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Selecting Best Water Source Using VIKOR Multicriteria Decision Tool (A Case study of Ozoro Community, Delta State Nigeria)

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ABSTRACT: The purpose of the study is to select best water source using VIKOR a Multicriteria decision tool (MCDM) for Ozoro Community that is densely populated due to the presence of Delta State Polytechnic Ozoro. The groundwater table is shallow and individuals resort to drilling of boreholes and hand dug wells and because such method of obtaining water is not well developed it has resulted to several health issues which include but not limited to typhoid, cholera, diarrhea and other water borne diseases. Water samples were collected from three major sources (groundwater, rain, and surface water) at different locations within the study area in the wet and dry seasons. The samples were analyzed for their physico-chemical and bacteriological parameters. The Water Quality Index (WQI) was determined to obtain Quality ratings for the sources while ratings for Capacity, Cost and Technology were obtained as secondary data. The VIKOR approach of MCDM tools was then utilized in selecting the best source. VIKOR results score for ground water is 0.9474, Rainwater is 0.5 and Surface water is 0.1692 for the wet season, while for the dry season, Groundwater is 1, Rain water is 0, Surface water is 0. 4778. This shows that the VIKOR method rank underground as best water source for both seasons, rain second in wet season and last in the dry season, surface water is last for the wet season and second for the dry season

I. INTRODUCTION

Water is found everywhere on earth from the polar ice caps to steamy geysers and wherever water is found, life is sure to be found as well. The NASA's motto, ―"follow the water'' in its hunt for terrestrial life have been derived from this observation (Ziervogel et al, 2010). The importance of water to life has been the reason why the earth is the only known planet to accommodate living organisms

Potable water supply is required to maintain community health. This potable water is gotten from low-risk water supplies obtained either from protected sources or supplied after treatment before usage (Mahwayi and Joseph, 2016). Unprotected water sources include springs, traditional wells and ponds which can however be improved upon instead of constructing new supplies. The amount of water required in a community can be estimated by carrying out a survey to obtain the opinion of community dwellers to ascertain their water consumption rate or by assuming an average water consumption of 98 liters per day for an individual. In the case of insufficient safe water and limited resources, emphasis should be placed on intermediate steps to provide larger amount of lower quality water (Howard et al, 2002).

One approach to solve challenging water problems is the MultiCriteria Decision Making (MCDM) method which comprises of VIKOR

Vise KriterijumskaOptimizacijaIKompromisnoResenje (VIKOR) method is a multi-attribute decision making methodthat defines ideal solutions and negative ideal solutions firstly, and then sorts the alternatives and chooses the best one in the light of all values of each alternative and the approach degree of ideal alternative. It is a compromise decision making method, which not only considers maximum group utility but also considers minimum individual regret. It was developed to solve decision problems with conflicting and non-commensurate (different units) criteria, assuming that a compromise is acceptable for conflict resolution, the decision maker wants a solution that is the closest to the ideal, and the alternatives are evaluated according to all established criteria. VIKOR is a decision-making method

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arising from linear programming (LP) metric aggregate function. Utilizing the MCDM will therefore give stakeholders in the water industry the best choice to make in choosing a water source for communities.

II. SIGNIFICANCE

This study will help stakeholders solve the problems associated with choosing an appropriate water source for Ozoro town which recently has been experiencing influx of people that has resulted to inefficiency of the available water supply system. The study of literature survey is presented in section III, Methodology is explained in section IV, section V covers results of the study, and section VI discusses Conclusion.

III. LITERATURE SURVEY

The Vikor method is a multicriteria decision making method which was first developed by SerafimOpricovic in his Ph.D. dissertation in 1979. It assumes compromise is acceptable for conflict resolution and the decision maker want a solution that is closest to the ideal by evaluating the alternative according to established criteria. It ranks the alternatives and determines the solution named compromise that is the closest to the ideal, (Mav et al, 2012). In order to solve the group decision making problems with ordinal interval preference information, a new decision method is proposed based on VIKOR method. The VIKOR method of compromise ranking determines a compromise solution, providing a maximum "group utility" for the "majority" and a minimum of an "individual regret" for the "opponent", which is an effective tool in multi-attribute decision making. By integrating the operational laws of ordinal interval and the concept of VIKOR method, the detail calculation steps are developed for the group decision making with ordinal interval preference information (Wanzhen, 2016).

VIKOR algorithm is based on modified fuzzy numbers stated as follows

Step 1: Express multi criteria decision making problem in the matrix format. There are m alternatives that can be defined as A_i (i = 1, 2... m) which will be evaluated based on the criteria selected that is C_j (j = 1, 2... n). Each criterion has five grade achievement g = 1, 2... 5. Subjective evaluation is done to determine the decision matrix $X = \{x_{ijg}, i = 1, 2, \dots \dots \dots, n; g = 1, 2, \dots \dots ., 5\}$.

Decision matrix can be expressed in Equation 1:

$$X = \begin{matrix} A_1 \\ A_2 \\ \vdots \\ A_M \end{matrix} \overset{\begin{matrix} c_1 & c_2 & \dots & c_n \end{matrix}}{\begin{bmatrix} x_{11} & x_{12} & \cdots & x_{1n} \\ x_{21} & x_{22} & \cdots & x_{2n} \\ \vdots & \vdots & & \vdots \\ x_{m1} & x_{m2} & \cdots & x_{mn} \end{bmatrix}}, i = 1, 2, \dots \dots \dots, m; j = 1, 2, \dots \dots ., n \quad (1)$$

$$W = [w_1, w_2, \dots \dots ., w_n] \quad (2)$$

where $A_1, A_2, \dots, A_M$ are the alternatives to be chosen, $C_1, C_2, \dots, C_M$ are the evaluation criteria, x_{ij} is the rating of alternative A_i with respect to C_j, w_j is the importance weight which the jth criterion holds.

Step 2: Construct a fuzzy decision matrix.

