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## Clean Water as a Source Reduction for Cholera: A Review of African Experience

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### Abstract

Uncontaminated water source is directly connected to improved sanitation and personal hygiene which is the key indicator responsible for the reduction of water related diseases globally. In the last four decades, statistics from the World Health Organization (WHO) Global Health Observatory (GHO) report showed that over 3.5 million cases of cholera were recorded in Africa with close to 400,000 cases recorded in Democratic Republic of Congo alone within the same period. This calls for concerted effort with less chances of re-occurrence necessitating this study which seeks to assess the importance of accessible clean water as a source reduction for cholera epidemic outbreak and re-occurrence in epidemic areas. The major parameters assessed include the causes, symptoms diagnosis, treatment, prevention, and control of cholera with emphasis on an engineering based solution. The outcome of the study shows that cholera

epidemic can be minimized and possibly eradicated by creating a sustainable platform for providing clean water for all. Improvements in water quality accompanied by other environmental interventions with education could prevent and reduce re-occurrence of faecal oral transmission of cholera.

**Keywords:** clean water, surface water, ground water, personal hygiene, sanitation

## **Introduction**

Water has been identified globally as one of the most important resources needed for the sustenance of human health and general wellbeing. In some instances, it is treated as an economic resource, or more conveniently as a social resource and even as a political resource. Water makes up about 60% of weight in men and 55% of weight in women [1].

Quality, quantity, and readily availability of water is very important to public health, whether it is used for drinking, domestic use, food production or recreational purposes. Clean water is water free from any form of impurities which can render it unfit for domestic, industrial, and agricultural usage. In another definition, drinking water, also known as potable water or improved drinking water is water safe enough for drinking and food preparation [2].

The United Nations (UN) General Assembly recognizes human right to water and sanitation, “everyone has the right to sufficient, continuous, safe, acceptable, physically accessible and affordable water for personal and domestic use” [3]. Despite all the laws put in place, clean water remains inaccessible to many, climate change and population growth is aggravating the challenge of increasing water scarcity.

It was reported that by 2025, half of the world’s population will be living in water-stressed areas [4]. Although, the Millennium Development Goal (MDG) number 7 on drinking water was met globally in 2010, forty-eight least developed countries of the world did not meet the target [2].

The MDG water target was measured by the proxy indicator of the use of ‘improved’ or ‘unimproved’ drinking-water sources. In a statement released by the WHO, not less than 1.8 billion people use a drinking water source that is contaminated with faecal matter which is linked to disease such as cholera [4].

A substantial proportion of water supplied through pipes is contaminated, especially where water supply is irregular or treatment is inadequate. Even where the source is good, water can be contaminated while being transported or stored, especially in environments where there is inadequate sanitation.

Cholera is an acute secretory diarrhea caused by the Gram-negative Bacterium *Vibrio cholera* [5]. Cholera infection is contracted majorly through the ingestion of food including fruits and vegetables or water contaminated by *Vibrio cholerae*.

The main source of water contamination during disease outbreaks is the faecal excretions of infected individuals. This causes infection in the intestine capable of killing even a healthy adult in a matter of hours [6;4;7]. Cholera’s diarrheal is in form of cloudy water and results in death through dehydration if not treated within a very short period of time or few hours [8].

It has been found to be mostly common in areas that lack clean water sources and sanitation services or located in densely urbanized areas where seasonal rains can periodically favor contamination of wells and surface waters. Most of the cases are recorded in developing countries where infrastructures to provide access to safe water and basic sanitation are lacking. In the last few years until very recently, at least 20 African countries reported over 100,000 cases of cholera to the World Health Organization [9]. Rainfall-induced contamination of unprotected water sources through latrine overflow and sewage may contribute to seasonality of cholera incidences.

Cholera outbreak or pandemic remains a re-occurring decimal in many under developed

countries of the world especially in the sub-Saharan African countries because of cultural or natural attachments to poor sanitary system; a total of 66% of the 632 reports meeting the search criteria of cholera outbreaks worldwide originated in the sub-Saharan Africa making it larger than any other worldwide [10]. This was fueled by long years of governmental neglects which is evident in the non-availability of potable water in many rural communities or settlements.

