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Megan Hannemann  
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# The Sub-Saharan Water Crisis: An Analysis of its Impact on Public Health in Urban and Rural Nigeria

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2015



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# Abstract

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Today, 11% of the global population still lacks access to clean water, one of humans' most basic needs. Those who lack a safe water source are largely concentrated in sub-Saharan Africa, where only 61% have access to safe water. Within this region, large disparities exist that hide the severity of the problem for some communities. The term "water crisis" is often used to describe the lack of water access throughout the world and the resulting consequences. In this thesis, the impact the water crisis has on public health in sub-Saharan Africa was analyzed using Nigeria as a model nation. Specific forces that contribute to the persistence of the water crisis and the public health outcomes were examined. Urban and rural Nigeria were researched separately, as each setting has its own set of obstacles concerning the water crisis and its own set of public health issues. It was found that in both urban and rural Nigeria, the increased transmission of water-related diseases was a significant burden caused by the water crisis. In Lagos, a city in southern Nigeria, the poor environmental conditions allow for the spreading of diseases through the fecal-oral route of transmission. Additionally, diseases that are typically found in rural setting are becoming more prevalent in Lagos due to the unkempt environment. In rural Nigeria, the lack of safe water sources makes the chances of contracting waterborne diseases very high. The control of water-related diseases is made worse in rural areas because it is difficult to get resources to an isolated rural area. This problem is exacerbated in places suffering from ongoing conflict. However, the prevalence of several diseases has decreased as the availability of water sources increases. By pointing out the severe public health consequences that the water crisis has on sub-Saharan Africa, the goal of this thesis is to inspire further progress towards water access for all.



# Introduction

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Water is essential to life on earth, and consequently, it is one of the most basic human needs. Aside from having many functions in the operation of the human body, water is necessary for human life in many ways. Without water, many food sources would not be viable. Crops would not be able to grow, livestock would not be able to survive, and fish would not have a home to live in. The development of civilization would not have been possible without the Earth's water coverage, as water has provided a means for transportation and a power source (Atteberry, 2010). Additionally, water is essential for proper sanitation and hygiene, which are necessary for the health of human beings.

However, the most obvious reason that water is a basic human need is because we have to intake water in order to survive. In the body, water has many functions, making it vital to survival. Each day, the body loses water to the environment through various routes, such as the excretion of urine and the production of sweat. Although the human body can produce a small amount of water, this cannot account for the amount that is lost daily (Kleiner, 1999). Therefore, humans rely on the consumption of water in order to replace what is lost. When the quantity and quality of water that is consumed is not sufficient, a person faces potential health risks. For example, dehydration occurs when the amount of water being lost from the body is greater than the amount that is being consumed. Dehydration causes a variety of symptoms, such as muscle spasms, dim visions, clumsiness, and delirium (Kleiner, 1999). Therefore, in order to maintain a healthy state in the body, it is essential that a person drinks the appropriate amount of water daily.

When looking at the importance of water for the proper functioning of the human body, it is important to not only consider the quantity of water consumed, but also the quality. When a



person drinks from a source that is not protected from contamination, they open themselves up to numerous health risks. Specifically, unsafe drinking water is often contaminated with microbes, which have the ability to transmit a wide variety of diseases to humans. It is estimated that 4% of all deaths could be attributed to water-related diseases (Pruss, Kay, Fewtrell, & Bartram, 2002). Some of the largest contributors to these numbers are diarrheal diseases. Approximately 11% of child deaths worldwide are attributed to a diarrheal disease, and of these cases, 88% are caused by unsafe water or improper sanitation (CDC, 2013). Therefore, the quality of drinking water cannot be overlooked when assessing water's role in public health.

Due to the importance of water to human health, water shortages can pose serious obstacles for improving global health. In 2012, there were still 780 million people in the world without access to safe drinking water (UNICEF, WHO, 2012). In response to this large need for safe water, along with the need for improvement in other public health areas, a call to action was made in 2000 in the form of the Millennium Development Goals.

## **The Millennium Development Goals**

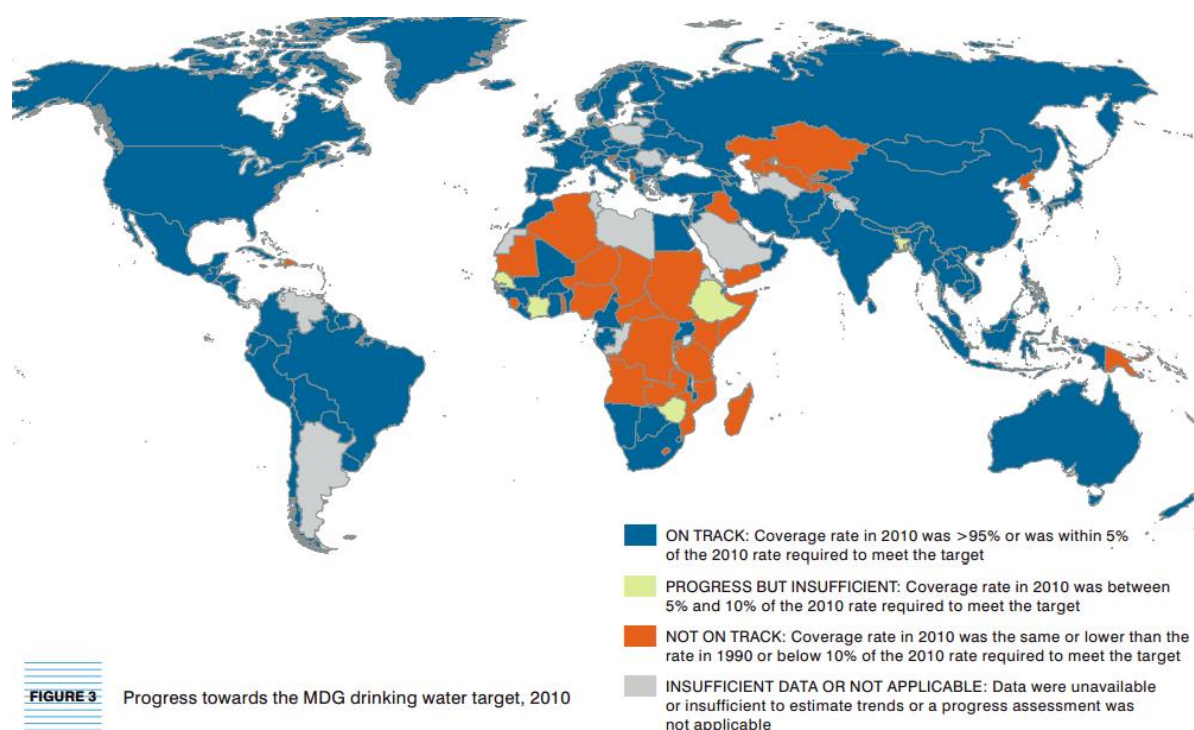
The Millennium Development Goals are a set of eight goals proposed by the World Health Organization (WHO) to improve the lives of many by helping them gain access to basic human rights. For example, the eradication of poverty and hunger, the promotion of gender equality, and the fight against HIV, malaria, and other communicable diseases are a few of the goals set forth. The goal that relates to the water crisis is Goal 7: to ensure environmental sustainability. Within this goal, there are several specific targets, such as the reduction of the percentage of the global population without access to safe water and sanitation by half. Also, there is a goal of improving the lives of 100 million slum dwellers through better access to safe water and sanitation (United Nations).

The progress on these goals is monitored through the use of surveys conducted by the WHO/UNICEF Joint Monitoring Programme (JMP) for Water Supply and Sanitation. Because most people do not know the quality of water they are drinking, the amount of people that drink safe water is determined by asking where they get their water from. The source of water is a good determinant of how clean it is. There are four types of sources: piped water, other improved water sources, unimproved water sources, and surface water. Piped water is household water, and it is considered an improved water source. Other improved water sources include public taps, boreholes, protected wells, or protected springs. Unimproved sources include unprotected dug wells, unprotected springs, carts with small tanks, or bottled water. Finally, surface water is taken from rivers, lakes, canals, ponds, or streams (WHO/UNICEF Joint Monitoring Programme for Water Supply and Sanitation).

Similarly, there are four types of sanitation facilities: improved sanitation facilities, shared sanitation facilities, unimproved sanitation facilities, and open defecation. Improved sanitation facilities include facilities that flush to some type of sewer system, septic tank, or pit latrine. Shared facilities would be considered acceptable facilities, but the fact that they are shared between more than one household makes them unimproved. Other unimproved sanitation facilities include pit latrines without a platform, hanging latrines, or bucket latrines; these facilities do not prevent human contact with feces. Finally, open defecation occurs in open spaces such as open bodies of water, forests, or bushes (WHO/UNICEF Joint Monitoring Programme for Water Supply and Sanitation).

It was reported in 2012 that the first few Millennium Development Goals had been met. These targets related to the reduction of poverty, the increase in access to safe water, and the improvement of lives of slum dwellers. Since 1990, over 200 million people living in slums

were introduced to an improved water source and/or an improved sanitation facility. Globally, the percentage of the population with improved access to water increased from 76% to 89%, meaning that nearly 200 billion people across the world had gained access to improved water sources (United Nations Development Programme, 2012). The achievement of these goals marks large strides in global health. However, these statistics can be misleading, as they hide the huge disparities that still exist in access to safe water. Many countries are still not on track to meet the goal individually. Additionally, the progress towards the goal for sanitation is unsatisfactory at this time. There is still a tremendous amount of work to be done to fix these remaining problems.



**Figure 1: Map of the World's Progress Towards the MDG for Water**

Source: (UNICEF, WHO, 2012)

As can be seen in Figure 1, many of the countries that need to make significant progress in order to meet the MDG for water are concentrated in sub-Saharan Africa. Of the 50 countries that make up sub-Saharan Africa, only 19 are predicted to meet the goal at this time.

## **Why Sub-Saharan Africa?**

An obvious question that arises is why is sub-Saharan Africa lagging so far behind the rest of the world in access to safe drinking water? Before addressing this question, it is important to note that the gap between sub-Saharan Africa and the majority of the world in achieving the MDGs may be perceived as larger than it is because of the methodology behind the MDGs. It is possible that the way the progress is monitored doesn't give enough credit to the improvements being made in sub-Saharan Africa. Because the achievement of the goals requires each country to halve the population without access to clean water and sanitation, countries that started off with a low percentage of people with access to clean water and sanitation have to make much more progress in order to meet the goal. For example, in 1990, it was reported that 14% of the population of Ethiopia, which is located in sub-Saharan Africa, had access to clean drinking water (UNICEF, WHO, 2012). Therefore, in order to meet the MDG, that country had to grant access to an additional 43% of its population. On the other hand, it was reported in 1990 that 89% of Colombia's population had access to clean water (UNICEF, WHO, 2012). Only 6% of their population needed to gain access to clean water in order to meet the MDG. So, for many of the countries in sub-Saharan Africa that start out with low baseline numbers, meeting the MDG targets is more of a challenge.

Moreover, the methodology behind the MDGs puts countries that are experiencing rapid population growth at a disadvantage. In these countries, it is possible that the amount of people that are gaining access to clean water is matched by the constantly increasing population, which

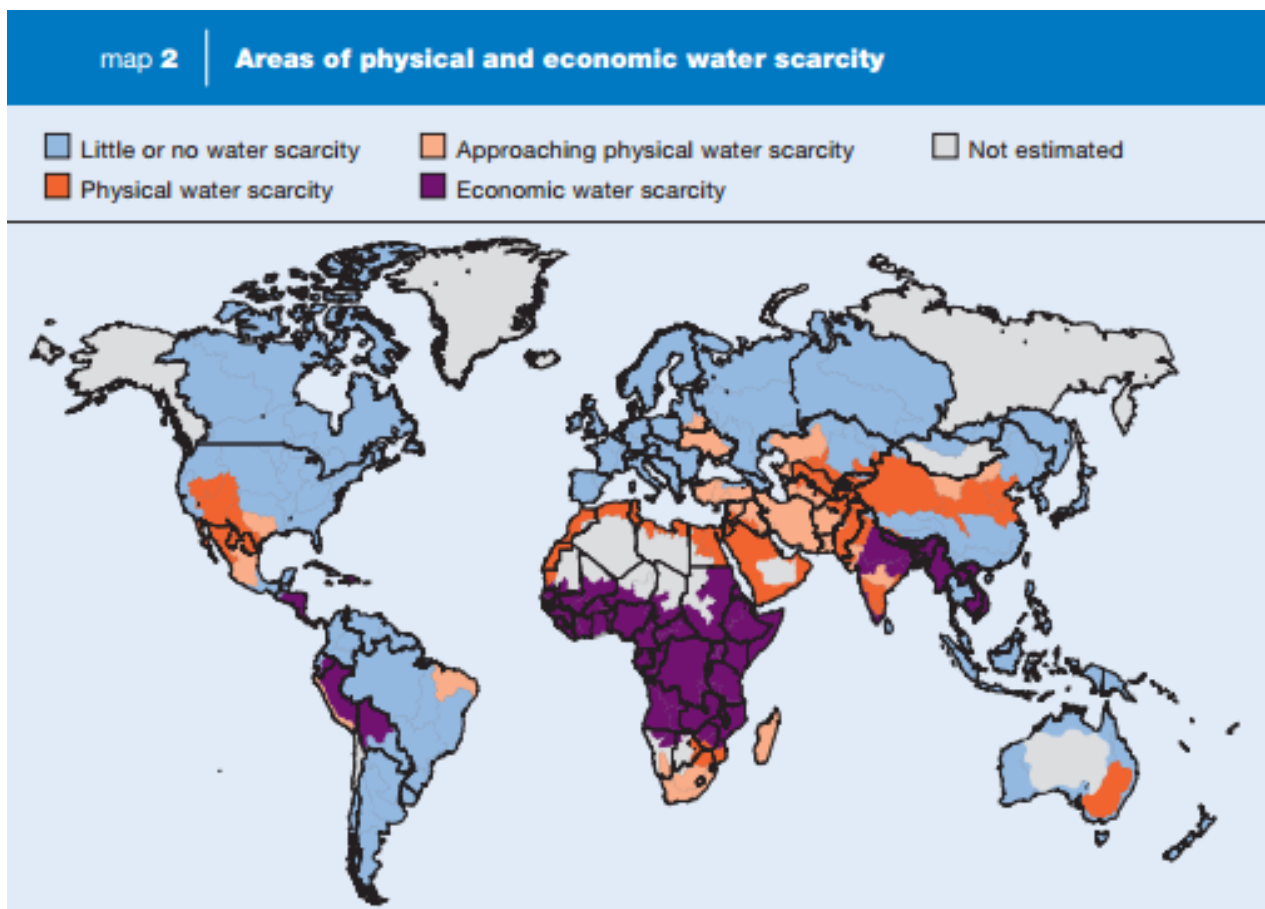
would hide any progress that is being made. Often, it is the poorer countries that experience the greatest population growth, and the region of sub-Saharan Africa is no exception. According to the Population Reference Bureau, the population of sub-Saharan Africa, which is currently 0.9 billion people, is expected to grow to 2.2 billion by the year 2050. This projected growth far exceeds any other world region, even that of Asia (Population Reference Bureau, 2013).

Therefore, it is easy to see how this rapid population growth would pose an added barrier for the countries of sub-Saharan Africa that are attempting to achieve the MDGs.

In order to more fairly demonstrate the progress that sub-Saharan Africa has made, along with other regions with low baseline percentages and fast population growth, the JMP created a new way to monitor progress. The ‘alternative indicator’ is defined as “the increase since 1995 in the number of people with access as a proportion of the current (2010) population” (UNICEF, WHO, 2012). This indicator demonstrates that even though some countries are still off track to meet the MDG, they have made significant strides in granting large populations access to clean water. In fact, according to this indicator, sub-Saharan Africa has shown more success than Eastern Asia (UNICEF, WHO, 2012). This is quite the contrast to the standard methodology, which shows sub-Saharan Africa lagging behind the rest of the world. Although this alternative indicator shows promise for the region of sub-Saharan Africa, the hard data cannot be overlooked. The fact of the matter is that 39% of sub-Saharan Africa’s population still does not have access to clean drinking water, while only 11% of the global population lacks access.

In order to fully understand the why sub-Saharan Africa lags behind, the terms physical and economic water scarcity need to be introduced. A physical water scarcity is when the water being harnessed for development is nearing the amount that can be provided by the land, meaning at least 75% of river flows are being utilized. In other words, a physical water scarcity

occurs when the environment is the largest barrier to meeting the water needs for a population. On the other hand, an economic water scarcity occurs when there is limited access to water but less than 25% of river flows are being utilized. In this situation, there could be a number of factors that are preventing the available water from being used, such as financial or institutional obstacles (International Water Management Institute, 2007). Today, it is estimated that 700 million people live in water-scarce regions, and this figure is expected to grow with climate change patterns and an increasing global population (United Nations, 2014). A map of the world demonstrating regions of economic and physical scarcity can be seen in Figure 2.