The aggregated fuzzy rating x_{ijg} of alternatives with respect to trapezoidal fuzzy numbers is modification from the method of arithmetic weighted average and calculated using the following equations given in Equation 3 and 4 and Table 1

$$\tilde{X} = \sum\nolimits_{i=1}^{m} \sum_{j=1}^{n} \sum\nolimits_{g=1}^{s} x_{ijg}, \otimes T_Z FN = [\widetilde{X_{ij}}]_{m \times n} = \begin{bmatrix} \widetilde{x_{11}} & \widetilde{x_{12}} & \dots & \widetilde{x_{1n}} \\ \widetilde{x_{21}} & \widetilde{x_{22}} & \dots & \widetilde{x_{2n}} \\ \vdots & \vdots & \vdots & \vdots \\ \widetilde{x_{m1}} & \widetilde{x_{m2}} & \dots & \widetilde{x_{mn}} \end{bmatrix} \quad (3)$$

$$\widetilde{w} = [\widetilde{w_1}, \widetilde{w_2}, \dots \dots \dots \dots, \widetilde{w_n}] \quad (4)$$

This method is mostly used in an aggregation process because of its simple and flexible operations and it fits well with the goals of the study. $\widetilde{X_{ij}}$ and$\widetilde{w}_j$ are linguistic variables denoted by trapezoidal fuzzy number where, $\widetilde{X_{ij}}$ is the rating

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of alternative A_j with respect to C_j, $\widetilde{w_j}$ is the importance weight of the jth criterion. A trapezoidal fuzzy number can be defined as $\tilde{x}_{ij} = (\tilde{a}_{ij}, \tilde{b}_{ij}, \tilde{c}_{ij}, \tilde{d}_{ij},)$.

Step 3: Evaluate the fuzzy importance weight of criteria.

The fuzzy weighted values for each criterion will be determined based on the importance of each criterion. Degree of importance of each criterion depends on the burden borne by each alternative. Fuzzy importance of criteria is given in Equation 4 as;

$$\widetilde{w_j} = \frac{\widetilde{S_j}}{\sum_{j=1}^{n} \widetilde{S_j}} \tag{4}$$

$\widetilde{s_j}$ is the standard deviation value for the criterion C_n. Standard deviation is given in Equation 5 as follows:

$$\widetilde{s_j} = \sqrt{\frac{1}{M}\sum_{m=1}^{M} (\tilde{x}_{mn} - \bar{\tilde{x}}_n)^2} \tag{5}$$

$\tilde{x}_{mn} \frac{1}{M}\sum_{m=1}^{M} \tilde{x}_{mn}$, $00 \leq \widetilde{w_j} \leq 1$and M = Total number of alternatives.

Step 4: Determine the fuzzy best value (x_j^*) and fuzzy worst value (x_j^-)

$$(x_j^*) = \max(\tilde{x}_{ij})$$

$$(x_j^-) = \min(\tilde{x}_{ij})$$

Step 5: Compute the normalized fuzzy decision matrix. The normalized fuzzy decision matrix is calculated to ensure that each criterion value between 0 and 1, so that all the criteria are the standard and are comparable with each other. In this situation, VIKOR method is using linear normalization to stabilize. Linear normalization formula indicated (Equation 6) by the score $\widetilde{S_\iota}$ and $\widetilde{R_\iota}$ as follows:

$$\widetilde{S_\iota} = \sum_{m=1}^{M} \widetilde{w_j}\left[\frac{\tilde{x}_j^* - \tilde{x}_{ij}}{\tilde{x}_j^* - \tilde{x}_j^-}\right] \; and \; \widetilde{R_\iota} = Max\left[\widetilde{w_j}\left(\frac{\tilde{x}_j^* - \tilde{x}_{ij}}{\tilde{x}_j^* - \tilde{x}_j^-}\right)\right] \tag{6}$$

Step 6: Compute the index VIKOR $\widetilde{Q_\iota}$

$$\widetilde{Q_\iota} = v\left(\frac{\tilde{S}_i - \tilde{S}^-}{\tilde{S}^+ - \tilde{S}^-}\right) + (1-v)\left(\frac{\tilde{R}_i - R^-}{\tilde{R}^+ - R^-}\right) \tag{7}$$

where, $\tilde{S}^+ = \max \tilde{S}_i$, $- \tilde{S}^- = \min \tilde{S}_i$

$\tilde{R}^+ = \max \tilde{R}_i$, $- \tilde{R}^- = \min R_i$

v is introduced as the weight in strategy of the maximum group utility.

From literature, it has been inferred that the VIKOR index value as given in Equation 6 above, is mostly taken as v = 0.5.

Step 7: Sorting the value of $\tilde{S}, \tilde{R}, \tilde{Q}$ in ascending order. The best alternative in order of $\tilde{Q}$ is the minimum possible value of $\tilde{Q}$ based on merit points that was done in this study and symbolized $A^{(1)}$, with the second alternative referred to $A^{(2)}$ and so on until an alternative with the largest value of $\tilde{Q}$ is expressed as $A^{(m)}$.

Step 8: The alternatives A that are in the best position with the minimum value of will be proposed as the best alternatives in providing a compromise solution if and only if satisfy two conditions:

C1: Acceptable advantage

The alternative A accepted as the best advantages when the difference index VIKOR $\tilde{Q}$ between alternative $A^{(2)}$ and $A^{(1)}$ must be greater than or equal to the value of DQ, or in other words is as given in Equation 7 below;

$$\widetilde{Q_{(A^{(1)})}} - \widetilde{Q_{(A^{(2)})}} \geq DQ = \frac{1}{M-1} \tag{8}$$

where, m is the number of alternatives.

C2: If condition one is not satisfied the result can also be considered valid if the best alternative is also ranked best by $\tilde{S}$ and/or $\tilde{Q}$.

