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SEASONAL VARIATION IN PHYSICO-CHEMICAL PROPERTIES OF GROUNDWATER AROUND KARU ABATTOIR

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Abstract

This study examined the effect of seasonal variation on the physical, chemical and biological properties of groundwater around Karu abattoir. Water samples were collected from different wells at different distances around the abattoir comprising Group A (within abattoir), Group B (60m from abattoir) and Group C (200-300m from abattoir) for wet and dry seasons. Parameters analysed are temperature, turbidity, TDS, TSS, pH, DO, BOD, total hardness, conductivity, iron content, nitrate, sulphate, E.coli and faecal streptococci. Result of the analyses showed that all the parameters have higher concentration during the wet season than in the dry season in all the Groups, except for BOD, sulphate and iron. Paired sample t-test results revealed that parameters such as TDS, conductivity, DO, nitrate, sulphate and iron have no significant variation in all the Groups. Most of the parameters have their mean values within the WHO standards in both seasons; however mean values for TSS, E.coli and faecal streptococci are higher than the guideline provisions, while DO does not meet the recommended values in both seasons; and BOD values are higher than WHO standard. The study concluded that the water, especially from Groups A and B, are more polluted during the wet season and recommended that it must be adequately treated if it is to be used for drinking.

Keywords: *Seasonal variation, Groundwater, Abattoir, Effluents, Water quality*

Introduction

UNESCO (2003) estimates that globally, groundwater provides about 50% of current potable water supplies, 40% of the demand of self-supplied industry and 20% of water use in irrigated agriculture. Over much of Africa, groundwater is the most realistic water supply option for meeting water demand. However, increasing demand and withdrawal, significant changes in land use pattern, vast industrial and agricultural effluents entering the hydrological cycle as well as seasonal variation, affect the quality and quantity of groundwater (Idoko, 2010). The determination of groundwater quality for human consumption is important for the well being of the ever increasing population. Groundwater quality depends, to some extent, on its chemical composition (Idoko and Oklo, 2007; Wadie and Abduljalil, 2010) which may be affected by natural and anthropogenic factors. Changes in groundwater recharge, due to seasonal variation, also affect the concentration of the water parameters.

Rapid urbanization, especially in developing countries like Nigeria, has affected the availability and quality of groundwater due to waste and effluent disposal practice, especially in urban areas.

Once groundwater is contaminated, its quality cannot be restored by just stopping the pollutants from source, this is because groundwater contamination may continue years after the waste source is in place (Ramakrishnaiah *et al.*, 2009; Makwe, 2012). As groundwater has a huge potential to ensure the supply of future demand for water, it is important that human activities on the surface do not negatively affect the precious resource.

Agricultural activities, especially abattoir operations, produce a characteristic highly organic waste with relatively high levels of suspended solid, liquid and fat. The improper disposal of these wastes onto lands and into water bodies leads to the contamination of the environment, one of which is the impairment of water quality (Abdul-Gafar, 2006).

There is high possibility that the effluents from the abattoir will percolate into the ground and pollute the groundwater. This study therefore seeks to determine the extent of pollution of the groundwater from the abattoir effluents through the qualitative analysis of groundwater samples taken from different existing wells at various distances from the abattoir. It also evaluates the influence of seasonal variation on the concentrations of the parameters.

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Study Area

Karu is one of the satellite towns in Abuja Municipal Area Council (AMAC) of the Federal Capital Territory, Nigeria. It is located about 7km north east of the Federal Capital City (FCC), off the Abuja–Keffi express way. It lies between latitudes 8° 59' 38.6"N and 9° 01' 39.6"N and longitudes 7° 33' 17.19"E and 7° 34' 49.61"E. Karu has an area of about 275 square kilometers. It is bordered to the north by Nyanya, to the south by Jikoyi, to the west by Kugbo and to the east by Mararaba (in Nasarawa State). Karu abattoir, which is the study area, is located close to a residential area. Its location therefore poses health risk to the residents due to the nature of wastes generated from the abattoir. Effluents from the abattoir are discharged into Tauga stream, which flows adjacent to the abattoir. The stream, it is characterized by flash floods due to increase in its volume during the rainy season and have a considerably reduced flow during the dry season (Balogun, 2001).