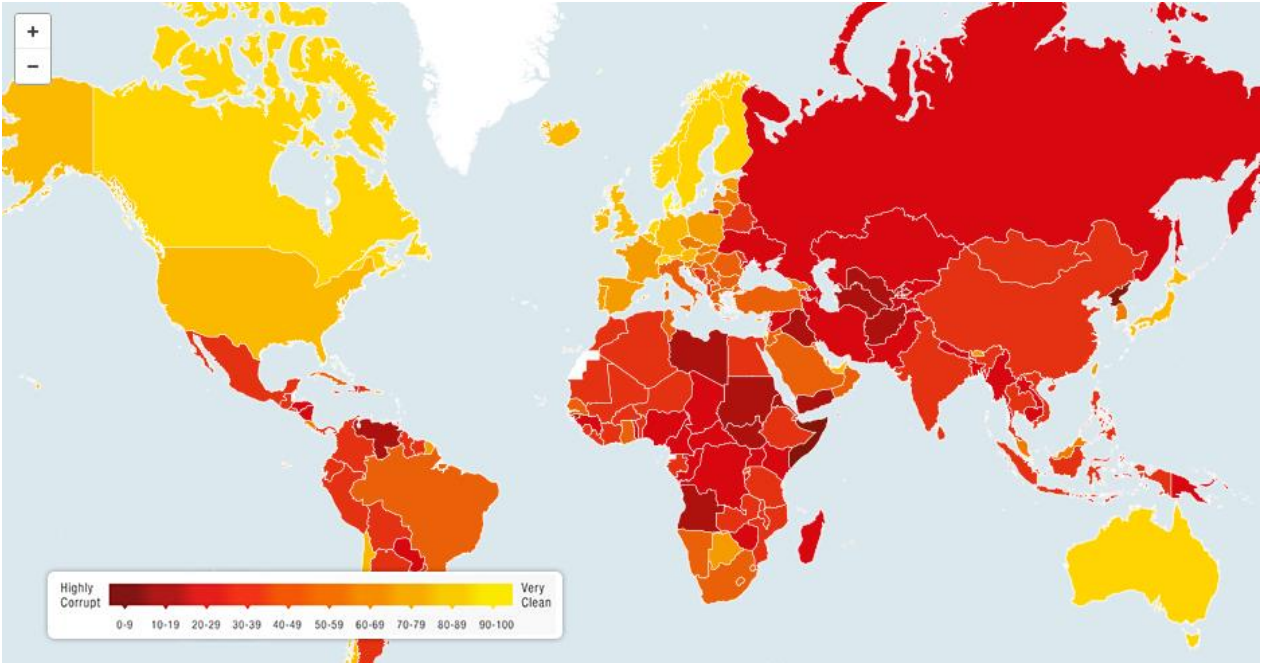
**Figure 2: Map of areas of physical versus economic water scarcity**  
 Source: (International Water Management Institute, 2007)

As can be seen in Figure 2, the water crisis in sub-Saharan Africa is largely attributed to economic scarcity. One factor that contributes to this is a lack of financial resources to implement the proper infrastructure to harness available water. The sub-Saharan African region ranks number one as the poorest region in the world, based on the measurement of gross domestic product (GDP) based on purchasing-power-parity (PPP) per capita (Pasquali). This measurement of a country's economy takes into account the size of the economy based on the population, along with inflation rates and the cost of living in each country. Besides the lack of financial resources available to the governments of sub-Saharan Africa, there is also a misuse of the resources available by the governments.

Widespread access to clean drinking water in many sub-Saharan African countries is hindered by weak or corrupt governments. Each year, a Corruption Perception Index is published by Transparency International, which ranks the countries of the world on a scale from 0 to 100 based on the perceived corruption of their public sectors (Transparency International, 2014). As can be seen in Figure 3, many of the countries in sub-Saharan Africa fall below a score of 50.

Countries that have a score below 50 suffer from 'endemic corruption', or systemic corruption. In these cases, corruption is a normal part of economic and political systems, and these systems are controlled by corrupt individuals and groups (CHR. Michelsen Institute). This endemic corruption is a contributor to the economic water scarcity in sub-Saharan Africa because it can prevent development, despite economic growth. For example, one byproduct of a corrupt government can be illicit financial flows, or money that is transferred from one country to another illegally (Global Financial Integrity). Money can be moved through drug cartels, the illegal activity of politicians that involves placing money in bank accounts in another country, a

human trafficker carrying cash in a briefcase across borders, and a variety of other methods. It is estimated that \$60 billion US dollars are exported illegally from Africa yearly, a value that exceeds other regions (Transparency International, 2014). This large sum of money is being diverted away from furthering the development of African countries. Additionally, in corrupt countries, the resources that are available are unequally distributed between the wealthy and the poor. This further stunts development, and therefore, this stunts the improvement in widespread access to clean water.



**Figure 3: Map of countries and their corruption perceptions index as of 2014**  
Source: (Transparency International, 2014)

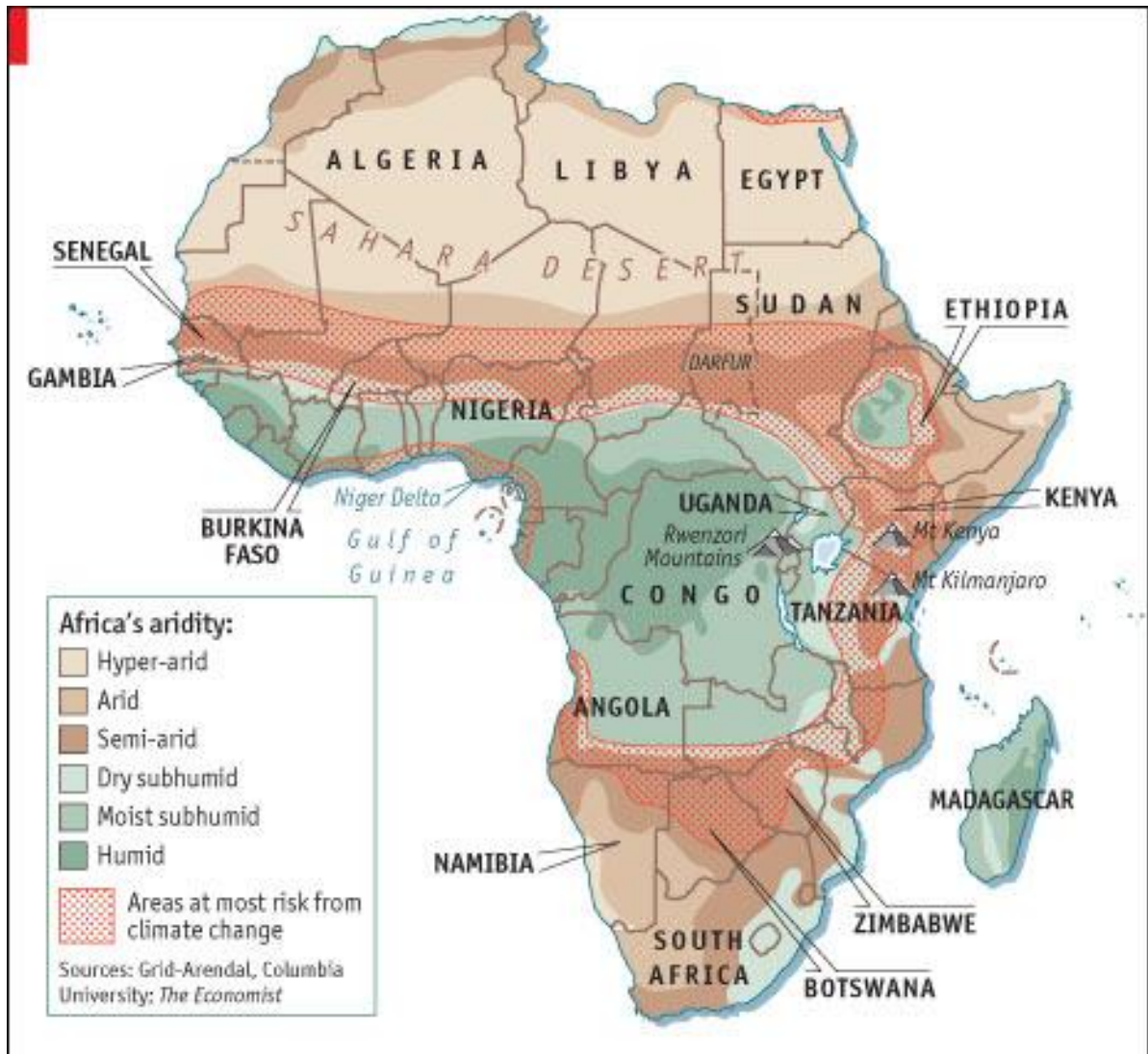
Although the water crisis in sub-Saharan Africa stems largely from economic obstacles, the area is not immune to geographic barriers. The region is divided into climatic zones that vary in temperature and rainfall, factors that affect the degree of physical water scarcity. The different climatic zones can be seen in Figure 4. First, there is the arid zone, which is characterized by a short rainy season followed by many months of drought and a high average



temperature (FAO, 1985), (McMaster, 2015). The next type of climate is semi-arid zone, which has a wet season and a long dry season, and temperatures that are similar to the arid zone.

Together, these climatic zones make up 43% of sub-Saharan Africa (FAO, 2008). There is also the dry sub-humid zone, which accounts for 13% of the region (FAO, 2008). This zone also has one wet season in the winter and has more pronounced temperature differences between winter and summer (FAO, 1985), (McMaster, 2015). The wet sub-humid zone has rainfall that is ongoing throughout the year, with the heaviest being in the summer (FAO, 1985). Finally, there is the humid zone, which has two wet seasons, separated by two dry seasons (FAO, 1985). Temperatures in this region vary based on altitude (McMaster, 2015). The wet sub-humid zone and the humid zone make up 38% of sub-Saharan Africa (FAO, 2008).

One other factor that affects the threat of physical water scarcity in some regions is desertification. Due to climate change, it is estimated that the Sahara Desert grows by 600 meters every year (Our Africa). Land that has been deforested for agriculture is more susceptible to this desertification because bare earth is more easily replaced by sand. Additionally, the semi-arid regions to the south of the Sahara desert are experiencing longer and more severe droughts. Figure 4 demonstrates the regions of Africa that will be most susceptible to climate change, along with the different climatic zones that are found across the continent.



**Figure 4: Map of regions most susceptible to climate change**

Source: (Drying up and flooding out, 2007)

Over time, these trends will lessen the amount of internal renewable water resources available to some countries. The amount of internal renewable water resources is a way of measuring the amount of available water in a country or region. They are defined by the annual amount of water that rivers and aquifers, or stores of water located underground, are refilled within a country or region by precipitation (UNEP). Because a result of climate change is less rainfall, certain regions' internal renewable water resources will be affected.

Clearly, there is a lot of variance between countries in terms of climate within the region of sub-Saharan Africa. This poses separate challenges for each country when dealing with water scarcity. Still, even in arid regions, better infrastructure would allow for better access to the water available. It is reported that sub-Saharan Africa's internal renewable water resources amount to 3,880 km<sup>3</sup> per year. However, the total amount that is being withdrawn from the region is only 120.0 km<sup>3</sup> per year, accounting for only 3% of the internal renewable water resources (FAO, 2008). Therefore, as a whole, the region of sub-Saharan Africa has available water resources; there is just a serious need for infrastructure in order to harness these resources.

### **Disparities within Sub-Saharan Africa**

While there is a large disparity in access to clean water between sub-Saharan Africa and the majority of the world, there are also many existing disparities within sub-Saharan Africa: between countries, between urban and rural areas, and between rich and poor populations. Although the general statistics for sub-Saharan Africa paint a troubling picture for the whole region in terms of water access, there are several countries that fall well above the averages. Of course, that means that there are countries within the region that fall well below average. For example, two extremes within the region are South Africa and Somalia. As of 2010, 91% of South Africa's population had access to clean water, compared to only 29% in Somalia (UNICEF, WHO, 2012).

Furthermore, country averages hide the large disparities that exist between urban and rural areas. Overwhelmingly, urban populations are far more likely to have access to clean water. For example, although 91% of South Africa's national population has access to water, this is true for only 79% of its rural population, compared to 99% of its urban population (UNICEF, WHO, 2012). Therefore, the country's average hides the fact that a fifth of the

population still faces water insecurity. Likewise, there is a wide gap between Somalia's urban and rural population; 66% of urban residents have an improved water source, compared to a mere 7% for rural residents (UNICEF, WHO, 2012). These trends are reflected regionally, as 83% of sub-Saharan's urban population has access, compared to 49% for rural populations. Although these statistics prove to be encouraging for urban settlements, they demonstrate the severity of the water scarcity in rural areas.

Finally, there are huge disparities between rich and poor populations in access to improved water sources. In order to assess the difference between the wealthy and the poor, the JMP divided the population of 35 countries in sub-Saharan Africa into fifths based on wealth. They found that the richest fifth of the population was far more likely to have access to clean drinking water. For the total population that was analyzed, only 35% of the poorest fraction had access to an improved water source. Interestingly, none of the 35% had access to piped water; all used other improved water sources, such as boreholes or protected wells. On the other hand, 89% of the richest fifth of the population in sub-Saharan Africa was found to have access to an improved water source, and 38% of this fifth has access to piped water (UNICEF, WHO, 2012). These trends are reflected in both rural and urban areas. Therefore, even though urban dwellers generally have better access to water, this does not always hold true when taking wealth into the equation. The poorest fifth of urban dwellers are as likely to have access to water as the richest fifth of rural residents, both at 59% with improved water sources (UNICEF, WHO, 2012).

Therefore, any progress that is made for each Millennium Development Goal needs to be viewed critically. On a global scale, the Millennium Development Goal relating to access to clean water has been met as of 2010. However, this does not signal the end of water scarcity problems throughout the world. Specifically, the region of sub-Saharan Africa lags behind most

of the world. Furthermore, there are many disparities within this region that need to be corrected in order to solve the problem of water scarcity. Hence, the accomplishment of the MDG for improved access to drinking water can be misleading.

In addition to covering up the existing disparities, the achievement of the MDG relating to water access is misleading because it overshadows the lack of progress that has been made with the related MDG for improved sanitation. The targets to improve access to safe water and sanitation facilities both fall into the broader goal to ensure environmental sustainability (United Nations). These goals go hand in hand in improving the public health of societies because improved access to water is not as helpful in preventing disease if human waste cannot be disposed of properly. Therefore, in order to meet standards of public health, there is still a lot of work that needs to be done globally in terms of improving sanitation facilities. As of 2010, 63% of the world population had access to improved sanitation facilities, compared to 49% in 1990 (UNICEF, WHO, 2012). In order to meet the MDG for sanitation, 75% of the world population needs to have gained improved sanitation by 2015. Hence, even on a global scale, the MDG is not on track to be met.

Sub-Saharan Africa is seeing even slower improvements, with a jump from 26% of the population with improved sanitation facilities in 1990 to 30% in 2010 (UNICEF, WHO, 2012). Just like with the target to improve water access, progress for the sanitation target has not been equal across countries, rural and urban areas, and poor and rich populations. Although percentage of the population of urban dwellers with access to improved sanitation facilities is greater than in rural areas, the percentage has not seen a jump since 1990, remaining at 43% (UNICEF, WHO, 2012). However, this is misleading due to the large increases in population in cities across sub-Saharan Africa. Since 1990, the urban sub-Saharan African population has

increased significantly from approximately 500 million to 800 million (UNICEF, WHO, 2012). Thus, although the percentage of the population with proper sanitation facilities remains at 43%, there has been a large increase in the number of people who have gained access. This is another example that demonstrates how the methodology behind the MDGs can be slightly misleading. Still, it is obvious that there still remains a large fraction of the population that needs to gain access to improved sanitation facilities.

## **Public Health Problems Caused by Lack of Water**

As has been discussed, there is still a lot of progress that needs to be made to grant safe drinking water to all of those who lack it. Although the achievement of the Millennium Development Goal for drinking water is a big accomplishment, it masks the large disparities that still exist. Additionally, the related MDG that calls for improvement in sanitation is far from being met. These lasting problems pose a number of obstacles for improving the well-being of regions that are affected.

### ***Water-related Disease***

One of the greatest problems surrounding the water crisis in Africa is the prevalence of water-related disease in regions that lack access to safe drinking water and improved sanitation facilities. There are several types of diseases that pertain to unsafe water; these include waterborne diseases, diseases that are transmitted through contact with water, and vector-borne diseases.

Waterborne diseases are caused by pathogens that live in water that humans drink. Types of waterborne pathogens include bacteria, viruses, protozoa, and parasites. Many of these diseases cause gastrointestinal problems, such as diarrhea. It is estimated that 4.1% of the global burden of disease is caused by diarrheal diseases, which accounts for years of life that are lost to

death and sickness. Of this burden, 88% could be prevented by access to clean drinking water and improved sanitation facilities (WHO). It is important to note that diarrheal diseases are passed through the fecal-oral route of transmission. Water that is contaminated with human or animal feces can infect someone in several ways. Of course, it is possible for the contaminated water to be ingested as drinking water. Also, food can become contaminated if unsafe water is used to clean it, or if hands that have come into contact with contaminated water touch the food. Another route would be if hands that were washed with contaminated water touched the mouth directly. The combination of unsafe water and poor sanitation facilities makes all of these routes possible. Without improved sanitation facilities, human excreta are not properly separated from human contact, increasing the likelihood of contaminated hands and food. Additionally, the lack of clean water increases the chances of drinking contaminated water and having contaminated food and hands, as lacking clean water prevents the use of proper hygiene practices (WHO). Therefore, diarrheal diseases are strongly linked to regions with insufficient water and sanitation. Some examples of waterborne diseases are cholera, hepatitis A, and typhoid fever.

In addition to waterborne diseases, there are also water-related diseases that can be transmitted through skin contact with parasites that have a part of their life cycle in water. One example is schistosomiasis, a disease caused by a flatworm parasite. Out of parasitic diseases, schistosomiasis is considered to be the second biggest threat to public health, behind malaria. The vast majority of cases, approximately 80%, are transmitted in sub-Saharan Africa (WHO). Another notable water-contact disease is dracunculiasis, more commonly known as guinea worm. This disease is also caused by a parasitic worm, but unlike schistosomiasis, dracunculiasis is close to being eradicated completely, as there were only 126 cases globally in 2014 (WHO, 2015).

The third class of water-related diseases consists of diseases that are spread by vectors that have part of their life cycle in fresh water. An example of this type of disease is malaria, which is caused by a protozoan parasite. Malaria causes a wide variety of symptoms, ranging in severity, based on what variety of parasite caused the infection. Humans are infected when they are bitten by a mosquito that has been infected by the parasite. These mosquitos require fresh bodies of water to develop in their larval stage, making this disease water-related. Accordingly, it has been found that the prevalence of malaria can increase in response to poor water management systems. It is estimated that 90% of malaria cases are found in sub-Saharan Africa (WHO).

