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MATHEMATICAL REPRESENTATION OF WATER QUALITY INDEX FOR THREE SELECTED WELLS IN THE THREE WARDS OF ZING METROPOLIS, NIGERIA

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ABSTRACT

The experiments were conducted at Taraba State Water and Sewerage Corporation, Environmental Laboratory, Jalingo, Headquarters Nigeria, where the water samples were brought from bore wells in (A1, A2 and B) wards in Zing metropolis, for analysis. It was found that only Temperature (A1=34, A2=35 and B=34) were outside the acceptable limit of WHO/NSDWQ. The results of the water parameters were entered into Microsoft excel, 2016 to determine the water quality index of each of the three locations. The results of the water quality index show that all the sources of the water are rated good. WQI model was developed and its coefficients were obtained when the values of calculated WQI were inputted into IBM (SPSS) regression model. The result show that the reliability of the model is 99.37% and an error of 0.00157. when the developed Equation values were compared with those from experiments it was found that there was a good agreement between them with errors ranging from 0.14 to 1.66%. Hence the established model could be employed to monitor the water quality rating within the confine of this research.

1. INTRODUCTION

Water is an inorganic, transparent, tasteless, odorless, and nearly colorless chemical substance, which is the main constituent of Earth's hydrosphere and the fluids of all known living organisms (in which it acts as a solvent) [1,2]. It is essential for all known forms of life, even though it provides no calories or organic nutrients.[3 stated that Water covers approximately 70.9% of the Earth's surface, mostly in seas and oceans and [4, 5] went further to said Small portions of water occur as groundwater (1.7%), in the glaciers and the ice caps of Antarctica and Greenland (1.7%), and in the air as vapor, clouds (consisting of ice and liquid water suspended in air), and precipitation (0.001%).

The use of water depends on its quality and purpose; generally, Water quality is defined by [6,7] as chemical, physical, and biological characteristics of water based on the standards of its usage. [8] stated that most used of water is guided a set of standards against which compliance, generally achieved through treatment of the water, can be assessed. The most common standards used to monitor and assess water quality convey the health of ecosystems, safety of human contact, extend of water pollution and condition of drinking water. Water quality has a significant impact on water supply and oftentimes determines supply options.

Groundwater is often cheaper, more convenient and less vulnerable to pollution than surface water. Therefore, it is commonly used for public water supplies. It provides the largest source of usable water storage in most part of the world [9]. Underground reservoirs contain far more water than the capacity of all surface reservoirs and lakes in most part of the world. Many municipal water supplies are derived solely from groundwater [10]. Using the values of individual's water parameter is not enough to interpret the quality of a source of groundwater; which is the fulcrum in this research. For instance, measurement of high quantities of Fluoride in a source of water cannot provide an insight to the suitability of the source. For the reason that various water parameters cannot provide adequate information with regards to quality of the water in a source, a water quality index, which is a single number (like a grade), is provided to expresses the overall water quality at a certain location and time based on several water quality parameters. [11] defined WQI as a mathematical tool that significantly minimizes the complex water quality data sets and provides a single classifying value that describes the water quality status of the water bodies or degree of pollution. Similarly, [12] put it as a single dimensionless number that describes the overview of the of the overall water quality status in a simple way by aggregating the measurements of selected parameters such as PH, nitrate, dissolved oxygen, heavy metals.

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 [13]. Water quality modeling also helps determine correlations to constituent sources and water quality along with identifying information gaps [14]. 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 [15, 13].

In this study three sources of borewell water were identified, each from the three wards in Zing metropolis, which are the three most patronized wells. The Physico-Chemical Water parameters chosen were the most important ones presented by [16], which are Temperature, Turbidity, PH and Electrical Conductivity/Salinity. Salinity occurs in groundwater when formation materials dissolved in water hence it is being replaced by Total Dissolved Solids (TDS). Fluoride was also included based on the research conducted by ([17, 18]) that there exist Fluoride in some groundwater wells in most wards in Zing Local Government Area (LGA), Nigeria, above acceptable limit by World Health Organisation (WHO)/Nigeria Standard of Drinking Water Quality (NSDWQ). Several methods have been used to calculate the water quality index (WQI) but the one adopted by [19. 20]); which is the weighted arithmetic mean method of assessment of water quality index is used in this study. [21] developed WQI model for each source of well water in their study area; in this research the WQI model to be developed will take care of all the sources of water in the study area, which is our priority. The model will also be used to monitor the water quality rating in the study area.

