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Full Length Research Article

EVALUATION OF SOURCES OF DRINKING WATER USING WATER QUALITY INDEX IN BAUCHI METROPOLIS, BAUCHI STATE, NIGERIA

Y.I. Garba*[1], M.Z. Karkarna[1], M. Yayagana[1], D.M. Musa[2]

[1]Department of Environmental Management, Bayero University Kano, Nigeria
[2]Department of Environmental Sciences, Federal University Dutse, Nigeria

*Corresponding Author's Email Address: binilidris@yahoo.com

ABSTRACT

The study evaluated drinking water quality from four different sources in the study area using Water Quality Index (WQI) method. Thirty-two (32) water samples were collected from Borehole, Well, Tap and Sachet water. The quality of water samples were determined using the physicochemical parameters such as pH, Color, Odor, Taste, Temperature, Turbidity, Alkalinity, Calcium, Bicarbonate, Lead, Nickel, Nitrate, Sulphate, Total Dissolved Solid (TDS), Arsenic, Cadmium, Chromium, Electrical Conductivity (EC), Copper, Fluoride. The results indicated that borehole water quality from Dan Amar ward and Makama B ward were rated poor water, Tirwin and Dawaki borehole were rated unsuitable. The well water samples from Hardo was found as poor water, and well from Dan Amar, Tirwin and Makama B and Makama A were unsuitable for drinking purpose. The tap water sample from Tirwin was poor and the tap water samples from Hardo and Dawaki were unsuitable for drinking purpose. All the sachet water samples were found to be excellent. The results also revealed that, the water quality index (WQI) for borehole water samples ranges from 5.34 to 727.75; well water ranges from 0.80 to 532.53; tap water ranges from 27.43 to 516.23 and finally sachet water ranges from 32.17 to 46.27. The calculated WQI indicates that 25% of water samples are excellent for drinking. 46.9% of the samples fall in good class of WQI.

Keywords: Water quality, Bauchi, Borehole, Well, Tap and Sachet water

INTRODUCTION

Water is an economic resource and essential component of human life. However, due to population detonation, urbanization and industrialization in most cities and urban centers results in large volume of effluent discharge that may affect the surface and groundwater quality. Since the effluent from discharges or run-off from solid waste disposal sites generally moves vertically downwards (Shrivastava *et al*., 2002; Ramakrishnaiah *et al*., 2009; Rao and Nageswara, 2013).

Bauchi town is considered as one of the fastest growing city in the Northern part of the country (Modibbo *et al*., 2017). Human activities directly or indirectly generate discharges into the water sources – rivers, lakes, and streams as well as underground water bodies. This foreign particles (pollutants) accumulates to contaminate the sources of water rendering it unhealthy for use and consumption. Pollutants are particles either in the liquid or solid form that changes the quality of water (Akpan & Ajayi, 2016). According to World Health Organization (WHO, 2004), water-related diseases are estimated to cause 1.8 million deaths each year, mostly in developing countries and have been the major cause of mortality and morbidity.

Suitability of water quality for various proposes like drinking could be distinguished based on the evaluation of the physical and chemical parameters through water quality indexes. Rating of water in the aspect of quality and consumption using the effect of individual parameters can be helpful in making decision by managers and administrative organizations (Zahedi, 2017).

Water quality index (WQI) is a technique of rating that provides the composite influence of individual water quality parameter on the overall quality of water. WQI has been calculated to evaluate the suitability of water quality, using the weighted arithmetic water quality index method, which classifies the water quality according to the degree of purity by using the most commonly measured water quality variables.

Quality water should be free from chemical and biological contaminations and must be acceptable in terms of colour, taste and odour in accordance with the World Health Organization guidelines on the quality of drinking water (Yasin and Bacha, 2015). Different sources of water such as wells boreholes, ponds and streams need to be protected from pollution and contamination by potential parasites, micro-organisms and harmful chemical substances (Maton *et al*., 2016).

MATERIALS AND METHODS

Study Area

Bauchi, Metropolis, the capital of Bauchi State is in the North Eastern Geopolitical Zone of Nigeria. It is located between Latitudes 10°16' 30" - 10°21' 0" North of the Equator and Longitudes 9°48' 0" and 9° 52'30"East of the Greenwich Meridian (Figure 1). It covers a total land area of 3,687 square kilometres (Gani *et al*., 2012; Ogwuche, 2013). Mean daily maximum temperature ranges from 27.0°c to 29.0°c between July and August and 37.6 °C in March and April (Haruna *et al*., 2012). The mean daily minimum ranges from 22.0°C in December and January to about 24.7°C in April and May. The sunshine hours' ranges from about 5.1 hours in July to about 8.9 hours in November. October to February usually record the longest sunshine hours in Bauchi. This study was conducted in eight (8) administrative wards in Bauchi metropolis.

