Nigeria Association of Hydrological Sciences, Proceeding of the 7th International Conference pp 188 – 196

COMPARATIVE WATER-QUALITY ASSESMENT OF BOREHOLE, RESERVOIR, AND HAND DUG WELL IN TAYI ABBATIOR, MINNA

Animashaun, I. M.[1]*, Mustapha, H. I[1], Otache, M. Y.[1], Mohammed, A. S.[1], Ojodu, A. B.[2], Rasheed, N. B[1] & Jibril, I.[3],

1. *Department of Agricultural & Bioresources Engineering, Federal University of Technology, Minna, Nigeria.*
2. *Shamras Health Diagnostic Center, Off Bosso Road, Minna, Niger State*
3. *Department of Agricultural Technology, College of Agriculture Mokwa, Niger State Nigeria.*

Corresponding author email: ai.iyanda@futminna.edu.ng

ABSTRACT

The quality of groundwater in many urban cities is being compromised by contaminants that are mostly anthropogenic. This study is aimed at comparing the water quality of groundwater in Tayi abattoir for drinking purposes. Twelve physicochemical and biological parameters (TS, pH, DO, BOD, Temperature, E. Coli, NO_3^- PO_4, Cl^-, EC, Mn^- and Pb) of water samples taken during the wet and dry seasons from Borehole (BH), Opened Reservoir (OR) and Hand dug well (HD) were assessed. All but four (Mn, Pb, Cl, and EC) of the assessed parameters were used to establish indices for the groundwater sources. The result of the analysis (pH [6.6, 6.46 and 7.05], TS [1080, 1394, and 1452 mg/L], EC [378, 292, 335 µs/cm], Cl [69, 41.3, and 57.92 mg/L], Nitrate [0.07, 0.11, and 0.12 mg/L], Phosphate [0.69, 0.7, 0.75 mg/L] Mn [0.11, 0.03, and 0.15 mg/L], and Pb [0.001, 0.00, and 0.001 mg/L] showed that while pH, EC, Cl, PO_4*, Mn, and Pb were within the established limits, TS and E. coli were above. The results of the water quality index showed that the BH (62.92), HD (49.31) and RV (45.34) water can be classified as medium, bad and bad respectively. The implication is that the three sources are not suitable as sources of drinking water until after treatment.*

Keywords: groundwater, water quality index, abattoir, physicochemical parameter

1.0 INTRODUCTION

Groundwater is an important fresh water source that augments insufficient pipe borne water systems due to its quality and quantity (Kumar *et al.,* 2015). Its increasing demand for is due to draft population growth, intense domestic activities and agricultural purposes (Ewusi *et al.,* 2013). However, it is affected by natural and anthropogenic threats particularly in urban areas (Hassan *et al.,* 2014, Subramani *et al*., 2005). Natural sources of groundwater pollution include inputs from the atmosphere, acid precipitation, soil and water rock reactions, while anthropogenic sources ranges from mining, land clearance, agriculture, domestic and industrial wastes (Ackah *et al.,* 2011).

Wastes are generated in abattoirs include animal blood, dung, bones, condensed meat, gut content, and urine. These wastes are either disposed in liquid/slurry or solid form. Liquid or slurry wastes are discharged into non-properly planned drainage system (gutter), while the solid wastes are often heaped few meters away from the abattoir, with little or no consideration for the water sources used for drinking and meat processing. This method of waste disposal seems to be the only available option as locations of abattoir in most areas are unplanned, as they most a times located near rivers or residential areas (Iware *et al.,* 2012). This improper ways of waste disposal is a major problem confronting many abattoirs with negative consequences on groundwater as the chemistry of the water is often altered (Hassan *et al.,* 2014). Continuous release of these wastes over a long period of time coupled with abattoir's operation (roasting and skinning) that involves the use of kerosene and vehicle tire can further degrade the quality of groundwater water when percolated (Hassan *et al.*, 2014).

