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Perception of Women in Water Supply and Associated Health Risks in the Use of Harvested Stored Rainwater in Enugu State, Nigeria

Angela Oyilieze Akanwa[1*], Ngozi Joe-Ikechebelu[2], Fredrick Aideniosa Omoruyi[3] and Chukwuebuka Nelson Alumuna[1]

[1] Department of Environmental Management, Faculty of Environmental Sciences, Chukwuemeka Odumegwu Ojukwu University (COOU), Uli Campus, P.M.B. 02, Anambra State
[2] Social Dimensions of Health, School of Public Health and Social Policy, University of Victoria, British Columbia, Canada
[3] Department of Statistics, Faculty of Physical Sciences, Nnamdi Azikiwe University, Awka, Anambra State

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Abstract

Rainwater harvesting (RWH) has become a necessity in many Nigerian communities due to water scarcity, particularly during the dry season. This study examines the perception of women in water supply and associated health risks in the use of harvested stored rainwater in Enugu-Ezike, Enugu State. Field observation, random in-depth interviews etc., are inclusive in the qualitative methods employed in the study. Laboratory analysis of physicochemical and bacteriological parameters of stored RWH samples (hand dug well and drinking vessels) were also carried out. Findings show that rural, poor and deprived women suffered consistent water stress and shortage in dry seasons and this accounts for 84% of them being dependent on stored rainwater harvesting. Findings show that RWH stored water is unfit for drinking and has health risks with high possibilities; it causes cholera and typhoid repeatedly in children. The study also shows other ramifications of water scarcity in the case study area, including the gendered burden of fetching water and the health implications of this.

Keywords: Community; Enugu-Ezike; Harvested rain water; Health risks; Water scarcity/quality; Women

✉ [1]*a.akanwa@coou.edu.ng

1. Introduction

Global shortage of water is a major concern and it is particularly a major problem in many developing countries. Its manifestations relate to water access, supply, quality and management and health risks (WHO, 2014; Totouom, 2012). According to WASH / Water Aid report (2019), it is alarming that 785 million people around the world, (one in every ten), lack access to clean water close to their living areas. Consequently, 310,000 children below five years die annually from diarrhoeal diseases caused by poor water and sanitation. This accounts for the huge loss of eight 800 children a day or one child every two minutes (WASH, 2019).

In Nigeria, more than 60 million (30% of the population) people lack access to basic clean water supply, 12 million lack decent toilets and 167 million lack hand washing facilities with soap and water (WASH, 2019). Notably, people who are domiciled in rural communities suffer more from severe shortage of water supply (Sivaranjani, et al, 2015). This occurs because there is little or no government operational water schemes/projects in most villages in Nigeria. Water is privately provided by each household and this result in heavy dependence on unprotected hand dug wells, streams, boreholes, water vendors and mostly stored rain water harvesting (Nwankwoala, 2011; Akanwa 2020).

Fletcher, et al. (2008) define rain water harvesting (RWH) as the collection, storage and use of rainwater for small-scale productive purposes. According to Oweis (2004), RWH is the concentration of rainwater through runoffs into smaller target areas for beneficial use. Also, Mati, et al. (2006) define RWH as the deliberate collection of rainwater from a surface known as catchment and its storage in physical structures or within the soil profile. Rainwater harvesting is a technique used for collection and storage of rainwater from catchments areas (Kun et al, 2004) and serves as a major source of water supply in rural areas. (Ishaku.et al. 2012 &Apex and Christian, 2019).

Water scarcity is particularly serious in rural areas, and women experience the additional burden of being responsible for its availability at home. Studies carried out by WHO (2000) and UNICEF (2016) reported that women and girls are faced with the task of collecting water in eight out of ten households. This involves walking far distances from their homes to wells or streams with significant amount of time and cost to access water (Luis, et al, 2002).

Media reports show for more than five decades, water scarcity has been a constant problem in Enugu State (Kenneth, 2021). In 2020, a state- of -emergency was declared in the state's water, sanitation and hygiene sector but water shortage still persists (WASH, 2019). For Enugu-Ezike, the study area of this research, persistent water shortage is linked to its lithostratigraphic formation. Enugu-Ezike is located in the Cross River basin and the Benue trough which is the best developed coal in the area (Ogbochie, 2011). Its elevations are about 1,000 metres (3,300 ft) (Nwagu et al, 2017) and it is underlain by sandstone while lowlands are underlain by Shale. According to Obidi et al, (2016), shales are highly compacted and indurated mudstones which are characterized by relatively poor permeability and this makes it difficult for residents to benefit from groundwater sources like boreholes and hand dug wells.

Also, another contributing factor to water problems is the high level of evapotranspiration in the area. The area is characterized by mean annual rainfall within 1,600 mm and mean annual evapotranspiration (ET) of about 1,560 mm (Ogbochie, 2011). The ET, however, exceeds total rainfall in most months of the year, which complicates the prevailing issues of water scarcity. Umuida community is located in Enugu-Ezike, in Igbo Eze North Local Government Area, Enugu State, Nigeria. Umuida community is one of the thirty-eight villages in Igbo-Eze North LGA (See Figures 1 & 2). It has latitude, 6^{0} 58′59" North and longitude, 7^{0} 23′ 42" East. It has an elevation of 311 meters (1,020 feet), above sea level. It is bounded by in the North by Ete Nawo, South by Obupka, East by Amufi and West by Akpanya (Ogbochie, 2011).

