communities lacked measurable coliform bacteria contamination, most households (90.1%) had some contamination in the drinking water. This study revealed poor water quality and sanitation practices surrounding drinking water. Findings from this study

will be utilized for an education program to encourage proper water storage and sanitation with the goal of increasing access to safe and clean water.

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## LIST OF ABBREVIATIONS

AIDS – Acquired Immune Deficiency Syndrome

CFUs – Colony Forming Units

ENDESA – Encuesta Demográfica y de Salud (National Demographic and Health Survey)

GDP – Gross Domestic Product

GIS – Geographic Information Systems

HIV – Human Immunodeficiency Virus

INAPA – Instituto Nacional de Agua Potable y Alcantarillados (National Institute of Potable Water and

Sewage

IRB – Institutional Review Board

mL – Milliliter

MGD – Millennium Development Goal

NGO – Non-governmental Organization

PAHO – Pan American Health Organization

PVC – Polyvinyl chloride

RD\$ - Dominican peso

SESPAS – Ministerio de Salud Pública y Asistencia Social (Ministry of Public Health and Social Assistance)

UN – United Nations

USAID – United States' Agency for International Development

WHO – World Health Organization

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## CHAPTER 1

### INTRODUCTION

Recent estimates indicate that over 1.1 billion people globally lack access to improved drinking water supplies. Globally, the sixth largest cause of mortality and the third largest cause of morbidity can be attributed to diarrheal disease, which is linked to water quality and sanitation. Despite the fact that many countries have implemented water treatment systems, these systems typically do not reach rural communities. Additionally, many of these systems are not maintained after they are built. Therefore, though water treatment systems exist within the community, many will lack the necessary working components for optimal operation (Montgomery & Elimelech, 2007). Although there has been a decrease in diarrheal mortality globally, there has been a well-documented increase in diarrheal morbidity (Kosek, Bern, & Guerrant, 2003). Since sanitation and water quality have an extremely large impact on the global burden of disease, water quality and sanitation within communities in the developing world has become one of the targets of the UN's Millennium Development Goals designed to reduce disease burden and increase quality of life (United Nations, 2009).

The Dominican Republic is a low-middle income country located in the Caribbean that has been selected to be one of the seven pilot countries for the UN's Millennium Development Project (United Nations, 2009). Despite the economic growth in recent years, there has not been a corresponding investment in basic infrastructure, such as investment in water quality and sanitation. This is exemplified in only 35.6% of aqueducts having water quality maintained, and only 11% of the urban population having continuous water service (USAID, 2006). The goal of this study is to determine the relationship between diarrheal disease and water quality in the peri-urban community of Constanza in the Dominican Republic.

### *The Setting*

The Dominican Republic is a country that resides of the eastern two-thirds of the island Hispaniola, the second largest island of the Greater Antilles, between the Atlantic Ocean and the Caribbean Sea. The country is separated from Cuba by the Wind Channel (also known as the Jamaica Channel) and Puerto Rico by the Mona Channel. The Dominican Republic has a land area of approximately 48,442 km<sup>2</sup> that is comprised of 31 provinces, 145 municipalities, and a national district. The country has a population of approximately 8.9 million inhabitants with approximately 176.8 persons per km<sup>2</sup> (US Department of State, 2009).

According to the United Nations, the Dominican Republic is considered a low-middle income country. In 2007, the Dominican Republic had a GDP of approximately US \$41.25 billion (ONE, 2007). That same year, inflation was estimated at 8.9% (ONE, 2007). However, in 2003, the economic sector was affected by a fiscal deficit, inflation of 42.7%, and a loss of 20% of the country's GDP resulted from banking fraud (PAHO, 2007). Currently, the service sector (tourism and transportation) constitutes 58.6% of the country's GDP. Industry accounts for 27.4% of the country's GDP (sugar refining, cement, pharmaceuticals, construction, and light manufacturing). Agriculture consists of 6.5% of the country's GDP (cocoa, bananas, tobacco, rice, plantains, beef, sugarcane, coffee), however very little agriculture is exported. The primary exports of the country are tobacco, meats, medical supplies, ferronickel, sugar, coffee, and textiles. The United States is the Dominican Republic's primary trading partner, with 75% of all exports (US Department of State, 2009).

Despite significant economic growth experienced by the Dominican Republic in recent years, primarily through the tourism sector, there has been little investment in social and human development. Public spending on health has remained relatively unchanged since 2002,

where public investment on health was estimated as 1.9% of the GDP. The most recent estimate of public spending on health demonstrates a slight increase in investment on health, which was estimated at 2% of the GDP in 2007. In 2005, approximately 40.9% of the population lived under the poverty line, defined as making less than \$94.20 US dollars monthly. Approximately 47.4% of the population is employed (62.8% of men and 32.0% of women) (Banco Central de la República Dominicana, 2008). Migration is prevalent; it has been reported that 1 in 10 Dominicans live in the United States (Pomeroy & Jacob, 2004).

The Dominican Republic is in a state of economic transition. In 2005, an agreement was made with the International Monetary Fund (IMF) to create monetary policies to contribute to GDP growth and economic reform. In addition to economic reform in conjunction with the IMF, the Dominican Republic is one of seven countries selected by the United Nations to pilot the United Nations Millennium Project. In accordance with the project's goals, a commission was formed to approximate the cost and strategies required to reach the Millennium Development Goals of rationalizing, redirecting, and mobilizing national resources as well as developing provincial and national plans to reach these goals (United Nations, 2009).

Constanza is located in the La Vega province approximately 140 km northwest of Santo Domingo. This municipality has a high elevation (approximately 1,200 meters above sea level), which results in a mountain climate that is conducive to the agriculturally-based local economy. The mountainous region where Constanza lies is well irrigated by streams and has many fertile valleys; the mild climate in the municipality allows for farming practices to occur year-round. The climate coupled with the terrain allows for the cultivation of commercial flowers, strawberries, legumes, potatoes, garlic, coffee beans, and a wide variety of vegetables. There are small clusters of communities, but typically households are dispersed throughout the countryside. Due to the rural nature of this municipality, quality and access to health care

presents a problem. The health surveillance within the region consists of 10 rural clinics that report health information to one municipal hospital, which reports to the provincial hospital in La Vega (Ugalde, 1984). As this surveillance system is highly fragmented, the level of consistency between the level to which communicable diseases are being reported by the health surveillance system and what is being experienced by the community of Constanza is not well documented.

### **Conceptual Frameworks:**

#### **Social Determinants of Health and Political Ecology**

Two conceptual models were utilized to understand the burden of disease in the municipality of Constanza: the Social Determinants of Health and the Political Ecology model.

##### *Social Determinants of Health*

The social determinants of health are considered to be societal conditions that can affect health and are able to be altered by redistribution of resources (Krieger, 2001). Specifically, the social determinants of health are utilized to explain health inequalities within, and even between, populations. The social determinants of health theory describes how health outcomes are strongly linked to access to resources. For example, if a population does not have access to clean water, sanitation, and basic healthcare, the health outcomes of that population will be lower than those populations that have access to those resources (Rose, 2001).

Many differences in health outcomes are linked to inadequate public policies. If a public policy such as implementing clean water is inefficient (i.e. clean water is not being adequately provided) groups with greater access to resources, generally groups with higher socioeconomic status, will have the ability to circumvent inefficient policy. Many groups with higher

socioeconomic status will be able to purchase means to have access to clean water, either by purchasing clean water outright or by purchasing a method to sanitize the water, whereas poorer populations generally do not have any other option but to drink whatever water is available, regardless of how contaminated the water may be (Marmot, 2001).

The social determinants of health have been predominately utilized to explain health disparities both between and within populations. Particularly, the social determinants of health have been used to explain health disparities of both chronic and communicable diseases at the social and policy levels. In the Latin American and Caribbean region, the social determinants of health have been predominately utilized to describe differences in health outcomes between socioeconomic classes (Casas, 2001).

Globally, the Latin American and Caribbean region has the most unequal distribution of resources in the world, and this inequality in access to resources is reflected in health outcomes between different socioeconomic groups (Casas, 2001). In lower socioeconomic groups, it has been found that the incidence of communicable diseases is much higher than those of higher socioeconomic status. Additionally, life expectancies of individuals of lower socioeconomic status residing in the Latin American and Caribbean region have been found to be lower than individuals of higher socioeconomic status residing in the Latin American and Caribbean region (Marmot, 2005). Furthermore, it has been determined that communicable diseases have a tendency to cluster both geographically as well as socially, especially in poorer communities. This is evidential that individuals that are exposed to similar social situations as well as similar access to certain resources are generally afflicted with similar health outcomes (Ehrenberg, 2005).

### *Political Ecology*

The theory of political ecology can be defined as an “interdisciplinary approach to the study of the interconnections between society and environment ... by anthropological perspectives that draw out the cultural meaning and practices through which people perceive, use and live in their environments” (Harper, 2004 p. 297). This theory explains how resources, particularly environmental resources, are distributed throughout societies as a result of culture, politics, history, and power. Particularly, those who have better access to environmental resources are those who traditionally have more cultural, political, and economic power. Additionally, much of this access to resources is mitigated by governmental actors. That is, the disparity of natural resource allocation is either further encouraged or discouraged by governmental actors (Budds, 2004).

Governmental policies regarding allocation of resources within populations can be used to reinforce current gaps between socioeconomic status and political power, which can influence health outcomes. This situation is exemplified in communities such as Kay, located in Haiti’s rural Central Plateau. This community was affected by a project drafted by the Haitian government to create the largest dam in Haiti. Once an agrarian community located in fertile valley, the creation of a large dam caused the valley where this community was located to become a reservoir. The rising floodwaters forced the population into the stony, barren hills located on both sides of the resultant reservoir, effectively destroying the local economy. The now landless peasants no longer had access to farmland, water, or electricity. Due to a multitude of problems, including political decision-making, migratory patterns, and natural resource allocation, populations such as these in rural Haiti have become refugees in their own country. Many of these refugee populations within Haiti suffer from poorer health outcomes, such as tuberculosis and HIV/AIDS, due to the lack of access to health services and natural



resources, such as clean water. This lack of resources causes these refugee populations to not adapt well to any change that is made to their environment, especially drought. As these refugees have virtually no political or economic power, their access to resources is effectively minimized (Farmer, 1996).

Additionally, the theory of political ecology also serves to explain how societies adapt to environmental change. Certain groups within society are unable to adapt as well as others to environmental change. There are many factors that can mitigate the ability for a group to adapt; however many of these factors are correlated to socioeconomic status, political power, and culture. The differences in political and economic power within societies results in certain groups being able to adapt to environmental change, others being unable to adapt, and certain groups being able to adapt in the short term, but this adaptation may be unstable. The result in environmental change in these societies is that adaptation to environmental changes occurs, however, it is extremely uneven throughout the society (Harper, 2004).

### **The Dominican Health Sector**

The national healthcare system in the Dominican Republic underwent significant reform in 1997 (Armada, Muntaner, & Navarro, 2001). The system is comprised of two subsystems: the collective health subsystem and the individual care subsystem. Both of these systems are overseen by the Ministerio de Salud Pública y Asistencia Social (SESPAS). The collective health subsystem is composed of a series of programmatic networks and public health programs that are directed at the control and prevention of priority health problems as well as health promotion. Most of these programs are financed solely by international donations and loans and receive government funding only during national emergencies; this, in combination with

these programs having very centralized, vertical structures, greatly limits their effectiveness and sustainability, which makes these programs in great need of restructuring and reform.

Currently, there are measures being undertaken to restructure some of these programs (Glassman, Reich, Laserson, & Rojas, 1999).

Of all public health programs in place, the programs that are the most highly organized and financed are designed to control and prevent communicable diseases that can realistically be controlled or eradicated. Examples of such programs are leprosy eradication programs, immunization programs, and disease control programs to prevent rabies, malaria, dengue fever, HIV/AIDS, and tuberculosis. The individual care subsystem is divided into both public and private health care providers; each sector of this subsystem is comprised of primary, secondary, and tertiary levels of care. Public health care providers are financed under the National Health Insurance and are divided into Regional Health Services, which are considered legally autonomous of each other (PAHO, 2007).

Overall, the health sector is extremely mixed in nature, being comprised of private institutions, nongovernmental organizations, and public institutions. SESPAS's health care system is organized among provincial, regional, and central levels and is considered to be the main provider of public services. The provincial level of SESPAS is in charge of ensuring local insurance coverage, establishing health facilities, ensuring access, quality, and performance of public and private healthcare providers, and ensuring that services are being delivered (Glassman et al., 1999).

#### *Health Indicators and Poverty*

According to the World Bank, in 2002, the minimum wage in the Dominican Republic was estimated at RD\$ 19, and the average annual income of Dominicans was estimated at RD\$ 46,287. Many households in the Dominican Republic receive remittances from abroad. The

average urban household receives RD\$ 7,627 a year in remittances, and the average rural household receives RD\$ 5,788 a year in remittances. By the end of 2004, approximately 687,000 (19.69%) of Dominicans were unemployed; the likelihood of an individual being unemployed significantly increased if one was not the head of household (i.e. women and youth) and if one lived in a household that received remittances (World Bank, 2006). Additionally, the highest amount of unemployment existed with those who work in the mining industry. According to the World Bank, approximately 4.9% of the population in the La Vega province are considered to be living in extreme poverty (unable to afford enough food to cover basic caloric intake), which is higher than the national average. After the economic crisis of 2004, poverty (not enough income to afford basic caloric intake and non-food expenditures) in the Dominican Republic spiked to 16% (1.5 million people) and 7% (670,000) fell into extreme poverty. Currently, 42 out of every 100 Dominicans is poor, and 16 out of every 100 Dominicans is extremely poor (World Bank, 2006).

Despite the high amounts of economic growth seen in 1997-2002, very few Dominicans in the lower economic class saw increases in income and improvements in quality of life. The Dominican Republic has a very unequal distribution of income in the region, with an average amount of unequal distribution in comparison with other countries in Latin America and the Caribbean, the most unequal region of income distribution in the world (World Bank, 2006).

Constanza is located in the Cibao Central geographic region of the Dominican Republic. In 2004, approximately 6.94% of homes were assessed to be made of poor building materials in this region. Additionally, 38.36% of homes had an impoverished appearance. Advances in access to electricity have been successful in urban areas, but a gap of coverage exists between urban and rural areas. Approximately 95% of urban homes have access to electricity, but only 78% of rural homes have access to electricity (World Bank, 2006). Relatively high coverage in the

region is juxtaposed to high irregularity in the provision of this service particularly in the more rural communities.

#### *Demographic Transition in the Dominican Republic*

The Dominican Republic is in a state of demographic transition. The demographic shift in the country is marked by a drastic increase in the urban population between the years of 1993 to 2007 (from 35% to 64.4%). Between the years of 2000 and 2007, life expectancy from birth rose from 68.6 years (66.5 for men and 70.8 for women) to 72.0 years (68.9 for men and 75.2 for women). The gross birth rate declined from 24.5 per 1,000 population to 23.0 per 1,000 population; and the general fertility rate fell from 2.8 births per woman to 2.7 births per woman (PAHO, 2008). The gross mortality between the years of 2000 and 2007 rose from 5.9 per 1,000 population to 6.0 per 1,000 population. Overall, the population has seen an increase of 1.4% between 2007 and 2008. These factors have led to significant changes in the country's age structure (PAHO, 2008; PAHO, 2007; Pomeroy & Jacob, 2004).

#### *Chronic and Infectious Diseases*

In 2005, illness due to the circulatory system was the leading cause of death (33.7%) in adults, followed by external causes (14.7%), and malignant neoplasms (13.9%). Communicable diseases, mainly AIDS and tuberculosis, accounted for 10.7% of morbidity in 2005; however, underreporting estimated these two conditions at 50%. Malaria and dengue are endemic within the region, and a significant public health problem is diarrheal infectious diseases (Achezar et al., 2008; PAHO, 2008).

Diarrheal morbidity among children under 5 years of age is a concern in the Dominican Republic that is specifically monitored. Currently, diarrheal disease is the leading cause of pediatric mortality and morbidity in the Dominican Republic (Thind, 2003). The Encuesta Demográfica y de Salud (ENDESA) reported that 14.7% of children under 5 had been reported to

have diarrhea two weeks before the survey was conducted in 2007 (a 0.7% increase from 2002), with infants under 6 months old (12.7%) and children between 6 and 24 months old (24%) being the age groups with the highest incidence of diarrheal morbidity. Morbidity from diarrheal disease in children under 5 years of age accounted for 3.7% of deaths in this age group in. Additionally, 52.5% of children under 5 years of age seek treatment for diarrheal disease from a healthcare provider, and 40.5% of children under 5 use oral rehydration therapy to treat diarrheal disease (Achechar et al., 2008; PAHO, 2008). Approximately 65.5% of schoolchildren are infected with intestinal infectious diseases, particularly *Entamoeba coli* (26.7%), *Blastomyces hominis* (27%), and *Giardia lamblia* (17.7%) (PAHO, 2008).