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Table 1: Linguistic variable for grading

A. Linguistic Variable	B. Trapezoidal Fuzzy Numbers (TzFN)
C. Very good (g5)	D. (8,9,10,10)
E. Good (g4)	F. (6,7,8,9)
G. Fair (g3)	H. (3,4,5,7)
I. Poor (g2)	J. (1,2,3,4)
K. Very poor (g1)	L. (0,0,0,2)

Description of Study Area: Ozoro is the head quarter of Isoko North LGA in Delta South Senatorial district. It is a fast growing community with a population of 186,000 people (National Population Commission, 2020). It is situated within 5°32'18"N and 6°12'58"E. Below is a Satellite imagery of Ozoro the study area given in Figure 1.

Figure 1: Satellite Imagery of Ozoro (Source: Google Maps)

IV. METHODOLOGY

Materials employed in the study work are test tube, water sample source, global positioning system (GPS), computer statistical software, stopwatch, thermometer, and conductivity meter. The methods adopted are:

(A) Identification of alternative sources of water in Ozoro: The available sources of water supply in the area are groundwater, rainwater harvesting and water from streams.

(B) **Sampling Locations**

The sampling locations are presented in Table 2 and represented also with letters and number for referencing

Table 2: Sampling Location

GROUNDWATER	SURFACE WATER	RAIN WATER
Delta State Polytechnic (Female Hostel) (1)	Ijamorie River (A)	Delta State Polytechnic (Female Hostel) (A)

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First Bank (2)	Owe Lake (B)	Ala Square (B)
Divisional Police Headquarters (3)	Owhelogbo Stream (C)	Daily Market (C)
Ala Square (4)	Idheze Stream (D)	Owhelogbo Junction (D)
Notre Dame College (5)	Uto Lake (E)	Town Hall (E)
Daily Market (6)		
Owhelogbo Junction (7)		
King's Palace (8)		
St Paul's Anglican Church (9)		
Town Hall (10)		

Establishing criteria for selecting and evaluating

In this study the criteria were limited to three, which are:

i. Water Quality: fifteen water samples were collected from the river and various private premises using boreholes in the dry and wet seasons. For rain water only five samples were collected from different roofs in wet season. Collection, preservation and transportation of the water samples to the laboratory followed the standard guidelines. The water samples were analyzed in the field and laboratory in order to obtain the concentration of nineteen (19) physico-chemical and bacteriological water sample quality parameters after standard methods for the examination of water and wastewater quality (APHA, 2017). The parameters tested for include temperature, pH, electrical conductivity (EC), Total Dissolved Solids (TDS) and dissolved oxygen (DO), biochemical oxygen demand (BOD),nitrate (NO_3), sulphate (SO_4), bicarbonate (HCO_3),chloride (Cl^-),potassium (K), sodium (Na), magnesium (Mg),calcium (Ca), iron (Fe), copper (Cu), cadmium (Cd), lead (Pb)and zinc (Zn).

Evaluation of Water Quality Index (WQI) Of Water Samples

The WQI was evaluated using the weighted arithmetic method of calculating WQI and the mathematical functions of the Microsoft excel. Ten to thirteen chosen important parameters and drinking water quality standards recommended by the WHO, EU and NSDWQ were considered. Equation below is utilized in calculating the WQI.

$$\mathrm{WQI} = \sum \mathrm{Sl_i} \qquad (8)$$

Where

$\mathrm{Sl_i} = \text{sub} - \text{index of ith parameter} = W_i \times q_i$

$$\text{Relativeweight } (W_i) = \frac{w_i}{\sum_{i=1}^{n} w_i} \qquad (9)$$

$$\text{Quality rating scale } (q_i) = \frac{c_i}{s_i} \times 100 \qquad (10)$$

w_i = weight of each parameter

n = number of parameters

c_i = concentration of each parameter in each water sample in mg/l

q_i = rating based on concentration of ith parameter

S_i = standard value

Water Quality Assessment: Water quality rating of each of the various water sources were obtained by determining the water quality index (WQI). The lower the index, the higher the rating with the highest being rated as Excellent and lowest as Unsuitable.

ii. Capacity: The capacity rating for each source of water was obtained as secondary data from water authorities. For the purpose of this project the rating was simplified to indicate sources with excellent

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(very high-water availability), good (high water availability), average, poor (low availability) and unsuitable (very low availability) based on expert judgment.

iii. Evaluation of cost of water.

The cost implication of installing, operating and maintaining of the three sources of water supply were estimated. The costing method aimed at providing an incremental price in present day monetary terms (year zero) of water supply technology. Since costing consist of all resources required to put in place, the following resources were considered

i. Capital costs: The term capital goods is formally defined as meaning the stock of goods which are man-made and used in production (as opposed to consumption). Fixed capital goods (durable goods such as buildings and machinery) are usually distinguished from circulating capital goods (stocks of raw materials and semi-finished goods which are rapidly used up.
ii. Recurrent costs: comprised all expenditures (staff, parts and materials) that are required to keep a system operational and in good condition (maintenance) after installation have been completed. Depending on the accounting policy of the provider, certain fixed costs, may need to be covered recurrently on an annual basis (De Moel, Verberk& van Dijk, 2006).