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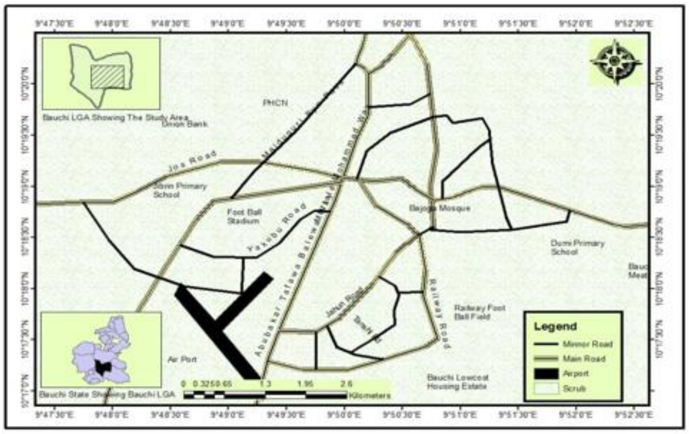

Figure 1. Study Area Showing Bauchi Metropolis

Sample Collection

Water samples were collected from four different sources of drinking water in parts of Bauchi metropolis; Borehole, Well, Tap and Sachet water. A total of 32 water samples were collected from eight administrative wards, that is; Dan Iya, Dan Kade, Dan Amar, Makama A, Makama B, Tirwin, Hardo and Dawaki ward. Samples were collected in clean 1 litre plastic jars with screw caps for physicochemical analysis. For the chlorinated water samples, about 2.5 ml sodium thiosulphate was added into each sampling bottle to stop the chlorination process during transportation (Yasin and Bacha, 2015).

Physicochemical Analysis of Water Samples

pH and Temperature were measured by the use of AMTAST pH-MV-Temp. (AMT01) meter; TDS and EC were obtained by using a TDS and EC meter (hold) and Turbidity was obtained by using JENWAY 470 cond. Meter. The temperature of all the water samples was determined using a simple mercury-in-glass thermometer; Colour was determined by visual comparison using Lovibond colour disc (Pt-Co); Sulphate was measured by the use of Nephelometric Turbidity Meter; The Ultra-Violet (UV) Spectrophotometer 752N was calibrated and used to measure nitrates (NO3). Total alkalinity and bicarbonate were done by titrating 100 ml of the samples with 0.02 M HCl solution using methyl orange as indicator and chloride by titrating 100 ml of the samples with a standard solution of 0.0257 M AgNO3 solution using 1.00 ml solution of 5.00% K2Cr2O4 as indicator. Total hardness was estimated titrimetrically using 0.01M ethylenediaminetetraacetic acid (EDTA) and ammonium buffer (pH 10.1) for each water sample (25 ml). Calcium was obtained through analysis by Labtech Digital Flame photometer. Heavy metals such as copper, nickel, lead, arsenic and chromium were determined using Atomic Absorption Spectrophotometer.

Determination of Water Quality Index (WQI)

The calculation of the WQI was done using weighted arithmetic water quality index which was originally proposed by Horton (1965) and developed by Brown *et al*., (1972), which have been widely used by many scientists (Tyagi1 *et al*., 2013; Chowdhury *et al*., 2012; Balan *et al.*, 2012). The weighted arithmetic water quality index (WQI) is in the following form:

$$\mathbf{WQI} = \frac{\sum_{i=1}^{n} W_i Q_i}{\sum_{i=1}^{n} W_i}$$

Where n is the number of variables or parameters
Wi is the relative weight of the i^{th} parameter
Qi is the water quality rating of the i^{th} parameter
The unit weight (wi) of the various water quality parameters are inversely proportional to the recommended standards for the corresponding parameters.

Relative Weight (W_i)

Relative weight (Wi) was calculated by a value inversely proportional to the recommended standard (Si) of the corresponding parameter:

$$\mathbf{W_i = 1/S_i}$$

Quality Rating (Q_i)

According to Brown et al (1972), the value of Q_i is calculated using the following equation:

$$\mathbf{Q_i = 100\,[\,(V_i - V_{id}) / (\,S_i - V_{id})]}$$

Where Vi is the observed value of the ith parameter
Si is the standard permissible value of the ith parameter
V_{id} is the ideal value of the ith parameter in water. All the ideal values (V_{id}) are taken as zero for drinking water except pH (Tripaty and Sahu, 2005). For pH, the ideal value is 7.0 (for natural/pure water).

