Assessment of the Impact of Abattoir Effluent on the Water Quality of River Kaduna, Nigeria

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Abstract The discharge of untreated high-strength wastewater into water bodies results in water quality deterioration of the receiving waters. The aim of this study was to assess the impact of abattoir wastewater discharge on the water quality of river Kaduna, Nigeria. Water samples were collected from river Kaduna at three points: 100m upstream of the abattoir discharge point, at the discharge point, and 100m downstream of the discharge point for a 6-month period (July- September in the rainy season and October-December in the dry season). Physico-chemical analyses were conducted on the collected samples in the laboratory using standard methods. The pH was within a fixed band of 6-8. The downstream 5-day biochemical oxygen demand of the receiving river water increased significantly to 75% in July and up to 192% in December. Suspended solids, chemical oxygen demand, ammonia-nitrogen, total nitrogen and total phosphorus followed a similar trend. Dissolved solids, dissolved oxygen, nitrate-N, iron, zinc and cadmium also increased appreciably. The downstream levels of these parameters were higher than their corresponding upstream values, indicating that the discharge of the abattoir wastewater into the river has negatively impacted the river water. The dilution of the waste in the river water was not enough to reduce them to acceptable levels. This research demonstrates that abattoir wastewater impacts the river water negatively. The findings can be useful in identifying water quality problem areas and planning of engineering interventions as well as basis for legislation.

Keywords: abattoir wastewater, impact, river Kaduna, pollution, water quality

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1. Introduction

The discharge of untreated wastewater into surface water bodies such as streams, rivers, lakes and oceans results in the pollution of such water environments. This pollution of surface water bodies, resulting from anthropogenic activities, is a growing concern worldwide [1,2]. The elevated levels of nutrients (nitrogen and phosphorus) in surface water due to pollution accelerate the growth of oxygen-depleting microbes, destroy the aquatic ecosystems and result in eutrophication [3]. Eutrophication causes many adverse effects on the water body including increased biomass of phytoplankton and macrophyte vegetation, increased blooms of gelatinous zooplankton (marine environment), growth of benthic and epiphytic algae, increased toxins from bloom-forming algal species, loss of commercial and sport fisheries, reduced carbon available to food webs, increased taste and odour problems, reduced species diversity, increased treatment costs prior to human use, and decreased aesthetic value of the water body [4,5].

In Nigeria, many streams and rivers get polluted as a result of the discharge of untreated wastewater and other organic wastes directly into them [6,7,8]. Thus, river pollution is becoming a central issue in water management in Nigeria [9]. One of the major sources of river pollution is livestock production activities [10] especially in terms of nutrient pollution [11]. Animal faeces and urine can be a source of pollution if not properly managed. If the animals are not housed, there may also be issues of erosion and sediment transport into surface waters due to their grazing activities. The runoff of animal wastes into surface water poses a great risk of pollution [12]. The waste from abattoirs, where the animals are slaughtered, pose another risk due to its high biochemical oxygen demand (BOD), nutrients and pathogens content [13,14].

The location of abattoirs in Nigeria tend to be near water bodies for easy access to guaranteed water for processing activities [15]. The wastewater generated from the various abattoir activities - abattoir wastewater - typically comprises water generated from cleaning operations, animal blood, dissolved solids, oil and grease, gut contents, and urine [16,17]. The contamination of surface water from abattoir wastewater constitute significant environmental and health hazards [18] due the elevated levels of biodegradable organic matter, sufficient alkalinity, and adequate phosphorous, nitrogen and micronutrient concentrations [17].

In Kaduna metropolis, the abattoir wastewater at Tudun Wada Abattoir is conveyed via a natural channel called
blood river’ to discharge directly into River Kaduna without any form of treatment. While some organic waste can be diluted in the river to very low concentration and subsequently self-cleansed by natural biological processes in the river, high strength wastes like abattoir wastewater may take a longer time to degrade. Some waste may not biodegrade at all depending on the chemical oxygen demand (COD) to BOD ratio [19].

Thus, the aim of this research was to estimate the extent of surface water pollution arising from the runoff and direct disposal of the abattoir wastewater into river Kaduna through water quality monitoring.

2. Materials and Methods

2.1. Description of Study Area

The study was conducted on river Kaduna around Tudun Wada abattoir area of Kaduna metropolis, Kaduna State, Nigeria. Tudun Wada lies between latitudes 10° 28’ 14”N and 10° 30’ 45” N; and between longitudes 7° 24’ 40”E and 7° 26’ 50”E. Figure 1 below presents a map of the study area.

