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Physico-chemical Quality of Harvested Rainwater from Some Settlements in Uyo, Nigeria

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Authors' contributions

This work was carried out in collaboration amongst all authors. Author EAM designed the study and performed the laboratory analyse. Author IIU performed the statistical analyses and plotted all the graphs. Author GAE managed the literature searches and wrote the first draft. All authors read and approved the final manuscript.

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ABSTRACT

The use of harvested rainwater for domestic purposes is on the increase in Nigeria, as public water is inadequate as a result of population increase. This study sought to determine the quality of harvested rainwater from some settlements in Uyo, Nigeria, and assess the suitability of the water for domestic household use. Harvested rainwater samples were collected from selected household tanks at Ikot Ntuen Oku, Afaha Oku, Ikot Oku, Mbiabong and Ifa Atai areas of Uyo. Analyses for physico-chemical parameters including pH, electrical conductivity, total dissolved solids, turbidity, total hardness, total alkalinity and acidity, dissolved oxygen, total suspended solids, were done using standard APHA methods. Trace metals were measured using atomic absorption spectrophotometric techniques. The physicochemical parameters measured were below the WHO limits for portability except for dissolved oxygen. The pH values recorded ranged from 5.54 to 6.38 with an overall mean of 5.90; TDS levels ranged from 9.68 to 15.02 mg/l with an average value of 11.8 mg/l while the turbidity values ranged from 2.3 to 3.8NTU. For the nutrients, nitrate levels ranged from 0.97 to 2.1 mg/l with a mean of 1.55 mg/l while the chloride levels ranged between 2.12 and 4.42 mg/l with a mean value of 3.65 mg/l. Levels of trace metals were within WHO recommended limits except for Fe, Cd, and Cu. Some of the results indicated that Cr level was

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0.001 mg/l for all sampling points while Zn levels ranged from 1.04 to 1.75 mg/l with a mean value of 1.44 mg/l. Correlation studies showed that Fe was from natural sources while Cr, Mn, Cu, Zn and Cd were from anthropogenic sources. These results indicated expected adverse effects from the consumption of the harvested rainwater with respect to Fe, Cd and Cu. Appropriate treatment of the rainwater to improve quality before use is recommended. This will help improve the water quality and provide portable water for households in the communities.

Keywords: Harvested; rainwater; household tanks; suitability; consumption; portability; Uyo.

1. INTRODUCTION

Water is an essential resource that is needed for the survival of all living organisms. The availability of this treasured resource is however increasingly being threatened as the population of humans increases and the demands for high quality water for domestic and economic purposes go up [1]. Globally, there is shortage of potable water. As a result, different means and ways of assessing and storing water are being explored. Several types of water sources, such as wells, ponds, rivers or springs are traditionally used for different purposes and they may not be operational all year.

One of the free sources explored to cushion the effects of water shortages is rainwater harvesting [2]. Rainwater harvesting is practiced in areas that have considerable amount of rainfall but do not have conventional water supply systems [3]. When rain falls, water is collected either directly or through catchment systems for storage and eventual use. The technology involves gathering rainwater from the roofs of houses, schools, etc., using gutters and downpipes (made of local wood, bamboo, galvanized iron or PVC), and channeling it to storage containers that range from simple pots to large tanks. Water may then be obtained from the storage tanks by a tap, hand-pump, or bucket-and-rope system.

As rain falls from the clouds to the ground, it washes pollutants from the air and in the process, take up pollutants [4]. The quality of water collected in a rainwater harvesting system is affected by factors such as the nature of the catchment system and the roof materials, environmental pollution from industries, automobiles as well as the presence of dirts, debris and birds or rodents droppings on roofs and rainwater catchment systems [3]. These contaminants might cause health risks from the consumption of contaminated water from the harvesting systems [5].

