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RURAL HARVESTED RAINWATER: EFFECT OF ROOF TYPES AND ITS DESIGN ON WATER QUALITY AND HEALTH: A CASE FOR CBP APPROACH IN ANAMBRA STATE

Angela Oyilieze Akanwa

Chukwuemeka Odumegwu Ojukwu University (COOU), Uli, Campus, Faculty of Environmental Sciences, Department of Environmental Management, Anambra State, Nigeria.
Email: angela.akanwa1@gmail.com

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ABSTRACT

The rainwater quality harvested from rooftops in remote African communities has become a huge concern due to its potential risks on community health. This study addressed the effect of harvested rainwater quality and the design of the collection system from 3 common roof types on public health in Orsumoghu, Ihiala, LGA in Anambra State. This study employed the case study approach and mixed methods. Mixed methods combined the survey and laboratory methods. The survey method included field observation, interviews, photography and 250 questionnaires were randomly sampled. The laboratory method employed physic-chemical and biological analysis of rain water sampled from three (3) common rooftop systems in the area (aluminum, concrete, and zinc). The parameters analyzed were pH, temperature, hardness, conductivity, turbidity, TSS, TDS, COD, sulphates, Zinc, Lead, Cadmium and Coliform. Findings from the study showed that the poor design of RWHS coupled with mining and agricultural activities may have increased the concentration of atmospheric pollutants in the area. Findings proved that pH and three heavy metals (Zn, Ca and pb) were all above the WHO acceptable limits. Coliform as the bacterial indicator was present in the samples from aluminum and zinc roofs. However, concrete roof was free from pathogenic contamination. ANOVA analysis showed that there a difference between quality of harvested rainwater and WHO standard. To address this challenge this study recommended a community-based participatory research (CBPR) as an all-inclusive tool to promote rooftop RHW design as a rural development project that would protect the rainwater quality and minimize health risks.

Contribution/Originality: This paper contributes the first comprehensive analysis identifying (CBPR) as a tool for the sustainable rural development RHW project. It highlights the peculiar limitations of Rooftop RWH design in Orsumoghu where regulations, sanitary design and fittings are absent and hence, during collection varied pollutants are introduced leading to health risks.

1. INTRODUCTION

The right to clean drinking water void of health risks is particularly a problem in most African remote areas. Changing climate, population growth, human activities, inadequate water supply and health negligence are some of the factors that have negatively affected water sources [1, 2]. Rainwater harvesting has played significant economic, social and environmental roles in rural African culture. It is estimated that more than half a million people spread across Africa, Caribbean Islands, Central and South America regions including Honduras, Brazil, and Paraguay depend on rain water harvesting for numerous domestic purposes [3, 4].

RWHS is a dependent water supplement with many benefits accrued to it. It can be protected from pollutants and less expensive [5]. It is an easy and flexible technology that communities can install and manage since it does not depend on terrain, geology, or infrastructure management schemes [3]. It provides water easily without the herculean task faced by women and children in walking long distances in search of portable water.

RHWS is harnessed through a rooftop system though rural areas in Africa do not operate well-designed /maintained systems and hence is easily contaminated during collection and can have health risks on humans when ingested [6]. Several studies have confirmed that roof harvesting systems can affect rainwater quality and cause health hazards on humans when ingested; Christopher, et al. [7]; Carolina and Mendez [8]; Bello and Nike [6] among others.

According to the Nigerian 1991 population census, Orsumoghu community has a population of 88,006 persons and is a fast growing community heavily dependent on rainwater collection and storage. The rural architecture is basically made of Zinc, aluminum and concrete roofing materials which is mostly found in most Nigerian rural areas Bello and Nike [6] and based on their raw materials, they can affect the quality of harvested rain water by introducing contaminants. Also, environmentally, pollutants such as debris, dirt, dust and animal droppings deposited on rooftops can be introduced during rainfall and easily find their way into harvested water stored for drinking and other purposes.

Hence, harvested rain water from rooftops can equally be contaminated by heavy metals which can cause various health effects as it makes its way from the clouds to collection systems [7]. Studies have confirmed that high value of pH causes bitter taste of water, affects mucous membrane, cause corrosion (). In addition, high amount of hardness in drinking water leads to health risks like heart diseases and poor lathering of soap that can deteriorate the quality of clothes [9]**.** In respect to this, the need to evaluate the harvesting methods and determine the quality of rainwater especially for vulnerable rural residents is imperative and a necessity. Hence, this study investigated effect of harvested rainwater quality and the design of the collection system from 3 common roof types on public health in Orsumoghu, Ihiala, LGA in Anambra State. The following objectives were pursued:

1) To identify the challenges of current RWH operational practices in the study area.
2) To determine the physic-chemical and bacterial parameters of rainwater quality from (zinc, aluminum and concrete roofs) and compare with WHO standards.
3) To determine the extent of heavy metals levels present in the sampled rainwater.
4) To determine possible health dangers faced by the residents and to suggest better rainwater harvesting practices in the study area.
5) To propose the adoption of a sustainable community based RWH design for sanitary water supply as a development project for rural residents.

1.1. Concept of CBPR in RTWH Design as a Rural Sustainable Project

According to the Agency for Healthcare Research and Quality defined CBPR as a collaborative research approach designed to ensure and establish structures for participation by communities affected by the issue being studied, representatives of organizations, and researchers in all aspects of the research process to improve health and well-being through taking action including social change [10].

CBPR ensures that the local community has the right to participate in making decisions that affect their lives as well as a right to information and transparency from those responsible for providing assistance. So that the community will be better protected through knowledge, their capacity to identify, develop and sustain solutions will be strengthened and humanitarian resources will be used more effectively for policy or social change [11].

Majority of the RWHS in rural areas in Nigeria are not properly designed and managed from the rooftop structure, collection system, and storage capacity. Also, there have been limitations in developing RWH systems in rural areas due to a non- adopted technical standards and guidelines. Also, technology, equipment and material and installation costs are high with no customized policies or regulations enforcing its adoption [9, 12].