In disaster management, the role of effective water management needs to be properly defined since cholera is a water borne disease driven directly by climate-induced variations in coastal aquatic reservoirs of *Vibrio-cholera* [11]. It is worthy to note that cholera infection results in the dehydration of the body fluids necessitating quick replacements of the fluids loss in the process however, non-vaccine base preventive measures encourage personal hygiene improvement [12,13].

Several methods have been used for a long time but the basic pre-requirement which is common to them all is the purity of the water used for the procedure. This mechanism emphasizes more on the need for a readily accessible clean water source and supply system both at the rural and urban settlements. A strongly constructed water system facility which is devoid of leakages driven by the basic hydrologic and hydraulic principles is very important in combating the scourge [14; 15].

Hydrology is the science that deals with the occurrence, distribution, movement and properties of waters and their relationship with the environment within each phase of the hydrologic cycle [16]. Hydrologists have successfully classified water sources into two major categories. These include surface water (water that is collected on the ground, stream, river, seas and oceans) and groundwater (obtained by drilling wells and boreholes, it is water located below the ground surface in pores and spaces in the rock). Surface and ground water are sourced every day for various purposes which include water sourced for domestic, recreational, agricultural, and industrial activities [16].

Majority (91%) of public water systems are supplied by ground water while 68% of community water system users received their water from a surface water source [17]. The surface water which was harvested is constantly replenished through precipitation. A sizable portion of the unused surface water is lost through evaporation and seepage into ground water supplies. Protecting source water from contamination may reduce cost of treatment and risks to public health, although, most of the community based drinking water, especially from surface water sources, are treated before being supplied to homes.

Furthermore, the design and construction of a water treatment facility is important to the overall water quality management. The location of water facility and the source of the water itself cannot be ignored especially in mitigating the outbreak of epidemics. Due to inadequate or non-existing water treatment facilities in the developing countries of the world, there is usually a competition for scarce clean potable water [18]. This has in most cases limit the capacity and possibility of curtailing the outbreak of cholera epidemics especially when the sanitary facilities are in poor state as well. Groundwater undergoes self-purification naturally, contamination of groundwater due to non-compliance with public health rules, especially through seepage, most often open a fault line [4].

This study aims at evaluating the link between a reduced availability or accessibility to clean water and cholera epidemic outbreak with a focus on the African experience, Africa is considered to be a new homeland of cholera as it accounts for 99% of the officially reported cholera cases worldwide [19]. This review established the role of water resources and environmental management in cholera mitigation and prevention strategies. The developmental effort will propel the much-needed gains in the management of public water system in a bid to improve accessibility to clean potable water and disease re-occurrence.

## **Cholera Epidemics**

### ***Causes, Symptoms, and Mode of Cholera Transmission***

Cholera is an infectious disease that causes severe watery diarrhea, which can lead to

dehydration and even loss of life if untreated. It is caused by eating food or drinking water contaminated with a bacterium called *Vibrio-cholera* [20]. This bacterium is Gram stain-negative, comma-shaped and has a flagellum (a long, tapering, projecting part) for motility and pili (hair-like structures) used to attach to tissue [21].

*Vibrio-cholerae*, contaminate food or water mostly through feces from a person with the infection. An estimated 3 to 5 million cases and over 100,000 deaths occur each year around the world [8]. Common sources include drinking water (contaminated at its source and during storage) and food (contaminated during or after preparation including fruits and vegetables, freshened with contaminated water, and eaten raw).

Other sources are vegetables grown with water contaminated with human wastes, undercooked or raw fish, and seafood caught in waters polluted with sewage [20]. The infection is mainly spread through contaminated fecal matter, which can be consumed orally or because of poor sanitation and hygiene, like unwashed hands. Signs and symptoms of cholera include severe watery diarrhea accompanied by vomiting, which can quickly lead to dehydration [20].