The population of Enugu-Ezike was 350,000 in 2006 with a project increase of 3.2% (National Population Census, 2006). In 2021, the 453,000 people in the location indicate large population with low access to drinkable water supply. Water scarcity is worse during the dry season. In such a period, people are forced to walk long distances with their vessels in search of water from one stream or water vendor to another for their households. Because of persistent water scarcity, communities now depend heavily on (RWH) technology as a means of water supply (Nwagu et al. 2017). Through it, rain water is stored during wet season in order; to serve them during the dry season. Realistically the stored water may have immediate, severe and significant environmental and health consequences.

The target of this study is the investigation of the challenges community women face in providing water for their households. The study also focusses on the health risks associated with the water quality of harvested and stored rain water used for drinking and domestic activities in Umuida community, Enugu-Ezike, Enugu State, Nigeria. Meeting the high level of water demanded by women in relation to water access, quality and sanitation is expedient in accomplishing sustainable development goals (UNESCO, 2015) particularly sustainable development goals (3) and (6) for good health and clean water respectively and gender equity in the study area.

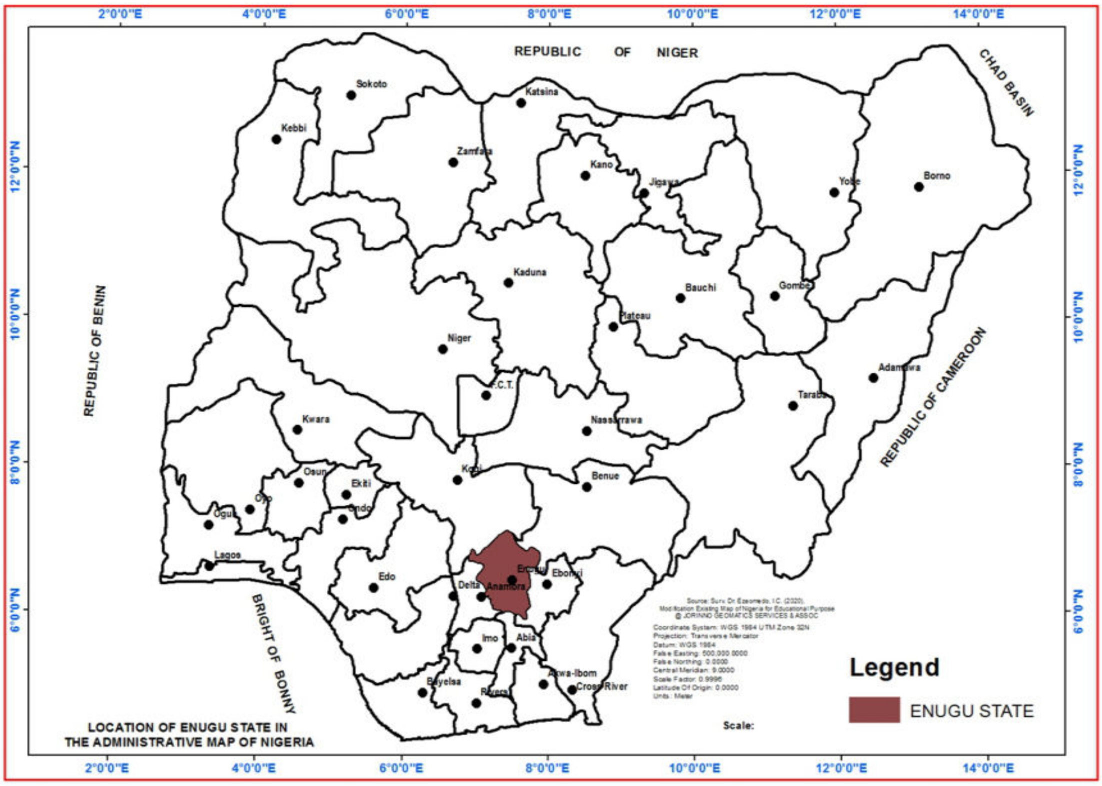

Figure 1: Location of Enugu State in the Map of Nigeria

Source: Authors, 2021

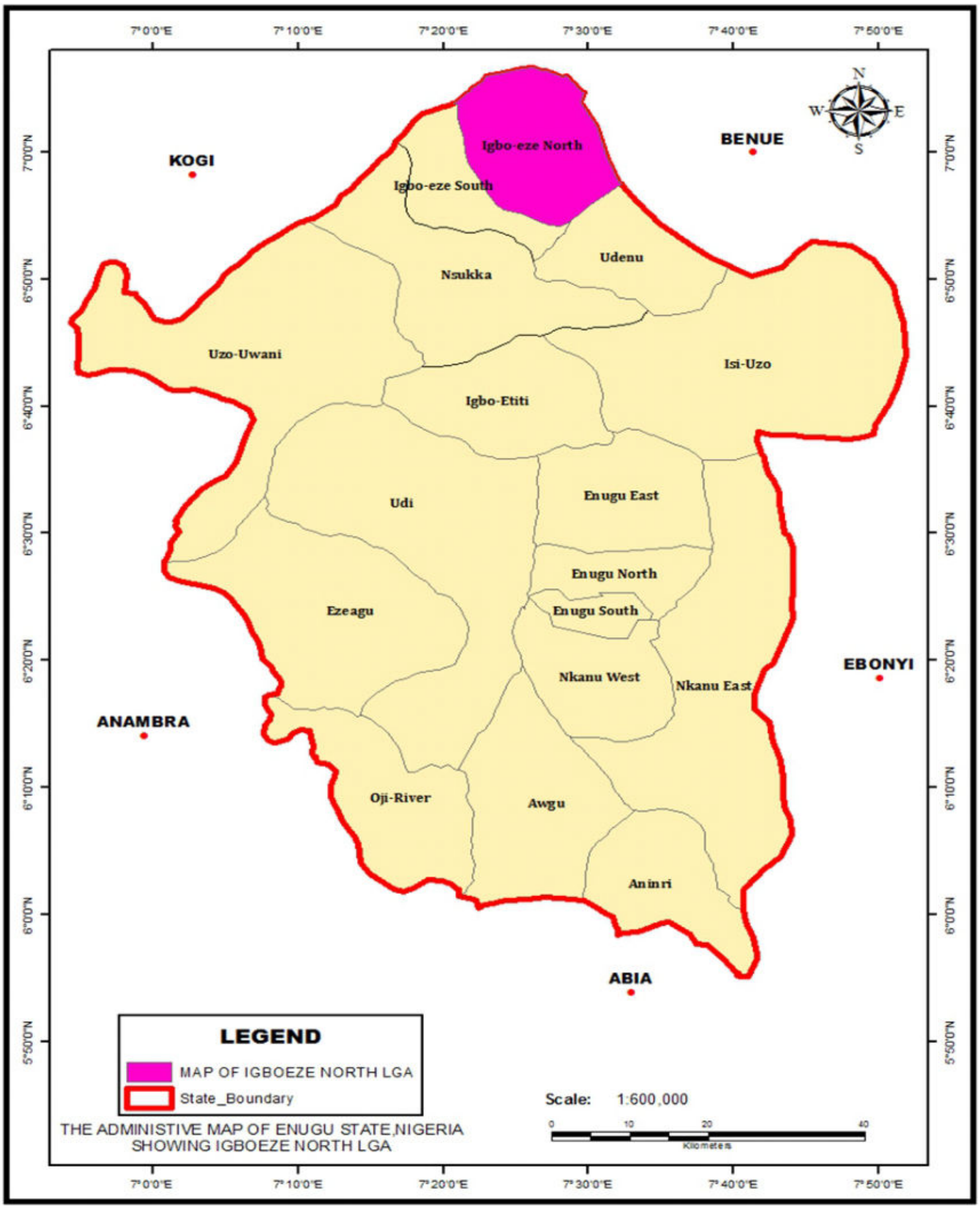

Figure 2: Map of Enugu State showing the location of Igbo Etiti North LGA

Source: Authors, 2021

2. Literature Review

2.1. Concepts of Sustainable Development and Community Health

According to a report of the World Commission on Environment and Development (Brundtland Commission) in (1987), sustainable development can be referred to as the development of smart policies that are action driven and pursues the security of future generational needs while meeting present demands. It comprises both 'sustainability' as a long-term pursuit and 'sustainable development'_ as the many processes and pathways to accomplish a given goal. Besides, Lynn and Eda (2014) define sustainable development as the practice of improving global processes of productivity by substituting consumed resources with other resources of equal or greater value without environmental degradation or endangering planetary health/life.

As a concept, sustainable development is interconnected with public health. This is in consideration of the broad conceptualization of public health systems as all the general efforts, services and contributions toward improving, and conveying valuable public health services within a desired location (Centers for Disease Control and Prevention, 2019). The two concepts, 'sustainable development' and 'public health' are driven toward a scenario where the society's living conditions, health, wellbeing and resources are sustained to meet anthropogenic needs without reduction in the quality and equilibrium of the biological processes. Human health has become a global need and can be easily triggered by any inadequacy especially water which is an essential resource as well. Poor water access and supply affects all other aspects of human life and activity.

