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Determination of Water Poverty Index Using Composite Index Approach and Simple Time Analysis Approach

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Abstract— *Growth in human population creates a continuous increasing demand for potable water and matching the demand with the supply of potable water has resulted in loss of human resources and capital, thus affecting activities of nearly every household. This study focused on determination of Water Poverty Index (WQI) using composite index approach and simple time-analysis approach for assessment of water-stressed communities in Mkpat Enin Metropolis. The study adopted an experimental survey design to evaluate water stressed area through administration of a researcher-developed questionnaire. The questionnaires were randomly given to 1000 respondents from each of the five studied communities and the total number of questionnaire issued was 5000 and it was structured in two parts: Part 1 relates to the demographic data of the respondents and Part 2 of the questionnaire focused on two sections as follows: (i) Water sources, quality, quantity and availability in Mkpat Enin metropolis; (ii) Indicators for the computation of water poverty index: resources, access, capacity, use and environmental integrity. All data collected were analyzed using descriptive statistics and modified water poverty index models. The results of the ranking of WPI from the two approaches showed that Ikot Oyoro is the most water-stressed community in the study area with least WPI value of 17.53 points (composite index approach) and highest WPI value of 0.30 points (simple time-analysis approach) while Ikot Akpaden is the least water stressed community in the study area with highest WPI value of 27.54 points (composite index approach) and lowest WPI value of 0.16 points (simple time-analysis approach). Based on the results of the study, it is recommended that improved water harvesting from both surface and underground sources should be encouraged to provide sufficient water for the water-stressed communities in Mkpat Enin metropolis. This will not only improve health, but will also save time since time is power as well as enhancing economic productivity of the inhabitants of the study area.*

Keywords— *Water poverty index, Questionnaire, Respondent, Household, Metropolis.*

I. INTRODUCTION

An adequate supply of safe and clean water is one of the most important factors for sustaining human life and for achieving sustainable growth and development. Water is life and therefore the provision and accessibility of potable water should be paramount to any responsible government (Sullivan, 2007). The importance of water in human life makes its scarcity to be associated with poverty and becomes an offense to human dignity and right (Molle and Mollinga. 2003). According to Usoh *et al. (*2017), a high level of water availability and soil with nutrient together with conducive climate usually ensure an optimal yield and any restriction in the supply of any of these factors is likely to induce a decrease in crop yield and food security. Glawe and Visvanathan (20l0), stated that water availability supports livelihoods in various ways, and the link between access to water and poverty is an established and recognized fact (Stephen *et al.,* 2013). The sensitization of masses becomes highly imperative on this relationship since the provision of a sustained, reliable and safe water still remain a challenge for vast number of people worldwide (Sullivan, 2007). Nta *et al.* (2017) noted that various forms of solid waste generated have destroyed most water bodies and aquatic lives as well as causing human death. Inappropriate waste disposal has major negative consequences on water bodies and human health (Usoh *et al.,* 2022) and lack of appropriate water conservation measures has led to degradation of natural resources like water (Ahuchaogu *et al.,* 2022). Environmental pollution has been a major problem in some States and other urban areas in Nigeria and other parts of the world due to improper waste management system which has attributed to environmental degradation (Usoh *et al.,* 2023a). Thus, in the wake of a growing concern about both the unchecked rise of water poverty and the local and global consequences of water scarcity, the relationships between water and poverty are the object of discussion. They have become an important indicators giving direction to managerial policy and allocation of resources. Several indicators have been used to describe water availability or access and these indicators do offer relative measures of achievement which can serve to direct policy towards the improvement of performance (Carter *et al.,* 2009).