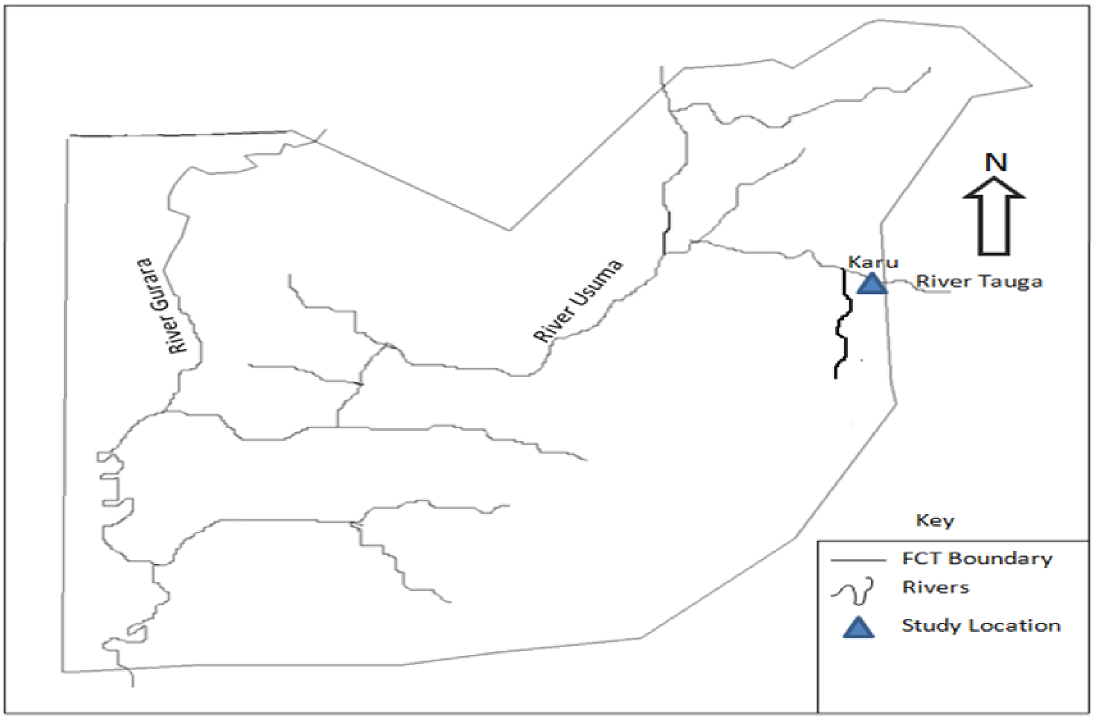

Figure 1 Location of the Study Area
Source: FCDA, 2011

Materials and Methods

Sampling Procedure

Fifty-Four water samples were collected from nine existing wells located around the abattoir. Three of these wells were located within the abattoir vicinity, three were located about 60meters away from the abattoir and the last three were located 200m-300m away from the abattoir. The water samples were collected using 1 litre plastic containers that were treated with 3-4ml of nitric acid and then rinsed with the water samples to be collected. The well water was drawn up and poured into the plastic containers, the containers were labeled and grouped into three as follows:

- Group A samples: collected within the abattoir
- Group B samples: collected 60m away from the abattoir
- Group C samples: collected 200-300m away from the abattoir

After collection, the samples were stored in a cooler containing ice block. This was meant to maintain a temperature of 3-4°C for preservation. The water samples were collected for six months from July-September 2011 (wet season) and from November, 2011- January, 2012 (dry season).