#### *Water and Sanitation*

Target 10, Goal 7 of the Millennium Declaration is designed to “*Halve by 2015 the proportion of people without sustainable access to safe drinking-water and sanitation*” (United Nations, 2009). The Millennium Declaration was created by the United Nations (UN) in September 2000. This declaration is a set of development goals designed to decrease global poverty and increase quality of life of billions of people by 2015, and each Millennium Development Goal is intended to target a specific aspect of poverty or disease burden (United Nations, 2009).

Basic sanitation services and water are still not accessible to the entire population of the Dominican Republic as evidenced by 1.5 million individuals without access to piped water (Abreau, 2005)). In 2007, it was reported that 86.1% of the population had access to potable water (Abreau, 2005). In rural areas 62% of the population had access to potable water, through access to faucets connected to an aqueduct less than 500 meters from the home (USAID, 2006). Between 1990 and 1998, an average of US \$90.0 million was allocated to potable water and sanitation annually; however, only \$2.1 million of these funds were allocated to

sanitation. The number of individuals that receive intra-home coverage (water that is piped into the home) has decreased (from 45.0% in 1993 to 37.4% in 2002) due to individuals migrating to outside urban areas (Abreau, 2005).

Vast inadequacies in the operation and maintenance of water systems as well as the lack of basic disinfection and treatment of the water are prevalent throughout the country, especially in rural areas (Abreau, 2005). Within the populations that actually receive water coverage, basic service indicators, such as sewer treatment, uninterrupted service, and quality of potable water, have been found to be in critical condition (Abreau, 2005). It has been reported that approximately 52% of liquid waste remains untreated before it is disposed of in bodies of water.

Of the water services that are provided, there have been great discrepancies between quality and coverage throughout the country, particularly between urban and rural areas. Coverage was more prevalent in urban areas (91.7%) over rural areas (73.3%). Basic sanitation services were received by 96.2% of the population in the same year, with more coverage in urban areas (97.9%) over rural areas (92.5%) (Abreu, 2005). The number of individual homes that have direct connections to a sewer system network is 20.1% of the population, primarily in urban areas (31.4% of the urban population). A sewer system network serving the rural population is non-existent (USAID, 2006). The trend of rural populations having less access and quality of services is seen across the board for all water services rendered. Coverage of adequate sewage disposal (i.e. latrines or connections to the sewer system network) is extended to 93.2% of the population, but 96.4% of the urban population has the coverage whereas only 87.7% of the rural population has adequate sewage disposal. Chlorination systems are installed in only 61.4% of the aqueducts (87.4% urban, 47.4% rural). Water quality control is maintained in only 35.6% of the aqueducts, with a large discrepancy seen between urban (67.9%) and rural

(18.2%) communities. Continuous water service is never seen by rural communities, and only 11.0% of urban populations receive continuous water coverage (USAID, 2006).

Water service is provided by the Instituto Nacional de Agua Potable y Alcantarillados (INAPA). Standards for potable treated water were created in a 1997 agreement made between the Dominican Republic and PAHO. This agreement states that there can be no fecal coliforms in water that enters the water distribution system, water that is carried in the water distribution system, or water that is utilized for human consumption. It was also established that total coliform count is not utilized to determine water quality. This agreement also establishes that water quality is managed by SESPAS ("Reglamento Calidad del Agua Potable," 1997). The Dominican Republic is one of the few nations in Latin America where water sanitation is managed by the Public Health State Secretariat that is not directly and commonly coordinated with potable water programs. Consequently, sanitation of water is extremely difficult to coordinate within the governmental infrastructure, largely due to the lack of a central organization that maintains the set standards and ensures that these standards are met. Despite the fact that there has been a significant increase in resource allocation within the government to provide services to the population, the majority of resource allocation has been directed at building new services, not maintaining the existing infrastructure (Witter & Carrasco, 1996).

The lack of access to dependable water services has become highly politicized. There have been a number of protests in the country due to interrupted water service (Ponce, 2009). Some individuals have reported water service being interrupted for over one month, and these customers had to search for water by walking long distances to fetch water from the nearest river (Ponce, 2009). If they can afford it, community members with access to the resources often purchase large bottles of purified water for consumption, rather than drink the water

provided by INAPA; however, until recently, there has been an extreme lack of oversight in terms of ensuring that the bottles of purified water coming from the water treatment plants are of high quality. In a recent mandate by SESPAS, 270 of the 481 water treatment plants (56%) were audited for having the necessary infrastructure for testing water before it was bottled for consumption; and over half (150 plants) were slated to be closed down for not maintaining the necessary equipment (Altagracia, 2009).

#### *Water Quality and Diarrheal Disease*

Diarrheal disease related to unsafe water accounts for approximately 1.6 million deaths worldwide annually. Recent estimates by the WHO estimate that globally, approximately 1 billion people do not have access to an improved water source (WHO, 2009). Diarrheal diseases are caused by enteric pathogens that infect the gastrointestinal tract and are shed from the host into the environment through excreta. Once shed into the environment, enteric pathogens can be transmitted by either person-to-person contact or ingested through infected food or water (Leclerc, Schwartzbrod, & Dei-Cas, 2002).

There are four epidemiological categories that are utilized to classify water-related infectious diseases: water-based, water-washed, waterborne, and water-related infectious pathogens (Leclerc, Schwartzbrod, & Dei-Cas, 2002). Water-based infectious pathogens survive in water for a necessary component of their lifecycle. Water-washed pathogens are transmitted due to an inadequate amount of water that is available for bathing or washing. Waterborne infectious pathogens are transmitted through the ingestion of water that is fecally contaminated. Water-related infectious pathogens are transmitted through an insect vector that either breeds in or bites near water (Bradley, 1977). The literature reveals that the majority of interventions that are devised to target diarrheal disease are directed toward waterborne pathogens. There are three classes of waterborne pathogens: bacterial, viral, and parasitic. It



has been well documented that, in developing countries, all three pathogens pose a significant threat in terms of increased risk of diarrheal disease as well as overall quality of health (Eisenberg et al., 2006).

There have been a number of epidemiological field studies that have focused on identifying the correlation between water quality and diarrheal disease with two dominant paradigms: water quality as it relates to the environment and water quality as it relates to the household (Esrey, 1985). Assessing water quality as it relates to the environment and forming interventions first emerged in the International Water, Sanitation, and Hygiene Decade (1981-1990). The dominant paradigm in this period emphasized that a larger impact on diarrheal disease reduction is achieved via environmental, rather than household, improvements in water quality. A review of 67 studies from 28 countries conducted by Esrey et al. in 1985 indicated that improvements in only household water quality decreased diarrheal morbidity by a median of 16% (range 0-90%); however, an improvement in environmental factors such as water availability and source water quality leads to a reduction in diarrheal morbidity by a median of 37% (range 0-82%) (Esrey, 1985).

Later in 1991, this review was updated and expanded to cover 144 studies where the effects of water quality were correlated to the reduction of specific pathogens that are associated with waterborne illness. It was found that a median reduction in diarrheal morbidity due to improvements of sanitation alone was 27%, hygiene led to a 33% reduction, water quantity led to a 27% reduction, water quantity as well as sanitation led to a 20% reduction, a 17% reduction was found for water quality alone, and a 16% reduction was found for water quality coupled with sanitation (Esrey, 1991). This expanded literature review reaffirmed initial findings that the intervention that has the least impact on reducing diarrheal morbidity is improving water quality. These two reviews formed the dominant paradigm of focusing studies

and interventions away from household water quality and toward a more environmentally-centered focus of sanitation and water quantity (Clasen & Cairncross, 2004).

Despite these findings, there has been a significant decrease in diarrheal mortality, but not morbidity in the past decade (Kosek et al., 2003). This has created a shift in the paradigm from environmentally-centered studies and interventions to household water quality within the past decade. A recent review of 21 studies reveals that there is a median reduction of diarrheal morbidity of 42% when the general microbiological quality of the water in the household is improved (Clasen & Cairncross, 2004). This pronounced decrease in diarrheal morbidity can be attributed to the fact that previous studies focused on environmental sanitation and water quality at the source, not at the household level. The increase in the quality of water that is actually consumed within the household has become the focus of this paradigm shift in the approach to reduce diarrheal disease morbidity and mortality (Arnold & Colford, 2007; Clasen & Cairncross, 2004; Fewtrell et al., 2005; Gundry, Wright, & Conroy, 2004).

Given the information gathered on poor access to water, piped sewer systems, and diarrheal morbidity, this study will seek to understand the access to quality water among household members in Constanza. As most areas in the Dominican Republic do not have access to piped water or sewer systems in the home, it will be imperative to determine if the lack of sewer access affects overall quality of water for consumption. Since most diarrheal diseases are transmitted via fecal-oral contamination, this study will seek to determine if there is a possible connection between water quality and access to water with diarrheal disease morbidity among community members in Constanza.

## CHAPTER 2

### METHODS

This study sought to determine the socio-cultural determinants of infectious disease and to describe water use and water handling practices in the region of Constanza. Data collection methods employed include: participant observations, household surveys, microbiological water analysis, and Geographic Information System (GIS) mapping. Arrangements for data collection were approved by the Institutional Review Board (IRB) of Indiana University Bloomington campus (Appendix 1).

#### Household Surveys and Participant Observations

Household surveys were employed to examine the socio-cultural determinants of water use and burden of diarrheal disease among community members (Appendix 2). These surveys were employed to examine the perceptions of community members about infectious diseases and to uncover local views regarding the socio-cultural factors that may be connected to water use from water sources located in the community (Ehrenberg & Ault, 2005).

The household survey contained 17 questions modeled after the Dominican Republic Demographic and Health Survey (DHS) (Achezar et al., 2008). These surveys collected demographic information (age, gender, number of individuals living in the house, etc.) and self-reports on diarrheal disease and stomach problems experienced by members of the household in the last 30 days prior to the survey. Health seeking behaviors were examined through questions related to actions taken to remedy the diarrheal disease once onset occurred (i.e. frequency of going to a healthcare professional, actions taken by the healthcare professional, medications taken, etc.). Information was obtained regarding water for consumption within the households (such as the source of potable water, source of water for bathing and washing clothing, and actions taken to clean potable water). General information on type of sanitation

facilities within the house as well as electrical supplies were also collected from each household interviewed.

These surveys were conducted in 11 different communities throughout the municipality of Constanza. Seven communities were selected for this study by the director of the municipal public health hospital based on clinical observations that appeared to indicate a higher number of diarrheal disease cases from these seven communities. The remaining four communities were selected based on their proximity to the Pantunfla River that runs through the municipality. These communities were selected by the local partnering NGO, Clúster Ecoturístico Constanza.

A non-probability sample of 88 households across the 11 communities was selected, 8 households per community. In accordance with standards set forth by IRB approval, only individuals over the age of eighteen were interviewed. Additionally, each individual was required to give oral consent to participate in the study.

#### *Water Sampling*

Samples of water used for consumption at the household level were collected at the time of survey, and were also collected from the eleven different communities included in the study (Appendix 3). Additionally, environmental samples were collected throughout the community as follows: samples of the river that runs throughout the municipality, as well as samples from the aqueducts and water treatment plants that provide potable water to the community. To determine basic levels of water quality and sanitation, the water samples collected were analyzed to quantitate coliform bacteria present in the stream. This was accomplished using Coliscan Easygel media (Micrology Laboratories, Goshen, Indiana), which is an EPA-approved method of determining water quality (Micrology, 2009).

*Escherchia coli* is one of the most well established indicator organisms utilized to determine basic sanitation of water used for consumption. Coliscan media was utilized to culture both *E. coli* and coliform bacteria. This method was selected because of its ideal condition for the field, given that the media is already prepared and it is able to be poured and set at room temperature. Utilizing this methodology avoided the costly laboratory infrastructure typically required for preparing media. The Coliscan method has been utilized throughout the literature and within the industry as a reliable, consistent method in determining water quality through the presence of coliform bacteria (Olstadt, Schauer, Standridge, & Kluender, 2007; Manafi, 2000).

#### *Geographic Information Systems*

Geographic Information Systems (GIS) was utilized to map the location of water samples within the municipalities as well as the distance of self-reported diarrheal disease from tested water sources. GPS coordinates were obtained for each household and for the selected locations of environmental water samples (e.g. aqueducts, river). These were incorporated into GIS software (Google Earth) to assess spatial relationships between diarrheal disease occurrence and water quality.

## CHAPTER 3

### RESULTS

#### *Household Surveys*

Demographic data and information on gastrointestinal problems were collected during the period of June 24 and July 13, 2009, a total of 88 household surveys were conducted in 11 selected communities (8 households for each community) throughout the municipality of Constanza. Bilingual researchers conducted the household surveys with assistance from collaborators from the local NGO providing institutional support. Data was collected on 374 individuals residing in the 88 households. Adults of 18 years or older were interviewed in each household. The interviews were conducted with the head of household or someone designated by the head of household to respond to the questions. Seventy-nine adults were self-identified as head of the household.

The average household size was 4.3 individuals, ranging from 1-11, with a standard deviation of 1.8. El Chorro had the largest mean household size of 6 individuals, whereas Palero had the smallest mean household size of 3.4 individuals.

#### *Age and Gender*

The mean age of individuals surveyed was 27.9 years with a range of 6 months to 100 years. The average age of females within the household sample was 29 years with a range of 6 months to 100 years. The average age of males within the surveyed households was 27.0 with a range of 8 months to 80 years. An age distribution of all household members participating in the study can be seen in Figure 1.

Approximately 46.8% of respondents were female. Children aged 0-4 years represented 7.8% of the sample, with 48.3% of respondents being male and 51.7% being female. Children aged 5-9 years represented 11.2% of the sample, with 38.1% of respondents being female and

61.9% being male. Children aged 10-14 represented 10.7% of the sample, with 60% of respondents being males and 40% being females. The age group comprising the largest percentage of the sample size is the 15-24 years age group, representing 21.7% of the sample, with 56.8% of individuals in this age group being males and 43.2% being females.

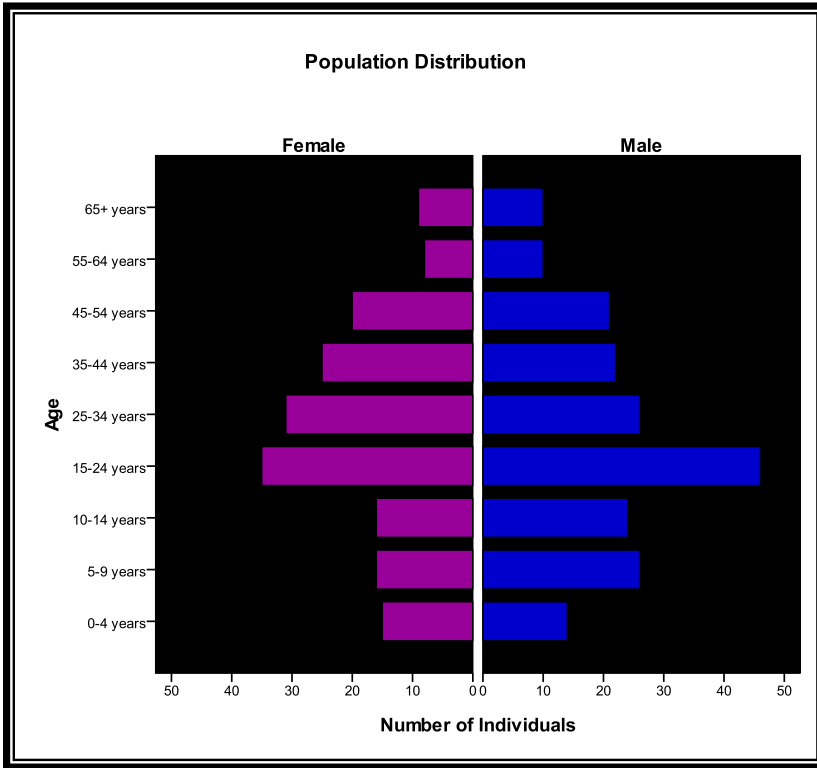
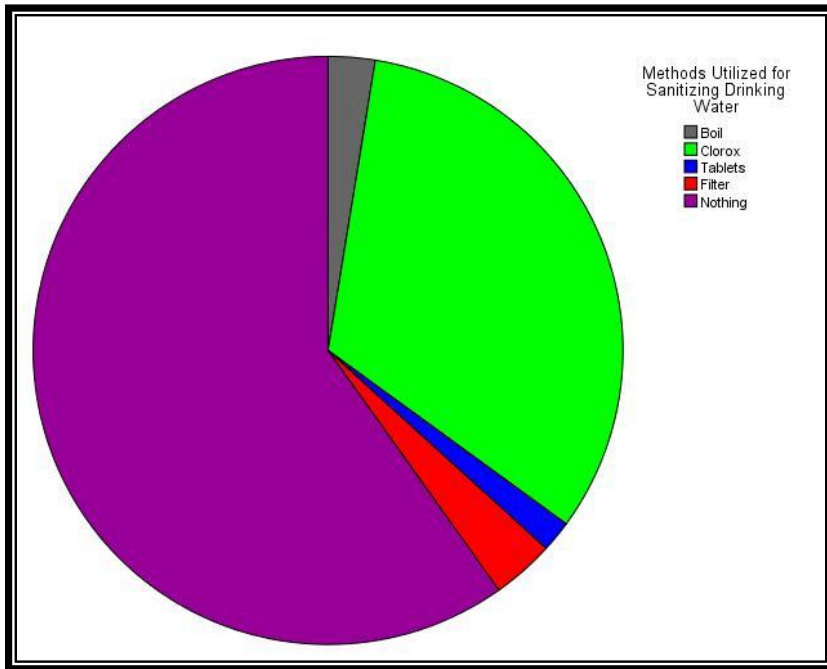


Figure 1: Population Distribution

The majority of households interviewed obtained water from the faucet, with 56 of 88 (63.6%) households obtaining their drinking water from this source. The community of Cañada Seca had the largest amount of households reported obtaining drinking water from the faucet, with all 8 households using faucet water for drinking. The community of Tireo had the least amount of households reporting the use of potable water from the faucet, with only one household. Approximately 48.2% of households using water from a faucet took additional measures to clean the water prior to consumption. The primary method to clean water was to

use chlorine, with 41.1% of households using this method to clean the water. Other methods utilized to clean the water prior to consumption were to both boil and filter the water. These methods were reported by two households in the sample. Sixty-four percent of households using water from the faucet for drinking water had at least one household member reporting diarrheal disease within the previous month. Individuals reporting diarrheal disease broken down by method of sanitizing water for consumption are depicted in Figure 2. Of these households, approximately 55.6% reported not taking any measures to clean the water prior to consumption, and approximately 36.1% of households reporting diarrheal disease utilized chlorine to sanitize water from the faucet that was utilized for consumption. Of these households, all individuals that utilized a filter to clean their potable water had a member of the household reporting diarrheal disease.