The prevalence of water-related diseases in sub-Saharan Africa has a huge impact on public health. Because many of these diseases are spread through the fecal-oral route, the number of people without access to clean water and improved sanitation facilities pose a barrier to overcoming these diseases. However, as gradual progress is made towards reaching the MDG for clean water and sanitation, there should be a decrease in the number of global cases of diarrhea and other water-related diseases.

### ***Gender Inequalities***

Another concern for countries without access to safe drinking water is the gender inequality that arises. In sub-Saharan African societies, the responsibility of collecting water generally falls on the females, both women and girls. Based on 25 countries in the region, it is estimated that in 71% of the households this holds to be true. Specifically, 62% of the water collection is carried out by women and 9% by girls (UNICEF, 2003). There are several harmful consequences for females that result from collecting water. First, the task of collecting water itself is no easy feat. The trip to collect water can be anywhere from a few minutes to a few



hours, and the container that is normally used, the jerry can, weighs about 40 pounds when full (The Water Project). These trips occur every day, sometimes twice a day, which adds up to be a significant amount of strenuous activity for anyone, but especially young girls. Additionally, that is a lot of time that is wasted on water collection that could be used for other things. It is estimated that collectively, 40 billion hours are utilized for water collection across sub-Saharan Africa every year (The Water Project). With a current population of 800 million people in sub-Saharan Africa, that means that on average, every person spends 50 hours, or more than two full days, collecting water each year. As has been established, the strain of water scarcity is far greater on some than others. Therefore, some people are not spending any time collecting water, while some are spending far more than 50 hours a year on water collection.

Due to the large amount of time spent collecting water, children have less time and energy to dedicate to schoolwork. This chore, along with other responsibilities at home, cause many impoverished children to drop out of school. A study was done in Tanzania, a country in eastern Africa, to determine the correlation between time spent collecting water and school attendance. It was found that there was a 12% increase in school attendance when water was within a 15 minute walking distance versus a walking distance of more than 30 minutes (UNICEF). Because the responsibility of walking far distances is more likely to fall on girls rather than boys, it would make sense that water scarcity would increase the likelihood of girls dropping out of school over boys, hindering opportunities for future employment opportunities. Another reason that girls are held back from school is due to sanitation reasons. Because sanitation facilities are lacking in many schools, once girls hit puberty, they are forced to stay home when they are menstruating. Furthermore, girls become ‘prisoners of daylight’; when there are no latrines, it is considered improper for a girl to defecate in the daylight, forcing her to

wait for darkness (UNICEF). This waiting can cause discomfort, along with several serious illnesses.

Another negative consequence for women facing water scarcity is the increased likelihood of attack, either physical or sexual. When women and young girls walk many miles by themselves, they are opening up themselves to attack. This is especially true in areas that are already plagued by conflict and violence. Additionally, because many females are only free to defecate at night, there is a high risk of attack on outings to fields or roadsides (UNICEF).

Because women are heavily affected by the water crisis, many organizations have begun to turn to females as leaders in water projects. Because the responsibility of water collection mainly falls on females, they have a greater stake in having a close, safe water source. Consequently, it seems that when women are involved in projects, they have greater success rates. In a study carried out by World Bank, projects were 6-7 times more effective when women were involved (UNICEF). In addition to having a higher success rate, another benefit in including women is elevating their position in communities as leaders. Both on a local and larger scale, women have been stepping into positions of leadership in the 'water world'. On a grander scale, this means positions such as ministers on the African Ministerial Council on Water (AMCOW), which works to guide countries in managing water resources in a sustainable way. On a more local scale, women can get involved in the decision-making behind where to put new water facilities, and the management and repair of facilities already in place (Water for Life 2015, 2006). Finally, another benefit to including women in water projects is that it makes progress towards achieving another Millennium Development Goal. MDG 3 calls for increased gender equality, in terms of equal access to higher education, job opportunities, and government

participation. Water projects allow women to become empowered with leadership positions and increase the amount of time that girls can focus on schoolwork.

### ***Increase in Conflict***

Another layer to the water crisis is the issue of conflict and its relation to water scarcity and climate change. Some argue that increases in temperature and decreases in precipitation lead to a higher likelihood of violence breaking out. The reasoning behind these arguments revolves around the idea that climate change impacts economic growth and welfare. When a society is unsatisfied with economic position, there is more likely to be conflict and violence. This is especially true for heavily-agrarian Africa, which relies on the environment for economic stability. It is estimated that 50% of Africa's GDP is agriculture-based, and more than two-thirds of employment opportunities across the continent are provided by the agricultural sector (Burke, Miguel, Satyanath, Dykema, & Lobell, 2009). Therefore, it is easy to see why climate changes could rock the economic stability of the region. Additionally, proponents of this argument suggest that large-scale migrations due to climate change could also lead to conflict over land (Hendrix & Salehyan, 2012).

There have been several studies done to gather data that support these claims. In 2009, research was published that used a historical analysis of temperature and conflict to determine their quantitative relationship. It was found that historically, an average change in temperature of 1°C over the course of a year caused a 4.5% increase in the likelihood of conflict during that same year (Burke, Miguel, Satyanath, Dykema, & Lobell, 2009). This claim makes sense when it is considered that a 1°C increase in temperature leads to a 10-30% decrease in crop production (Burke, Miguel, Satyanath, Dykema, & Lobell, 2009). Likewise, a study from 2012 demonstrated that large deviations in rainfall from the standard annual amount lead to an

increase in the probability of conflict. This study looked at different types of conflict and found that the likelihood of political conflict increased in both wet and dry years, while violent conflicts are slightly more likely in wet years (Hendrix & Salehyan, 2012). Again, because both water scarcity and overabundance can create difficulties with crop production, it makes sense that any serious deviation in rainfall would increase chances of conflict.

However, many argue that the relationship between climate change and conflict needs to be viewed as correlational rather than causal, as there are many other factors that contribute to the outbreak of conflict. It has been found that the economic development of a country plays a role in determining the degree to which conflict is affected by climate change. Also, it has been found that rural, non-industrialized regions have a stronger link between climate change and conflict. Therefore, Africa is highly susceptible to this correlation. Additionally, opponents of this argument point out that many other political, economic, and social factors play a role in determining whether or not there will be an outbreak of conflict (Jaeger, 2014).

It is also possible that this connection between conflict and climate change could be stronger in sub-Saharan Africa due to the existing water scarcity problem. Because the region is already faced with the problem of economic water scarcity, many areas rely on consistent rainfall to meet water needs. The impending climate change, causing longer dry periods, more heavy rainfall in some areas, and lighter rainfall in others, could disrupt these consistent rainfall patterns. This could result in greater physical water scarcity in regions throughout sub-Saharan Africa, which would exacerbate the problem. It is easy to see how a decrease in availability of an already scarce resource could lead to frustration amongst populations. Although this frustration may not be the primary cause of conflict, it could play a role in aggravating tensions that aren't directly related to environmental resources, such as ethnic or political tensions.

Therefore, water scarcity and climate change could be a factor in stimulating conflict in sub-Saharan Africa.

Between water-related disease, gender inequality, and increased conflict, the water and sanitation crisis in sub-Saharan Africa has a profound effect on the public health of the region. However, in any given location, there will be a different set of challenges and consequences relating to the water crisis. Each country, and each city or community within that country, has its own story. The remainder of the thesis will focus on Nigeria. The goal of focusing on one country is to better demonstrate why the water crisis is still occurring and what the public health outcomes are.

## **Introduction to Nigeria**

Nigeria, located in West Africa along the coast of the Gulf of Guinea, is the most populated country in Africa. As of 2014, the population of Nigeria was 177 million people, and is expected to grow 2.47% annually (CIA). Amongst this population, there are 250 different ethnic groups. The largest groups are the Hausa and the Fulani in the north, the Yoruba in the southwest, and the Igbo in the southeast. Since the country obtained independence from Great Britain in 1960, the tensions between different ethnic and religious groups have posed challenges to establishing a stable government. The government is classified as a federal republic, consisting of 36 states (CIA). Nigeria's economy is largely based in agriculture and oil production. Nigeria's GDP of 502 billion US dollars tops all other African countries, and ranks at 31<sup>st</sup> compared to the world. However, the Nigeria GDP per capita comes in at 180<sup>th</sup> compared to other countries, with \$2800 per person. The wealth of the nation is distributed unevenly, with 70% of the population falling under the poverty line (CIA). Therefore, Nigeria still faces

numerous political, economic, and social obstacles moving forward, especially as the population continues to grow rapidly.

In terms of water and sanitation progress, Nigeria does not fall at either end of the extreme in comparison to other sub-Saharan countries. Nigeria, along with sub-Saharan Africa as a whole, is not on track to meet the MDGs. As of 2010, 58% of the Nigerian population had access to safe drinking water, compared to 61% of the sub-Saharan population. For sanitation, 31% of Nigerians have access to improved facilities, while 30% of individuals in the sub-Saharan region have access (UNICEF, WHO, 2012). Therefore, for both water and sanitation progress, Nigeria falls somewhere in the middle of countries in the region. However, that is not to say that Nigeria is not free from its own unique set of obstacles relating to the water crisis. It can be argued that some of the problems that Nigeria faces today regarding the water crisis are the result of its colonial history. Additionally, there are several obstacles that exist today that are preventing better access to water and sanitation in the future.

### ***A Brief History of Water and Sanitation Infrastructure***

Nigeria's lack of consistent water and sanitation infrastructure dates back to the colonial period. The development of infrastructure did not occur until the late nineteenth century, when colonialism took hold of the area. Nigeria was colonized by Great Britain at the turn of the century, and did not gain independence until 1960. Consequently, the presence of the European power had a considerable effect on the development of water and sanitation infrastructure. It can be argued that the introduction of water and sanitation facilities was a positive effect of colonialism. However, the inconsistency with which the infrastructure was introduced has created lasting inequalities.

For over a century before Nigeria was established as an official colony, Great Britain had a presence in the region. Europeans' primary goal at the time was to exploit the region economically, but they did not have interest in political control (Afigbo, 1972). This changed around the late 19<sup>th</sup> century, when other European powers began to meddle in the region. Around the same time, the Berlin Conference was held, establishing guidelines for the colonization of Africa. Afterwards, the 'Scramble for Africa' ensued, and the European powers raced to establish claim over the continent. Originally, Great Britain established two protectorates in the region that is now Nigeria: one in the north and one in the south. These were later combined in 1914 to form the Colony and Protectorate of Nigeria (Webster, 1990).

Before the union of the north and the south, there were several differences between the two protectorates. One of these differences was the difference in opinion with regards to segregation between Europeans and Africans. A large problem in West Africa is malaria, which deterred a large European population from settling down, unlike some of the colonies in East Africa that had a large white settler population. For the Europeans that did risk living in West Africa, Great Britain established a policy of segregation between settlers and the indigenous population to lower the risk of disease transmission. However, due to the limited evidence that segregation prevented the vector-borne disease from spreading, it is believed that this policy was favored because of the racial ideologies that existed at the time (Njoh, 2012).

The governor of the northern protectorate, Frederick Lugard, was a huge proponent for segregation. Besides its proposed health purposes, he believed that segregation was a practical governance tool because it was easier to rule people when they were separated by ethnicity. He mandated that European residences be a certain distance away from the residences of the indigenous population. On the other hand, the south protectorate was governed by William

MacGregor from 1898 to 1903. MacGregor, who was a medically trained doctor, was against a segregationist policy because he argued that it was not the best way to combat malaria. He developed a plan with several parts: all Europeans should take quinine, an antimalarial medicine, Africans living in the city Lagos should be given free quinine, and there should be public health campaigns to educate on how to prevent mosquitos from entering one's surroundings, such as using mosquito nets and eliminating standing water when possible. However, his anti-segregationist plan lost out when the north and south protectorates were amalgamated in 1914, and Lugard's segregationist plan was enforced throughout Nigeria (Njoh, 2012).

The nature of the political and social structure that was set up by Lugard throughout Nigeria had several effects on the way water and sanitation infrastructure was introduced throughout the area. First of all, the segregation throughout the colony allowed for an unequal distribution of infrastructure. Around the same time that colonialism was taking hold of Nigeria, ideas linking the physical environment to public health were spreading around Europe. Therefore, in the late 19<sup>th</sup> century, there were social reform movements across Europe that aimed to promote healthy environments through the installation of better infrastructure. This movement was spread to African colonies; however, in Europe, the aim was to improve the lives of the masses, whereas in Africa, the goal was to create a safe environment for the European minority (Njoh & Akiwumi, 2011).

One reason for the focus on just Europeans rather than the masses was related to the financial situation for British colonies. It was a common policy that colonies had to raise the funds for any improvements internally. In other words, any funds that were devoted towards the development of a colony came from the exploitation of its natural resources or the taxation of its citizens. The European countries rarely donated any money to the infrastructure of its colonies.



Therefore, the colonies were working on small budgets, so they were limited in the amount of infrastructure that could be built (Njoh & Akiwumi, 2011). Because it is the colonial officials making the decisions about development, the Europeans were favored as the recipients for the new infrastructure. At the time, there were arguments made by Europeans that the African residents didn't require improved water and sanitation facilities because they had been living without them before the colonial period. However, the colonial development left the unimproved sources more polluted than in the precolonial era (Philip, 2007). Therefore, the African masses were more at risk to disease than they had been previously, and they were without better infrastructure to compensate for the negative change.

Segregation also worked in the favor of Europeans because the best land was selected for the European enclaves. This meant that they were put on land that was elevated and well-drained. This eliminated the amount of standing water in the environment. Standing water is harmful in an environment because it can increase the chances of water-related diseases. For example, the host of malaria has part of its lifecycle in water, so the presence of standing water can increase the prevalence of mosquitos carrying malaria (Njoh & Akiwumi, 2011).

As can be expected, the list of grievances against the colonial state began to grow as the inequality between the implementation of water and sanitation facilities became apparent. Throughout the colonial period, there were several protests that broke out in relation to these disparities. A notable example occurred in the southern city of Lagos, when the Governor who followed Lugard in office, Walter Egerton, attempted to forcefully remove 350 Africans from an ideal piece of land in order to establish a European enclave (Njoh & Akiwumi, 2011). Not only were Africans being removed from their land, but the land that they were moved to was not equipped with health infrastructure. Therefore, Egerton's action caused a large response in the

form of petitions. Eventually, the Europeans began to build infrastructure in African areas. However, it can be argued that the spreading of facilities was still self-serving for the Europeans. Their actions were intended to appease the Africans, which would allow them to continue to exploit the colony economically without further protest. Additionally, the prevention of epidemics in African communities was important in order to preserve the labor force for European projects. Therefore, although protests did lead to some changes in the distribution in infrastructure, the motivations behind the changes were self-serving and inequalities remained.

The movement towards independence for Nigeria began after World War II, although there were some protests before that period, such as the ones in relation to segregation. The period leading up to independence was relatively peaceful. Great Britain was willing to gradually hand over power to Nigerians, and they did so through a series of constitutions. One of the greatest challenges that Nigeria faced was deciding whether the region should be given independence as a federation or separate states. The area where the British established the Nigerian protectorate was divided up into many ethnic groups in precolonial times. When it came time for independence, many of these groups wanted autonomy. However, it was eventually decided that Nigeria should remain a federation. From there, there was a debate over how involved the British should be following independence. On one hand, the south generally argued that Africans should have control of their government. The prominent religion in the south is Christianity; this is due to the presence of missionaries in the south during the precolonial and colonial period. Although the missionaries could be imposing when introducing Christianity, they offered education to any African who reached out to them. As a result, the south had a much larger population of educated Africans who were willing to take control of the Nigerian government. In the north, the dominant religion is Islam. Africans in the north were

not offered the same educational benefits as the Africans in the south. Therefore, many in the north supported the idea of the British remaining in power after independence. Otherwise, they feared that the Christian southerners would become the dominant group in government, leaving them as the less powerful ethnic group. These ethnic and regional tensions that were existent during the 1960s are still manifested in present-day society. It was ultimately decided that Nigeria's government would consist of three separate parliamentary governments, along with a federal executive with representatives from both the north and the south (Aluko).

The period of colonialism has had a large impact on the distribution of water and sanitation infrastructure in present-day Nigeria. Many of the cities in sub-Saharan Africa today expanded from colonial towns. Because infrastructure was only built in certain areas in colonial towns, cities throughout the region are still faced with inequalities in infrastructure. Furthermore, rural areas were often ignored entirely when it came to building infrastructure. Once colonialism ended, municipal governments found themselves lacking in funds, especially in the 1980s and 90s, when a global depression hit. Therefore, the infrastructure that was built in the colonial period was not maintained properly. Additionally, the government could not afford to build new infrastructure for a rapidly growing population. Thus, the inconsistent infrastructure throughout the country today can be largely attributed to inequalities during the colonial period and lack of finances in the post-colonial period.

### ***Obstacles for Present-Day Nigeria***

There are a variety of hurdles that are unique to Nigeria in overcoming the water and sanitation crisis. For example, the rapid population growth that characterizes Nigeria poses an ongoing challenge for the country. The annual growth rate in Nigeria for the year 2013 was 2.47%, which is a significant jump considering the population already sits at 177 million (CIA).

The quickly increasing population can overshadow any progress that is made in granting access to water and sanitation. For instance, based on the percentage of population that has access to sanitation, Nigeria has actually gone backwards from the year 1990 to 2010. In 1990, 37% of the population had access to improved sanitation facilities; this fell to 31% by the year 2010 (UNICEF, WHO, 2012). However, these statistics hide the fact that there was a small fraction of the population that gained access to improved sanitation facilities during this time period. Using the alternative method of determining progress towards the MDGs, it becomes more obvious that Nigeria has made some progress, albeit not very much. It is estimated that 6% of the 2010 Nigerian population has gained access to sanitation facilities since 1995 (UNICEF, WHO, 2012). Although this progress still leaves Nigeria far from reaching the MDG for sanitation, it paints a slightly more positive picture for the progress that has been made.