Temperature, turbidity, and electrical conductivity were determined at the point of collection of the samples. The water samples were conveyed to the Sheda Science and Technology Complex (SHESTCO), Abuja, where they were analysed for selected physical, chemical and biological properties accordingly. Other parameters analysed includes; total dissolved solids, total suspended solids, pH, dissolved oxygen, biological oxygen demand, total hardness, iron content, nitrate, sulphate, coliform bacteria (*Escherichia coli*) and faecal streptococci. The parameters were statistically analysed and the groundwater quality was also compared with the World Health Organisation (2008) guideline for drinking water quality.

Methods of Analyses

Temperature was determined by dipping a mercury-in-glass portable thermometer into the water samples to obtain the reading; Turbidity, by the nephelometric method (using HACH 2100AN turbid meter) (APHA, 1998); total dissolved solids, by Gravimetric Method (Kazi *et al*., 2009); total suspended solids, by running a given amount of the water sample through a filter. The filter and residue were dried in oven. TSS was then calculated by subtracting weight of filter from that of filter and residue, and divided by the volume of water (Kazi *et al*., 2009); electrical conductivity was determined using the Jenway conductivity meter (4510 model), by dipping the probe into the container of the water samples until a stable reading was obtained and recorded; pH level was determined by the use of HANNA pH meter (Model HI 28129). Total hardness, by using standard solution of sulphuric acid with solochrome black T as indicator (Ekwebelem, 2010). Dissolved oxygen was determined using the Winkler azide method (Pejman *et al*, 2009); BOD was determined using the relationship $BOD= DO_1-DO_2$ (Agbaire and Obi, 2009), same as in DO above (Winkler azide method) but was titrated after 24hours; Iron content, by the Atomic Absorption Spectrophotometry (ASS), the concentration was read using UV spectrophotometer (Model: 01-0960-00) at 510nm. Nitrate was analyzed by cadmium reduction and ascorbic acid method (using HACH DR2800 spectrophotometer); and Sulphate by turbid metric method using barium chloride and concentration reading through UV spectrophotometer (Model: UV-1601) (Ademoriti, 1996). The fecal bacteria (*E.coli* and faecal streptococci) was determined using the membrane filter technique. This technique determines the number of colony forming units per 100 mL (cfu/100 ml) of water sample (APHA, 1998). The mean for each of the parameters were calculated for each season and the result obtained were statistically analysed using the paired sample student t-test.

Results and Discussion

Results from analysis of selected parameters (physical, chemical and biological) for the dry and wet seasons are presented in Tables 1, 2 and 3 respectively. These also show statistical deductions from the data set.

In the Group A water samples, mean values of temperature, TDS, TSS, pH, DO, total hardness, iron, *E. coli* and faecal streptococci are higher during the wet season; while those of electrical conductivity, BOD, nitrate and sulphate are higher during the dry season as shown in Table 1. The mean values for turbidity is however the same for both the wet and dry season.

Paired sample student t-test for Group A water samples in Table 1 shows that for most of the parameters, such as turbidity, TDS, conductivity, DO, BOD, nitrate, sulphate, iron content, E. coli and faecal streptococci, their calculated values ($t_{calculated}$) are less than the table values (at $P \leq 0.05$), indicating no significant seasonal variation; whereas other parameters such as temperature, total suspended solids, pH and total hardness have their calculated values greater than the table values, therefore they show significant seasonal variation. The percolation of water into the soil is accompanied by filtration and this could explain the reason for the non significant seasonal variation in the concentration of most of the groundwater parameters for Group A.

The result in Table 2 shows that for Group B water samples, parameters such as temperature, turbidity, TSS, electrical conductivity, pH, BOD, total hardness, *E. coli* and faecal streptococci have higher mean values during the wet season; while the other parameters such as TDS, DO, nitrate, sulphate and iron have higher mean values during the dry season. The result of the paired sample student t-test for Group B (Table 2) shows that parameters, such as TDS, conductivity, pH, DO, BOD, total hardness, nitrate, sulphate and iron content, have their calculated values ($t_{calculated}$) less than the table values at $P \leq 0.05$, hence indicating no significant seasonal variation; but other parameters such as temperature, turbidity, TSS, E. coli and Faecal streptococci have their calculated t values greater than the table values, and therefore shows significant seasonal variation.

