

# Impact of Urban Livestock Production on Groundwater Quality in Kaduna Metropolis, Nigeria

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**Abstract** Groundwater is the main source of water for most city dwellers in Nigeria. In this study, the impacts of urban livestock production on groundwater quality in Kaduna metropolis were assessed through water quality monitoring. Groundwater samples were collected from wells located around 2 abattoirs (Tudunwada and Kawo abattoirs) and in 8 livestock-keeping households for a 6-month period (July- December). Physico-chemical analyses were conducted on the samples using standard methods. Results indicate that groundwater is negatively impacted in terms of 5-day biochemical oxygen demand, chemical oxygen demand, nitrate-nitrogen, total phosphorus and cadmium; and this impact is of great concern as the values for these parameters are well in excess of established limits. There is negative impact in terms of pH, electrical conductivity, total dissolved solids and zinc but this impact is not a concern as most of the values are within limits. However, no impact was observed on groundwater quality in terms of calcium as it showed no definite pattern of variation. Similarly, iron exhibited very low concentrations in the samples with a few exceptions in the months of July and August for the two abattoir sites. Lead was not detected in any of the samples throughout the study period. This study indicates that livestock keeping and processing activities have negative impact on groundwater quality in Kaduna metropolis. The groundwater pollution due to urban livestock production emanates from point sources and control measures can be easily applied.

**Keywords:** *abattoir, groundwater quality, Kaduna metropolis, livestock-keeping households, urban livestock production, wells*

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## 1. Introduction

Urban livestock production refers to the rearing and processing of animals within municipalities (towns and cities). Examples of these animals and the products derived from them include: cattle for milk, beef and hide; goats for meat; sheep for mutton and hide; poultry for eggs and meat; and pigs for pork. In addition to providing meat and other animal-related products, urban livestock production is a source of additional income [1] for the poorly remunerated employed civil servants and traders [2] as well as retired urban dwellers. Other benefits include: employment generation for the unemployed, opportunities for organic waste recycling and uplifting of social status [3]. It also contributes to the food supply of urban households that cannot afford to purchase all their food needs. Urban livestock production further serves to balance out the animal protein demand in the city and the supply from the rural areas where there may be issues of declining production, inefficient marketing and distribution due to decaying or non-existent infrastructure especially in developing countries.

In the early part of the 20th century, many municipalities were against urban livestock production due to perceived

public health risks of rearing domestic animals in close proximity to humans [4]. The concern arose from the side effects arising from urban livestock production like the pollution of soil and groundwater resulting from animal excreta and animal remains [5,6] if there is no proper management in place. Additionally, if the animals are not kept on an intensive system, there may be issues of animal waste littering which may be unsightly as well as pose health hazards since livestock are known reservoirs of several zoonotic pathogens [7]. Furthermore, the waste from abattoirs, where the animals are slaughtered, pose another risk due to its high biochemical oxygen demand (BOD), nutrients and pathogens content [8,9]. Other animal-products processing industries like dairies and tanneries also have polluting effluents with attendant human and environmental health impacts.

However, due to increasing urbanization, urban livestock production is correspondingly expanding in order to feed municipal populations as well as generate household income [10] as stated earlier. In particular, the increasing demand for eggs, meat and milk is a major driving force for the expansion of urban livestock production [11]. The animals are kept under intensive systems or semi-intensive system [12] giving room for environmental-friendly management system if proper

planning is done. In Nigeria too, the rearing of domestic animals in urban centres is a common practice.

In Kaduna metropolis, households that keep animals do so using intensive, semi-intensive or free range systems. At the abattoirs, the rumen contents of the slaughtered animals are heaped outside the abattoir and later spread on the bank of river Kaduna. This allows the liquid portion to simultaneously infiltrate into the ground and evaporate into the atmosphere. The management of the abattoir wastewater is another issue of concern.

Public water supply in Kaduna metropolis, like in most Nigerian cities, is not steady. This leads residents to resort to the abstraction of groundwater through private boreholes and hand-dug wells to supplement the public water supply. Hence, the quality of the groundwater within the metropolis is very important.

In this study, the aim was to investigate the effects of urban livestock keeping and processing activities on the groundwater quality in Kaduna metropolis through water quality monitoring.

