EQA - International Journal of Environmental Quality
ISSN 2281-4485 - Vol. 49 (2022): 34-42
Journal homepage: https://eqa.unibo.it/

published by

Models of water quality index for monitoring of available drinking bottled water consumed within Jalingo municipal

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Article info
Received 18/05/2022; received in revised form 12/07/2022; accepted 10/08/2022
DOI: 10.6092/issn.2281-4485/14911

Abstract
This study was carried out to develop a model of water quality index to be used for quality control of available bottled water consumed within Jalingo municipal. Six (6) different products of available bottled drinking water samples were obtained from Jalingo main market. The parameters of this bottled water were analyzed in the Environmental Laboratory of Taraba State Water Supply and Sewage Corporation (TAWASCO) Headquarters, Jalingo. Results of the analysis showed that values of temperature of all the six bottled water samples have exceeded the permissible value, but has no health implication, while results for turbidity, pH, Dissolved oxygen and electrical conductivity values were below the permissible limit. Results gotten from the analysis, through appropriate equations and the use of Minitab 19, were used to determine Water Quality Index (WQI) of the bottled water samples and it was observed that BW_3 had a water quality status of excellent and BW_2 and BW_4 had good as the water quality status while BW_1, BW_2 and BW_6 had water quality status as poor. The model equation has a reliability (R^2) of 90.3% and error of 9.7%. The experimental values of the water quality index were compared with those from the model equation and the results showed there were very little errors ranging from 0.00 to 0.48; indicating that there was a significant agreement between the values of WQI obtained by experiments and the ones from model equation. Finally, it was concluded that, in terms of both water quality index/parameters, the various bottled water samples are safe and fit for consumption and the equation could be employed for quality control of the available bottled water consumed within the confined of this study.

Keywords
Parameter, Modeling, Assess, Equation

Introduction

Water has been defined by Reece and Jane (2013) as the solvent of life. No living creature can stand the test of time without water. Virtually no activity can work successfully without involving water. Water quality has been defined by Cordy and Gail (2014), Johnson *et al.* (1997) as the chemical, physical, and biological characteristics of water based on the standards of its usage. These standards mostly are used to monitor and assess water quality in order to convey the health of ecosystems, safety of human contact, extend of water pollution and condition of drinking water. The parameters for water quality are determined by the intended use. Work in the area of water quality tends to be focused on water that is treated for potability, industrial/domestic use, or restoration of an environment/ecosystem, generally

DOI: 10.6092/issn.2281-4485/14911

for health of human/aquatic life.

According to UN report, eight hundred and forty-four (844) million people, that is just 1 in 10 of the global population in 2015 were still living without access to basic drinking water services (UNW-DPAC, 2015); the Un report in 2018 further said only 71% were using safely managed drinking water service (UN, 2018), and sadly 58% of 159 million people who were still collecting drinking water directly from surface water lived in sub-Saharan Africa (WHO-UNICEF-JMP, 2017) and the situation is still the same 1 in 3 people do not have access to safe drinking water (WHO, 2019). According to the World Health Organization's 2017 report, safe drinking-water is water that does not represent any significant risk to health over a lifetime of consumption, including different sensitivities that may occur between life stages. The availability and quantity of drinking water are nothing without quality, because poor quality of drinking water leads to health problems which can even cause death (WHO, 2017). Therefore, several companies are involved in purification and packaging water in bottles for direct drinking where tap water is inaccessible or when the quality of tap water cannot be trusted (Janan, 2015).

The Water Quality Index represents a numerical expression which has the purpose of establishing the ecological state of a body of water (Gazzaz *et al*., 2012; Ismail and Robescu, 2017). Horton (1965) proposed the first water quality index (WQI), a great deal of consideration has been given to the development of 'water quality index' methods with the intent of providing a tool for simplifying the reporting of water quality data. Tyagi *et al*. (2013) and Feng *et al*. (2016) stated that Water quality indices vary according to the water quality parameters used in the index, as well as toward the algorithm of calculation and the scale of water quality rating. Method of water quality index (WQI) numerically sums up set of different water quality parameters into one value. It is primarily developed as an auxiliary tool for summarizing data of water monitoring and reporting of the wider public, which is why it is rather general in nature (Brown *et al*., 1970). The Valentina *et al*. (2018) presented four the most common methods of calculating WQI, which includes National Sanitation Foundation-Water Quality Index (NSF-WQI); Oregon Water Quality Index (OWQI); Weighted Arithmetic Water Quality Index Method and The Canadian Council of Ministers of the Environment Index (CCME-WQI).