Symptoms of cholera can begin as soon as a few hours to five days after infection; it can be mild but sometimes they are very serious. It was reported that one in ten (5-10%) infected persons will have severe disease characterized by profuse watery diarrhea, vomiting and leg cramps leading to dehydration, shock, and kidney failure [8]. The dehydration is characterized by rapid heart rate, loss of skin elasticity (the ability to return to original position quickly if pinched), dry

mucous membranes, including the inside of the mouth, throat, nose and eyelids coupled with low blood pressure thirst and muscle cramps.

| S/<br>No | Researchers                                                                                                                                       | Country | Overview of epidemics                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | Interventions                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |
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| 1        | Ujah <i>et al.</i> , 2015 [22]; Okeke <i>et al.</i> , 2014 [23]; Adagbada <i>et al.</i> , 2012 [24]; WHO, 2012 [25]; UNICEF [26]; OCHA,2013 [45]; | Nigeria | Cholera pandemic reached Nigeria in late 1970 leading to an epidemic of 22,931 cases and 2,945 deaths with case fatality rate (CFR) of 12.8% in 1971 [22; 23; 24; 25], [23]. The figure moved to a total of 105,483 cases and 3,913 deaths with CFR of 3.7% by 2013 [23; 26]. In 1999, an outbreak of cholera was reported in Kano (Northern Nigeria) and the epidemic was traced to the interruption of domestic water supply for some days which forced the populace to use any available water; 815 cases with 28 deaths were recorded from the city that year [25]. It is worthy of note that the largest outbreaks were reported in the Northern states in Nigeria spreading to the neighboring countries around Lake Chad; Niger, Chad and Cameroun [23; 26]. The 1996 cholera outbreak in Ibadan (Southwest Nigeria) was attributed to contaminated potable water sources, street vended water and not washing of hands with soap before eating food. Drinking water sold by water vendors was also connected with increased risk of contracting the disease. In Kwara state, it was reported that the cholera epidemic claimed at least 40 lives in five days. In Katsina state, the outbreak of the disease was linked to faecal contamination of well water from sellers. The recent 2010 outbreak of cholera in Nigeria was speculated to be directly related with sanitation and water supply. The hand dug wells and contaminated ponds being relied on by most of the Northern states as source of drinking water was a major transmission route during the outbreak. In some regions, the outbreak was attributed to rain which washed sewage into open wells and ponds where people obtain water for drinking and domestic needs [22; 23; 24]. There were no reports of treatment or purification of these waters before use. Considering 2006 National population census report and forecasting for 2016, Nigeria is endowed with a population of 188million, just over half of this population | Interventions by UNICEF, WHO, and Ministries of Health with provision of high test hypochlorite (HTH) to disinfect affected hospitals and communities, cartons of water purification tablets distributed at household levels had yielded results. Response is however hindered by lack of accurate data of cases and casualties. Lack of Capacity to respond to the outbreak at the community level with emergency water treatment and sanitation was reported. The problem is more critical in rural areas where the outbreak is prevalent [45]. |

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|   |                                                                                          |            | have access to potable water and appropriate sanitation [25].                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
| 2 | UNICEF [26]; Doldersum, 2013 [27]; Dzotsi <i>et al.</i> , 2014 [28]; United Nations [46] | Ghana      | Cholera was first reported in Ghana in 1970 and by 2013, a total of 55,784 cases with 1,095 deaths have been reported with CFR of 2% [26]. Main outbreaks were reported in densely populated Greater Accra, Ashanti and in bordering coastal regions. It was found that the hydrological procedure was very important in a cholera diffusion model for Kumasi Ghana [27]. The model revealed that 75% of cholera infection emanates via river that was contaminated by run-off from the dumpsites. It is reported that close to three million people (11% of population) rely on surface water to meet their daily needs, leaving them vulnerable to water related illnesses and diseases, 70% of all diseases in Ghana are caused by unsafe water and poor sanitation. In another report of outbreak investigation in Greater Accra region, there was significant association between consuming vended satchet water and foods with the outbreak, the principal mode of transmission was by ingestion of contaminated water and food [28]. In 2014, cholera outbreak in Ghana hit 17,000 with 150 deaths; it was reported that the outbreak manifested after heavy rains exposed the filth. | The concern of UN partners in the outbreak of 2012 yielded a provision of USD312,440 from United Nations Emergency Response Fund (CERF) to two United Nations agencies, to support cholera response. Forms of advocacy includes effective case management, drinking-water treatment, increase public awareness and evidence based behavior change activities with a focus on key hygiene messages [46]. Preparedness and response plans to be developed and implemented. |
| 3 | Gujral <i>et al.</i> , 2013 [7]; WHO, 2013 [29]; Langa <i>et al.</i> , 2015 [30]         | Mozambique | Cholera has been present in Mozambique since 1973. The country has a population of 18million ;5.2 million of this live in the urban area while the rest 12.8million live in the rural area. A total of 77% of the urban population have access to improved water source while 29% of the rural are privileged with same. Cholera epidemics mainly occur during the period from December to June, coinciding with the rainy season [7; 29; 30]. This might have been due to rainfall induced overflow of latrines contaminating wells and surface waters. In 2009, reported cases of cholera in Mozambique accounted for one-third to one-fifth of all cases reported in Africa [30]. During the 2009-2011 epidemic, the country reported 25,431 cases of which 220 deaths were identified with CFR of 0.87% [29] while 2015 outbreak affected five of the country's eleven provinces affecting                                                                                                                                                                                                                                                                                               | Targeted water chlorination was suggested short term intervention into the epidemic with a long-term intervention of improved water and sanitation [7].                                                                                                                                                                                                                                                                                                                  |