### 2.1. Description of the Study Area

The study was conducted in Kaduna metropolis, Kaduna State, Nigeria. Kaduna metropolis lies between latitudes 10°N and 11°N, and between longitudes 7°E and 8°E, and at an altitude of 645m above sea level [13]. Kaduna is characterized by two distinct seasons in the year: the dry season and the rainy season. The dry season runs from late October to March and is characterized by cold and dry conditions with the 'harmattan' wind that blow from north-east towards the south-west. The rainy season, which runs from April to early October, is characterised by warm and humid conditions with winds blowing from the south-west towards the north-east. The average monthly temperature for the city is between 26°C and 34°C [13].

River Kaduna passes through the middle of the metropolis. On the northern bank of the river, Tudunwada abattoir is located in Kaduna South local government area (LGA) while the Kawo abattoir is located in the Kawo area of Kaduna North LGA. The livestock-keeping households used in the study were randomly selected from Chikun, Kaduna South and Kaduna North LGAs. Figure 1 below presents a map of the study area.

## 2. Materials and Methods

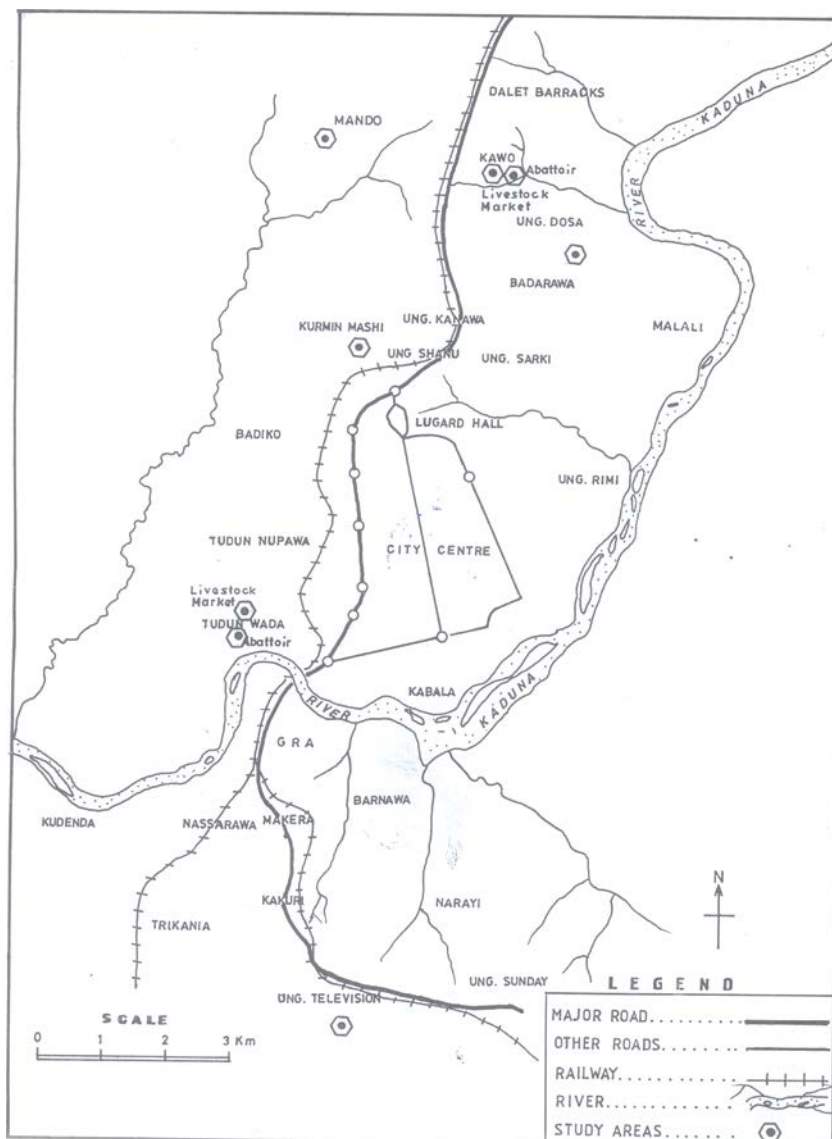


Figure 1. Map of the Study Area

## 2.2. Reconnaissance Survey

A reconnaissance survey of the site was done to get information regarding the kinds of animals kept, the rearing system, existing waste management practices and sources of water. The survey revealed that rumen contents at the Tudunwada and Kawo abattoirs are heaped outside the abattoir and later spread on the bank of river Kaduna or directly discharged into the river. The wastewater emanating from abattoir activities in Tudunwada is conveyed to a natural channel called 'Blood River' that empties into river Kaduna. At Kawo, the abattoir wastewater is conveyed via an unlined channel into a sanitary line.