Water quality modeling involves water quality based data using mathematical simulation techniques. Water quality modeling helps people understand the eminence of water quality issues and models provide evidence for policy makers to make decisions in order to properly mitigate water (Tang *et al*., 2019). Water quality modeling also helps determine correlations to constituent sources and water quality along with identifying information gaps (Preston, 2019). Due to the increase in freshwater usage among people, water quality modeling is especially relevant both in a local level and global level. In order to understand and predict the changes over time in water scarcity, climate change, and the economic factor of water resources, water quality models would need sufficient data by including water bodies from both local and global levels (Bozorg-Haddad *et al*., 2017; Tang *et al*., 2019).

Bottled drinking water is currently a popular but expensive source of drinking water in Nigeria like elsewhere in Africa, especially in cities where the majority of rich people are concentrated because they believe that it is safe as it undergoes further treatment before being packaged (AF-Shahaby, 2015). Bottled water quality is generally considered as water of good or acceptable quality; that is why it is been consumed in most offices, institutions (schools, Hospitals, industries and social events. Bottled water has been the most patronized in offices, during social events, institutions, industries and even homes of wealthy people; the water is hygienic, generally considered of acceptable quality and highly reliable; this has also been the practice in Jalingo municipal. The concentrations values of physicochemical parameters were not labeled on bottled water consumed in Jalingo municipal and there are no available models of water quality index of bottled water consumed in Jalingo metropolis. Therefore this research is aimed at developing a model of water quality index to be used for quality control of available bottled water consumed within Jalingo municipal.

Materials and Methods

Study area

Figure 1 shows the map of Jalingo metropolis, which is the headquarters of Taraba State-Nigeria, lies at latitude 8°54' to 9°01'N and longitude 11°22' to 11°30'E. It is situated within the Northern Guinea Savannah ecological zone. It is bounded to the North

DOI: 10.6092/issn.2281-4485/14911

by Lau LGA, to the East by Yorro LGA, to the South and West by Ardo-Kola LGA. Nine of the ten wards are located within the metropolis, these include Barade, Kona, Maji Dadi, Sarkin Dawaki, Sintali A, Sintali B, Turaki A, Turaki B and Kachalla Sembe wards. Part of Ardo-Kola (Taraba state university and kasuwan Bera) and part of Yorro (Santuwa community where Yagai Academy is sited) are in the metropolitan (Yusuf *et al*., 2020).