|   |                                                                                                                 |          |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |
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|   |                                                                                                                 |          | 5000 people and killing 46 of them.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |
| 4 | WHO,2008 [31]; WHO,2016 [32]; Mpazi and Mnyika, 2005 [33]; Traerup <i>et al.</i> , 2010 [47]; UNICEF, 2015 [48] | Tanzania | <p>The first ten cholera cases were reported in 1974 and since then, more cases were reported each year with a CFR averaging 10.5% [31]. The first major outbreak occurred in 1992 with 18,526 cases, 2,173 deaths and CFR 11.7% while a very important epidemic was recorded in 1997 when 40,249 cases, 2231 death and CFR 5.54% from seven of the twenty-six regions of Tanzania were affected [31]. Tanzania was found to have the highest number of cases in Africa in 1997 (40,249) and 1998 (43,000) compared to Guinea Bissau (20,555), Kenya (17,200), Chad (8,801) and Mozambique (8,708) in 1997 and Kenya (18,000), Uganda (18,000) and Somalia (14,708) in 1998. The country had one of the highest case fatality rates in East Africa (5.6) with 2,268 deaths out of 40,226 cases. Assessment of the main factors associated with the spread of the infection are limited access to safe water and sanitation; lack of capacity of water supply institutions to chlorinate and conduct regular water quality monitoring and assessment [32; 33]. Traerup <i>et al.</i>,2010 [47] reported that the cost of reactive adaptation to cholera attributed to climate change impacts by year 2030 in Tanzania is projected to be in the range of 0.02 to 0.09 percent of GDP for the lower and upper bounds respectively. Total costs, including loss of lives are estimated in the range of 1.4 to 7.8 percent of GDP by year 2030. Costs of additional cholera cases and deaths attributed to climate change impacts in Tanzania by the year 2030 largely exceed the costs of preventive measures such as household chlorination.</p> | <p>Tanzania's preventive measures are mainly hygiene, water and sanitation programmes established outside the health sector [47]. Other response at the refugee camp are intensive behavior change messaging, improvement of hygiene and sanitation measures, early treatment and case management. UNICEF contributed to key health sector strategic plans that set the national agenda for five years, ensuring that priorities were given maternal and neonatal mortality issues. [48].</p> |

### **Diagnosis and Treatment of Cholera**

Cholera is diagnosed by taking a stool sample or a rectal swab to a laboratory for analysis. This involves checking for the presence of cholera bacterium which is a major causative organism [34]. The results obtained from the laboratory analysis whether positive or negative will help in taking a decision on possible treatment. Early diagnosis is very important in mitigating a possible epidemic outbreak [10; 19; 22; 24]. Every case with likely symptoms must be properly analyzed in a designated clinic and stool sample analyzed in the laboratory. This is important for a holistic review of the sanitation and hygiene conditions in that area.

