Journal homepage: www.fia.usv.ro/fiajournal
Journal of Faculty of Food Engineering,
Ştefan cel Mare University of Suceava, Romania
Volume XVIII, Issue 4- 2019, pag. 308 - 314

FOOD AND ENVIRONMENT SAFETY

APPLICATION OF WATER QUALITY INDEX IN THE DRINKING WATER QUALITY ASSESSMENT OF A SOUTHEASTERN NIGERIA RIVER

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Received 18th October 2019, accepted 27th December 2019

Abstract: *The physico-chemical parameters of Ikwu River were studied between January and June 2016 in 3 stations to assess its drinking water quality using water quality index. Weighted arithmetic water quality index (WAWQI) method was used. Thirteen parameters were evaluated which included temperature, pH, electrical conductivity (EC), dissolved oxygen, total dissolved solid (TDS), chemical oxygen demand (COD), nitrate, alkalinity, phosphate, sulphate, chloride and calcium. The physico-chemical parameters recorded were within acceptable limits except dissolved oxygen and pH. One-way analysis of variance (ANOVA) showed that pH, EC, TDS, COD and Calcium were significantly different and station 2 was observed to be the source. The Water Quality Index (WQI) for stations 1 and 3 were 56.49 and 57.21 respectively; categorised as poor drinking water quality while station 2 was 79.70; categorised as very poor drinking water quality. This study also showed that pH and dissolved oxygen were the contributing parameters that rendered Ikwu River unfit for drinking. It was concluded that water of Ikwu River is unsuitable for human consumption.*

Keywords: *Physico-Chemical, Anthropogenic, Limits, Potable water, Ikwu River.*

1. Introduction

Rivers have always been the most important freshwater resources, ancient civilizations have flourished along their banks while most developmental activities are still depends on them [1]. Man's utmost concern since the beginning of civilization has been the search for good quality domestic water. One of the world most challenging environmental problems resulting in the increasing demand for domestic water is the scarcity and search for clean freshwater [2]. Rivers and streams are sources of water for the domestic and other uses for rural community dwellers along the water fronts [3]. Water is essential in the sustenance of life, and a satisfactory (adequate, safe and accessible) supply must be made available to all [4]. Since it is directly linked with human welfare, the quality of water is of great concern to mankind [5]. Surface water (lakes, rivers, streams, springs, etc.) and ground water (borehole water and well water) are the two principal natural sources of drinking water [6, 7]. Water pollutants that exceed certain standards are a threat to public health [8]. Consequently, monitoring of surface water quality is an important issue for evaluating spatiotemporal variations of the surface water resources [9]. Water resources challenges have long existed in sub-Sahara Africa, but their impacts have been exacerbated by recent trend such as increasing urbanization, industrialisation, agriculture and climate change. These challenges highlight the fact that the quantity and quality of water available is rapidly diminishing [10]. Water quality indices are tools to evaluate the conditions of water quality and require basic knowledge of water quality assessment like any other tool [11]. It is an acceptable way of expressing water quality with a reliable standard of measurement which reflects changes in the critical components of water [12]. Water Quality Index (WQI) is a method of expressing an aggregated numerical value showing level of water quality [13]. It simplifies large amounts of water quality data in a reliable way that can be appreciated by the decision-makers and general public [14].The overall water quality of a certain location and time derived from a number of water quality parameters can be presented in a single number using Water quality index (WQI) [15]. The aim of this study is to assess the drinking water quality of Ikwu River using Water Quality Index.

2. Matherials and methods

Study Area and sampling stations

The portion of Ikwu River studied is located in Ohuhu Community, along Umuahia – Uzoakoli Road, Umuahia, Abia State, Nigeria. It is located within 5º34'11.988″ - 5º34'48.000″N and 7º28'44.400″ - 7º28'52.764E (Figure 1). The river is near the popular Oban International Market in Umuahia. The river flowed through Umuire and Umuegwu Okpula villages before discharging into the Imo River basin [16]. Three sampling stations were selected along the river for the purpose of this study. Station 1 on the right side along Umuahia-Uzoakoli Road; is the upstream and control station. There were limited human activities such as extraction of water for horticultural, agricultural and drinking purposes. Raffia palm (*Rafia africana*) was the dominant plant while *Reissantia indica* was the dominant aquatic macrophyte; Station 2 which is about 150 metres downstream of Station 1 was located on the left side of Umuahia – Uzoakoli Road. In the upper part of this station, bathing, washing of cars, tricycles and motorcycles as well as abstraction of water for drinking were observed. Cattle are also watered in the station by Fulani herdsmen; resulting in defecation into the water. *Napoleona vogelli*, *Aneilema aequinoctiale* and *Diplazium sammatii* were the common aquatic macrophytes encountered and Station 3, about 530m downstream of station 2 was located within Umuire village and serve as a major source of water for domestic purposes. Aquatic macrophytes, *Hyptis suaveoleus* and *Solenostemon monostachyus* were encountered. Abstraction of water for drinking, washing of clothes, fermentation of cassava and bread fruit, bathing and swimming are some of the human activities observed in this station.