Similarly, at the livestock-keeping households (LKHs), manure is collected and heaped outside uncovered. A few farmers bag the manure and keep it under the shade for sale to crop farmers who use it for soil amendment. Unsold manure at livestock markets is disposed of at waste disposal sites used by the Kaduna State Sanitation Authority. The location of these LKHs, type of animal kept and method of animal waste management are shown in Appendix 1.

## 2.3. Sampling Points

Water samples were collected from existing wells as follows: two (2) wells at Tudunwada abattoir, two (2) wells at Kawo abattoir, and one (1) well from each of the eight (8) LKHs randomly selected from Chikun, Kaduna South and Kaduna North LGAs for the study. In addition, one well each was selected at least 100m away from the Tudunwada and Kawo abattoirs to serve as control. The same thing was done for the LKHs.

## 2.4. Water Sampling

Grab water samples were collected from the selected existing wells as stated above each month, from July to December, using the buckets and ropes in regular use at the wells. The water samples were collected in 1-litre plastic bottles and taken to the laboratory for analyses. The collection of samples was done for a period of six

consecutive months to capture water quality trends in the rainy season months (July to September) and dry season months (October to December). All the samples collected were transported to the laboratory and analysed within 2 hours of collection.

## 2.5. Laboratory Analyses

The following physico-chemical tests were conducted on the collected samples in the laboratory: pH, electrical conductivity (EC), total dissolved solids (TDS), 5-day biochemical oxygen demand (BOD<sub>5</sub>), chemical oxygen demand (COD), nitrate-nitrogen, total phosphorus, calcium, iron, zinc, lead and cadmium.

The pH was analyzed in-situ using Henna pH meter while EC and TDS were analyzed in the laboratory using standard methods. Chemical analyses were conducted in the laboratory according to the *Standard Methods for the Examination of Water and Wastewater* [14]. All the instruments were calibrated and standardized before using them for analyses. The determination of heavy metals was carried out by atomic absorption spectrophotometer techniques (Perkin-Elmer model 3110 equipped with HG500 graphite furnace), in flame or flameless mode, depending on element.

## 3. Results and Discussion

For ease of understanding, the meanings of the abbreviations used in the tables are presented below.

TAW	Tudunwada Abattoir Wells
TACW	Tudunwada Abattoir Control Well
KAW	Kawo Abattoir Wells
KACW	Kawo Abattoir Control Well
LKH	Livestock-keeping Household
NLKH	Non-livestock Keeping Household

### 3.1. pH

The pH values of all the samples tested are presented in [Table 1](#) below.

**Table 1. Variation of pH within the Study Period**

Months	July	August	September	October	November	December
<b>TAW Range</b>	6.09 - 6.60	6.32 - 6.59	6.52 - 7.51	6.74 - 6.95	6.61 - 7.02	6.27 - 7.89
<b>TAW Mean</b>	6.35±0.36	6.46±0.19	7.02±0.7	6.85±0.15	6.82±0.29	7.08±1.15
<b>TACW</b>	6.82	6.9	5.81	6.78	6.9	6.8
<b>KAW Range</b>	6.42 - 6.70	6.17 - 6.48	6.07 - 6.38	6.32 - 6.38	6.52 - 6.90	6.89 - 7.65
<b>KAW Mean</b>	6.56±0.20	6.33±0.22	6.23±0.22	6.35±0.22	6.71±0.27	7.27±0.53
<b>KACW</b>	6.81	6.72	6.67	6.48	6.72	6.75
<b>LKH Range</b>	6.34 - 6.78	6.04 - 7.00	6.39 - 6.92	6.23 - 8.01	6.45 - 7.61	6.81 - 7.27
<b>LKH Mean</b>	6.56±0.25	6.52±0.31	6.66±0.18	7.12±0.73	7.03±0.41	7.04±0.17
<b>NLKH</b>	6.8	6.95	6.85	6.84	6.92	7.27

The pH of a water sample is particularly important if the water is to undergo some form of chemical treatment e.g. coagulation/flocculation, disinfection, etc. The average pH values for samples from the Tudunwada abattoir wells were in excess of the control well from September to December. Most of the pH values fall within the range recommended by both the World Health Organisation (WHO) and Nigerian Standards for Drinking

Water Quality (NSDWQ) which is 6.5 - 8.5 [15,16]. This implies that although there is impact on groundwater in terms of pH, this impact is not of a concern.