Early studies have shown that waste produced from abattoir could pose threat to groundwater, surface water and the environment at large. Osibanjo and Adie (2007) opined that physiochemical parameters of Oshunkaye stream in Ibadan city was compromised by effluent from Bodija abattoir and Hassan *et al.* (2014) attributed bad water quality of groundwater in Ikotun area of Lagos state to effluent discharge from abattoir. Hence there is need for the assessment of available fresh water sources around abattoirs.

The use of indices for water assessment has been strongly advocated by agencies responsible for water supply and control of water pollution (Balogun *et al.*, 2012). The index serves as a tool for assessing the suitability of water quality for certain functions which include domestic use such as drinking (Ketata-Rokbani *et al.*, 2011). It helps in harmonizing complex water quality data into information that is easily understood by all (Ahaneku and Animashaun, 2013).

Thus, this study is aimed at assessing and comparing water quality of available groundwater within Tayi abattoir, Minna for meat processing and drinking purposes and to establish respective index for each of the groundwater sources.

2.0 MATERIALS AND METHODS

2.1 Description of the Study Area

The study was carried out at the abattoir situated in Tayi Village, Minna on three groundwater sources. Minna lies on the geographical coordinates of 9° 36' 50" N (latitude), 6° 33' 24" E (longitude). The abattoir was sectioned into two based on the type of processes carried out slaughtering and processing section (skin and bone removal/sking burning). The water sources are Borehole (BH), opened reservoir (RV) which receives it water from the underground via a motorized pump both found within the abattoir premises, and a hand dug well (DW) found about 300 meters away from the abattoir.

