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Impact of Slaughterhouse Effluents on Groundwater Quality: Evidence-Based Assessment in Tudun-Wada and Kawo Residential Suburbs, Kaduna, Nigeria

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Abstract

Pollution of groundwater by slaughterhouse effluent has been documented to have negative health and environmental consequences. Tudun-Wada and Kawo residential suburbs of Kaduna city are known to house slaughterhouses where effluent is mostly discharged indiscriminately into the environment. Eighteen water samples were obtained from six existing hang dug wells representing six sampling points with varying distances in the study area. Group A (K1 and T1) is located within the slaughterhouses, Group B (K2 and T2) is located 60-130 meters away from the slaughterhouses and Group C (K3 and T3) is 80-200 meters away from the slaughterhouses. Standardized methods were employed to analyze temperature, pH, total dissolved solids (TDS), total suspended solids (TSS), dissolved oxygen (DO), bacterial oxygen demand (BOD), chemical oxygen demand (COD), electrical conductivity (EC), nitrate, sulphate, total coliform and faecal coliform of the sampled water. Results indicated that the mean pH values obtained in T1, T2, T3, and K1 are significantly ($p> 0.05$) different from each but are significantly ($p< 0.05$) different from the ones obtained in K2 and K3. Except for T3, which was in line with WHO and NSDWQ requirements, all of the groups had high feacal coliform and total coliform counts. Owing to the results recorded in this study, water drawn from hand-dug wells near slaughterhouses should be subjected to sanitary treatment before drinking and other uses. Again, we advised the state environmental protection agency to actively monitor the activities of the slaughterhouses and ensure compliance with health and safety standards.

1. Introduction

Environmental pollution has typically become a threat to humanity's and the ecosystem's existence. Some pollution effects can create metabolic disturbances and unwanted alterations, which can result in serious injuries and health risks (Ubwa et al., 2013). A slaughterhouse is a premise approved and registered by the monitoring authority for slaughtering and inspection of animals, as well as processing, proper preservation, and storage of meat products for human use (Ekpetere et al., 2019). Furthermore, slaughtering of these animals results in a large supply of meat, which serves as a good source of protein, and the production of useful by-products such as leather, skin, blood, and bones. The processing activities involved result in environmental pollution and other health issues that can endanger animal and human health (Aniobi et al., 2020). In many underdeveloped nations, basic sanitary practices in slaughterhouses are essentially non-existent, resulting in untreated waste and wastewater created during slaughterhouse processes being released into the nearby surface water or the ground without being treated (Jin et al., 2018). The authors further reported that, wastewater percolates through the soil to underground water, polluting not only the receiving surface water but also the soil and underground water. In-addition, dumping slaughterhouse waste indiscriminately could pollute surface and subsurface rivers, as well as the air and soil. Similarly, large levels of organic pollution in the blood have an impact on receiving soil and water, which depletes the dissolved oxygen level in the water bodies.

Water is a vital natural resource that supports life on Earth (Amoo et al., 2021a), since humans can go for weeks without eating but cannot go for days without drinking water because water is required to restore lost fluids through normal physiological activities. The volume of water available in portable forms comes from groundwater, springs, rivers, and lakes, with only approximately 3% of the total volume coming from these sources (Elemile et al., 2019). Furthermore, the ineffable relevance of water to life is due to the fact that no human activity can be carried out without the involvement of water. According to Amoo et al. (2021b), water provides life and performs a variety of activities for which there is no substitute. Groundwater is the most prevalent source of potable water globally, and its elemental makeup indicates how safe it is for humans, animals, and plants. Contamination of groundwater is different from contamination of surface water because of its influence (Amoo et al., 2021b). In developing and densely populated countries like Nigeria, contamination and pollution of natural water sources have emerged as a major concern (Jin et al., 2018). The authors reported further that, water contamination makes water unfit for human consumption and increases the cost of treatment to attain acceptable quality.