Statistics on access to water in Nigeria are conflicting, due to divergent definitions, indicators and methodologies applied by different agencies, as there is hardly any monitoring sector [6]. As of year 2000, about 80% of all government-owned water systems in small towns were non-operational [7]. For example, out of the 85 million people living in urban and semi-urban areas, less than half have reasonable access to reliable water supply [8]. According to the World bank [7], water production facilities in Nigeria are “rarely operated to capacity due to broken down equipment, or lack of power or fuel for pumping.” “The scarcity” of potable water has resulted in the practice of harvesting water in rural communities, especially in the rainy season for domestic use throughout the year.

Akwa Ibom state, Nigeria is located in the south-southern part of Nigeria. The climate of Akwa Ibom State can be described as a tropical rainy type which experiences abundant rainfalls with high temperature. The mean annual temperature of the state lies between 26 and 28℃, while the mean annual rainfalls ranged from 2000 to 3000 mm, depending on the area. Naturally, maximum humidity is recorded in July while the minimum occurs in January. Evaporation is high with annual values that range from 1500 to 1800 mm.

Many studies have been conducted on the physicochemical characteristics and health risks of harvested rain water from other places [1,3,5,9]. However, no such reports are available for Akwa Ibom, Nigeria. This study was therefore designed to assess the physicochemical properties of harvested rainwater in Uyo, Akwa Ibom state in Nigeria and assess the suitability of the harvested water for domestic use.

2. METHODOLOGY

2.1 Description of the Study Area

The study area was Uyo in Akwa Ibom State, Nigeria. It lies at Latitude 5.0333° North and Longitude 7.9167° East. It has a total land mass of 115 km^2 and lies 45m above the sea level. Rainfall is significant most months of the year and the short dry season has little effect. It is the largest city in the State and has a mix of urban and rural settlements. Five (5) semi-rural settlements were selected for the study, they were; Ikot Ntuen Oku, Afaha Oku, Ikot Oku, Mbiabong and Ifa Atai. Map of the study area showing sampling locations are shown in Fig. 1.

2.2 Sample Collection

Harvested rain water samples were collected from six selected household tanks at the five study locations. The tanks were made of plastic (PVC) materials connected to aluminum roofing sheets using PVC pipes. A total of 30 water samples were collected for the study using polyethylene bottles. Sampling was done fortnightly between the months of May and August, 2015. Prior to the collection of samples, bottles were washed several times with de-ionised water and left to drip dry. At the site, the containers were rinsed twice with the rain water samples before filling the bottles with the rain water. The water samples were subsequently taken to the laboratory for analyses.

2.3 Determination of Physicochemical Parameters in Harvested Rain Water

Methods for the measurement of physicochemical parameters are routine. Laboratory analyses of rain water samples for pH, electrical conductivity, total dissolved solids and turbidity were determined using a portable pH meter model 3320 JENWAY combined conductivity/TDS meter and nephelometer respectively. Total hardness, total alkalinity and acidity were determined using titrimetric methods. Dissolved Oxygen and total suspended solids were determined using a TDS-salinometer model #18579 and gravimetric methods respectively. Nitrates, phosphates, fluorides, chlorides and sulphates were determined using a UV-visible smart spectrophotometer (model 2000) as described by [10]. The determination of trace metals was carried out using the flame atomic absorption spectrophotometer Unicam' 969 equipped with air-acetylene atomization gas mixture as described by [11].