Table 1 Paired Sample t-test for Difference in Concentration between Wet and Dry Season Groundwater Parameters (GROUP A)

Parameter	Pair	Mean± Std. Error	N	Std. Dvtion	d.f	t calculated	P≤0.05	Rmks
Temperature	wet season	29.44 ±0.18	9	0.53	8	4.051	2.31	S
	dry season	27.83 ±0.24	9	0.71				
Turbidity	wet season	2.33 ±0.24	9	0.71	8	0.00	2.31	NS
	dry season	2.33 ±0.17	9	0.50				
TDS	wet season	38.67 ±4.55	9	13.65	8	1.616	2.31	NS
	dry season	34.89 ±3.22	9	9.65				
TSS	wet season	48.78 ±1.98	9	5.93	8	6.615	2.31	S
	dry season	24.89 ±2.10	9	6.31				
Conductivity	wet season	358.33 ±20.51	9	61.54	8	-1.765	2.31	NS
	dry season	422.11 ±22.59	9	67.77				
pH	wet season	7.28 ±0.23	9	0.68	8	3.200	2.31	S
	dry season	6.48 ±0.13	9	0.38				
DO	wet season	20.70 ±1.95	9	5.86	8	1.474	2.31	NS
	dry season	19.53 ±1.71	9	5.14				
BOD	wet season	5.21 ±0.30	9	0.90	8	-0.346	2.31	NS
	dry season	5.36 ±0.42	9	1.27				
T/Hardness	wet season	145.56 ±8.24	9	24.73	8	5.098	2.31	S
	dry season	135.11 ±8.39	9	25.18				
Nitrate	wet season	0.014 ±0.005	9	0.014	8	-0.512	2.31	NS
	dry season	0.016 ±0.004	9	0.013				
Sulphate	wet season	7.87 ±0.21	9	0.62	8	-4.146	2.31	NS
	dry season	8.99 ±0.16	9	0.50				
Iron	wet season	0.06 ±0.02	9	0.05	8	0.159	2.31	NS
	dry season	0.05 ±0.02	9	0.05				
E.coli	wet season	101.33 ±4.77	9	14.31	8	1.459	2.31	NS
	dry season	89.11 ±5.26	9	15.78				
F.streptococci	wet season	59.89 ±6.18	9	18.55	8	1.603	2.31	NS
	dry season	47.44 ±3.52	9	10.55				

Note: S= significant, NS= not significant.

Table 2 Paired Sample t-test for Difference in Concentration between Wet and Dry Season Groundwater Parameters (GROUP B)