Goal 6 of the SDGs embraces an all-inclusive safe water and hygiene. It is aimed at improving the environmental conditions so as to maximize health conditions and removal of infectious diseases. Achieving safe water supply will improve human health, wellbeing, knowledge exchange, gender equality, decent work, sanitation and economic productivity for all. The connectivity of SDG 6 is to other SDGs makes this study expedient.

Globally, women are particularly associated with water stress and supply. Observations have shown that two hundred million hours (a huge amount of time) in total are invested in water collection per day and worse still, the quality of water remains questionable (Cherutich et al. 2015). The search for water becomes a daily routine because water access is extremely low in developing countries (Cherutich et al. 2015). Obviously, water supply affects gender, health, sanitation, hygiene among others and all these indicate the need for water policies, action and sustainable water development.

Water Aid reported that in Enugu State, more than half of the population experience inadequate water supply. This promotes poverty and poor health while escalating stunted growth risks in one out of every ten children in the area. The prevalent water stress has encouraged majority of the populace to adopt rainwater harvesting options. It has become more expedient in regions faced with rainfall unpredictability, poor water supply/management and climate change (Akanwa, 2020). According to Adefusisonye et al. (2016), RWH has been proposed as one of the beneficial means to provide water supply especially in rural poor economies, though its harvesting and storage process could pose health risks.

Water quality of RWH in many Nigerian communities is uncertified and may expose people to health risks (Peiyue & Jianhua, 2019; Ajibade et al. 2015; Centers for Disease Control and Prevention, 2019). Several studies that investigate the physico-chemical and microbiological quality of harvested rainwater from rooftops have confirmed that pollutants do compromise such waters (Campisano & Modica, 2012; Egwuogu et al,2016; Adeniyi & Olabanji, 2015; Alfred & Gloria, 2012; Sazakli et al, 2007; Akanwa 2020) thereby there are high possibilities of threat to community health and life.

Proper collection and storage of drinking water in clean vessels and regular treatment are vital in maintaining human health and wellbeing (Li & Wu, 2019). However, pollutants can intercept the collection and storage process especially during RWH via many avenues. These include the technology covering the RWH system, type of roof materials, and the emission of fumes, dust from anthropogenic activities (Sojobi et al. 2015; UNEP, 2018). For instance, Enugu State is an agrarian community, dominated by abundant grassland vegetation within its forest-savannah transition vegetation. This provides arable lands for huge agricultural activities that releases dust. Consequently, the particles of such dust can settle on rooftops and other rural activities that could serve as sources for water pollution (Nwagu et al, 2017; Ogbochie, 2011). Other human actions, based on the level of hygiene, could increase the risk of microbiological contamination of rainwater during harvesting and storage in the home (Bello & Nike, 2015).