2. MATERIALS AND METHODS

Study Area

Zing lies between longitude 10^0 and 11^0 E and latitude 9^0 and 10^0 N of the equator with land area of 1,030km^2 and estimated population of about 127,363 ([22]. The area falls within the transitional belt of savanna in North eastern Nigeria. It has a temperature range of 25^0 C to 33^0 C in both rainy and dry seasons with good climatic conditions for agricultural activities. The study area is endowed with a lot of natural resources such as mountains, natural grasslands, rocks, peasant and commercial farmers, shallow streams and good weather conditions for habitation. The study area (see Figure 1) covered three wards in Zing metropolis which are Zing A1, Zing A2, and Zing B.

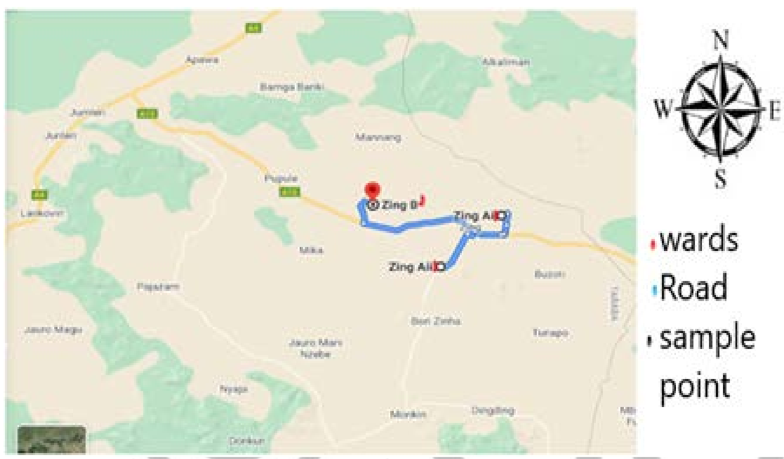

Table 1: Bore wells location

S/N	WARDS	LOCATION	LABEL
1	Zing (A1)	Jidonko	A1
2	Zing (A2)	Angwan Kuka	A2
3	Zing (B)	Sabon-Layi	B

Figure 1: Map of the study area

Physico-Chemical Analysis of Water Sample

Well water samples were collected from the most patronized wells in wards of Zing metropolis, as presented in Table 1. The water samples were collected with plastic containers which were initially subjected to pre-treatment by washing with dilute HCL (0.05ml), rinsed using distilled water air-dried in a dust proof environmental condition. At the point of collection, the containers were again rinsed with the appropriate samples thrice. Thereafter, the water samples are introduced into the containers and corked securely. The Laboratory analysis of the different physical and chemical parameters of the water sample were done at the Taraba State Water Suppy and Sewarage Corporation (TAWASCO), Environmental Laboratory, Jalingo, Headquarters and according to the methods prescribed in [23, 24]. The physico-chemical parameters examined include: Temperature (Temp, ^{0}C), Turbidity (Turb, NTU), pH, Total Dissolved Solids (TDS, mg/l) and Fluoride (Fluo, mg/l).

Calculation of Water Quality Index

This study made use of five (5) Physico-Chemical properties of water in the calculation of the WQI. The evaluation of the WQI was made on the basis of the standards of drinking water quality specified by the WHO/NSDWQ as approved by the Standard Organization of Nigeria (SON). The weighted arithmetic mean method of evaluation of water quality index is used in this study [22, 23].

The WQI is given in Equation (Eqn) (1) $WQI = \frac{\Sigma Q_i w_i}{\Sigma w_i}$ -----------------(1); The quality rating scale (Q_i) for each parameter will be calculated via Eqn. (2); $Q_i = \left[\frac{v_i - v_0}{s_i - v_0}\right] X100$ ----------------(2);

Where, $v_i =$ estimated concentration of the n^{th} parameter in the analyzed water sample; v_0 = Ideal value of analyzed water parameter in pure water sample which is usually zero except PH = 7.0 $S_i =$ recommended standard value of n^{th} parameter which for this study will be WHO/NSDWQ the unit weight (W_i) for each water quality parameter is evaluated using Equation (3); $w_i = \frac{k}{s_i}$ ----------------------(3); Where, k = proportionality constant and can be evaluated by equation (4): $k = \frac{1}{\Sigma \frac{1}{s_i}}$---------(4) The water quality index rating describes the range with which each of the calculated water quality index falls into. [24] defined the rating as Excellent, Good, poor, very poor and unsuitable/ unfit for drinking, as shown in Table 2. Calculated WQI of 100 and above indicates that the water is unfit for drinking while low calculated index indicates excellent water fit for drinking.