Increase in population growth has created increasing demand for potable water (Usoh *et al.*, 2023b). Water shortages relate to inability of the society to access small volume of water needed for drinking and domestic purposes. In most cases in developing world, women and children particularly spent most of their productive time trekking long distances sourcing for water. Akpabio and Ekanem (2014) in their study observed high occurrence of potable water access burdens on general population of Akwa Ibom State especially the vulnerable group

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as well as reckless incidence of exploitation of the aquifers for private market. Records at Akwa lbom State Water Company Limited (AKWCL) show no evidence of budgetary provision for water sector over the years and Akwa Ibom State Rural Water and Sanitation (AKRUWATSAN) shares the same story (Akpabio and Ekanem, 2014). This implies that water project development and management are in practice outside the realm of the state development and political agenda. Research has shown that more than four million people die yearly due to waterborne diseases linked to potable water scarcity and shortage of safe drinking water (TWAS, 2015). The deteriorating situation of water scarcity and water quality is often slow and not readily noticeable as the water system adapt to the changes until an apparent alteration of the water occurs (Zahraa *et al.*, 2012). These have pose serious concerns and in a quest to tackle these challenges, it requires that relevant monitoring tool like Water Poverty Index (WPI) be employed in the study area for assessment and evaluation of the level of water stress in order to arrive at a decision which will assist in the policy making.

Water Poverty Index (WPl) is defined as the aggregate index that describes lack of fresh water. Fresh water as a natural resource represents a fundamental key to sustainable livelihoods for health, economy and development. In 2002, Sullivan designed and introduced water poverty index as an alternative water assessment tool. Steven *et al*, (2013) states that water poverty index is designed to identify and evaluate poverty level in relation to water resource availability. Water Poverty Index is calculated in some approach using five components including resources, access, capacity, use and environment with indicators describing these components. The evaluation of WPI can be determined through various methods such as: matrix index approach, composite index approach, simple time-analysis approach and gap index approach. Among these methods, composite index approach and simple time-analysis approach were selected for this work due to its simplicity and ability to simplify WPI data without compromising the technical integrity of the data. Hence, the objective of this research was to identify the sources of household water supply in the study area and to determine water poverty index in selected communities around Akwa Ibom State University in Mkpat Enin metropolis.

II. Methodology

2.1 Study Area

This research was carried out at selected communities around Akwa Ibom State University in Mkpat Enin Metropolis of Akwa Ibom State (Figure 1). Mkpat Enin is in the south southern Nigeria and is located between 4°35" and 4° 40" north latitude and 7° 45" and 7° 50" east longitude. Mkpat Enin is in the equatorial zone, which has wet and dry seasons. The most notable attribute of the equatorial environment according to Robert (2015), is its year-round temperature consistency. It sits at an altitude of approximately 185 meters above sea level and has an area of 322.352 square kilometers.