*Figure 2: Methods Utilized for Sanitizing Drinking Water*



The second most frequently reported source of water utilized for consumption by household members was bottled water, with 34.1% of all households reporting using this source of water for consumption. The community of Tireo had the most households reporting as using bottled water for consumption with six households. Conversely, none of the households in Cañada Seca reported using bottled water for consumption. The majority of respondents in the sample (76.7%) took no methods to sanitize water prior to consumption, six households used chlorine to sanitize the water, and one household boiled the water prior to consumption. Of the households that reported using bottled water for consumption, 66.7% of these households reported having at least one household member having diarrheal disease within the past month. Approximately 80% of these households report not taking any other measures to sanitize their water; three of these households utilized chlorine and of these households reported boiling the water prior to consumption.

Most households (86.4%) reported using water from the faucet for bathing and laundry. Of these households, 65.8% had at least one household member report diarrheal disease within the past month. The second most prevalent source of water for bathing and cleaning clothing was the use of a cistern (12.5% of households interviewed). Approximately 54.5% of all households using water from a cistern for bathing and cleaning clothing had at least one family member reporting diarrheal disease within the past month.

All households interviewed had access to a sanitary facility. Approximately 69.3% of households interviewed had access to sanitary facilities located in the home. Twenty-seven percent of households had access to sanitary facilities that were located outside the home and 3% had access to sanitary facilities that were located both inside and outside the home. The community reporting to have the most sanitary facilities within the home was El Eden, with all eight households having indoor sanitary facilities. Conversely, the community that had the

lowest number of sanitary facilities located indoors was El Chorro, with six households. Of all households reporting diarrheal disease within the prior month, 71.9% these households had sanitary facilities located inside the home; 22.8% had sanitary facilities located outside the home; and all three households reporting having sanitary facilities both inside and outside the home reported at least one household member as having diarrheal disease within the past month. Respondents were asked to self-report diarrheal diseases and stomach problems that occurred within the prior month. Of all households interviewed, 57 of the 88 households had at least one respondent self-reporting diarrheal disease within the past month. The community that had the highest number of households with at least one member of the household reporting diarrheal disease was La Sabina with 7 of 8 households reporting diarrhea. Of all households interviewed, approximately 177 respondents reported as having diarrheal disease within the past month. Individuals self-reporting diarrhea broken down by community is depicted in Figure 3.

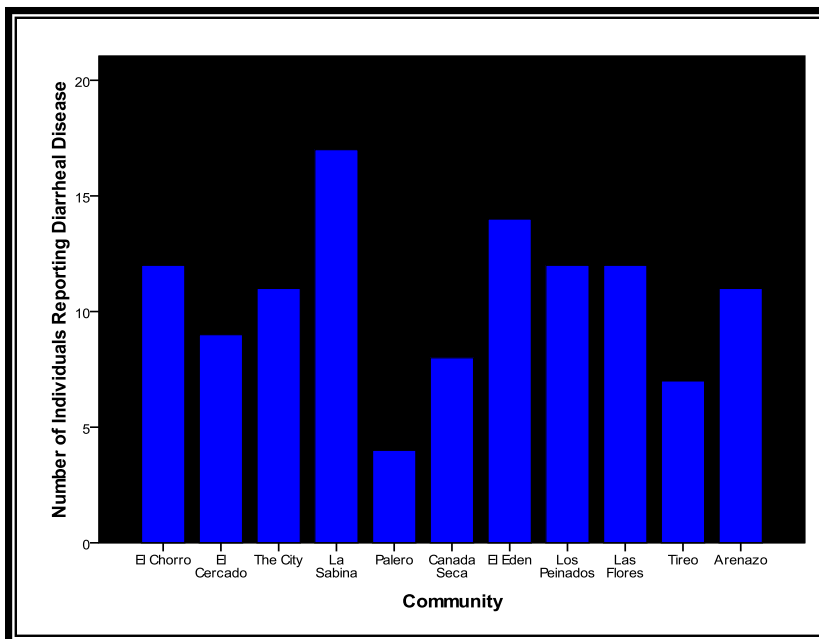
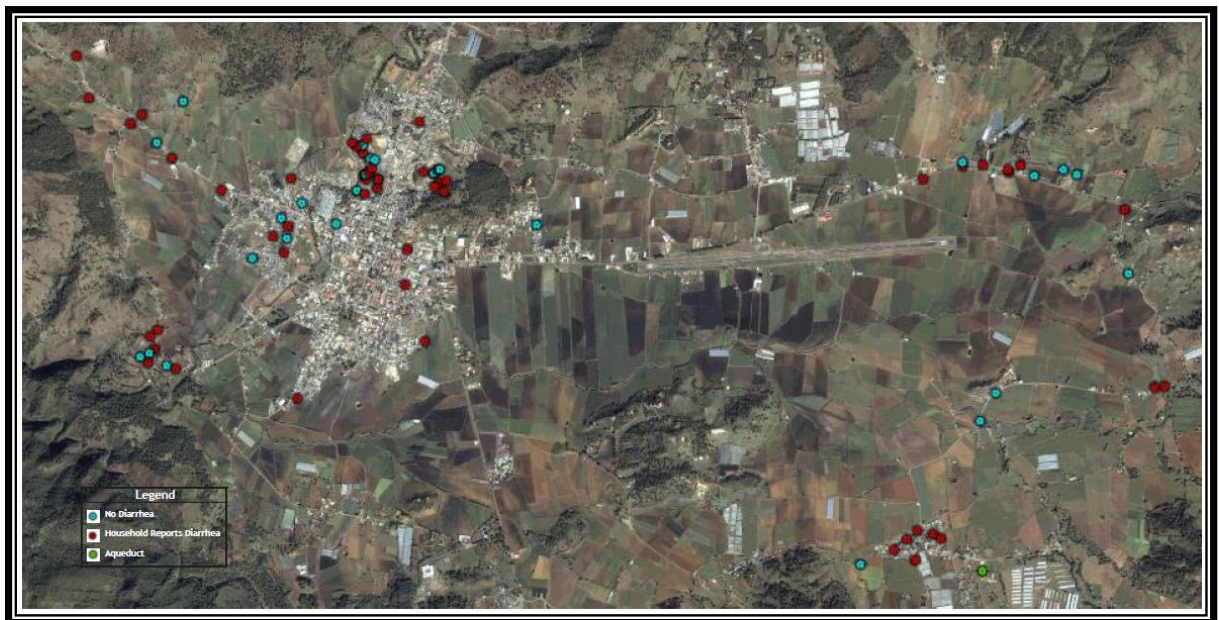


Figure 3: Number of Individuals Reporting Diarrheal Disease by Community

Of these 177 individuals, approximately 19.2% reported as seeing a health care provider for their symptoms. Palero had the smallest amount of households with at least one individual reporting diarrheal disease, with 3 of 8 households reporting diarrheal disease. The community that had the highest number of individuals reporting diarrheal disease was La Sabina with 17 household members reporting diarrheal disease. The community with the least amount of individuals reporting diarrheal disease was Palero with four individuals. Health care seeking behavior varied according to community. Los Peinados had the highest amount of individuals exhibiting symptoms of diarrheal disease seeking a health care provider, with 50% of respondents seeking healthcare, whereas El Chorro had the least amount of individuals seeking health care, with no individuals with diarrheal disease seeking care. Households with diarrheal disease for the Constanza municipality minus Tireo are depicted with GIS in the map below in Figure 4.



*Figure 4: GIS Map of Households Reporting Diarrheal Disease*

Descriptive data shows that males exhibit the highest number of self-reported cases of diarrheal disease, with 32.7% of all males having diarrheal problems 30 days prior to the survey disease, accounting for 55.6% of all cases of diarrheal disease reported by heads of households. The communities of El Eden and Los Peinados had the highest number of males reporting diarrheal disease, with 10 members each. Conversely, La Ciudad had the smallest amount of males reporting diarrheal disease, with three respondents. Approximately 29.7% of all women report having diarrheal disease, making up the remaining 44.4%, of the reported cases of diarrheal disease. La Ciudad had the highest number of females reporting diarrheal disease, with eight females, whereas Tireo had the smallest number of females reporting diarrheal disease, with only two individuals. Females account for the majority of individuals reporting visiting a doctor for their symptoms, with 38.5% of women reporting seeking a health care provider due to diarrheal disease, which accounts for 58.8% of all respondents seeking a healthcare provider for their symptoms. Only 21.5% of males reported visiting a doctor for their symptoms of diarrheal disease.

Diarrheal disease was more frequently reported for the 65+ age group with 68.4% of cases in this age group experiencing diarrhea in the last 30 days prior to the survey. Figure 5 shows individuals with diarrheal disease by age group. Health care seeking behavior in this age group is much higher than the average, with 46.2% of respondents seeking health care for their symptoms, compared to children aged 0-4 years that had the fewest number of respondents seeking health care (10%). The age group with the second highest number of individuals experiencing diarrheal disease is the 45-54 age (41.5% of cases). Conversely, the age group with the fewest number of individuals experiencing diarrheal disease was children aged 10-14 (12.5%). The age group that has the highest number of individuals seeking healthcare behavior is the 55-64 age group, with 85.7% of all respondents that experienced diarrheal disease seeking

a healthcare provider for their symptoms. Conversely, the 15-24 age group had the least amount of individuals seeking healthcare, with only 7.7% of individuals experiencing diarrheal disease within this age group.

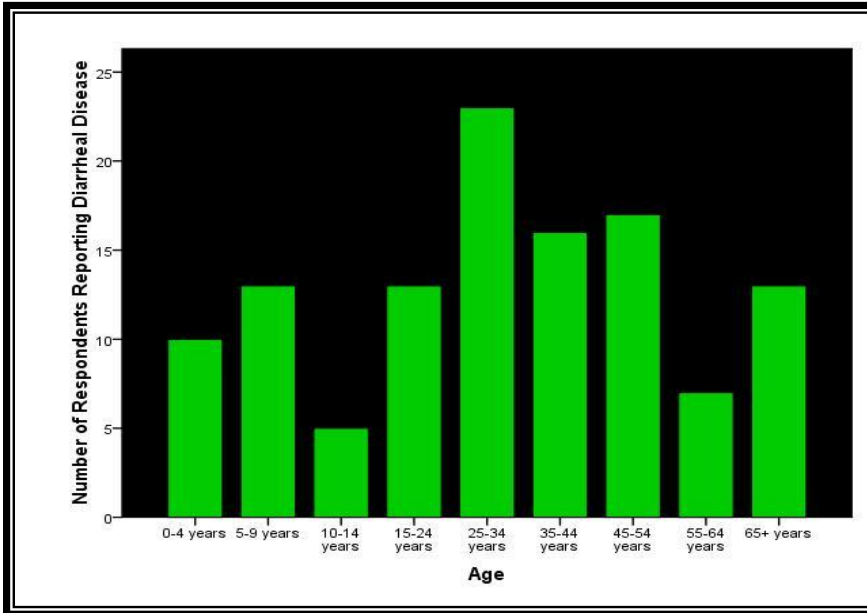


Figure 5: Number of Respondents Reporting Diarrheal Disease by Age

#### PARTICIPANT OBSERVATIONS

##### *El Chorro.*

Participant observations indicate that the community of El Chorro (Figure 6) is among one of the poorer communities of the Constanza municipality. This community is located by the River Pantunflas. There are no paved roads within the community, and very few homes had indoor plumbing. Respondents from this community reported receiving water from an aqueduct located in the La Culata community, about 15-20 kilometers away; however, a few homes on the very edge of the community reported receiving water from a different source.



Figure 6: El Chorro

Ethnographic data suggest that there was a large discrepancy between the quality of housing and use of water and water quality. Homes that consisted of corrugated building materials generally had sanitary facilities that were located outside, and were often shared with other households. In contrast, homes that were made of concrete seem to have better water quality and sanitary facilities located in the home, including indoor plumbing; however, it was not apparent that there was any sort of septic system located in the community. Additionally, participant observations revealed that concrete homes appeared to utilize bottled water as the primary source of water for consumption as well as the use of a cistern while houses made of corrugated materials did not.

Children were seen washing their hands in the water runoff found in the gutters of the street. There was a significant amount of wastewater runoff pouring into the street from the houses in the community. Most of the water was grayish and cloudy, with the appearance that it was from bathing or doing laundry. It appeared that any wastewater that emanated from the

homes was washed down the street. With the exception of the few homes that are made of concrete, virtually every household in this community receives their water from a public water faucet. Homes that receive water from a public water faucet take the water from a spigot located between a few houses or on the side of the road, and then the residents fill jugs that in turn fill up a large container resembling a trashcan. Children were seen bathing in their yards in a large tub of grayish water, which was obtained from an outdoor faucet. This community also had a significant amount of exposed white PVC pipes that came from various housing units, but it was not entirely clear where these pipes were going.

#### *El Cercado.*

The community of El Cercado (Figure 7) had a very pronounced presence of missionaries from the United States. This community was located between the center of the city and the community of El Chorro. In the center of the community, there was an orphanage named “Arca Para Niños”. I obtained an environmental sample from the well of this orphanage, as some of the staff of the orphanage were concerned about the water quality that was coming from the well. During the visit to this community, it was found that most of the residents had not had potable water access for over nine days. During this time, water was delivered via trucks that came through the community to the households, and many individuals were using bottled water for consumption and cooking. Water was eventually restored to these homes as water sampling and household interviews commenced. The water that was used for sampling in this community was water that household members reported as being consumed in the household for the majority of the month. As with the community of El Chorro, there were a significant amount of individuals in this community who utilized a public, outdoor faucet to obtain water. There were not many rooftop cisterns located in the community of El Cercado. Based on the number of

houses that were made of cement and number of paved roads that went throughout the community, El Cercado appeared to have access to more resources compared to El Chorro. Behind the cement homes and paved roads were little enclaves of houses that are made from wood and corrugated materials. These homes did not have direct access to the paved roads and were only accessible by foot. Regardless of the building materials of the homes, many of these homes had washing machines that were located in the doorways of the home.

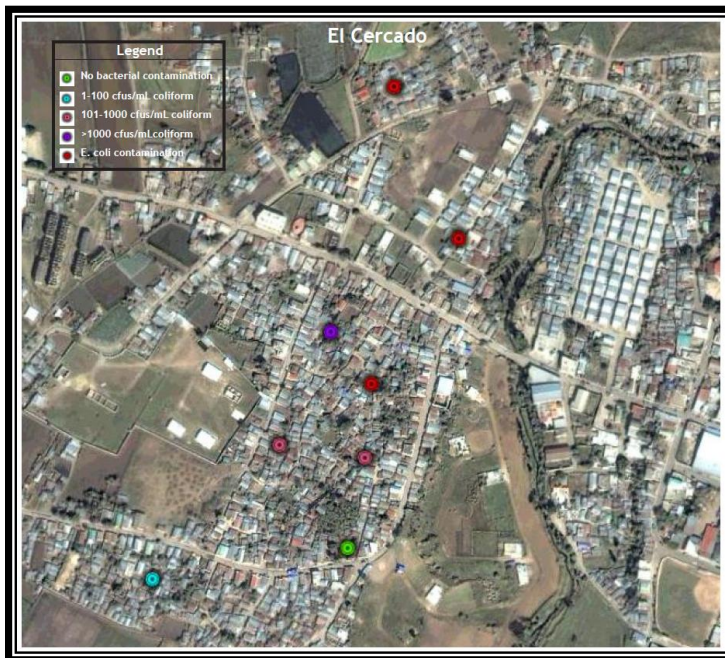


Figure 7: El Cercado

#### *The City.*

The municipal center of Constanza, known as La Ciudad (Figure 8), consisted mostly of paved roads and concrete houses. Overall, the municipal center appeared to be of a higher socioeconomic status than any of the other communities that were visited. Most of the homes had indoor plumbing and cisterns that were housed on the roofs. There was some grey water that was found to be flowing in the gutters; however, it was significantly less in amount than the other communities in this study. There were no outdoor faucets that were shared among



homes for the households that were interviewed, and the outdoor use of water (i.e. children bathing outside) was not visible in or around any of the homes that were visited. It appeared that the municipal center of Constanza had the most access to INAPA's resources and the most properly functioning water supply. Household members did not mention interruption in water supply to the extent that was experienced by other communities in this study. Participant observation did however reveal that some businesses, such as hair salons, were using barrels of water for clients rather than using sinks. Additionally, there exists a facility designed to handle the wastewater produced by the city's inhabitants housed in the city's municipal center; however, key informants indicated that this facility was only partially built, and has never been operational.