### 3.2. Electrical Conductivity

The EC values of all the samples tested are presented in [Table 2](#) below.

**Table 2. Variation of Electrical Conductivity ( $\mu\text{S}/\text{cm}$ )**

Months	July	August	September	October	November	December
<b>TAW Range</b>	1100 - 3900	1100 - 3900	1600 - 1760	1300 - 1680	2200 - 2600	1235 - 1320
<b>TAW Mean</b>	2500 $\pm$ 1800	2500 $\pm$ 1980	1680 $\pm$ 113	1490 $\pm$ 268	2400 $\pm$ 283	1278 $\pm$ 60
<b>TACW</b>	120	180	510	310	120	125
<b>KAW Range</b>	510 - 900	480 - 3700	790 - 1500	620 - 970	212 - 635	190 - 210
<b>KAW Mean</b>	705 $\pm$ 276	2090 $\pm$ 2277	1145 $\pm$ 502	795 $\pm$ 247	424 $\pm$ 299	200 $\pm$ 14
<b>KACW</b>	300	420	420	340	135	125
<b>LKH Range</b>	115 - 850	120 - 1000	470 - 1670	125 - 990	117 - 1640	106 - 960
<b>LKH Mean</b>	495 $\pm$ 201	479 $\pm$ 338	960 $\pm$ 393	594 $\pm$ 317	563 $\pm$ 495	434 $\pm$ 301
<b>NLKH</b>	209	150	371	201	312	213

EC values for all samples were above their corresponding control values throughout the study period. Most of the values for the two abattoirs were in excess of the maximum value recommended for drinking water by NSDWQ - 1300  $\mu\text{S}/\text{cm}$  [16]. For the livestock keeping households, all the average values were within the limits throughout the study period. This clearly indicates that livestock keeping and processing has affected the

groundwater quality in terms of EC. For the LKHs, although there is impact on the groundwater quality, all the values are within established safe limits.

### 3.3. Total Dissolved Solids

TDS values of all the samples tested are presented in Table 3.

**Table 3. Variation of Total Dissolved Solids ( $\text{mg}/\text{L}$ )**

Months	July	August	September	October	November	December
<b>TAW Range</b>	300 - 720	400 - 650	401 - 1600	471 - 1030	150 - 180	140 - 175
<b>TAW Mean</b>	510 $\pm$ 297	525 $\pm$ 177	1001 $\pm$ 848	750 $\pm$ 396	165 $\pm$ 21	158 $\pm$ 25
<b>TACW</b>	120	250	142	35	50	126
<b>KAW Range</b>	200 - 753	100 - 200	602 - 700	690 - 754	147 - 165	145 - 168
<b>KAW Mean</b>	477 $\pm$ 391	150 $\pm$ 71	651 $\pm$ 69	722 $\pm$ 45	156 $\pm$ 13	157 $\pm$ 16
<b>KACW</b>	210	140	450	546	139	86
<b>LKH Range</b>	80 - 148	90 - 160	87 - 160	85 - 280	35 - 350	31 - 202
<b>LKH Mean</b>	107 $\pm$ 8	119 $\pm$ 27	117 $\pm$ 25	152 $\pm$ 60	134 $\pm$ 118	98 $\pm$ 72
<b>NLKH</b>	105	110	126	121	57	36

The NSDWQ maximum permitted value for TDS in drinking water is 500  $\text{mg}/\text{L}$  [16]. WHO on the other hand, states that drinking water becomes greatly and progressively unpalatable at TDS concentrations above 1000  $\text{mg}/\text{L}$  [15]. The abattoir wells had TDS values above the NSDWQ limit of 500  $\text{mg}/\text{L}$  from July to October. This corresponds to the rainy season when the animal waste would have been dissolved by the water that infiltrated and percolated into the soil. The LKHs had TDS below the limits throughout the study period. However, the TDS

values obtained for the abattoir wells and LKHs were all above their corresponding controls, indicating an impact of livestock keeping and processing on groundwater quality.

### 3.4. Biochemical Oxygen Demand

The results obtained for BOD<sub>5</sub> ( $\text{mg}/\text{L}$ ) are presented in Table 4 below.