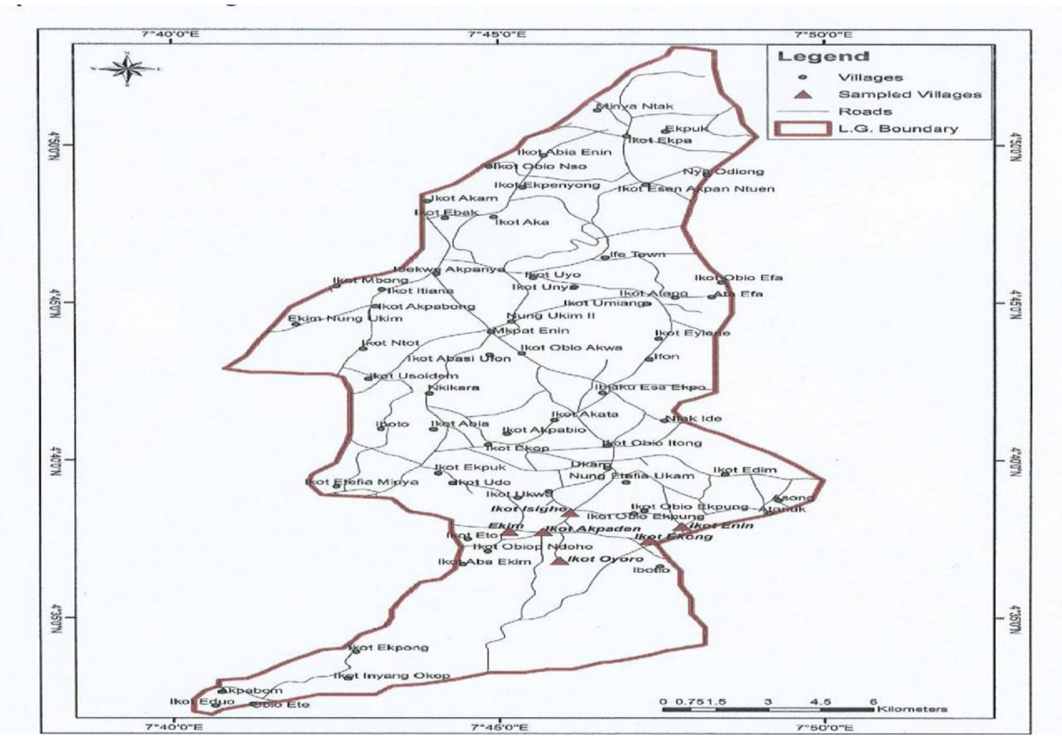

Figure 1: Map of Mkpat Enin Local Government Area (Source: AISMLS, 2020).

2.2 Research Design

The study adopted an experimental survey design to evaluate water stress area in selected communities around Akwa Ibom State University in Mkpat Enin metropolis using water poverty index and through administration of a researcher-developed questionnaire.

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2.3 Population and Sample Site

All households around Akwa Ibom State University (AKSU) in Mkpat Enin metropolis constituted the total population for the study. Judgmental sampling technique was used to select five communities as case study around Akwa Ibom State University (AKSU), Mkpat Enin metropolis. The criterion for this choice was the researcher's adjudge level of development (in terms of infrastructures) in these communities which portrays them as poverty vulnerable and closeness to the tertiary institution (AKSU).

2.4 Instrument for Data Collection

Questionnaires were randomly given to 1000 respondents from each of the five studied communities around AKSU in Mkpat Enin metropolis. Each respondent represents a household. The total questionnaires issued were 5000 and it was structured in two parts: Part 1 relates to the demographic data of the respondents and Part 2 of the questionnaires was further divided into two sections as follows: (i) Water sources, quality, quantity and availability in Mkpat Enin metropolis.
(ii) The indicators for the computation of water poverty index: resources, access, capacity, use and environmental integrity.

2.5 Methods of Evaluation of Water Poverty Index

The WPI is designed mainly to provide a tool with which water engineers and water managers can evaluate water situation in different locations in a holistic way. In order to make strong comparisons in the values of water poverty index estimated in each of the selected communities, WPI values were computed using Composite Index approach and Simple Time-analysis approach.

2.5.1 Composite Index Approach

According to Steven *et al.* (2013), composite index approach is based on the combination of relevant variable components collected and summed, to an index, based on the range of values on each variable in that location. In this approach, the index was constructed from a series of variables which captured the essence of what is being measured using national scale (Carter *et al.,* 2009). A simple relationship for computing WPI taking into consideration all the key variables are as follows:

$$\mathrm{WPI} = \mathrm{WaA} + \mathrm{WsS} + \mathrm{Wt}(100 - \mathrm{T}) \qquad (1)$$

Where
WPI = Water Poverty Index.
A = Adjusted water availability (%).
S = Population with access to safe water and sanitation (%)
T = Index to represent time and effort taken to collect water for the household

For the purpose of this study, (T) was modified to take account of gender and child labor issues as follows: (100 — T). Since A, S, and T are all defined to be between 1 and 100, the relationship in equation (1) is therefore modified as follows:

$$\mathrm{WPI} = \frac{1}{3}(\mathrm{WaA} + \mathrm{WsS} + \mathrm{Wt}(100 - \mathrm{T})) \qquad (2)$$

where Wa, Ws and Wt are the weight given to A, S and T respectively.

2.5.2 Simple Time Analysis Approach

In this method, WPI is constructed using the bottom-up approach considering variables such as total time taken in collecting water and volume of water collected in each trip. For the household with pipe borne water, the volume and time taken to collect water per head is assumed to be the same across members of the household. Using simple time-analysis approach, the index is determined as follows:

$$\mathrm{WPI} = \frac{\mathrm{T}}{\mathrm{V}} \qquad (3)$$

where
T = Total time (in minutes) spent per person in a day to collect water.
V = Volume of water collected in liters.

2.6 Method of Data Analysis

All data collected were analyzed using descriptive statistics (range, mean and standard deviation). Also, modified water poverty index model by Yahaya *et al.* (2009) as given in equation 3.2 and equation 3.3 above were employed in the calculation of water poverty index. Also, figures were used for clarification of results to enhance discussion.