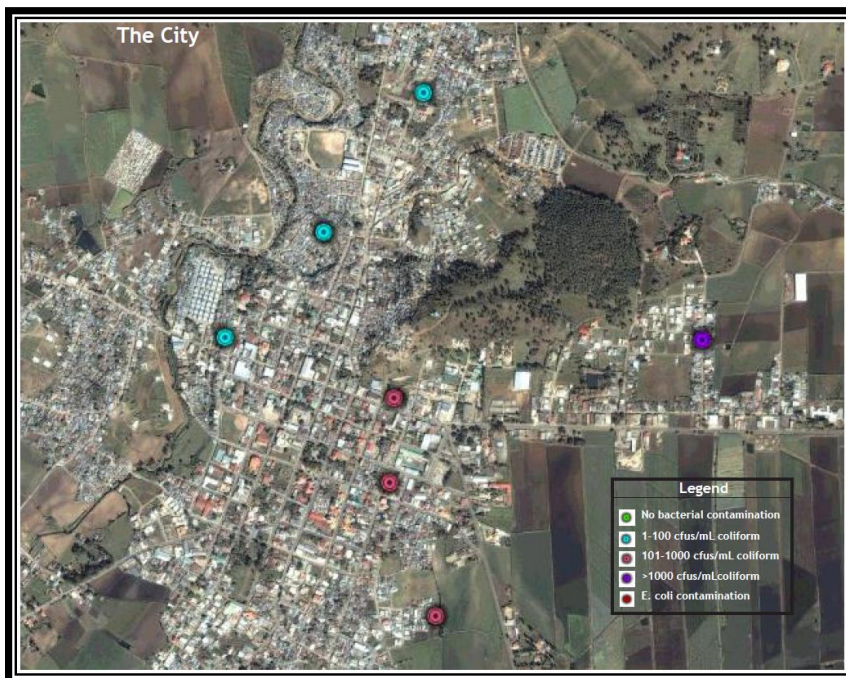


Figure 8: The City

*La Sabina.*

Other than the municipal center, La Sabina (Figure 9), located within agricultural fields, appeared to have more resources than the other communities studied. Many of the homes were gated, and a considerable amount of households had well-groomed dogs as pets. This community also had a nice school and a very new-looking clinic. There was a marked presence of small streams that were located throughout La Sabina, and a large stream that divided the community, with a strong, sulfuric smell emanating out of this larger stream.

Most of the homes located in this community are made of concrete, but there are some homes present in the community that are wooden in structure. Most of these homes were located on the outskirts of La Sabina, usually on dirt roads, and are spread out more than any other community visited. Additionally, this community comprised a square that was surrounded by agricultural fields on all four sides. There was a significant amount of wastewater that was flowing in the gutters in this community (more than what was observed in any other community). This wastewater flowed into an irrigation ditch that divided the community from the agricultural fields. These irrigation ditches appeared to be part of a system that drained into the stream, however, as the ditches were extremely polluted with trash and motor oil, the water in the irrigation system was not draining properly.

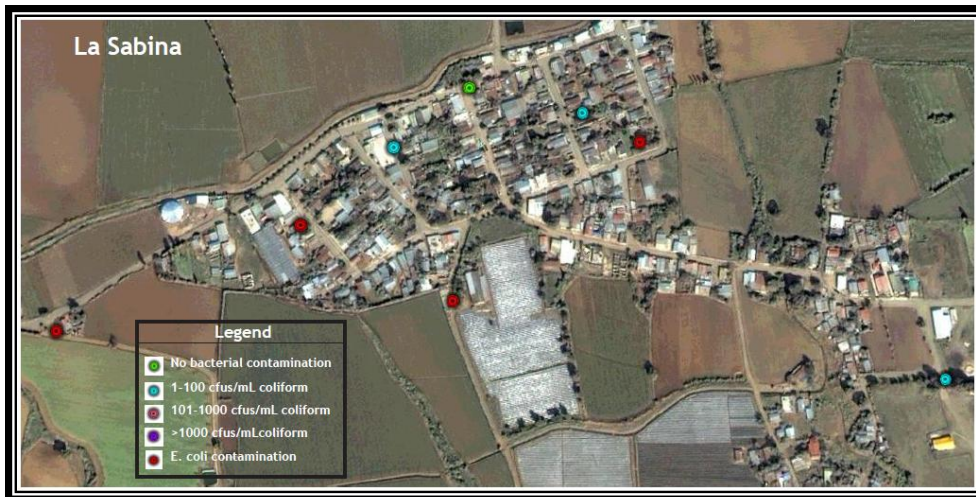


Figure 9: La Sabina

*Palero.*

The community of Palero (Figure 10) lies just east of La Sabina, with a series of fields separating the two communities. All of the roads in the area of Palero are unpaved. Most of Palero's homes line a road that circumscribes the base of a mountain, with half of the homes aligning one side of a road, with fields aligning the other side. The beginning of the community of Palero consists of a large stream that is much cleaner than the stream that was seen in La Sabina. A marked difference in household materials was observed depending on the location of the home in the community. Most of the houses located in the western half of Palero (Palero Abajo) were constructed from wooden materials, whereas most of the houses located on the eastern half of the community were made of cement (Palero Arriba). A section of road that is directed to the north consists mainly of wooden houses; however the northernmost tip of the road (that merges with Cañada Seca) consists of cement houses and businesses.

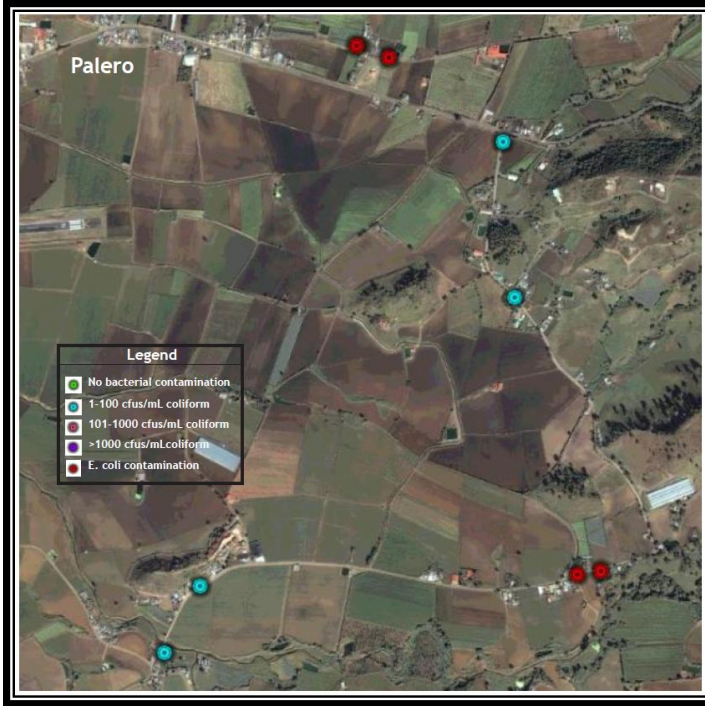


Figure 10: Palero

On the side of the road that borders the fields, there were a series of exposed white pipes coming through the cement that encased them. Some of these pipes were broken and spraying water, and appeared that these pipes drained into the stream that marked the entrance into the community. Gutters lined the roads, however, the gutters were not as deep as the ones observed in La Sabina, and there was not as much water running through them comparatively. Many individuals in this community were washing their vegetables in the gutters that carried graywater down to the stream.

*Cañada Seca.*

This community was extremely small, running alongside the road going out of town toward Tireo. Cañada Seca (Figure 11) consists of an even mix of houses comprised of either wooden materials or cement. The main thoroughfare in the community was paved; however

the road parallel to the main road was not paved and very broken. Most of the homes that aligned the paved road were made of cement, and the quality of housing appeared to be related to the quality of road construction. Houses farther away from the paved road appeared to be made of poorer materials. Most individuals in this community had communal bathrooms that were shared with neighbors, retrieved water from public faucets, and housed them in large barrels in the kitchen. This observation was consistent, regardless of the quality of the home.

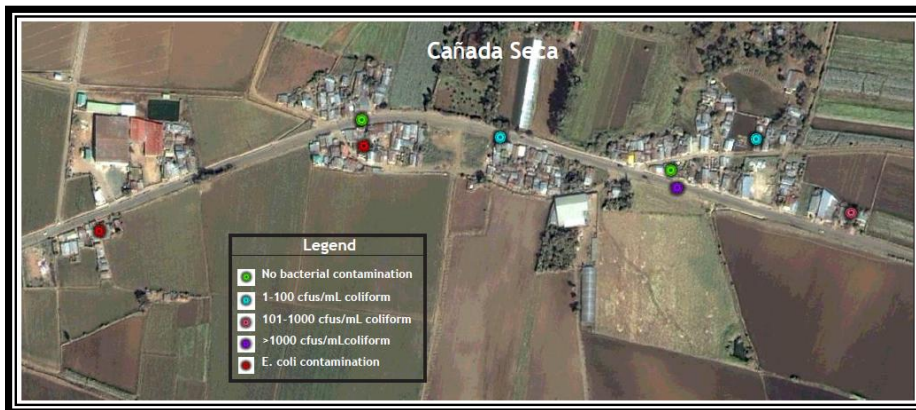


Figure 11: Cañada Seca

#### *El Eden.*

Despite the fact that this community did not have any paved roads, every home in El Eden (Figure 12) was made of cement, and there was a significant amount of space present between homes. El Eden is situated close to the River Pantunflas and is beside Barrio Las Flores. Virtually every home in this community had a visible electric washing machine to clean clothes. Homes in this community receive water from cisterns that are located beneath or above the home. Some homes that are located extremely close together share the same cistern beneath the home. Water in this community is obtained via truck, and many individuals in this community reported that the expected truck delivery of water was late by a few days. When the truck deliveries are late, individuals in this community use bottled water for consumption

and bathing. This community had the largest amount of visible cisterns than any other community in this sample.



Figure 12: El Eden

#### Los Peinados.

Los Peinados (Figure 13) is considered one of the poorer communities in Constanza and borders the river Pantunflas. Most of the homes in this community were made of corrugated materials, however, some cement homes could be found in the portions of the community that were closer in proximity to the municipal center of Constanza. The farther the community extended from the municipal center, higher degrees of overcrowding and cruder housing was present. Virtually all homes in this community received water from a public faucet and stored the water in a barrel in the home. There were no cisterns in this community; however, water appeared to be omnipresent. Wastewater was flowing between the homes in the community, and many women were cleaning the floors of the domiciles with grayish brown water. The closer the community was in proximity to the river Pantunflas, the more trash, food, and

wastewater could be seen draining into the river. Many children could be seen bathing in tubs containing grayish brown water outside the homes.



Figure 13: Los Peinados

#### Barrio Las Flores.

The community Barrio Las Flores (Figure 14) borders the river Pantunflas and is also considered to be one of the poorer communities in the municipality of Constanza, and was extremely similar to Los Peinados. Virtually all homes in this community received water from a public faucet, and there were very few visible cisterns on the homes. The main road at the entrance to this community was paved, and the homes that lined this road were made from cement. As the homes were located farther from the municipal center and closer to the river Pantunflas, houses were made from corrugated materials. The homes that were located the closest to the river were extremely close together, and some homes located right beside the river were very difficult to reach by foot. There was much wastewater flowing between the

homes, as in Los Peinados; and the closer the homes ran together, the more wastewater ran between them. The area right by the river smelled like rotten food. This community had the largest amount of unclothed children than any other community that was visited. Children were seen walking around the river barefoot, and the shores of the Pantunfla River were surrounded with animal excrement and litter.



Figure 14: Barrio Las Flores

#### Tireo.

The community of Tireo (Figure 15) appears to be an area of moderate socioeconomic status and is rather similar to the community of La Sabina. The entire community of Tireo is surrounded by agricultural fields. The main street in the town is paved. The side streets that emanate from the main road are both paved and unpaved, but the unpaved roads are in good condition. Most of the houses in this community were made from cement and were gated, and the houses that were closest to the main road had cisterns on the roof. All homes interviewed



in this community had indoor plumbing and sanitary facilities that were located inside the home; and most use bottled water for consumption. Some of the communities that are located right outside of Tireo do not have access to a public faucet and obtain their drinking water from the river for consumption.

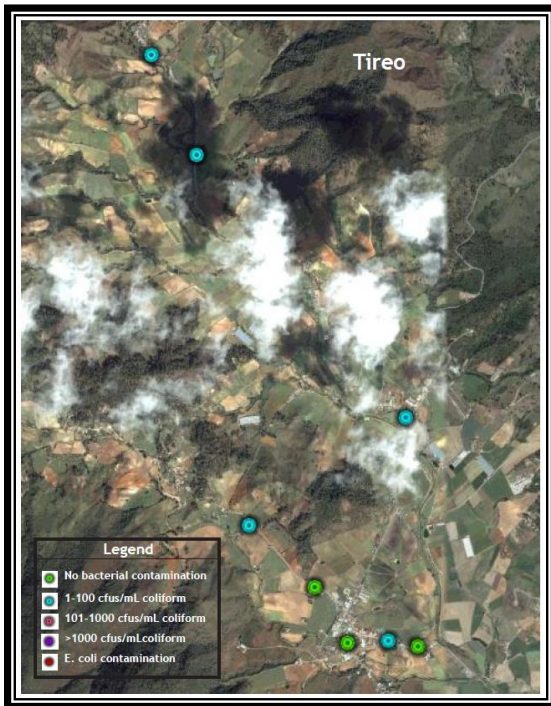


Figure 15: Tireo

*Arenazo.*

The community of Arenazo (Figure 16) consisted of a combination of cement homes and homes made from wood or corrugated materials. No roads in this community were paved, but the quality of the unpaved road varied considerably, corresponding to the quality of the home. Homes that were located by the main road were made of concrete and were located very close to the road. There were small enclaves of homes made of corrugated materials and wood located slightly off of the road; however, one had an obstructed view of the presence of these homes from the main road. The cement homes had cisterns on the roof and indoor plumbing.

In this community, unless one has a cistern on the roof of the home, water is retrieved from a public faucet. Some of the corrugated homes that were located beside some of the cement homes shared outdoor sanitary facilities and public faucets to receive water. Female community members could also be seen washing clothing in a bucket with water beside the public faucet that was shared between 6-7 homes. Most of the homes in this community were offset from the main road by a deep ditch approximately 1.5 meters deep and 1 meter wide, with wooden planks providing access to the domicile from the road.

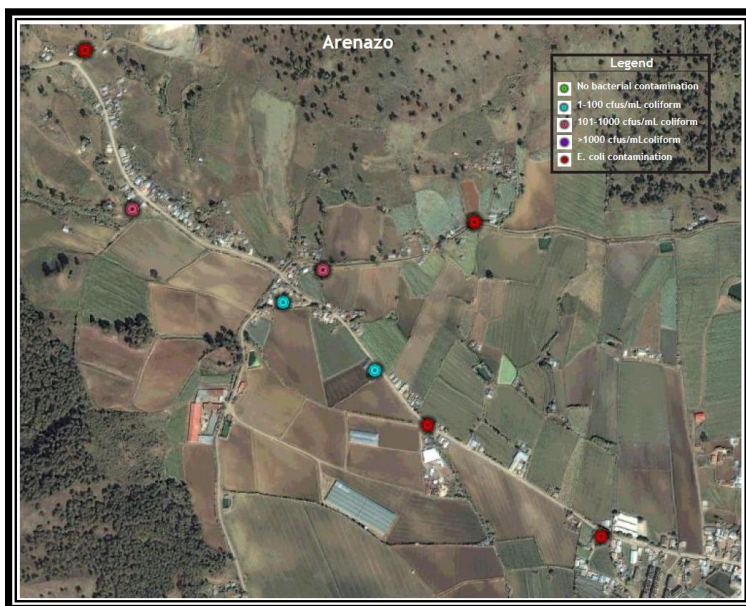


Figure 16: Arenazo

#### *Aqueducts and Water Access*

Community access to aqueducts is extremely inconsistent from community to community. Many of the populations outside of the city center break into the main line of the water supply coming from the aqueduct and use PVC pipes to connect the main water pipe to a public faucet that multiple families can use. As many individuals steal the water in this manner, INAPA is unable to determine which aqueducts serve which communities. However, according

to the director of the Constanza branch of INAPA, a recent law has passed mandating that INAPA knows which households are receiving water from which aqueducts. This information will be obtained via a census for all communities of Constanza, in an effort to make community members start to pay for water delivery. INAPA charges clients by how many faucets the household has access to, not how much water is used. There are a total of five aqueducts that currently serve Constanza's city center; this number will be increased to six with a new aqueduct in La Sabina becoming functional in late 2009. There are three additional aqueducts, El Río, Arroyo Frío, and Tireo (est. 2004), that serve the communities of El Río and Tireo. Although Arroyo Frío is considered an aqueduct, it is actually a river from which unprocessed water is piped into homes. The two main aqueducts that serve Constanza are the Río Grande aqueduct and La Culata aqueduct (built 1987). Additionally, Palero (est. 1994), Los Secanos (est. 2007), La Cienaga (est. 1992), and La Sabina (est. 2007) serve the various zones of the municipality. The above map (Figure 17) indicates the approximate zones of aqueduct coverage identified by the director of INAPA's Constanza branch.

