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A Comparative Analysis of the Weighted Arithmetic and Canadian Council of Ministers of the Environment Water Quality Indices for Water Sources in Ohaozara, Ebonyi State, Nigeria

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***Abstract*:- This study compared the Weighted Arithmetic and Canadian Council of Ministers of the Environment water quality indices on water sources in Ohaozara, Ebonyi State, Nigeria. Water samples were collected from two communities of Uburu and Okposi in Ohaozara Local Government Area. Borehole sample was collected from Uburu while hand dug well sample was collected from Okposi. These samples were collected in the months of May and June 2021, presenting a total of four samples. The Weighted Arithmetic Water Quality Index (WAWQI) and the Canadian Council of Ministers of the Environment Water Quality Index (CCME-WQI) analytical methods were used in the determination of the water quality index (WQI). The results revealed that the WAWQI value for hand dug well in the month of May and June were 10.379 and 9.445 respectively, representing a water quality status of excellent for each month. However, the WAWQI value for the borehole sample in the month of May and June indicated 89.371 and 100.19 respectively, representing a water quality status of very poor and unfit for drinking in that order. The high WQI values of the borehole sample revealed the presence of toxic heavy metal contaminants of lead and arsenic in the water source as observed in the physicochemical analysis. The CCME-WQI value for the hand dug well sample indicated 53.513 while the CCME-WQI value for the borehole sample showed 49.668 with both water sources having a water quality ranking of marginal. This meant both water sources were frequently threatened and their conditions far from desired levels. The study revealed that while both indices provided a single number to describe water quality status and are widely utilised globally, the WAWQI is more sensitive to toxic heavy metal contaminants due to the use of unit weight calculation in the WQI determination. It showed that the WAWQI is better suited to be applied in the study area to alert consumers due to the abundance of solid mineral deposits in the study area and the potential for water pollution. Comparatively, the study also revealed that CCME-WQI is more moderate to all contaminants due to the use of scope (F1), Frequency (F2) and Amplitude (F3) calculation in the determination of the WQI which resulted to the marginal water quality ranking obtained for both the borehole and the hand dug well water samples.**

Keyword: Water, Quality, Indices, Water Sources, Weighted Arithmetic, Canadian Council of Ministers of the Environment.

INTRODUCTION

Water is life. It is required daily in all activities of living organisms on earth to sustain life and livelihood. 97.5% of the nearly 70% water covering the earth is salt water. Sadly, only 1% of the available 2.5% fresh water is accessible for human consumption (Mishra and Dubey 2015, USGS 2019, UNESCO 2020). The high demand for water in areas where there is insufficient water quantity leads to water scarcity.

Water scarcity is therefore a major global problem affecting many communities around the world. Sustained water scarcity leads to water stress. According to the United Nations, over 2 billion people live in countries experiencing high water stress. It is predicted that by the year 2025, half of the world will be living in water stressed conditions (UNESCO 2020). Water stress occurs basically when the demand for good quality water exceeds the available amount over a sustained period. This eventually leads to communities being forced to use the available poor-quality water when good quality water is not available. Communities are also made to ration available water quantity to avoid conflicts which are regular occurrences in communities with water shortages. Health problems from infected water are also common phenomena in areas with water scarcity (Hunter, MacDonald & Carter 2010, Gusikit & Lar 2014, Tarrass and Benjellon, 2012). The risk of living in water stressed conditions leads to communities being vulnerable to water scarcity challenges. Contaminated water sources increase the risk of diseases to the vulnerable people. Therefore, it is pertinent that monitoring and assessment of water quality status is performed to help decision makers take the needed action to make good quality water available to the people at the required time. Simple methods like the water quality index (WQI) becomes imperative in helping to determine the water quality status of water sources at a particular place and time.

WQI was first developed by Horton in 1965 to determine the quality of both surface and ground water. Thereafter, several other water quality indices were developed which included the National Sanitation Foundation Water Quality Index (NSFWQI), Canadian Council of Ministers of the Environment Water Quality Index (CCME-WQI), Weighted Arithmetic Water Quality Index (WAWQI), Oregon Water Quality Index (OWQI), British Columbia Water Quality Index (BCWQI) and so on. Several researchers have applied these indices to studies across the world (Oni and Fasakin, (2016), Kumar and Dua (2009), Iyama and Edori (2013), Otene and Nnadi (2019).