According to Aniobi et al. (2020), slaughterhouse effluents can significantly increase the levels of phosphorus, nitrogen, total solids, and material organisms in the receiving water body, lowering the water quality. In many underdeveloped countries, such as Nigeria, slaughterhouses are typically located near residential areas, and in most cases where shallow wells are nearby, the effluents from these slaughterhouses percolate in the soil and leach into the aquifers, rendering nearby water sources unfit for human consumption (Hassan et al., 2014). The authors further reiterated that as a result, determining the quality of water in residential areas near slaughterhouses will aid in determining the health effects on inhabitants who rely primarily on this nearby water source for drinking and other domestic purposes. This is especially essential because most people in underdeveloped nations, particularly in "Africa," mistakenly assume that just because water is drinkable does not mean it is safe to drink. Owing to this, this study was conducted in Tudun-Wada and Kawo areas in Kaduna city to assess the impact of slaughterhouse effluents on the quality of groundwater.

2. Materials and methods

2.1 Description of the study area

Kaduna State is the 18th state of the Federal Republic of Nigeria, and it is located in the country's Northwest. According to Bunnu et al., (2015), Kaduna is located between latitudes 10 °N and 11 °N, and longitudes 7 °E and 8 °E (Figure 1), at a height of 645 meters above sea level, with a population of 1,561,000 people and at 2.55 percent annual growth rate as of 2010. In-addition, River Kaduna runs through the heart of the city, cutting the state in two (Kaduna North and South). Kawo slaughterhouse is in Kaduna north, while Tudun-Wada slaughterhouse is in Kaduna central. The Kaduna state climate is part of Nigeria's tropical wet and dry climate. The rainy season runs from April through October. The area receives between 1204 to 1567 mm of annual rainfall, average daily temperatures of 27 to 33 °C, and relative humidity of about 99 percent during the wet season and less than 55 percent during the dry season (Amin, 2006).

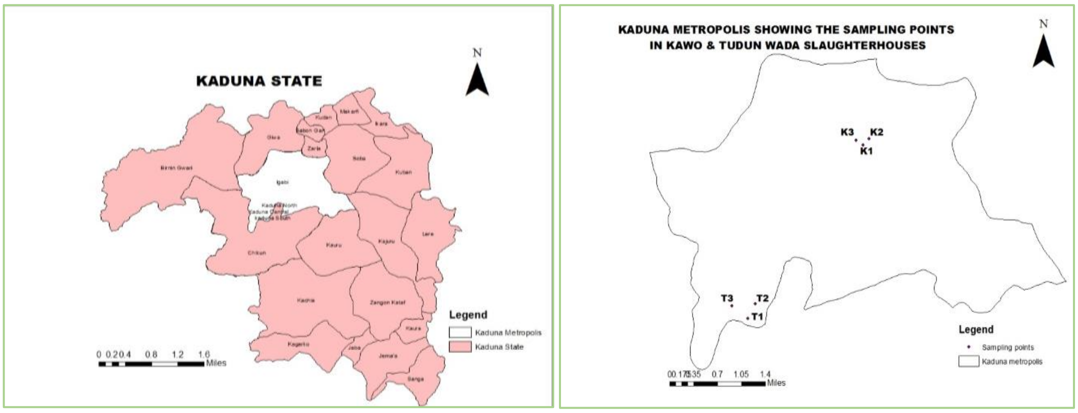

Figure 1: Location of the sampling points in Kaduna, Nigeria.