Evaluation of Data Using VIKOR

i. Percentage rating: The VIKOR method involves the use of linguistic variable scale which requires the various grade rating of alternative sources and since the sources in this project were rated in more than one location it is required that they are expressed in percentages. The percentage rating was computed using the WQI results, Capacity rating and linguistic variables for grading (Refer to Table 1)
ii. Obtaining a fuzzy decision matrix for wet season: a fuzzy decision matrix for wet season was obtained by collecting the data from the percentage rating obtained in step 1 above using Equation 3
iii. Computation of fuzzy weight (FZW), mean FZW and standard deviation:
FZW were computed using Table 1, fuzzy decision matrix and Equation 3.
Mean fuzzy weight ($\bar{\tilde{x}}$) was computed using, $\bar{\tilde{x}} = \frac{\sum \tilde{x}}{n}$, where,$\tilde{x}$ are the various FZW for the given row, n number of sources.
Standard deviation $S_j$was calculated using Equation 5
iv. Calculation of important FZW (W_j), best FZW (Xij^+), and worse FZW (X_{ij}^-): Important FZW (W_j), was computed using Equation 4;
The best and worse FZW ware obtained from the maximum and minimum FZW.
v. Calculation of Score, Rank and Index VIKOR ($\widetilde{Q}_\iota$)
The score (S_i) and Rank (R_i) of the various sources were computed using equation 6;
Si+, Si-, Ri+, Ri- and INDEX VIKOR were computed using Equation 7 and values from Table 20
where, $\tilde{S}^+ = \max \tilde{S}_i , - \tilde{S}^- = \min \tilde{S}_{i,} \tilde{R}^+ = \max \tilde{R}_i , - \tilde{R}^- = \min R_i$
vi. Then the alternative with the highest$\widetilde{Q}_\iota$ value was selected as the best alternative.
vii. Finally, a validity test was carried out using, condition one and two termed C1 (Acceptable Advantage) and C2 respectively, Microsoft excel was employed in computation.

V. RESULTS

Water Quality of Various Sources

The results of the water quality were obtained from both field and laboratory analysis of water samples collected from ten locations in the dry season as presented in Table 3 while the results for the wet season and other two sources for both the dry and wet seasons are presented in Table 4, 5, 6 7, 8 and 9

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Table 3: Dry season groundwater quality from ten locations

P/L	Temp	pH	EC	TDS	DO	BOD	NO_3	SO_4	HCO_3	Cl	K	Na	Mg	Ca	Fe	Cu	Cd	Pb	Zn
1	25.83	5.22	229.50	45.00	9.00	7.20	0.90	3.00	25.90	22.50	1.53	1.98	4.50	18.00	0.01	0.054	0.054	0.270	1.620
2	24.84	6.60	193.50	54.00	11.70	6.30	0.90	1.80	0.00	27.00	1.89	4.32	1.80	18.00	1.35	0.108	0.002	0.009	1.170
3	24.75	5.13	157.50	54.00	9.00	5.40	0.10	1.80	12.92	9.00	1.53	3.78	2.43	13.50	0.27	0.081	0.001	0.009	0.054
4	23.40	6.03	490.50	99.00	8.10	3.60	2.70	6.30	11.13	54.00	3.96	7.74	5.04	68.40	0.27	0.009	0.009	0.001	0.054
5	22.68	5.22	247.50	94.50	9.90	3.60	0.90	3.60	6.37	22.50	3.60	5.49	4.95	16.20	1.80	0.342	0.018	0.001	1.899
6	23.76	5.04	175.50	45.00	11.70	6.30	0.90	1.80	21.60	13.50	1.44	3.42	1.71	30.60	0.54	0.044	0.003	0.017	0.135
7	23.67	5.49	171.00	171.00	10.80	5.40	1.80	4.50	0.07	36.00	5.13	9.63	4.77	59.40	0.36	0.045	0.001	0.001	0.324
8	25.20	5.58	45.00	148.50	8.10	5.40	0.90	5.40	34.20	45.00	3.42	9.81	6.48	63.00	0.27	0.603	0.009	0.027	1.350
9	23.76	5.31	679.50	234.00	9.00	3.60	0.90	7.20	12.80	49.50	5.85	13.95	8.02	68.58	7.65	0.108	0.018	0.009	1.512
10	24.66	5.31	189.00	49.50	8.10	4.50	0.10	1.80	11.30	18.00	2.25	4.59	2.07	29.70	0.01	0.005	0.001	0.001	0.007
Minimum Value	22.68	5.04	45.00	45.00	8.10	3.60	0.10	1.80	0.00	9.00	1.44	1.98	1.71	13.50	0.01	0.01	0.00	0.00	0.01
Maximum Value	25.83	6.60	679.50	234.00	11.70	7.20	2.70	7.20	34.20	54.00	5.85	13.95	8.02	68.58	7.65	0.60	0.05	0.27	1.90
Mean	24.26	5.49	257.85	99.45	9.54	5.13	1.01	3.72	13.63	29.70	3.06	6.47	4.18	38.54	1.25	0.14	0.01	0.03	0.81
Median	24.21	5.31	191.25	74.25	9.00	5.40	0.90	3.30	12.05	24.75	2.84	5.04	4.64	30.15	0.32	0.07	0.01	0.01	0.75
Standard Deviation	0.95	0.48	186.01	65.16	1.42	1.28	0.76	2.04	10.92	15.62	1.59	3.72	2.14	23.42	2.32	0.19	0.02	0.08	0.76

Table 4: Groundwater (wet season)