In addition, the limited awareness of RWH best management practices provides occasion for poor designs with leakages, cracks, and pollution and resultant health risks [13, 14]. CBPA is an action research that would best provide the appropriate means to deal with these limitations while promoting productivity, agriculture, healthy living, awareness, economic viability, social cohesion and through a well-designed RTWHS. Further, CBPR will promote the involvement of both men and women since rooftop RWH systems is an indispensible social, economic, recreational and environmental resource used by the households in the community.

According to Hatum and Worm [15] rainwater harvesting system consists of at least the following components; rainfall, roof surface to collect rainwater, delivery systems (gutters) to transport the water from the roof or collection surface to the storage reservoir and storage reservoirs or tanks to store the water. This is shown in Figures 1 and 2.

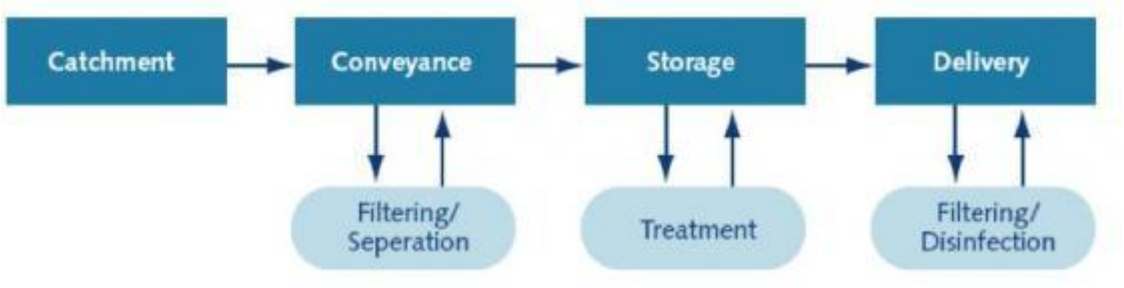

Figure-1. Showed the Process of a drinking water RWH system.

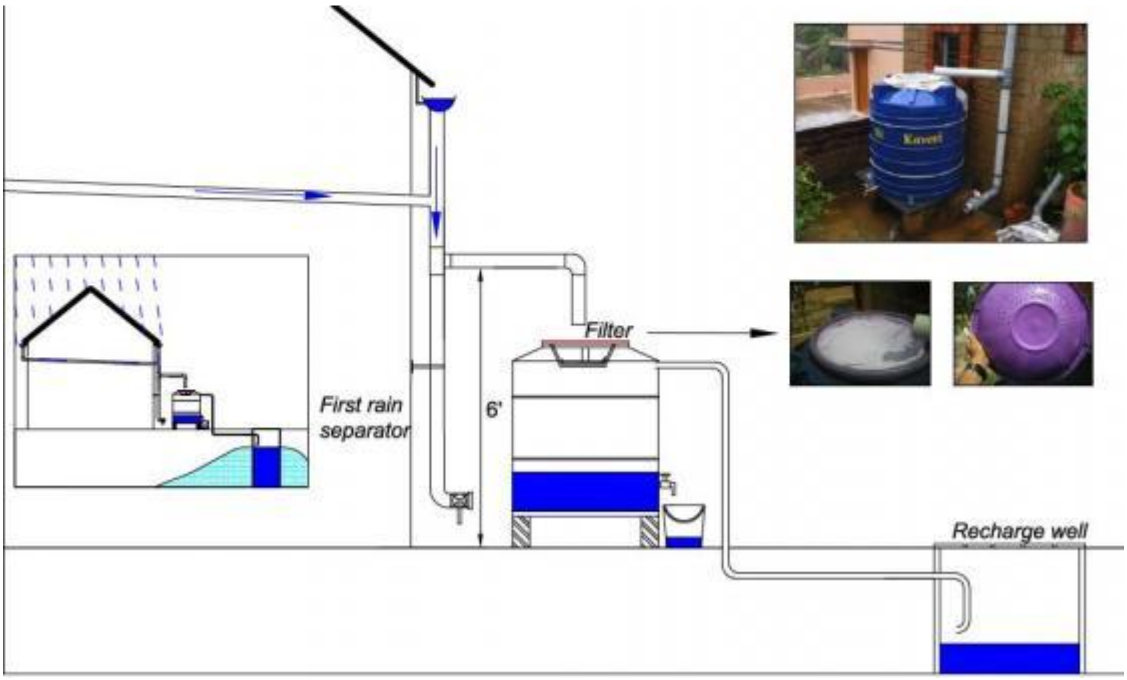

Figure-2. Illustration of water flow scheme of a RTRWH system. Basic components: roof, gutters, first flush device (first rain separator), rain barrel with filter and tap and recharge well.
Source: Rainwater Club [16]

1.2. Study Area

Orsumoghu is located in Ihiala LGA in Anambra State. It shares boundaries with Akwa-etiti in the South, Azia in the North, in the East with Amichi and in the West with Nnewi. The geographical co-ordinates of Orsumoghu are Latitudes $5^{0}54'0''$ N and $5^{0}50'30''$N and Longitudes $6^{0}54'$ $0''$E and $6^{0}57'$ $30''$E. Figure 3 showed the map of the study area- map of Ihiala Local Government Area. As at 1991, it was given that the annual growth rate of the population was 2.8%, (Department of Health, Ihiala LGA). In 2018 the annual growth rate had increased to 3.2%

with a projected population of 194,342 persons. An increasing population puts more pressure on water supply demands, hence increased dependence on rainwater harvesting.

Orsumoghu lies on an elevation of about 170metres above sea level and has a sloppy and flat topography with clay, loamy, laterite and sandy soil that encourage agricultural activities in the study area. Its geology is a sedimentary rock formation which has huge sand and gravel deposits that has also escalated mining activities in the area. The major river exists to the North and comprises of Urasi River which links with River Niger through Okija and Atani (Information office, Ihiala LGA).

Rainfall is the key climatic variable and there is a marked alternation of wet and dry seasons in Orsumoghu community. The dry season extends from November to March annually. The main monthly temperature in the study area varies between 25.36^{0}C in July and 28.19^{0}C in February. The rainy season usually begins in February or March marked by the incidence of high winds as heavy storms prevail in April or early May. The study area is located in the Southeast region where the greatest precipitation is experienced with a total mean annual rainfall of 2,000 and 3000mm. With marked evidence of climate variability the area is characterized by high rainfall intensity throughout the wet season with floods and heavy thunderstorms that stretch from April to September. The intensity of rainfall is high and the subsequent rain water harvesting by the community thus justifies the choice of Orsumoghu community as a case study for this research.