Globally, physiochemical and micro bacterial analysis of water samples has proven to be a key element of studies that relate to investigation of water quality analysis. This approach helps to give an insight to physical characteristics of water that appeal to the sense of taste or smell, suspended solids, turbidity, colour, and temperature as well the chemical characteristics. From the foregoing, there is the need to carry out analysis of water samples from storage tanks and wells to detect, identify and quantify the current physiochemical and bacteriological parameters of harvested rain water in the community. These parameters will also be compared to regulatory standards in order to draw conclusion on the quality level of the harvested/stored rain water.

3. Material and Methods

Adopting the qualitative and quantitative (experimental) methods enabled the investigation of the process of water access, supply, storage, quality and the health risks of (RWH) on community women. The mixed method covered field observation, key informant interviews, photography, discussions, and random interviews. All these and laboratory analysis were used to gather primary data employed in this study. Using mixed methods provided a broader spectrum for depth of understanding and collaboration of complex problems in this study (Creswell 2012). Also, this approach helped to explain both the process and result of an event through complete observation, reconstruction and investigation of the case under study. Secondary data were collected from relevant literature and related documents and studies.

3.1 Method of Sampling

Purposive sampling technique was the dominant technique used in this study and it was employed in selecting Umuida Community based on its poor access to water supply and heavy dependence on rain water. Purposive sampling was used to ensure that the voices and views of participating key women and some male informants on the problem under study were appropriately represented. Using purposive sampling technique (convenient and snowball methods), we collaborated with the local Umuida Community Women Group Leader to recruit women participants for this study. We used the following inclusion criteria for all the participants: 18 years of age and above, confirmed residents of 20 years and above. Based on the recommendations made by several studies on sample sizes –interviews - for qualitative studies should be between 5 and 50 participants (Dworkin, 2012; Vasileiou et al, 2018; Guest et al, 2006), this study adopted 35 participants since the study include similar segments. We deemed it sufficient in explaining and addressing the research problem.

A total of 20 randomly selected community members were interviewed with semi structured questions while 10 female and 5 male key informants were subjected in-depth interviews. They include married/single women, heads of households, widows, a local chief, community women leaders, farmers and other people within the locality who were also contacted for relevant information.

All informal interactions and dialogues with indigenes were recorded. Interviews were carried out in Igbo and English languages. Effective interpretation to English language was done and different variables covering the educational background, marital status, occupation, and socio-economic data of the perceptions of the interviewees to the goal of the study.

3.2. Collection of Rain Water Samples

Sample locations for RWH and stored water were randomly selected from two-common storage facilities large vessels (drums) and hand dug wells. Necessary precautions were carried out to avoid contamination during sampling since the whole processed was handled by researchers.

3.3 Physico-Chemical Analysis

The physic-chemical parameters analyzed were pH, temperature, hardness, conductivity, turbidity, total suspended solids, total dissolved solids, COD, sulphates and coliform. Heavy metals analyzed include zinc, lead, and cadmium in order, to determine their concentration levels. Turbidity by Nephlometric Turbidity unit (NTU), TDS using APHA2510 ATDS 139 tester, conductivity using APHA 1998, BOD was determined by the respirometric method, dissolved oxygen (DO) Content of the samples was determined before and after the incubation, while heavy metals lead, zinc and cadmium was analyzed using atomic absorption spectrophotometer (AAS).

3.4 Microbiological Analysis

Total and fecal coliform bacteria tests were used to assess bacteriological (RWH) stored water quality. This process was targeted at examining the level of hygienic quality since total and fecal coliform describes faecal contamination and indicates the level of pathogenic risks. Further, all bacteriological parameters covering total coliform (TC), total bacteria count (TBC) and confirmatory fecal coliform test were carried out by the concerned professional who ensured that all standard processes were adopted (APHA Standard Methods for the Examination of Water and Wastewater 1998; APHA, 2012).

4. Results/Discussion

4.1 Socio-Economic Characteristic of Participants

The data from in depth interviews, key informant interviews, observation, photographs, and laboratory analysis were presented and discussed. Findings from the study showed that interviewees where females (80%) because women were the target population. However, about 20% of the males were randomly selected for interviews and as key informants too. All males interviewed accepted to participate freely in the study. Notably, the inclusion criterion for males was to balance the study noting that valuable information could be derived from them.

Results of age range and sex data collected from respondents in Umuida Community revealed that most of the sampled participants age bracket fell between (18 and 50) years. The dominance of an active and young women group in this study presents an opportunity to start up the process for a rural water development plan. Also, this showed that most of them were matured and could provide necessary information. According to World Bank data (2019), 104 million females against 106 million males make up the population in Nigeria. Over the past five decades, female population grew tremendously from 29.3 million to 104 million at an annual rate that reached a maximum of 2.98%. This large female population calls for attention to the challenges of water access, supply, storage and health risks faced by rural women in their struggle to keep their household clean and safe.

Findings also showed that 59% of the sampled population were married while 20% were single, 4% were widowers, 12% were widows, 5% were separated. It was also noted that most households in the location had between 4 to 7 children. It is evidenced that the sample size is dominated by a large population of married people with children. This increased their need for constant water supply and also highlighted a greater responsibility for women and their children. Further, the educational status of the residents showed that 42% of the participants had obtained elementary school (primary), and 28% attained junior (secondary) level of education. Also, 3% had tertiary level of education, 15% had non-formal education while 13% had vocational studies. It can be inferred that the participants could read and write. With their moderate literacy levels, they were able to furnish the researchers with vital information during the interactive sessions.