P/L	Temp	pH	EC	TDS	DO	BOD	NO_3	SO_4	HCO_3	Cl	K	Na	Mg	Ca	Fe	Cu	Cd	Pb	Zn
1	22.14	5.49	324.00	63.00	9.00	6.30	0.90	4.50	38.60	18.00	2.34	4.95	4.77	75.60	0.27	0.135	0.003	0.006	0.171
2	26.64	5.31	1719.00	585.00	9.90	5.40	1.80	17.10	7.41	148.50	5.13	31.95	14.85	226.80	1.44	0.450	0.072	0.180	1.710
3	21.96	4.77	2187.00	495.00	11.70	4.50	1.80	19.80	2.11	202.50	12.24	29.52	1.45	167.40	0.18	0.324	0.009	0.009	1.053
4	21.78	5.04	517.50	108.00	10.80	5.40	0.10	6.30	16.00	45.00	3.96	11.34	4.59	55.80	0.36	0.005	0.001	0.001	0.006
5	25.47	3.96	243.00	45.00	10.80	6.30	2.70	1.80	7.70	13.50	1.62	3.06	3.60	56.70	0.45	0.162	0.001	0.001	0.271
6	25.56	5.58	2025.00	603.00	10.80	5.40	2.70	25.20	6.10	261.00	31.32	64.89	21.24	330.30	0.18	0.190	0.007	0.005	0.180
7	33.72	5.31	621.00	193.50	9.90	5.40	0.10	4.50	19.80	31.50	7.74	13.32	9.27	189.00	0.18	0.032	0.005	0.018	0.023
8	23.94	5.58	688.50	175.50	9.00	4.50	1.80	4.50	11.70	49.50	6.93	12.06	12.87	145.80	0.81	0.081	0.004	0.005	0.135
9	25.11	5.49	634.50	235.00	9.00	4.50	1.80	6.30	6.10	49.50	8.73	17.91	0.86	97.20	2.07	0.054	0.001	0.003	0.159
10	21.96	4.77	2187.00	495.00	11.70	4.50	1.80	27.90	32.70	292.50	23.13	47.16	23.22	259.20	0.27	0.117	0.001	0.001	0.105
Minimum Value	21.78	3.96	243.00	45.00	9.00	4.50	0.10	1.80	2.11	13.50	1.62	3.06	0.86	55.80	0.18	0.01	0.00	0.00	0.01
Maximum Value	33.72	5.58	2187.00	603.00	11.70	6.30	2.70	27.90	38.60	292.50	31.32	64.89	23.22	330.30	2.07	0.45	0.07	0.18	1.71
Mean	24.83	5.13	1114.65	299.80	10.26	5.22	1.55	11.79	14.82	111.15	10.31	23.62	9.67	160.38	0.62	0.16	0.01	0.02	0.38
Median	24.53	5.31	661.50	214.25	10.35	5.40	1.80	6.30	9.70	49.50	7.34	15.62	7.02	156.60	0.32	0.13	0.00	0.01	0.17
Standard Deviation	3.61	0.51	809.06	220.66	1.06	0.71	0.92	9.73	12.20	106.26	9.64	19.88	8.07	92.49	0.64	0.14	0.02	0.06	0.55

Table 5: Rain water (wet season)

Parameters	Wet Season
Temperature	22.5
pH	6.83
Turbidity NTU	2.82
Alkanlity	20.2
Ca^{2+}	1.70
Mg^{+}	0.55
Cl^{-}	4.89
CO_2	4.08

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EC	0.00
Coliforms	0.00
Conductivity	29.94

Table 6: Surface water (Stream water) dry and wet Season

Parameters	A		B		C		D		E	
	DRY	WET	DRY	WET	DRY	WET	DRY	WET	DRY	WET
Temp.	24.61	24.61	24.65	24.65	25.46	22.61	25.01	25.01	24.75	24.75
pH	6.14	6.21	6.21	6.45	6.12	6.27	6.22	6.54	6.13	6.22
TDS	3.71	2.28	9.8	7.79	0.02	9.0	0.16	50	0.11	17.2
Ca	30.97	78.76	38.0	69.92	38.0	79.81	36.96	58.91	17.1	56
Mg	26.64	45.51	25.2	42.9	27.9	40	11.59	38.0	20.34	41.68
DO	4.75	3.00	4.78	3.66	4.61	3.2	4.70	3.82	4.91	5.35
BOD	1.03	1.87	1.03	2.39	1.04	3.41	1.10	1.92	0.80	3.79
SO_4^{2-}	0.03	2.10	0.03	2.10	0.04	1.10	0.01	2.43	0.01	2.25
NO_3^-	1.4	2.84	1.22	2.53	0.8	3.0	0.9	2.66	0.9	2.7
Cl	10.8	16.6	10.8	17.6	11.7	23.2	9.9	24	11	23.6
TSS	16.55	38.0	10.3	34.2	14.0	30.8	10.0	40.2	12	38
EC	3.87	0.04	9.08	0.06	6.9	0.01	16.2	0.03	7.16	0.14

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Table 7: Watre Quality Index For Groundwater Wet Season

Water Quality Parameter	pH	TDS	Cl	SO4	HCO3	NO3	Ca	Mg	Na	QUALITY RATING (qi)									Parameter Index (Si) = qi * Wi									WQI	Type of Water
WHO Standard Values (Si)	7.5	500	250	100	100	50	75	3	200	qi = (ci/si)*100																			
Relative Weight (Wi)	0.122	0.148	0.155	0.132	0.164	0.076	0.092	0.076	0.076																				
SAMPLE LOCATION CODE	MEASURED VALUES (Ci)									pH	TDS	Cl	SO4	HCO3	NO3	Ca	Mg	Na	pH	TDS	Cl	SO4	HCO3	NO3	Ca	Mg	Na		
1	5.49	63.00	18.00	4.50	38.60	0.90	75.60	4.77	4.95	73.20	12.60	7.20	4.50	38.60	1.80	100.80	159.00	2.48	8.93	1.86	1.12	0.59	6.33	0.14	9.27	12.08	0.19	40.52	GOOD
2	5.31	585.00	148.50	17.10	7.41	1.80	226.80	14.85	31.95	70.80	117.00	59.40	17.10	7.41	3.60	302.40	495.00	15.98	8.64	17.32	9.21	2.26	1.22	0.27	27.82	37.62	1.21	105.56	UNSUITABLE
3	4.77	495.00	202.50	19.80	2.11	1.80	167.40	1.45	29.52	63.60	99.00	81.00	19.80	2.11	3.60	223.20	48.33	14.76	7.76	14.65	12.56	2.61	0.35	0.27	20.53	3.67	1.12	63.53	POOR
4	5.04	108.00	45.00	6.30	16.00	0.10	55.80	4.59	11.34	67.20	21.60	18.00	6.30	16.00	0.20	74.40	153.00	5.67	8.20	3.20	2.79	0.83	2.62	0.02	6.84	11.63	0.43	36.56	GOOD
5	3.96	45.00	13.50	1.80	7.70	2.70	56.70	3.60	3.06	52.80	9.00	5.40	1.80	7.70	5.40	75.60	120.00	1.53	6.44	1.33	0.84	0.24	1.26	0.41	6.96	9.12	0.12	26.71	GOOD
6	5.58	603.00	261.00	25.20	6.10	2.70	330.30	21.24	64.89	74.40	120.60	104.40	25.20	6.10	5.40	440.40	708.00	32.45	9.08	17.85	16.18	3.33	1.00	0.41	40.52	53.81	2.47	144.64	UNSUITABLE
7	5.31	193.50	31.50	4.50	19.80	0.10	189.00	9.27	13.32	70.80	38.70	12.60	4.50	19.80	0.20	252.00	309.00	6.66	8.64	5.73	1.95	0.59	3.25	0.02	23.18	23.48	0.51	67.35	POOR
8	5.58	175.50	49.50	4.50	11.70	1.80	145.80	12.87	12.06	74.40	35.10	19.80	4.50	11.70	3.60	194.40	429.00	6.03	9.08	5.19	3.07	0.59	1.92	0.27	17.88	32.60	0.46	71.07	POOR
9	5.49	235.00	49.50	6.30	6.10	1.80	97.20	0.86	17.91	73.20	47.00	19.80	6.30	6.10	3.60	129.60	28.67	8.96	8.93	6.96	3.07	0.83	1.00	0.27	11.92	2.18	0.68	35.84	GOOD
10	4.77	495.00	292.50	27.90	32.70	1.80	259.20	23.22	47.16	63.60	99.00	117.00	27.90	32.70	3.60	345.60	774.00	23.58	7.76	14.65	18.14	3.68	5.36	0.27	31.80	58.82	1.79	142.28	UNSUITABLE