**Table 4. Variation of 5-day Biochemical Oxygen Demand ( $\text{mg}/\text{L}$ )**

Months	July	August	September	October	November	December
<b>TAW Range</b>	60 - 80	80 - 150	100 - 180	70 - 70	20 - 190	20 - 60
<b>TAW Mean</b>	70 $\pm$ 14	115 $\pm$ 49	140 $\pm$ 57	70 $\pm$ 0	105 $\pm$ 120	40 $\pm$ 28
<b>TACW</b>	50	50	50	20	7	20
<b>KAW Range</b>	80 - 90	80 - 170	30 - 60	60 - 60	40 - 50	30 - 50
<b>KAW Mean</b>	85 $\pm$ 7	125 $\pm$ 64	45 $\pm$ 21	60 $\pm$ 0	45 $\pm$ 7	40 $\pm$ 14
<b>KACW</b>	20	90	38	30	60	20
<b>LKH Range</b>	8-16	7 - 170	5-13	4-19	20 - 60	10-30
<b>LKH Mean</b>	11 $\pm$ 4	39 $\pm$ 54	10 $\pm$ 3	8 $\pm$ 5	30 $\pm$ 16	25 $\pm$ 8
<b>NLKH</b>	5	6	7	3	4	20

Most of the BOD<sub>5</sub> values are above 20  $\text{mg}/\text{L}$ , the discharge consent for treated wastewater [17]. However, this value is too high for drinking water. All the values

obtained for the abattoir wells and LKHs were all above their corresponding controls, indicating an impact on groundwater quality, though very small.

### 3.5. Chemical Oxygen Demand

Table 5 below presents the results obtained for COD (mg/L) throughout the study period.

Table 5. Variation of Chemical Oxygen Demand (mg/L)

Months	July	August	September	October	November	December
TAW Range	304 - 336	184 - 240	350 - 380	370 - 490	310 - 420	160 - 170
TAW Mean	320±23	212±40	365±21	430±85	365±78	165±7
TACW	201	160	95	262	250	68
KAW Range	264 - 312	280 - 320	180 - 210	180 - 360	169 - 200	121 - 125
KAW Mean	288±34	300±28	195±21	270±127	185±22	123±3
KACW	156	160	170	270	68	47
LKH Range	152 - 213	161 - 270	150 - 270	141 - 214	62 - 188	31 - 131
LKH Mean	167±27	214±46	206±42	187±22	124±44	71±33
NLKH	96	102	106	97	66	41

The COD values are higher in magnitude than their corresponding BOD<sub>5</sub> counterpart in section 3.4 above. This is because COD is a measure of wastes which are both biodegradable and non biodegradable, hence covering a broader spectrum [18]. COD showed a similar pattern of variation as BOD<sub>5</sub>. As with BOD<sub>5</sub>, all the values

obtained for the abattoir wells and LKHs were all above their corresponding controls.

### 3.6. Nitrate - nitrogen

The results obtained for nitrate - nitrogen in mg/L are presented in Table 6 below.

Table 6. Nitrate-nitrogen Variation (mg/L)

Months	July	August	September	October	November	December
TAW Range	40 - 51	54 - 72	64 - 85	53 - 53	77 - 80	54 - 56
TAW Mean	46±8	63±13	75±15	53±0	79±2	55±1
TACW	15	13	26	16	12	12
KAW Range	36 - 40	42 - 50	52 - 69	43 - 44	29 - 31	37 - 41
KAW Mean	38±3	46±6	61±12	44±1	30±1	39±3
KACW	30	26	20	18	11	11
LKH Range	15 - 38	13 - 46	13 - 52	14 - 42	10-26	10-89
LKH Mean	20±7	24±11	30±13	28±9	16±6	35±24
NLKH	12	12	12	15	12	12

In order to protect bottle-fed infants against methaemoglobinaemia (blue-baby syndrome), WHO recommends 50 mg/L limit as nitrate ion or 11 mg/L as nitrate-nitrogen [15]. The NSDWQ on the other hand, stipulates a maximum permitted nitrate concentration of 50 mg/L in drinking water [16]. The nitrate-N levels in the abattoir wells and LKHs samples were all above their corresponding controls, indicating that livestock rearing and processing has effects on the groundwater quality. The high levels of nitrate - nitrogen are attributable to the interaction between livestock wastes in the vicinity of the

wells and well water occasioned by unhygienic anthropogenic activities at the sites. In addition, the nitrate-N in the faeces and urine of animals around the sites moves with the infiltrating water through the soil into wells [19].