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The WQI provides a simple number that describes the quality of water that makes it easy to understand. It states the overall water quality at a certain location and time using the measured values of selected water quality parameters. In most cases, it is used to determine the potability of surface water and groundwater.

This study therefore aims to compare the water quality index estimates from two commonly used indices of weighted arithmetic water quality index (WAWQI) and the Canadian Council of Ministers of the Environment Water Quality Index (CCME-WQI) based on analysis done on two major water sources of borehole and hand dug well from Ohaozara, Ebonyi State, Nigeria.

MATERIALS AND METHODS

The Study Area

The study area lies approximately latitude 5°56'N and Longitude 7°55'E. It has an area of 312km^2 with a population of 148312 according to the National Population Census of 2006. Ohaozara Local Government Area has its headquarters in Obiozara Uburu. Other important towns within the LGA are Okposi and Ugwulangwu. There are thirteen LGAs in Ebonyi State with Ohaozara as one of them and located in the southern part of the state, particularly in Ebonyi South Senatorial zone. The LGA is bordered by Enugu State to the west, Onicha LGA to the North, Ivo LGA and Parts of Afikpo South LGA to the south and Afikpo North LGA and parts of Afikpo South to the East. The people of Ohaozara LGA are predominantly of the Igbo ethnic group. The study area is in the rainforest region with two major seasons of rainy and dry just like the rest of the state. The average temperature in the area is 28 degC. The people of Ohaozara engage in farming as a major occupation alongside trading which is common among the Igbo ethnic group. Crops like yam, rice, cassava, maize are grown in large quantities within the study area.