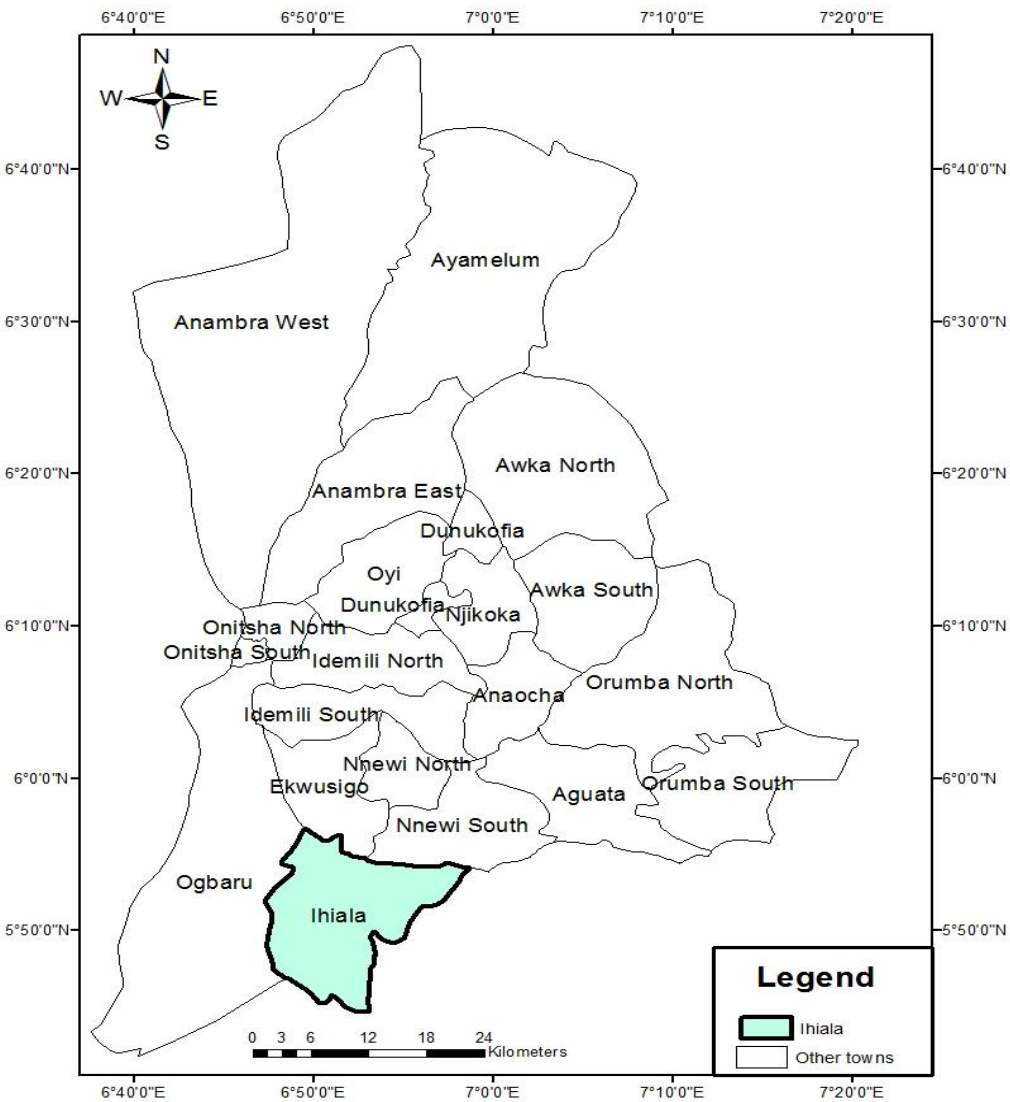

Figure-3. Map of Anambra State showing Ihiala local government area.

2. MATERIAL AND METHODS

The study adopted the mixed method and case study approach which focused on the both the operational method of rain water harvesting and the health implications of harvested water quality in the community. The mixed method covered field observation, interviews, photography and random sampling of questionnaires. Adopting the case study approach required that this research went beyond quantitative statistical results to provide qualitative explanation of conditions. This approach employed both quantitative and qualitative data that helped explain both the process and result of an event through complete observation, reconstruction and investigation of the case under study.

2.1. Method of Sampling

The study also employed both non-probability and probability sampling techniques. A purposive sampling technique was adopted to select the community based on the heavy dependence on rain water. A sample size of 250 was obtained using Yamane [17] formula from the share of the projected population which resulted to an annual growth rate of 3.2 and 194,342 persons.

After obtaining the sample size of 250, the stratified random sampling technique using odd numbers (1, 3, 5, 7, 9 etc.) was applied in the selection of household respondents for the administration of structured questionnaires in the community. The simple random sampling was used to avoid bias by giving all units in the target population equal chances of being selected. Furthermore, a purposive sampling technique was again used to identify key informants who were interviewed. The key informants included; Heads of household, Landlords, Community Chief and women. On observation the opinions of women were heavily solicited since they were actively involved in water collection and storage in the area.

2.2. Collection of Rain Water Samples

A field survey aimed at identifying common RHW rooftop materials and the storage media was embarked on in the Orsumoghu community. Sample locations of rainwater harvesting systems were randomly selected. A random sampling technique was employed in selecting the three residential houses and (3) common rooftop materials in the area namely aluminum, concrete, and zinc. The dwellings with the above stated rooftop materials were selected randomly and harvested rainwater samples were collected after the early rainfall (first flush) of rains in the month of April, 2019. The several flushes were to prevent the collection of polluted rainwater. Precaution was taken to ensure that no accidental contaminations occurred during sampling. Sample containers were soaked in acid solution overnight prior to sample collection, followed by proper rinsing with distilled-deionized water and the rainwater. The temperature and pH of the rainwater samples were measured immediately after collection with a hand held Temp/pH meter. Samples for microbial analysis were kept with a sterilized capped bottle to arrest the further growth of bacterial prior to analysis. They were then taking to the laboratory for microbial and physicochemical analyses.