III. RESULTS AND DISCUSSION

3.1 Demography of Respondents

Tables 1 and 2 present the distribution of sex and educational qualification of the respondents. The percentage distribution for each classification of the analyzed variables was expressed relatively to the total number of the retrieved questionnaires being administered. Gender distributions of the respondents showed that majority (53.3 %) of the respondents were male. This may be attributed to the sampling frame. The sampling frame was households and since the instrument was administered to household head which are mostly male. Therefore, the male respondents dominated the sample population.

TABLE 1: Distribution of Respondents by Sex

Sex	Frequency	Percentage (%)
Male	2665	53.3
Female	2335	46.7
Total	5000	100

TABLE 2: Distribution of Respondents by Education

Educational Qualification	Frequency	Percentage (%)
Degree	2585	51.7
Secondary	1665	33.3
Primary	750	15
Total	5000	100

Educational information of the respondents showed that the highest occurring level of education was Degree holders with 51.7 %, followed by secondary school with 33.3 % while the least was primary school with 15 %. The high proportion of tertiary education may suggest that these respondents are functionally literate, that can handle advance environmental problems in the study area.

3.2 Water Sources and Availability in Mkpat Enin Metropolis

Figure 2 presents the distribution of major water sources in the five selected communities around Akwa Ibom State

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University in Mkpat Enin metropolis. Borehole, rain, well, stream and pipe borne water were the five major sources of water analyzed at Ikot Oyoro, Ikot Obio Ndoho, Ikot Ekong, Ikot Akpaden and Ekim in Mkpat Enin metropolis. From the result, Ikot Akpaden community depends more on borehole water. Rain and well were not harvested in the area due to the season being dry. Ikot Oyoro and Ekim communities have a good number of pipe borne water compared to other communities in the study area. Ikot Oyoro and Ikot Obio Ndoho communities depend on stream water besides borehole for water supply. Ikot Ekong and Ikot Akpaden communities depended more on borehole and pipe born water. The source of water being a man-made source was attributed majorly to insufficiency of natural supply. This was because the season of the assessment was dry season with very little amount of rain water. Also, stream source was reduced in volume.

