QUANTITY, QUALITY AND STORAGE OF HARVESTED RAINWATER FOR POULTRY PRODUCTION IN NORTHERN AKWA IBOM STATE, NIGERIA

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ABSTRACT

Adequate water supply is a growing constraint for poultry producers because they are not served by government piped water network and individuals must make alternative arrangements for their water needs. Adequate water supply is a growing constraint for poultry producers. Roof-harvested rainwater of adequate quantity and acceptable quality provides alternative supply of water but needs storage during non- rain periods. This study investigates the adequacy of harvested rainwater, quantity and storage requirements as well as quality assessment for small and medium scale layer chicken production in Akwa Ibom State. The research design for the study is basically survey design and experimental design. The instruments used for investigation are questionnaire survey, face to face interview and observation. Experimentation was done in the laboratory to investigate physical, chemical and microbiological samples of rain water from the households in Akinima community. Monthly rainfall, water use, housing characteristics and average roof catchment areas data were input to the mass curve principle and used to predict the maximum storage for the production scales. The dimensionless graph principle was then employed to scale down the maximum storage to the required storage. Average demand in all the LGAs in the study was less than 50% and 42% of supply for 500 and 1000 chicken population respectively. Water quality index assessment of the rainwater based on WHO standards showed excellent quality ranging between 0.876 – 38.453 in all the LGA's. These findings establish that rainwater can be harnessed for poultry production in the study area. The study can be extrapolated to other areas.

KEYWORDS: Akwa Ibom State, Poultry production, Rainwater storage, Water harvesting, Water quality index.

1. INTRODUCTION

Water is an important component of broiler-farming success. It not only influences birds' performance and growth, but also has a direct impact on biosecurity, feed conversion and profitability. (Fairchild and Ritz, 2012). Many poultry farmers, particularly in rural parts of Akwa Ibom State do not have reliable source of water (Eja *et al*., 2020). Governments' interventions through the provision of hand-operated boreholes and wells are often community-based. In Northern part of Akwa Ibom State, the geological condition and mineral-based water pollution makes it difficult for groundwater extraction. Similarly, in the southern part of the state, saline water intrusion and petroleum based pollution impair water quality (Akpabio, 2009). These problems can also be found in other tropical parts of the world, where rainwater harvesting has arisen as a possible solution to mitigate this situation (Sánchez *et al*., 2015). Consequently, there is a very wide gap between water needs and supplies across the Northern and Southern parts of Akwa Ibom State. As a result, there is high dependence on rainwater harvesting as an alternative source of water supply especially for rural dwellers (Chiagoziem and Chioma, 2015).

Securing rainwater for poultry production entails the determination of the demand, the supply and storage requirements for water. Developing ideal storage depends on rainfall amount and variability, catchment surface area, type of roofing materials, collection efficiency and water use rates (Eli *et al*., 2021). The storage tank size is by far the largest factor of the total installation cost hence, its optimization is vital. The mass curve analysis (Olsen and Baetz, 2005) is used to estimate storage requirement and the dimensionless graph principle is employed to scale down the tank size for the scenario where demand is lower than supply.

Furthermore, rainwater quality explicated by the risk of pollution especially due to commercial and industrial activities, urbanization and dense traffic affects rainwater use (Udousoro and Unanaowo, 2015) and make quality assessment of water inevitable. Threats to health can be identified and prevented through water quality monitoring and assessment. Water Quality Index (WQI) is one of the most effective approaches for quick estimation and communication of information on the quality of any water resource to decision makers. The WQI is a mathematical equation used to transform large numbers of water quality data into a single number and promotes understanding of water quality issues by integrating complex data and generating a score that describes water quality status (Reza and Singh, 2010).

Not much research has been done to assess the quantity and storage needs and acceptability in quality of rainwater for poultry production in Akwa Ibom State. Scanty data exist on water quality indices for the assessment of different water resources in Akwa Ibom State including stream, borehole and pipe borne water (Etim *et al*., 2013), and Groundwater (Umoh *et al*., 2020). Data for Water Quality Index of Rainwater for Uyo Metropolis has been reported by Udousoro and Unanaowo (2015). However, there is no data on the water quality index of harvested rainwater for other parts of the state mostly Northern Akwa Ibom where there is compelling need for rain water harvesting. Hence, the present study aimed at determining the supply and storage requirements of rainwater using the mass curve analysis and assessment of quality through WQI of rainwater harvested in the five northern Local Government Areas (LGAs) of Akwa Ibom State in Nigeria.

2. MATERIALS AND METHODS

2.1 Description of the study area

Northern Akwa Ibom State comprises five LGA's and represents 27 and 21.4% of total land area and population respectively of the state (Figure 1).