2.2 Water Sampling

Water samples were obtained from six existing hand-dug wells in and around the slaughterhouses shown in Figure 1. Three water samples were collected from each sampling point three times a month making a total number of eighteen water samples. Water samples from Group A (K1, T1) were collected from the hand-dug wells within the slaughterhouses, Group B (K2, T2) were collected from the hand-dug wells that are 60 – 130 meters away from the slaughterhouses while Group C (K3, T3) were collected from the hand-dug wells that are 80 – 200 meters away from the slaughterhouses (Table 1). Water samples were collected between the hours of 11:00 am and 3:00 pm on each day. Water sample collection was done towards the end of the wet season in September 2020. Adopting the method described by (Adeleye et al., 2020), water samples were collected in sterile one (1) liter plastic containers rinsed with de-ionized water before being used at the point of collection (USFDA, 2018). Upon collection, all water samples were immediately transported in a cooler containing an ice pack to Accurate Alessandria Water Laboratory in Barnawa, Kaduna state for onward analyses.

Table 1: Distance of sampling points from the slaughterhouses with elevation and its coordinates.

SP	Latitude (°)	Longitude (°)	SP to SH	Distance from SH (m)	Elevation (m)
T1	10° 30’ 10.548” N	7° 24’ 37.112” E	TW1 – TW2	130	575.43
T2	10° 30’ 14.444” N	7° 24’ 39.015” E			579.84
T3	10° 30’ 9.6060” N	7° 24’ 30.443” E	TW1 – TW3	200	583.51
K1	10° 34’ 37.401” N	7° 27’ 12.401” E	K1 – K2	60	617.13
K2	10° 34’ 39.042” N	7° 27’ 11.088” E			610.32
K3	10° 34’ 39.876” N	7° 27’ 12.698” E	K1 – K3	80	608.27

SP= Sampling points; SH= Slaughterhouse; T= Tudun Wada; K= Kawo

2.3 Physicochemical and bacteriological analyses of the water samples

Temperature, pH, total dissolved solids (TDS), total suspended solids (TSS), dissolved oxygen (DO), biological oxygen demand (BOD), chemical oxygen demand (COD), electrical conductivity (EC), nitrate, and sulphate were determined using (APHA, 2017) documented analytical procedures. Total coliforms (TC) and faecal coliforms (FC) were determined using the membrane filtration procedure outlined by (WHO, 2006).

2.4 Data Analysis

Data obtained were subjected to descriptive and inferential statistics. Results were summarized using tables and bar charts. Physicochemical and bacteriological parameters were subsequently compared with permissible standards of WHO (2006); NSDWQ (2007). One-way analysis of variance (ANOVA) was carried out using SAS software package version 9.1 to evaluate variations in the physicochemical and bacteriological attributes of water samples across sampling points. Significant means were separated using Duncan's Multiple Range Test (DMRT).

3. Results and discussions

The mean temperature of the measured water samples varied throughout the locations, ranging from 26.4 to 31.80 °C (Table 2). According to Murhekar (2011), water polluted with effluents invariably raises its temperature and dissolved oxygen levels. The authors reported further that, most slaughterhouses in Nigeria have groundwater temperatures between 28.5 and 28.8 °C. The temperatures recorded in this study were within the NSDWQ permitted range of 38 °C. However, the temperatures were higher than the WHO permissible range of 25 °C (Figure 2). It can be observed that the mean temperature in T1, T2, T3, K1, and K2 are not significantly ($p > 0.05$) different from each other while the mean temperature in K3 is significantly ($p < 0.05$) different from T1, T2, and T3 (Table 3a). The temperature ranges of the sampled water detected in this study is in-concord with the one reported by Hassan et al., (2014); Elemile et al., (2019); Adeleye et al., (2020) in their respective study areas.

The mean pH values were within NSDWQ and WHO permissible limits, with the exception of K2 and K3, which were below the limits (Figure 2).

Table 2: Mean values of the water parameters measured from the sampling points.