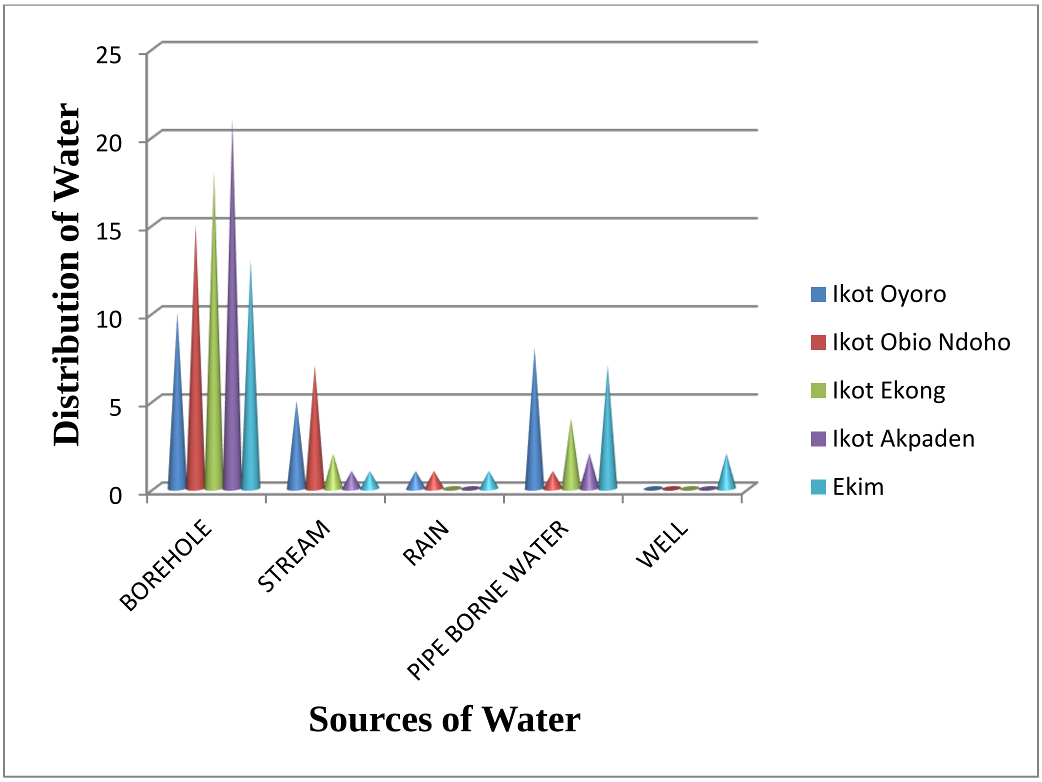

Figure 2: Distribution of Water Sources in the Study Area

3.3 Determination of Water Poverty Index

3.3.1 Composite Index Approach

Figure 3 shows the computed WPI values for the communities using the composite index approach. From figure 3, the results of water poverty index (WPI) obtained using composite index approach showed that Ikot Akpaden community has the highest value of WPI (27.54) while Ikot Oyoro community has the least value of WPI (17.53). This simple analysis shows that Ikot Oyoro community is the most water-stressed community in Mkpat Enin metropolis while water stress was considered to be least at Ikot Akpaden community. The results also showed that dwellers at Ikot Oyoro community still derive their drinking water from a variety of sources such as direct withdrawal from streams and pipe borne water and the community has the least number of borehole facilities (Table 3). Ikot Akpaden community on the other hand had the highest number of boreholes which is at close fetching distance from the residence of the respondents. The people of Ikot Akpaden community rarely visit the stream to harvest water for domestic use.

The relationship between water poverty index and average water fetching time for the communities show that the relationship is not strong (R^2 = 0.68). Thus, WPI can be forecasted even when the water fetching time is known but the result will not be dependable due to a fairly strong relationship. This results is thus in line with Yahaya *et al*, (2009) who computed WPI using composite index approach. A similar result of water poverty index values against average volume of water obtained from each community shows a very weak relationship (R^2 = 0.28). However, the WPI ranges found in this study utilizing the composite index approach are wider than those obtained by Yahaya et al. (2009) in a comparable season. This demonstrates that villages in Akwa Ibom State (south-southern Nigeria) are less water-stressed than those in Ondo State (Western Nigeria). This is likely due to the high levels of precipitation in south-southern Nigeria. This increases the likelihood that natural water reservoirs will be recharged, ensuring that rural people have access to enough water.