Also, the occupational status of the participants confirmed 54% were farmers while 22% were involved in the sales of food products in the local market. 14% were involved in palm wine tapping and selling of goods and 10% were involved in other business activities (sand mining, palm oil sales/ production, and artisanship). Since the age brackets of the respondents were mainly active (18–50) years, it also reflected in their highest occupational structure (farming and sale of food products) and also seen in their highest levels of education (primary and secondary).

The study area is predominately inhabited by farmers, palm wine tappers and fishermen who cultivate and tap wine as their sources of income and livelihood. Umuida Community is characterized by high levels of underdevelopment, deprivation and negligence. Observation indicated the absence of local government interventions in providing essential facilities such as electricity, water supply, housing, roads and healthcare (See plate 1).

Plate 1: These show the high levels of poverty, poor sanitary and hygiene conditions in the study area.
Source: Researchers' survey, 2021.

Findings from interviews and discussions revealed that the 84% of the participants practice RWH and storage as their most dependable water supply. While 16% have other means of water supply which include nearby springs, boreholes and water vendors available in the community. The community has no rivers or streams but a few springs that are inadequate to meet the water supply need of the teeming population and its elongated perennial water shortage.

The various uses of harvested and stored rain water in the study area showed that 48% of the participants drink the water and use it for other domestic activities while 24% use it for fish farming. 18% for irrigation and gardening, 6 % use it for sand mining activities and other related works such as block moulding. 4% use it for industrial activities such as palm oil production. Notably, it can be concluded that majority of the inhabitants use rain water for domestic work, fishing and farming activities.

Notably, the rain water harvesting methods in Umuida Community showed that 68% employed roof tops method in harvesting rain water into drums and vessels while 32% use ground water systems to harvest rain water by constructing hand dug wells. Plate 2 shows an open hand dug underground system for harvesting and storing rainwater. The conditions are unclean and could be accessible to pollutants. Plate 3 is a closed underground water system used for harvesting and storing rainwater.

Plate 2: Shows the unsanitary condition of shallow hand dug system for RWH in the dry season.

Source: Researchers' survey, 2021

Plate 3: Shows a coverable underground well system built for RWH in the community.

Source: Researchers' survey, 2021

Results from in-depth interviews and observation revealed that a combination of RWH and storage is an essential part of water supply for the community. Based on observation, it serves as a small-rural method though there is the absence of proper sanitation hygiene and lack of scientific approach that should protect RWH water from pollutants. One of the interviewed leaders noted that their wells can hardly retain water for long during the dry season. He went further to explain that...

> *..... this is because the soil type is responsible for the low supply of water from the wells during dry season and even the urban areas have similar water stress. Enugu means "hilltop", so that the city is set on a hill, added to, the fact, it is underlain with shale components because the land is rich in coal deposits. The soil collects water but cannot retain it for long periods making people suffer from consistent water shortage.*

Notably, water scarcity is intensified so much, that even harnessing borehole/ wells is difficult due to the geology of the area. It easily aids water seepage added to the varying climate showing extremes in rainfall and evapotranspiration levels (Nwagu et al, 2017; Akanwa et al, 2011).

Findings from interviewed participants revealed that 66% of the women affirmed that it is their responsibility is to collect water for the household with their female children. Twenty-two (22%) of the participants reported that it is the duty of their children to supply water to the household. 12% indicated that men in the community were involved in water collection during dry seasons. Notably, all the respondents affirmed that during the wet seasons, enough water is stored in vessels and wells to last for a long time. However, due to the rising demand of water for numerous activities, the stored water is usually exhausted thereby placing the burden on the women to search for more water. The women leader complained that because of the increased number of persons in their households and water demand, stored rain water hardly lasts throughout the dry seasons. They have to search of water to meet with all domestic needs. The leader for the women group described the discomfort they face as the dry season ensues:

> *... I and my daughters have to walk a distance of about 35 minutes or more depending on where we get water from a spring source. If we are lucky the spring water is still flowing, we can get from there or we move further to a nearby community to either use their stream or buy from water vendors which is expensive and we have to go several times to get enough water to last for few days. Most times, there are long queues in areas with borehole since is the only water source for numerous communities***.**

During in-depth interviews, one of the male interviewees emphasized that, it is the responsibility of the women and young girls to fetch water, firewood, cook while the men work either in their farms, palm wine business or other handiwork to provide for the family

> *... our men are responsible for working in their farms, palm wine business and other businesses to support the family. The women too work on the farms to support the family business but they have to fetch water, cook, clean the house after which they work in the farms particularly planting, weeding and harvest seasons. Our women are hardworking and very supportive***.**

The female youth leader, confessed during an interview session that the whole process of sourcing for water is strenuous.

> *... I miss out a lot on other educational and recreational activities because I am usually tired after fetching water early in the mornings from 6am and late in the evenings by 5:00p.m. I have to go for 5 trips daily to fill our drum. This makes me feel sleepy while in the classroom. It is like my life is tied around fetching water unlike my brothers who have free time to play and visit their friends*

after working in the farms. I usually have neck and back pains from carrying water on my head all the time.

Another community woman during an in-depth interview shared her experience during dry season in providing water for her household.

…. I am excited whenever the wet seasons arrive since it can last for about 5 months because our walking long distances, buying water and constant pains ends. This because we channel our vessels, drums and wells to collect rain water and store it. The dry season is usually dreaded because even in my pregnant condition I have to join other women in providing water. Every pregnant woman prays to give birth during the rainy season because the stress and pains are really bad at dry period. When I save enough money from the sale of farm products, I can hire wheelbarrow and pay someone to help me fill the family drum.