Table 8: Rain Water Water Quality Index For Wet Season

Water Quality Parameter	pH	TDS	Cl	SO4	HCO3	NO3	Ca	Mg	Na	QUALITY RATING (qi)									Parameter Index (Si) = qi * Wi									WQI	Type of Water
WHO Standard Values (Si)	7.5	500	250	100	100	50	75	3	200	qi = (ci/si)*100																			
Relative Weight (Wi)	0.122	0.148	0.155	0.132	0.164	0.076	0.092	0.076	0.076																				
SAMPLE LOCATION CODE	MEASURED VALUES (Ci)									pH	TDS	Cl	SO4	HCO3	NO3	Ca	Mg	Na	pH	TDS	Cl	SO4	HCO3	NO3	Ca	Mg	Na		
A	8.03	33.77	9.56	40.35	18.25	0.05	9.9	11.92	40.35	107.07	6.75	3.82	40.35	18.25	0.10	13.20	397.33	20.18	13.06	1.00	0.59	5.33	2.99	0.01	1.21	30.20	1.53	55.93	POOR
B	9.17	36.4	5.62	39.97	22.81	0.07	11.13	10.69	39.97	122.27	7.28	2.25	39.97	22.81	0.14	14.84	356.33	19.99	14.92	1.08	0.35	5.28	3.74	0.01	1.37	27.08	1.52	55.34	POOR
C	8.67	30.2	11.67	34.66	17.98	0.08	9.71	8.33	34.66	115.60	6.04	4.67	34.66	17.98	0.16	12.95	277.67	17.33	14.10	0.89	0.72	4.58	2.95	0.01	1.19	21.10	1.32	46.87	GOOD
D	8.87	50.53	9.01	31.07	23.09	0.06	10.33	11.89	31.07	118.27	10.11	3.60	31.07	23.09	0.12	13.77	396.33	15.54	14.43	1.50	0.56	4.10	3.79	0.01	1.27	30.12	1.18	56.95	POOR
E	8.57	33.07	4.11	29.04	15.72	0.07	7.11	9.41	29.04	114.27	6.61	1.64	29.04	15.72	0.14	9.48	313.67	14.52	13.94	0.98	0.25	3.83	2.58	0.01	0.87	23.84	1.10	47.41	GOOD

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Table 9: Surface Water For Water Quality Index For Wet Season

Water Quality Parameter	pH	TDS	Cl	SO4	HCO3	NO3	Ca	Mg	Na	QUALITY RATING (qi)									Parameter Index (Si) = qi * Wi									WQI	Type of Water
WHO Standard Values (Si)	7.5	500	250	100	100	50	75	3	200	qi = (ci/si)*100																			
Relative Weight (Wi)	0.122	0.148	0.155	0.132	0.164	0.076	0.092	0.076	0.076																				
SAMPLE LOCATION CODE	MEASURED VALUES (Ci)									pH	TDS	Cl	SO4	HCO3	NO3	Ca	Mg	Na	pH	TDS	Cl	SO4	HCO3	NO3	Ca	Mg	Na		
A (DRY)	6.14	3.71	10.8	0.03	2.92	1.4	30.97	26.64	1.74	81.87	0.74	4.32	0.03	2.92	2.80	41.29	888.00	0.87	9.99	0.11	0.67	0.00	0.48	0.21	3.80	67.49	0.07	82.82	VERY POOR
A (WET)	6.21	2.28	16.6	2.1	9.8	2.84	78.76	45.51	0.27	82.80	0.46	6.64	2.10	9.80	5.68	105.01	1517.00	0.14	10.10	0.07	1.03	0.28	1.61	0.43	9.66	115.29	0.01	138.48	UNFIT FOR DRINKING
B (DRY)	6.21	9.8	10.8	0.03	0.01	1.22	38	25.2	1.77	82.80	1.96	4.32	0.03	0.01	2.44	50.67	840.00	0.89	10.10	0.29	0.67	0.00	0.00	0.19	4.66	63.84	0.07	79.82	VERY POOR
B (WET)	6.45	7.79	17.6	2.1	0.41	2.53	69.92	42.9	0.26	86.00	1.56	7.04	2.10	0.41	5.06	93.23	1430.00	0.13	10.49	0.23	1.09	0.28	0.07	0.38	8.58	108.68	0.01	129.81	UNFIT FOR DRINKING
C (DRY)	6.12	0.02	11.7	0.04	3.12	0.8	38	27.9	4.36	81.60	0.00	4.68	0.04	3.12	1.60	50.67	930.00	2.18	9.96	0.00	0.73	0.01	0.51	0.12	4.66	70.68	0.17	86.83	VERY POOR
C (WET)	6.27	9	23.2	1.1	7.92	3	79.81	40	1.04	83.60	1.80	9.28	1.10	7.92	6.00	106.41	1333.33	0.52	10.20	0.27	1.44	0.15	1.30	0.46	9.79	101.33	0.04	124.97	UNFIT FOR DRINKING
D (DRY)	6.22	0.16	9.9	0.01	1.94	0.9	36.96	11.59	4.73	82.93	0.03	3.96	0.01	1.94	1.80	49.28	386.33	2.37	10.12	0.00	0.61	0.00	0.32	0.14	4.53	29.36	0.18	45.27	GOOD
D (WET)	6.54	50	24	2.43	2.34	2.66	58.91	38	1.23	87.20	10.00	9.60	2.43	2.34	5.32	78.55	1266.67	0.62	10.64	1.48	1.49	0.32	0.38	0.40	7.23	96.27	0.05	118.25	UNFIT FOR DRINKING
E (DRY)	6.13	0.11	11	0.01	3.16	0.9	17.1	20.34	0.45	81.73	0.02	4.40	0.01	3.16	1.80	22.80	678.00	0.23	9.97	0.00	0.68	0.00	0.52	0.14	2.10	51.53	0.02	64.96	POOR
E (WET)	6.22	17.2	23.6	2.25	3.56	2.7	56	41.68	0.92	82.93	3.44	9.44	2.25	3.56	5.40	74.67	1389.33	0.46	10.12	0.51	1.46	0.30	0.58	0.41	6.87	105.59	0.03	125.88	UNFIT FOR DRINKING