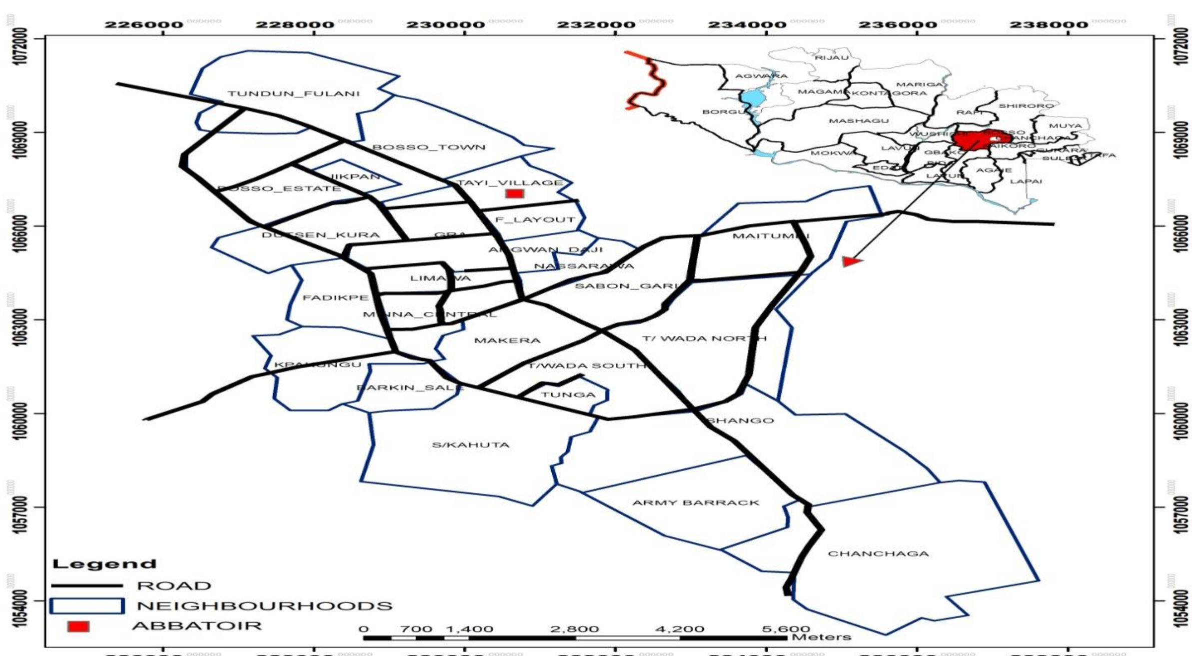

Fig. 1 Map of the study area

2.2 Water Sampling and analysis

Water samples were collected from the three groundwater sources at the peak of raining and dry season. The samples were collected three times in each season in sterilized plastic bottles and analyzed for twelve parameters using standard methods recommended by the American Public Health Association, APHA (2003). The parameters assessed were; Temperature, pH, electrical conductivity (EC), dissolved oxygen (DO) total solid (TS), biological oxygen demand (BOD), total phosphate, nitrate (NO_3), chloride (Cl), manganese (Mn), lead (Pb) and *E. coli*. Nigerian Standard for Drinking Water Quality (NSDWQ, 2007) and World Health Organization (WHO) standards were adopted as guidelines. The results were statistically analyzed using SPSS 16.0 package and Duncan Multiple Test was used for separating the mean.

2.3 Water Quality Index

In this study, National Sanitation Foundation Water Quality Index (NSF- WQI) was adopted to evaluate the quality of groundwater samples from the study area. The index is one of the most widely used water quality index due to its simplicity and suitability for assessing water for potability (Giriyappanavar and Patil, 2013). Like some other indices, it uses a mathematical averaging function for the computation. To achieve this; pH, temperature, DO, TS, BOD, NO_3, PO_4, and *E. coli* were selected. The results of the physicochemical and bacteriological analysis were transferred to a weighting curve chart which converted each selected parameter in their various standard units into a unit-less sub-index. Weights were assigned to the parameters (Table 1) using Delphi method based on the importance of the parameters in drinking water. Numerical values obtained from the quality index curve were multiplied by the average "weighting factor". The overall water quality index was thus obtained by adding up water quality index for each of the considered parameters using equation 1.

Table 1: Weight Assigned to water parameters using Delphi method

Selected parameter	Average weight
pH	0.12
DO (% saturation)	0.20
BOD (mg/L)	0.11
Temperature (mg/L)	0.11
Nitrate (mg/L)	0.12
TS (mg/L)	0.08
PO_4 (mg/L)	0.10
E.coli (cfu/100ml)	0.16

The NSF WQI $=\sum_{i=1}^{n} Qi\ wi$ 1

Where,

Q_i= sub-index for ith water quality parameter;

W_i= weight associated with ith water quality parameter;

n= number of water quality parameters.

The obtained index value was then compared against a given class (Table 2) in order to rank it appropriately as described byGiriyappanavar and Patil (2013).

Table 2: Water quality rating based on NSF Computation

Range	Quality	Description of Water Quality
90-100	Excellent	meets all criteria for use as a source of drinking water
70-90	Good	narrowly violates criteria for use as a source of drinking water
50-70	Medium	sometimes violates criteria, possibly by a wide margin, for use as a source of drinking water
25-50	Bad	often violates criteria for use as a source of drinking water by a considerable margin
0-25	Very bad	does not meet any criteria for use as a source of drinking water

Source: Rajankar *et al.* (2009)

3.0 RESULTS AND DISCUSSION

3.1 Physicochemical Parameters of the Water

The pH value of groundwater is an important parameter which determines its suitability for domestic purposes. Deviation of pH value of water from established limit could be as a result of natural factors (underlining rock, soil), or as a result of industrial influence and biological activity (Kalra *et al.*, 2012). The pH value of the three groundwater considered varies; BH has the highest mean value (6.58) and reservoir has the lowest pH value (6.34). However, the pH value of the three groundwater fell within the threshold limit of 6.5- 8.5 by NSDWQ (2007) and WHO (2004). The variations in pH among the samples were not statistically significant at 5% (Table 3).

Consideration of temperature as a vital parameter in water assessment depends on the state (potable or polluted) of the water source (Ahaneku and Animashaun, 2013). In this study, the temperature of the assessed groundwater was 26.80 ^{0}C, 27.70 ^{0}C, and 27.90 ^{0}C for Borehole, hand dug well and reservoir respectively. They were all above 25^{0}C recommended by WHO.