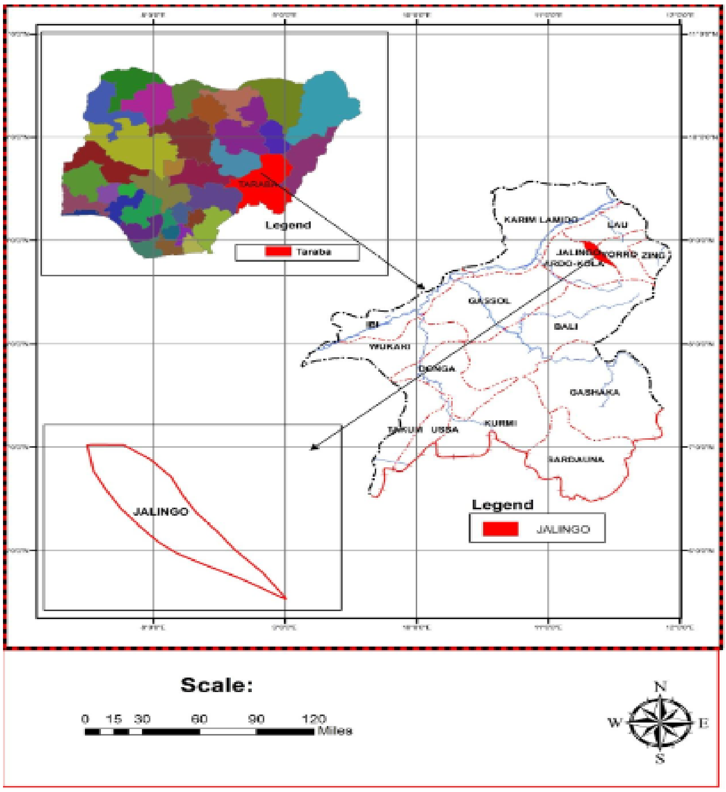

Figure 1. *Map of the study area (Yusuf et al, 2020).*

Physico-chemical analysis of bottled water sample

Six (6) different available bottled water products were obtained from Jalingo main market, where each of the bottles were designated as $BW_{1,}$ $BW_{2,}$ $BW_{3,}$ $BW_{4,}$ BW_5 and BW_6 respectively. Sources of the products could not be specified for some incriminating reasons. These bottled water samples were taken to the Environmental Laboratory of Taraba State Water Supply and Sewage Corporation (TAWASCO), Jalingo, Headquarters for analysis of the various physical and chemical parameters and in accordance with the standard methods prescribed by APHA (2005), WHO (2014). The physico-chemical parameters examined included: Temperature (Temp, ^{0}C), Turbidity (Turb, NTU), pH (-), Dissolved Oxygen (DO, mg/l) and Electrical conductivity (EC, µS/cm). The realized physical and chemical parameters values were compared with the standards of drinking water quality specified by World Health Organisation (WHO)/Nigeria Standard of Drinking Water Quality (NSDWQ) as approved by the Standard Organization of Nigeria (SON). The comparison will help to know whether values of the parameters are below/above the permissible level before drawing conclusion to the status of the aforementioned consumed bottled water.

Determination of water quality index (WQI)

The Water Quality Index for the bottled water were calculated for the five parameters namely: DO, EC, pH, Temp and Turb for the six samples of different bottled water to assess the suitability of the water for drinking purposes. The evaluation of the WQI was made on the basis of the standards of drinking water quality specified by WHO/NSDWQ as approved by the Standard Organization of Nigeria (SON). The weighted arithmetic mean method of evaluation of water quality index was used in this study. The WQI is given in Equation [1] as;

$$\mathrm{WQI} = \frac{\Sigma Q_i w_i}{\Sigma w_i} \quad [1]$$

DOI: 10.6092/issn.2281-4485/14911

The quality rating scale Q_J for each parameter was calculated via Equation [2].

$$Q_i = \left[\frac{v_i - v_0}{s_i - v_0}\right] X100 \qquad [2]$$

where, = Estimated concentration of the n[th] parameter in the analyzed water sample; = Ideal value of analyzed water parameter in pure water sample which is usually zero except PH = 7. 0 and DO = 14.6mg/l; = Recommended standard value of n[th] parameter (WHO/NSDWQ).

The unit weight () for each water quality parameter was evaluated using Equation [3].

$$w_i = \frac{k}{s_i} \qquad [3]$$

where; k = proportionality constant and can be evaluated by Equation [4].

$$k = \frac{1}{\sum \frac{1}{s_i}} \qquad [4]$$

The water quality index rating describes the range with which each of the calculated water quality index falls into. The WQI rating has been defined by Chatterrji and Raziuddin (2002) as Excellent (0-25), Good (26-50), poor (51-75), very poor (76-100) and unsuitable/ unfit (>100) for drinking. Calculated WQI of 100 and above indicates that the water is unfit for drinking while low calculated index indicates excellent water fit for drinking.

Relationship between water quality index/ parameters

WQI Model to be used is in the form of a polynomial terms as presented in Equation (5) where the values of the obtained WQI and that of the water parameters were entered into Minitab stat 19 software to determine coefficients which were transform, by trial and error method, to exponents and a constant in Equation [5].

$$Y_i = {x_1}^{a_1} + {x_2}^{a_2} + {x_3}^{a_3} - {x_4}^{a_4} - {x_5}^{a_5} + K \qquad [5]$$

The variables in Equation (5) are defined as represents WQI for each values of the respective water parameters, = Temp (0'c), = Turb (NTU), = PH, = DO (mg/l), = EC (µS/cm) are the corresponding values of the water parameters; represent the i[th] value of the corresponding exponent and k is the constant.