Another factor that contributes to Nigeria's water crisis is the geography of the country, along with the impending climate change. Nigeria is covered by several climatic zones. Stretching across the north of the country is the semi-arid region, which generally has a short rainy season and a long dry season, causing a short growing season of approximately 90 days. This region is mostly characterized by grassland. To the south of that is the sub-humid zone, which consists of one longer rainy season, allowing for 180-270 days in the growing period. The sub-humid zone is a mix between the grassland in the north and the forests in the south. The southernmost part of the country is characterized by the humid zone, which has two rainy seasons, and experiences 270-365 growing period days. This region is occupied by woody forests towards the north and tropical rainforests along the coast (FAO, 1985).

Located in Nigeria are several significant bodies of water. The Niger River runs through the country, entering in the northwest corner and exiting in the south as it flows into the Gulf of

Guinea. The Niger important in sustaining internal renewable water resources, as it tops off 13 lakes throughout the country (Kennedy). Another significant body of water is Lake Chad in northeastern Nigeria. It is shared between the countries of Nigeria, Chad, Cameroon, and Benin. Unfortunately, Lake Chad has decreased considerably in size over the past half-century. In 1963, the surface area of the lake was about twenty times as large as it was in 2007 (UNEP, 2008). This loss could be attributed to several factors. First, all of the countries situated along the lake front have diverted water away from Lake Chad to use for large-scale irrigation projects. Additionally, the Lake Chad region has faced climate change over the 50 year period. Because the area surrounding the lake was heavily used for agriculture, there was a significant amount of deforestation in the region. Regions that have been deforested are more susceptible to climate change. Also, semi-arid regions, such as the Lake Chad region, are vulnerable to climate change. Therefore, the combination of unsustainable human projects and climate change has left the region covered in vegetation rather than freshwater (UNEP, 2008).

Although climate change is becoming a growing problem in the north of Nigeria, the internal renewable water resources (IRWR) in the country are still plentiful. The total IRWR for the country amounts to  $221 \times 10^9 \text{ m}^3/\text{year}$ , while the amount of water being withdrawn yearly adds up to  $13.11 \times 10^9 \text{ m}^3/\text{year}$  (FAO). Therefore, only 4.5% of the available water resources in the country are being utilized. The majority (53%) of this withdrawal is being used for agricultural purposes, with municipal withdrawals only accounting for 31% of the total withdrawals (FAO). The remaining withdrawals are used for industrial purposes. In the future, the amount of IRWR should remain mostly consistent, but the IRWR per capita will decrease as the population continues to increase. However, it is predicted that there should still be ample amount of water

for domestic purposes; the greater concern is not having enough water for agricultural usage in the future (Rijsberman, 2006).

Another factor that contributes to the availability of water in Nigeria is the political instability. The Nigerian government is classified as a federal republic, which means that the individual 36 states have some self-governing power, but they are overseen by the central government (CIA). Before the most recent constitution was implemented in 1999, the country was governed by military rule for over a decade. Since then, the country has been governed by civilian rule, although many of the elections have been marked by corruption and violence (CIA). Unfortunately, this corruption is commonplace in the government of Nigeria. As was discussed earlier, many of the countries in sub-Saharan have governments that are perceived as highly corrupt, and Nigeria is no exception. According to the Corruption Perception Index, Nigeria has a score of 27 out of 100, which ranks it at 136<sup>th</sup> out of the 175 countries that were evaluated (Transparency International, 2014). This means that Nigeria falls amongst the bottom fourth of countries in terms of corrupt governments. Because it has a score below 50, Nigeria is classified as a country with endemic corruption, which means that the government is controlled by corrupt individuals or groups.

The corruption of the government has a large effect on the economic stability of the country as well. As was mentioned previously, a common result of a corrupt government is a large amount of illicit financial flows, which is money that leaves the country illegally. For the past ten years, Nigeria has led sub-Saharan Africa in the largest amount of illicit financial flows annually (Kar & Spanjers, 2014). However, as Nigeria has the largest GDP of all other African counties, it would make sense that the illicit financial flows would be proportionately larger. Nevertheless, on average, from 2003-2012, Nigeria was responsible for nearly a quarter of the

illicit financial flows coming from sub-Saharan Africa, with Nigeria accounting for 12 billion US dollars out of the 53 billion US dollars that leave the region illegally (Kar & Spanjers, 2014). This illegal use of Nigeria's finances demonstrates the economic instability of the country. Rather than being spent on internal development projects, such as sanitation and water facilities, large amounts of money are being diverted illegally from the country. A major cause of this problem is a lack of transparency in government spending, which is the result of a corrupt government.

Along with the corruption of the government, ongoing conflict is a source of political instability in Nigeria. Much of this conflict is created by the activities of Boko Haram, an Islamic militant group that operates in northeastern Nigeria. From January to August of 2014, the group was responsible for over 2,500 civilian deaths, 650,000 displaced citizens within Nigeria, and 80,000 displaced citizens in surrounding countries (Human Rights Watch). Additionally, Boko Haram has kidnapped many young girls, forced young men to join their ranks, and demolished numerous villages. The actions of Boko Haram have several negative effects on the public health of the country in relation to water and sanitation. The displacement of such large numbers of people exacerbates water scarcity problems because populations of people are flocking to regions that are already short on water coverage. Therefore, people turn to unsafe water sources, putting themselves at risk for water-related diseases. Additionally, many of the displaced people end up in refugee camps, where tight quarters create hot spots for spreading disease.

Another source of conflict is tension between pastoralists and farmers in northern-central states. As climate change exacerbates the problem of water scarcity, the two different groups have to compete for resources. In 2014, this competition resulted in violence that took the lives

of 1,200 people (Human Rights Watch). Therefore, the water crisis can be both a cause and an effect of conflict; water scarcity can spark existing tensions and lead to conflict, but conflict can also worsen the problem by displacing large numbers of civilians and spreading disease.

Between the corruption of the public sector of government, economic instability, and the various conflicts occurring throughout the country, the government of Nigeria has many large obstacles to tackle in the future in order to become a developed country. With such large barriers creating political instability, it is easy to see how the efforts of the government can be diverted from the water crisis at hand.

In summary, Nigeria falls around the median for countries in sub-Saharan Africa in terms of access to improved water and sanitation facilities, with 58% of the population having access to clean water and 31% having access to improved sanitation facilities (UNICEF, WHO, 2012). However, as is the case with every country, Nigeria has its own complexities that pose obstacles for overcoming the water crisis and improving the public health of the nation, such as a history of inequality in infrastructure distribution, rapid population growth, climate change, and political instability.

## **Outline for the Remainder of the Thesis**

Clearly, general trends indicate that sub-Saharan Africa needs to make great strides in order to overcome the lack of water access that plagues much of the continent. This region lags behind most of the world in providing safe water and sanitation facilities to its population. Additionally, there are many disparities, between countries, urban and rural areas, and poor and wealthy populations, that need to be overcome in order to rectify the wide range of public health problems caused by the water crisis. Nigeria, the focus of this thesis, falls around the median of sub-Saharan countries in terms of access to water and sanitation. The following chapters will



examine the water crisis in Nigeria more in depth. First, the focus will be on Lagos, the largest city in Nigeria. Several of the challenges that are unique to the city will be addressed. Then, several diseases that are prevalent in Lagos will be used to demonstrate the public health impact that the water crisis has on urban environments. In the following chapter, the discussion will turn to rural Nigeria. The challenges faced in eliminating the water crisis will be presented within a rural context, and the resulting public health consequences will be discussed. Although rural and urban communities in sub-Saharan Africa suffer from a lack of access to water and sanitation, the experiences in each setting are vastly different. The following chapters should give insight into these variances and demonstrate the wide-array of public health problems that exist in both contexts.

# Urban Nigeria

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Generally, cities throughout sub-Saharan Africa are more equipped with improved water and sanitation infrastructure than their rural counterparts. In Nigeria, 74% of the urban population has access to an improved water source, compared with 58% of the total country. Likewise, 35% has access to improved sanitation facilities, compared with 31% of the total population (UNICEF, WHO, 2012). However, cities are not free from public health woes caused by lack of access to water and sanitation, as there are still extreme disparities within urban populations. A perfect example of this phenomenon is Lagos, a city that is responsible for approximately 25% of Nigeria's GDP, but has 66% of its population living in slums (World Population Review, 2014).

Lagos is situated on the southern coast of Nigeria, and it is considered to be one of the 36 Nigerian states. Due to its location on the Atlantic Ocean, Lagos has been used as an important port city since colonial times. For the majority of Nigeria's colonial and post-colonial history, Lagos served as the administrative capital of the country, up until 1991 when the capital was moved to the central city of Abuja (Njoh, 2012). However, Lagos remains as an economic hub for the country of Nigeria, being responsible for 65% of the country's industrial and commercial activity (Adelekan, 2010). Still, the wealth of Lagos is not evenly distributed among its residents.

Lagos has been called "the mega-city of slums", due to the large amount of the population living in overcrowded, filthy areas. In 2012, it was announced that Lagos surpassed Cairo as the most populous city in Africa. The population in 2014 was estimated by different sources to be somewhere between 17 to 21 million people (World Population Review, 2014). By the end of 2015, it is expected that Lagos will reach of population of 25 million people, making it

the 3<sup>rd</sup> most populous city in the world (World Population Review, 2014). This population growth is due to both the natural growth within the city and migration of outsiders into the city. Due to the large amount of economic activity in Lagos, it is logical that people would flock to the city from surrounding states and countries in order to gain economic opportunities; however, immigrants often find themselves disillusioned and living in the slums. Because a large portion of this population growth will occur in the slums, where infrastructure is already lacking, the existing obstacles to public health will be exacerbated.

In this chapter, several obstacles that are specific to Lagos in bringing an end to the water crisis will be addressed. Then, the impact of the water and sanitation crisis on public health in Lagos will be evaluated. Specifically, the epidemiology of several water-related diseases will be analyzed with respect to the urban environment. Although Lagos faces its own set of challenges, many of the themes throughout this chapter can be applied to other sub-Saharan cities. The conclusion of this chapter will highlight some of these themes.

## **Specific Obstacles for Lagos**

Although there are general trends common throughout Nigeria, Lagos has its own specific challenges. These obstacles include a history of inequality in infrastructure, a topography dominated by wetlands, and climate change that favors more intense floods.

Towards the beginning of the colonial period, Lagos was known for its premium infrastructure, including street lights, parks, and water and sanitation facilities. Of course, the majority of this infrastructure was built in European enclaves, excluding Africans from the benefits of the modern city. At the end of the colonial period, many of the Europeans withdrew from their previous settlements, leaving the well-developed areas for the African elite to occupy. For several years after colonialism ended, the water and sanitation facilities for the city remained

in good working condition. However, as the population of the city began to grow rapidly, the Africans living in the periphery of the city began to move into the areas that were previously European enclaves. The extra burden caused by the greater population increased the need for maintenance of water and sanitation infrastructure. With the global depression in the 1980s, the Nigerian economy took a hit, and the municipal governments were unable to generate a significant amount of revenue. Consequently, the maintenance of these facilities was overlooked, and the infrastructure began to deteriorate. Additionally, during this time, the government hardly took any initiative to build new infrastructure (Njoh, 2012).

Thus, entering the 1990s, Lagos was left mostly with the remains of rundown infrastructure from the colonial era. Especially with the rapid population growth, the municipal government has been fighting an uphill battle to install proper water and sanitation facilities for the city of Lagos. As of 2012, only 35% of the population of Lagos obtained their daily water needs from public, government-supplied water. In the public water system, 60% of the piped water is lost in leakages, indicating the poor quality of existing infrastructure. Additionally, Lagos remains without a central waste management system (Njoh, 2012). The lack of functioning water and sanitation facilities can be partially attributed to a history of not providing infrastructure for the entire Lagos area in the colonial area, along with the inadequate maintenance of existing infrastructure in the post-colonial period.

Furthermore, Lagos, and Nigeria in general, has a history of inequality between genders. The dynamics between men and women in relation to household water collection is a factor that may be preventing further progress towards access to clean water. Since precolonial times, it has primarily been the women who have been responsible for the water collection. In some cases, females would even sell water at markets in Lagos. However, as piped water was introduced in

1915, men became more involved in the business of selling water, although women kept their traditional role of collecting water for their households (Acey, 2010). Therefore, the position of women changed with respect to water. No longer did they have total control over water collection; they became dependent on men in order to complete the task. In Nigeria, societal norms already place females in a position inferior to men, so this loss of authority for women is significant.

Although southern Nigeria has been more progressive towards gender equality, especially in cities such as Lagos, there is still a gap between the genders on social issues. For example, it is estimated that 36% of women are employed, but the majority work in unskilled positions (World Trade Press, 2010). It is difficult for women to obtain high-level jobs because men are often selected over women, even if females receive the same higher-level education. However, many girls will stop school after primary school due to lack of family financial resources; most families prefer to spend money on boys' educations, as they have a better chance of securing a higher-level position. Of the 500 available ministerial and National Assembly positions in the Nigerian government, only 18 belong to women. However, they have fared better in the judiciary branch, holding 20% of chief judge positions throughout the country. In Lagos, 60% of the chief judge positions belong to women, demonstrating some of the progress that urban women have made (World Trade Press, 2010).

Although collecting water can be a hassle and a source of stress for women, it also gave them power in precolonial society. Now, men sell water at prices that are extremely elevated. Generally, water is sold in sachets at 5 Naira a piece. Water sold at this price is 200 times more expensive per liter than water that is supplied by the government through pipes (Acey, 2010). Consequently, women have to be dependent on the men selling water, and often times, they need

to depend on their husbands for money to buy the water, since women are often in lower-paying jobs. This dynamic between the women and men is damaging, as it limits female authority over a sphere of life that they used to have full control over. Additionally, it has been reported that many of the institutions that make water-related decisions tend to exclude women (Akiyode, 2011). Because women have high stakes in the water crisis, water improvements are generally more successful when women are involved (UNICEF). Therefore, this exclusion of women is a hindrance to progress towards better water access.

Another unique barrier that Lagos faces in rectifying the water and sanitation crisis is the geography. Lagos sits on the coast of the Atlantic Ocean, and it is approximated that 42% of Lagos is composed of wetlands. The city is only 15 meters above sea level on average (Njoh, 2012). Ideally, the abundance of water in the region should be able to be harnessed to improve the water shortage situation, but much of the water in the region has become polluted. This pollution is due partially to lack of sanitation infrastructure; people living in lower-income areas must improvise, and often times, human waste ends up in the environment. Also, there have not been sufficient anti-littering campaigns conducted by the government of Lagos, resulting in another source of environmental pollution (Njoh, 2012). Moreover, the ground water in the region is not a great option for clean water. In Lagos, the water table is relatively high, which means groundwater can be found only 3 meters into the ground. However, the soil of Lagos is porous, which enables sewage and wastewater to leak into the groundwater and pollute it. Thus, unprotected well water is often unsafe for drinking (Njoh, 2012).

Furthermore, the topography of Lagos makes it prone to flooding, especially with the impending climate change. Lagos is located in the humid zone of Nigeria, which means that it is characterized by two rainy seasons and two dry seasons. Generally, the stronger rainy season

occurs from April to July and the weaker rainy season occurs from October to November. However, a study conducted from 1971 to 2005 found that the second half of the 34 year period was characterized by shorter but more intense rainy seasons (Adelekan, 2010). The higher intensity in rainfall leads to more flooding in the Lagos area, especially with the lack of a functioning drainage system.

The flooding has negative consequences in terms of the public health of the city. For example, floods often amplify the transmission of water-related diseases. For waterborne diseases, flooding increases the runoff of sewage into water wells, which in turn increases the amount of pathogens in people's drinking water (Njoh, 2012). The transmission of water-contact diseases is augmented because there is more standing water throughout the region, increasing the chances of a person coming into contact with a parasite. Finally, flooding can promote the spreading of vector-borne disease because the standing water creates more breeding spaces for vectors, such as mosquitos.

Often times, the slums of Lagos are built on the most unfavorable land, creating a situation where large populations and geography work together to create a seemingly hopeless picture for a future of access to water and sanitation. For example, one of the largest slums of the city, Makoko, is not even built on land; it is a neighborhood that floats entirely on water. In Figure 5, an image of the extensive water community can be seen.



***Figure 5: An image of the slum Makoko***

Source: (Stuart)

Makoko is a fishing village with an estimated population of 85,000 people, as of 2009 (Ayeni, 2014). The area is full of public health hazards. Because of its location, it is a natural collector for rainwater during floods. Many of the buildings are built haphazardly on wooden stilts, but these can only go so far in protecting housing from floods, and often seasonal flooding results in destruction (Stuart). Furthermore, as was discussed, flooding can lead to the runoff of waste from residential and industrial areas. Because floodwater is collected in the Makoko area, the water becomes polluted, leading to a greater transmission of water-related diseases (Njoh,



2012). Although Makoko is an extreme example, there are many slums surrounding Lagos that face problems of large populations and troublesome geography.

In summary, problems relating to water and sanitation in Lagos are affected by the city's history and geography. At the beginning of the post-colonial era, some water and sanitation infrastructure remained in parts of the city, but with the growing population, this infrastructure has proven to be far from sufficient. Without proper financial and institutional resources, the municipal government has been unable to keep up with the maintenance of old infrastructure or the building of new infrastructure. Therefore, the water and sanitation facilities cannot support the population of Lagos. This problem is worsened by the area's geography; Lagos is a city surrounded by water, but much of this is polluted, which makes for a high transmission of water-related disease. The increase in flooding only exacerbates this problem. These obstacles create a bleak picture for Lagos in terms of the fixing the water crisis and improving public health.