WP	**T1**	**T2**	**T3**	**K1**	**K2**	**K3**
Temp (°C)	31.80± 2.06	30.70± 1.10	31.40± 1.06	28.50± 0.51	29.50± 0.98	26.40± 1.05
pH	6.70± 0.31	6.90± 0.15	7.20± 0.21	6.73± 0.31	5.60± 0.30	4.90± 0.15
EC (µs/cm)	400± 11.55	499± 14.98	499± 9.29	389± 33.50	387± 13.65	390± 18.03
TDS mg/L)	602± 9.87	591± 30.20	599± 10.50	556± 13.01	558± 23.18	564± 16.29
TSS (mg/L)	70± 1.53	59± 2.08	62± 4.58	66± 2.65	65± 2.52	51± 3.00
Sulphate (mg/L)	102± 0.58	101± 1.53	101± 0.58	110± 1.15	109± 1.53	109± 7.77
BOD (mg/L)	26± 2.53	22± 1.53	16± 1.73	34± 5.03	29± 1.73	22± 1.53
COD (mg/L)	22.08± 0.10	22.08± 1.61	22.07± 0.94	29.05± 0.51	29.05± 1.03	28.00± 3.09
DO (mg/L)	7± 1.00	6± 0.58	0± 0.00	6± 1.15	4± 0.58	3± 0.58
Nitrate (mg/L)	0.8± 0.21	1.0± 0.21	1.1± 0.15	0.5± 0.10	0.7± 0.06	0.9± 0.06

T= Tudun-Wada; K= Kawo; WP= Water parameters; Temp= Temperature; EC= Electrical conductivity; TDS= Total Dissolved Solid; TSS= Total Suspended Solid; BOD= Biochemical oxygen demand; COD= Chemical oxygen demand; DO= Dissolved oxygen

Table 3a: Mean variation in the physicochemical parameters of sampled water across sampling points.

SP	**Sampled water parameters**				
	Temperature (°C)	pH	EC (µs/cm)	TDS (mg/L)	TSS (mg/L)
T1	31.8^{a}	6.7^{a}	400.0^{b}	602.0^{a}	70.0^{a}
T2	30.7^{a}	6.9^{a}	499.0^{a}	591.0^{a}	59.0^{bc}
T3	31.4^{a}	7.2^{a}	499.0^{a}	599.0^{a}	62.0^{ab}
K1	28.5^{ab}	6.7^{a}	389.0^{b}	556.0^{a}	66.0^{ab}
K2	29.5^{ab}	5.6^{b}	387.0^{b}	558.0^{a}	65.0^{ab}
K3	26.4^{b}	4.9^{c}	390.0^{b}	564.0^{a}	51.0^{c}

Note: SP= Sampling points. Means with the same letter(s) in the same column under the same variable are not significantly different from each other at $p > 0.05$, using Duncan's multiple range test.

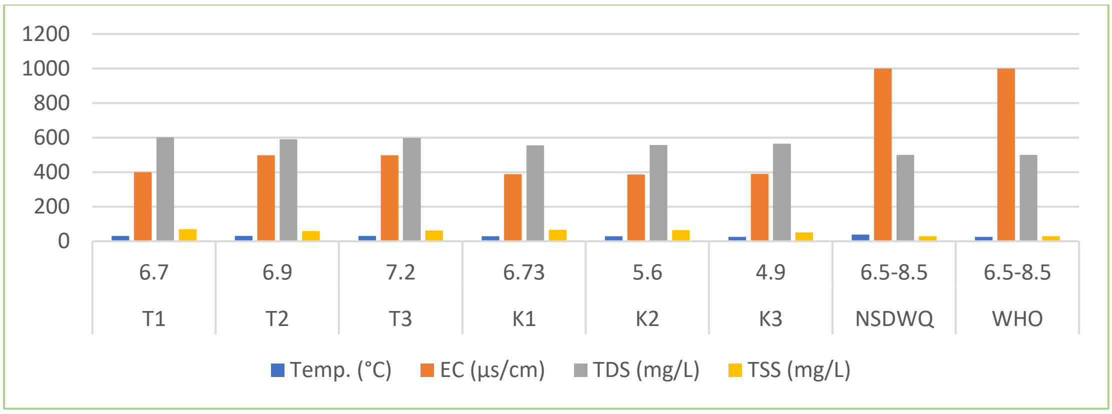

Figure 2: Comparison of pH, Temperature, EC, TDS, and TSS with regulated standards.