The area is located between latitudes 5^{O}.00 and 5^{O} 31'N and longitudes 7^{O} 30' and 8^{O} 15' E and has a tropical climate marked by two distinct seasons: The dry season (November – March,) and the Wet season (April – October). The wet season is usually interrupted by a short dry period in August. Average temperature of the state ranges from 23 to 31°C. Annual rainfall average of 2000 and 2100 mm are recorded on the northern and southern fringes respectively (AKSG, 2021).

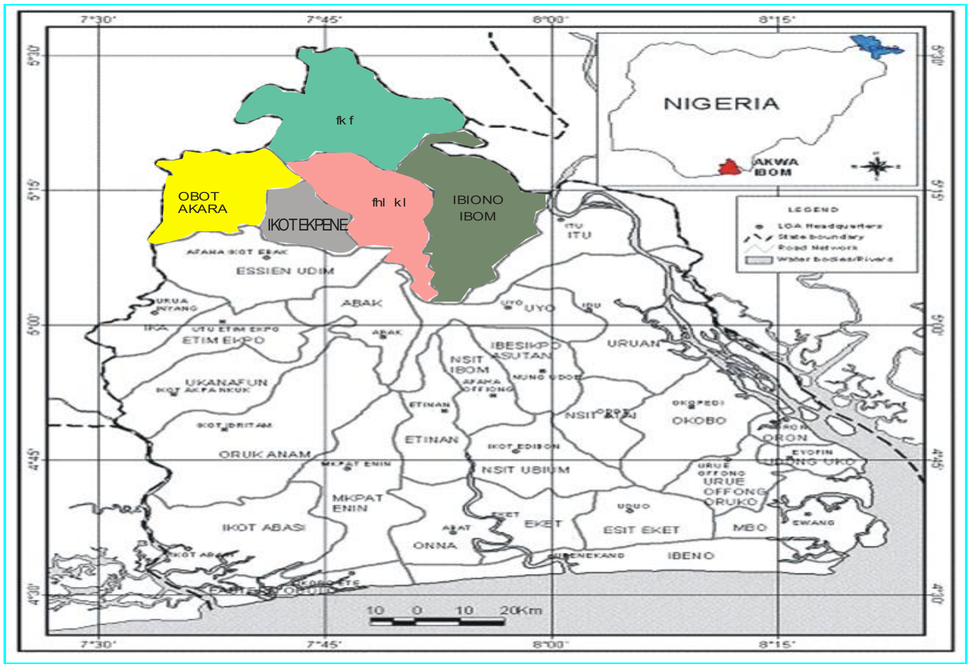

Figure 1**:** Map of Akwa Ibom State showing the study area.

2.2 Sample Size and Sampling Techniques

The research design for the study is basically survey design and experimental design. The instruments used for investigation are questionnaire survey on scale of poultry production, observation on roof materials and direct measurements on floor area to verify the rainwater harvesting and utilization practices as well as available rainwater for harvesting. Experimentation was done in the laboratory to investigate physicochemical properties of rainwater samples from the study area.

The population for the study consisted of all poultry farmers registered with the Ministry of Agriculture in Akwa Ibom State numbering 3082. Twenty-four farmers respectively were selected at random from the five (Ibiono, Ikono, Obot Akara, Ikot Ekpene and Ini) participating LGA's through balloting. A total of 60 poultry houses covering the five participating LGAs were visited between November and March for interviews and direct measurement of characteristics of poultry houses. The direct measurements included the length, width, floor area, roof area, number of birds, roofing materials and type of roof of the poultry houses. .

Event sampling of rainwater in the study area was undertaken at ten sampling locations randomly selected from the sampled poultry houses during the month of March, May, July and November to capture the effect of the major seasons on the rainwater quantity and quality. Rainwater was collected from poultry roof catchments in well labeled one litre plastic bottle washed with distilled water and fitted with plastic funnel of 35 cm diameter. The assembly was placed on a wooden stool two meters high and sited in an open space away from obstruction. Rainwater samples collected for physiochemical analyses were transported under controlled temperature in a cooler and refrigerated at 4^{O}C in the laboratory till all the parameters were analyzed at Akwa Ibom Water Company (AKWC) laboratory, Uyo.

2.3 Catchment area

The total amount of rain water that is available depends on the size of the catchment area (A). For a roof of length L m and width W, the roof area can be expressed as (Equation 1).

$$A = LW \tag{1}$$

where:
A = catchment area (m^2),
L = roof length (m),
W = roof width (m)

2.4 Rainwater supply and demand

Actual monthly rainfall data for one decade (2012-2021) for the study area was obtained from the
Victor Attah International Airport, Akwa Ibom State, on the southern fringe of the study area and Michael Okpara University of Agriculture, Umudike on the northern border of the study area respectively. These locations represent the situation of the study area. The rainfall records were combined to estimate the cumulative rainwater supply (Oti and Skinner, 2012) (Equation 2).

$$S = \sum [APZ] \tag{2}$$

where,
S = Cumulative rainwater supply (m^3),
A= Catchment area (m^2),
P= Rainfall over given time period (mm),
Z = Runoff coefficient (which depends on the type of roofing material).