<u>Results and Discussion</u>

Physico-chemical data

The research was conducted on six (6) different available bottled water products which are consumed within Jalingo municipal. Results of the analyzed water parameters are displayed in Table 1. The results showed that the values of Temperature were in the range of 30.5°C to 32.6°C, of which all the values exceeded the permissible value (25°C), reason being that the temperature of water changes with environment. Moreover, water temperature does not really have direct health implication according to Nigerian Industrial Standarad (NIS-554-2015).

Table 1. *Physico-chemical parameters data.*

Sample	Temp (°)	TURB (NTU)	pH (-)	DO (mg/l)	EC (µS/cm)
BW_1	32.3	0.11	6.31	1.64	137.3
BW_2	31.7	0.24	6.07	1.85	49.7
BW_3	32.4	0.12	4.58	1.82	30.9
BW_4	32.6	0.65	5.68	1.87	4.8
BW_5	30.5	0.12	6.73	1.59	389
BW_6	30.6	0.20	6.32	1.58	252

DOI: 10.6092/issn.2281-4485/14911

Turbidity of the water ranges from 0.11 NTU to 0.65 NTU, which shows that the values were below the acceptable limit of WHO/NSDWQ (5 NTU) and this goes in line with the research conducted by Icyimpaye (2019) and that of Bapper and Younis (2016). pH of the water ranges from 6.07 to 6.73, which are also below the allowable limit (8.5). The result also shows that the water was slightly acidic (soft). The findings of the present study is in agreement with the findings by Momani (2006) and Sasikaran *et al* (2012). Dissolved oxygen (DO) from this study ranged from 1.52 mg/l to 1.87 mg/l, which is low and below the permissible level (8mg/l), which could be attributed to high temperature and confinement of the water bottles. The values of (EC) ranged from 4.8 µS/cm to 389 µS/cm, which fall within the permissible level (1000 µS/cm) and has also agreed with the study conducted by Elisabet *et al*. (2019), Icyimpaye (2019). However, it is observed that the water in BW_4 has the least value of 4.8µS/cm and BW_5 has the highest value of 389 µS/cm. The label on bottled water consumed in Jalingo does not contain the composition of the parameters and that makes it difficult to compare between the measured and the source values, unlike that of Bapper and Younis (2016) where the compositions were included on the labels, which makes the water quality control easier.

Water quality index data

Data of water parameters gotten in Table 1, through the variables in Equations (1 to 4), were inputted into Microsoft excel 2016 to determine the water quality index of the six (6) brands of bottled water as presented in Table 2. The results show that the water quality index of these six (6) brands of bottled water has BW_3 as excellent, BW_2 and BW_4 as good while BW_5, BW_1 and BW_6 were rated as poor. Bapper and Younis (2016) in their study also had the results of their WQI ranging from excellent to poor rating while the results of Elisabet *et al*. (2019) were excellent and good grade, which is better than that of the present study and the study by Bapper and Younis (2016).

Water quality index (WQI) models

A mathematical relationship was developed in Equation (5) and the exponents and constant were determined as presented in Equations (6 to 11). The results showed that the reliability of the model R^2 = 90.3% and error of 0.097, hence there was a significant agreement between them. The developed equation for each brand are presented as;

Developed model of water quality index of BW_1

$$Y_1 = {x_1}^{a_1} + {x_2}^{a_2} + {x_3}^{a_3} - {x_4}^{a_4} - {x_5}^{a_5} + K$$

$$Y_1 = 32.3^{0.554} + 0.11^{0.170} + 6.31^{2.422} - 1.64^{4.178} - 137.3^{0.866} + 35.862 \quad [6]$$