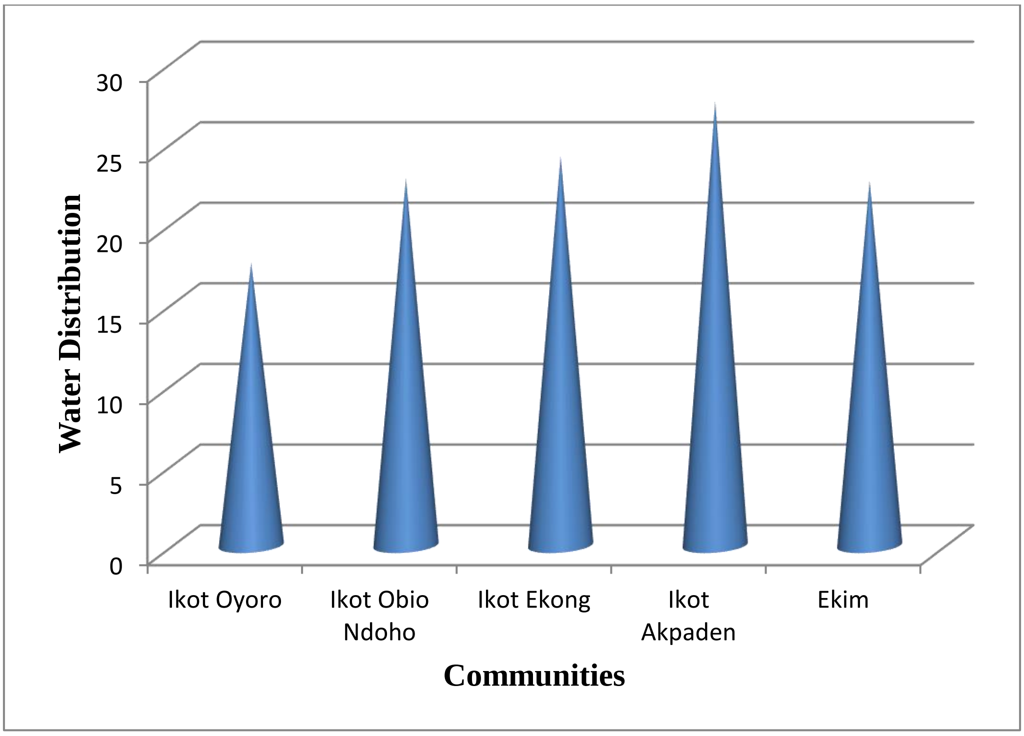

Figure 3: WPI (Composite Index Approach) for Communities in Mkpat Enin Metropolis

TABLE 3: Frequency of Visit by Dwellers to the Water Sources in the Study Area

S/N	Community	Borehole	Stream	Rain	Pipe Borne Water	Well
1.	Ikot Oyoro	10	5	1	8	0
2.	Ikot Obio Ndoho	15	7	1	1	0
3.	Ikot Ekong	18	2	0	4	0
4.	Ikot Akpaden	21	1	0	2	0
5.	Ekim	13	1	1	7	2

3.3.2 Simple Time Analysis Approach

Figure 4 shows the computed WPI values for the communities using Simple Time-analysis approach. The results of water poverty index (WPI) obtained using Simple Time-analysis approach showed that Ikot Oyoro community has the highest value of WPI (0.30 minsL^{-1}) while Ikot Akpaden community has the least value of WPI (0.l6 minsL^{-1}). This simple analysis shows that Ikot Oyoro community is the most water-stressed community in Mkpat Enin metropolis while water stress was considered to be least at Ikot Akpaden community by Simple Time-analysis approach. The results also showed that the dwellers at Ikot Oyoro community fetch less volume of water with a greater time probably because some of the residents still derive their drinking water from streams (Table 3) which are far away from the residential area. Ikot Akpaden residents on the other hand fetch water from sources (borehole and pipe borne water) that are at close proximity to their residential area and thus can have more volume of water at a less time. The relationship between water poverty index and average water fetching time for the communities show that the relationship is not strong (R^2 = 0.56). Thus, WPI cannot be forecasted even when the water fetching time is known. This result is also in line with Yahaya *et al.*, (2009) who computed WPI using the simple time-analysis approach. A similar result of water poverty index values against average volume of water obtained from each community shows a very weak relationship that the relationship (R^2 = 0.14). The ranges of WPI values found in this study utilizing the temporal analysis approach, however, are less than those obtained by Yahaya et al. (2009) in a comparable season.

3.4 Ranking of the Water Poverty Index Results

The WPI ranking for the five communities from the computations of the two different approaches are as presented in Table 4. From the results of the study, the values of the water poverty index using composite index approach indicates that Ikot Akpaden community is least water-stressed while Ikot Oyoro is most water-stressed community. On the other hand, the computed water poverty index using simple time-analysis approach indicates that Ikot Akpaden community is least water-stressed while Ikot Oyoro is most-water stressed followed by Ekim. From Table 4, both approaches show that Ikot Akpaden is the least water-stressed community in the study area. Ikot Oyoro ranked last in both composite index and simple time-analysis approaches. From these computations, Ikot Oyoro tends to be the most water-stressed community in Mkpat Enin metropolis.