Cholera can be successfully treated by immediate replacement of the body fluids and salts lost through diarrhea. Most cases can be treated with oral rehydration solution, a prepackaged mixture of sugar and salts to be mixed with water and taken in large amounts. This procedure helps reverse dehydration and restores potassium levels following the onset of acute diarrhea [6]. This solution is used and acceptable throughout the world to treat diarrhea. Severe cases also require intravenous (IV) fluid and antibiotics replacement. With prompt rehydration, less than 1% of cholera patients die. Antibiotics shorten the course and diminish the severity of the illness, but they are not as important as receiving rehydration [34].

### **Cholera Epidemic Prevention**

Clean water, sanitation and proper hygiene are critical to good health, without which health interventions would not succeed [6]. Preventive measures of infectious diseases such as cholera borders on water availability, water quality, waste management and community hygiene education. WHO leads global efforts to prevent transmission of waterborne diseases by advising Governments on the development of health-based targets and regulations [4]. They produce a series of water quality guidelines, including that which centers on drinking-water, safe use of wastewater and safe recreational water environments. Furthermore, the guidelines for drinking water quality include the promotion of Water Safety Plans to identify and prevent risks before water is contaminated and they are based on managing risks.

Tap water meets drinking water quality standards in the developed world, a small proportion is consumed or used in food preparation while other typical uses include washing, toilets and irrigation [24; 27].

Water may be unacceptable due to levels of toxins or suspended solids, most water however requires some type of treatment before use, even water from deep wells or springs. Reduction of water borne diseases and development of safe water resources is a major public health goal in developing countries [4] The extent of treatment depends on the source of the water. Water treatment technologies include both community scale and household scale point of use designs whose ability to reduce disease is a function of both their ability to remove microbial pathogens if properly applied and social factors such as ease of use and cultural appropriateness [35].

Proper treatment of water sources and maintenance of clean water sources for domestic usage remains pivotal in the efforts for reduction. An important process in water treatment is filtration as it functions both at community scale and household scale. In the filtration process, water is passed through a filter to remove all the infectious micro-organism and mostly suspended solids, in the process clean water is obtained. In a research conducted in Bangladesh, filtration reduced the number of cholera cases when nylon net or sari cloth was used, compared with those who did not filter their water [36]. In emergency situations where conventional treatment systems have been compromised, water borne pathogens may be killed or inactivated by boiling [2].

Boiling water before drinking is effectively the better practice, because it will kill all waterborne pathogenic microorganisms [36]. Researchers and experts recommend boiling as a major water treatment procedure especially in rural settlement including areas highly prone to epidemic outbreak. Other techniques, such as chemical disinfection and exposure to ultraviolet radiation (including solar UV) have been demonstrated in a collection of randomized control trials to significantly reduce levels of water-borne disease among users in low-income countries [37].

### **Water Treatment Procedures as an Engineering Based Solution to Cholera Outbreak**

Water treatment can be viewed as any process that makes water more acceptable for a specific end-use, which may be drinking, industry, irrigation, river flow maintenance, water recreation or many other uses [38]. Water treatment removes existing water contaminants or reduces their concentration so that water becomes fit for its desired end-use. The processes involved in removing the contaminants include physical processes such as settling and filtration, chemical processes such as disinfection, coagulation and biological processes such as slow sand filtration. Simple filtration can be used at point of use. The recommended level of treatment for municipal water treatment is the full-scale treatment procedure [27].

The standard procedures used for municipal water treatment globally are:

- Pre-chlorination: Used for algae control and arresting biological growth.
- Aeration along with pre-chlorination: Used for removal of dissolved iron and manganese
- Coagulation: Used for flocculation or slow-sand filtration.
- Coagulant aids (polyelectrolytes): is used to improve coagulation and for thicker floc formation
- Sedimentation: is used for solids separation, that is removal of suspended solids trapped in the floc
- Filtration: Used to remove particles from water
- Disinfection: Used for killing bacteria viruses and other pathogens.