### 3.7. Total Phosphorus

Table 7 below presents the results obtained for total phosphorus (mg/L) throughout the study period.

Table 7. Variation of Total Phosphorus (mg/L)

Months	July	August	September	October	November	December
TAW Range	1.0 - 1.1	0.9 - 1.4	4.6 - 5.8	4.8 - 13.2	5.0 - 22.9	1.3 - 1.5
TAW Mean	1.1±0.1	1.2±0.4	5.2±0.8	9.0±5.9	14.0±12.7	1.4±0.1
TACW	0	0	5.4	7.0	4.4	1.1
KAW Range	1.0 - 1.1	1.0 - 1.0	5.0 - 5.8	5.1 - 9.2	4.2 - 4.6	1.0 - 1.2
KAW Mean	1.1±0.1	1.0±0	5.4±0.6	7.2±2.9	4.4±0.3	1.1±0.1
KACW	1.0	1.0	4.2	4.0	1.0	0.9
LKH Range	0.4 - 4.8	0.9 - 5.1	1.0 - 9.2	1.0 - 8.1	0.0 - 8.2	0.0 - 4.9
LKH Mean	2.4±1.0	1.6±1.5	4.7±2.7	3.5±2.4	2.9±2.7	1.9±1.8
NLKH	1.0	0	1.0	0.9	0.5	1.0

Phosphorus is very essential for animals. It is required for normal soft and skeletal tissue (e.g. bones and teeth) development [20]. Hence animal waste and other organic wastes have relatively high levels of phosphorus [21,22,23]. A significant portion of the total phosphorus in soil solution is present as dissolved organic phosphorus [24]. The dissolved organic phosphorus infiltrates and percolates with soil water. One of the undesirable effects of phosphorus' presence in water is depletion of dissolved oxygen. In surface waters, other negative effects may include: eutrophication and death of aquatic animals. Total

phosphorus levels were very low for all the samples. These concentrations were however, equal or above their corresponding controls, pointing to the contribution of animal wastes to the relatively higher levels of in abattoir and LKH samples.

### 3.8. Calcium

The results obtained for calcium in mg/L are presented in Table 8 below.

Table 8. Variation of Calcium (mg/L)

Months	July	August	September	October	November	December
TAW Range	14 - 30	18 - 32	17 - 44	20 - 65	30 - 51	40 - 54
TAW Mean	22±11	25±10	31±19	43±32	41±15	47±10
TACW	20	20	25	50	30	20
KAW Range	17 - 36	25 - 82	16 - 16	48 - 51	63 - 82	15 - 18
KAW Mean	27±13	54±40	16±0	50±2	73±13	17±2
KACW	30	35	30	46	46	29
LKH Range	2 - 9	3 - 8	5 - 10	7 - 16	5 - 17	2 - 13
LKH Mean	3.8±2	4.6±1.6	6.7±1.7	11.5±3.2	10.1±3.8	5.8±3.6
NLKH	2.5	3.8	5.1	8.5	9.0	4.9

The presence of calcium in water is not known to cause physiological effects to humans [25], hence both NSDWQ and WHO have no limit for it in drinking water. However, calcium and magnesium are responsible for water hardness which leads to more soap consumption during laundry. Calcium showed no definite pattern of variation. Some control values were more than the tested samples.

This shows that livestock activities around the sites had no direct influence on the calcium concentration.

### 3.9. Iron

The results obtained for iron in mg/L are presented in Table 9 below.

Table 9. Variation of Calcium (mg/L)

Months	July	August	September	October	November	December
TAW Range	0 - 28.9	0 - 14.5	0.1 - 0.3	0	0.1 - 0.7	0.2 - 0.3
TAW Mean	14.5±20	7.3±10	0.2±0.1	0	0.4±0.4	0.3±0.1
TACW	0	0	0.1	0	0	0
KAW Range	0 - 7.2	6.8 - 7.2	0.1 - 0.1	0- 0.3	0 - 0.1	0
KAW Mean	3.6±5.1	7.0±0.3	0.1±0	0.2±0.2	0.1±0.1	0
KACW	1.0	0	0	0	0	0
LKH Range	0	0	0.1 - 0.3	0	0	0
LKH Mean	0	0	0.2±0.1	0	0	0
NLKH	0	0	0.2	0	0	0