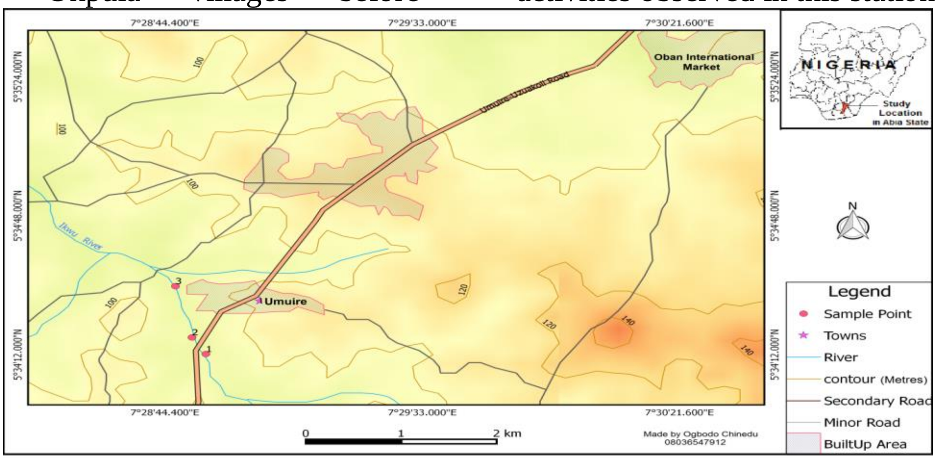

Fig. 1: Map of Umuahia, Southeast Nigeria showing the sampling Stations of Ikwu River.

Sample Collection and Analysis

Water samples were collected from Ikwu River monthly from January to June 2016. The samples were stored in sterilized 1litre plastic bottles and then taken to the laboratory for analysis. The physicochemical parameters were analyzed using standards methods described by [17]; as follows: Water temperatures and pH (Digital pH meter/ thermometer (Hach EC 20), Electrical Conductivity (HACH Conductivity Meter (HACH CO. 150), TDS (Gravimetric Method), DO (Winkler Method with azide Modification), COD (Open Reflux Method), Nitrate, sulphate, and chloride (Hach DR 1900 UV Spec), Phosphate (Stannous Chloride Method), Sodium (Technicon auto analyzer flame photometer IV), Calcium and Alkalinity (Titrimetic Method). All the results were statistically analysed using single factor ANOVA to test for significant difference among the stations and Tukey Pairwise test was performed to determine the location of any significant difference. The PAST software package (Version 3.24) was used in the analysis [18]. The weighted Arithmetic index method as described by [19] was used for the calculation of WQI in this study. Thirteen (13) parameters were evaluated and World Health Organisation (WHO) Drinking Water Quality guideline [20] was used as the recommended standard. The Weighted arithmetic water quality index (WAWQI) method is used in the classification of the water quality based on the level of purity; using the most commonly measured water quality parameters (Table 1). The method has been widely used by the various scientists [15, 21 – 26] and the calculation of WQI was made as described by [12] using the equation:

$$WQI = \frac{\Sigma Q_i W_i}{\Sigma W_i} \qquad (1)$$

The quality rating scale (Q_i) for each parameter is calculated by using this expression:

$$Q_i = 100\left[\frac{V_i - V_o}{S_i - V_o}\right] \qquad (2)$$

Where,

V_i is estimated concentration of ith parameter in the analysed water, V_o is the ideal value of this parameter in pure water. V_o = 0 (except pH = 7.0 and Dissolved Oxygen = 14.6 mg/l), S_i is recommended standard value of ith parameter.

The unit weight (Wi) for each water quality parameter is calculated by using the following formula:

$$Wi = K/S_i \qquad (3)$$

Where, K = proportionality constant.