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ESTIMATED COST OF WATER SOURCE DEVELOPMENT

The estimated cost of water source development for Ozoro community gotten from primary and secondary data is shown in Table 10.

The population is 186,000 as obtained from national census 2006.

Litre per capital demand is 98litre per person per day (Sawere and Ibuku, 2016)

Yearly water demand is 98*186,000*365= 6,653,220,000lcp

Cost benefit analysis (CBA) = cost/water demand.

Cost rating is obtained by comparing the CBA of each of the three souces with lowest CBA value being the best and the highest being the worst (Jesper and Johnson, 2014

Table 10: Estimated Cost of Water Source Development

S/N	Description	Cost (₦)		
		Groundwater	Rainwater	Surface water
1	**PRELIMINARIES**			
	Site preparation	200,000.00	800,000.00	1,200,000.00
	Hydrological survey	150,000.00	-	750,000.00
	Detail design	500,000.00	1,500,000.00	1,000,000.00
	Site Acquisition	2,000,000.00	300,000.00	3,000,000.00
2	**CAPITAL COST**			
	Borehole Drilling/ appurtenances	273,230,880.00	-	-
	Surfacewater Intake structures	-	-	816,154,400.00
	Rainwater harvesting structures	-	326,461,760.00	-
	Storage	91,992,000.00	446,528,000.00	204,260,000.00
3	**REOCCURRENT EXPENDITURES**			
	Operation and maintenance cost (per year)	14,261,144.00	122,559,000.00	105,020,720.00
	Treatment	114,992,000.00	98,463,840.00	195,392,000.00
	TOTAL COST	**497,325,994.00**	**999,312,600.00**	**1,131,385,120.00**
	CBA (₦/L)	**74.33**	**152.20**	**170.05**

CRITERIA RATING FOR THE VARIOUS SOURCES

The results of the criteria rating for the three water source are summarized in Tables 11 to 13

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Table 11: Criteria Rating for Groundwater

Location	Quality		Capacity		Cost	
	Wet	Dry	Wet	Dry	Wet	Dry
1	good	Good	Excellent	good	Good	good
2	unsuitable	Excellent	Excellent	excellent	Good	good
3	poor	Excellent	Excellent	excellent	Good	good
4	good	Good	Good	average	Good	good
5	good	Good	Excellent	excellent	Good	good
6	unsuitable	Excellent	Excellent	excellent	Good	good
7	poor	Good	Excellent	excellent	Good	good
8	poor	Good	Good	poor	Good	good
9	good	Poor	Average	excellent	Good	good
10	unsuitable	Excellent	Excellent	good	Good	good

Table 12: Criteria Rating for Rain Water

Location	Quality		Capacity		Cost	
	Wet	Dry	Wet	Dry	Wet	Dry
1	poor	Unsuitable	good	unsuitable	poor	poor
2	poor	Unsuitable	good	unsuitable	poor	poor
3	good	Unsuitable	good	unsuitable	poor	poor
4	poor	Unsuitable	average	unsuitable	poor	poor
5	good	Unsuitable	good	unsuitable	poor	poor

Table 13: Criteria Rating for Surface Water

Location	Quality		Capacity		Cost	
	Wet	Dry	Wet	Dry	Wet	Dry
1	unsuitable	poor	excellent	good	poor	poor
2	unsuitable	poor	excellent	average	poor	poor
3	unsuitable	poor	good	unsuitable	poor	poor
4	unsuitable	good	excellent	poor	poor	poor
5	unsuitable	poor	excellent	poor	poor	poor

Percentage rating of alternative sources

The VIKOR method involves the use of linguistic variable scale which requires the various grade rating of alternative sources and since the sources in this project were rated in more than one location it is required that they are expressed in percentages. The percentage rating, (Table 14) were computed using data from Tables 11 to Table 13.