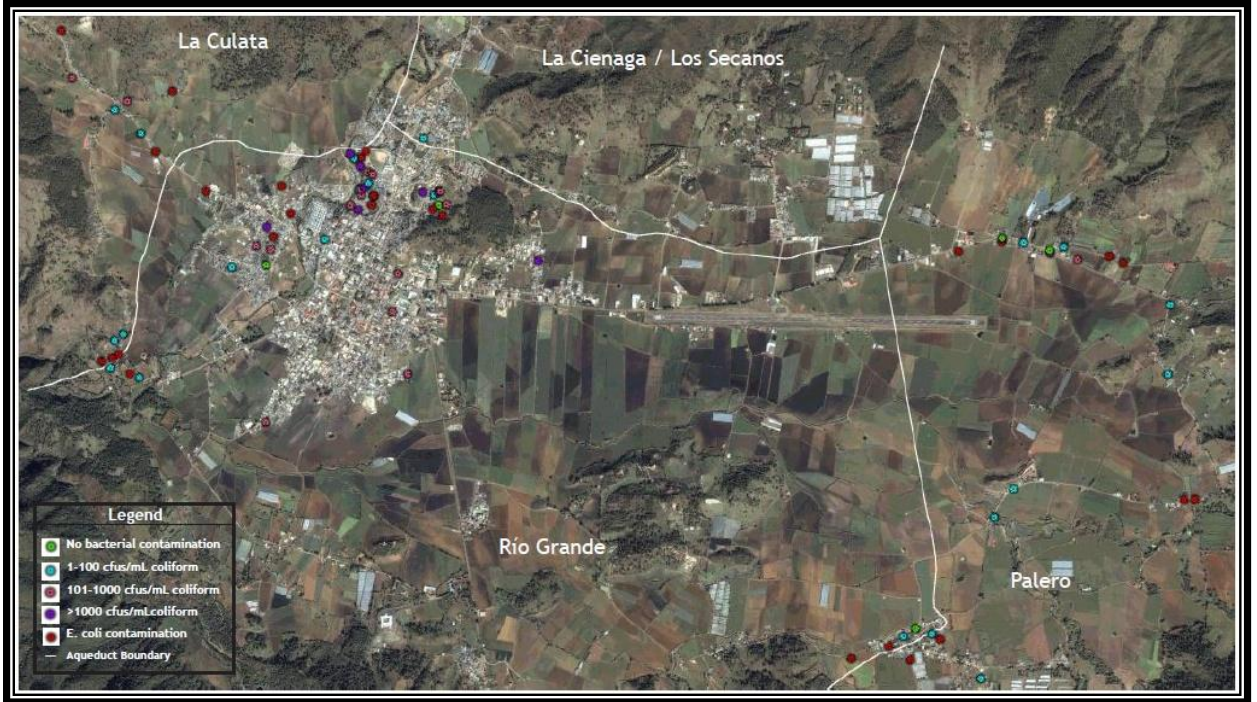


Figure 17: Aqueducts and Water Quality

### *Microbiological Water Quality*

It was determined that 81 households (92.0%) had some level of microbial contamination in the potable water. Levels of coliform bacterial contamination in the drinking water are depicted in Figure 18. *E. coli* contamination was present in 28 (31.8%) of households. Households that had indoor sanitary facilities had a higher prevalence of *E. coli* contamination in the water (36.1%) than households that utilized outdoor sanitary facilities (20.8%). However, outdoor sanitary facilities appeared to have a higher prevalence of coliform bacteria contamination (95.8%) compared to households that had access to indoor sanitary facilities (86.9%). Additionally, levels of coliform bacterial contamination appeared to have the greatest impact on *E. coli* contamination. Fifty percent of the 16 households that had extremely high levels of coliform bacterial contamination (> 1,000 cfus/mL) also had *E. coli* contamination in the drinking water. Thirty households that had moderate levels of coliform bacterial contamination (101-1,000 cfus/mL), with 16 (53.3%) also having *E. coli* contamination in the water. Households with relatively low levels (1-100 cfus/mL) of coliform bacterial contamination (37.5%) had the least amount of households with *E. coli* contamination in the drinking water (15.2%). Of the 28 households with *E. coli* contamination of the drinking water, 82.1% (n=23) reported obtaining drinking water from the faucet. However, the only other water source indicating *E. coli* contamination was bottled water with five households (17.9%). The trend of heavy microbial contamination with water from a faucet is conserved with coliform bacterial contamination. Of the 16 households having the highest amount of coliform bacterial contamination (>1,000 cfus/mL), 12 (75%) reported obtaining their drinking water from the faucet.

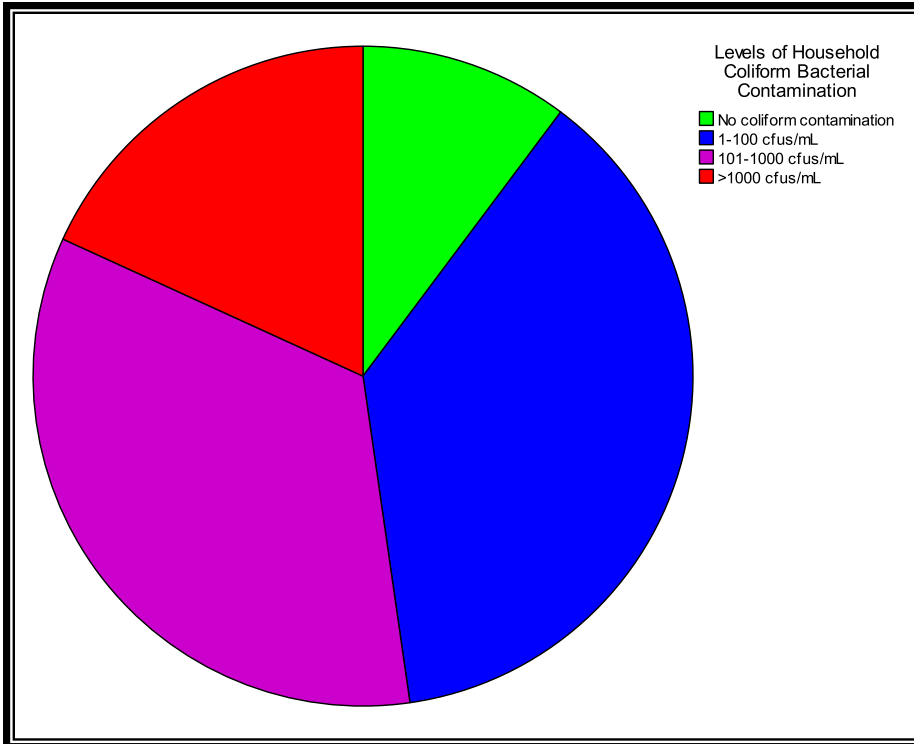


Figure 18: Household Levels of Household Coliform Bacterial Contamination

Of the households that had *E. coli* contamination in the drinking water, most (64.3%) reported taking no measures to sanitize the drinking water. The second highest amount of households that had *E. coli* contamination in the drinking water (32.1%) reported using chlorine to sanitize the water. This trend was also consistent with coliform bacterial contamination. The two methods of sanitizing water that also had the highest levels (>1,000 CFUs/mL) of coliform bacterial contamination were nothing (no method) (56.3%) and using chlorine (37.5%). This was also observed with moderate levels (101-1000 CFUs/mL) of coliform bacterial contamination, with nothing (no method) accounting for 60% and using chlorine for sanitation accounting for 36.7% of households with moderate levels of coliform bacterial contamination. The prevalence of these two methods of water sanitization having the most bacterial contamination could be

due to the fact that these two methods are utilized as the primary means of sanitizing drinking water in 93.2% of the households interviewed.

The four communities with the highest amount of households with *E. coli* contamination in the drinking water are: El Chorro, La Sabina, Palero, and Arenazo, with four households (50%) having *E. coli* contamination in the drinking water. Households having *E. coli* contamination in the drinking water, broken down by community, is depicted in Figure 19. The communities containing the least amount of households with *E. coli* contamination in the drinking water are The City and Tireo, with each not having any households with *E. coli* contamination in the drinking water. The three communities with the highest amount of coliform bacterial contamination in the drinking water are: Las Flores, El Cercado, and Los Peinados, with each having three households with high levels (>1,000 CFUs/mL) of coliform bacteria in the drinking water. Contrastingly, El Chorro, La Sabina, Palero, and Tireo did not have any households with high levels of coliform bacterial contamination in the drinking water. Moderate levels (101-1000 CFUs/mL) of coliform bacterial contamination were more evenly spread among communities, with 3.75 households per community (range 0-4) reporting moderate levels of bacterial contamination in the drinking water.

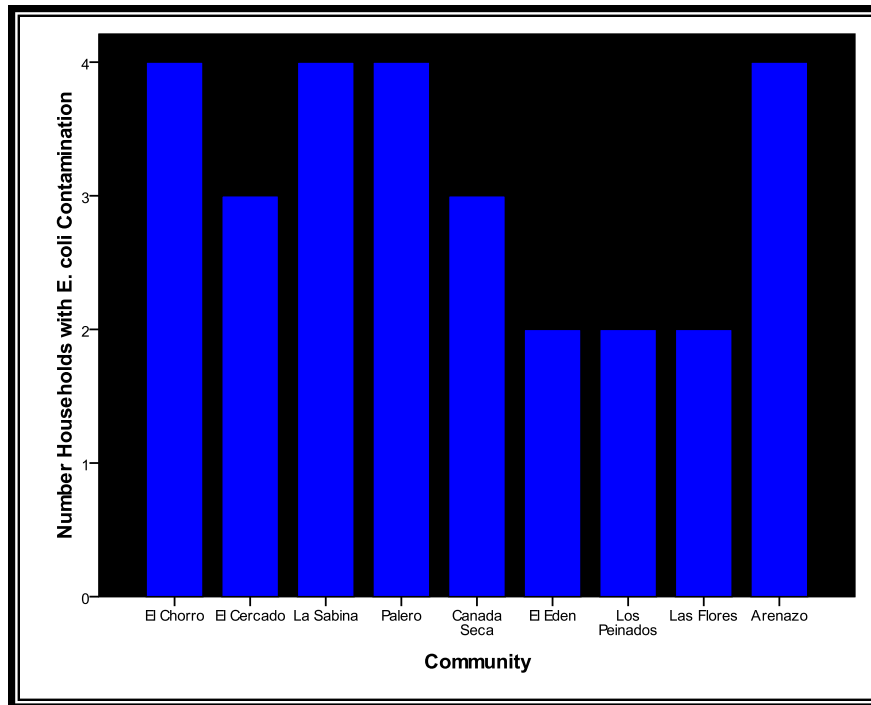


Figure 19: Households with *E. coli* Contamination by Community

Of the 57 homes that self-reported at least one household member having diarrhea, 67.9% also had *E. coli* contamination in the drinking water. Additionally, 32.1% of households that had a member self-report diarrheal disease did not have any *E. coli* contamination in the drinking water. Of the 57 homes that self-reported at least one household member having diarrheal disease, 89.5% also had some level of coliform bacterial contamination in the drinking water, as depicted in Figure 20. Only six households self-reporting a family member having diarrheal disease did not have any bacterial contamination in the drinking water.



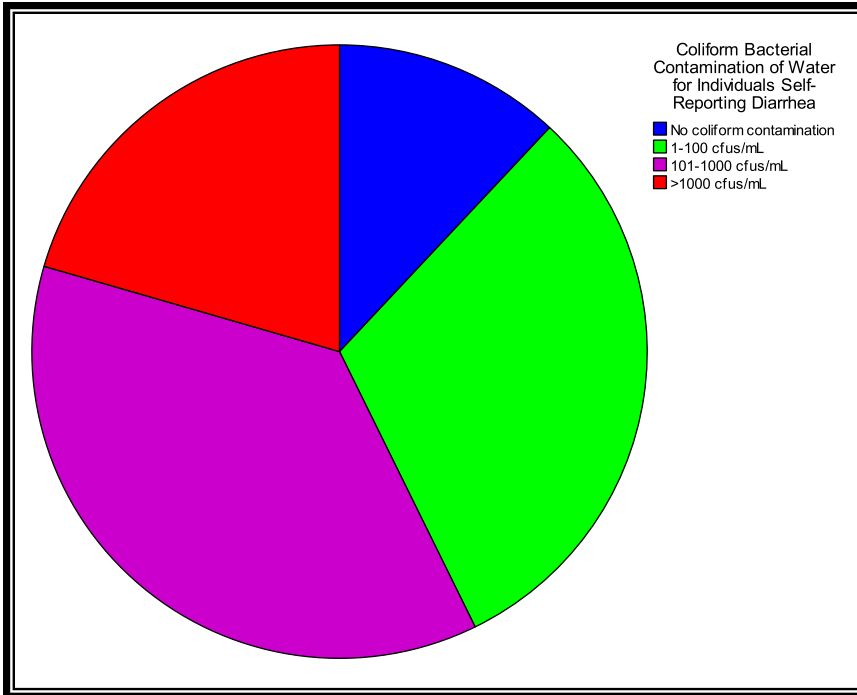


Figure 20: Coliform Bacterial Contamination among Individuals Self-Reporting Diarrhea

Categorized frequency data for the entire sample population is displayed in Table 1, which obtained from the entire population participating in household interviews. Clustering of diarrheal disease morbidity can be seen with individuals who have indoor sanitary facilities (21%) as well as drinking water that is obtained from a faucet (21%). Of the 114 individuals self-reporting diarrheal disease in the previous month, 37.6% had *E. coli* contamination in the drinking water. Additionally, 88.0% (n=103) of individuals self-reporting diarrheal disease had coliform bacterial contamination in the drinking water. Coliform bacterial contamination of individuals self-reporting diarrheal disease is depicted in Figure 20. Only 14 individuals (12%) self-reported having diarrheal disease without any microbial contamination in the drinking water. Overall, 257 individuals (68.7%) self-reported as not having any diarrheal disease in the past month. Of these individuals, 7.7% (n=13) had high levels (>1,000 CFUs/mL) of coliform bacterial contamination in the drinking water. Additionally, 31.5% (n=53) of these individuals

had moderate levels (101-1,000 CFUs/mL) of coliform bacterial contamination in the drinking water. Individuals not self-reporting diarrheal disease but having high levels of coliform bacterial contamination as well as *E. coli* contamination in the drinking water accounted for 6.7% of individuals participating in the study. Overall, 89 individuals (23.8%) self-reported not having diarrheal disease but had *E. coli* contamination in the drinking water. Contrastingly, three individuals (1.2%) self-reported as having no diarrheal disease, with the drinking water only having *E. coli* contamination without any coliform bacterial contamination.

Of the 57 homes that self-reported at least one household member having diarrhea, 67.9% also had *E. coli* contamination in the drinking water. Additionally, 32.1% of households that had a member self-report diarrheal disease did not have any *E. coli* contamination in the drinking water. Of the 57 homes that self-reported at least one household member having diarrheal disease, 89.5% also had some level of coliform bacterial contamination in the drinking water. Only six households self-reporting a family member having diarrheal disease did not have any bacterial contamination in the drinking water.

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Individuals not self-reporting diarrheal disease but having high levels of coliform bacterial contamination as well as *E. coli* contamination in the drinking water accounted for 6.7% of individuals participating in the study. Overall, 89 individuals (23.8%) self-reported not having diarrheal disease but had *E. coli* contamination in the drinking water. Contrastingly, three individuals (1.2%) self-reported as having no diarrheal disease, with the drinking water only having *E. coli* contamination without any coliform bacterial contamination.