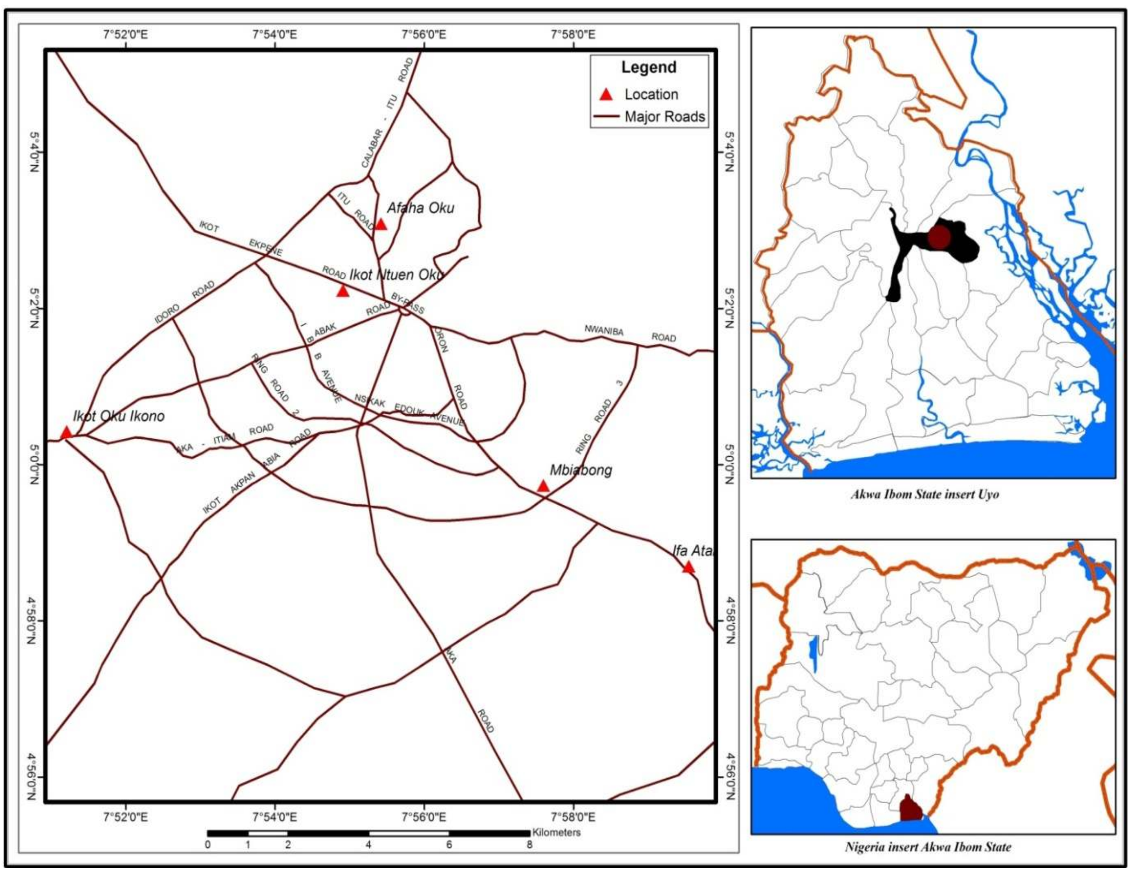

Fig. 1. Map of Akwa Ibom showing sampling locations

2.4 Statistical Analysis

Means of results were compared using analysis of variance (ANOVA) and differences were considered significant at P = 0.05. Pearson's correlation analysis was used to determine the relationship between pairs of parameters.

3. RESULTS AND DISCUSSION

3.1 Physicochemical Parameters

The results for the physicochemical analyses of harvested water from Uyo are presented in Table 1. The pH values recorded ranged from 5.54 to 6.38 with an overall mean of 5.90. The highest pH of 6.38 was recorded from tanks at Afaha Oku and the least were from Ifa Atai tanks. These values indicted that the harvested water to be slightly acidic and below the WHO recommended values of between 6.5 and 8.9. According to [1,12], the pH values of the tank water indicate that industrial and motor vehicle emissions did not contribute significantly to rainwater in the locations where these samples were taken. However, it has been reported that tanks may neutralise some acidity through reaction with dust and organic matter also collected in the tank [1,12]. The mean pH value of harvested water obtained from this study was lower than the mean value obtained from Ayanfuri, Ghana, reported by [12]. It was comparable to values obtained from Wukari and Anambra state, Nigeria, reported by [3,13], respectively. It was however, higher than pH values of harvested rain water from Obuasi, Ghana, reported by [14]. Statistically, there were no significant differences ($p > 0.05$) in pH among the study areas.

The conductivities of the harvested water were generally low with values ranging from 10.4 to 31.6 µs/cm and a mean value of 23.28 µs/cm. The values were lower than the WHO standard limit of 900 µs/cm for drinking water. As noted by [15], the low electrical conductivity of harvested rainwater shows minimum atmospheric contamination with particulate matter. The values reported in this study are comparable to those obtained in other studies reported by [16,1,15]. The results generally indicate good atmospheric condition of the areas sampled.