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Table 14 Percentage Rating of Alternatives

CRITERIA	GRADE	GROUND		RAIN		SURFACE	
		Wet	Dry	Wet	Dry	Wet	Dry
QUALITY	Excellent (g1)	0	0.4	0	0	0	0
	Good (g2)	0.4	0.5	0	0	0	0.2
	Average (g3)	0	0	0	0	0	0
	Poor (g4)	0.3	0.1	1	0	0	0.8
	Unsuitable (g5)	0.3	0	0	1	1	0
CAPACITY	Excellent (g1)	0.7	0.6	0	0	0.8	0
	Good (g2)	0.2	0.2	1	0	0.2	0.2
	Average (g3)	0.1	0.1	0	0	0	0.2
	Poor (g4)	0	0.1	0	0	0	0.4
	Unsuitable (g5)	0	0	0	1	0	0.2
COST	Excellent (g1)	0	0	0	0	0	0
	Good (g2)	1	1	0	0	0	0
	Average (g3)	0	0	0	0	0	0
	Poor (g4)	0	0	1	1	1	1
	Unsuitable (g5)	0	0	0	0	0	0
	Poor (g4)	0	0	0	0	1	1
	Unsuitable (g5)	0	0	0	0	0	0

VIKOR Result for Wet Season

Tables 15 to 20 are the presentation of the results obtained using the VIKOR approach

Table 15: Fuzzy decision matrix for wet season

CRITERIA	GRADE	GROUND	RAIN	SURFACE
QUALITY	Excellent (g1)	0	0	0
	Good (g2)	0.4	0.4	0
	Average (g3)	0	0	0
	Poor (g4)	0.3	0.6	0
	Unsuitable (g5)	0.3	0	1
CAPACITY	Excellent (g1)	0.7	0	0.8
	Good (g2)	0.2	0.6	0.2
	Average (g3)	0.1	0.4	0
	Poor (g4)	0	0	0
	Unsuitable (g5)	0	0	0
COST	Excellent (g1)	0	0	0.2
	Good (g2)	0	0	0.2
	Average (g3)	0	0.2	0
	Poor (g4)	0.6	0.8	0

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	Unsuitable (g5)	0.4	0	0.6

Table16: Fuzzy Weight (FZW), Mean FZW and Standard Deviation

FUZZY WEIGHT (x_{ij})					MEAN FZW	STANDARD DEVIATION (S_j)
		GROUND	RAIN	SURFACE		
QUALITY	A	2.7	3	0	1.9	1.35
	B	3.4	4	0	2.4667	1.76
	C	4.1	5	0	3.0333	2.18
	D	5.4	6	2	4.4667	1.76
CAPACITY	A	7.1	4.8	7.6	6.5	1.22
	B	8.1	5.8	8.6	7.5	1.22
	C	9.1	6.8	9.6	8.5	1.22
	D	9.5	8.2	9.8	9.1667	0.69
COST	A	0.6	1.4	2.8	1.6	0.91
	B	0	1.2	3.2	1.4667	1.32
	C	1.8	3.4	3.6	2.9333	0.81
	D	3.2	4.6	5	4.2667	0.77

Table 17: Important FZW (W_j), Best FZW, and Worse FZW (X_{ij}^-)

IMPORTANT FZW	BEST FZW	WORSE FZW	W_j*(Xij$^+$ - Xij)/(Xij$^+$- Xij$^-$)		
			GROUND	RAIN	SURFACE
0.08	3	0	0.0075071	0	0.07507131
0.10	4	0	0.0147016	0	0.09801098
0.12	5	0	0.021797	0	0.12109432
0.10	6	2	0.0147016	0	0.09801098
0.07	7.6	4.8	0.0121159	0.0678	0
0.07	8.6	5.8	0.0121159	0.0678	0
0.07	9.6	6.8	0.0121159	0.0678	0
0.04	9.8	8.2	0.0072454	0.0386	0
0.05	2.8	0.6	0.0505945	0.0322	0
0.07	3.2	0	0.0734497	0.0459	0
0.04	3.6	1.8	0.0448253	0.005	0
0.04	5	3.2	0.0429437	0.0095	0
0.03	3.7	2.4	0	0.0296	0.015918
0.04	4.4	2.8	0	0.0378	0.0094581
0.05	5.1	3.2	0	0.0486	0.00255697
0.04	6.4	4.8	0	0.0378	0.0094581

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Table 18 Score, Rank

SCORE (S_i)			RANK(R_i)			MAX SCORE	MIN SCORE
GROUND	RAIN	SURFACE	GROUND	RAIN	SURFACE	Si+	Si-
0.314114	0.4886	0.4295788	0.0734497	0.0678	0.1210943	0.488625	0.31411

Table 19: Index VIKOR

MAX. RANK Ri+	MIN RANK Ri-	INDEX VIKOR(Q)		
		GROUND	RAIN	SURFACE
0.121094316	0.06784926	0.9474087	0.5	0.1692

Table 20: Check for compromise

A1-A2	DQ	condition 1 check
0.4474	0.25	Satisfied

VIKOR Result for Dry Season

VIKOR method for dry season is a repetition of the wet season VIKOR method demonstrated above only that the data used are those obtained in the dry season. To save space only the final result for the dry season is presented on Table 21

Table 21: VIKOR Result for Dry Season

INDEX VIKOR(Q)			A1-A2	DQ	condition 1 check
GROUND	RAIN	SURFACE			
1	0	0.4778867	0.5221	0.25	Satisfied

VI. CONCLUSION

VIKOR results show ground water is 0.9474, Rain water is 0.5 and Surface water is 0.1692 for the wet season, while for the dry season, underground water is 1, Rain water is 0, Surface water is 0. 4778. This shows that the VIKOR method rank underground as best source for both seasons, rain water second in wet season and last in the dry season, surface water is last for the wet season and second for the dry season.It could be clearly seen that ground water is best alternative. This is as a result of its good WQI and Capacity rating for both seasons. However, considering the poor ratings of rain water one could have quickly suggested that it will be the least in performance whereas rain water was rated as the second best in the wet season. This can only be achieved as a result of the logical and systematical approach that is embedded in multicriteria decision making tools. Surface water being the second best in the wet season was rated last in the wet season.

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