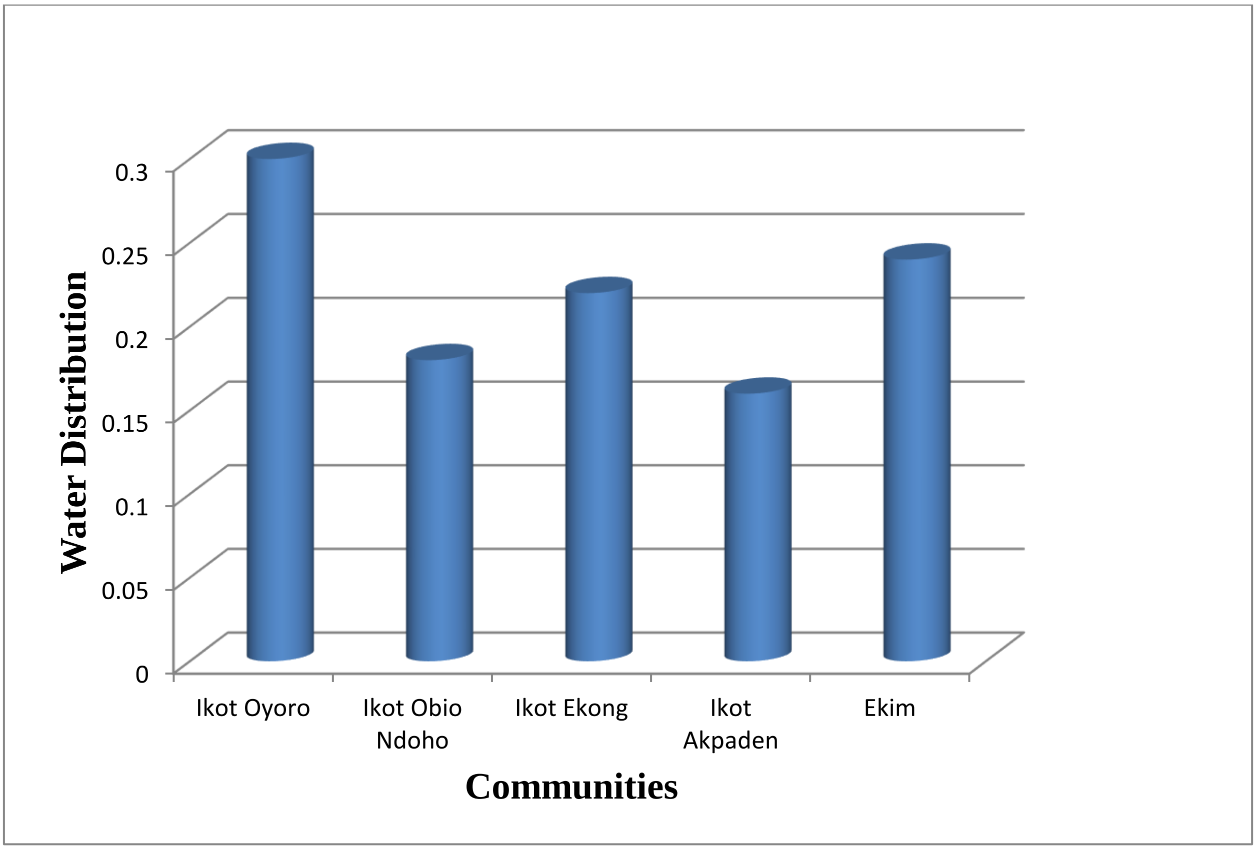

Figure 4: WPI (Simple Time Analysis Index Approach) for Communities in Mkpat Enin Metropolis

TABLE 4. WPI Ranking for Communities in the Study Area

S/N	Community	Composite Index Approach	Time Analysis Approach
1	Ikot Oyoro	5	5
2	Ikot Obio Ndoho	3	2
3	Ikot Ekong	2	3
4	Ikot Akpaden	1	1
5	Ekim	4	4

IV. CONCLUSION

The study evaluated water poverty index using two approaches; composite index approach and simple time-analysis approach to determine the degree of water stress in five communities in Mkpat Enin metropolis. The results obtained from the composite index approach showed that Ikot Akpaden is the least water-stressed community and Ikot Oyoro is the most water-stressed community. The results also showed that using simple time-analysis approach Ikot Akpaden is still the least water-stressed community and also Ikot Oyoro is the most water-stressed community. The results obtained using both composite index approach and simple time-analysis approach showed that Ikot Akpaden community was ranked the least water-stressed community based on the computation of water poverty index and Ikot Oyoro was ranked the most water-stressed community. The results as presented here test our standardized data set and are expected to enhance our understanding of the adverse effects of water poverty to human growth and development and to re-strategize to prevent the occurrence of virtual water where water resources are insufficient for agriculture, drinking and other domestic purposes.

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