2.3. 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 were 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).

2.4. Microbiological Analysis

Total and fecal coliform bacteria tests were used to assess bacteriological rain water quality. These tests are used to index hygienic quality because total and fecal coliform are usually associated with faecal contamination and thus, their numbers reflect the degree of pathogenic risks. Fecal coliform (FC) is the most widely used indicator to determine the possible presence of pathogenic organisms. All bacteriological parameters including total coliform (TC), total bacteria count (TBC) and Confirmatory Fecal coliform test were conducted using the multiple tube fermentation technique (MPN method) using Lauryl tryptose broth for the Presumptive Phase of total and faecal coliforms and Brilliant green lactose bile broth and EC Medium for the Confirmation Phases of Total coliform and Faecal coliform. The water quality analysis was carried out in accordance with the APHA Standard Methods for the Examination of Water and Wastewater [18]; APHA [19].

2.5. Statistical Analysis

Results were interpreted with descriptive statistics such as tables, charts, and percentages. Analysis of Variance (ANOVA) was employed to investigate the significant difference between the mean values of the physic-chemical and microbiological parameters of the RWH in the community and the values of the WHO standards.

3. RESULTS/ DISCUSSION

The main focus of this study was to examine the current RWH system practices thereby analyzing the water quality with respect to standard values and possible health dangers it might pose to rural dwellers. A demographic data covering sex, age, occupation, marital status and common sources of water supply were gathered. Interviews and observation assessments were employed to describe the existing RWH system. In addition, the physiochemical, biological and ANOVA analysis were provided. The sexes of the respondents indicated that majority of the respondents were males (62.8%) and women accounted for (32.7%). This sex structure depicts a typical example of an African-Nigerian family representation where males are mostly household heads while women are relegated to upkeep of the home. It also showed that male participation in research process is higher than females. This necessitates advocacy campaigns and intense education on women involvement in research process and the removal of cultural/religious/ethnic barriers since water supply is a domestic need carried out by mostly women in the African culture. Hence, there is need to include women in environmental protection, public health and sustainable water development studies.

The` study also revealed that the highest age distribution was 25.60% covering 31-40 years followed by 24% which falls between 41-50 years, 19.60% for 26-30 years and 19.20% between 21-25 years, 5% are between 18-20 years and 5.60% are above 51 years and above. The age structure showed that majority of the respondents are predominantly youthful, which falls within the age (31-40) years. The dominance of the youth in the area presents a large pool of labour for economic activities undertaken in the area. This is also an indication of a ready labour force to motivate others in initiating a rural sustainable rainwater harvesting project.

Table 1 showed that the occupation of the respondents were majority were farmers (27.20%), sand miners (23.60%), civil servants (22.40%), while traders were (20.80%) and fishermen (6%). This showed that the major activities were agriculture and sand mining which explains the youthful nature of the community's age distribution thus presents a right pool of active and energetic labour force. Also, agriculture and mining operations has the potentials of dust, debris, chemicals and particles during operation.

Table-1. Occupation of the respondents.

Occupation	Traders	Farmers	Fishermen	Civil servants	Sand Mining	Total
Frequency	59	52	15	56	68	250
Percentage	20.80%	27.20 %	6%	22.40%	23.60 %	100%

Source: Field work (2020).

Table 2 indicated that 51.6% of the respondents are married, 26% were single, 16.4% were either widowed or widowers, while 6% were divorced. The marital statuses of the respondents' showed that majority of them are married. This is an indication that the water demand for domestic and other uses in the community will be very high. Given that the African- Nigeria culture propagates large families with an average of 6-7 household. This emphasizes the need for a well-developed RWH rural project in order, to maximize water quality and quantity since the numbers of the respondents that are married are highest (51.60%).

Table-2. Marital status of the respondents.

Marital status	Married	Single	Widowed/widower	Divorced	Total
Frequency	129	65	41	15	250
Percentage	51.60%	26%	16.40%	6%	100.00%

Source: Field work (2020).

3.1. Common Sources of Water Supply in the Study Area

Figure 3 showed the common sources of water supply adopted by the respondents in the community. 8.4% of the respondents use water from the adjoining Urashi River, 16% use water from boreholes, 62% use rainwater harvested from roof tops, 13.2% use water from the stream. This revealed that majority of the residents make use of rainwater source than other sources of water supply.

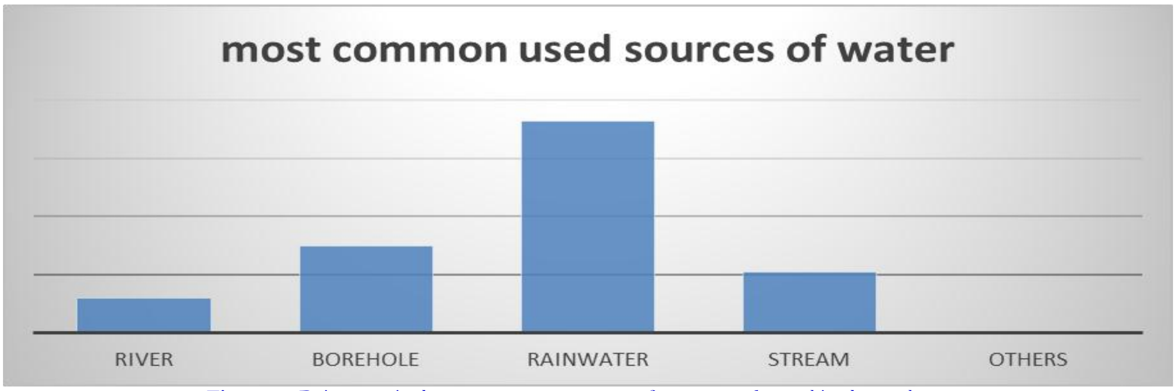

Figure-4. Rainwater is the most common source of water supply used in the study area.