## **Results of Poor Sanitation and Water in Urban Areas**

Due to the lack of access to water and sanitation facilities in Lagos, there are significant negative health effects for the city. Specifically, there is an increased transmission of water-related diseases in Lagos because of poor water and sanitation conditions.

In cities, there are both negative and positive impacts of living in a city in terms of disease transmission. For example, one benefit of living in a city is that there are generally higher salaries offered than in their rural counterparts. Also, education levels are commonly higher in urban areas. This higher concentration of wealth and knowledge allows for better surveillance and control of diseases. Likewise, cities often have the resources to promote good health practices using campaigns through the media (Alirol, Getaz, Stoll, Chappuis, & Loutan, 2011). Another benefit is that the urban environment is usually not conducive to the

transmission of some diseases, such as malaria, which requires standing water as a breeding environment for the mosquitos that carry the disease. However, cities without controlled environmental conditions, such as Lagos, do not experience this benefit. It is important to note that many of these advantages are enjoyed unequally amongst urban populations. For example, the entire population of a city does not have access to premium health care services that are typically offered in urban environments. This is especially true of developing cities such as Lagos, where there are large disparities in socioeconomic status.

On the other hand, there are many downfalls to living in a city. For one, the population density tends to be much higher in a city. Areas with high population density lead to more human contact, which increases the likelihood of a disease being transmitted, especially diseases spread through the fecal-oral route. Rapid population growth also causes problem for cities because generally, an increase in population correlates negatively with the portion of the population that is vaccinated against infectious diseases (Alirol, Getaz, Stoll, Chappuis, & Loutan, 2011). Having a large group of people that are unprotected from disease living in the same area can create a hotspot for an epidemic breakout. Additionally, cities face the problem of having large numbers of immigrants. Immigration introduces new diseases to urban environments; in some cases, diseases that are typically considered rural can become a risk factor for cities due to migration (Alirol, Getaz, Stoll, Chappuis, & Loutan, 2011). Finally, people without improved sanitation facilities are left with fewer options than their rural counterparts. In rural societies, solid waste can be composted or burned, but these are not always viable options in cities. Therefore, solid waste can accumulate in the physical environment, causing pollution of runoff water and increasing the transmission of various diseases (Alirol, Getaz, Stoll, Chappuis, & Loutan, 2011).

Clearly, there are many factors unique to urban environments that promote the transmission of disease. Lagos, which is severely lacking in proper health infrastructure, is especially vulnerable to these risk factors. Next, several diseases that are prevalent in Lagos will be introduced in order to better illustrate the epidemiology behind water-related disease in an urban environment.

## ***Cholera***

Cholera is a waterborne disease that is transmitted through the fecal-oral route. It is an infection of the intestine that causes an enterotoxin to be produced. This toxin results in painless diarrhea which causes dehydration, along with vomiting in most patients. Because the dehydration associated with cholera occurs rapidly, the disease can kill within hours and the mortality rate is relatively high at 50% when the disease is left untreated. Luckily, cholera can be cured with the simple treatment of oral rehydration salts. This method focuses on rehydrating the body, causing the symptoms such as diarrhea to subside. With this treatment method, the mortality rate drops to 1%, even without the use of any antibiotics (WHO, 2014). Compared to treatments of some other diseases, this treatment is cheap and relatively easy to administer.

Cholera outbreaks can vary in intensity and length, but they happen on a regular basis in Nigeria. For example, Nigeria's largest outbreak occurred in 1991, with 59,478 reported cases and 7,654 confirmed deaths. On the other hand, in 2008, 5,140 cases and 247 deaths were reported (WHO, 2012). Cholera epidemics can vary from several months to over a year (Ayeni, 2014). While cholera outbreaks occur frequently in rural Nigeria, there have been recorded cases of cholera in Lagos in the past few years, such as 13 reported cases and 3 deaths in an outbreak of 2013 (Osborne, 2013). Furthermore, there have been studies conducted that demonstrate a number of risk factors for cholera in Lagos.

For example, a study was conducted in the floating slum of Makoko that investigated water samples and residents' perceptions of the disease. First, based on the biological results of the study, the area of Makoko is at risk for outbreaks of the waterborne disease. Water samples were collected from household storages around the area. This storage water came from either unprotected wells or the Lagos lagoon. The study looked for the presence of fecal coliforms in the water samples. Fecal coliforms are a type of bacteria that are found in the GI tract of humans and animals. They are excreted in fecal matter, and although they are mostly harmless, several varieties, such as *Vibrio cholera*, cause disease. Testing for fecal coliforms in water is important because it is an indicator for the degree to which a water sample has been contaminated with human or animal waste (Jolley & English). The study looking at water in Makoko found that there was variation in the amount of fecal coliforms found in water samples, ranging from zero to  $2.1 \times 10^6$  colony-forming units per gram of water. However, the World Health Organization recommends that water with any amount of fecal coliforms should not be consumed (Ayeni, 2014). The study also looked for the presence of *Vibrio cholera* specifically. It was found that 37% of the water samples contained the bacterium *Vibrio cholera* (Ayeni, 2014).

These results demonstrate that the household water in Makoko is often contaminated with fecal matter. This water is likely used for drinking, washing food, and washing hands; all of these are different aspects of the fecal-oral route of disease transmission, and promote the spreading of waterborne disease. Moreover, this study proves that approximately a third of water samples in Makoko contain fecal coliforms that directly cause cholera. These results demonstrate that there are risk factors for cholera in Makoko based on biological evidence.

The study also looked at the perceptions of Makoko residents towards the disease cholera. These perceptions were determined through surveys of the Makoko population. The

survey group was divided evenly between female and male. Within the group, there was also variation in the amount of time that the respondents had lived in Makoko. First, the study found that approximately 20% of respondents claimed to have been diagnosed with cholera, but only 6.7% of respondents could remember an outbreak of cholera in the area (Ayeni, 2014). Furthermore, the study looked at participants' understanding of the way the disease is transmitted. When asked what the primary agent of transmission was, approximately 40% answered "flies", 50% answered the "environment", and the rest answered "unknown". The study also asked participants about the best ways to prevent the disease. A health campaign was chosen by 8% of participants, better sanitation and environmental health was chosen by 72%, and the use of drugs was chosen by 20% (Ayeni, 2014).

These results indicate that knowledge about the disease and how it is transmitted is lacking for some of the residents of Makoko. Although many participants realized that the environment was important in the spreading of cholera, over a third chose flies as the mode of transmission. This is significant because when the residents are knowledgeable about how the disease is spread, they can take actions towards disease prevention. For example, one way that participants can avoid hazardous environmental conditions is by boiling the water that they use to drink and wash food. People are less likely to do this if they don't understand the role of poor environmental conditions, such as dirty water, in cholera transmission. Therefore, the fact that there is a lack of knowledge about cholera in Makoko poses another risk factor for the region.

Due to the fecal-oral route of transmission, cholera is a disease that is easily prevented with clean drinking water, functioning sanitation facilities, and proper hygiene practices. Additionally, the disease has a low mortality rate when it is treated with oral rehydration salts, a treatment that is relatively cheap and easy to administer (WHO, 2014). Therefore, presence or

lack of cholera outbreaks in an area is telling of its social development. The fact that some areas of Lagos still suffer from cholera outbreaks with fairly high mortality rates demonstrates the grim picture for the public health of the city.

### ***Schistosomiasis***

Schistosomiasis is caused by a flatworm parasite and it is considered a water-contact disease because it is obtained through skin contact with the larvae of the parasite. These larvae are prevalent in freshwater because they develop in freshwater snails. Once the larvae enter the human body, they enter the bloodstream, and are deposited in the intestines or bladder. There, they make eggs, which cause inflammation and the symptoms associated with the disease. An infected individual can pass on the disease by excreting urine containing eggs into water, where they will hatch, and enter a snail for development (WHO).

The initial symptoms consist of a rash, fever, and cough. As the parasite develops, a variety of more severe symptoms can develop, depending on which systems are affected. Often times, the liver, spleen, kidney, and bladder are impacted. This can result in an enlarged liver or spleen, or blood in urine. It is rare that the nervous system is impacted, but when it is, seizures or paralysis can occur. Additionally, in children, there is a positive correlation with schistosomiasis and stunted growth or cognitive development. The drug praziquantel cures the disease by killing the parasite in the body, which eliminates the symptoms associated with the disease. However, this is often only administered in areas where schistosomiasis is highly prevalent (WHO).

Generally, schistosomiasis is considered to be a rural disease. This could be due to the fact that there are more bodies of freshwater in rural areas. Additionally, this disease tends to be more prevalent in certain occupations, such as agriculture and fishing, due to the greater amount

of contact with water (Adewole & Fafure, 2012). Therefore, it would make sense that rural communities that are based in these occupations would have a high rate of schistosomiasis. However, as was discussed before, schistosomiasis illustrates the point that rural diseases can become urban due to the large number of immigrants entering cities. Several studies have examined Lagos and found that schistosomiasis is a significant public health problem in different areas throughout the city.

One study was carried out in Epe, a key port town that is situated on the Lagos Lagoon, where the main occupation is fishing (Encyclopaedia Britannica). The goal of the study was to determine whether or not schistosomiasis could be a threat to an urban community. Therefore, the authors looked not only at the prevalence of the disease in humans but also at the ability of the local freshwater snails to act as hosts for the parasitic larvae. First, to look at the prevalence in humans, the study looked at the urine of individuals ranging from six to thirteen years of age from two different primary schools. These schools were chosen due to their proximity to freshwater. They determined the presence of *Schistosoma haematobium*, the organism responsible for causing urinary schistosomiasis, in the urine samples using methods in molecular biology. It was found that 57% of the students' urine was infected at the first school, and 40% was infected at the other school. Additionally, the study looked for hematuria, or blood in the urine, a common symptom for urinary schistosomiasis, in the samples collected. It was found that 16% of the urine samples were positive at the first school, compared to 29% at the other school (Akinwale, et al., 2011). These results indicate that this disease is endemic in these schools, as almost 50% of participants were found to have traces of schistosomes. Additionally, this study demonstrates that the typical ways of detecting schistosomiasis, such as looking for hematuria, are not as accurate as more advanced methods of detection. This is significant

because the impact of this disease on the health of communities could be underestimated using traditional methods. However, it is important to note that this study only focuses on children in schools. Therefore, for future studies it would be helpful to examine the prevalence of infection in adults and children who don't attend school to fully understand the weight of this disease on public health in urban communities.

This study also looked at the ability of freshwater snails in the area to act as hosts for *Schistosoma haematobium*. A total of 14 *Bulinus truncatus* snails were collected from the area and tested for schistosome infection using the same molecular techniques as were used for the urine testing. It was found that seven of the snails were infected (Akinwale, et al., 2011). These results indicate that the species *B.truncatus* is a viable host for the *S. haematobium* larvae. Therefore, this study provides evidence that there are risk factors for schistosomiasis in the urban environment of Lagos. Without these freshwater snails' presence, any rural immigrants entering Lagos would be unable to transmit the disease to other individuals. However, because they are present, the disease has become endemic in some parts of Lagos and it is important to understand the behaviors responsible for the endemic.

Unlike cholera, schistosomiasis is not spread through the fecal-oral route of transmission. Consequently, the spreading of schistosomiasis occurs through a different set of behaviors. For example, engaging in recreational activities such as swimming or fishing would enhance one's chances of contracting the disease. Also, bathing or washing clothes or dishes in freshwater can increase one's chances of being infected. It has been reported that children are the most likely to suffer from schistosomiasis because they are the most likely to engage in these activities (Akinwale, et al., 2011). This is unfortunate because children are at risk for more lasting consequences, such as stunted growth and cognitive development, which could hinder the



development of the country (WHO). There has not been a consensus between different studies on which gender is more at risk for schistosomiasis. For instance, in the study conducted on school-age children in Epe, it was found that males were infected more often (Akinwale, et al., 2011). However, in another study conducted on school-age children in the Igbokuta village of Lagos, females were found to be infected more frequently (Oluwasogo & Fegbemi, 2013). In both cases, it is argued that the gender with the greater infection rate has more frequent contact with water. It is argued that females are in contact with water more due to their domestic responsibilities such as fetching water and washing clothes and dishes. On the other hand, it is argued that males engage in recreational activities such as swimming more often. Additionally, males are found more in the occupation of fishing than women are, leading to a greater amount of water contact. Regardless of which argument proves to be true, the spreading of schistosomiasis could be reduced with better water and sanitation facilities, along with more wide-spread education about the risk factors relating to the disease.

Like cholera, the high prevalence of schistosomiasis in Lagos demonstrates that water and sanitation facilities are seriously lacking throughout the city. Better facilities could greatly reduce the number of cases throughout the city. For example, having access to an improved water source would reduce the need for people to visit bodies of freshwater, since they could use it to bathe and wash their clothes and dishes. However, some of the population would still be exposed to freshwater when swimming and fishing. Therefore, sanitation facilities would also be helpful in reducing the number of cases. If there were better sanitation facilities, urine and stool that are infected with parasitic larvae would be separated from freshwater sources, preventing the larvae from infecting snails and ending the cycle of transmission. Furthermore, better education could reduce the number of cases of schistosomiasis in Lagos. If the residents of Lagos were

more knowledgeable about the disease and the way it is transmitted, they could take simple measures to prevent contracting the disease, such as wearing gloves and shoes when in contact with water, boiling water that is used to wash dishes and clothes, and discouraging children from swimming in bodies of water (Oluwasogo & Fegbemi, 2013).

Without these improvements, Lagos is an environment that encourages the spreading of schistosomiasis. Many of the slums of Lagos are built on land that is swampy, or even on water in the case of Makoko. This standing water makes an ideal environment for snails. The presences of snails, coupled with lacking sanitation facilities in the slums create a perfect recipe for the transmission of schistosomiasis. Even on land that is less swampy, the flooding the city often experiences leads to an abundance of standing water for the freshwater snails to thrive in. Additionally, the flooding increases the amount of waste runoff in bodies of water. This is problematic because schistosomiasis is transmitted through the excretions of an infected individual. Finally, the large number of rural migrants that come to Lagos leads to new cases of the disease being brought into the city. Therefore, the endemicity of schistosomiasis in Lagos illustrates the importance of maintaining proper water and sanitation facilities in a city. Otherwise, urban environments can become susceptible to the spreading of rural diseases.

## ***Malaria***

Malaria is considered to be the most significant parasitic disease when looking at public health impact globally, as it is estimated that over 1 million people die of the disease each year (WHO). It is caused by a protozoan parasite, either *Plasmodium falciparum*, *P. vivax*, *P. ovale*, or *P. malariae*. Any of these species can infect the *Anopheles* mosquito, which is responsible for the transmission of the disease. A mosquito can be infected when it bites an infected person, as some of the blood it ingests will contain the parasite. After the parasite develops in the mosquito

for a period of time, the mosquito can begin to pass it on to new human or animal hosts when it bites them. The parasite will travel to the liver in humans, where it divides and grows, and then enters into red blood cells (WHO). There are a wide range of symptoms caused by malaria, including fevers, headaches and muscle aches, nausea, vomiting, diarrhea, jaundice, and anemia. There are also more severe symptoms in some cases, such as convulsions, comas, or kidney failure (WHO). Malaria is classified as a vector-borne disease, which is water-related because the vector requires water for a part of its lifecycle. The *Anopheles* mosquito requires fresh water to breed in.

Generally, cities don't provide the most favorable environments for the *Anopheles* mosquito, so transmission is hindered in cities. Many cities don't have enough standing water to provide breeding environments for the mosquitoes. In cities where there is standing water, it is often polluted, which prevents mosquitoes from breeding there. Therefore, there is generally a smaller population of *Anopheles* vectors living in cities, and those that live in cities are less likely to be carrying the *Plasmodium* parasite. Nevertheless, malaria can be found in many cities in sub-Saharan Africa, Lagos included. It is estimated that there are 200 million people living in African cities that are infected with the disease out of the 600 million people who are infected throughout Africa. (Alirol, Getaz, Stoll, Chappuis, & Loutan, 2011).

In Lagos, the highly contaminated bodies of freshwater should prevent the transmission of malaria throughout the city. However, the prevalence of urban malaria is increasing in Nigeria. Researchers have investigated the patterns of *Anopheles* breeding throughout Lagos to better understand this trend. In one study, water samples were collected from various potential breeding sites throughout metropolitan Lagos between April and June, which is considered the peak malaria season. These water samples were tested for *Anopheles* larvae. Additionally,

variables such as pH, turbidity, oil content, dissolved oxygen, and the presence of heavy metals were recorded for each water sample. These variables were used to analyze the degree to which the water samples were polluted. It was found that 24.3% of the 292 breeding sites tested contained *Anopheles* larvae, indicating that the mosquitos are able to breed at these sites. The great majority of the sites that tested positive, approximately 85%, were classified as polluted, with low dissolved oxygen, turbidity, high oil content, and the presence of metals Fe, Cu, and Pb. The content of these three metals in the water was threefold higher than is found in a natural breeding habitat for *Anopheles* mosquitos (Awolola, Oduola, Obansa, Chukwurar, & Unyimadu, 2007). Therefore, these results demonstrate that the *Anopheles* mosquitos are adapting to breed in polluted waters.

This is problematic for Lagos, as there is a plethora of creeks, swamps, and lakes in the metropolitan area. Additionally, the regular flooding leads to standing water throughout the city, increasing the number of potential breeding sites for mosquitos. While the polluted waters are risk factors for other diseases, such as cholera and schistosomiasis, the pollution has actually helped to prevent the spread of malaria in the past. However, now that mosquitos are adapting, it is more important than ever that strides be made to better manage the city's water resources. A better water management system could decrease the amount of standing water, which would limit the number of potential breeding sites for mosquitos. Otherwise, the incidence of malaria in Lagos will continue to rise.