[39, 40]

### **Epidemics Management through Efficient Water Resources Facility Management**

#### ***Water Sources and Management Techniques***

Surface water losses occur through evaporation into the atmosphere and seepage into the ground water bodies. Water from ground water is obtained majorly by drilling wells and boreholes which has its sources from aquiferous rocky layers. Although, most of the treated public water is sourced from surface water storage system, groundwater provides readily

accessible clean water in many communities [17]. Even though there is abundant water stored in different facilities, many communities still lack access to clean water especially in the developing nations of the world. This is partly due to a major deficiency in water treatment management and a lack of will by the Governmental authorities. It will be difficult if not impossible to prevent an epidemic outbreak like cholera if these problems are not resolved. For an effective water system management, some basic functional tools must be assessed. The major dictators are the available sources of water, water treatment facilities options, sanitary facilities' needs, frequency of precipitation, hydrological factors, hydraulics facilities and the lithological nature of an area [41]. These tools determine the most preferred option for sourcing water including the choice of water treatment adopted. For an area with a lithological profile that supports underground water flows with continuous recharge, most of the water management challenges are reduced. Although, certain parameters must be assessed to determine ground water sustainability, such as soil permeability, soil porosity, seepage velocity and seepage direction [41]. To determining possible area of fracture and quantify the water storage capacity of a groundwater source, basic tests such as pumping test and hydraulic conductivity are necessary [17]. Surface water requires proper treatment to maintain endpoint purity, there are different types of water treatment options, municipal water treatment plant and simple filtration continues to find wider acceptance.

Losses in water distribution systems can be between several percent in well maintained systems up to more than 50 percent in developing countries with most of the losses originating from leaks [14]. It is important to strategically search and control leaks on a regular basis. The procedures include step testing or by temporary placing acoustic loggers. These methods are known as leak localization. This is usually followed with pinpointing to get the exact position of the leak which is accomplished with ground microphones, leak-noise correlators, or gas leak detection. Once leakages are blocked, the chances of impurities entering the water system will be seriously minimized. Contaminants infiltration into the water bodies occurs in most cases due to

lack of adherence to regulations stipulated by relevant health and environmental agencies [17]. This occurrence has been found to be one of the major causes of most epidemic outbreaks. A leak proof water treatment facility must be maintained to ensure a sustainable water management plan with epidemics prevention control mechanism.

### **Surface Water Management and Epidemic Control**

Effective surface water management plan is key to developing a robust epidemic control plan especially for water borne diseases like cholera. Surface water is a major source of water for community dwellers [17]. The bacterium (*Vibrio cholerae*) which is responsible for cholera infection thrives easily in open non-flowing surface water storage points making it a highly risky platform for the spread of cholera epidemics. *Vibrio cholerae* is classified into more than 200 serogroups based on the “O” antigen of the lipopolysaccharide but only “O1” and “O139” serogroups cause cholera epidemic [42]. It grows easily in water of low salinity when it is warm and contains a sufficient organic nutrient which is a typical environment that most surface water provides [43]. Surface waters must be well protected from faecal contact by putting in place prohibitive laws which guides against illegal encroachment and also, educate the communities. Practices which encourages sourcing for water from eroded sources must be discouraged. Figure1 shows a typical eroded surface water located in Ilesha- Baruba area of Kwara State, Nigeria where villagers often draw water while figure 2 shows a community taking water for domestic use in Oke-ose, Nigeria.

### **Water Resources Hydraulics Management**

Design, construction and management of water resources hydraulics are major requirement for the maintenance of a clean water source. The drainage system must be properly designed and maintained as it is one of the most important hydraulic facilities in a typical city setup. Engineering failure is a major cause of most medical challenges. Investment in hydraulic structures and facilities is very important to maintaining quality water management. Contaminated water can be purified by constructing wastewater treatment facilities [18].



Figure 1: Eroded Surface Water along Ilesha- Baruba/Gwananra Road of Kwara State in Nigeria



Figure 2: Water for domestic use in Oke-ose

Irrigation and drainage system facilities are important component of efficient water supply facilities [44]. Water resources management requires multi-sectoral investments from local, national, and international agencies to meet the immediate needs and for sustainable developments. The role of water investments as infrastructures services which serve as both intermediate goods and final goods should not be overlooked in water planning [18].

### **Cholera Epidemic Outbreak Case Analysis**

In the last four decades, there has been an increase in the number of cholera cases or epidemics recorded especially in the least developed countries of the world most of which are African countries, positive attitudes towards cholera prevention was however observed in some of those countries according to Mpazi and Mnyika (2005) [33]. The WHO Global Health Observatory data showed a major upsurge in the number of cases recorded with occasional breaks. The data are updated regularly and the total annual figures are properly documented. Figure 2 shows an overview of cholera cases recorded in the last four decades across the West African countries. Nigeria recorded the highest cases and this is followed by Ghana with Gambia

recording the least number of cases.