WQI for BW_1 = 51.18

Developed model of water quality index of BW_2

$$Y_2 = {x_1}^{a_1} + {x_2}^{a_2} + {x_3}^{a_3} - {x_4}^{a_4} - {x_5}^{a_5} + K$$

$$Y_2 = 31.7^{0.664} + 0.24^{-0.060} + 6.07^{2.017} - 1.85^{3.890} - 49.7^{0.805} + 32.456 \quad [7]$$

WQI for BW_2 = 47.32

Developed model of water quality index of BW_3

$$Y_3 = {x_1}^{a_1} + {x_2}^{a_2} + {x_3}^{a_3} - {x_4}^{a_4} - {x_5}^{a_5} + K$$

$$Y_3 = 32.4^{0.414} + 0.12^{0.640} + 4.58^{1.946} - 1.82^{4.831} - 30.9^{0.650} + 26.040 \quad [8]$$

WQI for BW_3 = 22.49

DOI: 10.6092/issn.2281-4485/14911

Developed model of water quality index of BW_4

$$Y_4 = {x_1}^{a_1} + {x_2}^{a_2} + {x_3}^{a_3} - {x_4}^{a_4} - {x_5}^{a_5} + K$$
$$Y_4 = 32.6^{0.592} + 0.65^{2.401} + 5.68^{1.844} - 1.87^{4.495} - 4.8^{-0.291} + 29.100 \quad [9]$$

WQI for BW_4 = 44.59

Developed model of water quality index of BW_5

$$Y_5 = {x_1}^{a_1} + {x_2}^{a_2} + {x_3}^{a_3} - {x_4}^{a_4} - {x_5}^{a_5} + K$$
$$Y_5 = 30.5^{0.481} + 0.12^{0.870} + 6.75^{2.168} - 1.59^{5.461} - 389^{0.556} + 30.176 \quad [10]$$

WQI for BW_5 = 58.07

Developed model of water quality index of BW_6

$$Y_6 = {x_1}^{a_1} + {x_2}^{a_2} + {x_3}^{a_3} - {x_4}^{a_4} - {x_5}^{a_5} + K$$
$$Y_6 = 30.6^{0.265} + 0.20^{0.490} + 6.32^{2.072} - 1.58^{5.523} - 252^{0.462} + 28.344 \quad [11]$$

WQI for BW_6 = 51.53

Model verification

The values of the water quality index (WQI) of the various brands were determined and compared with that of Equations (6 to 11) as presented in Table 2. The results showed there were very little errors ranging from 0.00 to 0.48; indicating that there was a significant agreement between the values of WQI obtained by experiments and the ones from equations.

Table 2. *Model validation.*

SAMPLES	WQI (EQN)	WQI (EXPT)	%ERROR
BW_1	51.18	51.18	0.00
BW_2	47.30	47.32	0.042
BW_3	22.50	22.51	0.044
BW_4	44.60	44.60	0.00
BW_5	58.07	58.06	0.017
BW_6	51.53	51.78	0.48

Conclusions

This study assessed the physico-chemical parameters of six (6) brands of available bottled water presently sold within Jalingo metropolis main market. The samples were analyzed at the Environmental Laboratory of Taraba State Water Supply and Sewage Corporation. Results gotten from the analysis, through appropriate equations, were used to determine Water Quality Index of the bottled water samples. WQI equation was also developed. Based on these the following conclusions can be drawn:

- all the water parameters in all the bottled water are within the permissible level except temperature which can be ascribed to environmental variability and has no health implications. In terms of physico-chemical parameters, the various bottled water samples are suitable for consumption.

DOI: 10.6092/issn.2281-4485/14911

- water quality index of these six (6) bottled water has BW_3 as excellent, BW_2 and BW_4 as good while BW_5, BW_1 and BW_6 were rated as poor. With regards to Water quality index, all the respective bottled water samples are fit for consumption.
- the developed Water Quality Index and their corresponding water parameters agreed with each other with reliability of $R^2 = 90.3\%$ and error of 9.7%.
- values of WQI from experiments were compared with those from equations and they also agreed with each other with very little errors ranging from 0 to 0.48. The equation could be employed for quality control within the confined of this research.

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