## **Conclusions**

In this section, the city of Lagos has been used to highlight the factors contributing to the water crisis and the resulting public health consequences in an urban area. Although some of the

ideas presented in this chapter are unique to Lagos, many of the themes can be applied more broadly to urban areas throughout sub-Saharan Africa.

One of the factors that contributes to the lack of water and sanitation infrastructure in Lagos is the history of inequality that dates back to the colonial era. When Great Britain took control of Nigeria as one of its colonies, it implemented the policy of racial segregation in all colonial towns. Most infrastructure improvements were directed at European enclaves. Once the colonial period ended, some of the existing infrastructure was not properly maintained, especially during the 1980s and 1990s when a global depression hit Nigeria hard. Additionally, as the city continued to grow, the government could not keep up with providing new infrastructure to the outskirts of the city. Many of the cities across sub-Saharan Africa may have experienced a similar history that led to a lack of sufficient infrastructure. The British implemented their policy of racial segregation throughout all of their colonies, resulting in areas of the city with top-notch infrastructure and others with none whatsoever. The French, the other dominant colonial power, did not segregate solely on race; they segregated based on culture. Unlike their British counterparts, they encouraged Africans to assimilate into French culture. If Africans did this, they were able to live in the European enclaves (Mazrui, 2004). However, this still set the stage for inequality in infrastructure throughout the city.

Also, the inequality between genders stretches to other cities throughout sub-Saharan Africa. Women throughout the region face problems similar to the ones seen in Lagos. For example, many women have to spend a significant part of their day tracking down water for their families. Women are faced with a higher chance of being victims to violence in cities. Finally, women are still underrepresented in local governments (Inter-Agency Network on Women and Gender Equality). Therefore, the exclusion of women in decision-making about infrastructure is

a problem that is prevalent throughout sub-Saharan Africa. Strides towards gender equality could benefit many cities throughout the country, by increasing progress towards improved water access and the MDG for female empowerment.

Although some of the obstacles seen in Lagos can be applied to other urban areas, there are several that are unique to Lagos. For example, the rate of population growth poses a problem to the city that other sub-Saharan African cities do not face. Not only is Lagos concerned with maintaining old infrastructure, but also with building new infrastructure for a rapidly growing city, both demographically and physically. Additionally, Lagos' geography creates a distinct set of obstacles for the city. As a city built largely on swampland and water, it seems counterintuitive that there would be a water shortage problem. However, the surface water is polluted with runoff industrial and human waste. The groundwater, which is often tapped into for improved water sources, is also contaminated due to the porous nature of the soil. Furthermore, the flooding that occurs frequently in the area increases the amount of runoff that enters these water sources. This flooding is increased by climate change; although many regions in sub-Saharan Africa have begun to feel the effects of climate change, each region experiences climate change differently. Some regions face increased flooding, some face more severe droughts, and some face no changes at all. Therefore, the increase in flooding is unique to Lagos and other cities that fall in the tropical belt along the coastline of West Africa.

Although Lagos was used here as a case study, the factors that contribute to the persistence of the water crisis can be seen in many cities throughout sub-Saharan Africa. The lack of water and sanitation management has created an unhealthy environment that is favorable for the transmission of many diseases. In this chapter, cholera, schistosomiasis, and malaria were used as examples to demonstrate the dynamics in play that lead to the transmission of

water-related disease in Lagos. However, it is important to note that there are other prevalent water-related diseases in Lagos other than the three that were discussed in detail. For example, typhoid fever, a bacterial waterborne disease, and hepatitis A, a viral waterborne disease, are seen frequently throughout the city.

When looking at the epidemiology of cholera, schistosomiasis, and malaria in Lagos, several trends emerge. First of all, it is apparent that because the environment in Lagos is not being controlled, diseases that are typically rural are becoming urban threats. The transmission of schistosomiasis in Lagos is possible because the standing water throughout the city is not taken care of. Thus, freshwater snails that can serve as hosts for the parasite are able to survive in the city. The prevalence of malaria, a disease that is typically found in rural areas, is increasing in Lagos. Once again, the standing water throughout the city acts as an environment for an animal vector that transmits the disease. In the case of malaria, that vector is a mosquito. Better water management systems that could prevent standing water from collecting in the city would decrease the transmission of these diseases. However, controlling diseases with animal vectors poses a problem, especially when they are able to adapt to a variety of environments. Even if standing water was cleared throughout the city, the Lagos Lagoon would still provide a breeding site for mosquitos. Although the polluted waters of the lagoon promote the spreading of other water-related diseases, the pollution should hinder activities of malaria vectors. However, the mosquitos have been able to adapt, so the prevalence of malaria remains high in the city.

Another trend that is observed in Lagos is the increased transmission of diseases through the fecal-oral route. This can be attributed to several geographical features of the city. For example, the fact that Lagos is built mostly on wetlands makes it difficult for the city to prevent

the contamination of water sources, especially considering the lack of sanitation facilities. Human waste often times ends up in the freshwater sources throughout the city. The flooding that is frequently seen in Lagos only adds to this problem, because flooding pushes runoff waste into the lakes and creeks throughout the city. The high likelihood of water contamination is a risk factor for diseases, like cholera, that are spread through the fecal-oral route. A person can contract a disease if they drink this dirty water, if they use it to wash their food, or if it comes into contact with hands that then touch food. Because there are many risk factors for waterborne diseases in Lagos, the role of health education becomes more important. People have a better chance of avoiding disease if they take preventative steps, such as boiling their water. However, people only know to take these steps if their importance is made known to the public.

These trends can be applied to other cities throughout sub-Saharan Africa. Although cities generally have better access to water and sanitation facilities than their rural counterparts, there are often large disparities seen in cities. Many have large slum communities that lack appropriate water and sanitation and have large population densities. Therefore, the environment in some urban areas throughout sub-Saharan Africa may be just as unfavorable as it is in Lagos. Poor environmental conditions favor the transmission of rural diseases and diseases that are spread through the fecal-oral route. Thus, the transmission of water-related diseases is a problem that plagues cities across the continent. The large burden that is caused by these diseases could be relieved with the improvement in water and sanitation infrastructure. Next, the focus will turn to rural Nigeria.



# Rural Nigeria

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As was discussed in the introduction, it is generally rural areas that are more lacking in access to water and sanitation facilities. As of 2010, 43% of rural Nigeria had access to improved water sources and 27% had access to improved sanitation facilities, compared to 58% and 31% of the national population, respectively. There has been improvement in rural water access coverage over the past twenty years, as only 30% of the population had access to water in 1990. However, the percent of the population with access to improved sanitation facilities has declined from 1990, when 36% of the rural population had access (UNICEF, WHO, 2012). This decline can be attributed to a population growth that surpasses any increases in infrastructure.

It is estimated that half of Nigeria's population lives in a rural setting, although this percentage is predicted to decrease as the urban populations swell (UNICEF, WHO, 2012). Despite the fact that population density is much higher in cities, the large rural Nigerian population places a strain on the available land and resources. Generally, poverty is more widespread in rural areas than in the country's cities. It is estimated that 80% of the rural population lives below the poverty line, meaning they are surviving on less than the equivalent of 1.25 US dollars per day. The vast majority, approximately 90%, of the rural population receives their income from the agricultural sector (International Fund for Agricultural Development). Although agriculture accounts for a significant fraction of Nigeria's GDP, about 25%, the lucrateness of rural agriculture is hindered by poor infrastructure, such as lack of roads, irrigation systems, and other technologies (National Bureau of Statistics, 2014). Additionally, conflict is seen throughout rural Nigeria, which only exacerbates the widespread poverty. These problems, combined with the water and sanitation crisis, create a host of public health concerns for rural Nigeria.

In this chapter, the causes and effects of the lack of access to water and sanitation in rural Nigeria will be investigated. First, some difficulties specific to rural Nigeria in overcoming the water crisis will be addressed. Next, public health implications relating to lack of water and sanitation will be discussed. Specifically, the diseases hepatitis A, dracunculiasis, and cholera will be used to exemplify the epidemiology of water-related diseases in a rural setting. Finally, ideas from this chapter that are applicable to other rural areas throughout sub-Saharan Africa will be identified.

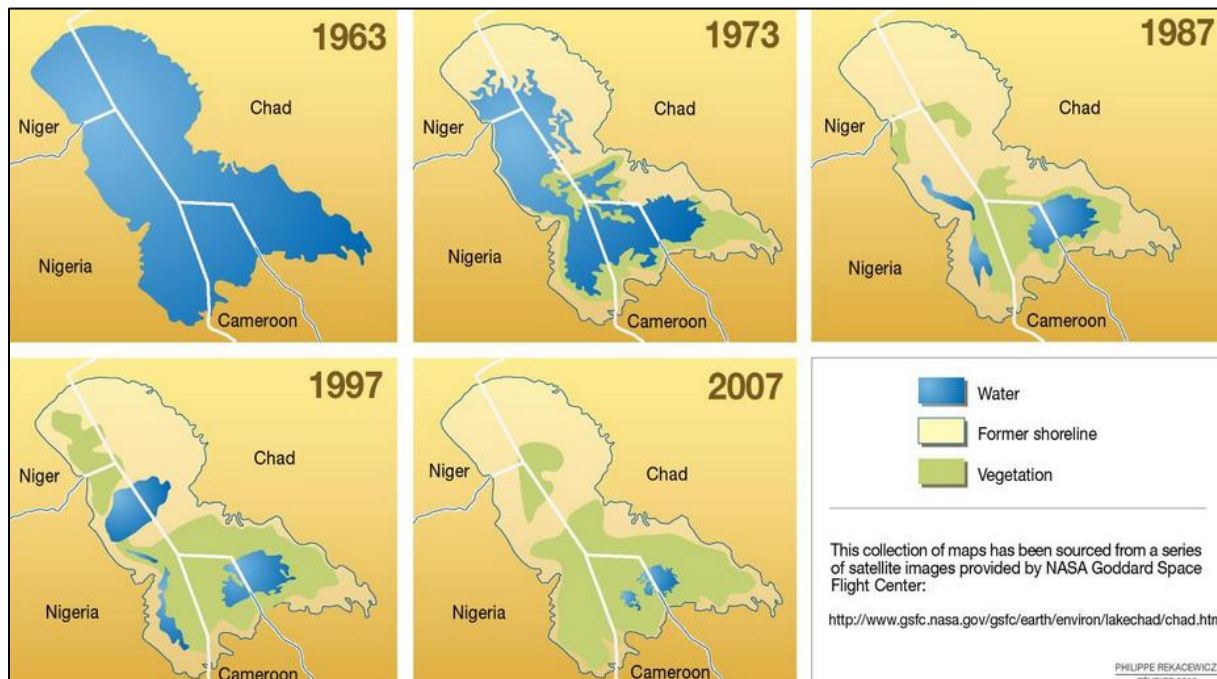
### **Specific Obstacles for Rural Nigeria**

Rural areas have a set of obstacles that are different from urban areas when it comes to overcoming the lack of access to improved water and sanitation infrastructure. For rural Nigeria, these problems include climate change that leads to excessive droughts and conflict throughout various regions. These obstacles can be seen in rural areas in other sub-Saharan countries.

Rural regions of Nigeria that are located in the north of the country are highly susceptible to climate change. However, unlike Lagos in the south, where climate change is causing shorter and more intense floods, the north has been experiencing increasing desertification. The northern region of the country is classified as a semi-arid zone, which is prone to desertification. This is especially true of land that has been subject to deforestation. Generally, semi-arid zones are characterized by one wet season with rainfall ranging between 750 and 1250 mm, followed by one dry season (FAO, 1985). As desertification occurs, the wet season becomes shorter and the average rainfall decreases. Therefore, the droughts become longer and more severe (Our Africa). This is problematic for the water crisis because it limits the amount of internal renewable water resources in the area. However, because the area has not come close to withdrawing all of its IRWR, the lack of infrastructure still poses the biggest problem. Still, if

the problem of desertification progresses, then the region could face problems dividing up resources for agricultural and domestic purposes in the future.

Also, in areas experiencing desertification, it is possible for bodies of water to actually dry up. This is true of Lake Chad, which has been reduced to approximately one twentieth of its original size (UNEP, 2008). The progression of the disappearance of the lake can be seen in Figure 6.



**Figure 6: The disappearance of Lake Chad from 1963 to 2007**

Source: (UNEP, 2008)

The disappearance of the lake is caused by the overuse of its water resources. As can be seen in Figure 6, the lake sits between four countries: Nigeria, Niger, Chad, and Cameroon. All four countries have been diverting water away from the lake for years for irrigation purposes (UNEP, 2008). These unsustainable projects coupled with the desertification from climate change have produced disastrous results for the region. First of all, the disappearance of the lake has depleted the area of freshwater resources. It will be more difficult to build effective water

infrastructure when there are fewer water resources to harness. Additionally, the loss of the lake hurts the agricultural productivity of the area. The decrease in productivity has the ability to devastate the region economically and increase the prevalence of poverty (UNEP, 2008).

In addition to climate change, the conflict existing in some rural areas hurts the country's ability to overcome the water crisis and its public health consequences. This conflict stems from the Islamic militant group Boko Haram. The group, which operates mostly in the northeastern states of Nigeria, aims to overthrow the western-influenced Nigerian government in favor of an Islamic-based government. Boko Haram is responsible for regular violent attacks since 2009 that target schools, politicians, police, and a variety of other groups. Essentially, anything that can be connected with Western ideals is a potential target for Boko Haram (National Counterterrorism Center).

The activities of the militant group halt progress towards better water and sanitation access in several ways. First of all, the destructive nature of their attacks can destroy infrastructure that has been put in place. Additionally, their activities in a particular area will dissuade humanitarian groups or governmental organizations from entering the region to construct new infrastructure (Gayer, Legros, Formenty, & Connolly, 2007). Therefore, Boko Haram is a barrier to progress because they are limiting the amount of functioning infrastructure in the area where they operate. Limited infrastructure will force families to walk farther to collect water for the household. Often times, this responsibility falls on the girls and women. This is particularly problematic because the longer women and girls have to walk to collect water, the more susceptible they are to attack. This is especially true in a region that is already ridden with violence.

Boko Haram also amplifies the public health consequences caused by the water crisis. In areas where they operate, it is harder to maintain surveillance of diseases and control the spreading of them. It can also be difficult to get medical resources into the region due to dangerous roads. This makes the treatment of disease more difficult than it would be without violence. Finally, conflict promotes migration into violence-free regions or out of the country. This migration allows for the spreading of diseases to new regions that were not affected previously. Additionally, refugee camps that are used to protect people from insurgents are a hot spot for disease transmission with limited water and sanitation infrastructure and high population density (Gayer, Legros, Formenty, & Connolly, 2007).

Climate change and conflict, particularly in the north, have aggravated the water crisis in rural Nigeria. These factors make the installation of new infrastructure and the maintenance of old infrastructure more difficult. Additionally, they can contribute to the higher transmission of disease. These problems combined with the serious lack of access to improved water and sanitation facilities in rural Nigeria have led to a host of public health issues.

## **Results of Poor Sanitation and Water in Rural Areas**

As is the case for urban areas, there are some traits of rural areas that lead to decreased transmission of diseases and some that lead to increased transmission. One factor that curbs the transmission of disease transmission in rural areas is the lower population density. It is harder to spread diseases when there is less contact between individuals. Additionally, rural populations have more options when it comes to solid waste disposal. When sanitation facilities are lacking, waste can be composted or burned, which is not usually an option in cities (Alirol, Getaz, Stoll, Chappuis, & Loutan, 2011). The better disposal of waste greatly decreases the transmission of diseases spread through the fecal-oral route.

However, there are many negative consequences to living in a rural area. For example, rural populations do not always have access to the same resources as their urban counterparts. This could be due to the fact that some rural areas are isolated from other areas due to a lack of roads. If transportation is limited to an area, it is difficult to get medical supplies there. Additionally, rural areas tend to lack the advanced laboratory facilities that are seen in cities. Thus, it is harder to diagnose patients that come in with symptoms common to many diseases, such as a fever. This leads to overtreatment, and antibiotics are given to patients who don't need them. This unnecessary use of antibiotics could lead to a population of bacteria with higher resistance to drugs (Petit, 1994). Also, in rural areas, knowledge about good health habits is not as concentrated as it is in cities. Therefore, initiatives to spread this information through health education campaigns are not as wide-spread through rural areas as they are through urban areas (Alirol, Getaz, Stoll, Chappuis, & Loutan, 2011). A lack of knowledge about transmission of disease makes it harder to prevent it. Finally, rural areas typically have lower access to water and sanitation than their urban counterparts (UNICEF, WHO, 2012). Furthermore, the facilities that are in place are not always maintained as well. Therefore, the spreading of water-related diseases is prevalent throughout rural areas in developing countries. The epidemiology of hepatitis A, cholera, and dracunculiasis will be explored within the context of rural Nigeria in order to demonstrate the impact of the water crisis on public health in the region.

### ***Hepatitis A***

Hepatitis A, a waterborne virus, is a disease that causes inflammation of the liver. It is spread throughout the fecal-oral route of transmission, so it is found frequently in areas without improved water and sanitation facilities. Therefore, it is primarily found in developing, rural areas. Hepatitis A is generally not a fatal disease, and treatment is not necessary because the

disease tends to resolve itself after several weeks, or months in more extreme cases. However, the disease causes a number of symptoms that can render a person unable to work or attend school. These include diarrhea, nausea, fevers, jaundice, and dark-colored urine (WHO, 2014). Hepatitis A can be prevented by drinking clean water and using proper hygiene practices when possible. Additionally, there is a vaccine against hepatitis A that prevents the transmission of the disease (WHO, 2014).

Interestingly, hepatitis A does not affect children the same way it affects adults; generally, children do not experience the symptoms associated with the disease (WHO, 2014). Because the antibodies that are developed from exposure give that person immunity in the future, a child that is exposed to the disease will not be affected by the disease again. Therefore, in areas where the median age for population immunity is low, the burden of the disease is actually smaller, even though the disease is considered to be more endemic.