Most of the women during interview and discussion agreed to the plight they go through the dry seasons and this responsible for adapting to rainwater harvesting. But the local Chief's wife added that

….I don't suffer or undergo the extent of stress other women go through because my husband owns a car and this makes it easy for us to collect water during scarcity. In the dry season, most of our wells are dried up and we are left with muddy water. We still fetch and leave it overnight so we can collect the clean surface water. We don't drink it because of its brown colour, but we use it to wash clothes and water our garden.

Findings from the study noted that basically majority (66%) of the community women are involved in providing water for their households. They get occasional help from the men and male children since water collection is culturally perceived as a woman's job. Water scarcity and supply is seen as a personal problem for women in the study area because of the perceived feminine related activities tied to the use of water (drinking, cooking, cleaning and washing). The women travel regularly back and forth for about 35 minutes daily (3kilometre) and an average of five trips and pay expensively to buy water. In many cases, water vendors are paid to transport water particularly in the dry season when water scarcity is intense and stored rainwater and wells are dried up. Worse still, the study area by observation is located in a chain of hills running through the length and breadth of the land area. All the interviewed respondents agreed that they experience regular pains from their heads, backs and legs due to the stress of water supply and walking on hilly pathway. One of the elderly women interviewed shared her experiences on water shortage in the study area.

….I am too old to walk long distances to fetch water because of arthritis. So, I have to beg my grandchildren to come over and help me. When they are not available because they have to be in school, I have to pay expensively to someone who uses a wheel barrow to fill my drum for me. My daughter is heavily pregnant and she has to use her children or pay someone to help out. It is so expensive to have water during dry season here.

Water supply is essential to women's health particularly elderly, pregnant and nursing mothers. However, they are equally disturbed by water stress incurred from walking long distances in search of water and carrying heavy vessels. Again, drinking uncertified water can endanger the life of women and men, including pregnant and nursing mothers.

Amy and Jennifer (2012) confirm the findings of this study. They affirmed that in all developing countries, women are given the responsibility of collecting water and they spend extended time in water collection. UNICEF (2016) reports that water collection wastes a significant amount of time and its victims are women and girls. A similar study carried out in South Africa by Geere et al (2010) indicates that women supplied the largest amount of water. Also, they were primarily responsible for providing water throughout the entire six local villages studied. Moreover, female children were thirty-one percent, male children about ten percent while adult males constituted only three percent of those with responsibility for domestic water fetching. Again, another study by Sorenson et al. (2011) investigates water supply by women and children in fifteen sub-Saharan countries and finds out that women are the main suppliers of water in more than half of the households studied.

Only two of the fifteen countries, Cameroon and Nigeria, had lower amount of the families' who described women as their main providers of water. In these studied countries, Cameroon and Nigeria, women supply water to their households about forty-five and forty-six percent respectively. Notably, children are the main providers of water across 15 countries, constituting only five percent in Guinea-Bissau and thirty-nine percent in Burundi. Further, another study also agrees with findings of this study that children are exposed to intense pains from supplying water to their homes and the extreme discomfort is closely linked to the travel time and distances experienced in supplying water (Geere et al, 2010).

Notably, findings showed that the community has resorted to rain water harvesting through the use of water vessels, medium-and-big size kegs, buckets and shallow hand dug wells that are 50 feet or less or deep (See Plates 2& 4). Majority of the hand dug wells are open while are closed to prevent entry of pollutants (See Plates 2 &3), However, RWH storage is carried out in the community privately by households through rooftops and communally through wells, though the storage approach lacks sustainable design. However, the present approach in the study area is opposed to drinking water and sanitation guidelines by WHO (2014).

Plate 4: Showing the various water vessels and containers used for storing harvested rain water in the study area.

Source: Researchers' survey, 2021

Studies have shown that across African countries water scarcity is common and persistent. UNICEF (2016) and WHO (2000) report that mothers and girls walk far distances of over six kilometers in search of water and in most cases the water sources are polluted. Over three million children, added to fourteen million women walk distances of an hour daily to supply water for their homes (dayhttps://www.worldvision.org/clean-water-news-stories/walk-water-6k).

Similarly, according to a study carried out by Graham et al. (2016) in twenty -four sub-Saharan countries, it is estimated that over three million children and about thirteen million women are major providers of water in their homes covering a distance of more than thirty minutes. Generally, in most developing nations, about sixty-two percentages of women and girls are likely suppliers of water than men who account for only thirty-eight percentages.

Sanjay Wijesekera, the UNICEF global head of water for sanitation and hygiene, adds that…

> *"Just imagine: 200 million hours is 8.3 million days, or over 22,800 years, it would be as if a woman started with her empty bucket in the Stone Age and didn't arrive home with water until 2016. Think how much the world has advanced in that time. Think how much women could have achieved in that time. When water is not on premises and needs to be collected, it's our women and girls who are mostly paying with their time and lost opportunities,"*

4.2 Results of Physio-Chemical, Heavy Metals/Microbiological Pollution of Sampled Harvested Rainwater Quality and Health Risks

The result of physio-chemical and bacteriological analysis of RWH stored rain water samples are presented in Table 1 and the compliance levels of WHO (2011) and NESREA standards as well. Two different harvested rain water samples were analyzed from shallow hand dug well **(A)** and drinking water vessel **(B)** for physio-chemical and bacteriological parameters. Table 1 showed that there were variations in the values of physical parameters and heavy metals analyzed. It was deduced that temperature, TDS, TSS, conductivity, DO, chloride, copper, iron, nitrate and sulphate were all within the acceptable limits of NESERA/WHO standards. However, colour, odour, pH, turbidity, Biochemical oxygen demand (BOD), chemical oxygen demand (COD) and fluoride all exceeded the acceptable limits of National Environmental Standards and Regulations Enforcement Agency (NESREA) and World Health Organization (WHO) standards while heavy metals such as arsenic, cadmium, lead, manganese and zinc all slightly exceeded the acceptable limits of NESERA/WHO standards as well. The pH of sample A (well) and sample B (Vessels) were 5.78 and 5.84 respectively. This indicated that the samples pH had higher acidic content which can affect the solubility of many toxic and nutritive chemicals.