Total dissolved solids (TDS) concentrations ranged from 9.68 to 15.02 mg/l with an average value of 11.8 mg/l. These values are within the recommended WHO limit of 600 mg/l for portable water. This indicates that the harvested water is good and can be used as portable water. Storage of the water may be responsible for the low TDS, as dissolved solids can precipitate following storage and deposit at the bottom of storage containers thereby reducing the levels of dissolved solids in the water [10]. TDS values obtained in this study were higher than the values obtained from other places like, Ile-Ife, Nigeria and Ayanfuri, Ghana, reported by [1,17] respectively. The values however, lower than values obtained from Oko, Nigeria, reported by [13].

Alkalinity, acidity and hardness had respective values which ranged from 32 to 64 mg/l, 40 to 64 mg/l and 28 to 40 mg/l. Alkalinity of the water was below the WHO limit of 1000 mg/l. The alkalinity recorded in this study were however higher than those reported by [1,13]. According to [10], alkalinity of water results from the presence of HCO_3^-, CO_3^{2-} and OH^- . The results show low availability of the ions in the water.

The general mean for hardness was 34.2 mg/l which was low compared to WHO standard value of 500 mg/l. Hardness of water results from the effects of calcium carbonate and magnesium carbonate on water [16] and hardness of water has been linked to heart diseases [18,19]. However since the harvested water were soft, there were no expected adverse effect of the water for domestic use. Acidity of water in this study is below the WHO maximum contaminant levels. The low acidity showed that the harvested water would not possess corrosive properties. The variability of the parameters across the locations ($P<0.05$) might be attributed to differences in environmental conditions and anthropogenic activities among the various locations.

Turbidity values ranged from 2.3 to 3.8NTU. These values were low compared to the WHO limit of 5 NTU. High turbidity reflects the presence of particulate matter in the atmospheric air that is highly influenced by anthropogenic activities such as mining. Low turbidity values recorded in this study might be due to the fact that the harvested water were sampled from rural communities with no mining or other major particulate producing anthropogenic activities. The results recorded in the present study are different from those obtained from other areas in Nigeria, reported by [3,16]. The results are also different from those obtained from Ghana, reported by [1,15]. The turbidity of harvested water from the areas sampled conformed to the acceptable standards guidelines for potable water.

The dissolved oxygen (DO) contents of the analysed water were between 9.8 and 12.8 mg/l. Although there were no variations in the DO values of water harvested from the study locations except at Mbiabong, the DO values were higher than the WHO limits of 1- 4 mg/l. The higher values may be due to high microbial loads or a product of photosynthesis due to algae growth in the tanks. DO is one of the most important indicators of water quality. It makes the water taste better. However, high levels of DO may speed up corrosion in water pipes [20].

3.2 Nutrients

The concentrations of nutrients in harvested water are shown in Fig. 2. Mean sulphate level was 5.85 mg/l which was lower than the WHO limit of 400 mg/l. Mean nitrate concentration was 1.55 mg/l which was lower than the WHO limit of 10 mg/l. Concentration of phosphate was 2.1 mg/l which is comparable to the WHO limits of 2.5 mg/l. Chloride concentration was 3.65 mg/l. This value was far lower than the 250 mg/l limit set by EPA for portable water. The concentration of fluoride for harvested water was 0.69 mg/l which was below EPA set limit of 2.0 mg/l. Conentration were all below recommended limits and their levels would not pose threat to human health from consumption of the harvested water.