Dissolved oxygen (DO) is an important parameter which regulates the distribution of flora and fauna (Ahaneku and Animashaun, 2013). Absence of DO in water results in anaerobic condition, putrefaction and the development of foul smell (Jadhav *et al.*, 2014). The higher the value of DO, the better the quality of the water, since low value of dissolved oxygen is an indication of the presence of industrial waste rich in organic matter and nutrient. The dissolve oxygen (DO) in the study was found to be within 58.8% - 68.8% (5.20 mg/L to 6.20 mg/L) for the three water sources. Though, no limit is established by WHO and NSDWQ for DO, the obtained values for the three groundwater sources were above the minimum limit (5 mg/L) of the Canadian Council of Ministers of the Environment (Ahaneku and Animashaun, 2013).

Electrical conductivity is a method for obtaining an estimate of dissolved solids in water samples (Chukwu *et al*., 2008). Electrical conductivity of the samples ranges from 291 µS/cm –378 µS/cm. Though, borehole has the highest conductivity (377 µS/cm),the three water samples were all found within the specified limits (1000 µ/cm) of WHO and NSDWQ for drinking water. According to Jeihouni *et al.* (2014), groundwater of less than 1000 is said to have optimum quality, while greater than 1000 and 2000 are rated as medium and poor respectively. The EC value observed in this work is in line with what was reported by Ewusi *et al.* (2013). The variations in electrical conductivity among the three groundwater samples were statistically significant at 5%.

The values of biological oxygen demand (BOD) measured ranged between 2.10 mg/L to 8.90 mg/L. BOD is the amount of oxygen needed for the biological decomposition of organic matter under aerobic condition. It indicates how much oxygen is required for microbes to oxidize a given quantity of organic matter (Chukwu, 2008). The borehole water has BOD of 2.20 mg/L which was the lowest while the reservoir has the highest BOD of 3.40 mg/L. Though, the mean BOD value of the hand dug well (6.80 mg/L) was not statistically different from reservoir (5%), they are both significantly different from Borehole. The BOD of the three water sources was however, within tolerable range (20 mg/L) of WHO standard for drinking water. The value observed agrees with the finding of Chukwu *et al*. (2008)

The borehole had a mean total solid value of 1080 mg/L, hand dug well has 1390 mg/L and reservoir has 1450mg/l. This showed that reservoir has the highest total solid while the borehole water has the least. TS in bore well and reservoir are significantly different (at 5%) both were not from well. The three samples were above the tolerable WHO limit of 1000 mg/L for drinking water. High Total solids in water is associated with unpalatable taste as well as probable corrosion of containing vessel (Kruawal *et al*., 2005)

Table 3: Statistical Evaluation of Groundwater Quality Parameters

Ground Water		pH	DO % Sat.	BOD mg/L	TS mg/L	Tempt. ^{0}C	*E.coli Cfu/100*	NO_3^- mg/L	PO_4 Mg/L	Cl^- mg/L	EC µS/cm	Mn^- mg/L	Pb mg/L
BH	Mean	6.58[a]	68.80[a]	2.80[a]	1080[a]	26.80[a]	1.00[a]	6.17[a]	0.69[a]	69.00[a]	378[a]	0.11[a]	0.001[a]
	SD	0.07	1.60	0.70	120	0.70	1.00	1.09	0.01	0.47	1.15	0.02	0.001
	Min	6.51	67.20	2.10	960	26.10	0.00	5.08	0.67	68.00	376	0.11	0.001
	Max	6.65	70.40	3.50	1200	27.50	2.00	7.26	0.69	68.95	378	0.14	0.003
DW	Mean	6.40[a]	61.00[a]	6.80[b]	1390[ab]	27.70[a]	11.00[b]	28.10[b]	0.7[a]	41.30[b]	292[b]	0.03[b]	0.000[a]
	SD	0.30	3.00	1.60	241	0.40	3.00	1.50	0.015	0.10	1.02	0.01	0.000
	Min	6.10	58.00	5.20	1150	27.30	8.00	26.50	0.67	41.30	291	0.03	0.000
	Max	6.70	64.00	8.40	1640	28.10	14.00	29.50	0.7	41.50	293	0.04	0.002
RV	Mean	6.34[a]	58.80[b]	7.40[b]	1450[b]	27.90[a]	13.00[b]	29.07[b]	0.73[b]	57.92[c]	335[c]	0.15[c]	0.001[a]
	SD	0.07	2.59	1.50	95	0.50	4.00	6.24	0.02	0.075	1.15	0.01	0.001
	Min	6.27	56.25	5.90	1360	27.40	8.00	22.40	0.72	57.85	333	0.14	0.001
	Max	6.41	61.44	8.90	1550	28.40	17.00	34.10	0.75	58.00	335	0.16	0.003
	WHO	6.5-	-	20.00	1000	-	0	50.00	0	200	1200	0.10	0.010
	NSDWQ	6.5-8.5	-	-	-	AM	0	50.00	-	250	1000	0.20	0.010