The mean pH values obtained in T1, T2, T3, and K1 are significantly ($p > 0.05$) different from each but are significantly ($p < 0.05$) different from the ones obtained in K2 and K3 (Table 3a). The variation in mean pH values recorded in this study indicates a mild acidity of the water samples found in that category. Interestingly, these mean pH values are consistent with those reported by Ekpetere et al., (2019); Elemile et al., (2019); Aniobi et al., (2020). The findings of this study are equally consistent with the report of Omotayo et al., (2017) in their respective study areas. However, the results are in contrast with the report of Adeleye et al., (2020) who documented pH range (7.2 – 7.8), and Tadessa et al., (2018) who reported pH range (8.2 – 10.5) in their study areas.

The mean electrical conductivity (EC) values recorded in the sampling points ranged between 387 and 499 µS/mL (Table 2). The mean EC values obtained in T2 and T3 are significantly ($p < 0.05$) different from the ones obtained in T1, K1, K3 which are not significantly ($p > 0.05$) different from each other (Table 3a). The mean EC recorded in this study is within the NSDWQ and WHO permissible limits (1000 µS/cm) (Figure 2). Olugbenga & Davids, (2019); Adeleye et al., (2020); Amoo et al., (2021b), obtained similar results from their respective study areas. However, the finding of Onwughara et al., (2013), who reported an EC of 9.32 µS/cm in their study, is in contrast to the mean EC values recorded in this study (Figure 4). According to WHO (2006), who has no established guideline value for electrical conductivity in drinking water thus comparison was done.

As depicted in Table 2, the results of the total dissolved solids (TDS) ranged from 556 to 601 mg/L. The results recorded were above the permissible standards of NSDWQ and WHO (Figure 2) permissible limits of 500 mg/L in all of the studied locations. However, the mean TDS recorded in all the sampling points are not significantly ($p > 0.05$) different from each other (Table 3a). Because of the higher concentrations of TDS recorded in this study, the quality of the water sampled in this study can be said to be poor quality. High levels of TDS in drinking water have been linked to cancer and coronary heart disease (Yashoda et al., 2014). The current findings are consistent with those of Tadessa et al., (2018), but differ from those of Hassan et al., (2018), who reported levels between 140 and 145 mg/L.

The total suspended solids (TSS) values were found to range between 51 and 70 mg/L (Table 2). These concentrations are well above NSDWQ and WHO limits (30 mg/L) in all the sampling points, which implies that the water is unsafe for human consumption (Figure 2). Mean TSS concentrations recorded in T2, T3, K1, and K3 are not significantly ($p > 0.05$) different from each other but the concentrations obtained in T1 and K3 are significantly ($p < 0.05$) different from each other (Table 3a). Makwe and Chup (2013) did report a similar trend reported in this study. The findings in this study are consistent with those of Hassan et al., (2014) as they all reported high TSS in their respective study areas.

The mean sulphate (SO_4) concentrations measured in the sampling points ranged from 101 mg/L to 110 mg/L (Table 2). These results are slightly above WHO and NSDWQ (100 mg/L) recommended limit (Figure 3). Mean sulphate concentrations are not significantly ($p > 0.05$) different from each other across all the sampling points (Table 3b). The considerably high sulphate values recorded in this study could be due to seepage of slaughterhouse effluent into the soil and which invariably pollutes groundwater (Chukwu, 2008). According to Asibor and Ofuya (2019), who reported similar trends in their studies. In contrast to this study, Elemile et al., (2019) reported sulphate concentrations ranging from 9.78 mg/L to 16.0 mg/L and 4.21 mg/L to 8.57 mg/L respectively in their study areas. However, sulphate concentration higher than the permissible limits (100 mg/L) is considered unsanitary (WHO, 2006).