The cumulative demand for rainwater was estimated by summing the daily per capita basic requirements (D) for layer chickens and attendants use for the number of days (N) in the given month (Oti and Skinner, 2012) (Equation 3).

$$D_C = \sum [DN] \tag{3}$$

where:
D_c = Cumulative demand (m^3/day),
D = Daily per capita demand (litres/capita/ day),
N = number of days in the given month.

2.5 Storage requirement

The per capita basic water requirement (BWR) was estimated as 182 litres per day for each poultry attendant where there is running water in the kitchen, bathroom and laundry (Mustafa and Yusuf, 2012). The BWR for the layer chicken was estimated at 35 litres per 100 birds per day (Mustafa and Yusuf, 2012). Equation (2) and (3) were combined to give storage requirement in Equation (4) (Olsen and Baetz, 2005) which was used for the mass curve analysis.

$$S_k = \sum [APZ - DN] \qquad 4$$

where:

S_k = Storage requirement after month k (m^3)

$$S = MAX\lfloor S_k \rfloor \qquad 5$$

where:

S = Maximum storage requirement (m^3)

Equation 4 was iterated twelve times with values incrementing by one accordingly. When the difference between supply and demand reached a maximum, the resulting volume became the required storage capacity of the rainwater harvesting system (Equation 5). The mass curve and dimensionless graph principles (Oti and Skinner, 2012) make up the core rainwater simulation methods used in this study. The calculations comprising the simulations that give rise to the dimensionless graph are based on the conventional rainwater supply equations considered for the condition of rainfall in the state as stated in Equation 4. The basis of the dimensionless graph is the assumption that demand must always be less than supply (Oti and Skinner, 2012). As such average annual supply values need to be scaled-down based on percentages to obtain corresponding demand figures.

$$D_c = S_p \qquad 6$$

where:

p = percentage for scaling-down average monthly supply.

The cumulative values of average annual supply and average annual demand are then compared to estimate the final storage as given in Equation 7.

$$V_{max} = S_{kp} \qquad 7$$

where:

V_{max} = scaled-down volume of tank, (m^3)

The data could be plotted in a graph and used as reference for reading off different demand levels.

2.6 Water Quality Index

To get a comprehensive picture of overall quality of rainwater, the WQI was used. WQI is defined as a rating reflecting the composite influence of different water quality parameters on the overall quality of water (Kothari *et al*., 2020). The World Health Organization (WHO) standard specified for drinking water (WHO, 2022) was used for the calculation of WQI. The WQI was computed through three steps. First, each of the fourteen parameters in the study was assigned a weight (w_i) according to its relative importance in the overall quality of water for drinking purposes Second, the relative weight (W_i) of the chemical parameter was computed using Equation 8, (Kothari *et al*., 2020).

$$W_1 = \frac{w_1}{\sum_{i=1}^{n} w_1} \qquad 8$$

where:

W_1 is the relative weight,
w_i is the weight of each parameter and,
n is the number of parameters.

In the third step, a quality rating scale (qi) for each parameter is assigned by dividing its concentration in each water sample by its respective standard according to guidelines, and the result is multiplied by 100.

$$q_i = \left(\frac{C_1}{S_1}\right) \times 100 \qquad 9$$

where:

q_i is the quality rating,
C_1 is the concentration of each chemical parameter in each water sample in mg/L,
and S_1 is the WHO drinking water standard for each chemical parameter in mg/L.

For computing WQI, the sub index (SI) is first determined for each chemical parameter, as given below (Kothari *et al*., 2020).

$$SI = W_i \times q_i \qquad 10$$

The water quality index is then computed by Equation 11 (Kothari *et al*., 2020) as:

$$WQI = \sum SI_{i-n} \qquad 11$$

where:

SI_i is the sub index of ith parameter,
W_i is relative weight of ith parameter;
qi is the rating based on concentration of ith parameter, and
n is the number of chemical parameters.

The computed WQI values are classified into five categories: excellent water (WQI < 50); good water (WQI = 50 –100); poor water (WQI = 100–200); very poor water (WQI = 200–300); and water unsuitable for drinking (WQI > 300).

3. RESULTS AND DISCUSSION

Scale of poultry operation and characteristics of poultry houses are presented in Tables 1 and 2.
In Tables 1 and 2, the scale (number of chicken) of poultry operation is equivalent to characteristics (operation) of poultry houses. In Table 1, majority of the farmers in the study area

(65.8%) operate at the small scale level. The medium scale farmers constitute 30.8% while the large scale farmers constitute only 3.4% of the layer producers in the study area.