Table 1:
Water Quality Rating as per Weight Arithmetic Water Quality Index Method

WQI Value	Rating of Water Quality	Grading
0 – 25	Excellent Water Quality	A
26 – 50	Good Water Quality	B
51 – 75	Poor Water Quality	C
76 – 100	Very Poor Water Quality	D
> 100	Unsuitable For Drinking Purpose	E

Source: [19].

3. Results and discussion

The summarised results of the physico-chemical parameters analysed in the Ikwu River water samples and the calculated water quality index (WQI) are presented in Table 2.

Most of the parameters (electrical conductivity, total dissolved solids, nitrate, sulphate, chloride, chemical oxygen demand, phosphate, sodium and calcium) evaluated were generally within acceptable limits and lower in stations 1 and 3, except dissolved oxygen. Some of the parameters were significantly different and point to station 2 as the source of the variation. The more serious problem observed in this study was pH and dissolved oxygen, which had values outside acceptable limits and point to pollution attributed to increased human activities.

The temperature values ranged between 22.0 and 28.0 ºC. The lowest temperature values were recorded in stations 2 and 3 in January 2016 while the highest temperature value was recorded in station 1 in February 2016. The water temperatures were influenced by seasons. There was no significant difference in temperature (P > 0.05) in all the stations. Though the temperature values recorded in this study were within acceptable limits, some were relatively high; [27] observed that temperature has a significant effect on the flavour of tap water, and a temperature that is 20 to 25 ºC cooler than body temperature is generally considered to provide optimum taste. Cool water is more palatable than warm water and high water temperature enhances the growth of microorganisms and may increase taste, odour, colour and corrosion problems [28].

Table 2

Summary of physico-chemical parameters and WQI recorded at Ikwu River, Umuahia, Nigeria

Parameters	Station 1 X±S.E.M	Station 2 X±S.E.M	Station 3 X±S.E.M	p-value	WHO Standard[20]
Water Temperature (ºC)	25.85 ± 0.78 (22.0 – 27.5)	25.92 ± 0.81 (22.0 – 27.5)	26.45 ± 0.92 (22.0 – 28.0)	P > 0.05 F = 3.02	40
pH	6.58 ± 0.27^{a} (5.46 – 7.34)	8.46 ± 0.48^{b} (7.22 – 10.32)	6.39 ± 0.38^{a} (5.14 – 7.45)	P < 0.05 F = 8.74	6.5 - 8.5
Electrical Conductivity (µS/cm)	22.85 ± 1.56^{a} (18.5 – 27.8)	36.97 ± 2.88^{b} (28.4 – 45.5)	26.38 ± 1.96^{a} (22.1 – 33.6)	P < 0.05 F = 11.1	100
Total dissolved solids (mg/l)	15.3 ± 1.03^{a} (12.4 – 18.6)	24.78 ± 1.93^{b} (19.0 – 30.5)	17.68 ± 1.32^{a} (14.8 – 22.5)	P < 0.05 F = 11.2	500
Dissolved oxygen (mg/l)	5.42 ± 0.57 (4.2 – 7.7)	4.72 ± 0.39 (3.9 – 6.3)	5.9 ± 0.35 (4.5 – 6.8)	P > 0.05 F = 2.91	> 5
Chemical oxygen demand (mg/l)	25.93 ± 1.57^{a} (18.6 – 29.5)	49.08 ± 9.31^{b} (35.5 – 94.0)	39.93 ± 2.68^{a} (33.4 – 49.4)	P < 0.05 F = 4.23	100
Nitrate (mg/l)	2.8 ± 0.13 (2.5 – 3.3)	3.0 ± 0.13 (2.5 – 3.5)	2.68 ± 0.11 (2.3 – 3.0)	P > 0.05 F = 2.53	50
Alkalinity (mg/l)	0.63 ± 0.18 (0.28 – 1.19)	0.69 ± 0.17 (0.38 – 1.25)	0.73 ± 0.15 (0.16 – 1.2)	P > 0.05 F = 1.93	50
Phosphate (mg/l)	1.24 ± 0.15 (0.86 – 1.88)	1.46 ± 0.16 (0.98 – 2.14)	1.36 ± 0.30 (0.75 – 2.44)	P > 0.05 F = 2.00	100
Chloride (mg/l)	6.23 ± 0.22 (5.3 – 6.8)	6.78 ± 0.41 (5.3 – 8.4)	6.73 ± 0.25 (5.9 – 7.7)	P > 0.05 F = 2.99	250
Sulphate (mg/l)	0.42 ± 0.02 (0.37 – 0.48)	0.66 ± 0.15 (0.3 – 1.27)	0.75 ± 0.14 (0.28 – 1.13)	P > 0.05 F = 2.82	200
Sodium (mg/l)	4.81 ± 1.16 (2.55 – 9.8)	5.7 ± 1.04 (2.8 – 9.2)	3.86 ± 0.47 (2.24 – 5.7)	P > 0.05 F = 2.71	250
Calcium (mg/l)	13.01 ± 1.86^{a} (8.0– 20.0)	22.77 ± 1.10^{b} (17.6 – 25.3)	13.65 ± 0.38^{a} (12.6 – 15.0)	P < 0.05 F = 18.4	75
WQI	56.49	79.70	57.21		