Table 3b: Mean variation in the physicochemical parameters of sampled water across sampling points.

SP	**Sampled water parameters**				
	Sulphate (mg/L)	BOD (mg/L)	COD (mg/L)	DO (mg/L)	Nitrate (mg/L)
T1	102.0^{a}	26.0^{ab}	22.1^{b}	7.0^{a}	0.8^{ab}
T2	101.0^{a}	22.0^{bc}	22.1^{b}	6.0^{ab}	1.0^{a}
T3	101.0^{a}	16.0^{c}	22.1^{b}	0.0^{d}	1.1^{a}
K1	110.0^{a}	34.0^{a}	29.1^{a}	6.0^{ab}	0.5^{b}
K2	109.0^{a}	29.0^{ab}	29.7^{a}	4.0^{bc}	0.7^{ab}
K3	109.0^{a}	22.0^{bc}	29.7^{a}	3.0^{c}	0.9^{ab}

Note: SP= Sampling points. Means with the same letter(s) in the same column under the same variable are not significantly different from each other at p> 0.05, using Duncan's multiple range test.

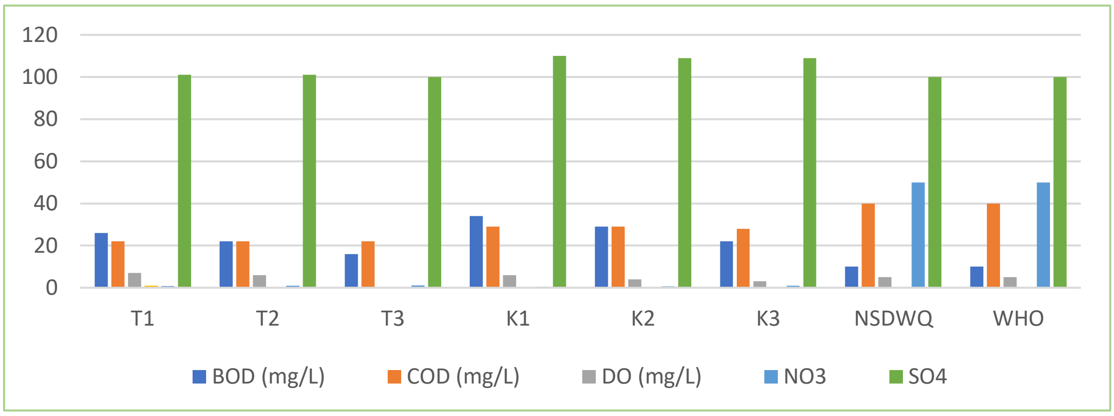

Figure 3: Comparison of BOD, COD, DO, Nitrate and Sulphate with regulated standards.

The biological oxygen demand (BOD) values decreased down the locations, with T1 and K1 having the highest values and T3 and K3 having the lowest values (Table 2). All of these values are above the allowable limits of NSDWQ and WHO (10 mg/L) regarding drinking water quality guidelines (Figure 3). However, BOD values obtained in T3 and K1 are significantly (p< 0.05) different from each but the values obtained in T1, T2, K2, and K3 are not significantly (p> 0.05) different from each other (Table 3b). As the estimated BOD values obtained in the study are above the permissible limits, the influence of the effluents indiscriminately discharged from the slaughterhouses on the current status of the groundwater quality cannot be ruled out. In contrast to this study, Aniobi et al., (2020) found lower BOD range (0.05 – 2.88 mg/L) and (3.42 – 5.43 mg/L) which are below NSDWQ and WHO recommended limits in their respective study areas. Elemile et al., (2019); Olugbenga & Davids (2019) equally found similar trends in their studies.

The mean chemical oxygen demand (COD) results presented in Table 2 for all water samples taken from the sampling points indicate that it ranged between 22.08 mg/L and 28.7 mg/L. These mean COD values are within NSDWQ and WHO allowable limits of 40 mg/L (Figure 3). This finding is in line with the reports of Ogbonna and Ideriah (2014) in their respective study areas. Interestingly, the COD values recorded in T1, T2, and T3 are significantly (p< 0.05) different from the COD values obtained in K1, K2, and K3 (Table 3b).