Table 1. Physicochemical parameters of harvested rainwater samples collected from five semi rural settlements in Uyo

Parameters	Study locations				
	Ikot Ntuen Oku	**Afaha Oku**	**Ikot Oku**	**Mbiabong**	**Ifa Atai**
pH	5.81	6.38	6.12	5.65	5.54
Conductivity(µs/cm)	31.6	23	20	19.4	22.4
TDS (mg/l)	15.02	11.49	10.4	9.68	12.42
TSS (mg/l)	24.86	4.15	4.32	15.68	5.72
Alkalinity (mg/l)	64	48	64	32	60
Acidity (mg/l)	56	64	40	48	58
Hardness (mg/l)	36	32	28	40	35
DO (mg/l)	11.4	10.6	12.2	9.8	12.8
Turbidity (NTU)	3.8	3.1	2.3	2.7	3.2

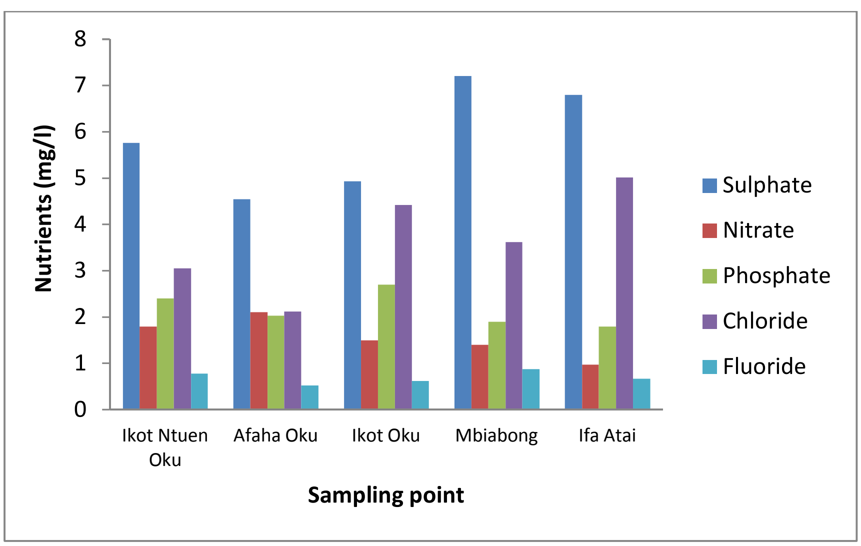

Fig. 2. Nutrients levels in the harvested rainwater samples

3.3 Trace Metals

The levels of trace metals in harvested rain water are shown in Fig. 3. The mean concentration of Fe was 0.54 mg/l. The Fe concentrations of most of the harvested water samples exceeded WHO limits 0f 0.3 mg/l for portability. Concentrations of Cu was 0.37 mg/l. The mean value was lower than 0.4 mg/l WHO limit. Cr level of the harvested water samples was 0.001 mg/l for all sampling points. This value was lower than the WHO limit of 0.05 for portable water. Concentrations of Zn was 1.44 mg/l. There is no health based guideline value for Zn in drinking water. Zn is an essential element, although it gives an undesirable astringent taste to water at levels above 4 mg/l [21]. The average concentration level of Zn in the harvested water samples indicated that the harvested water were palatable for drinking.

Mean Cd concentrations was 0.29 mg/l. This value was higher than the WHO limit of 0.003 mg/l Cd for portable water. Cd accumulates in the human body affecting negatively several organs such as liver, kidney, lung, bones, placenta, brain and the central nervous system [3]. The source of Cd in the water is however not known from this study.

Mean Cu concentrations was 0.29 mg/l. There were no significant variations (P<0.05) in the Cu levels among the various locations. The Concentrations of Cu obtained from this study were lower than the WHO limit of 1.0 mg/l for portable water. Trace metal concentrations varied from results obtained in other studies by [12,22,23,24]. These might have been due to differences in environmental factors and anthropogenic activities in the location of those other studies. The metal levels were higher than the WHO guideline values for portable water except for Cu, Cr, Mn and Zn.

3.4 Correlation Studies

Pearson's correlation matrixes for pairs of measured variables are shown in Table 2. Low to negative correlations existed for TDS and trace metals, indicating different sources to their inputs other than particulate matter. Similarly, low to negative correlations existed between TDS and the measured anions, showing different sources of their contamination and interactions in the water.