Parameter	Pair	Mean ± Std. Error	N	Std. Dvtion	d.f	$t_{calculated}$	P≤0.05	Rmks
Temperature	wet season	29.28± 0.24	9	0.71	8	4.243	2.31	S
	dry season	27.78 ± 0.17	9	0.51				
Turbidity	wet season	2.56 ± 0.18	9	0.53	8	4.400	2.31	S
	dry season	1.33 ± 0.67	9	0.50				
TDS	wet season	25.67 ±1.97	9	5.92	8	-2.388	2.31	NS
	dry season	29.67 ±3.13	9	9.39				
TSS	wet season	40.00 ±1.97	9	5.92	8	6.837	2.31	S
	dry season	23.44 ±1.38	9	4.13				
Conductivity	wet season	356.33 ±29.57	9	88.70	8	1.537	2.31	NS
	dry season	292.00 ±18.09	9	54.27				
pH	wet season	6.46 ±0.22	9	0.67	8	1.154	2.31	NS
	dry season	6.17 ±0.13	9	0.39				
DO	wet season	12.64 ±0.59	9	1.76	8	-0.565	2.31	NS
	dry season	12.87 ±0.76	9	2.28				
BOD	wet season	5.16 ±0.42	9	1.26	8	0.052	2.31	NS
	dry season	5.12 ±0.40	9	1.20				
T/Hardness	wet season	111.56 ±20.64	9	61.93	8	0.245	2.31	NS
	dry season	110.44 ±19.92	9	59.77				
Nitrate	wet season	0.03 ±0.009	9	0.03	8	-2.419	2.31	NS
	dry season	0.08 ±0.016	9	0.05				
Sulphate	wet season	6.47 ±0.13	9	0.39	8	-1.762	2.31	NS
	dry season	6.89 ±0.21	9	0.65				
Iron	wet season	0.05 ±0.02	9	0.06	8	-1.142	2.31	NS
	dry season	0.10 ±0.03	9	0.08				
E.coli	wet season	24.44 ±2.58	9	7.73	8	11.852	2.31	S
	dry season	4.00 ±1.37	9	4.12				
F.streptococci	wet season	17.67 ± 1.76	9	5.27	8	12.309	2.31	S
	dry season	1.00 ± 0.71	9	2.12				

Note: S= significant, NS= not significant.

Table 3 Paired Sample t-test for Difference in Concentration between Wet and Dry Season Groundwater Parameters (GROUP C)

Parameter	Pair	Mean± Std. Error	N	Std. Dvtion	d.f	$t_{calculated}$	P≤0.05	Rmks
Temperature	wet season	28.83 ±0.17	9	0.50	8	4.00	2.31	S
	dry season	27.83 ±0.17	9	0.50				
Turbidity	wet season	1.44 ±0.18	9	0.53	8	0.426	2.31	NS
	dry season	1.33 ±0.17	9	0.50				
TDS	wet season	19.22 ±1.06	9	3.19	8	1.540	2.31	NS
	dry season	17.89 ±0.70	9	2.09				
TSS	wet season	27.89 ±1.62	9	4.86	8	3.878	2.31	S
	dry season	21.56 ±1.24	9	3.71				
Conductivity	wet season	333.56 ±26.01	9	78.03	8	-3.837	2.31	NS
	dry season	511.67 ±27.98	9	83.93				
pH	wet season	6.16 ±0.18	9	0.53	8	1.475	2.31	NS
	dry season	5.90 ±0.06	9	0.17				
DO	wet season	9.10 ±0.36	9	1.07	8	-1.349	2.31	NS
	dry season	9.40 ±0.34	9	1.03				
BOD	wet season	3.79 ±0.28	9	0.84	8	2.705	2.31	S
	dry season	3.33 ±0.26	9	0.79				
T/Hardness	wet season	241.11 ±4.46	9	13.38	8	2.588	2.31	S
	dry season	233.11 ±5.34	9	16.03				
Nitrate	wet season	0.008 ±0.004	9	0.01	8	0.00	2.31	NS
	dry season	0.008 ±0.003	9	0.01				
Sulphate	wet season	3.84 ±0.16	9	0.49	8	-6.020	2.31	NS
	dry season	4.99 ±0.18	9	0.53				
Iron	wet season	0.11 ±0.0	9	0.06	8	-0.839	2.31	NS
	dry season	0.13 ±0.02	9	0.06				
E.coli	wet season	0.00 ±0.00	9	0.00	8	0.00	2.31	NS
	dry season	0.00 ±0.00	9	0.00				
F.streptococci	wet season	0.00 ±0.00	9	0.00	8	0.00	2.31	NS
	dry season	0.00 ±0.00	9	0.00				

Note: S= significant, NS= not significant.