Mathematical Representaion of Water Quality Index

WQI can be represented in a mathematical form as demonstrated in Eqn. (5); $y_i = c_1x_1 + c_2x_2 + c_3x_3 + c_4x_4 + c_5x_5 + k$-----------------------------(5)

y_i Represents WQI for each values of the respective water parameters x_1 = Temperature (0'c), x_2 = Turbidity, x_3 = PH, x_4 = TDS, x_5 = Fluo are the corresponding values of the water parameters, where, c_1,c_2,c_3,c_4,c_5 are coefficients and k is a constant, all to be determined by IBM 21 regression model.

Table 2: Rating of WQI

WQI	0-25	26-50	51-75	75-100	>100
RATING	excellent	good	poor	very poor	Unfit
GRADE	A	B	C	D	E

Table 3: Water Parameters data

LOCATION	TEMP (^{0}C)	TURB (NTU)	pH	TDS (mg/l)	FLUO(mg/l)
A1	34	2.36	6.6	340	0.62
A2	35	0.13	6.39	167	0.77
B	34	3.08	6.01	406	0.6

3. RESULTS AND DISCUSSION

Physico-Chemical Parameters Data

Results gotten from analysis of the water parameters are presented in Table 3. The results show that the values of the water parameters in all the three location are within the acceptable level except Temperature.

Water Quality Index Data

Data of water parameters gotten, through the variables in Equation (1 to 4), were inputed into microsoft excel 2016 to determine the water quality index of the three locations, as presented in Table 4. The results show that the water quality index of all the three locations are in the range of 38.30 to 42.08, which indicate that the water in all the three locations are of good quality.

Table 4: Determined WQI

LOCATION	WQI	TEMP (oC	TURB (NTU)	PH	TDS(mg/L)	FLUO (mg/L)
A1	40.94	34	2.36	6.6	340	0.62
A2	38.3	35	0.13	6.3	167	0.77
B	42.08	34	3.08	6.01	406	0.6

Table 5: Summary of model coefficients

EQN.	COEFFICIENTS	R^2	ERROR
(5)	K = 61.66 C1 = -0.19 C2 = -4.03 C3 = -1.251 C4 = 0.0468 C5 = -20.10	99.37%	0.00157

Water Quality Index Model Coefficients

A mathematicals relationship was developed in Equation (5) and the cofficients and constan were determine when the data of the various water quality index and their correspondence water quality parameters were entered into an IBM (SPSS) 21 model. Results, as presented in Table 5, show that the reliability of the model R^2 = 99.37% and error of 0.00157.

Model validation.

Determined values of water quality index from experiments were compared with those from developed Equation (5), as presented in Table 6. The results show that the error for water quality index ranges from 0.00149 to 0.00166 which indicated that there is good agreement between the values from experiments and those from the Equation.

Table 6: Model Validation

	c1	x1	c2	x2	c3	x3	c4	x4	c5	x5	K	WQI (Eqn)	WQI(expt)	%error
A1	**-0.19**	**34**	**-4.03**	**2.36**	**-1.251**	**6.6**	**0.0468**	**340**	**-20.1**	**0.62**	**61.66**	**40.87**	**40.94**	**0.00149**
A2	-0.19	35	-4.03	0.13	-1.251	6.3	0.0468	167	-20.1	0.77	61.66	38.93	38.3	0.0166
B	-0.19	34	-4.03	3.08	-1.251	6.01	0.0468	406	-20.1	0.6	61.66	42.2	42.08	0.00291

4. CONCLUSION

Base on the development of the WQI model, the following conclusions can be drawned:

- The water parameters in all the three locations are within the permissible limit of WHO/NSDWQ except Temperature.
- Water quality index in all the three locations are of good quality and fit for all purposes.
- The WQI model is highly efficient with a reliability value of 99.37% and error of 0.00157.

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