Table 1: Percentage Questionnaire Responses on Scale of Poultry Operation

Number of chicken	Frequency	Per Cent	Scale of production
< 500	79	65.8	Small
500-1000	34	28.3	Medium
1000-3000	3	2.5	Medium
3000-5000	2	1.7	Large
>5000	2	1.7	Large
	120	100	

Table 2: Percent Response on Characteristics of Poultry Houses

Direct measurement			Observed	Calculated	
Floor area(m^2)	Frequency	Percent	Roof materials	Roof Coefficient	Catchment (m^2)
100<200	42	60	*CGS	0.85	18.7
200-400	24	34	CGS	0.85	374
400-1000	2	3	CGS	0.85	935
1000-1800	1	1.4	CGS	0.85	1683
>1800	1	1.4	CGS	0.85	1870
	70	100			

*CGS: Corrugated galvanized sheet.

The dominant roof material is corrugated galvanized sheet (CGS). Other roof of the poultry house may be thatched, tiled, asbestos or concrete one depending on the cost involvement. Table 2 indicates that 96.6% of available space is utilized by small and medium scale producers.

3.2 Rainwater storage requirements based on supply and demand

Tables 3-5 show the spread sheet calculation for sizing the storage tanks for 500 chickens using the mass curve principle for Ibiono/Ikono, Obot Akara/Ikot Ekpene and Ini LGA's respectively. The mass curve method is more commonly used for determining the capacity of a storage reservoir (Oti and Skinner, 2012). It takes into consideration the accumulated supply and demand from the tank and; the capacity of the tank is calculated as the greatest excess of water above consumption. For Table 3, the greatest excess of water above consumption (shown in bold face in all the tables) occurred in December with a storage requirement of 271.2 m^3.

The monthly average rainfall data are presented in column number (2). The rainfall trend shows a gradual increase from the month of March up to the peak in September after which it prominently decreases from December to February. These three months are the dry months of the year. The mean annual rainfall ranged between 1754-2294 mm resulting in monthly rainwater supply of between 342 - 429 m^3 for roof catchment of 203.5m^2 and 500-layer chicken. Tables 6-8 show the calculation for sizing the storage tanks for 1000 chickens for Ibiono/Ikono, Obot Akara/Ikot Ekpene and Ini LGA's respectively. It takes into consideration the accumulated supply and demand from the tank and again the capacity of the tank is calculated as the greatest excess of water over and above consumption. For Table 6, the greatest excess of water over and above consumption occurs in November with a storage requirement of 538.9 cubic meters.

Table 3**:** Sizing of storage tank for 500 layer chickens using mass curve for Ibiono/Ikono LGA

Months	Monthly Rainfall (mm)	Monthly Supply (m^3)	Cum. supply	Monthly Demand (m^3)	Cum. Demand	Total Storage (m^3)
January	20.2	3.5	3.5	13.39	13.4	-9.9
February	21.7	3.7	7.2	12.53	26.9	-19.7
March	174.5	30.2	37.4	13.39	39.3	-1.9
April	188.6	32.6	70.0	12.96	52.3	17.7
May	260	49.1	119.1	13.39	65.7	53.4
June	261.6	45.3	164.4	12.96	78.6	85.8
July	320.0	55.4	219.8	13.39	92.0	127.8
August	302.0	52.2	272.0	13.39	105.4	166.6
September	324.1	56.1	328.1	12.96	118.4	209.7
October	280.3	48.5	376.6	13.39	131.8	244.8
November	121.6	21.0	379.6	12.96	144.7	252.9
December	18.3	31.7	429.3	13.39	158.1	**271.2**
Total	2293.5			158.09 m^3		

Table 4: Sizing of storage tank for 500 layer chickens using mass curve for Obot Akara/Ikot Ekpene

Months	Monthly Rainfall (mm)	Monthly Supply (m^3)	Cum. supply	Monthly Demand (m^3)	Cum. Demand	Total Storage (m^3)
January	15.3	2.6	2.6	13.39	13.4	-10.8
February	19.1	3.3	5.9	12.53	26.9	-20.0
March	139.5	24.1	30.0	13.39	39.3	-9.3
April	151.1	26.1	56.1	12.96	52.3	3.8
May	208.5	36.1	92.2	13.39	65.7	26.5
June	209.3	36.2	128.4	12.96	78.6	49.8
July	239.5	41.4	169.5	13.39	92.0	77.5
August	241.5	41.8	211.3	13.39	105.4	105.9
September	259.3	44.9	256.2	12.96	118.4	137.8
October	224.1	38.8	295.0	13.39	131.8	163.3
November	97.0	16.8	311.8	12.96	144.7	167.1
December	21.7	37.5	349.3	13.39	158.1	**191.2**
Total	1825.			158.09		

Table 5: Sizing of storage tank for 500 layer chickens using mass curve for Ini LGA.