Table 1.1: Water Quality Classification based on WQI value

WQI value	Rating of water Quality	Grading
<50	Excellent	A
50-100	Good	B
100-200	Poor	C
200-300	Very Poor	D
> 300	Unsuitable for drinking purpose	E

Source: (Ramakrishniah *et al*., 2009; Yisa & Jimoh, 2010)

RESULTS AND DISCUSSION

Table 1: Relative Weight Physicochemical Parameters

S/N	Parameter	Relative Weight (Wi)	WHO & NSDWQ Standard Value
1	pH	0.12	8.5
2	EC	0.00	1000
3	TDS	0.00	500
4	Turbidity	0.67	1.5
5	Alkalinity	0.01	100
6	Hardness	0.01	150
7	Nitrate	0.02	50
8	Calcium	0.01	75
9	Bicarbonate	0.01	100
10	Sulphate	0.01	100
11	Copper	1	1
12	Fluorite	0.67	1.5
13	Nickel	50	0.02
14	Lead	100	0.01
15	Chromium	20	0.05
		$\sum$ Wi =172.524	

Table 2: Quality of Borehole Water Samples Relative to Water Quality Index (WQI).

Sample Code/Location	WQI Value	WQI Class
BH1 (Makama A)	22.21	Excellent water
BH2 (Dan Iya)	727.75	Unsuitable for Drinking
BH3 (Dan Iya)	68.09	Good water
BH4 (Dan Amar)	184.58	Poor water
BH5 (Dan Amar)	93.66	Good water
BH6 (Tirwin)	330.34	Unsuitable for Drinking
BH7 (Dan Kade)	42.43	Excellent water
BH8 (Hardo)	5.34	Excellent water
BH9 (Dawaki)	29.96	Excellent water
BH10 (Makama B)	170.40	Poor water
BH11 (Makama B)	12.58	Excellent water
BH12 (Makama A)	27.60	Excellent water

BH-Borehole Water

From table 2 indicated that BH1 (Makama A), BH7 (Dan Kade), BH8 (Hardo), BH9 (Dawaki), BH 11(Makama B), BH12 (Makama A) were excellent for drinking based on of water quality index (WQI) rating, followed by BH3 (Dan Iya) and BH5 (Dan Amar) were good for drinking purpose, and then followed by BH4 (Dan Amar) and BH10 (Makama B). Finally BH2 (Dan Iya), BH6 (Tirwin) were rated as unsuitable for drinking, which means that the borehole water samples were contaminated. The poor quality of BH4 (Dan Amar) and BH10 (Makama B) may be due to improper construction, animal waste, proximity to toilet facilities, sewage, refuse dump site and various human activities that lead to the contaminations. Such areas were considered as high density residential neighborhood. Water samples from BH2 (Dan Iya), BH6 (Tirwin) were found to be unsuitable for drinking, this could be due to some agricultural activities taking place in the area, chemical like organic fertilizer or manure applied to agricultural fields may contaminated the ground water sources (Shittu *et al*., 2008). Majority of residents are farmers and farming activities in the environment may be the cause of contaminant. Long term usage of boreholes may lead to deterioration of the water quality, because the pipeline may become corroded and in most cases clogged with sediment (Onemano and Otun, 2003).

Table 3: Quality of Well Water Samples Relative to Water Quality Index (WQI) Values.

Sample Code/Location	WQI Value	WQI Class
WW1 (Dan Iya)	99.94	Good Water
WW2 (Dan Amar)	329.57	Unsuitable for Drinking
WW3 (Tirwin)	326.50	Unsuitable for Drinking
WW4 (Dan Kade)	94.29	Good Water
WW5 (Hardo)	157.12	Poor Water
WW6 (Hardo)	39.59	Excellent
WW7 (Dawaki)	91.80	Good Water
WW8 (Makama B)	0.80	Excellent Water
WW9 (Makama B)	345.23	Unsuitable for Drinking
WW10 (Makama A)	532.53	Unsuitable for Drinking