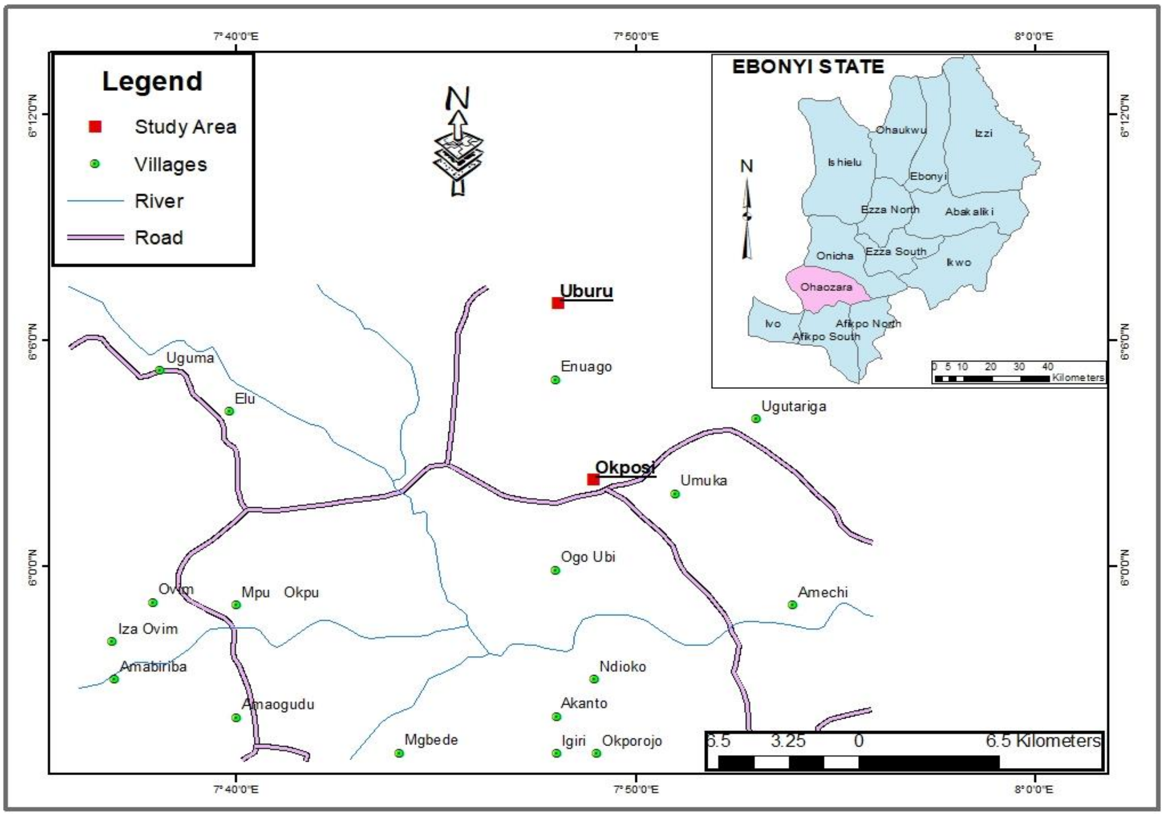

Figure 1: Ohaozara LGA showing communities

Sample and Sampling Method

The samples were collected from two communities namely Uburu and Okposi. While borehole sample was collected from Uburu, hand dug well sample was collected from Okposi. These samples were collected in the month of May and June 2021 which presented a total of four samples. The WAWQI and CCME-WQI methods were used in the determination of the WQI. Electrical Conductivity (EC), pH, Total Dissolved Solids (TDS), Total Suspended Solids (TSS), Total Hardness (TH), Arsenic (As), Zinc (Zn), Copper (Cu), Lead (Pb), Iron (Fe), Heterotrophic plate count (HPC) and Total Coliform (TC) were the Physicochemical and microbiological parameters analysed. The microbiological parameters such as Total Coliform count was analysed using the Most Probable Number (MPN) – multiple tube technique for coliform enumeration. The physical parameters like the pH, TDS and TSS were analysed in-situ. Other parameters like the heavy metals of Zinc, Lead, Arsenic Copper, and Iron were analysed using the Atomic Adsorption spectroscopy.

Water Quality Index Determination

This study adopted the use of the WAWQI and CCME-WQI methods in determining the WQI and subsequently compared the results of the samples. The National Standard of Drinking Water Quality (NSDWQ) and World Health Organisation (WHO) were used as standards in the analysis of the water quality index of the water samples.

Weighted Arithmetic Water Quality Index

The WAWQI has been widely used by researchers globally for the determination of water quality index. Patel and Desai (2006), Das, Panigrahi and Panda (2012), Oni and Fasakin (2016), Tiwari and Mishra (1985), Singh (1992).

The WAWQI is calculated using the following expressions:

$WQI = \sum QnWn / \sum Wn$. Therefore,

$Wn = K/Sn$

Where Wn = unit weight for nth parameter

n = Number of water quality parameters

Sn= standard permissible value for nth parameter

k = proportionality constant.

$Qn = 100[Vn - Vio] / [Sn - Vio]$

Qn = Quality rating for the nth water quality parameter

Vn = Estimated value of the nth parameter at a given water sampling station

Sn = Standard permissible value of the nth parameter (NSDWQ/WHO)

Vio = Ideal value of nth parameter in pure water (i.e., 0 for all other parameters except the parameters pH and Dissolved oxygen (7.0 and 14.6 mg/l respectively)

The unit weight is calculated by a value inversely proportional to the recommended standard value Sn of the corresponding parameter.

Therefore, the weighted arithmetic water quality index rating and status is as given in table 1.

Table 1: WAWQI Ranking and Status

Ranking	**Water Quality Status**
0-25	Excellent
25-50	Good
51-75	Poor
76-100	Very poor
>100	Unfit for drinking

Canadian Council of Ministers of the Environment Water Quality Index

This method of WQI was developed in 2001 for reporting simplified water quality data. It is a universally acceptable model for evaluating water quality index and has been applied globally by several researchers Damo and Icka (2013), Rabee, Hassoon and

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Mohammed (2014), Murtala and Edwin (2013) and useful to technical professionals, policy makers and the public in understanding water quality status.

The CCME-WQI model consists of three measures of variance from selected water quality objectives of Scope, Frequency and Amplitude. Scope (F1) represents the percentage of variables that do not meet their objectives, frequency (F2) the percentage of individual tests that do not meet objectives, and amplitude (F3) the amount by which failed test values do not meet their objectives. These factors after calculation, produce a value between 0 and 100 that represents the overall water quality, where 0 represents the "worst" water quality and 100 represents the "best" water quality. The CCME-WQI values are then converted into rankings by using the index categorization as presented in Table 2.0.

CCME-WQI is calculated with the following equation:

F1= (Number of failed variables / Total number of variables) x 100

F2= (Number of failed test / Total number of failed test) x 100

The F3 is calculated in three steps:

Step 1: Calculation of excursion.

Excursion is the number of times by which an individual concentration is greater than (or less than, when the objective is a minimum) the objective.

When the test value must not exceed the objective:

Excursion i = (Failed test value / Objective) – 1

When the test value must not fall below the objective:

Excursion i = (Objective / Failed test value) – 1

Step 2: Calculation of the Normalised Sum of Excursion (nse).