Months	Monthly Rainfall (mm)	Monthly Supply (m^3)	Cum. supply	Monthly Demand (m^3)	Cum. Demand	Total Storage (m^3)
January	41.1	7.1	7.1	13.39	13.4	-6.3
February	18.2	3.1	10.2	12.53	26.9	-15.7
March	136.2	23.6	33.8	13.39	39.3	-5.5
April	148.5	25.7	59.5	12.96	52.3	7.2
May	202.9	35.1	94.6	13.39	65.7	28.9
June	190.7	33.0	127.6	12.96	78.6	49.0
July	230.2	39.8	167.4	13.39	92.0	75.4
August	239.8	41.5	208.9	13.39	105.4	103.5
September	253.9	43.9	252.8	12.96	118.4	134.4
October	159.7	27.6	280.4	13.39	131.8	148.6
November	98.3	17.0	297.4	12.96	144.7	**152.78**
December	20.6	3.6	301.0	13.39	158.1	142.9
Total	1754.1			158.09		

Table 6**:** Sizing of storage tank for 1000 layer chickens using mass curve for Ibiono/Ikono LGA

Months	Monthly Rainfall (mm)	Monthly Supply (m^3)	Cum. supply	Monthly Demand (m^3)	Cum. Demand	Total Storage (m^3)
January	20.2	6.8	6.8	21.14	21.1	-14.6
February	21.7	7.3	14.1	17.78	38.9	-24.8
March	174.5	58.7	72.8	21.14	60.1	12.7
April	188.6	63.5	136.3	20.46	80.5	55.8
May	260.6	87.5	223.8	21.14	101.7	122.1
June	261.6	87.9	311.7	20.46	122.1	189.6
July	320.0	107.7	419.4	21.14	143.3	276.1
August	302.0	101.7	521.1	21.14	164.4	356.7
September	324.1	109.1	630.2	20.46	184.9	445.3
October	280.3	94.3	724.5	21.14	206.0	518.5
November	121.6	40.9	765.4	20.46	226.5	**538.9**
December	18.3	6.2	771.6	21.14	247.6	524.0
Total	2293.5		8849.02	247.60		

Table 7: Sizing of tank for 1000-layer chicken with mass curve for Obot Akara/Ikot Ekpene

Months	Monthly Rainfall (mm)	Monthly Supply (m^3)	Cum. supply	Monthly Demand (m^3)	Cum. Demand	Total Storage (m^3)
January	15.3	5.1	5.1	21.14	21.1	-16
February	19.1	6.4	11.5	17.78	38.9	-27.4
March	139.5	47.0	58.5	21.14	60.1	-1.6
April	157.1	52.9	111.4	20.14	80.5	30.9
May	208.5	70.2	181.6	21.14	101.7	79.9
June	209.3	70.5	252.1	2014	122.1	130.0
July	239.5	80.6	332.7	21.14	143.3	189.4
August	241.5	81.3	414.0	21.14	164.4	249.6
September	259.3	87.3	501.3	20.14	184.9	316.4
October	224.1	75.4	576.7	21.14	206.0	370.7
November	97.0	32.7	609.4	20.14	226.5	**382.9**
December	21.7	7.3	616.7	21.14	247.6	369.1
Total	1831.9		675.4	247.6		

Table 8: Sizing of storage tank for 1000 layer chickens using mass curve for Ini LGA.

Months	Monthly Rainfall (mm)	Monthly Supply (m^3)	Cum. supply	Monthly Demand (m^3)	Cum. Demand	Total Storage (m^3)
January	14.1	4.7	4.7	21.14	21.1	-16.5
February	18.2	6.1	10.8	17.78	38.9	-28.1
March	136.2	45.8	56.6	21.14	60.1	-3.5
April	148.5	50.0	106.6	20.46	80.5	26.08
May	202.9	68.3	174.9	21.14	101.7	73.2
June	190.7	64.2	239.1	20.46	122.1	117.0
July	230.2	77.5	316.6	21.14	143.3	173.3
August	239.8	80.4	397.0	21.14	164.4	232.6
September	253.9	85.5	482.5	20.46	184.9	297.6
October	209.7	70.6	553.1	21.14	206.0	347.1
November	89.3	30.1	583.2	20.46	226.5	**356.7**
December	20.6	6.9	590.1	21.14	247.6	342.5
Total	1754.1		649.1	247.6		

Table 9: Adjusted tank volume for 500 layers in Ibiono/Ikono LGA).