Of the 24 individuals (20.5%) that had high levels (>1,000 CFUs/mL) of coliform bacterial contamination in the water and self-reported with diarrheal disease, most individuals (n=6) were from the 25-34 age group, followed by the 45-54 age group. Of the 43 individuals (36.8%) that had moderate levels (101-1,000 CFUs/mL) of coliform bacterial contamination in the water and self-reported diarrheal disease, an equal amount of individuals (n=6) reported from the 5-9, 35-44, 45-54, and 65+ age groups. Of the 44 individuals self-reporting with diarrheal disease and having *E. coli* contamination in the drinking water, individuals from the 5-9 and 35-44 age groups accounted for the largest amount of individuals reporting (n=8). Of children under the age of 5 years self-reporting diarrheal disease (n=10), two had high levels of coliform bacterial contamination, three had moderate levels of coliform bacterial contamination, and four had *E. coli* contamination in the drinking water. Only one child from this age group did not have any contamination in the drinking water and still self-reported with diarrheal disease. Of children aged 5-9 years self-reporting diarrheal disease (n=13), one had high levels of coliform bacterial contamination, six had moderate levels of coliform bacterial contamination, and eight had *E. coli* contamination in the drinking water. Three children from this age group did not have any contamination in the drinking water and still self-reported with diarrheal disease.

**Table 1***Frequency Analysis of Self-reported Data Obtained From Household Interviews*

	Male	Female	0-4 years	5-9 years	10-14 years	15-24 years	25-34 years	35-44 years	45-54 years	55-64 years	65+ years	Diarrhea	Doctor	E coli	Coliform
<b>Male</b>	0.53	0.00	0.04	0.04	0.04	0.09	0.08	0.07	0.05	0.02	0.02	0.14	0.05	0.17	0.43
<b>Female</b>	0.00	0.47	0.04	0.07	0.06	0.12	0.07	0.06	0.06	0.06	0.03	0.17	0.04	0.18	0.48
<b>Faucet</b>	0.36	0.30	0.06	0.08	0.08	0.14	0.11	0.08	0.07	0.03	0.03	0.21	0.05	0.30	0.62
<b>Well</b>	0.01	0.01	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
<b>Bottled</b>	0.16	0.15	0.02	0.02	0.03	0.07	0.04	0.05	0.04	0.02	0.02	0.10	0.04	0.06	0.26
<b>Other</b>	0.01	0.01	0.00	0.00	0.00	0.01	0.00	0.00	0.01	0.00	0.00	0.01	0.00	0.00	0.01
<b>Boil</b>	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.01	0.01	0.01	0.02	0.02
<b>Clorox</b>	0.18	0.16	0.03	0.02	0.05	0.09	0.05	0.06	0.02	0.02	0.01	0.10	0.03	0.24	0.31
<b>Tablets</b>	0.01	0.01	0.00	0.00	0.00	0.01	0.00	0.00	0.01	0.00	0.00	0.01	0.00	0.01	0.01
<b>Filter</b>	0.01	0.01	0.00	0.01	0.00	0.01	0.00	0.01	0.00	0.00	0.00	0.01	0.00	0.02	0.03
<b>Nothing</b>	0.33	0.28	0.05	0.09	0.06	0.12	0.10	0.06	0.07	0.03	0.03	0.19	0.06	0.35	0.54
<b>Inside</b>	0.36	0.33	0.04	0.07	0.08	0.16	0.09	0.09	0.09	0.04	0.04	0.21	0.07	0.27	0.62
<b>Outside</b>	0.16	0.13	0.04	0.04	0.04	0.05	0.06	0.03	0.02	0.00	0.02	0.09	0.02	0.08	0.27
<b>Both</b>	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.01	0.00	0.01	0.02
<b>Diarrhea</b>	0.17	0.17	0.03	0.04	0.01	0.04	0.06	0.04	0.05	0.02	0.04	0.31	0.09	0.12	0.28
<b>Doctor</b>	0.04	0.05	0.00	0.01	0.00	0.00	0.02	0.01	0.00	0.02	0.02	0.09	0.09	0.04	0.09
<b>E coli</b>	0.18	0.17	0.03	0.05	0.05	0.08	0.05	0.04	0.03	0.02	0.01	0.12	0.04	0.36	0.35
<b>Coliform</b>	0.48	0.43	0.07	0.10	0.10	0.20	0.13	0.12	0.09	0.04	0.04	0.28	0.09	0.35	0.90

Of the 175 females that participated in this study, sixty-five females (37.1%) had drinking water that had *E. coli* contamination and 91.4% (n=160) had coliform bacterial contamination in the drinking water. Of the 52 females in this study that self-reported diarrheal disease in the previous month, 20 females (38.5%) had *E. coli* contamination in the drinking water. Additionally, of the females self-reporting diarrheal disease, 11 females (21.2%) had high levels (>1,000 CFUs/mL), 20 females (38.5%) had moderate levels (101-1000 CFUs/mL), 17 females (32.7%) had low levels (1-100 CFUs/mL), and 4 females (7.8%) had no coliform bacterial contamination in the drinking water. Females aged 25-34 years (n=4) had the highest amount of individuals self-reporting diarrheal disease with high levels (>1,000 CFUs/mL) of coliform bacterial contamination. Additionally, females aged 25-34 (n=6) had the largest amount of

individuals self-reporting diarrheal disease with low levels (1-100 CFUs/mL) of coliform bacterial contamination. Females aged 45-54 years (n=4) had the highest amount of individuals self-reporting diarrheal disease with moderate levels (101-1,000 CFUs/mL) of coliform bacterial contamination. This trend is also observed with *E. coli* contamination, with females in the 25-34 (n=6) and 35-44 (n=5) age groups being the highest number self-reporting diarrheal disease. Three females under the age of 4 years reported diarrheal disease; however, none of these females had drinking water with *E. coli* contamination or high levels of coliform bacterial contamination. Of the five females with self-reported diarrheal disease aged 5-9 years, three had drinking water with *E. coli* contamination and one had water with high levels of coliform bacterial contamination. Results from chi-squared analysis are displayed in Table 2, which includes categorized, self-reported data obtained from household interviews. Chi-squared analysis reveals that water source has a significant relationship to the method of water sanitation, the household sanitary facilities, and the presence of *E. coli* in the drinking water.

**Table 2**

*Chi-squared Analysis of Self-reported Data Obtained From Household Interviews*

	Sex	Water Source	Water Sanitation	Sanitary Facilities	Age Group	Diarrhea	Doctor	<i>E. coli</i>	Coliform
Sex	----	0.891	0.971	0.808	0.766	0.539	0.140	0.549	0.517
Water Source	0.891	----	0.000	0.000	0.470	0.480	0.330	0.000	0.011
Water Sanitation	0.971	0.000	----	0.280	0.098	0.902	0.284	0.009	0.605
Sanitary Facilities	0.808	0.000	0.280	----	0.280	0.311	0.737	0.066	0.074
Age Group	0.766	0.470	0.098	0.280	----	0.000	0.000	0.727	0.337
Diarrhea	0.539	0.480	0.902	0.284	0.000	----	0.000	0.577	0.301
Doctor	0.140	0.330	0.284	0.737	0.000	0.000	----	0.274	0.438
<i>E. coli</i>	0.549	0.000	0.009	0.066	0.727	0.577	0.274	----	0.000
Coliform	0.517	0.011	0.605	0.074	0.337	0.301	0.438	0.000	----

Of the 199 males that participated in this study, 68 males (34.2%) had drinking water that had *E. coli* contamination and 89.4% (n=178) had coliform bacterial contamination in the drinking water. Of the 65 males (32.7%) in this study that self-reported diarrheal disease in the previous month, 24 males (36.9%) had *E. coli* contamination in the drinking water. Additionally, of the males self-reporting diarrheal disease, 13 males (20.0%) had high levels (>1,000 CFUs/mL), 23 males (35.4%) had moderate levels (101-1000 CFUs/mL), 19 males (29.2%) had low levels (1-100 CFUs/mL), and 10 males (15.4%) had no coliform bacterial contamination in the drinking water. Males aged 10-14 and 15-24 years (n=3) had the highest amount of individuals self-reporting diarrheal disease with high levels (>1,000 CFUs/mL) of coliform bacterial contamination. Males aged 5-9 years (n=4) had the highest amount of individuals self-reporting diarrheal disease with moderate levels (101-1,000 CFUs/mL) of coliform bacterial contamination. Additionally, males aged 15-24 and 45-54 years (n=4) had the largest amount of individuals self-reporting diarrheal disease with low levels (1-100 CFUs/mL) of coliform bacterial contamination. Males in the 0-4 (n=4) and 5-9 (n=5) age groups contained the highest number self-reporting diarrheal disease with *E. coli* contamination in the drinking water. Seven males aged 0-4 years reported diarrheal disease. Four of these males had *E. coli* contamination in the drinking water and two of these males had high levels of coliform bacterial contamination in the drinking water. Of the eight males with self-reported diarrheal disease aged 5-9 years, five had drinking water with *E. coli* contamination and zero had water with high levels of coliform bacterial contamination.

## CHAPTER 4

### DISCUSSION

#### *Social Determinants of Health*

Social determinants of health are considered to be societal conditions that can affect health and are able to be altered by redistribution of resources. Societal conditions in this sense refer to both the natural and built environment, such as access to resources and policies (Kreiger, 2001). A recent study by the Pan American Health Organization reveals that social determinants of health form a significant role in health outcomes. It has been revealed that countries which provide better access to basic sanitation and health services to the population have lower mortality rates than countries that may have better or equal economic performance, but have large disparities in access to income or resources (Casas, 2001). Additionally, it has been determined that the Latin American and Caribbean region has the most unequal distribution of income in the world. Overall population patterns, with regard to health and disease, parallel societal divisions based on socioeconomic status throughout this region (Ehrenberg, 2005).

The concept of having adequate access to safe water and sanitation resulting in negative health outcomes among certain poorer socioeconomic groups is exemplified throughout Constanza. One large issue facing the water quality of many Dominicans in the region is the existence of unenforced and inefficient sanitation policies. Despite INAPA and PAHO establishing policies in 1997 mandating that no fecal coliforms can be present in water for human consumption, approximately many households surveyed were found to have fecal coliform contamination in the water for consumption ("Reglamento Calidad del Agua Potable," 1997). The Dominican Republic is one of the few nations in Latin America where water sanitation is managed by the Public Health State Secretariat that is not directly and commonly

coordinated with potable water programs. Not having this coordination creates a significant structural barrier in providing efficient auditing of water quality in Constanza. Additionally, sanitation of water is extremely difficult to coordinate within the governmental infrastructure, largely due to the lack of a central organization that maintains the set standards and ensures that these standards are met. Despite the fact that there has been a significant increase in resource allocation within the government to provide services to the population, the majority of resource allocation has been directed at building new services, not maintaining pre-existing infrastructures (Witter & Carrasco, 1996). These barriers that exist within the infrastructure are significant determinants of health outcomes to Dominicans in this region.

As efficient means of providing clean water and sanitation is not explicitly built into the infrastructure of the water sector in the Dominican Republic, it is necessary that clean water is procured at the household level. In this context, the richest families purchase bottled water for consumption ; many other Dominican families are unable to afford bottled water and drink water from public faucets or faucets within the home. For these populations, SESPAS recommends that individuals should boil water prior to consumption. Unfortunately, because gas prices are extremely expensive (at RD\$62.54 per gallon at the time of field work) (Ministerio de Industria y Comercio, 2010) in the Dominican Republic, many households who are unable to afford the governmentally-sponsored recommendations elect to use chlorine to purify water used for consumption. Chlorine needs to be purchased at the household-level, but the poorest families who cannot afford this method of sanitizing water are left with few or no options but to drink water directly from the tap without any measures to sanitize the water. Additionally, chlorine is the least efficient means of purifying water than any of the other aforementioned options. Although chlorine is effective in killing bacterial pathogens and provides residual



resistance to re-infection, it is not efficient in sanitizing against protozoan parasites and viruses (Ashbolt, 2004; M. LeChevallier, 1992).

The structure that exists in the water sector perpetuates poor access to safe and clean water to those of lower socio-economic status, resulting in poorer health outcomes. In the current social and economic context of the community of Constanza, it appears that for a household of low socioeconomic means to have access to clean water, a household must have the resources to circumvent the structural barriers that exist due to insufficient clean water and an inefficient infrastructure to deliver safe water to community members. Consequently, differences in health outcomes essentially parallel socioeconomic divisions. This is exemplified throughout and between communities surveyed in Constanza; households that are made from higher-quality materials (i.e. concrete) are more likely to use bottled drinking water or to take methods to sanitize the water. In contrast, households made from poorer materials (i.e. wood and corrugated) are more likely to drink water from the faucet and less likely to utilize methods to sanitize the water. Additionally, overall water quality appeared to depend greatly on the community in which a household resided. For example, many individuals in Constanza city proper were found to have cleaner water by less *E. coli* and coliform bacterial contamination than those households in poorer communities like El Chorro.

#### *Political Ecology*

These findings can also be linked to the theory of political ecology. Individuals who have less political power and access to economic resources will, in turn, have less access to natural resources. This will also shape how those individuals adjust to access these resources. It is clear in certain communities within the Constanza municipality that certain households lack access to basic water services. Many of these individuals link a public water faucet to governmentally owned water mains via PVC pipes, thereby creating access to water for these communities.

These poorer populations are given no alternative but to create their own access to water because they are not included in the infrastructure of the community. This means of obtaining access to water through illegal linking puts great strains on the current water supply infrastructure, as it is not sustainable to the entire population. As a result, the entire community suffers water supply outages (Harper, 2004).

Individuals of higher socioeconomic status within the community do not have the same issues when obtaining access to water. These individuals who have higher socioeconomic status and political power are able to have their water delivered directly to the home so they may have indoor plumbing. Although these individuals have convenient access to water in the home, they typically utilize bottled water for consumption, as many of the water pipes are contaminated due to the introduction of PVC pipes into the water mains as well as interrupted service creating backflow into the pipes. Individuals of higher socioeconomic status in these communities are also able to regulate their own access to water by having cisterns in their homes. These cisterns hold water that is brought to the home via pipes for times when services are interrupted or not delivered via truck. These combined resources of water delivery, bottled water, and the backup supplies with the use of cisterns enables the individuals who have more economic and political resources to have more access to the natural resources within the community (Harper, 2004).

It is important to note that political ecology is not just limited to the overt access to natural resources, but it is also manifested in policies. It has been found that water and sanitation policies in the Dominican Republic are inefficient. According to USAID, water quality control and service by government agencies is maintained in only 35.6% of aqueducts. A large discrepancy in provision of services is observed in rural areas versus urban areas (67.9% of aqueducts are maintained in urban areas versus 18.2% in rural areas) (USAID, 2006). The

tendency to have more access to services in urban communities rather than rural communities is observed throughout the Constanza municipality. This observation is linked to the fact that more economic and political resources are located in urban areas rather than rural areas.

Communities that are located in the city center are able to have more access to piped water within the household versus rural, poorer communities that are on the outskirts of the city center that are required to use public faucets to obtain water on the household level.

*Theoretical framework in the social, historical, and economic context.*

The relationship that community members have with water is not simply an issue of access to water and the socio-economic status of individuals within the community. There are historical, social, and economic factors that are intricately related to access to water within these communities. Participant observations within Constanza revealed many dynamics within the society that have strong roots to the previous socioeconomic and political climate of the region. Consequently, access to water in Constanza is strongly linked to the political ecology of the region.

The Dominican Republic had an oppressive dictatorship from 1930-1961 by a military strongman named Rafael Trujillo. Trujillo's existence in the Constanza valley was omnipresent during his reign and still is to this day. This is represented by an immense, white building overlooking the valley that was once a hotel Trujillo used to meet with dignitaries and throw parties. Due to Constanza's unique temperate climate in the Caribbean and fertile soil, the Constanza valley was able to produce crops that were unable to be cultivated in other areas of the Caribbean such as strawberries, potatoes, and garlic. Trujillo had the goal of developing agriculture into this community by distributing land among colonists that were recruited throughout the world, namely Hungary, Spain, and Japan. Although the Hungarian's presence in the valley was relatively short-lived, the Spaniards and Japanese remain in the valley to this day.

Additionally, assistance from the Spanish and Japanese governments currently in Constanza solidifies the presence of past relationships that existed in the valley. The largest water treatment plant in the valley that serves most of the residents was built and maintained by the Japanese. Also, the Spanish government maintains a consulate in Constanza, even though the population in the valley is only estimated at 80,000.

The incentives given to these groups from the 1930's until the 1960's have resulted in the Spanish, Japanese, and Dominican high class becoming the primary landowners in the valley. The presence of the landowners is ubiquitous throughout the region, with large, gated homes sitting on the outskirts of the city center. As the electrical grid and water systems were constructed in the region, these homes obtained direct access to water and electricity and are documented by the Dominican public works system. In contrast, beside these large homes resides smaller corrugated housing where the poorer families live. The majority of the corrugated homes are built on land that is not owned by the homeowner. As the homeowners of lower socioeconomic status do not own the land they reside on, they do not have access to utilities such as water and electricity. This has caused many of the poorer homeowners in Constanza to "steal" water and electricity by wiring their homes to the electrical grid and connecting public faucets to water mains via PVC pipes. These homes that exist due to these "stolen" utilities has resulted in a significant amount of homes in the valley to be undocumented by government services.