The normalized sum of excursions is the collective amount by which individual tests are out of compliance. This is calculated by summing the excursions of individual tests from their objectives and dividing by the total number of tests (both those meeting objectives and those not meeting objectives).

$$nse = \sum_{n=1} \text{excursion i} / \text{number of tests}$$

Step 3: Calculation of F3.

F3 is calculated by an asymptotic function that scales the normalized sum of the excursions from objectives to yield a range from 0 to 100.

F3 = (nse / 0.01nse + 0.01)

Therefore,

$$WQI = 100 – [(\sqrt{F1^2 + F2^2 + F3^2}) / 1.732)]$$

Table 2: CCME WQI index categorization scheme

Ranking	WQI Value	Description
Excellent	95 - 100	Water quality is protected with a virtual absence of threat or impairment conditions very close to natural or pristine levels
Very Good	89 - 94	Water quality is protected with a slight presence of threat or impairment conditions close to natural or pristine levels
Good	80 - 88	Water quality is protected with only a minor degree of threat or impairment, conditions rarely depart from natural or desirable levels
Fair	65 - 79	Water quality is usually protected but occasionally threatened or impaired conditions, sometimes depart from natural or desirable levels.
Marginal	45 - 64	Water quality is frequently threatened or impaired, conditions often depart from natural or desirable levels.
Poor	0 - 44	Water quality is almost always threatened or impaired, conditions usually depart from natural or desirable levels

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RESULTS AND DISCUSSION

The result of the weighted arithmetic water quality index for the two water sources were presented in tables 3.0, 4.0, 5.0 and 6.0. In table 3.0, the hand dug well water sample collected in the month of May showed a WQI value of 10.37. Similarly, in table 4.0, the WQI for the hand dug well water sample collected in the month of June indicated a value of 9.44. Borehole water sample collected in the month of May showed a WQI value of 89.37 as presented in table 5.0 while the borehole water sample collected in the month of June showed a WQI value of 100.19 as shown in table 6.0. These results as summarized in table 7.0 revealed that the hand dug well water source in Okposi community presented an excellent water quality status in both months of May and June as against the borehole water source in Uburu that indicated a very poor water quality status for the month of May and an unfit for drinking water quality status for the month of June. Reviewing the results of the WQI for the hand dug well water source in tables 3.0 and 4.0, it was observed that the physicochemical and microbiological analysis conducted showed that parameters like Zinc, Iron, Total Coliform and Heterotrophic plate count all exceeded the NSDWQ / WHO acceptable limits. These parameters had very minimal negative impact on the WQI outcome, rather a water quality status of excellent for the hand dug well water samples were obtained for each of the months of May and June. This finding agrees with studies on WAWQI conducted by Etim et al (2013), Pathak, Prasad and Pathak (2015).

TABLE 3: WAWQI ANALYSIS FOR HAND DUG WELL WATER SAMPLE COLLECTED IN MAY 2021

Parameters	(Sn)	1/Sn	∑1/Sn	K=1/∑(1/Sn)	Wn=K/Sn	(Vo)	(Vn)	Vn/Sn	Vn/Sn * 100=Qn	Wn*Qn
Ph	8.5	0.11764706	204.90598	0.00488029	0.0005742	7	6.3	0.1	10	0.00574151
Conductivity	1000	0.001	204.90598	0.00488029	4.88E-06	0	20	0.02	2	9.7606E-06
Zn	3	0.33333333	204.90598	0.00488029	0.0016268	0	49.96	16.653333	1665.3333	2.70910156
Fe	0.3	3.33333333	204.90598	0.00488029	0.0162676	0	0.836	2.7866667	278.66667	4.5332444
Pb	0.01	100	204.90598	0.00488029	0.4880287	0	0.0001	0.01	1	0.4880287
Cu	1	1	204.90598	0.00488029	0.0048803	0	0.0002	0.0002	0.02	9.7606E-05
Arsenic	0.01	100	204.90598	0.00488029	0.4880287	0	0.0005	0.048	4.8	2.34253778
TH	150	0.00666667	204.90598	0.00488029	3.254E-05	0	127.08	0.8472	84.72	0.00275639
TDS	500	0.002	204.90598	0.00488029	9.761E-06	0	0.202	0.000404	0.0404	3.9433E-07
TSS	500	0.002	204.90598	0.00488029	9.761E-06	0	0.088	0.000176	0.0176	1.7179E-07
TC	10	0.1	204.90598	0.00488029	0.000488	0	60	6	600	0.29281722
THPC	100	0.01	204.90598	0.00488029	4.88E-05	0	105.2	1.052	105.2	0.00513406
		204.90598			1			**Water Quality Index**		**10.3794696**