The result of the analyses for the Group C water samples shows that parameters such as temperature, turbidity, TDS, TSS, pH, BOD and total hardness have higher mean values during the wet season; whereas the mean values of conductivity, DO, sulphate and iron are higher during the dry season. However, the mean values of nitrate, *E. coli* and faecal streptococci have the same mean values for both wet and dry season (Table 3). The parameters, which show significant seasonal variation from the results of the paired sample student t-test for the Group C water samples shown in Table 3 includes temperature, TSS, BOD and total hardness. These parameters have their calculated values ($t_{calculated}$) greater than the table values at P≤0.05. Most of the parameters however show no significant seasonal variation because their calculated values are less than the table values. These parameters are turbidity, TDS, conductivity, pH, DO, nitrate, sulphate, iron content, E. coli and Faecal streptococci. As explained earlier, the filtration process which occurs during groundwater recharge could account for the absence of a significant seasonal variation in these parameters. The distance between the abattoir and the Group C sampling points (200-300m away from the abattoir) could also be a determining factor, the impact of the abattoir effluents on the groundwater is hardly felt at this distance.

Comparing the seasonal variation in the concentration of the parameters across the three Groups of groundwater samples (A, B and C), depicts the influence of certain factors such as precipitation, groundwater recharge, distance and weather.

Mean temperatures of the groundwater samples across the groups are higher during the wet season and ranged from 28.83°C to 29.44°C while those of the dry season ranged from 27.78°C – 27 83°C. The lower temperatures during the dry season are probably due to the Harmattan cold which causes water temperature to reduce.

Mean turbidity values for Group A groundwater samples are the same for both the wet and dry season (2.33NTU). In Groups B and C however, the mean turbidity values are higher during the wet season (as seen in Table 1-3). The slight variation in turbidity values between Group A samples and the others could be due to the close proximity of the Group A samples to the abattoir. Lower turbidity values during the dry season are probably due to less groundwater recharge and the filtration. The turbidity values across the Groups are within the World Health Organisation (WHO, 2008) recommended value of 5NTU.

Mean total dissolved solids in the samples across the Groups are higher during the wet season (A=38.67mg/l, B=29.67mg/l and C=19.22mg/l) than the dry season (A=34.89mg/l, B=25.67mg/l and C=17.89mg/l) as shown in tables 1-3. The TDS increases in the wet season could be attributed to weathering intensity; and the increased amount of groundwater recharge. There is also a reduction in the TDS with distance from the abattoir. The TDS values for both seasons are within the WHO (2008) 1000mg/l tolerance limits.

The amount of suspended solids present in the groundwater samples across the Groups is higher during the wet season (as shown in Tables 1-3). This again, could be due to the increased weathering intensity and groundwater recharge during wet season. Reduction in TSS during the dry season is as a result of water filtration. Similar to that of the TDS above, there is also a reduction in the TSS with distance from the abattoir. The wet season mean TSS values for Groups A and B are higher than the 30mg/l WHO (2008) recommended value for drinking water, whereas that of Group C and the dry season mean TSS values across the Groups are within the recommended value (see Tables 1-3).

Electrical conductivity of the groundwater samples is not consistent in both seasons (Wet: A=358.33µs cm/l, B=356.33µs cm/l and C=333.56µs cm/l. Dry: A=422.11µs cm/l, B=292.00µs cm/l and C=511.67µs cm/l). However there is reduction in electrical conductivity from Group A down to Group C during the wet season.

The acidity of the waters samples increases in the wet season across the groups with mean pH values for Groups A, B and C as (7.28, 6.46 and 6.16) while the dry season pH values are (6.48, 6.17 and 5.90) for the Groups. This may be attributed to acidic conditions initiated by higher precipitation. Also there is increased acidity with increased distance from the abattoir. An acceptable pH for drinking water is between 6.5 and 8.5 (WHO, 2008), therefore only the wet season Group A samples meet the standard.

Dissolved Oxygen of Groups A and B groundwater samples in the wet season are 20.70mg/l and 12.87mg/l respectively and they are higher than those of the dry season (19.53mg/l and 12.64mg/l respectively). The case is however the reverse for the Group C samples.