Mean value with same superscript are not significant

Borehole water has a mean *Escherichia coli (E-Coli)* value of 1 cfu/100ml, and the well and reservoir has a respective mean value of 11 cfu/100ml and 13 cfu/100ml. The existence of *E. coli* in the three groundwater indicated that none of the three groundwater sources is good for drinking as no tolerance level is established by WHO and NSDWQ for this microorganism. Pathogenic microorganisms are the most the most dangerous water pollutant in term of human health as they are responsible for spread of dangerous disease like hepatitis, cholera, dysentery, typhoid and diarrhea (Amin *et al.*, 2012). Though, the organism content in the borehole was minimal, there is still a need for boiling and chlorination before consumption. Our result agrees with the findings of Chukwu *et al*. (2008) in the existence of the organism in borehole, even though a higher value was recorded in their work as a group of organism was considered.

The mean nitrate content of the borehole, hand dug well and reservoir were 6.17 mg/L, 28.10 mg/L, and 29.07 mg/L respectively. Though, the nitrate content of both hand dug well and reservoir are

higher and significantly different (at 5%) from borehole, they are all within the established limit of 50 mg/L for WHO and NSDWQ standard of drinking water.
Phosphate is an important water parameter with an adverse effect of digestive problems when occur in high levels in water (Oram, 2014). The concentrations of phosphate ranged between 0.67mg/L and 0.75 mg/L. The opened reservoir has the highest mean concentration (0.73 mg/L) of phosphate present while borehole has the least (0.69 mg/L). There is no significant different between borehole and the hand dug well but they are both significantly different from reservoir (at $p < 0.05$).
Chloride (Cl) concentration varied in the three samples. Nevertheless, samples fell below the specified limit of WHO and NSDWQ for drinking water. Borehole has a concentration of 68.48 mg/L, hand dug well has concentration of 41.37 mg/L and the chloride level in the reservoir was 57.92 mg/L. Chlorides are generally limited to 250 mg/L in supplies intended for public use (WHO, 2008). However, in groundwater Cl less than 50 mg/L gives optimum water quality, less than 200 mg/L is medium and above 200 mg/L is considered poor (Jeihouni *et al.*, 2014)
Concentration of manganese in the three assessed groundwater ranged from 0.03 mg/L to 0.15 mg/L. The borehole water sample has a mean value of 0.11 mg/L, hand dug well water sample has 0.03 mg/ L, and reservoir water sample has 0.15 mg/L. The result shows all the three water sources were within established limit of WHO (0.4 mg/L) and NSDWQ (0.2mg/L) for drinking water. Excess manganese in human body could lead to Neurological disorder (NSDWQ, 2007), but low concentration of manganese implies that the water would not promote the growth of algae (Nwankwoala *et al.*, 2011).
The concentration of lead present ranged between 0.00 mg/L to 0.003 mg/L. While presence of lead was detected in borehole and reservoir, the hand dug well was free of it. The presence of lead in BH and RV both situated within abattoir premises could be attributed to the use of tire for roasting operation. However, the lead content is below the WHO and NSDWQ limit for drinking water.