Source: Researchers Calculation (2021)

Table 4: WAWQI Analysis for Hand Dug Well Water Sample Collected in June, 2021

Parameters	(Sn)	1/Sn	∑1/Sn	K=1/∑(1/Sn)	Wn=K/Sn	Ideal Value (Vo)	Mean Conc. Value (Vn)	Vn/Sn	Vn/Sn * 100=Qn	Wn*Qn
Ph	8.5	0.11764706	204.90598	0.00488029	0.0005742	7	6.4	0.1	10	0.00574151
Conductivity	1000	0.001	204.90598	0.00488029	4.88E-06	0	20	0.02	2	9.7606E-06
Zn	3	0.33333333	204.90598	0.00488029	0.0016268	0	50.47	16.823333	1682.3333	2.73675652
Fe	0.3	3.33333333	204.90598	0.00488029	0.0162676	0	0.728	2.4266667	242.66667	3.94760996
Pb	0.01	100	204.90598	0.00488029	0.4880287	0	0.0001	0.01	1	0.4880287
Cu	1	1	204.90598	0.00488029	0.0048803	0	0.0001	0.0001	0.01	4.8803E-05
Arsenic	0.01	100	204.90598	0.00488029	0.4880287	0	0.0004	0.04	4	1.95211481
TH	150	0.00666667	204.90598	0.00488029	3.254E-05	0	126.96	0.8464	84.64	0.00275378
TDS	500	0.002	204.90598	0.00488029	9.761E-06	0	0.256	0.000512	0.0512	4.9974E-07
TSS	500	0.002	204.90598	0.00488029	9.761E-06	0	0.146	0.000292	0.0292	2.8501E-07
TC	10	0.1	204.90598	0.00488029	0.000488	0	63	6.3	630	0.30745808
THPC	100	0.01	204.90598	0.00488029	4.88E-05	0	107	1.07	107	0.00522191
		204.90598			1			**Water Quality Index**		**9.44574463**

Source: Researchers Calculation (2021)

Similarly, the physicochemical and microbiological analysis conducted for the borehole water samples for the months of May and June as revealed in tables 5.0 and 6.0 showed that parameters like Zinc, Lead, Total Hardness and Total Coliform all exceeded the NSDWQ / WHO acceptable limits. However, while Zinc, Total Hardness and Total Coliform parameters had very minimal negative impact on the WQI outcome, Lead had a major negative impact on the WQI value with 60.02 in May and 70.27 in June. Additionally, Arsenic, a toxic heavy metal contaminant which was about 50% of the NSDWQ / WHO acceptable limits as observed in tables 5.0 and 6.0 and still within limits, had a significant negative impact on the WQI outcome with 23.42 in May and 23.91 in June.

Table 5: WAWQI Analysis for Borehole Water Sample Collected in May

Parameters	(Sn)	1/Sn	∑1/Sn	K=1/∑(1/Sn)	Wn=K/Sn	(Vo)	(Vn)	Vn/Sn	Vn/Sn * 100=Qn	Wn*Qn
Ph	8.5	0.11764706	204.90598	0.00488029	0.0005742	7	6.4	0.1	10	0.00574151
Conductivity	1000	0.001	204.90598	0.00488029	4.88E-06	0	20	0.02	2	9.7606E-06
Zn	3	0.33333333	204.90598	0.00488029	0.0016268	0	87.17	29.056667	2905.6667	4.72682912
Fe	0.3	3.33333333	204.90598	0.00488029	0.0162676	0	0.167	0.5566667	55.666667	0.90556437
Pb	0.01	100	204.90598	0.00488029	0.4880287	0	0.0123	1.23	123	60.0275306
Cu	1	1	204.90598	0.00488029	0.0048803	0	0.006	0.006	0.6	0.00292817
Arsenic	0.01	100	204.90598	0.00488029	0.4880287	0	0.0048	0.48	48	23.4253778
TH	150	0.00666667	204.90598	0.00488029	3.254E-05	0	205.48	1.3698667	136.98667	0.0044569
TDS	500	0.002	204.90598	0.00488029	9.761E-06	0	0.3101	0.0006202	0.06202	6.0535E-07
TSS	500	0.002	204.90598	0.00488029	9.761E-06	0	0.126	0.000252	0.0252	2.4597E-07
TC	10	0.1	204.90598	0.00488029	0.000488	0	55	5.5	550	0.26841579
THPC	100	0.01	204.90598	0.00488029	4.88E-05	0	90	0.9	90	0.00439226
		204.90598			1			**Water Quality Index**		**89.3712471**