Dissolved oxygen (DO) levels in all water samples declined from (K1 – K3) and (T1 – T2), with T3 having zero value (Table 2) while DO values of K2 and K3 were within the allowable limit in drinking water (Figure 3). USFDA (2018); Aniobi et al., (2020), reported DO ranging from 3.2 to 3.8 mg/L, 5.6 to 7.0 mg/L, and 3.08 to 7.78 mg/L respectively in their studies. However, DO ranges recorded in this study are contrary and above those reported by Makwe and Chup, (2013) in similar slaughterhouses. However, the DO values obtained in T3 and K3 differed significantly ($p < 0.05$) from one each. Mean DO values recorded in this study are above NSDWQ and WHO recommended limit (5.0 mg/L) indicating that the degree of pollution of the groundwater by the effluent was minimal. This finding is in agreement with the reports of Mulu et al., (2013) but differs from those of Ezeoha and Ugwuishi (2011).

The mean nitrate (NO_3) concentrations obtained from water samples from K1, K2, and K3 were between 0.5 and 0.9 mg/L, whereas those in T1, T2, and T3 were between 0.8 and 1.1 mg/L (Table 2). The mean nitrate concentrations in all of the sampling points are below WHO and NSDWQ recommended limit (50 mg/L) (Figure 3). Nitrate concentrations recorded in this study fell below those reported by Elemile et al., (2019) in their respective study areas. However, there is a significant ($p < 0.05$) difference in the mean nitrate concentrations between the water samples obtained in T3 and K1 (Table 3b). It has been reported that excessive nitrate levels can cause blue-eye syndrome in small children and pregnant women (Elemile et al., 2019). Furthermore, high nitrate and phosphate concentrations may cause eutrophication in the water body (Adeolu et al., 2016).

Table 4 shows the mean of the total coliform (TC) count, which ranged from 11 to 109 CFU/100 mL with T1 having the highest count (109 CFU/100 mL) and T3 having the lowest (11 CFU/100 mL). Apart from K3 that recorded 0 CFU/100 mL FC count, the remaining sampling points recorded TC and FC counts higher than 0 CFU/100 mL recommended by WHO and NSDWQ as the allowable limit in potable water (Figure 4). However, the TC and FC count across the sampling points are significantly different from each other (Table 4). The presence of TC and FC counts in water samples indicates the presence of opportunistic pathogenic bacteria like the species of Klebsiella and Enterobacter, which can multiply in water environments, as well as pathogenic pathogens like species of Salmonella, Shigella, Campylobacter, and pathogenic Escherichia coli (WHO, 2006). If the sampled water harboring the TC and FC counts recorded in this study are consumed, it can potentially lead public health crisis in the study area. According to USEPA (2015), water consumers may contract gastroenteritis, dysentery, cholera, typhoid fever, and salmonellosis as a result of the presence of enteric pathogens in the water meant for human consumption.

Table 4: Mean Variation of Total and Feacal coliform counts in the sampled water.

SP	**TC (CFU/100 mL)**	**FC (CFU/100 mL)**
T1	$109.0^a \pm 1.53$	$83.0^a \pm 1.15$
T2	$44.0^d \pm 1.53$	$14.0^c \pm 1.15$
T3	$11.0^f \pm 0.58$	$0.0^d \pm 0.00$
K1	$82.0^b \pm 2.08$	$27.0^b \pm 1.73$
K2	$52.0^c \pm 3.79$	$11.0^c \pm 1.53$
K3	$18.0^e \pm 1.15$	$2.0^d \pm 0.58$

Means with the same letter(s) in the same column under the same variable are not significantly different from each other at $p > 0.05$, using Duncan's multiple range test.