Annual demand	Annual supply	Demand as % of supply	Total storage	% Storage of supply	Therefore volume of tank
158.09 m^3	429.3 m^3	158.09/439.3 x 100 = 37%	271.2 m^3	271.2/429.3 x 100 = 63%	63% x 271.2 = 170 m^3

Table 10: Adjusted tank sizes for studied LGAs

LGA	Nos. of Layers	(2) Roof catchment (m^2)	(3) Mean annual rainfall (mm)	(4) Annual demand (m^3)	(5) Annual supply (m^3)	(6) Demand as % of supply	(7) Total Storage (m^3)	(8) % storage of supply	(9) Adjusted Volume of tank (m^3)
Ibiono/	500	205.5		158	429.3	37	271.2	63	170
Ikono	1000	396	2294	248	771.6	32	538.9	70	376.4
ObotAkara/	500	203.5		158	349.3	45	191.2	55	104.7
Ikot Ekpene	1000	396	1826	248	616.7	40	382.9	62	237.7
Ini	500	203.5		158	301	52	152.7	50	77
	1000	396	1754	248	590.1	42	356.7	60	215.6

The monthly demands which are the sum of 182 litres/day for one attendant sanitation and 50 litres/100 chickens per day are given in column number (4). The variation in the consumption during the different months of the year is accounted for by considering the number of days in the month. Total demand in all the LGAs in the study was 158 and 248 m^3 for 500 and 1000 layer chickens respectively for all the LGAs in the study. From Tables 6 - 8, total demand was 37, 45 and 52 per cent respectively compared to total rainwater supply from 203.5 m^2 roof catchment and 500 chickens.

Similarly, total demand for 1000 chickens and roof catchment of 396 m^2 shown in Tables 6-8, were 32, 40 and 42 per cent of total rainwater supply. Apart from the dry months of the year when demand was greater than supply, supply was far greater than demand in the study areas. Consequently, demand as percentage of supply for 500 chickens (Tables 3-5), was only 37 percent for Ibiono/Ikono, 45 percent for Obot Akara/Ikot Ekpene and 52 percent for Ini LGAs.

Equally, for 1000 chickens (Tables 6-8), 32, 40 and 42 were the percentages of demand to supply. The total storage to meet the demands is shown in bold type in tables 3-5 and 6-8 respectively. The total storage presented in column number (6) is the difference between the monthly supply and the monthly demand (Helou and Shaheen, 2000). Clearly these values are very high compared to the demands and will result in very large and expensive storage structure. Thus, the dimensionless graph principle (Oti and Skinner, 2012), can be applied to adjust the storage tank volumes calculated in the field to a level commensurate with the demand based on the level of production and study area.

Table 9 shows the computation of adjusted tank volume for Ibiono/Ikono LGA from maximum storage of 253 m^3 to adjusted volume of 170m^3 which is 33 per cent less than the maximum storage. The adjusted tank volumes for the different production levels and roof catchments in the studied LGA's are presented in Table 10. The adjusted tank volumes are less than the total annual demand but greater than the total dry month demands except for Ibiono/Ikono LGA which could be attributed to sampling errors which is a major deficiency of the Rippl method.

In order to be able to use rainwater all year round, a minimum storage capacity of 3 months during the critical dry period is needed. If other sources of water are used to meet non-potable uses, with some level of discipline in water use pattern, the adjusted size of the storage tank could be reduced to a much more affordable size.

Since rainwater supply is higher than the demand in the considered scales of production, rainwater is adequate and farmers may take all their water needs from the rainwater harvesting systems (RWHS) that has the catchment areas used in this study. Using prefabricated cisterns will lower the initial cost of storage tank since type of tank materials will often govern the choice of tank size.

3.3 Quality of rainwater

The results of the mean characteristics of the harvested rainwater are shown in Table 11.

Table 11 indicates the mean characteristics of rainwater in Northern Akwa Ibom State. Temperature of sampled rainwater varied in the LGAs with a decreasing trend as one moves from Uyo, the state capital with mean annual temperature of 33.4 °C towards Abia State with mean annual temperature of 32.4 °C**.** The rainwater temperatures in these areas were 30.9, 30.2, 29.1, 29, and 28.2 °C for Ibiono Ibom, Ini, Ikot Ekpene, Ikono and Obot Akara respectively.

Table 11: Mean Characteristics of rainwater in Northern Akwa Ibom State

S/N	Parameter	Unit	Ini LGA	Obot Akara LGA	Ikot Ekpene LGA	Ikono LGA	Ibiono Ibom LGA	WHO Standards
1	Temperature	^{O}C	30.2	28.2	29.1	29.0	29.0	25^{O}C
2	Electrical Conductivity		32.7	32.5	33.1	32.6	32.6	1000
3	TDS	mg/L	65.9	65.5	67.0	65.7	65.7	250.00
4	TSS	mg/L	131.2	130.4	133.3	130.8	130.8	250.00
5	Colour	Pt/co	10.0	10.0	12.2	9.9	9.9	15.0
6	Turbidity	NTU	37.0	36.7	37.6	36.9	36.9	5.00
7	Nitrate	mg/L	1.6	2.1	1.8	1.8	2.5	4.00
8	Sulphate	mg/L	16.8	16.0	100.2	16.7	132.9	250.00
9	Iron	mg/L	0.20	0.20	0.26	0.19	0.26	0.3
10	Chloride	mg/L	36.8	35.1	39.8	36.7	41.5	250
11	pH	-	8.1	7.8	7.9	8.0	7.8	6.5-8.5
12	Cadmium	mg/L	0.00	0.00	0.00	0.00	0.01	0.003
13	Chromium	mg/L	0.00	0.001	0.00	0.002	0.001	0.05
14	Lead	mg/L	0.00	0.00	0.001	0.00	0.016	0.01