Table 1: Result of Physio-Chemical Analysis of Stored Harvested Rain Water in Umuida

S/N	Parameters	Sample A (Hand Dug Well)	Sample B (Drinking Water Vessels)	WHO Standard	NESERA
1	Temperature	29.4	27.5	30 (°C)	Ambient
2	Colour	65	45	15(mg/l)	15(mg/l)
3	Odour	Present	Present	Absent	Absent
4	pH	5.78	5.84	6.5-8.5	6-9
5	Turbidity (NTU	14.3	3.3	5(NTU)	5(NTU)
6	TDS	2.6	2.6	600	600(ppm)
6	TSS (mg/l)	3.3	3.2	50 Max.	30 Max.
7	Conductivity (µs/cm)	38.2	22.1	1000	500 Max
8	DO (mg/l)	11	5.7	50 Max.	50 Max
9	BOD (mg/l)	136	36	50 Max	50 (mg/l)
10	COD (mg/l)	129.3	57.3	100 Max.	100 Max.
11	Chloride (mg/l)	6	4	200	250
12	Iron	0.00353	0.0021	< 1	0.006(mg/l)
13	Arsenic (ppm)	0.0063	0.0008	0.001(mg/l)	0.001(mg/l)
14	Cadmium (ppm)	0.0076	0.001	0.003(mg/l)	0.003(mg/l)
15	Copper (ppm)	0.112	0.021	5(mg/l)	1(mg/l)
16	Lead Pb^{2+} (ppm)	0.162	0.154	0.01(mg/l)	0.01(mg/l)
17	Zinc Zn^{2+} (ppm)	0.113	0.113	0.03(mg/l)	0.03(mg/l)
18	Nitrate (mg/l)	8.886	8.450	**10**	**10**
19	Fluoride (mg/l)	0.204	0.133	0.003(mg/l)	0.05 Max
20	Manganese (ppm)	0.315	0.024	0.05(mg/l)	0.05(mg/l)
21	Sulphate (mg/l)	92.587	83.946	250(mg/l)	200(mg/l)
22	Faecal coliform	10	8	0(CFU/ml)	0(CFU/ml)
23	Total coliform	**30**	**23**	0(CFU/ml)	0(CFU/ml)

Source: Research Laboratory, Awka (2021)

Therefore, the presence of acidic components can negatively affect humans noting that acidic increase causes most metals to increase in water solubility and toxicity.

Most pollutants can be easily identified by testing physical parameters such as colour, odour, turbidity and water taste. However, pollutants can indicate a negative taste or odor and affect human wellness levels (Sharma & Bhattacharya, 2017). The turbidity levels of samples A (14.3NTU) and B (3.3NTU) showed that sample **A** of harvested/stored rainwater from the well was above the acceptable NESERA/WHO standard while sample **B** from the covered vessels were within the limit. The high turbidity value in the sampled open well water could be traceable to farming and mining activities possibly transported by run off during storms and seeps dust particles, silt, sediments and large number of organic materials into storage systems thereby increasing turbidity.

Further, the odour and colour in both samples exceeded the permissible limits though the colour value for well water was higher. This is an indication of the presence of organic substances, that are although harmless, could affect the taste and smell of the water even at low concentrations (Sharma & Bhattacharya, 2017). Growth of algae from decaying matter could be the major natural source while the worst-case scenario is traced to man-made actions such as presence of wastes from households and manufacturing wastes or farming practices within the vicinity (Sigworth, 1961; Hartung, 1960).

The analyzed water samples showed that both BOD and COD were high exceeding the acceptable limits in the sampled well water. There are functional similarities between BOD and chemical oxygen demand (COD) analysis. They both assess the number of organic compounds in water. The BOD value from sampled well water was 136(mg/l) while the sampled vessel was 36(mg/l). The BOD from the well is higher than the acceptable limit while the BOD from vessel is within the limit. Therefore, a low(er) BOD shows good water quality while a high(er) BOD indicates polluted water.

Similarly, the value of COD from sampled (**A**) well water was 129.3(mg/l) while the sample **(B)** water in drinking vessel was 57.3(mg/l). This showed that COD levels were higher in sampled well water while the value for the sampled vessel was within the acceptable limits of NESERA/WHO. COD shows the level of oxygen required by reactions in a given solution. Its presence is used to inform the number of organics in water. Increasing COD content indicates a high occurrence of pollutants in water.

Findings also proved that heavy metals slightly exceeded the acceptable limits as regulated by NESERA/WHO. The recorded value of the samples for arsenic ranged from 0.0008 to 0.0063 (mg/l). There was significant difference between the sampled well and vessel water where the average concentration of arsenic in well water was above WHO/NESREA permissible limit of 0.001 (mg/l). Findings, also proved that manganese slightly exceeded the acceptable limits of NESEREA/WHO with recorded values ranging from 0.02 to 0.315(mg/l). The sampled well water was higher (0.315mg/l) than the sampled vessel water (0.02mg/l) where the average concentration of manganese was above WHO/NESREA permissible limit of 0.05 (mg/l). It possible that the presence of Mn in sampled hand dug well could be traced to the increase of certain organisms that produce an unpleasant taste, odour and colour and affect fabric and plumbing fixtures which can also cause health risk to human life (Sigworth, 1961).