A large population of the community has adapted to RWH source probably due to its flexibility and the many benefits associated with rainwater harvesting. This has made it a welcomed, widely accepted, and increasingly-promoted alternative for the water demands in the community. It is noted that the climatic factors of the area encourage a long time (7 months) of consistent rainfall pattern and only a 5 month period of dry season. This gives rural dwellers the privilege of rain water harvesting and even storage over the 5 month dry periods and hence, its dependency.

3.2. Common Rooftop Types /Challenges of Current RWH operational practices

The study identified that most of the rural population in Orsumoghu community live in cement built residential houses with rooftops made from zinc, aluminum and concrete materials See Figures 5, 6, 7& 8. It was also noted that cement was the preferred material for the construction of other buildings such as schools, churches and health centers. Information from key informants confirmed that the adoption of RWHS is as old as the existence of the community and has become enshrined in their lifestyle. The men also confirmed that in their community it is their responsibility to channel the rain water flow at the rooftops and position the water storage vessels while the women collect and store harvested water in larger vessels. The women leader also confirmed that harvested rain water collection and storage is a culture that was handed over from generations before them. She also said that it was the duty of women to use buckets during rainfalls to collect water which is used for various uses such as drinking, cooking, bathing, dish and clothe washing and gardening. The informants highlighted their dependence on rain water since costs from water vendors are expensive and cannot meet the large demands that would satisfy their daily domestic needs. This cost about 3,000 naira (8.28 USD) during wet season and 5,000 naira (13.80 USD) during dry season. Based on observations and as seen in Figures 5, 6, 7 & 8 the rainwater harvesting designs in the community were poorly built. This happened to be a general practice as most houses had similar unsanitary arrangements. Majority of the rooftops had no construction used on them which is supposed to provide a strong support to gutters (perpendicular to the edge of the building) that drain water away from the roofs. Generally, the runoff from the rooftops were not properly guided as the linings of the roof materials drain water directly or through folded sheets of zinc material into open buckets, jerry cans, large water vessels placed at strategic positions of high rain water runoff.

Figure-5. RWH system from concrete roof type.

Figure-6. RWH system from Zinc roof type.

Source: Reseachers field work, 2020.

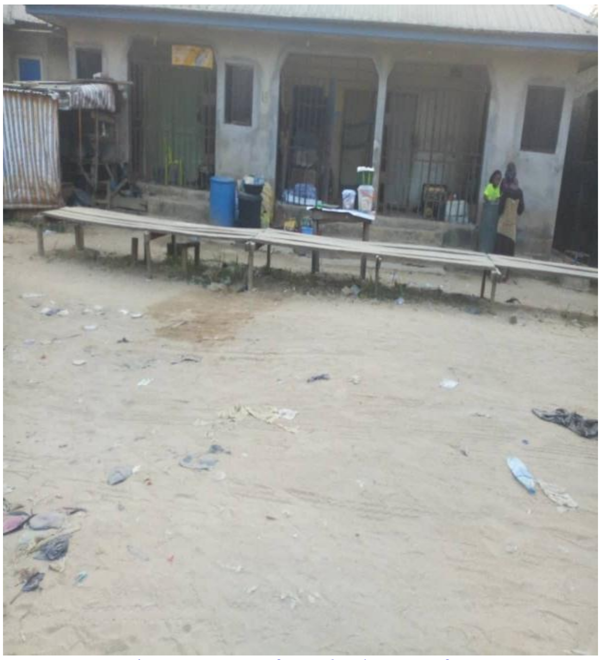

Figure-7. RWH from aluminum roof type.

Figure-8. Poor rooftop catchment.

Source: Reseachers field work, 2020.

Obviously, there is a common misconception regarding the application RWHS in Orsumghu community, that all you need is rain, a roof serving as a water flow channel and a vessel for water storage. However, this approach is called "tanking" or an "open system" and cannot be relied upon to deliver the required water volume and quality. It can easily allow pollutants to interfere with harvested water with possible dangers to rural health. A similar study carried out by Kim, et al. [20] in Korea agreed to the fact that the quality of captured water from roof top depends on both roof top quality and other surrounding environmental conditions.

3.3. Results of Physic-Chemical Parameters of Harvested Rainwater Quality from (Zinc, Aluminum and Concrete Roofs)

The study discovered variations from the results of the physic-chemical parameters, Coliform and heavy metals (Zn, Pb, Cd) analyzed from 3 different roof types. However, majority of the parameters indicated that the quality of the sampled harvested rainwater meets the acceptable limits of both WHO and NERESA standard. This can be attributed to the fact that most of the pollutants in atmosphere are washed away after 5– 20 minutes of heavy rainfall. However, there were variations in the heavy metals (zinc, lead and cadmium) and other parameters such as the pH and coliform which happened to vary from the acceptable limits.

The differences in the values of the parameters with respect to acceptable standards showed their impact on the quality of rainwater. From the chemical analysis, the pH in the aluminum (Sample A) was 5.94, the concrete roof (Sample B) was 6 and the zinc roof (Sample C) was 5.25. This indicated that the aluminum and zinc (higher metallic content) rooftops had higher acidic content than the concrete roof material. This showed all the rainwater samples where slightly acidic. The pH of water affects the solubility of many toxic and nutritive chemicals. Therefore, the availability of these substances can be detrimental to humans. As acidity increases, most metals become more water soluble and more toxic. Also, the acidity levels of the rainwater could be as a result of the zinc material used for the rooftop.

Moreover, case studies have also indicated that rainwater with a pH lower than 6.5 can be corrosive on structures and dissolve metals and leach them in stored rainwater [21]. Further, in harvested rainwater, sources of contamination may be traced from the catchment and storage structures as stated by Mendez, et al. [22] and Gikas and Tsihrintzis [23] or can be carried and deposited on the roof by the wind and washed into the stored rainwater [24].

Table-3. Result of the physiochemical and biological parameters of water samples.