Conductivity which indicates the value of dissolved salt was 32.7, 32.5, 33.1, 32.6, and 33.6 μ/S cm for Ini, Obot Akara, Ikot Ekpene, Ikono and Ibiono Ibom respectively. Total dissolved solids (TDS) of the rainwater was 65.9, 65.5, 67.0, and 65.7, 67.7 mg/l for Ini, Obot Akara, Ikot Ekpene, Ikono and Ibiono Ibom respectively. TDS describes the inorganic salts and small amounts of organic matter present in solution in water. TDS, or salinity, indicates levels of inorganic ions dissolved in water. Calcium, magnesium, and sodium salts are the primary components that contribute to TDS. High levels of TDS are the most commonly found contaminants responsible for causing harmful effects in poultry production. The values in this study are within allowed limits (WHO, 2022) of 250 mg/L. The values for TSS were 131.2, 130.4, 133.3, 130.8, and 134.7 for Ini, Obot Akara, Ikot Ekpene, Ikono and Ibiono Ibom respectively. Total suspended solids (TSS) cause water to be cloudy. The results obtained in this study are lower than WHO standard of 500 mg/L and therefore has no effect on the quality of the water. The values for colour of the rainwater were 10.0, 10.0, 12.2, 9.9, 12.76, for Ini, Obot Akara, Ikot Ekpene, Ikono and Ibiono Ibom respectively. Colour is usually due to the presence of decaying organic material or inorganic contaminants such as iron, copper, or manganese. As a general observation, a reddish-brown color may indicate the presence of iron, while a blue color indicates the presence of copper. Turbidities were 36.7, 37.6, 36.9, and 42 for Ini, Obot Akara, Ikot Ekpene, Ikono and Ibiono Ibom respectively. Turbidity results from the suspension of materials such as silt, clay, algae or organic materials in water. Levels of turbidity above 5 ppm result in unpalatable water and indicate surface contamination. All the physical parameters of harvested rainwater conformed to the WHO minimum standards for potable water. The nitrate values obtained in this study ranged between 1.6 and 2.5 mg/l. The lowest value was recorded in Ini while the highest value in the study was recorded in Ikot Ekpene LGA. Presence of nitrate in water usually indicates contamination by runoff containing fertilizer or human and animal wastes. Chronic nitrate toxicity causes poor growth, anorexia, and poor coordination. Grizzle *et al*. (1996) demonstrated that nitrate nitrogen levels in the drinking water as low as 3 to 5 mg/l depress broiler growth rate. Sulphate values in the sampled rainwater varied between 16.0 and 132.9 mg/l. These values are below the WHO minimum standard of 250.0 mg/l for poultry drinking water. Suphate occur in rainwater due to the release of industrial effluent into the environment through gas flaring which is rampant practice in Akwa Ibom State (Afangideh and Udokpoh, 2021). This explains the relative higher values in urbanized areas of Ikot Ekpene and Ibiono Ibom LGAs respectively (Table 11). The values of Iron obtained in this study ranged between 0.20 and 0.26 mg/l. The lowest value was recorded in Ini while the highest value in the study was recorded in Ikot Ekpene and Ibiono Ibom LG areas. These values are below the WHO limit of 0.3 mg/l in drinking water. Iron if present in water in large quality could make water bitter and unpalatable for drinking. High levels of iron may encourage the growth of bacteria, which can lead to diarrhea.

Chloride values in the sampled rainwater varied between 35.1 and 41.5 mg/l. These values are within acceptable limits and therefore will have no ill effect on the poultry. Too much chloride has a detrimental effect on metabolism. Studies have shown that a level of 14 ppm (13.97 mg/l) in drinking water can be detrimental to broilers if combined with 50 ppm of sodium (Tabler *et al*., 2014). pH values of 8.1, 7.8, 7.9, 8.9, and 7.8 were recorded for Ini, Obot Akara, Ikot Ekpene, Ikono and Ibiono Ibom respectively. pH indicates the acidity or alkalinity of the rainwater. The values recorded in this study shows that the acidity of the rainwater are below the WHO (2022) standard signifying that rainwater from those locations are slightly acidic. Birds accept water on the acid side (pH less than 7) better than they do water on the basic (or alkaline) side (pH greater than 7). A pH in the range of 6.2 to 6.8 works better for chickens (Tabler *et al*., 2014).

3.4 Water Quality Index

Water quality rating and calculated relative unit weight (Wi) values of each parameter are given in Table 12.