Lead slightly exceeded the acceptable limits of NESEREA/WHO with recorded values ranging from 0.154 to 0.162 (mg/l). The sampled well was higher (0.162mg/l) than the sampled vessel water (0.154mg/l) where the average concentration of lead was above WHO/NESREA permissible limit of 0.01 (mg/l). Lead is responsible for many growth problems in children though it causes high blood pressure and kidney problems in adults (Kim, 2005).

Findings showed that the sampled well water was higher (0.0076 mg/l) in cadmium exceeding the acceptable limits of NESEREA/WHO of 0.003 (mg/l) than the sampled vessel water (0.001mg/l). The vessel water was within the permissible limits of WHO/NESREA. Considerably, the level of water pollution is dependent on the nearby groundwater source to its formation (Duruibe et al, 2007). The geology of the study area is sedimentary rock. It includes sandstones, calcareous shale and shelly limestone and Enugu State has high deposits of coal as well (Nwagu et al, 2017). Palm oil processing could also be a source of cadmium in the well water. This could be why there is Cd in harvested and stored water in well, but absent in stored water in vessel.

Fluoride exceeded the acceptable limits of NESEREA/WHO in both samples. It recorded values in the sampled well (0.204mg/l) while the sampled vessel water (0.133mg/l) and the permissible values WHO/NESREA for fluoride is 0.003 (mg/l). Sources of fluoride may be geogenic happenings, industrial activities, burning of coal or anthropogenic actions while weathering of fluoride-bearing minerals from rocks could be responsible for increased fluoride levels in water. The over use of wells and boreholes sources could trigger high fluoride concentration in the water. However, their negative effects endanger the young and old by causing dental and skeletal fluorosis among others (Liu et al, 2007).

The laboratory analysis discovered 10 counts for faecal coliform and 30 counts for total coliform count of the E-coli bacterial in sampled well water. The sampled vessels recorded 8 counts of faecal coliform and 23 counts of total coliform bacterial. The presence of coliform microorganisms in the water sources is an indication of faecal contamination and pathogenic bacterial species such as Shigella spp, Salmoella spp, or Vibro cholerae. Their sources are largely from the environment traceable to faeces of humans and animals. During our interview sessions several women agreed that their children are always sick.

> *…. My children, 5, 3, 2 years are always stooling and vomiting and they have fever and complain of headache and body weakness all the time. We have taken them severally to the community healthcare center and also treat them locally with herbs. They recovered briefly only for these symptoms to keep recurring.*

Obviously, the high microbial content of the water samples is also an indication that the water used by the community is not fit for consumption. This could be a possible reason for the prevalence of symptoms of cholera and typhoid among children in the study area. WHO (2001) reports that infectious and water-borne diseases including cholera, typhoid, hepatitis, polio, crptosporidiosis, ascariasis and schistosomiasis are caused by consumed polluted water. Again, evidences that signify poor sanitary and hygiene practices employed by the households over the conditions of storage tanks/vessels (See Plates 1, 2 and 3) exist. Of note, the area is forested with trees located within dwelling places and animal faeces from birds and chickens on trees overlying rooftops can be washed into water vessels. Regrettably, reports from interviews with the participants indicated that the water quality standards of the RHW was not assessed before drinking. Notably, open defecation is practiced in the community and this can be washed into hand dug wells during wet seasons.

5. Conclusion

The combination of qualitative and quantitative (experimental) approaches affords this study the deeper understanding of experiences in the context of water stress, supply and quality in the area. Capitalizing on the theoretical assumptions of qualitative approach, we described the real perception of the sample population on water provision in a rural setting. Again, we provided data that showed a general basis for research into water supply noting that for such areas with historical water problems, an approach that recognizes the role of women is the most appropriate to diagnose such problems.

Additionally, the collaboration of quantitative (experimental) approach provided relevant information on the variation in well water and harvest/stored rain water quality. It established the health implications of adapting to stored RWH as a dependable source of water supply for drinking and other domestic activities in the study area. It offered an enormous potential for generating new pathways for rural women participation in providing permanent solutions to the water stress and health risks. Unarguably, water crisis is mainly a woman's problem. As major stakeholders, women need to congregate and take positive actions in making their voices heard and water available at their doorsteps.

It is noted that women are absent when decisions are made over water supply and quality. Policies that mention or allow women contribute in water resources management (UN-Water 2021) exist in only few countries (lower than fifty). At the local level, there is need for gender-sensitive approaches that would aid in promoting women involvement/inclusiveness in all aspects of water production from engagement, knowledge exchange, policy making, planning, development, treatment, distribution and management among others.

Again, Enugu State Rural Water Supply Agency (ENRUWASA) has initiated several water schemes since 2017 to deal with water scarcity by providing motorized boreholes but either the project is abandoned or water facilities are not functioning. Also, in 2020, three organizations namely Water Aid Nigeria, the South Saharan Development Organization (SSDO) and Coca Cola Foundation, in joint collaboration with Enugu State celebrated the completion of 300 million water projects in many LGAs. Unfortunately, some of the water projects served the communities for only two months after inauguration while others could only give dirty water not fit for drinking and others completely stopped working. Reoccurring operational challenges such as poor service coverage, low maintenance, poor administration and allocation of adequate funds are some of the endless problems with government water provision. This keeps increasing water stress and the use of unsafe water by vulnerable women and communities.

Finally, prioritizing clean water supply and closing health risks are critical in rural communities for optimizing water resources, improving local services, enhancing water quality treatment, information dissemination and risk communication and promoting multi-sectoral collaboration. It is recommended that coordinated, collaborative, multi-sectoral interventions towards water supply and the monitoring of waterborne diseases should be implemented through a sustainable water/health development approach.

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