Parameters (Unit Mg/L)	Sample A Aluminum roof/system	Sample B Concrete roof/system	Sample C Zinc roof/system	WHO Std.	FMENV Std
pH	5.94	6	5.25	6.5-8.5	6-9
Temperature	15	11	20	25	25
Colour	Colourless	colourless	Colourless	-	-
Odour	Unobjective	unobjective	Unobjective	-	-
Nitrates	9.96	12.34	15	4.00	
Sulphates	212.2	198.75	150.18	250.00	
TSS	0.56	1	0.72	50	30
TDS	31.5	73.44	25.25	250	2000
zinc	04.98	04.43	05.43	3	<1
Lead	1.76	0.21	2.43	0.01	<1
Cadmium	0.01	0.52	1.45	0.003	<1
Hardness	90	85	88	100	
Conductivity	7	16	24	100	-
Turbidity	48	25	19	50	-
Coliforms	12CFU	10 CFU	14 CFU	10 CFU	10 CFU
COD	93.33	150	110.32	-	-
BOD	400	277	331	-	30
Phosphate	0.02	0.67	0.09	-	

Source: Field work, (2020).

It is evident that the poor designs, rooftops and practices of rural RWHS have affected the quality of harvested rain water in the area. This is also an indication that the collected rain water may be detrimental to the health of the rural dwellers when ingested or used for other domestic uses without treatment. Other studies have affirmed that human health consequences are linked to the type of rainwater harvesting systems design and maintenance [21, 25].

3.4. Results of Heavy Metals/Microbiological Pollution of Harvested Rainwater Quality and Health Risks

It is given that these heavy metals, arsenic, cadmium, cobalt, chromium, copper, mercury, manganese, nickel, lead, tin, uranium, and titanium are classified as highly toxic [21]. Findings in this study showed that the lead content in Sample A, (aluminum rooftop) had 1.76, sample B (concrete) had 0.21 and Sample C (zinc) had 2.43 were higher than the acceptable [21] health guideline of 0.01. The zinc rooftop had the highest value of (2.43) followed by aluminum material. The presence of lead in rain water is traceable to environmental activities and rain water collection from zinc rooftop. When rainwater comes in contact with zinc roofs, the lead content used to coat the zinc roof dissolves or corrodes in rainwater and hence, contaminates the rain water making it unfit for drinking [26-28]. Besides, zinc roof used, the sand mining and agricultural activities in the area could be major contributors to the release of dust particles deposited on rooftops. A similar study carried out in Australia investigated by Magyar, et al. [27] opined that lead flushing along with roof structure was believed to be sourced from rainwater lead content. Further, Huston, et al. [29] in his study also confirmed the detection of lead and in higher proportions showed that the rainwater samples were connected to high industrial activity. Previous studies discovered that there is health risks associated with lead contamination in rainwater. Studies found that lead contamination can trigger mental and personality disorder in children, while long term exposure of lead in adults can cause anemia and damage the human Intelligence Quotient (IQ) and the reproductive organs in males [30, 31]. In pregnant women, longer exposure to lead can trigger miscarriage and lead can freely pass from the mother to the child and trigger lead prenatal contamination [30, 32].

Also, cadmium content in Sample A was (0.01), sample B, (0.52) and Sample C, (1.45). All the values of cadmium content in the 3 samples were higher than the WHO acceptable limits of (0.003). The highest cadmium content was Sample C the zinc roof material, followed by Sample B, the concrete rooftop and the aluminum material. Cadmium is a toxic metal and is a cumulative toxin according to Morais, et al. [33] and Mudgal, et al. [34] it affects kidneys, human reproductive and endocrine systems, and disturbs bones metabolism

Zinc content indicated its highest values in Sample C, (05.43mg/l), followed by Sample A, (04.98mg/l) and Sample B, (04.43mg/l). Findings showed that samples from zinc roofing sheets had the highest values of zinc concentration, followed by aluminum and concrete tiles rooftops. The 3 rooftops all have metallic components in them though the zinc rooftop is made purely from fine zinc sheets. This is an indication that rainwater from zinc rooftop is contaminated due to corrosion. Metallic materials are the predominant materials of construction used for rooftops in the area and unfortunately, they are generally susceptible to corrosion consequently, major corrosion and degradation acts on metals and alloys. Short exposures of rainwater contaminated with zinc can have adverse health effects such as stomach cramps, nausea and vomiting. However, long exposure can result in anemia, damage of pancreas and decrease levels of high-density lipoprotein (HDL) cholesterol [35].

The microbiological analysis results Table 3 showed that higher levels of coliforms were detected in the sampled rain water. The confirmatory coliform test was positive in Samples A (aluminum rooftop) with total coliform (TC) of 12 MPN/100mL and Sample C (zinc rooftop) (TC) of 14 MPN/100mL. Sample B, (concrete rooftop) was within the acceptable standards of WHO recording the lowest total bacteria counts (TC) of 10MPN/100mL. These findings showed poor microbiological quality of the rainwater probably caused by birds and animals that live around rural area. Also, fecal matter that contains these microorganisms can also be carried with the dust and windstorms and deposited on catchment areas. This finding is supported by a study carried by Ahmed, et al. [36].

From the foregoing, it can be seen that a difference exists between the mean value of the data collected by the researcher and the standard given by WHO In order to verify if this difference is significant or not (that is, not caused by some error that might have been encountered during the cause of collecting the data) ANOVA was conducted. The ANOVA was used to verify if the mean difference between the parameter value and WHO standard is significant or not. From Table 4, the critical value was obtained from the F-distribution to be 1.29 at 0.05 significant level with the degree of freedom of numerator (d. f. N) = 13 and the degree of freedom of denominator (d. f. D) = 14.

$F_{critical}$ (13, 14 at 0.05) = 2.50

From the ANOVA table above, the $F_{calculated}$ was obtained to be 1.29

The summary of the hypothesis test is given in Table 4.

Table-4. Summary of hypothesis test.

Groups	Count	Sum	Average	Variance		
pH	2	13.43	6.715	1.23245		
Nitrates	2	61.85	30.925	727.7113		
Sulphates	2	487.58	243.79	75109.13		
Temperature	2	54	27	8		
TSS	2	50.65	25.325	1217.711		
TDS	2	284.18	142.09	23289.14		
Zinc	2	17.07	8.535	61.27245		
ead	2	1.11	0.555	0.59405		
Cadmium	2	0.513	0.2565	0.128525		
Hardness	2	188.25	94.125	69.03125		
Cnductivity	2	121.25	60.625	3100.781		
Turbidity	2	76	38	288		
Phosphates	2	1.22	0.61	0.3042		
Coliform	2	21.88	10.94	1.7672		
ANOVA						
Source of Variation	SS	Df	MS	F	P-value	F crit
Between Groups	124420.2	13	9570.781	1.289927	0.320711	2.507263
Within Groups	103874.8	14	7419.628			
Total	228295	27				

Source: Field work, (2020).