There have been several studies to demonstrate that rural Nigeria is endemic with hepatitis A. For instance, in one study, the prevalence of hepatitis A was studied in a population of children in a rural area of southern Nigeria. In the study, blood samples of 406 children were tested for HAV (hepatitis A virus) antibodies. Antibodies for hepatitis A are developed in an individual after they have been exposed to the disease. Therefore, the presence of HAV antibodies in a person's blood indicates that they have contracted the disease at some point. The study found that 55% of the 406 children tested positively for HAV antibodies. In another study done in Nigeria, the result was comparable but slightly lower, at 42% (Ikobah, Okpara, Ekanem, & Udo, 2015). The difference could be attributed to the fact that the other study was conducted in an urban environment. Additionally, it was found that the median age for the 224 individuals that had the HAV antibody was 9 years of age (Ikobah, Okpara, Ekanem, & Udo, 2015). The

“midpoint of population immunity” is often used as a measurement for the degree of endemicity in an area. An area with a median age of less than 5 years is considered to be very highly endemic, a median age between 5 and 14 years indicates high endemicity, a range between 15 and 34 years indicates intermediate endemicity, and an age of 35 or above indicates low endemicity (Jabobsen, 2014). Therefore, the region in southern Nigeria that was investigated for this study was found to be “highly endemic” for hepatitis A. Age is significant when measuring endemicity for HAV because lower median ages demonstrate that people are exposed to the disease early on in life. The reason for early exposure is typically related to a serious lack of water and sanitation infrastructure.

This study also looked at the prevalence of HAV immunity in relation to a variety of other variables. For example, the role of gender was looked at in relation to the disease. It was found that both genders were equally as likely to have HAV immunity at a young age (Ikobah, Okpara, Ekanem, & Udo, 2015). This makes sense, because both genders would be drinking the same contaminated water throughout their childhood. Additionally, the association between the source of water and prevalence of hepatitis A was investigated. There did not appear to be a strong correlation, but it was found that individuals that got their water from boreholes had the greatest chance of having HAV antibodies, at 64% (Ikobah, Okpara, Ekanem, & Udo, 2015). This is concerning, because it could demonstrate that some sources that are considered safe, such as boreholes, are still prone to contamination. This might be the case in rural areas because the improved water sources are not maintained properly. It is important to have trained community members in rural areas that are knowledgeable about the maintenance of water sources. However, because the correlation between the use of boreholes and the prevalence of HAV



antibodies is not very strong, a number of other factors could be contributing, such as frequency of hand washing and contact with other infected individuals.

Although hepatitis A remains an endemic disease in Nigeria, there are studies that demonstrate a shift towards lower endemicity throughout West Africa. In the 1990s, the midpoint of population immunity was somewhere in early childhood throughout West Africa, indicating that the region could be classified as highly endemic (Jabobsen, 2014). However, as the study on Nigerian children demonstrates, along with other studies throughout West Africa, some regions have begun to make shifts towards higher midpoints, indicating a decrease in endemicity. This correlates largely with improvements in water and sanitation facilities that have been made in the past 20 years. The decline of endemicity is an optimistic sign for Nigeria and the rest of West Africa, and it demonstrates the positive impact better water and sanitation facilities can have on public health. However, as the endemicity decreases, the burden of the disease will actually increase. When the number of children exposed to HAV decreases, there will be a greater number of adults that will be susceptible to the disease. Therefore, more of the individuals that are exposed to the disease will experience symptoms.

As the access to improved water and sanitation facilities increases, the use of various prevention strategies will become important in stopping the transmission of hepatitis A in adults. For example, the practice of proper hygiene practices will become increasingly important. Even in areas that have safe water and improved sanitation, infected food can cause outbreaks of hepatitis A. These outbreaks can be prevented if individuals wash their food and their hands before touching food. In addition to the fecal-oral route, hepatitis A can be spread by making direct contact with an infected individual. This route of transmission can also be prevented through the practice of proper hand-washing. The role of health education is important in

ensuring proper hygiene throughout an area, especially in rural areas. Often times, health education campaigns are concentrated in cities. It is important that knowledge about public health is not taken for granted in rural areas, and initiatives should be put in place in regions of high endemicity. By educating communities on the way hepatitis A and other waterborne diseases are spread, they will be more inclined to engage in behaviors that will prevent transmission. Another option for preventing the spread of hepatitis A is the use of vaccinations. As fewer children gain natural immunity to the disease, it may be beneficial to instill artificial immunity in populations through the use of vaccines. As of now, there is no universal vaccine program in Nigeria or other West African countries (Jabobsen, 2014). However, as endemicity decreases, greater use of vaccinations should to be considered in these countries.

Although trends indicate that the endemicity of hepatitis A is decreasing in West Africa, there are still many regions, especially rural areas, that are highly endemic. The lack of improved water and sanitation facilities is directly related to the high rates of childhood immunity. The lack of maintenance of these facilities could also be a factor contributing to high prevalence of the disease. Additionally, the lack of education about the disease in rural areas increases the likelihood of transmission. Hopefully, the percentage of the population with access to water and sanitation infrastructure will continue to increase in rural areas. This will be a double-edged sword, because it will cause a decrease in HAV endemicity, but it will increase the morbidity of the disease as more adults become infected. Thus, the prevention methods of health education and vaccination will become increasingly important in rural areas.

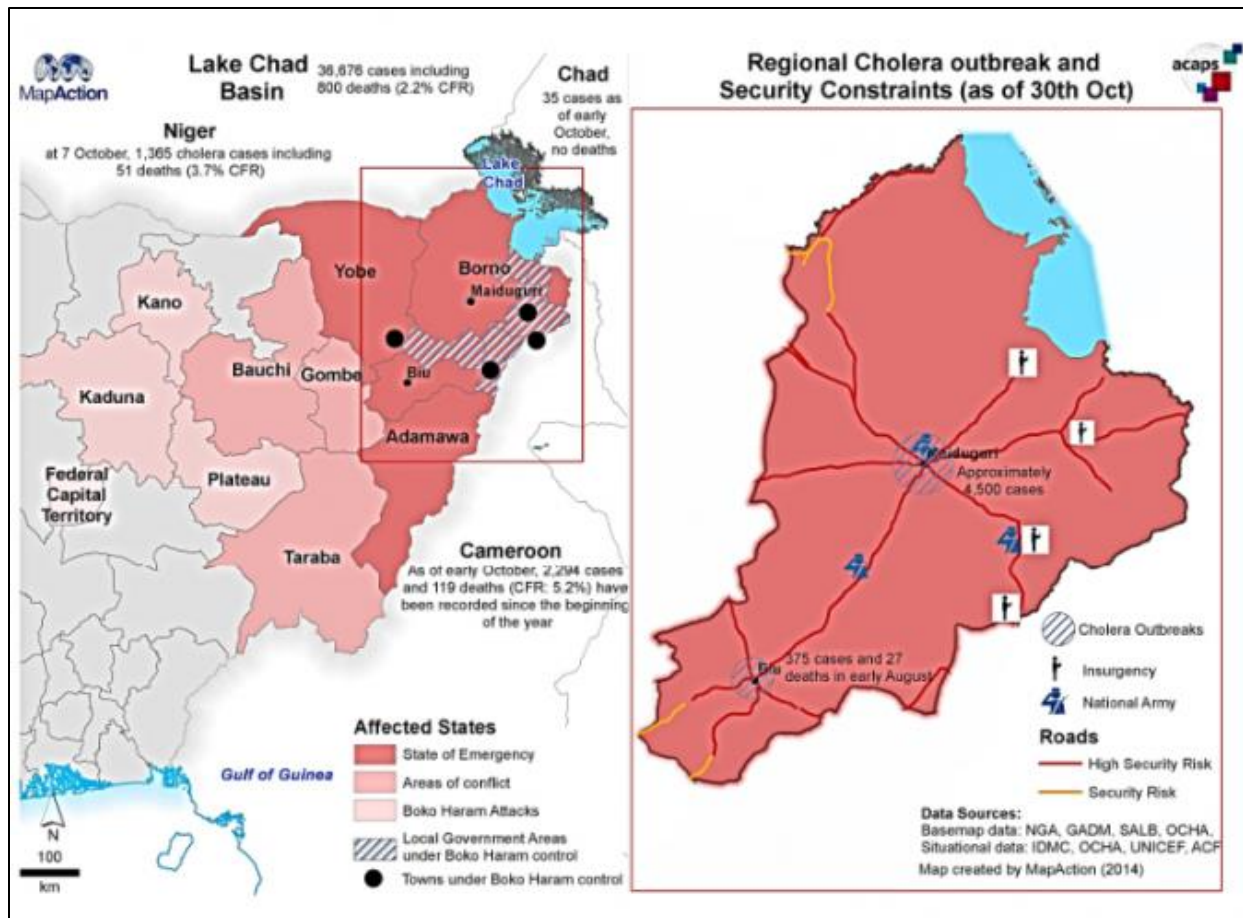
## ***Cholera***

Cholera, as was discussed in the chapter on urban Nigeria, is a waterborne disease caused by the bacterium *Vibrio cholera*. The disease causes diarrhea and severe dehydration, and it can

cause death if not treated properly. Outbreaks of cholera occur frequently throughout rural Nigeria, and they vary in length and intensity. The most recent outbreak recorded occurred throughout 2014. Between January and December of 2014, approximately 36,000 cases of cholera were reported throughout Nigeria (WHO, 2015). Of these cases, 755 resulted in death, so the mortality rate for this outbreak is 2%. This is a relatively high mortality rate when compared to other infectious diseases. For example, it was determined from data from 19 countries that the H1N1 influenza outbreak of 2009 had a mortality rate of 0.02% (Roos, 2013).

The outbreak of 2014 has been concentrated in northern Nigeria. The majority of this region is classified as rural. Water and sanitation facilities are lacking in this region; hand-dug wells and ponds are popular sources of water. Both of these sources can be easily contaminated with fecal matter from cholera patients because they are unprotected (Adagbaba, Adesida, Nwaokorie, Niemogha, & Coker, 2012). Besides a lack of improved water and sanitation, the conflict in the north is a risk factor for cholera.

As was mentioned, some rural areas in the northeast of Nigeria are plagued by ongoing attacks from the Islamic militant group Boko Haram. The cholera outbreak that occurred throughout 2014 was exacerbated by this violence. As can be seen in Figure 7, the outbreak hot spots fell in the middle of the high security risk areas.



**Figure 7: Map of cholera outbreak of 2014 and Boko Haram activity**  
Source: (relief web, 2014)

This figure demonstrates the difficulty of controlling a cholera outbreak in a region that is plagued by conflict. All of the roads that lead to the two sites of outbreak in Borno state have been deemed “high security risk”. Hindered transportation in and out of the problem site creates challenges for curbing the outbreak. For example, the dangerous roads prevent proper surveillance of the disease. Without surveillance, it is difficult to know the extent of the problem and how to go about controlling the outbreak. Humanitarian organizations cannot travel to the afflicted area to distribute supplies, such as oral rehydration salts, which are used to treat the infected individuals, or chlorinated tablets, which prevent contaminated water from infecting more individuals (Hussain, 2014). Also, if a severe case arises, the infected patient cannot go

outside of the area to seek advanced treatment. Finally, the lack of transportation prevents the building of new water and sanitation infrastructure in the area, which would help to prevent the transmission of cholera by providing clean drinking water. Therefore, the lack of access to the sites of outbreak can lead to a greater amount of cases and a higher mortality per recorded cases. Although the lack of transportation options in this case are related to the Boko Haram insurgents, the problem could arise in other rural areas throughout the country due to a lack of infrastructure. The lack of roads in other regions would present the same problems in surveying and controlling cholera outbreaks.

The conflict in northern Nigeria is also a risk factor for cholera transmission because it increases the migration of individuals into different regions and across borders. When the people migrating have been infected with cholera, they are likely to pass on the disease to surrounding areas via the fecal-oral route. For the outbreak of 2014, Cameroon and Niger have reported a few thousand cases each. In Cameroon, 85% of these cases have been in the Lake Chad region, adjacent to the Nigerian region under Boko Haram control (relief web). Further evidence for the role of immigrants in spreading the disease is seen in the pattern of cholera cases in Niger. It is reported that 96% of cases in the Diffa region of Niger, located next to Lake Chad, have occurred in refugee camps (relief web). Refugee camps provide an ideal environment for diseases to spread. Often, they do not have sufficient water or sanitation facilities to accommodate the large influx of people. Consequently, it only takes one immigrant infected with cholera to cause a significant outbreak in a refugee camp

Cholera is a disease that is easily treated and easily prevented. However, the violence that is taking place in rural northern Nigeria is making the containment of cholera difficult. For one, the violence interferes with the safety of transportation in the area. This hinders the ability

of various organizations to provide supplies that can prevent and treat cholera. Furthermore, the insurgents force civilians across the borders of surrounding countries, leading to the outbreak of cholera in those countries. The environments of refugee camps that immigrants find themselves in only boost the transmission of cholera. Finally, the violence in these rural areas deters the implementation of new water and sanitation facilities. This may be the most significant effect of the conflict in northern Nigeria because it not only hinders the fight against cholera, but also against other water-related diseases. Therefore, the insurgents combined with the lack of water and sanitation access in rural northern Nigeria are producing major public health issues.

### ***Dracunculiasis***

Dracunculiasis, otherwise known as guinea worm, is classified as a water-contact disease. It is caused by drinking the parasite *Dracunculus medenisis*, but it is passed on when the worm emerges from the skin of an infected person and comes into contact with water, making it a water-contact disease rather than a waterborne disease. Dracunculiasis is a notable disease because it is very close to being eradicated, with only 126 global cases reported in 2014 (WHO, 2015). This is a massive reduction from 1986, when it was estimated that there were 3.5 million global cases (The Carter Center). Its eradication will mark the first parasitic disease to be eliminated globally. In Nigeria, the last case was reported in 2008 (The Carter Center).

As was mentioned, humans contract the disease by ingesting the parasite. However, they don't drink the guinea worm larvae directly. First, the larvae must infect water-fleas, which are then consumed by humans when drinking contaminated water. The first symptom appears about a year later when the fully grown worm, which is 60-100 cm long, surfaces from the skin, producing a stinging lesion. Although this disease does not cause death, it causes crippling pain for weeks that renders the infected individual immobile and unable to work, attend school, or

contribute to household chores. Along with the pain, the emergence of the worm is accompanied by nausea, vomiting, and a fever. Because the pain is soothed by water, the patient will put the affected body part in water, which allows the worm to release larvae when it emerges. These larvae will then infect water-fleas and the cycle will start again (WHO, 2015).

Several features of dracunculiasis transmission make its eradication possible using a several-step program. For example, the disease can only be contracted by drinking contaminated water; it cannot be passed from human to human or from animal to human. Additionally, it is easy to detect when the worm is protruding from the skin because there is a skin lesion and the emergence is generally seasonal, so many will complete the cycle at the same time. Consequently, specific villages and individuals can be targeted when trying to eradicate the disease. In 1986, an eradication program was introduced by the Carter Center, along with several partners such as the World Health Organization, UNICEF, and the countries themselves, in Pakistan, Ghana, and Nigeria (Hopkins & Ruiz-Tiben, 1991). The program consists of three steps: the detection of guinea worm throughout the country in order to determine a baseline, the enactment of intervention strategies, and the containment of detected cases.

The first step involves the surveying of every village in the country in order to determine where the disease is endemic, and also to determine the baseline for future progress. In 1988, the first baseline survey was conducted in Nigeria, and surveyors found cases of dracunculiasis in approximately 6000 villages across the country. The number of cases found totaled 650,000, which greatly exceeded the estimated amount prior to the survey (Hopkins & Ruiz-Tiben, 1991). Thus, the surveillance step is essential in order to know the true extent of the problem. Once this is known, interventions are made in each of the villages. Generally, this involves the training of local primary health care workers, as this allows for more frequent surveillance in villages.