Table 12: Water quality rating and unit weight of Rainwater in Northern Akwa Ibom State

S/N	Parameter	Unit	Ini LGA	Obot Akara LGA	Ikot Ekpene LGA	Ikono LGA	Ibiono Ibom LGA	WHO Standards	Relative weight (W_1) $W_1 = \frac{w_1}{\sum_{i=1}^{n} w_1}$
1	Temperature	O^C	120	112.8	116.4	116.0	116.0	25^OC	0.074
2	Electrical Conductivity	uS/cm	3.27	2.82	3.31	3.26	3.26	1000	0.002
3	TDS	mg/L	26.36	26.20	26.80	26.28	26.28	250.00	0.007
4	TSS	mg/L	52.48	52.16	53.32	52.32	52.32	250.00	0.007
5	Colour	Pt/co	66.67	66.67	81.33	66.0	66.0	15.0	0.124
6	Turbidity	NTU	740	734	752	733	738	5.00	0.371
7	Nitrate	mg/L	40	52.5	45.0	45.0	62.5	4.00	0.464
8	Sulphate	mg/L	6.72	6.4	40.08	6.68	53.16	250.00	0.007
9	Iron	mg/L	66.67	66.67	86.67	63.33	86.67	0.3	6.82
10	Chloride	mg/L	14.72	14.04	15.92	14.68	16.6	250	0.007
11	pH	-	73.33	53.33	60.0	66.67	53.33	6.5-8.5	0.218
12	Cadmium	mg/L	0	0	0	0	3.33	0.003	618.150
13	Chromium	mg/L	0	2.0	0	4.0	2.0	0.05	37.089
14	Lead		0	0	0	0	160	0.01	0.371
									$\sum W_1 = 849.897$

Table 12 presents the calculated water quality rating, and unit weight, while Table 13 presents calculated water quality index (WQI) and status of water quality based on Mishra and Patel (2001). Figure 2 presents the trend in water quality distribution in the study. Rainwater quality index values were 0.876 at Ini LGA, 0.966 at Obot Akara, 3.219 at Ikot Ekpene, 1.024 at Ikono and 38. 453 at Ibiono Ibom LGA's respectively.

Table 13: Calculated water quality index (WQI) and status for rainwater in Northern Akwa Ibom State

S/N	LGA	Water Quality Index	Water quality status*
1	Ini	0.876	Excellent
2	Obot Akara	0.966	Excellent
3	Ikot Ekpene	3.219	Excellent
4	Ikono	1.024	Excellent
5	Ibiono	38.453	Good

*0-25 (Excellent), 25-50 (Good), 51-75 (Bad), 76-100 (Very bad), 100 and above (Unfit) (Mishra and Patel, 2001)

According to Mishra and Patel (2001), index value 0.25 means that the water samples are excellent and 25 – 50 means that is good for human consumption, dissemination of wildlife and fish culture. This means that rainwater at Ini, Obot Akara, Ikot Ekpene and Ikono LGA's are excellent, while rainwater at Ibiono Ibom LGA is good for human consumption, dissemination of wildlife and fish culture which also includes poultry. Urbanization-driven anthropogenic atmospheric impurities picked up by rain contaminate rainwater and increase WQI. This is true for the high value of WQI recorded in Ibiono (38.453). Table 11 shows high concentrations of sulphate and lead in the rainwater samples of Ikot Ekpene and Ibiono. These are urban areas and sulphate occur in rainwater due to the release of industrial effluent into the environment through gas flaring and vehicle exhaust fumes which is rampant practice in the state. This explains the relative higher values of these metals in these areas which is consistent with other studies on the effect of urbanization on rainwater quality (Chiagoziem and Chioma, 2015; Pires *et al*., 2015).

4. CONCLUSION AND RECOMMENDATIONS

The study considered the supply and storage requirements of rainwater using the mass curve analysis and assessment of quality through WQI of rainwater harvested in the five northern Local Government Areas (LGAs) of Akwa Ibom State in Nigeria. Rainfall in the study area provides sufficient volume not uniformly distributed throughout the year. Therefore, storage will make rainwater available during periods without rainfall. Demand as percent of supply was between 37-52 and 32-42 m^3 for 500 and 1000 layers respectively. Average demand in all the LGAs in the study was less than 50% and 42% supply for 500 and 1000 chicken respectively. The storage as percent of supply was between 50-63 and 60-70 m^3 for 500 and 1000 layers respectively. Design of proper storage capacities will provide water throughout the year for commercial poultry production. The quality of rainwater in the study area on the average is excellent. This means Rainwater at Ini, Obot Akara, Ikot Ekpene and Ikono LGA's are excellent, while rainwater at Ibiono Ibom LGA is good for human consumption, dissemination of wildlife and fish culture which also includes poultry. However, urbanization-driven anthropogenic atmospheric impurities picked up by rain contaminate rainwater and increase WQI mostly for Ibiono Ibom LGA on the fringe of Uyo city, the capital of the state. It is recommended that modelling studies be carried out to extrapolate for other poultry stock sizes and areas of Akwa Ibom State and Nigeria at large.

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