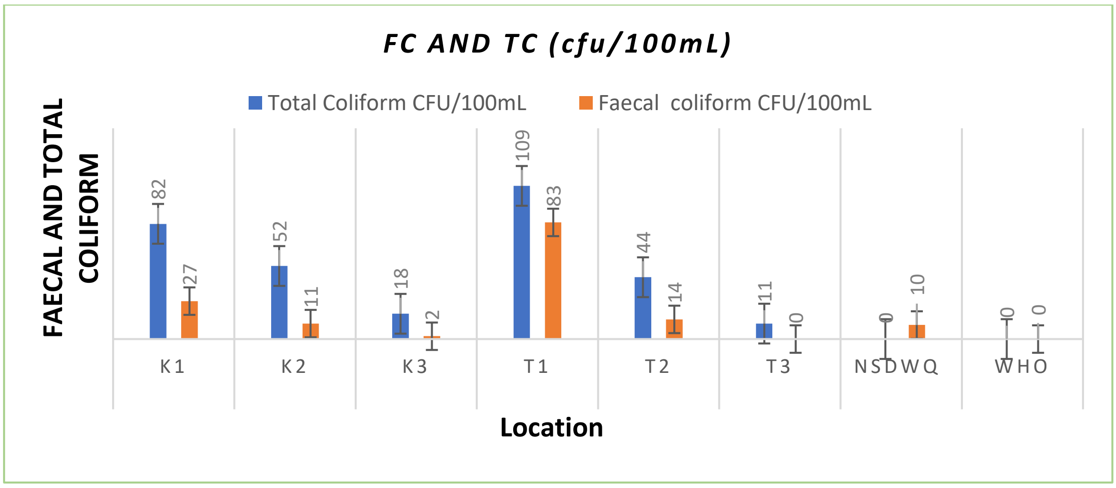

Figure 4: Mean Feacal and Total Coliform Counts within the sampling points and comparison with regulated standards.

Sample T1 and K1 had the highest FC count and T3 had the lowest FC count, ranging from 0 to 83 CFU/100 mL (Table 4). The presence of enteric pathogens in the sampled hand-dug wells suggests their growth in the water samples. The detection of these enteric pathogens in the sampled water can be attributed to its proximity to the slaughterhouses as effluents are indiscriminately discharged without any form of treatment prior to the final disposal. The proliferation of sewage, as well as natural wastes from human and animal excrement in water, tend to lead to its pollution (Yogendra and Puttaiah, 2008). Igbinosa and Uwidia (2018), have reported similar findings in their respective study areas. In the reports of these authors, it was concluded that slaughterhouse effluents, regardless of where they are dumped, are significant groundwater pollutants as witnessed in this current study.

4. Conclusion

The impact of slaughterhouse activities on groundwater quality in the vicinity of slaughterhouses in the residential suburb of Tudun-Wada and Kawo communities in Kaduna, Nigeria, was explored in this study. The quality of the groundwater decreased throughout the sampling points examined. Group A and B (K1, K2, T1, and T2) water samples had higher concentrations of most of the investigated parameters than Group C (K3 and T3) water samples. This is most likely due to the water samples in Group A and B proximity to slaughterhouses, which means they are subjected to the effect of slaughterhouse effluents percolating into the soil thereby polluting groundwater. Owing to the results obtained in this study, water samples from Group A and B are unsafe for human consumption unless it is treated properly. However, water obtainable from Group C hand-dug wells need a light treatment before it can be consumed.

5. Recommendations

Based on the results of the study, the recommendation is that;

✓ A pre-treatment system should be practiced before the effluents are discharged into the surrounding area.
✓ A new slaughterhouse should not be established near residential areas because of the potential impact on groundwater quality.
✓ Regular water treatment and monitoring are also suggested in the well with close proximity to slaughterhouse.
✓ The state environmental protection agency should closely supervise the slaughterhouse operations to ensure that they conform with health and safety regulations.

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