Decision rule: Accept H_o if F_{crit}>$F_{cal.}$, otherwise reject the H_o. Since F_{cal} (2.50) is greater than F_{crit}(1.29) at 0.05 significant level, the H_o is rejected and H_i is accepted. In other words, there is a significant difference between rainwater quality of Orsumoghu and World Health Organization (WHO) standard.

There were no findings on health risks of the presence of high concentration levels of heavy metals (zinc, lead and cadmium) in the study area. There could be quite a number of reasons for that, there may not be yet evidence of disease linked with drinking rainwater contaminated by metals in the community. There could also be that no case of health-related issues have been reported or diagnosed medically by health authorities since majority of the dwellers are involved in herbal medicine. More so, according to Oregon Health Authority [37] metal poisoning side effects are cumulative in scope and it takes time for the symptoms to appear, making incidents of metals poisoning hard to diagnose in a timely manner. Arguably, it has also been suggested that many people can develop immunity to rainwater pathogens or that they suffer from asymptomatic infections of minor infection with mild symptoms that go unnoticed or untreated [38].

4. RECOMMENDATIONS/CONCLUSION

The emphasis of this paper is to highlight the potential of RWH as a viable means to achieve household water security as well as promote the development of sustainable solutions to the water problems in the community. Harvested rainwater, though more reliable than some alternative sources, can become unsafe for potable uses. The three main sources of concern in this study were the unsafe design/maintenace and the construction of the system, debris that accumulates on the collection surface area and washes into the storage vessels, and possible health risks. The type of design and material used in RWH is critical to water quality. Making sure materials used are not dangerous to rural health since the metallic rooftops react with rainwater to contaminate it.

The study obtained physio-chemical and microbiological parameters values that were within WHO standards for portability except for pH, coliform and heavy metals (zinc, lead, cadmium) exceeded WHO standards. Anthropogenic activities such as mining activities and agriculture have influenced the ambient air quality negatively. The elevated heavy metals concentrations, acidity levels and bacteria in the rainwater makes water unwholesome for drinking and could have health risks in the nearest future. The findings from this study showed that roof types have significant effects on the quality of harvest rainwater.

It is given that anthropogenic activities such as agriculture and mining activities in the study area could have influenced the ambient air quality negatively and contributed to unsafe harvested rainwater. Owing to this, preventive measures for protecting the quality of the water and the health of the users include the use of a well-designed RWHS which will incorporate preventive measures against contamination.

Sanitary actions such as timely cleaning of gutter to ensure that water does not stagnate inside the gutter pipes which can lead to mosquito breeding. Trees should be trimmed to eradicate the access of birds and animals to the roof and remove leaves and animal droppings which contribute to organic loading and nutrient for bacterial growth. Health risks are minimized when proper precautions are taken.

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REFERENCES

[1] A. Akanwa, S. Onwuka, A. Okoye, and F. Onwuemesi, "Assessment of groundwater quality around open waste dump sites in Ifejika and Obosi in Anambra State, Nigeria," *Anachem Journal*, vol. 5, pp. 903-910, 2011.

[2] A. O. Akanwa and A. U. Okonkwo, "Challenges of water and sanitation coverage in Nigeria: Implications for best practice. On transforming Nigeria through the sustainable development goals: Options for environmental management," in *A Paper Presented at the Annual Conference for Environmental Management Association of Nigeria (EMAN),Nigeria, 6-8 Dec 2017*, 2017.

[3] UNEP, "Rainwater harvesting from rooftop catchments. Retrieved from the sourcebook of alternative technologies for freshwater augmentation in Latin America and the Caribbean." Retrieved from: www.oas.org/usde/publications/unit/oea59e/ch10.htm, 1997.

[4] Global Development Research Center (GDRC), *An introduction to rainwater harvesting -general description*. Osaka, Japan: GDRC, 2002.

[5] Texas Water Development Board (TWDB), "Texas guide to rainwater harvesting 2nd Ed," 1997.

[6] M. M. Bello and M. Nike, "Rainwater harvesting, quality assessment and utilization in Kwali Area, FCT, Abuja," *Journal of Engineering and Technology*, vol. 10, pp. 60-69, 2015.

[7] D. Christopher, K. Farahbakhsh, and C. Leidl, "Assessment of rainwater quality from rainwater harvesting systems in Ontario, Canada," *Journal of Water Supply: Research and Technology—AQUA*, vol. 58, pp. 117-134, 2009.Available at: https://doi.org/10.2166/aqua.2009.013.

[8] B. Carolina and Mendez, "Effect of roof material on water quality for rainwater harvesting system," *Published by Texas Water Development Board, Austin. International Rainwater Catchment Systems Association (IRCSA). Domestic Roof Water Harvesting for Low Income Countries*, 2010.

[9] S. K. Sharma, "Roof top rainwater harvesting technique in an urban area, a case study from India," *NOVATECH. Geological research Institue, India, Session 1.3*, 2007

[10] M. Visanathan, A. Ammerman, E. Eng, G. Gartlehner, K. N. Lohr, and D. Griffith, "CBPR: Assessing the evidence," *Evidence of Report/Technology Assessment N0 99 (MD): Agency for Healthcare Research and Quality*, 2004.

[11] B. A. Israel, A. J. Schulz, E. A. Parker, and A. B. Becker, "Review of community-based research: Assessing partnership approaches to improve public health," *Annual Review of Public Health*, vol. 19, pp. 173-202, 1998.Available at: https://doi.org/10.1146/annurev.publhealth.19.1.173.

[12] I. Jawad, M. Al-Ghazali, and M. Khorshid, "Effect of domestic storage tanks on the quality of drinking waters," *Environmental Monitoring and Assessment*, vol. 11, pp. 79-87, 1988.Available at: https://doi.org/10.1007/bf00394514.