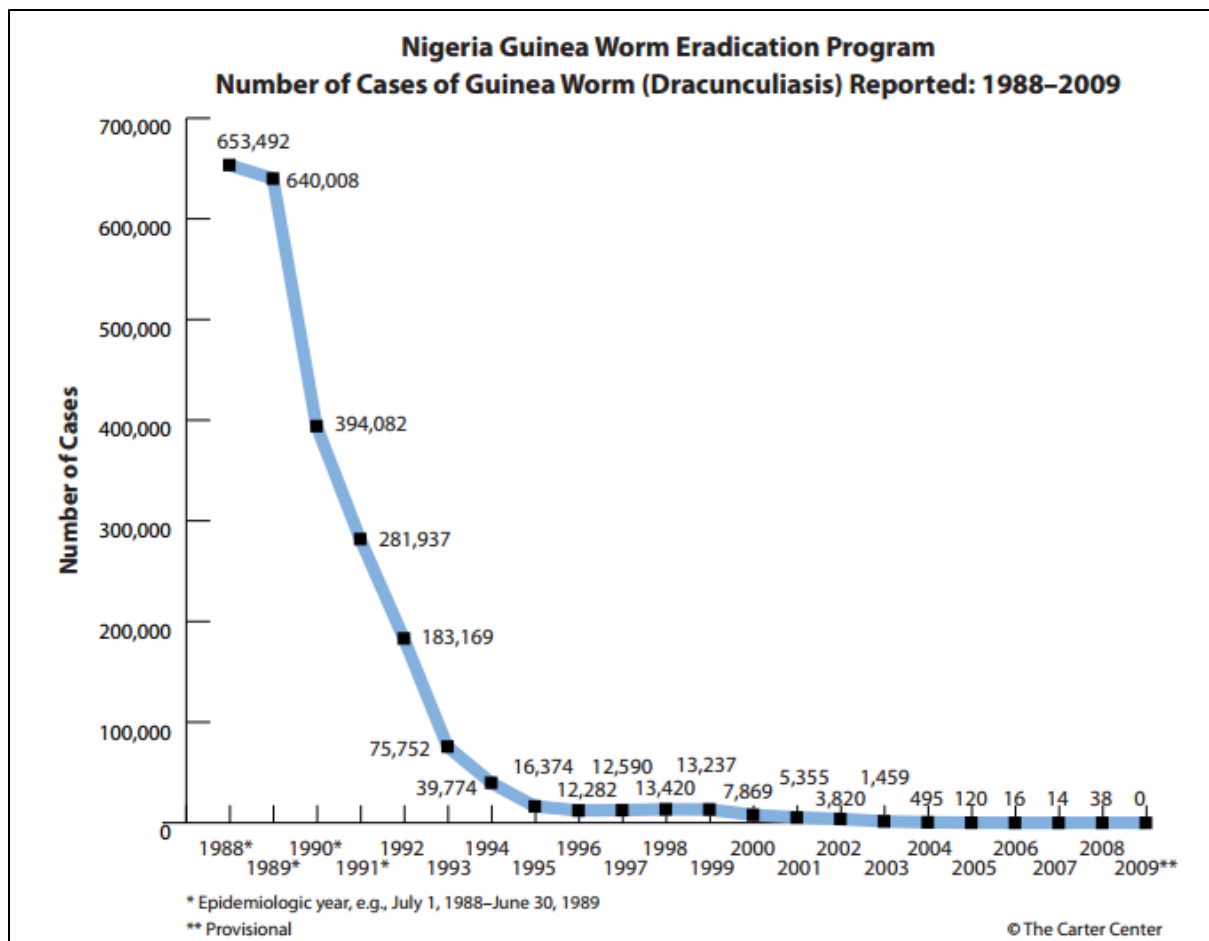
Then, these health care workers take on the responsibility of reporting new cases and implementing interventions. In Nigeria, a national survey was used for two years after the original in 1988. In 1991, the country began to count on the local health care workers exclusively (Hopkins & Ruiz-Tiben, 1991).

There are several interventions that are put in place to eliminate dracunculiasis, and often these are used in combination. First, health education plays a large role in the fight against dracunculiasis. Communities are instructed that dracunculiasis is contracted by drinking contaminated water. If safe water sources aren't available to a community, they can be taught to boil or filter their water with a cloth to protect themselves. Additionally, infected individuals are taught the importance of avoiding water sources that people use for drinking when the worm is emerging. Otherwise, they are likely to pass on the disease to other members of the community. Health education is an effective intervention because it is cheap, and it goes a long way in preventing more individuals from being infected. Another intervention is the installation of an improved water source in endemic villages. Due to the wide range of health benefits that an improved water source provides besides the elimination of guinea worm, it is the most favorable. But, expenses often create a barrier for this intervention being installed, especially in smaller villages. Still, when possible, priority is given to villages that are highly-endemic. The third intervention used is temephos, a type of larvicide that can be applied to contaminated water. It is effective in killing guinea worms, but it is not the most cost-effective solution. Also, topical treatment can be provided for infected individuals if it is available. Introducing this treatment to a community can be beneficial because it encourages infected individuals to reach out to local health care workers (Hopkins & Ruiz-Tiben, 1991).



The final stage of dracunculiasis eradication is known as case containment. Once the number of cases in a community is low enough, the local health care workers focus more on each infected individual. It is essential that these individuals avoid submerging themselves in water sources that people drink from when the worm is emerging from their skin. Furthermore, the rest of the community can be notified if there is a possibility that one of the infected individuals contaminated a water source (Hopkins & Ruiz-Tiben, 1991). The special attention to each case is what makes the final push towards eradication.

Although the three-step plan has proven to be effective in eliminating dracunculiasis, there have certainly been obstacles along the way. For example, because the eradication program is largely based in health education, it relies on the target population's willingness to accept new ideas and change behaviors accordingly. It was reported that even when a filter cloth is provided free of charge, village members did not always use it (The Carter Center). The guinea worm larvae are microscopic, so it is not obvious that the filter cloth is doing anything to prevent the disease. It is also not obvious that the submersion of the infected skin lesion in water is what releases the larvae and spreads the disease. Moreover, because the incubation period of the worm inside the human body is a year, it isn't clear that the drinking of contaminated water is the direct cause of the disease. Therefore, community members must trust the message that local health workers are delivering, even without direct evidence of the water's role in transmitting the disease (The Carter Center). However, it can be argued that the use of local health workers as the educators increases a community's willingness to learn. It is easier to trust someone that is a part of the community rather than an outsider. Therefore, the education program has been successful in many countries, Nigeria included. In Figure 8, the progress towards the eradication of dracunculiasis in Nigeria can be seen.



**Figure 8: The progress towards the eradication of *Dracunculiasis***  
 Source: (The Carter Center)

In Nigeria, the last case was reported in 2008 in a village in southeastern Nigeria. The worm of Grace Otubo, a 58-year-old woman of the village Ezza Nkwubor, emerged in November, marking a huge accomplishment for the public health system of Nigeria (The Carter Center). The fact that the last case can actually be tracked to a specific individual demonstrates the careful surveillance of guinea worm infections. Once the last case in a country is recorded, surveillance is continued for a few years. After several years without any cases, the World Health Organization certifies the country as having officially eradicated the disease (The Carter Center). Therefore, Nigeria has been officially free of dracunculiasis as of 2013. Although there

is still concern of immigrants bringing the disease into the country, the careful monitoring of guinea worm in other countries has decreased the likelihood of this happening.

The eradication campaign against dracunculiasis in Nigeria has contributed to a significant improvement in the public health of the nation in several ways. First of all, the campaign was successful in ridding the country of a disease that once had a large health impact in the country. In 1988, 650,000 cases were found throughout Nigeria (The Carter Center). In addition to the crippling pain that each of those patients endured, they also had to give up time that could have spent working or in school. Time lost for 650,000 individuals adds up to a huge loss of productivity for the country. This is especially true for rural populations, which are mostly composed of agricultural workers. The emergence of guinea worm is seasonal, and often overlaps with peak farming season (UNICEF, 2007). Therefore, the eradication not only had positive public health effects, but also positive economic consequences.

Aside from the eradication of the disease itself, the campaign against guinea worm has left behind several other beneficial legacies. For example, there is now a network of local health workers across the country that can continue to educate community members on the transmission of other diseases (Hopkins & Ruiz-Tiben, 1991). Additionally, part of the eradication campaign was the installation of improved water and sanitation facilities when finances would allow it. These facilities will prevent the transmission of other water-related disease in the future. Finally, this campaign is significant because it gives hope for a healthier Nigeria in the future. As President Jimmy Carter said when announcing the eradication of guinea worm in Nigeria, the country “provides yet another vivid reminder of how people in even the most marginalized circumstances can thrive when given the tools and knowledge to help themselves,” (The Carter Center, 2011). Although the country has a long way to go in fixing the water crisis and the

associated public health issues, this campaign proves that small actions, like education and other interventions, can go a long way in improving the public health of Nigeria one step at a time.

## **Conclusion**

In this chapter, several factors that contribute to the water crisis in rural Nigeria were discussed. These included the climate change and the conflict that are occurring in the north of the country. The climate change exacerbates the water crisis because it is depleting internal renewable water resources in the Lake Chad area, where there is already struggle to provide sufficient water sources for its population. Although the shrinking of Lake Chad is a unique feature of northern rural Nigeria, desertification in semi-arid zones is common throughout sub-Saharan Africa. It is estimated that the Sahara desert grows by 600 meters each year (Our Africa). Therefore, many other countries besides Nigeria will have decreasing internal renewable water resources in rural areas due to climate change.

The violence caused by Boko Haram is another factor that worsens the water crisis in northern Nigeria. Attacks by Boko Haram can damage existing water and sanitation infrastructure. Additionally, it is not likely that organizations will choose an area ridden with conflict to build new infrastructure. Fewer water sources will lead to increased walking distances for women and girls, which will open them up to further attack. Also, the decrease in infrastructure, along with the greater migration across borders to refugee camps, could lead to the greater transmission of water-related disease. The effects of the violence in Nigeria would be similar in other rural areas where conflict occurs. It is reported that 28 of the countries in the region have experienced war at some point since 1980 (Shah, 2012). Therefore, the effects of conflict can be felt throughout much of sub-Saharan Africa.

Furthermore, three diseases (hepatitis A, cholera, and dracunculiasis) were used to demonstrate some of the patterns of disease transmission that occur in a rural area. Some of these patterns can be applied to rural regions throughout sub-Saharan Africa. One trend that emerged was the difficulty of getting resources to rural areas. This problem is exacerbated by ongoing conflict in an area. Cholera provides a good example for the way disease can be affected by conflict and a lack of transportation options. In the most recent outbreak in northern Nigeria, the sites that are most affected are areas surrounded by high security risk roads. In other words, outside organizations cannot enter the area easily to provide treatment or prevention options. Although not all rural areas are stricken with conflict, many rural areas are isolated with few roads coming in and out. Therefore, the control of diseases is made more difficult in rural areas than they are in some urban areas.

It is also apparent that children are highly susceptible to contracting water-related diseases in rural areas. This was demonstrated by hepatitis A. Over half of the children in a rural community in Nigeria had been exposed to the disease. The fact that the majority of children have had exposure to hepatitis A is telling of how prevalent waterborne diseases are throughout rural populations. Ironically, exposure to hepatitis A for children is actually beneficial, since it grants them immunity for the remainder of their lives without having to endure severe symptoms. Therefore, as access to water and sanitation facilities increases, it will be important that adults are more careful in protecting themselves against the disease. In order to do so, they need to be knowledgeable about the way the disease is transmitted.

On that note, these rural diseases demonstrate the necessity of health education in preventing the spread of disease. No disease demonstrates this better than dracunculiasis, which was officially eradicated in Nigeria in 2013. Although better water sources were delivered

throughout rural Nigeria when it was possible financially, a large part of the fight against the disease was based in education. In endemic villages, local health workers instructed community members to use a cloth that was provided to them to strain contaminated water. Additionally, infected individuals were educated on how they could avoid passing on the disease to their peers. These tactics were enough to eliminate the disease completely from the country. Therefore, as the access to water and sanitation facilities improves, both in rural and in urban areas, health education cannot be forgotten as a method in preventing the spread of disease. Together, better water and education could lift a huge burden from the public health of Nigeria, and sub-Saharan Africa as a whole.

# Conclusion

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The goal of this thesis was to analyze the huge burden that insufficient water and sanitation has on the public health of Nigeria in an urban and a rural setting. This burden is due largely to the wide array of water-related diseases that are prevalent throughout the country. Many of these diseases are nonexistent in developed countries, but persist in sub-Saharan Africa due to the lack of access to improved water and sanitation facilities. By analyzing the public health impact on one country, the aim was to demonstrate the need for improvements throughout the region of sub-Saharan Africa. Therefore, this thesis serves as a call to action, much like the Millennium Development Goals did fifteen years ago.

Throughout this thesis, the achievement of the MDGs has been used as an indicator of a country's progress towards better water and sanitation. In 2000, it was established that all nations should have the goal of halving the percentage of the population without access to water and sanitation by the end of the year 2015. Today, as the deadline quickly approaches, the majority of countries in sub-Saharan Africa are still not within reach of this goal. Therefore, in September of 2015, the heads of states around the world will meet again to create a set of goals, known as the Sustainable Development Goals, for the next fifteen years (Kindornay & Twigg, 2015). Moving forward, it is important to consider the strengths and weaknesses of the MDGs in order to devise a plan that will be effective in inspiring future development throughout the world.

It can be argued that the principal strength of the Millennium Development Goals has been the mobilization of a wide variety of organizations to accomplish the same set of goals. By providing a concrete set of goals, it became easier for public organizations, private organizations, and nongovernmental organizations to collaborate on the movement towards better development worldwide (McArthur, 2013). Additionally, the establishment of the MDGs inspired closer

monitoring of progress towards each of the goals. The universal surveillance is beneficial because it has made progress seem more tangible than it did before.

Nevertheless, at their core, the MDGs are only a set of goals. There was no plan or budget proposed for achieving the goals. This was something that was critiqued when the goals were released. Without an established source of finances for development, it seemed that the burden had to fall automatically on developed countries. In fact, for several years, United States officials resisted using the term “Millennium Development Goals”, even though they were engaged in projects of social development in other countries. This was due to the fact that the MDGs seem to be “UN-dictated aid quotas” (McArthur, 2013). In fact, there were some guidelines for financial aid that were established in 2002. At a conference, it was agreed upon that developed countries should aim to donate 0.7% of their gross national income towards development in countries that needed it (McArthur, 2013). However, the burden of financial aid has fallen on a wide variety of organizations, many of them unrelated to governments. Therefore, the United States did eventually cave in 2005 and use the term “Millennium Development Goals” to describe its work in developing countries.

While the fact that the MDGs are merely a set of goals can be seen as negative, it can also be argued that that is what makes them so spectacular. Even without a concrete plan, the world has made great advances towards development since they were established in 2000. A call to action was what the world needed in order to take large strides in helping developing countries tackle some of their largest obstacles.

Therefore, similar to the Millennium Development Goals, this thesis will not provide a financial plan for the establishment of better water and sanitation facilities throughout sub-Saharan Africa. Rather, it is meant to call attention to this significant problem so it is more



likely to be rectified in the future. This thesis goes a step farther than the MDGs by analyzing the factors that contribute to the water crisis and the consequences of not eliminating the water crisis, rather than just stating that there is a problem. In both urban and rural Nigeria, there are a variety of health issues that are caused by the water and sanitation crisis. In urban Nigeria, the immigration of rural individuals into cities is causing the increase in transmission of diseases that are typically considered rural. The poor environmental conditions that are seen in several cities has allowed for this transmission. Additionally, the poor water management in cities is a favorable condition for the spread of diseases through the fecal-oral route. Rurally, the risk of contracting diseases is so high that the majority of children are infected before they reach adulthood. Furthermore, the transmission of water-related disease is exacerbated due to the difficulty of getting resources into a rural area. This is made worse in areas that are stricken by conflict. However, the decreased transmission of several diseases, such as guinea worm and hepatitis A, demonstrate the real progress that can be made when better water facilities and health education are used in conjunction to improve the public health of a region.

If the impact the water crisis has on public health is not enough to motivate change, then an argument can be made for the economic benefit of implementing more water and sanitation facilities. In Nigeria alone, it is estimated that 3 billion US dollars are lost annually to the poor sanitation facilities throughout the country, which accounts for 1.3% of Nigeria's GDP (Water and Sanitation Program, 2012). The majority of this, about \$2.5 billion or 83% of the total, comes from the money that is lost due to premature death. The lack of sanitation and water facilities is responsible for the 121,800 annual deaths in Nigeria related to diarrhea. These deaths are an economic burden because they cause a loss in productivity. Similarly, a loss of productivity is caused by time that is spent away from work or school due to sickness. This

contributes \$13 million, or 0.4% of the total money lost to sanitation problems. A large portion of time is also lost during the practice of open defecation. It is estimated that on average, a person who practices open defecation spends 2.5 days a year finding a private location to do so, leading to a total loss of \$243 million, or 8% of the total money lost. Finally, a significant amount of money is lost on healthcare costs for those who contract a water-related disease. This accounts for \$191 million, or 6% of the total \$3 billion that Nigeria loses annually (Water and Sanitation Program, 2012).

Clearly, the toll of poor water and sanitation on the economy of Nigeria is massive. It has been found that this toll put on the economy is much greater than the amount of money that would be needed to fix the problem. It has been estimated that for every 1 US dollar that is invested in the improvement of water or sanitation facilities globally, the economic return is anywhere from \$5 to \$28 (Hutton & Haller, 2004). The large variance is due to the assortment of sources that can be implemented. For improved water sources, these include piped water, a borehole, a protected well, or the use of chlorine to disinfect water upon drinking it. Some of these sources are more expensive to install and maintain. Often the more expensive sources are more convenient and safer. However, even if the water from cheaper sources, such as boreholes, is not perfectly clean, it is a step up from an unimproved source and will yield economic benefits. Similarly, there are a variety of improved sanitation facilities, such as a sewer connection, a septic tank, or a pit latrine (Hutton & Haller, 2004). There is also variance in the cost and effectiveness of each of these solutions, but all of them have a favorable cost-benefit ratio. Thus, it cannot be denied that the investment of money in these improvements is well worth it.

Therefore, even as December of 2015 approaches and the era of the MDGs comes to a close, the investment in water and sanitation infrastructure needs to continue. The Sustainable Development Goals that will be put in place for the next fifteen years will be finalized soon. It has been proposed that these goals should allow individual countries to establish their own set of goals, in addition to the universal targets that will be suggested (Kindornay & Twigg, 2015). Whatever framework the SDGs take, it is important that they are taken seriously because the job at hand is not complete. As of 2010, only 61% of the population of sub-Saharan Africa had access to a safe water source, and only 30% had access to an improved sanitation facility (UNICEF, WHO, 2012). That leaves 522 million people in the region that don't have the ability to drink a glass of water without having a fear of disease, which is something that should be considered a right, not a privilege. Thus, we cannot settle until this basic and essential human right is granted to everyone in all parts of the world.

# Acknowledgements

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The completion of my thesis would not have been possible without the help of many individuals. First of all, I would like to thank Sharon Crary for being my sponsor and providing guidance, encouragement, and expertise throughout the year. Also, thank you to the other members of my committee, Lynn Bedard, Mac Dixon-Fyle, and Brett O'Bannon. The knowledge they have shared with me about their respective disciplines has been invaluable. I would like to thank the Honors Scholar program for giving me the opportunity as an undergraduate student to spend a year learning and writing about a topic that interests me. Finally, I would like to give many thanks to my friends and family, for encouraging me to keep going even when the task ahead seemed impossible.

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