The BOD for the three groups of groundwater samples are higher during the dry season (A=5.36mg/l, B=5.16mg/l and C=3.79mg/l) and slightly lower during the wet season (A=5.21mg/l, B=5.12mg/l and C=3.33mg/l). The high BOD during the dry season could be due to the reduced groundwater recharge. All the water samples have BOD values which are higher than the WHO (2008) 0.0mg/l permissible limit.

The wet season groundwater samples have total hardness values that are higher than the dry season samples (as shown in Tables 1-3) across the groups. Interestingly, the Group C samples (wet and dry season) have higher mean total hardness values than Groups A and B samples, even though they are far from the abattoir effluent discharge point (200-300meters away). This could be due to other environmental factors other than the proximity to the abattoir. The groundwater samples across the groups are within the WHO (2008) 100-300mg/l limit for total hardness in water.

The nitrate and sulphate levels in the groundwater samples are higher during the dry season across the groups (as shown in Tables 1-3). However the concentration of nitrate is higher in Group B than in Groups A and C. This could be due to the reduction in groundwater recharge resulting from low precipitation, higher temperature and evaporation during the dry season (nitrate and sulphate). The nitrate and sulphate values are within the WHO (2008) guideline limits of 50mg/l and 250mg/l respectively.

The Group C groundwater samples have mean iron content higher (wet: 0.11mg/l, dry: 0.13mg/l) than those of Groups A (wet: 0.06mg/l, dry: 0.05mg/l) and B (wet: 0.05mg/l, dry: 0.10mg/l). The concentration is however higher during the dry season for Groups B and C water samples, probably due to increased concentration as a result of reduced groundwater recharge during the dry season. The mean values are within the 0.3mg/l WHO (2008). However, the higher concentration in the Group C samples may be attributed to other factors considering its distance from the point of discharge of the abattoir effluents.

E. coli and Faecal streptococci are present in Groups A and B groundwater samples and they are more during the wet season as shown in Tables 1-3. The high amount of these coliform during the wet season could be due to the fact that water availability favours the movement and reproduction of the organisms. *E. coli and* Faecal streptococci are absent in the Group C water samples and this could be due to the distance factor. The amount of *E. coli* and Faecal streptococci in Groups A and B are higher than the WHO (2008) recommended 0cfu/100ml of water.

Conclusion

The result of the analyses shows that most of the parameters have higher mean values during the wet season (see Table 1) in all the Groups, except for BOD, sulphate and iron which have higher mean values during the dry season. This was attributed to the increased amount of groundwater recharge in the wet season which results in soil saturation and consequently resulting in reduced filtration. Paired sample t-test results revealed that parameters such as TDS, conductivity, DO, nitrate, sulphate and iron have no significant variation in all the Groups, with other parameters showing different levels of seasonal variation across the groups. Most of the parameters have mean values within the World Health Organisation (2008) guidelines in both seasons. However parameters such as TSS, *E. coli* and faecal streptococci have values that are higher than the guideline provisions; BOD are higher than the WHO guideline recommended limit; and electrical conductivity values are inconsistent across the groups. Furthermore, the concentration of the pollutants reduces with distance from the abattoir. This therefore implies that the water is more polluted during the wet season due to soil saturation which results to lesser filtration. This result is in tandem with that obtained by Adekunle *et al.,* (2007) in Igbora, a rural settlement in Oyo state, southwestern Nigeria.

Recommendation

In view of the findings revealed by this study, it is recommended that there is the need for the treatment of the abattoir effluents into a non toxic state before they are discharged into the environment. Efforts should also be made by the regulatory agencies such as National Environmental Standards and Regulation Enforcement Agency (NESREA) and Abuja Environmental Protection Board (AEPB) to meet and enforce the international standards and recommendations for the location of abattoirs.

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