[13] R. R. Shretha, *Eco home for sustainable water management- A case study in Kathmandu.* Kathmandu: United Nation Development Program, 2010.

[14] Rainwater and Urban Design, presented at the IRCSA XIII Conference. Sydney, Australia, 2007.

[15] T. Hatum and J. Worm, *Rainwater harvesting for domestic USE.* Wageningen: Agrosima and CTA, 2006.

[16] Rainwater Club, *Rainwater harvesting: Rain barrel.* Bangalore: Rainwaterclub, 2011.

[17] Yamane, *Statistics: An introductory analysis*, 2nd ed. New York: Harper and Row, 1967.

[18] APHA Standard Methods for the Examination of Water and Wastewater, *Standard methods for the examination of water and wastewater*, 20th ed. Washington, D.C: American Public Health Ass WPCF and AWWA, 1998.

[19] APHA, *Standard methods for the examination of water and wastewater* 20th ed. Washington, D.C: American Public Health Ass. WPCF and AWWA, 1998.

[20] R. Kim, S. Lee, Y. Kim, J. Lee, S.-K. Kim, and S. Kim, "Pollutants in rainwater runoff in Korea: Their impacts on rainwater utilization," *Environmental Technology*, vol. 26, pp. 411-420, 2005.Available at: https://doi.org/10.1080/0959333260861854.

[21] WHO, *Adverse health effects of heavy metals in children.* Geneva, Switzerland: Children's Health and the Environment, 2011.

[22] C. B. Mendez, J. B. Klenzendorf, B. R. Afshar, M. T. Simmons, M. E. Barrett, K. A. Kinney, and M. J. Kirisits, "The effect of roofing material on the quality of harvested rainwater," *water Research*, vol. 45, pp. 2049-2059, 2011.

[23] G. D. Gikas and V. A. Tsihrintzis, "Effect of first-flush device, roofing material, and antecedent dry days on water quality of harvested rainwater," *Environmental Science and Pollution Research*, vol. 24, pp. 21997-22006, 2017.Available at: https://doi.org/10.1007/s11356-017-9868-6.

[24] R. Chance, T. D. Jickells, and A. R. Baker, "Atmospheric trace metal concentrations, solubility and deposition fluxes in remote marine air over the south-east Atlantic," *Marine Chemistry*, vol. 177, pp. 45-56, 2015.Available at: https://doi.org/10.1016/j.marchem.2015.06.028.

[25] C. Evans, P. J. Coombes, and R. Dunstan, "Wind, rain and bacteria: The effect of weather on the microbial composition of roof-harvested rainwater," *Water Research*, vol. 40, pp. 37-44, 2006.Available at: https://doi.org/10.1016/j.watres.2005.10.034.

[26] C. E. Chubaka, "Lead, Zinc, copper and cadmium content of water from South Australian rainwater tanks.," *International Journal of Environmental Research and Public Health*, vol. 15, p. 1551, 2018.

[27] M. I. Magyar, V. G. Mitchell, A. R. Ladson, and C. Diaper, "Lead and other heavy metals: Common contaminants of rainwater tanks in Melbourne," in *In Proceedings of the Water Down Under, article 409*, 2008.

[28] M. Kashem and B. Singh, "Metal availability in contaminated soils: I. Effects of floodingand organic matter on changes in Eh, pH and solubility of Cd, Ni andZn," *Nutrient Cycling in Agroecosystems*, vol. 61, pp. 247-255, 2001.

[29] R. Huston, Y. Chan, H. Chapman, T. Gardner, and G. Shaw, "Source apportionment of heavy metals and ionic contaminants in rainwater tanks in a subtropical urban area in Australia," *Water Research*, vol. 46, pp. 1121-1132, 2012.Available at: https://doi.org/10.1016/j.watres.2011.12.008.

[30] S. Martin and W. Griswold, "Human health effects of heavy metals," *Environmental Science & Technology*, vol. 15, pp. 1–6, 2009.

[31] E. Rossi, V. McLaughlin, J. Joseph, M. Bulsara, K. Coleman, C. Douglas, and A. Robertson, "Community blood lead survey with emphasis on preschool children following lead dust pollution in Esperance, Western Australia," *Australian and New Zealand Journal of Public Health*, vol. 36, pp. 171-175, 2012.Available at: https://doi.org/10.1111/j.1753-6405.2011.00814.x.

[32] WHO, *Childhood lead poisoning*. Geneva, Switzerland: NLM Classification, 2010.

[33] S. Morais, F. G. Costa, and M. de Lourdes Pereira, "Heavy metals and human health," Environmental Health-Emerging Issues and Practice, Jacques Oosthuizen, InTech,Open. DOI: 10,5772/29869. Retrieved from: https://www.intechopen.com/books/enviornmnetal-health-emerging-issues- and-practice/heavy-metals-and-human-health, 2012.

[34] V. Mudgal, N. Madaan, A. Mudgal, R. B. Singh, and S. Mishra, "Effect of toxic metals on human health," *The Open Nutraceuticals Journal*, vol. 3, pp. 94–99, 2010.

[35] Public Health Statement, "Department of Health and Human Services "ZincPublic Health Services services," Agency for Toxic Substances and Disease registry ATSDR #: 7440-66-6, Division of Toxicology, August, 2005.www.atsdr.cdc.gov/ Springfield, VA 22161, 2005.

[36] W. Ahmed, K. Hamilton, P. Gyawali, S. Toze, and C. Haas, "Evidence of avian and possum fecal contamination in rainwater tanks as determined by microbial source tracking approaches," *Applied and Environmental Microbiology*, vol. 82, pp. 4379-4386, 2016.Available at: https://doi.org/10.1128/aem.00892-16.

[37] Oregon Health Authority, "Heavy metals and your health: Frequently asked questions about testing, treatment and prevention," *OHA 9560*, 2016.

[38] P. S. Macomber, "Guidelines on rainwater catchment systems for Hawaii, Department of Natural Resources and Enviornmrntal Management, College of Tropical Agriculture and Human Resources, University of Hawaii at Manoa," 2001.