Sulphates correlated significantly with Zn, Cu and Fe, indicating possible similar sources or strong interactions among the measured species. Weak to negative correlations existed between nitrates and other species, indicating different sources for the input of nitrates into the water. For the trace metals moderate to strong correlations existed for Cd and Mn; Zn and Cu; and Cu with Mn. These indicated that the trace metals Zn, Mn and Cu are possibly influenced by the same anthropogenic sources that contributed to their atmospheric concentrations or there are strong interactions between them in the water. Sources of atmospheric Zn, Mn and Cu include municipal incineration, refuse burning and automobile exhaust. There were generally low correlations between Fe and the other trace metals, measured. This indicated different sources and no interaction between Fe and the other metals. Fe is a natural component of particulate matter; therefore its inputs into the water may be as a result of biogenic sources.

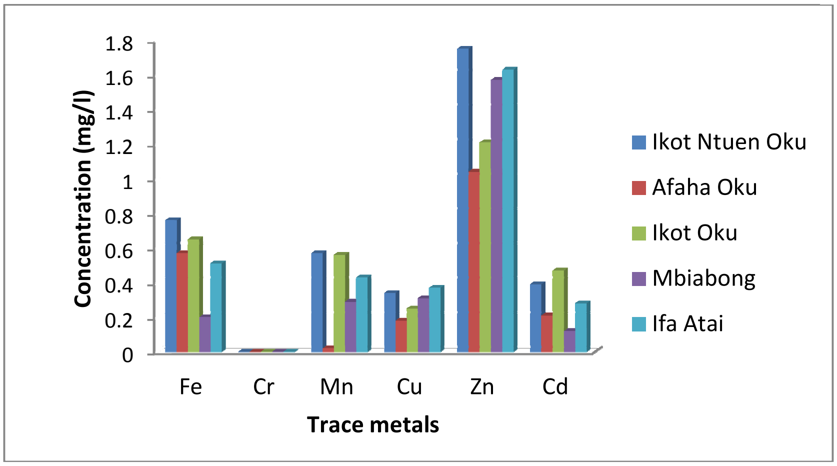

Fig. 3. Levels of trace metals in the harvested rainwater samples

Table 2. Pearson's correlation coefficients between pairs of variables

Parameter	TDS	Alk	SO_4^{2-}	NO_3^-	PO_4^-	Cl^-	F^-	Fe	Cr	Mn	Cu	Zn	Cd
TDS	1												
ALK	0.61*	1											
SO4	-0.09	-0.41	1										
NO3	0.19	-0.06	-0.73	1									
PO4	0.12	0.59	-0.6	0.32	1								
Cl-	-0.17	0.31	0.49	-0.93	-0.008	1							
F-	-0.04	-38	0.79*	-0.35	-0.16	0.19	1						
Fe	0.71*	0.89*	-0.66	0.37	0.63*	-0.13	-0.46	1					
Cr	*	*	*	*	*	*	*		1				
Mn	0.36	0.64*	0.2	-0.45	-56	0.62*	0.39	0.41	*	1			
Cu	0.41	0.19	0.8*	-0.74	-0.25	0.62*	0.68*	-0.09	*	0.63*	1		
Zn	0.51	0.09	0.76*	-0.5	-0.22	0.36	0.8	-0.07	*	0.57	0.94*	1	
Cd	0.39	0.9*	-48	0.01	0.85*	0.31	-0.26	0.82*	*	0.75*	0.06	-0.01	1

- *Correlation is significant at P =0.05 level (2 tailed)*

**Correlations for Cr were not calculated as the values were all about 0.001 mg/l*

4. CONCLUSION

In this study, the physicochemical parameters measured were below the WHO standard limits for portability except for dissolved oxygen. Levels of trace metals in the water were within recommended limits except for Fe, Cd and Cu. Correlation studies showed different sources for interaction between Fe and the other trace metals measured. The levels of Fe, Cd and Cu in the harvested water from the study sites, indicated expected adverse effects from the consumption of harvested water with respect to the three trace metals (Fe, Cd and Cu). It is recommended that the harvested rain water be treated appropriately before use for portable purposes. This will help complement or improve the water quality thereby providing portable water for households in the communities. Future studies would seek to identify the atmospheric contributions of the parameters measured in the harvested water as well as their bacteriological profile.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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