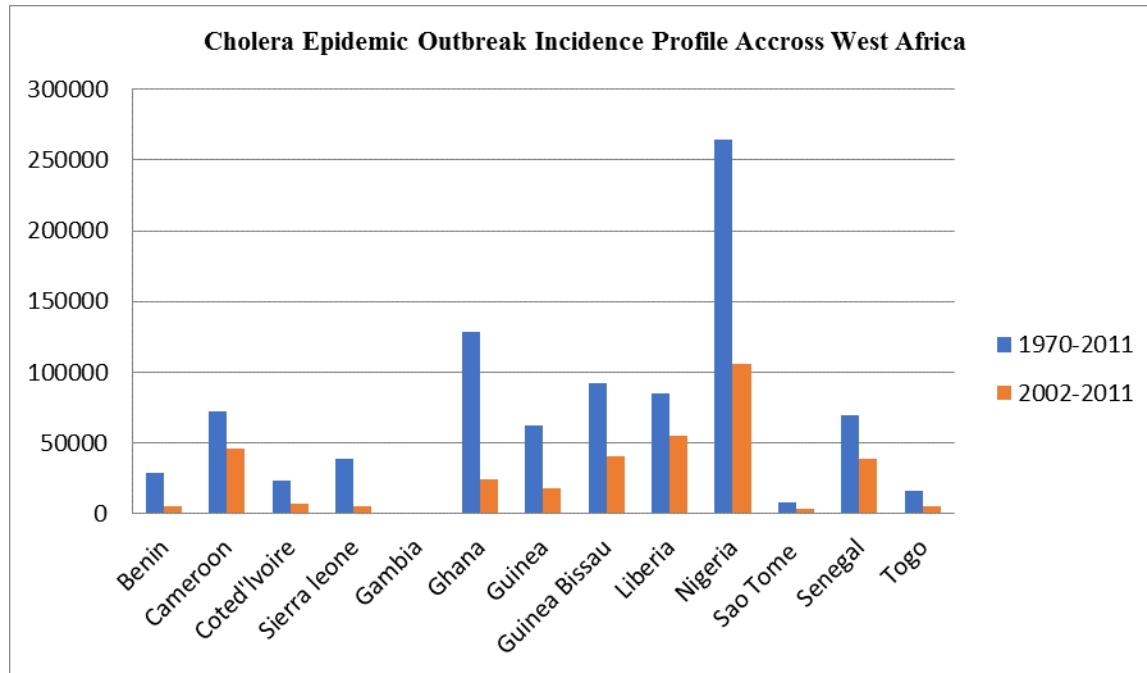


Figure 2: Cholera Epidemic Outbreak Figure across West African Countries  
Source: Rebaudet *et al.*, (2013)

Figure 3 shows the documented record of cholera outbreak across the South African Countries. Mozambique recorded the highest cases over the year assessed as Tanzania closely followed and Namibia recorded the least number of cases.

The most recent global epidemic outbreak was captured by the WHO Global Health Observatory data which shows that twelve (12) countries were affected globally as most of the documented cases were reported in Africa [32]. These countries include Cameroon, Democratic Republic (DR) of Congo, Ghana, Niger, Nigeria, South Sudan, Cuba, Dominican Republic, Haiti, Afghanistan, Philippines and Nepal. Figure 4 shows the outlook of the recent epidemic outbreak as obtained from the WHO Global Health Observatory report.