As many individuals that use utilities such as water and electricity are not paying for the service, there is not enough money to maintain these resources. This has resulted in the reinforcement of distrust between the Dominicans and the government that was partially developed during Trujillo's era. In recent history under Trujillo's brutal regime, many Dominicans had assets that were forfeited to the regime and many other Dominicans were

massacred due to ethnicity or political affiliations. Participant observations revealed that community members did not pay for their utilities because they were not receiving dependable resources (i.e. not having access to electricity 24 hours a day, not having continuous water service, not having access to clean water, etc.). An interview with the director of the INAPA branch in Constanza revealed that utilities were not dependable simply because individuals did not pay their bills. As many individuals “steal” their water from the water mains, INAPA is not aware of who is obtaining water service in Constanza and where those individuals are located. This results in more individuals procuring water from the structure than for the amount that the structure was designed. This burden on the system produces interrupted service and lack of infrastructure investment due to the lack of capital that is coming into the INAPA branch. Essentially, a vicious cycle exists between the government and the population: People will not pay a bill for services that are not rendered; and, services cannot be rendered if people do not pay their bills.

This structure creates an environment where community members depend on their own resources to obtain access to water. Participant observations revealed that there were different methods of obtaining and subsequently handling water that was largely dependent on socioeconomic status. Poorer families obtain access to water by attaching PVC pipes connected to public faucets to water mains. While water service is being provided, these households fill jugs of water from the public faucets and fill large containers located at the home that resemble trashcans. The water is stored, generally uncovered, in these containers until the water is used for cooking and drinking. Although boiling water is the official recommendation to sanitize the water from SESPAS, many of the poorer community members are unable to afford the propane required to boil water, and chlorine is utilized instead. Discussions with community members indicate that some residents are unsure as to what amount of chlorine to put in the water to

effectively sanitize it. Additionally, as there is no running water in the home, many individuals do not wash their hands frequently to prevent fecal-oral contamination of the water as many individuals obtain water using the same scoop that gets dipped in the water. This results in microbial contamination of the drinking water that is consumed in the household.

In contrast, individuals of higher socioeconomic status use a very different means of obtaining water in the household. These households have water that is directly piped into the household, and utilize cisterns that automatically hold water for times when service is interrupted. Once water service is interrupted, household members use the cistern water for bathing and washing clothing. Water for consumption and cooking in these households is generally limited to bottled water. Some households have even reported boiling or using chlorine in the bottled water due to distrust of the bottled water companies and to news reports at the time of the fieldwork stating that SESPAS was not accurately auditing these companies to ensure that the water was being appropriately purified before it was sold to consumers.

#### *Water Quality at the Household Level*

Water quality at the household level appeared to be extremely varied from community to community. From participant observations and household surveys, it appears that socioeconomic status is strongly linked to water quality. Most homes that were made from corrugated materials obtained the drinking water from a public faucet, whereas most homes that were made from concrete obtained their drinking water from bottled sources. This is exemplified in the community of Tireo. Overall, the community with the least amount of bacterial contamination in the drinking water was Tireo, however, it is important to note that virtually all homes in Tireo obtained drinking water from bottled sources. Arenazo and Los Peinados had the overall highest amount of microbial contamination in the drinking water; and,

both of these communities had a significant amount of households obtaining drinking water from the faucet. Additionally, all homes from which samples were obtained in Tireo were made from cement, whereas Arenazo and Los Peinados were poorer communities where most of the houses were made from wood and corrugated materials.

GIS analysis demonstrates some clustering of diarrheal disease and poor water quality according to community. Tireo appeared to have the least amount of microbial contamination and diarrheal disease morbidity than many of the other communities examined in the GIS analysis. It is important to note that Tireo was one of the more developed communities sampled, meaning that most homes in Tireo obtained drinking water from bottled sources and many of these homes were made of concrete, indicating that these individuals were of higher socioeconomic status.

Most cases of diarrheal disease and poor water quality in the GIS analysis seems to be clustered in the poorer areas of Constanza. The cleanest water and lowest diarrheal disease morbidity is located in the city center as well as Tireo. Both of these communities were of higher socioeconomic status than some of the other communities that were observed. Virtually all households interviewed had piped water in the home, cisterns on the roof, and bottled water for consumption. Lower diarrheal disease morbidity was also reported in the home. Better water quality and lower diarrheal disease morbidity can be explained with the social determinants of health. As these individuals of higher socioeconomic status have better access to resources, such as doctors and more effective means of obtaining clean water, cleaner water and better health outcomes are the result.

GIS analysis and mapping also demonstrates clustering of poorer water quality and higher diarrheal disease morbidity throughout the poorer areas of Constanza. The communities of El Chorro, Arenazo, and Los Peinados are where the poorer households interviewed live.

These households were not formally connected to the piped water system or the electrical grid and have to obtain access to these resources through unofficial means. This results in the majority of the homes in these communities utilizing less costly and less effective means of sanitizing and storing water. Many of these households store water in containers that leave the water prone to contamination while using methods such as chlorination to sanitize it. Very few of these households obtain bottled water for consumption. These households also do not seek medical attention as frequently as the households of higher socioeconomic status. Participant observations revealed that the poorer households within these communities also report gastrointestinal problems related to infectious disease at a higher frequency than the households of higher socioeconomic status. Many of the poorer households interviewed reported parasitic infections in addition to stomach problems, while the households of higher socioeconomic status had a tendency to report gastrointestinal problems more chronic in nature, such as indigestion.

Spatial analysis is also difficult to quantitate in Constanza because of the proximity of the different socioeconomic classes. There are certain communities, like Las Flores, where the vast majority of homes are of poorer socioeconomic status; however, many of these communities have individuals of higher socioeconomic status (i.e. concrete, fenced home with a cistern) neighboring individuals of lower socioeconomic status (i.e. corrugated home and no piped water). This observation explains the prevalence of households that exhibit cleaner water and no self-reported diarrheal disease morbidity juxtaposed among households that have poorer water quality and self-reported diarrheal disease morbidity. Since there is no simplistic method of generalizing communities as many of the communities are not simply homogenous in terms of socioeconomic status, coupled with the fact that sample sizes within these communities are so small, care must be taken to not oversimplify GIS analysis by generalizing



that one community is more likely to have poorer water quality or higher diarrheal disease morbidity. This study has revealed that the prevalence of diarrheal disease morbidity and water quality is not simply a question of who has access to water, but it is a complex relationship that depends on socioeconomic status, history, and distribution of resources.

#### *Water Quality Initiatives at the Household Level*

Since water quality is so poor at the household level, there are a number of interventions at the household level that are practiced to improve quality of water that is consumed. Currently, there are primarily three forms of water quality improvements that are practiced in the Dominican Republic: chlorination, boiling, and filtration. Each form of water treatment has different effects on the basic properties of the water treated as well as different levels of sanitation with regard to potential pathogenic organisms.

Chlorination is widely utilized throughout the Dominican Republic as a means of household water treatment. Currently, there are health promotion initiatives through SESPAS to encourage individuals to place free chlorine in water intended for consumption (SESPAS, 2009). A systematic review of the literature has indicated that chlorination alone can reduce diarrheal disease morbidity by approximately 30% (Arnold & Colford, 2007). Chlorination is able to eradicate bacterial contamination and provides residual disinfection properties that prevent recontamination of water. Despite the fact that chlorination is a relatively quick and cheap method of water treatment, there are limitations. Chlorination is not extremely effective at reducing protozoan pathogens or enteric viruses. It has been reported that certain forms of protozoan pathogens require as much as a 1000 fold increase in chlorine disinfection to have the same effects as bacterial disinfection rates with chlorine (Stauber, 2007).

Boiling is one other form of water disinfection that is utilized at the household level. For the prevention of diarrheal disease in children, SESPAS has created a health promotion

campaign to promote the boiling of drinking water for children. Boiling is the preferred method of water disinfection as mandated by SESPAS. This intervention can be particularly useful to individuals in poor regions because boiling is extremely cheap and it is efficient at disinfection for all three classes of potential intestinal pathogens (bacteria, viruses, and parasites).

Unfortunately, the efficacy of utilizing water boiling has been greatly reduced through a number of practices such as: not boiling water for enough time (which does not adequately disinfect water) and inadequate storage of water (which allows for recontamination) (McLennan, 2000; SESPAS, 2009).

The third method of water disinfection that is utilized in the Dominican Republic at the household level is filtration. Per capita, the Dominican Republic has the second highest number of biosand filters in the world (Stauber, 2007). Filtration as a form of water disinfection is highly useful because it is extremely effective for all three classes of potential intestinal pathogens. One of the major drawbacks of using filtration systems in the Dominican Republic is the cost of purchasing the unit; the units require some level of education to utilize properly, and the costs to maintain the units (Stauber et al., 2006; Palmateer et al., 1999).

#### *Water Quality Assessment*

Although *E. coli* is one of the most utilized indicator organisms used to determine overall water sanitation, it is important to note that it is not a universal indicator of overall microbiological water quality; there are many organisms that behave much differently than *E. coli*. In fact, there are various enteric viruses as well as parasitic organisms that have been demonstrated in various studies that behave differently than *E. coli* and are therefore more difficult to detect. For example, certain enteric viruses and protozoan parasites require such a varying number of organisms to cause an infection that they can be virtually undetected by testing the water. These organisms have also been shown to be resistant to chlorination;

therefore, if chlorination is used to kill the bacterial cells that would subsequently not appear on a bacteriological assay, such as quantitating coliform bacteria, water quality may appear to be high. Given this fact, there may be a large number of protozoan parasites or enteric viruses present that may lead to diarrheal disease (Ashbolt, 2004; M. LeChevallier, 1992).

There has been some speculation in the literature that using *E. coli* as an indicator organism in tropical climates may not yield accurate results, as *E. coli* is found to proliferate at warm temperatures. Since *E. coli* is used to determine if the water analyzed contains fecal contamination, results from water quality assays may be skewed since this indicator organism can at times be indigenous flora in tropical waters (Terry, 1988). This theory was disproven in a one year epidemiological-microbiological study by Moe et al. that was conducted to determine if there was any correlation between disease outcome and quantity of disease indicator organisms in tropical climates. This study sought to determine if water samples from tropical climates appeared to have a heightened amount of disease indicator organisms due to the proliferation of these organisms in warm, tropical water. It was determined that both *E. coli* as well as enterococci are the most accurate indicator organisms in determining diarrheal disease outcome in water in tropical climates, as there was the highest correlation between number of colonies present in the water with incidence of diarrheal disease (Moe, 1991).

Findings from Moe et al. seem to suggest that there is a threshold effect in water that is contaminated with *E. coli*. It appears that individuals that consume good (<1 *E. coli* per 100 mL) to moderately contaminated (2-100 *E. coli* per 100 mL) water did not have much of a discrepancy in diarrheal disease prevalence. This suggests that there are other routes of diarrheal disease transmission in these tropical communities. However, it has been suggested that grossly contaminated water (> 1000 *E. coli* per 100 mL) leads to a much higher incidence of diarrheal disease and that minimal interventions in the water supply could lead to a 10-fold

reduction in *E. coli* rates as well as leading to a significant decrease in morbidity due to diarrheal disease (Moe, 1991).

Enumeration of coliform bacteria has been utilized for determining the correlation between bacterial counts in water and other potential pathogens that can lead to diarrheal disease, such as the presence of parasites such as *Giardia* and *Cryptosporidium*. Studies have shown that coliform counts can be indicative of the risk of *Giardia* and *Cryptosporidium* in treated water. Although parasite counts are largely dependent on the status of the raw water; coliform counts can be utilized to determine the efficiency of water treatment. If water treatment plants are not working efficiently, it has been determined that a strong, positive correlation between coliform counts and number of *Giardia* and *Cryptosporidium* cysts and oocysts exists (M. LeChevallier, 1992).

## CHAPTER 5

### CONCLUSIONS

The primary focus of this study was to perform initial exploratory research in the municipality of Constanza on water quality and diarrheal diseases. Currently, there is very little evidence in the scientific literature surrounding factors around diarrheal disease and water quality in the Dominican Republic, and there is no evidence in the literature on the general situation of public health in the Constanza municipality. This study contributes to the body of knowledge on diarrheal disease and water quality in the Dominican Republic as well as advances the knowledge base about Constanza.

The results of this study suggest that socio-economic status appears to influence the link between access to safe and clean water and health outcomes. In the case of Constanza, water handling practices and poor access to safe and clean water results in stomach problems and diarrheal diseases among community members. Although poor access to clean water affects all members of the community, morbidity linked to poor water quality appears to affect disproportionately communities of lower socio-economic status.

#### *Limitations of Study*

This study has several logistic and methodological limitations that need to be identified. Although the study responded to needs identified by local members of the health care workforce (e.g. director of municipal hospital) and by members of the local NGO working on economic development, the design did not incorporate a random sampling of households or of environmental samples limiting the generalizability of the results. Ethnographic research brings the richness of the “being there” to understand the context and allowed the researcher to participate in everyday life in the communities visited. However, the length of fieldwork was limited to five weeks thus allowing only for a rapid ethnographic assessment of water use and

self-reported morbidity. Future research in this direction will benefit for extended fieldwork to define socio-cultural patterns that seem to be protective particularly of younger groups when it comes to morbidity linked to water use.

The analysis of water quality and the establishment of a field laboratory proved to be challenging. As electricity was not continuous in the site, it was logistically challenging to have access to an incubator that would have continuous access to electricity. An incubator was found in the public health hospital, but access the incubator was only limited to a couple of hours in the afternoon Monday through Friday. Therefore, samples could only be collected in the mornings of Monday through Thursday. This also limited the amount of samples that were able to be analyzed during this period to 88. Additionally, Coliscan media proved to be the most cost-effective means of obtaining information about basic water quality in the field as no laboratory infrastructure was present in the community; however this media was only able to detect coliform bacteria and *E. coli*. Hospital records and household surveys indicate a high prevalence of parasitic infections within the community. The prevalence of parasitic diseases and other potential pathogens that could be harbored in the water supply was not determined as it was not detected by the form of field laboratory methods employed.

Although the household surveys utilized for this study were modeled after the ENDESA, studies within the scientific literature indicate that one month is too large of a time period to accurately self-report diarrheal morbidity. Having a household member recall diarrheal morbidity for an entire household for the previous month allows recall bias to enter the study. For example, a household member may have difficulty recalling if a cousin who lives in the household has had diarrheal disease in the prior month simply because that type of discourse may not take place in the relationship. The recall bias in this study may have resulted in an increased amount of individuals not reporting diarrheal disease due to the household member

that was interviewed not knowing the status of other family members and reporting that these family members did not have diarrheal disease.

In addition to recall bias, the logistic regression analysis that was conducted on the quantitative data collected indicates that age is the only factor that is significantly related to diarrheal disease, particularly among the 25-34 year age group. This observation could possibly be attributed to most household members interviewed falling within this age group and accurately self-reporting their own diarrheal disease status but were unable to accurately report those of different age groups within the household. Consequently, overall diarrheal morbidity may appear much lower than what is actually present within the population. The etiology of diarrheal disease is also extremely complicated, and diarrheal disease can come from a variety of sources. A direct causal link to water is not the only method in which an individual can contract diarrheal disease. Consequently, it is important to note that contaminated water may not result in diarrheal disease and diarrheal disease may not be linked to the water. Also, asking household members to report diarrheal disease status over an entire month may be too long of a time period to accurately recall diarrheal disease occurrence.

As the sample size of this study is limited to eight households in 11 communities for a total of 88 households, it is difficult to accurately quantitate the data that was obtained in the water analysis and household surveys. There is a high amount of diversity in terms of socioeconomic both within and between communities within Constanza. When data is analyzed by community, the sample size is only eight households. As this sample size is so small, it does not have enough power to accurately describe numerically what is occurring in these households. The lack of power in the sample size also does not allow for the use of more sophisticated methods of statistical analysis.

The manner in which this study was conducted does not allow for more sophisticated statistical analysis to be conducted by comparing multiple variables. This is due to the fact that many of the observations that are made in this study surround behavioral patterns in the household. Many different factors can be attributed to how water is contaminated within the household, and the link between the occurrence of diarrheal disease and water quality is not necessarily causal. Consequently, the strong statistical relationship with diarrheal disease and other factors revealed in this study was not present.

Another limitation of this study surrounds the water quality analysis within the households. Water quality was assessed at the aqueducts and water treatment plants, but was not assessed straight from the faucets within the households. Household members were asked to provide a water sample that was used for drinking; however, as this water did not come straight from the faucet, it is difficult to determine if contamination occurred in the pipes from the aqueduct or if handling practices were responsible for water contamination. Future studies where water is analyzed at aqueducts, faucets or bottles where water is obtained, and after the water has been handled would be extremely useful in analyzing how water gets contaminated.

Despite the aforementioned limitations, this study has uncovered some structural factors and socio-cultural determinants of water use and health that contribute to the infectious disease burden in the municipality of Constanza. The findings of this study have potentially large ramifications for both community health and economic development in the region to improve awareness among community members of the ramifications of poor water quality not only for family members but for the nascent eco-tourism industry. The results from this study will be utilized by community members within the Constanza municipality for local interventions. Particularly, findings from this study can be utilized to develop and implement health education and awareness campaigns to promote clean and safe water handling practices.