Iron is an essential macro nutrient for the normal functioning of all living organisms, hence animal wastes would contain iron. Though iron is beneficial in human diet at low concentrations [26], elevated concentrations produce objectionable reddish-brown colour in the water due to the oxidation of ferrous iron to ferric iron. The concentrations of iron in the samples were generally low with a few exceptions in the months of July and August for the two abattoir sites. The reason for this high values in those months could be as a result of pieces of iron that may have come in contact with the water since the wells had no cover, or dust and other extraneous materials may have found their way into the wells. Generally, the concentration of iron in natural fresh waters ranges from 0.5 to 50 mg/L [15]. NSDWQ recommended limit in drinking water is 0.3 mg/L [16]. This is because iron concentrations above 0.3 mg/L cause staining of laundry

and plumbing fixtures [15]. Most samples met this standard during the study period.

### 3.10. Zinc

The results obtained for zinc in mg/L are presented in Table 10 below.

Zinc is an essential trace element found in almost all food; hence its source is diet. Drinking-water become unacceptable to customers at zinc concentrations above 3 mg/L [15]. Based on this, NSDWQ set a maximum threshold of 3 mg/L in drinking water [16]. None of the samples exceeded this value during the period of the study. However, all the samples were above their respective controls indicating an impact of livestock activities on groundwater quality. This impact, however, is of no concern.

Table 10. Zinc Variation (mg/L)

Months	July	August	September	October	November	December
TAW Range	0.16 - 0.23	0.16 - 0.36	0.36 - 0.43	0.36 - 0.51	0.14 - 0.25	0
TAW Mean	0.20±0.05	0.26±0.14	0.40±0.05	0.44±0.11	0.20±0.08	0
TACW	0.12	0.07	0.07	0.08	0.02	0
KAW Range	0.31 - 0.63	0.39 - 0.47	0.18 - 0.29	0.18 - 0.67	0.12 - 0.26	0
KAW Mean	0.47±0.23	0.43±0.06	0.24±0.08	0.43±0.35	0.19±0.10	0
KACW	0.06	0.63	0.62	0.4	0.04	0.21
LKH Range	0	0 - 0.50	0 - 0.61	0 - 0.39	0 - 0.27	0 - 0.21
LKH Mean	0	0.22±0.21	0.32±0.23	0.21±0.14	0.15±0.10	0.03±0.07
NLKH	0	0	0	0	0	0

### 3.11. Lead

Lead was not detected in any of the samples throughout the study period.

### 3.12. Cadmium

The results obtained for cadmium in mg/L are presented in Table 11 below.

Table 11. Variation of Cadmium (mg/L)

Months	July	August	September	October	November	December
TAW Range	0	0	0.06 - 0.09	0.03 - 0.06	0.06 - 0.06	0.05 - 0.05
TAW Mean	0	0	0.08±0.02	0.05±0.02	0.06±0	0.05±0
TACW	0	0	0	0	0	0.05
KAW Range	0	0	0.03 - 0.09	0.03 - 0.06	0.03 - 0.06	0.01 - 0.05
KAW Mean	0	0	0.06±0.04	0.05±0.02	0.05±0.02	0.03±0.03
KACW	0	0	0.03	0	0	0
LKH Range	0	0	0 - 0.03	0 - 0.03	0 - 0.03	0 - 0.90
LKH Mean	0	0	0.01±0.01	0.01±0.01	0±0.01	0.11±0.32
NLKH	0	0	0.03	0	0	0

Cadmium is a major health concern because it is known to cause lung, prostate and renal cancers [27]. Another big concern is cadmium's long half-life and persistence in the environment and in tissues [28]. In view of this, the guideline value of 0.003 mg/L has been set in both NSDWQ and WHO guidelines for drinking-water [15,16]. Cadmium was not detected in any of the samples in July and August but appeared in most sites from September to December. When it appeared, the detected levels were all above the NSDWQ and WHO maximum allowable concentration in drinking water. In the control samples, it was detected only in December at the Tudunwada abattoir, in September at Kawo abattoir and LKHs. However, the concentrations of cadmium in all the controls, when it appeared, were above the threshold. Also, the concentrations of the heavy metal in all the samples from September to October were above their corresponding controls. This indicates an impact of livestock wastes on groundwater; although the fact that the concentration of cadmium in the control samples were also above the threshold indicates that the presence of cadmium in groundwater may have also been contributed by natural sources.