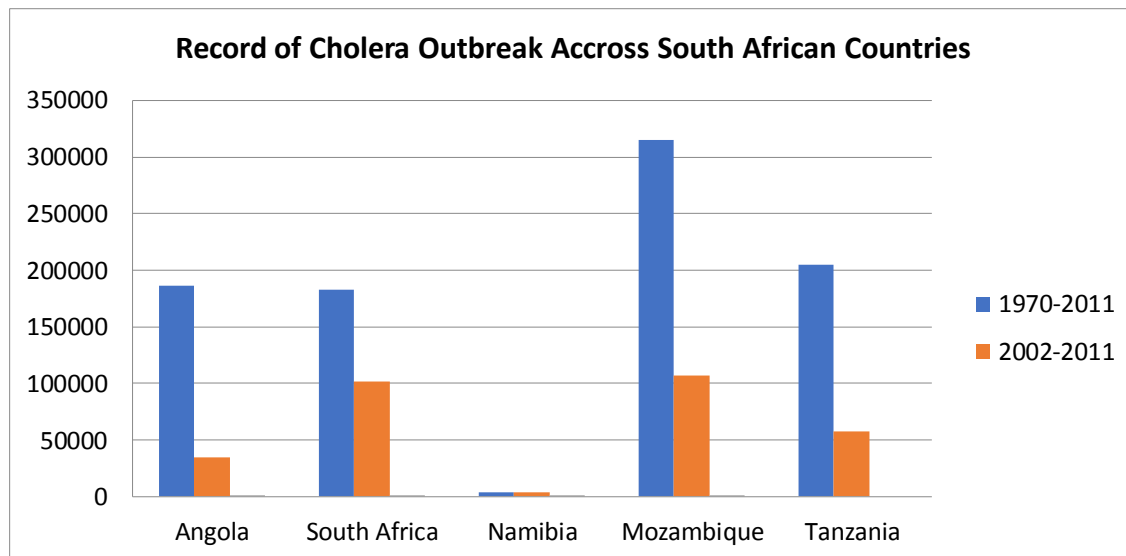


Figure 3: Record of Cholera Outbreak across South African Countries  
Source: Rebaudet *et al.*, (2013)

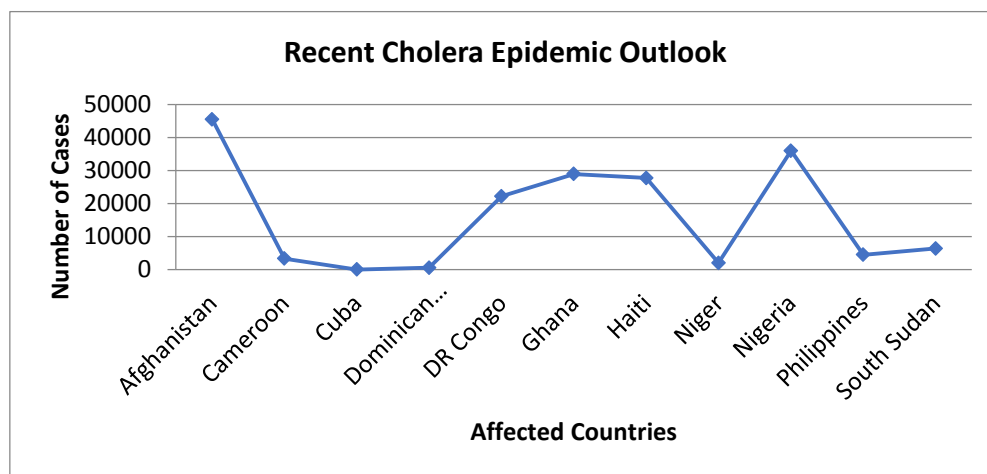


Figure 4: Recent Cholera Epidemics Outbreak  
Source: WHO, (2016)

## **Conclusion**

This study established the irreplaceable role clean water occupies in public health sustainability structure, particularly in the prevention and control of cholera. Although the term clean water is subjective depending on an individual's judgment, this research has successfully presented the minimum benchmark for water acceptability based on the internationally acceptable standards. This study further stressed the correlation between unsafe (untreated) or contaminated water and the spread of disease infections with emphasis on cholera. The outbreak of cholera epidemic can only be mitigated, prevented, and controlled when the water supply sources is free of pollutants or contaminants especially resulting from poor faecal waste management. There is a need for a multi-sectoral investment in water resources management to improve the quality and purity of municipal water supply. This study showed a major decline in the occurrence of cholera infection in areas where water was properly treated or filtered. The practice of open defecation must be stopped, health education encouraged, [49] and water must be properly treated or manually filtered at point of use before use. Prevention of groundwater infiltration by undesirable contaminants is essential as efforts must be directed at making water free from unnecessary impurities from source.

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