Source: Researchers Calculation (2021)

Table 6: WAWQI Analysis for Borehole Water Sample Collected in June

Parameters	(Sn)	1/Sn	∑1/Sn	K=1/∑(1/Sn)	Wn=K/Sn	(Vo)	(Vn)	Vn/Sn	Vn/Sn * 100=Qn	Wn*Qn
Ph	8.5	0.11764706	204.90598	0.00488029	0.0005742	7	6.4	0.1	10	0.00574151
Conductivity	1000	0.001	204.90598	0.00488029	4.88E-06	0	20	0.02	2	9.7606E-06
Zn	3	0.33333333	204.90598	0.00488029	0.0016268	0	85.97	28.656667	2865.6667	4.66175863
Fe	0.3	3.33333333	204.90598	0.00488029	0.0162676	0	0.195	0.65	65	1.05739552
Pb	0.01	100	204.90598	0.00488029	0.4880287	0	0.0144	1.44	144	70.2761333
Cu	1	1	204.90598	0.00488029	0.0048803	0	0.0088	0.0088	0.88	0.00429465
Arsenic	0.01	100	204.90598	0.00488029	0.4880287	0	0.0049	0.49	49	23.9134065
TH	150	0.00666667	204.90598	0.00488029	3.254E-05	0	200.17	1.3344667	133.44667	0.00434172
TDS	500	0.002	204.90598	0.00488029	9.761E-06	0	0.354	0.000708	0.0708	6.9105E-07
TSS	500	0.002	204.90598	0.00488029	9.761E-06	0	0.14	0.00028	0.028	2.733E-07
TC	10	0.1	204.90598	0.00488029	0.000488	0	54	5.4	540	0.2635355
THPC	100	0.01	204.90598	0.00488029	4.88E-05	0	88	0.88	88	0.00429465
		204.90598			1			**WQI**		**100.190913**

Source: Researchers Calculation (2021)

Lead and Arsenic are toxic heavy metal contaminants which contributed negatively to the WQI outcome of the borehole water samples. When compared with other parameters, the NSDWQ / WHO acceptable limits for Lead and Arsenic are very low (0.01mg/L). Therefore, it is observed that the weighted arithmetic water quality index is more sensitive to parameters with very low standard acceptable limits which eventually results to higher WQI value due to a higher unit weight calculation. The WQI value is usually high when the estimated analytical value (Vn) is close to or exceeds the standard acceptable limits (Sn) for parameters with very low standard acceptable limits than parameters whose standard acceptable limits are much higher even

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though their estimated analytical values (Vn) are close to or exceeds their standard acceptable limits. This finding is consistent with the study by Noori (2020) which compared the WQI result of WAWQI and CCME WQI for water samples in Iraq. The study concluded that WAWQI is sensitive to the presence of toxic contaminants, resulting to a higher and exaggerated WQI value due to the use of unit weight calculations in the weighted arithmetic WQI especially for parameters with very low standard acceptable limits. Ebonyi State of which Ohaozara LGA is a part of is blessed with abundant solid mineral deposits with potential of water sources contamination due to mining activities across the state. Ezeh and Chukwu (2011), Nwogha et al (2017), Okolo, Oyedotun and Akamigbo (2018).

In the analysis of the CCME-WQI conducted for hand dug well samples collected in the months of May and June, it was observed as presented in table 7.0 that the WQI value was 53.513, which was ranked at marginal water quality status. This indicated that the water quality is frequently threatened or impaired and that conditions often depart from natural or desirable levels. This can be said to be consistent with the findings indicating the physicochemical and microbiological parameters of Zinc, Iron, Total coliform, and Heterotrophic plate count all showed values exceeding the NSDWQ / WHO acceptable limits.