3.2 Water Quality Index

Water Quality Index for each of the three sources considered was determined with NSF using eight of the physiochemical and bacteriological parameters (pH, DO, BOD, Temperature, Nitrate, TS, PO_4, and *E.coli*) considered. The values of the various Q_i and W_i with their respective subtotal are presented in tables 3, 4 and 5. The borehole has a mean pH value of 6.58 with corresponding Q_i and W_i values of 70 and 0.12 respectively. The product of the two values (Q_i and W_i) gave a subtotal of 8.40. The addition of the subtotals of all the considered parameters gave an overall Water Quality Index of 62.92. This indicates that the borehole can be ranked as medium.
The hand dug well having a mean pH value of 6.40 and corresponding Q_i and W_i values of 68 and 0.12 respectively has a subtotal of 8.16 (Table 4). The overall WQI obtained upon the summation of all the subtotals was 49.31 indicating that the water source can be ranked as bad.
The open reservoir with WQI of 45.34 (Table 5) also falls into the same class with the hand dug well (bad). The results of the WQI for the three groundwater sources (Table 6) showed that none of the three can be used as a source of drinking water without treatment. However, medium ranked obtained for borehole showed that it is relatively better.
The “medium” and “bad” water quality rating obtained in this study for groundwater under the influence of the anthropogenic activities is in line with early studies (Kalra *et al.*, 2012; Kumar *et al.*, 2015)

Table 4: NSF WQI computation for bore well water

Parameter	Result Mean value	Q-value Q_i	Weight factor w_i	Subtotal $Qi * wi$
pH	6.58	70	0.12	8.40
DO (%sat)	68.8	73	0.20	14.60
BOD_5 (mg/L)	2.80	68	0.11	7.48
Temperature (^oC)	26.8	12	0.10	1.20
Nitrates (mg/L)	6.17	60	0.12	7.20
TS (mg/L)	1080	20	0.08	1.60
PO_4 (mg/L)	0.69	60	0.11	6.60
E.coli (cfu/100ml)	1.00	99	0.16	15.84
Total			1.00	$\sum_{i=1}^{n} Qi\, Wi$ =62.92

Table 5: NSF WQI computation for Hand dug well water

Parameter	Result Mean value	Q-value Q_i	Weight factor w_i	Subtotal $Qi * wi$
pH	6.40	68	0.12	8.16
DO (%sat)	61.00	60	0.20	12.0
BOD_5 (mg/L)	6.80	47	0.11	5.17
Temperature (^oC)	27.7	11	0.10	1.10
Nitrates (mg/L)	28.00	29	0.12	3.48
TS (mg/L)	1394	20	0.08	1.60
PO_4 (mg/L)	0.70	60	0.11	6.60
E.coli cfu/100ml)	11.00	70	0.16	11.20
Total				$\sum_{i=1}^{n}$ Qi Wi =49.31

Table 6: NSF WQI computation for Opened reservoir water

Parameter	Result Mean value	Q-value Q_i	Weight factor w_i	Subtotal $Qi * wi$
pH	6.34	64	0.12	7.68
DO (%sat)	58.84	56	0.20	11.2
BOD_5 (mg/l)	7.40	44	0.11	4.84
Temperature (^oC)	27.90	11	0.10	1.1
Nitrates (mg/l)	34.12	23	0.12	2.76
TS (mg/l)	1452	20	0.08	1.60
PO_4 (mg/l)	0.75	48	0.11	5.28
E.coli (cfu/100ml)	13	68	0.16	10.88
Total				$\sum_{i=1}^{n} Qi\, Wi$ =45.34

Table 7: Water quality rating of the abattoir water sources

SAMPLES	$\sum_{i=1}^{n} Qi\,Wi$	WQR
Bore well water	62.82	Medium
Hand dug well	49.31	Bad
Opened reservoir	45.24	Bad

*WQR= water quality rating

4.0 CONCLUSIONS

The physiochemical and bacteriological parameters of water samples collected from the Minna abattoir groundwater were determined. The Total solid and *E. coli* contents of the water sources were above W.H.O and NSDWQ standard for drinking water. This showed probable influence of abattoir waste on the water sources. The obtained result for National Sanitation Foundation Water Quality Index (NSF-WQI) further indicated that though, borehole water samples could be classified as medium, none of the three groundwater sources is qualified for usage as drinking water source. Hence there is need for treatment before their usage and a better hygienic environment should be ensured.

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