## APPENDIX 1: IRB APPROVAL



### INDIANA UNIVERSITY

OFFICE OF RESEARCH ADMINISTRATION

**To:** Cherie S. Blair  
Applied Health Science

**From:** IUB Human Subjects Office  
Office of Research Administration – Indiana University

**Date:** May 28, 2009

**RE: EXEMPTION GRANTED**  
Protocol Title: Uncovering the Infectious Disease Burden and Socio-Cultural Determinants of Water Use and Health in a Rural Community in the Dominican Republic  
Protocol #: 0905000329  
Sponsor: Internally funded: HPER-FRSP grant to faculty advisors Bonilla, Edwards and Ona, Mendel Research Grant, applied health science discretionary student research grant

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Your study named above has been accepted on May 27, 2009 as meeting the criteria of exempt research as described in the Federal regulations at 45 CFR 46.101(b), paragraph 4. This approval does not replace any departmental or other approvals that may be required.

As the principal investigator (or faculty sponsor in the case of a student protocol) of this study, you assume the following responsibilities:

- **Changes to Study:** Any proposed changes to the research study must be reported to the IRB prior to implementation. This may be done via an e-mail or memo sent to the IRB office. Only after approval has been granted by the IRB can these changes be implemented.
- **Completion:** Although a continuing review is not required for an exempt study, you are required to notify the IRB when this project is completed. In some cases, you will receive a request for current project status from our office. If we are unsuccessful in our attempts to confirm the status of the project, we will consider the project closed. It is your responsibility to inform us of any changes to your contact information to ensure our records are kept current.

Per federal regulations, there is no requirement for the use of an informed consent document or study information sheet for exempt research, although one may be used if it is felt to be appropriate for the research being conducted. As such and effective immediately, the IUB IRB will no longer stamp study information sheets / informed consent documents for exempt research. Please note that if you still choose to use these documents, you may use unstamped versions. **Please note that your study has been accepted without the use of a study information sheet.**

You should retain a copy of this letter and any associated approved study documents in your records. Please refer to the project title and number in future correspondence with our office. Please contact our office at (812) 855-3067 or by e-mail at [iub\\_hsc@indiana.edu](mailto:iub_hsc@indiana.edu) if you have questions or need further assistance.

Thank you.

**APPENDIX 2: HOUSEHOLD SURVEY - SPANISH**

**1 | Entrevista de hogar específica: AGUA**

Fecha:

Lugar:

Muestra de agua #:

Posición en el hogar de la persona entrevistada:

Coordenadas de GPS:

¿Cuántos viven en la casa?:

**Datos demográficos e historial gastrointestinal**

No. miembro hogar:	Sexo	Edad	Historia ¿Le dio diarrea? ¿Tuvo problemas estomacales o dolores en la barriga?	¿Fue al médico cuando tuvo ese problema de salud? ¿Qué le dijo el médico que tenía?	
				Si	No
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					
11					
12					
13					
14					
15					

**Condiciones de vida**

Acceso al agua

Si  No

Tipo de acceso del agua de consumo diario:  
(cocinar, tomar/beber, lavar alimentos)

- A. Potable (de llave)
- B. De pozo
- C. De botellón
- D. Cisterna
- E. Otro:

¿De dónde viene el agua? ¿Dónde busca el agua?

¿Cuándo buscó el agua?

¿Hace algo para limpiar el agua?

Si  No

**¿Qué hace?**

- La hierve
- Le echa cloros/blanqueador
- Le echa tabletas
- Otro:

Tiene electricidad

Si  
 No

Facilidades sanitarias:

Si  No  
 Adentro  Afuera

Tipo:

Agua para lavar la ropa: \_\_\_\_\_

Agua para bañarse: \_\_\_\_\_

**APPENDIX 3: HOUSEHOLD SURVEY - ENGLISH**

**1 | Household Interview: WATER**

Date:

Location:

Water Sample #:

Position in household of person interviewed:

GPS Coordinates:

How many live in the home?:

**Demographic information and gastrointestinal history**

No. household member:	Sex	Age	History Does the individual have diarrhea? Does the individual have gastrointestinal problems or stomach pains?	Did the household member seek medical attention for this problem? What was the diagnosis?	
				Yes	No
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					
11					
12					
13					
14					
15					

**Conditions in the Household**

Access to water

Yes       No

Type of water consumed daily:  
(cooking, drinking, washing food)

- A. Faucet
- B. Well
- C. Bottled
- D. Cistern
- E. Other:

Where does the water come from?

When was this water sample obtained?

Are there steps taken to sanitize water?

Yes       No

Method utilized to sanitize water:

- Boiling
- Chlorine
- Tablets
- Other:

Does the household have electricity

Yes  
 No

Sanitary facilities:

Yes       No  
 Inside       Outside

Type:

Water to wash clothing: \_\_\_\_\_

Water to bathe: \_\_\_\_\_

## APPENDIX 4: COMMUNITIES SELECTED FOR SAMPLING



### CAPACITY BUILDING, COMMUNITY HEALTH, AND ECONOMIC DEVELOPMENT IN THE DOMINICAN REPUBLIC

Component of project associated with this sampling:  
**Community and environmental health**

Title of subproject:

*Uncovering Infectious Disease Burden and Socio-cultural Determinants of Water Use and Health in a Peri-urban Community in the Dominican Republic*

#### Overview of sampling process

Community	Type of sample: HH – household ENV - environmental	Selection criteria	Status: check when done
Barrio Las Flores	HH	CETC	<input type="checkbox"/>
Los Peinados	HH	CETC	<input type="checkbox"/>
El Chorro	ENV (river) + HH	CETC	<input type="checkbox"/>
El Cercado	HH	CETC	<input type="checkbox"/>
La Ciudad (Rio Grande treatment plant)	ENV + HH	Hosp	<input type="checkbox"/>
La Culata	ENV	Hosp	<input type="checkbox"/>
La Sabina	ENV + HH	Hosp	<input type="checkbox"/>
Cañada Seca	HH	Hosp	<input type="checkbox"/>
El Eden	HH	Hosp	<input type="checkbox"/>
Palero Arriba & Abajo	ENV + HH	Hosp	<input type="checkbox"/>
Tíreo	ENV + HH	Hosp	<input type="checkbox"/>
Arenazo	HH	Hosp	<input type="checkbox"/>
El Río	ENV	Hosp	<input type="checkbox"/>
Arroyo Frío	ENV	Hosp	<input type="checkbox"/>

#### Descriptions

- CETC = suggested by Clúster Ecoturístico de Constanza. These are *barriadas de la ciudad*, neighborhoods of the city of Constanza located along the river Pantunfla.
- Hosp = Director of Hospital in Constanza. These are communities suggested by the Director of the main hospital in Constanza because of the high number of patients from these communities who present with diarrheal diseases and stomach problems.

- Environmental samples include water sample obtained from the river and water samples obtained from the water treatment plants.
- Household samples include samples of water used for consumption obtained from homes from any of the following: bottles/botellón, faucet, others.

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# Cheríe S. Blair

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## Education

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Master of Public Health	Research Concentration – Thesis Thesis Advisor: Dr. Zobeida Bonilla Thesis title: Uncovering infectious disease burden and socio-cultural determinants of water use and health in a peri-urban community in the Dominican Republic <i>Indiana University, Bloomington, Indiana</i>	May 2010
Bachelor of Science	Microbiology <i>Indiana University, Bloomington, Indiana</i>	December 2007
Bachelor of Arts	Chemistry, Political Science Minors: Spanish and West European Studies <i>Indiana University, Bloomington, Indiana</i>	December 2007

## Honors and Awards

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Indiana University Bloomington Sustainability Research Grant, <i>IU Graduate School</i>	2010
Community Social Assistance Grant, <i>Consejo Municipal de los Fondos Mineros, Constanza, RD</i>	2010
Discretionary Student Travel Grant, <i>Department of Applied Health Science</i>	2010
Travel Grant-In-Aid, <i>School of HPER</i>	2010
GHEC-Lancet Research Award Nominee, <i>Global Health Education Consortium</i>	2009
MPHA Student Travel Grant, <i>Department of Applied Health Science</i>	2009
APHA-PHEHP Best Student Abstract Award	2009
Discretionary Student Research Grant, <i>Department of Applied Health Science</i>	2009
Research Grant-In-Aid, <i>School of HPER</i>	2009
Mendel Summer Research Grant, <i>Department of Latin American and Caribbean Studies</i>	2009
Donald Ludwig Fellowship, <i>Department of Applied Health Science</i>	2009
Travel Grant, <i>Hutton Honors College</i>	2007
Member, <i>Hutton Honors College</i>	2003 – 2007
Dean's List	2003 – 2007

## Research Experience

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<u>Co-PI</u> , <i>Agua Para la Salud de Constanza, Constanza, Dominican Republic</i>	2009 – Present
○ Role: Creating, implementing, and evaluating a program promoting clean water and sanitation	
<u>Intern</u> , <i>Batey Relief Alliance, Santo Domingo, Dominican Republic</i>	2009 – Present
○ Assisting with the evaluation of a health program for HIV+ children	
<u>Graduate Research Assistant</u> , <i>Indiana University, Bloomington Indiana</i>	2009 - Present
○ Indiana Prevention Resource Center	
○ Role: Assisting with the epidemiologic and GIS analysis of tobacco use and prevention efforts in Indiana	
<u>Graduate Research Assistant &amp; Program Coordinator</u> , <i>RAICES Project</i>	2008 - Present
○ P.I.: Dr. Zobeida Bonilla, <i>Department of Applied Health Science</i>	
○ Role: household surveys, interviews, water quality monitoring assessment, training of community members on water quality assessment and monitoring techniques	
<u>Research Assistant</u> , <i>Indiana University, Bloomington, Indiana</i>	2005-2009
○ P.I.: Dr. Clay Fuqua, <i>Department of Microbiology</i>	
○ Role: Analyzing spontaneous tetracycline resistance and the interruption of the counterselection marker <i>sacB</i> by IS426, an <i>Agrobacterium tumefaciens</i> C58 insertion sequence	
<u>Physician Educator</u> , <i>Methodist Hospital, Indianapolis Indiana</i>	2009 – 2010
○ Department of Physician Education, Academic Affairs	

- Role: Assisted with grant writing and data analysis to optimize physician education programs

## Teaching Experience

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<u>Graduate Teaching Assistant</u> , <i>Indiana University, Bloomington Indiana</i>	2008-2009
○ H180: Stress Management, Spring 2009	
○ Instructor: Jon Peters	
○ F457: Strength and Resilience in the Family, Fall 2008	
○ Instructor: Julie James	
<u>Undergraduate Tutor</u> , <i>Indiana University, Bloomington, Indiana</i>	2007
○ M200: Introduction to Microbiology	
○ Instructor: Dr. Rick Mower	
<u>Undergraduate Teaching Intern</u> , <i>Indiana University, Bloomington, Indiana</i>	2007
○ L112: Biological Mechanisms	
○ Instructor: Dr. Yean W. Chooi Odle	
<u>Ombudsperson</u> , <i>Indiana University, Bloomington, Indiana</i>	2004
○ C343: Organic Chemistry Laboratory	
○ Instructor: Dr. Andrea Pellerito	

## Presentations

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- Blair, C.S., Z. Bonilla, F. Ona.** (2010) *Practices surrounding water use among community members in the Dominican Republic: Implications for social justice and public health*. APHA 138<sup>th</sup> Annual Meeting and Exposition – International Health Section, Denver, CO (Accepted).
- Blair, C.S., E. Pérez-Medina, M. Delgado, Z. Bonilla, F. Ona** (2010) *Una comunidad saludable: Implementing a meaningful health education and water sanitation program in the highlands of the Dominican Republic*. APHA 138<sup>th</sup> Annual Meeting and Exposition – PHEHP Section, Denver, CO (Accepted).
- Blair, C.S.** (2010). Water and Diarrheal Disease in the Dominican Alps. Part of panel discussion *Pakistani Doctors, Trails, Strawberries, and Aqueducts: Community Health and Tourism Development in the Dominican Alps* (Bonilla et al.). Dean of HPER Research Seminars, Bloomington, IN.
- Blair, C.S., Z. Bonilla-Vega, F. Ona, P. Edwards** (2010) *Factors surrounding diarrheal disease and water quality among community members in a peri-urban community located in the Dominican Republic*. 2010 GHEC Latin American and Caribbean Conference on Global Health, Cuernavaca, México.
- Blair, C.S., F. Ona, Z. Bonilla-Vega, P. Edwards** (2009) *Uncovering the infectious disease burden and socio-cultural determinants of water use and health in a rural community in the Dominican Republic*. 2009 APHA National Convention – PHEHP Awards Section, Philadelphia, PA.
- Blair, C.S., Z. Bonilla-Vega, P. Edwards, F. Ona.** (2009) *Estimating the burden of communicable disease in rural communities of the Dominican Republic: the impact of infectious disease epidemiology*. 2009 IPHA Annual Meeting, Indianapolis, IN.
- Morton, E.R., P.M. Merritt, M.E. Hibbing, T. Danhorn, C.S. Blair and C. Fuqua.** (2008) *Agrobacterium tumefaciens* utilizes a unipolar polysaccharide for adherence to surfaces. 2008 IBASM Annual Meeting, Muncie, IN.
- Blair, C.S., P.M. Merritt, and C. Fuqua.** (2007) Analysis of tetracycline resistance and interruption of the counterselection marker *sacB* by IS426, an *Agrobacterium tumefaciens* C58 insertion sequence. 28<sup>th</sup> Annual ASM Crown Gall Conference, Tempe, AZ.
- Morton, E.R., P.M. Merritt, M.E. Hibbing, T. Danhorn, C.S. Blair and C. Fuqua.** (2007) Polar surface attachment and biofilm formation of *Agrobacterium tumefaciens* requires contact-dependent extrusion of a unipolar polysaccharide analogous to the *Caulobacter* holdfast. 28<sup>th</sup> Annual ASM Crown Gall Conference, Tempe, AZ.

## Manuscripts in Preparation

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- Blair, C.S., P.M. Merritt, and C. Fuqua.** (2010) Analysis of tetracycline resistance and interruption of the counterselection marker *sacB* by IS426, an *Agrobacterium tumefaciens* C58 insertion sequence.
- Blair, C.S., F. Ona, and Z. Bonilla-Vega.** Uncovering infectious disease burden and socio-cultural determinants of water use and health in a peri-urban community in the Dominican Republic.
- Danhorn, T., P.M. Merritt, M.E. Hibbing, E.R. Morton, A.D. Tomlinson, C.S. Blair and C. Fuqua.** A unipolar polysaccharide produced by *Agrobacterium tumefaciens* functions as a holdfast-type adhesin.

## Professional Affiliations

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President, <i>Masters of Public Health Student Association</i>	2008 - Present
Member, <i>Global Health Education Consortium</i>	2009 - Present
Member, <i>American Public Health Association</i>	2009 - Present
Member, <i>American Public Health Association Student Assembly</i>	2009 - Present
Member, <i>Indiana Public Health Association</i>	2008 - Present
Member, <i>Alpha Chi Sigma</i> , Pre-professional Chemistry Fraternity	2004 – 2007
Member, <i>Student Affiliates of the American Chemical Society</i>	2004 - 2007

## Service

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- Volunteer, *Cluster Ecoturístico* and RAICES, conducted a fundraising campaign to collect monetary donations as well as hats and gloves for children aged 0-12 living in the community of El Convento in the Dominican highlands, Indiana University and Cluster Ecoturístico Constanza, Bloomington, Indiana and Constanza, Dominican Republic, Winter 2009 – 2010.
- President, *MPH Student Association*, conducted fundraising for public health research as well as worked to raise educational awareness surrounding HIV/AIDS and cancer in Southern Indiana, Indiana University, Bloomington, Indiana, 2009 – present.
- Instructor, *English as a Second Language*, instructed English as a second language to Spanish-speaking immigrants in the Bloomington community, Bloomington, Indiana, 2006 – present.
- Volunteer, *Rescantando el Río Pantunfla*, environmental and educational activity to clean the river in the community of Constanza, DR, and raise consciousness about environmental pollution and public health, Indiana University and Cluster Ecoturístico Constanza Collaboration, Constanza, Dominican Republic, Summer 2009.
- Supervisor, *Physics Day*, helped to create and supervise activities to educate local youth about physics and the basic sciences, Physics Program, Indiana University, Bloomington, Indiana, 2006.
- Supervisor, *Brownie Math and Science Day*, helped to create and supervise activities to educate young girl scouts about chemistry and to raise general interest among young girls in chemistry and the basic sciences, Chemistry Program, Indiana University, Bloomington, Indiana, 2004 – 2005.

## Skills and Languages

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- Proficiency in laboratory techniques in the fields of microbiology and molecular biology
- Proficiency in Microsoft 2007 applications (Excel, Word, PowerPoint, Access, and Outlook)
- Proficiency in GIS applications (MapMarker 13, MapInfo Professional)
- Proficiency in SPSS 17
- Languages spoken: Spanish