Table 7: CCME-WQI Analysis for Hand Dug Well Water Samples

Para-Meters	**pH**	**Cond**	**Zn**	**Fe**	**Pb**	**Cu**	**Ar**	**TH**	**TDS**	**TSS**	**TC**	**HPC**
NSDWQ /WHO	8.5	1000	3	0.3	0.01	1	0.01	150	500	500	10	100
May	6.3	20	49.96	0.836	0.0001	0.0002	0.00048	127.08	0.202	0.088	60	105.2
June	6.4	20	50.47	0.728	0.0001	0.0001	0.0004	126.96	0.256	0.146	63	107

F1	**F2**	**nse**	**F3**	**WQI**
33.333	33.333	1.88	65.273	53.513

Source: Researchers Calculation (2021)

Table 8: CCME-WQI Analysis for Borehole Water Samples

Para-Meters	**pH**	**Cond**	**Zn**	**Fe**	**Pb**	**Cu**	**Ar**	**TH**	**TDS**	**TSS**	**TC**	**HPC**
NSDWQ /WHO	8.5	1000	3	0.3	0.01	1	0.01	150	500	500	10	100
May	6.4	20	87.17	0.167	0.0123	0.006	0.0048	205.48	0.3101	0.126	55	90
June	6.4	20	85.97	0.195	0.0144	0.0088	0.0049	200.17	0.354	0.14	54	88

F1	**F2**	**Nse**	**F3**	**WQI**
33.333	33.333	2.749	73.329	49.668

Source: Researchers Calculation (2021)

Correspondingly, table 8 showed CCME-WQI value for the borehole water samples collected in May and June as 49.668. The result is lower than the hand dug well WQI and signifies a lower water quality than the hand dug well water samples. However, the WQI value still ranks within the marginal water quality status, indicating also that the water quality is frequently threatened or impaired and that conditions often depart from natural or desirable levels. In examining the data in table 8.0, lead which is a toxic heavy metal exceeded the NSDWQ / WHO acceptable limits together with Zinc, Total hardness, and Total Coliform. The scope (F1) which represents the percentage of variables that do not meet their objectives and the frequency (F2) which represents the percentage of individual tests that do not meet their objectives have the same values for the hand dug well and borehole water samples with 33.333 each. However, the amplitude (F3) which represents the amount by which failed test values do not meet their objectives is higher in the borehole water samples (73.329) when compared with the hand dug well water samples (65.273). This suggests that the toxic heavy metal (lead) together with other parameters contributed to the higher F3 value in the borehole samples as was observed in the physicochemical analysis due to how much their values exceeded the objective or standard acceptable limits. This finding is consistent with the studies on CCME-WQI conducted by Noori (2020), Khan, Khan and Hall (2005), Murtala and Edwin (2013).

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Table 9: Comparative Result of the Water Quality Index

Index Type	**Period**	**Water Source**	**WQI**	**Ranking/Status**
WAWQI	May	Hand dug well	10.379	Excellent
	June		9.445	Excellent
	May	Borehole	89.371	Very Poor
	June		100.19	Unfit for drinking
CCME-WQI	May & June	Hand dug well	53.513	Marginal
	May & June	Borehole	49.668	Marginal

Source: Researchers Calculation (2021)

In the comparative result on table 9.0, the WAWQI result for the hand dug well water sample showed 10.379 and 9.445 for the months of May and June respectively, representing a water quality status of excellent. This is a sharp contrast from the CCME-WQI result for the hand dug well sample in which the months of May and June required to be analysed together for the CCME-WQI result showed a WQI value of 53.513, representing a water quality rank of marginal. The marginal rank of the CCME water quality indicates frequently threatened or impaired water source where conditions often depart from natural or desirable levels. This status agrees with the physicochemical and microbiological analysis that indicated parameters like Zinc, Iron, Total Coliform and Heterotrophic plate count exceeded NSDWQ / WHO acceptable limits in the hand dug well samples. However, the WAWQI result which indicated excellent water quality status gives an impression of a pure water source with all known parameters within acceptable limits, contrary to the physicochemical and microbiological analysis which stated certain parameters exceeded acceptable limits as revealed in tables 3.0 and 4.0. This exaggeration in water quality status for the WAWQI is attributed to the use of unit weight calculation for each specific parameter which gives higher WQI to toxic contaminants with very low acceptable limits like heavy metal contaminants of lead and Arsenic and lower WQI to other contaminants with higher acceptable limits like Zinc, Iron, Total Coliform and Heterotrophic, suggesting the status of excellent for the hand dug well water samples analysed with the WAWQI. Correspondingly, that explains the reason for the WAWQI values for the borehole water samples of May and June indicating 89.371 and 100.19 respectively with water quality status of very poor and unfit for drinking.