## 4. Conclusion

Urban livestock production, in addition to providing meat and animal-related products, serves as additional income for low income earners, traders and retirees. It

however, poses some environmental pollution threats. This research assessed the impact of livestock keeping and processing activities on groundwater quality in Kaduna metropolis through water quality monitoring from July to December.

Findings indicate that urban livestock production has negatively impacted groundwater in terms of pH, EC, TDS, and zinc but this impact is not a concern as most of the values are within NSDWQ and WHO guideline values. In terms of BOD<sub>5</sub>, COD, nitrate-N, total phosphorus and cadmium, the levels detected show negative impact on groundwater of great concern. Cadmium's presence (concentrations well above NSDWQ and WHO limits) is also attributable to natural sources. However, urban livestock production showed no effect on groundwater in terms of calcium, iron and lead.

This research has shown that groundwater pollution caused by livestock wastes emanates from point sources: abattoirs and livestock-keeping households. This implies control measures can be easily applied at the source. The water quality data and pollution source information obtained from this research will be useful in identifying water quality problem areas and planning of engineering interventions.

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## Statement of Competing Interests

The authors have no competing interests.

## List of Abbreviations

BOD	Biochemical Oxygen Demand
BOD <sub>5</sub>	5-day Biochemical Oxygen Demand
COD	Chemical Oxygen Demand
DO	Dissolved Oxygen
EC	Electrical Conductivity
KACW	Kawo Abattoir Control Well
KAW	Kawo Abattoir Wells
LGA	Local Government Area
LKH	Livestock Keeping Household
NLKH	Non-livestock Keeping Household
NSDWQ	Nigerian Standards for Drinking Water Quality
TACW	Tudunwada Abattoir Control Well
TAW	Tudunwada Abattoir Wells
TDS	Total Dissolved Solids
TSS	Total Suspended Solids
WHO	World Health Organisation

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**Appendix 1: Location of livestock keeping households, types animal reared, and existing method of animal waste management**

Designation	Location	Use of the Well	Types of animals kept	Type of husbandry	Waste Management System
LKH1	Chiroma street in Chikun LGA	basic source of water for both human and animal consumption	Goats, pigs and poultry	Kept in separate confined housing systems	Animal manure is collected and kept in bags for sale to arable crop farmers. Unsold manure is disposed of at a nearby waste dump site.
LKH2	Iyaka street, Angwan mai Chibi , Television, Chikun LGA	Supplementary source of water for both human and animal consumption	Goats, sheep and poultry	Goats and sheep in a confined system; local chickens on a free-range system	Animal excreta (dung) are swept regularly together with feed remnants and dumped at a nearby waste disposal heap.
LKH3	Kaduna polytechnic Quarters along Kachia Road, Kaduna South LGA	Supplementary source of water for animal feeding only	Goats and poultry	Goats on a semi - intensive basis while poultry on intensive basis	Goats excreta is collected in solid form on an irregular bases and disposed of at a nearby dump site; poultry manure is collected together with litter on a batch by batch basis.
LKH4	Kaduna polytechnic Quarters along Kachia Road, Kaduna South LGA	Supplementary source of water for animal feeding only	Goats and poultry	intensive housing system	Animal wastes are collected in solid form, tied in bags and sold at low prices to arable crop farmers. Unsold manure is disposed of by dumping at the waste dump site along Kachia Road express way.
LKH5	Kaduna polytechnic Quarters along Kachia Road, Kaduna South LGA	Supplementary source of water for animal feeding only	Poultry only	intensive housing system	Birds excreta are swept regularly together with feed remnants and tied in bags and sold at low prices to arable crop farmers. Unsold manure is disposed of by dumping at the waste dump site along Kachia Road express way.
LKH6	Mando Road, Kaduna North LGA	Supplementary source of water for animal feeding only	Goats and sheep	open lot system	Animal dung are swept and kept in heaps and sold at low prices to arable crop farmers. The unsold manure remains heaped until a buyer is found for it.
LKH7	1 km from LKH6 along Mando Road, Kaduna North LGA	basic source of water for both human and animal consumption	Goats	semi intensive housing system	The pen is cleaned irregularly to collect animal manure in solid form. The manure is disposed of at a waste dumpsite nearby that is used by the community.
LKH8	Behind Kawo Abattoir	Supplementary source of water for animal feeding only	poultry	intensive basis	Poultry waste is disposed of together with the litter through the Kaduna state environmental sanitation agencies' disposal trucks, after each batch of broilers.