a, b = Means with different superscripts across the rows are significantly different at p<0.05; SEM= Standard Error of Mean.

The pH values ranged between 5.14 and 10.32. Some of the pH values were not within the acceptable limits set by WHO. The lowest pH value was recorded in station 3 in January 2016 while the highest pH value was recorded in May 2016 in station 2. Station 2 was significantly difference (P < 0.05) from the other stations. Some of the pH values were outside the acceptable limits and according to [29], extremes of pH as recorded in this study are attributable to pollution. Prolonged intake of water with low pH may predispose one to the dangers of acidosis, which Health Experts believe could lead to cancer or cardiovascular damage including blood vessels constriction and reduction in oxygen availability even at low levels [30]. Abnormal values of pH causes bitter taste to water, affect mucous membrane, cause corrosion and also affect aquatic life [31].

The dissolved oxygen values ranged between 3.9 and 7.7 mg/l. Some of the dissolved oxygen values recorded in this study was below acceptable limits (> 5 mg/l). The lowest dissolved oxygen value was recorded in February 2016 in station 2 while the highest dissolved oxygen value was recorded in June 2016 in station 1. There was no significant difference ($P > 0.05$) in all the stations. Some of the dissolved oxygen values are lower than acceptable limits. A high DO level in a community water supply is good because it makes drinking water taste better [32]. Organic wastes can enter a body of water in the of form leaves, grass clippings, dead plants and animals, animal droppings and sewage [33] and these organic materials eventually are broken down by bacteria, which require oxygen for decomposition process [34]. [35] reported that a low DO indicates a high COD. The highest COD value was recorded in station 2 and could be attributed to anthropogenic and seasonal influences. [33] and [28] reported that depletion of dissolved oxygen in water supplies can encourage the microbial reduction of nitrate to nitrite and sulphate to sulphide as well as mobilization of trace metals.

The results showed that the WQI varied from 56.49 to 79.70. The results indicated that stations 1 and 3 with WQI of 56.49 and 57.21 respectively, are of poor water quality (Grade C) while station 2 with WQI of 79.70 was considered very poor water quality (Grade D) when compared to the WQI standards for the weighted arithmetic index method by [19] in Table 1. The pH of the samples contributed to the high WQI values recorded in this study especially in Station 2, where pH contributed as high as 11.49 to the sum of the product of their quality rating scale and unit weight (Q_iW_i). In [36], pH contributed as low as 2.63 - 4.17 to Q_iW_i, which resulted in lower WQI values while in [25], pH contributed as high as 22.03 to Q_iW_i. Dissolved oxygen also contributed to high Q_iW_i especially in station 2, where anthropogenic impacts (including watering of cattle) were intense. The water quality index values recorded was a reflection of the nature and intensity of the anthropogenic activities going on in the river.

4. Conclusion

Based on the water quality index values recorded in this study, it can be concluded that waters of Ikwu River are unsuitable for human consumption especially in station 2; though it is the only source of water for drinking and other domestic uses in the area. Traditional system of water conservation includes certain activities that are restricted, while some sections of the river are demarcated for special purpose. Water can also be boiled, cooled and filtered before drinking.

5. Acknowledgments

We sincerely appreciate Mr. Mike Ndiuche of Department of Plant Science and Biotechnology, Michael Okpara University of Agriculture, Umudike, Nigeria, who identified all plants and aquatic macrophytes. We also appreciate Mr.

Chinedu Ogbodo of Department of Geography, University of Nigeria, Nsukka, Nigeria, who produced the study map.

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