The CCME-WQI value for the borehole water samples indicated 49.668, with a water quality ranking of marginal. This ranking is the same with the hand dug well sample, indicating that both water sources are contaminated with conditions not consistent with natural or desirable levels. Though both the borehole and hand dug well water sources have certain parameters exceeding acceptable limits, for both water sources falling within same water quality ranking in the CCME-WQI despite the differences in the toxicity of the contaminants could be arguably described as moderate. According to Noori (2020), the CCME-WQI is relatively lenient when compared with the WAWQI. The study stated that when there is high toxicity in a particular water source not exceeding the acceptable limits, the CCME-WQI indicates an excellent water source but the WAWQI for the same water source indicates an unfit for drinking or poor water quality status. According to the NSDWQ (2007), there are no known health impact from Zinc and Iron. Total coliform and heterotrophic plate count are used to assess the cleanliness and integrity of water systems (WHO 2011). However, Lead and Arsenic are toxic heavy metal contaminants that are carcinogenic (NSDWQ 2007). Therefore, water sources with toxic heavy metal contaminants close to or exceeding standard acceptable limits arguably should be ranked clearly lower than contaminants with no known health impact to consumers. Calmuc et al (2018) in their study stated that one of the demerits of the CCME-WQI is that all variables have the same importance in the determination of the water quality index.

Similarities of WAWQI and CCME-WQI

- The WA and CCME water quality indices provide a single number that describes the overall water quality status of sampled water sources.
- They both provide an opportunity for policy makers and stakeholders to make informed decision on water sources of a particular location and time based on the result of the water quality index.
- The WA and CCME water quality indices utilize ranks to describe water quality status from 0 – 100.
- Both water quality indices can be applied in the determination of water quality status for both surface and underground water sources.
- The WA and CCME water quality indices are internationally recognised and widely utilised tools for water quality status determination.

Differences between WAWQI and CCME-WQI

- The WAWQI utilises parameters from at least one water sample at a time to determine the WQI. The CCME-WQI utilises parameters from a minimum of two water samples collected over a period to determine the WQI.
- The WAWQI determines the WQI by calculating the unit weight of each parameter analysed from the water sample. The CCME-WQI determines the WQI by calculating the scope (F1), Frequency (F2) and Amplitude (F3) of the parameters (variables) analysed from the water samples.
- The WAWQI ranking begins from 0 – 25 (Excellent) to 100 and above (Unfit for drinking). The CCME-WQI ranking begins from 0 – 44 (Poor) to 95 – 100 (Excellent).

- The WAWQI is more sensitive to toxic contaminants with values close to or above acceptable limits resulting to higher WQI values tending towards unfit for drinking water quality status. The CCME-WQI is moderate to all contaminants. When above acceptable limits they tend towards poor water quality and when within acceptable limits, they tend towards excellent water quality status.
- The WAWQI is better suited to be applied in the study area to alert consumers due to its sensitivity to toxic heavy metal contaminants. Ohaozara and Ebonyi State in general is blessed with solid mineral deposits with potential of water sources contamination.

CONCLUSION

The study concluded that the WQI of the water sources varied depending on the type of Index being applied. The WAWQI showed that the hand dug well water source from Okposi community presented an excellent water quality status despite the presence of contaminants exceeding the acceptable limits while the CCME-WQI indicated a marginal water quality status. However, the borehole water source from Uburu community presented very poor and unfit for drinking water quality status due to the presence of toxic heavy metal contaminants like Lead and Arsenic while the CCME-WQI result for the borehole sample presented marginal water quality status. The use of different WQI tools presented different results depending on the method of calculation and the level of contaminants present in the water source. While the WAWQI utilised unit weight for its calculation, CCME-WQI utilised the scope (F1), Frequency (F2) and Amplitude (F3) for its calculation to determine the WQI. The study revealed that WAWQI is better suited to be applied in the study area due to its sensitivity to toxic heavy metal contaminants as observed in the physicochemical analysis. The CCME-WQI is more moderate to all contaminants which resulted to the water quality ranking of marginal for both the hand dug well and bore hole water sources as compared to the WAWQI ranking of excellent, very poor and unfit for drinking to both water sources. The application of WQI gives a general description of the water quality status for easy understanding and informed decision by policy makers and stakeholders. it is therefore recommended that all water sources be properly treated before consumption to safeguard the health of consumers.

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