WW = Well Water

WW8 (Makama B 0.80) and WW6 (Hardo 39.59) were found to be excellent for drinking based on water quality rating, followed by WW7 (Dawaki 91.8), WW4 (Dan Kade 94.29) and WW1 (Dan Iya 99.4) were rated as good water. WW5 (Hardo 157.12) was rated as poor, and the water samples from WW2 (Dan Amar 329.57), WW3 (Tirwin 326.5), WW9 (Makama 345.23) and WW10 (Makama A 532.53) were found to be unsuitable for drinking purposes based on water quality index rating.
WW2 (Dan Amar), WW3 (Tirwin), WW9 (Makama B) and 4 (Makama A), these areas were considered as high density residential areas, poor quality of water in the area could be as a result of high population density, human activities, septic tanks linkages, poor dumpsites close to the wells. This is justified by its proximity to dumpsite and footpath which are potential sources of metals. The characteristics of most wells are those not protected or without covers, making them easily contaminated with Coliform bacteria or other pollutants. As for good well, it is usually protected or has cover. Moreover, the wells are usually deep and pipes are used to collect the water and therefore minimize the possibility of contamination.

Table 4: Quality of Tap Water Samples Relative to Water Quality Index (WQI) Values.

Sample Code/Location	WQI Value	WQI Class
TP1 (Dan Iya)	50.21	Good Water
TP2 (Dan Amar)	27.43	Excellent Water
TP3 (Tirwin)	132.54	Poor Water
TP4 (Dan Kade)	60.10	Good Water
TP5 (Hardo)	516.23	Unsuitable for Drinking
TP6 (Dawaki)	396.72	Unsuitable for Drinking

TP = Tap Water

The results in table 4 revealed that TP2 (Dan Amar 27.43) was excellent for drinking based on water quality index (WQI) rating, followed by TP1 (Dan Iya 50.21) and TP4 (Dan Kade 60.10) were rated as good water. TP3 (Tirwin 132.54) was rated poor and finally TP5 (Hardo 516.23) and TP6 (Dawaki) were unsuitable for drinking. The poor quality of TP3 (Tirwin) TP5 (Hardo) and TP6 (Dawaki) could be as a result of the pipe system which is very old and most of the pipes are in poor condition. There are leakage and breakage through which contaminants from outside the pipe might enter and get mixed with the supplied water. Due to lack of adequate water these pipes are often out of pressure. Moreover, due to inadequate layout of water supply lines and gutter lines there might be crossing between them. This might cause fecal contamination. Thus, it is very much possible that even if there is water, while entering the pipes it might no longer fit to drink and pleasant at the user's end.

Table 5: Quality of Sachet Water Samples Relative to Water Quality Index (WQI) Values.

Sample Code/Location	WQI Value	WQI Class
SW1 (Dan Iya)	32.17	Excellent Water
SW2 (Tirwin)	35.60	Excellent Water
SW3 (Dan Kade)	41.77	Excellent Water
SW4 (Dawaki)	46.27	Excellent Water

SW = Sachet Water

Table 5 indicates that Sachet water from SW1 (Dan Iya), SW2 (Tirwin), SW3 (Dan Kade) and SW4 (Dawaki) were all excellent based on rating of water quality index. The findings indicates that all sampled sachet water are free from contamination of some pollutants. Water quality continues to be the primary topic of interest; sachet water has the potential to be a transformative public health intrusion for low income households by eliminating the need for unsafe water storage vessels (WHO, 2011).

Water Quality Index is an excellent tool to classify the water quality of different water sources. It is a means to summarize large amounts of water quality data into simple terms for reporting the quality of water in a consistent manner. Water Quality Index is a good method that converts complex water parameters into a simple indicator of water quality by using fifteen physicochemical parameters on the basis of Weighted Arithmetic Index method (Seleem *et al.,* 2015; CCME, 2001). The water quality index (WQI) for borehole water samples ranges from 5.34 to 727.75; well water ranges from 0.80 to 532.53; tap water ranges from 27.43 to 516.23 and finally sachet water ranges from 32.17 to 46.27. The calculated WQI indicates that 25% of water samples are excellent for human uses while 46.9% of the samples fall in good class of WQI. Eventually, 28.1% of samples lie in poor water class.

Conclusion

From the findings, tap and sachet water sources were found to be suitable for drinking and should be patronized over and above other sources of water due to its level of purity. Also, application of Water Quality Index (WQI) in this study has been found useful in assessing the overall quality of water and to get rid of judgment on quality of the water. This method appears to be more systematic and gives comparative evaluation of the water quality of sampling stations. It is also helpful for the public to understand the quality of water as well as being a useful tool in many ways in the field of water quality management

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