![Map of the study area](image)

2.2. Water Sampling

Grab water samples were collected from river Kaduna at three points: 100m upstream of the abattoir discharge point on river Kaduna (TAUS), at the discharge point (TADP), and 100m downstream of the discharge point (TADS). The water samples were collected in 1-litre plastic bottles held in the middle and immersed about 10-20cm in water against flow [20]. The collected samples were 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 of July to September, and dry season months of October to December. All the samples collected were transported to the laboratory and analyzed within 2 hours of collection.

2.3. Laboratory Analyses

Physico-chemical tests were conducted on the collected samples in the laboratory. The following physical parameters were measured: pH, temperature, conductivity, total suspended solids (TSS) and total dissolved solids (TDS). Chemical parameters measured include: dissolved oxygen (DO), 5-day biochemical oxygen demand (BOD5), COD, nitrate-nitrogen, ammonia-nitrogen, total nitrogen, and total phosphorus. BOD and COD are known to be indicators of organic pollution in water [21]. The water samples were also tested for the following heavy metals: iron, zinc, lead and cadmium.

2.4. Methods of Analyses

The pH and temperature were analyzed in situ using Henna pH/temperature meter while conductivity, TSS 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 [20]. 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 Discussions

3.1. Physical Parameters

This section presents results of the physical parameters tested on the water samples. The results are accompanied by discussion. In the results figures, TADP stands for water samples collected from the Tudun Wada abattoir discharged point on river Kaduna, TAUS stands for water samples collected from river Kaduna 100m upstream of the abattoir discharge point, and TADS stands for water samples collected from river Kaduna 100m downstream of the abattoir discharge point.

3.1.1. Temperature and pH

The temperature and pH variation during the study period are presented in Figure 2 and Figure 3 below.

The temperature decreased evenly towards the harmattan months of October, November and December. This is expected as the weather is usually cooler due to the dry cold North-easterly wind and dust clouds that screen most of the radiation. As with pH, there is no pattern of temperature variation between the three sample collection points.

From Figure 3, the pH values fluctuated from month to month within a fixed band of 6 - 8. There is no pattern of pH variation between the three sample collection points. Peak values were experienced in November and December. This could be as a result of the increase in algae populations (which made the water greenish in color) by their photosynthetic activity which could have increased the number of hydroxyl ions [22]. Most pH values are within the world health organization (WHO) recommended range of pH values (6.5 - 8.5) for even drinking water [23].

3.1.2. Conductivity

The variation in conductivity of the collected samples is presented in Figure 4 below.

Conductivity varied irregularly within the study period. This was expected as conductivity is related to the total dissolved solids in the water.

3.1.3. Solids

Figure 5 and Figure 6 below present the total suspended solids (TSS) and total dissolved solids (TDS) respectively. Figure 5 shows a continuous increase of TSS month after month within the study periods. This is attributable to increased runoff inflow from the catchment area from
the month of July to August, and reduced dilution of the river water from October to December when there is no more rainfall.

Figure 6 indicates high TDS values in the rainy months of August, September and early October with August and September recording the highest values. This agrees with earlier findings reported [24] and can be attributed to the increased inflow of surface runoff volume during those months. TDS values obtained were generally below the 1000 mg/L upper limit set by WHO above which water becomes significantly and increasingly unpalatable [23].

From Figure 7, there is a peak experienced for the last three months of the study period. This could be as a result of the absence of the runoff component of organic matter from the catchments, lower temperatures as a result of harmattan fog as well as wind-induced mixing due to increased wind speed within the period. The sag in the dissolved oxygen in September is attributable to the fact that samples collection was carried out under rain, samples may have included bottom sediments as a result of the turbulence caused by runoff inflow and rain drops impacts.

3.2.2. Biochemical Oxygen Demand

The variation in the BOD$_5$ of the samples is presented in Figure 8 below. The BOD$_5$ values were higher from October to December except for the sample at the abattoir discharge point (TADP). This may be as a result of the decreased volume of water in the stream and river which no longer enjoyed the dilution from direct precipitation and runoff but was still subject to a considerable volume of wastes from the abattoir (TADP) and upstream textile industry discharges (TAUS). This pattern of variation was also obtained by Irekpita [24] on the profiling of pollution on river Kubani.

3.2.3. Chemical Oxygen Demand

The COD values obtained from the tests are presented in Figure 9 below.

From Figure 7, there is a peak experienced for the last three months of the study period. This could be as a result of the absence of the runoff component of organic matter from the catchments, lower temperatures as a result of harmattan fog as well as wind-induced mixing due to increased wind speed within the period. The sag in the dissolved oxygen in September is attributable to the fact that samples collection was carried out under rain, samples may have included bottom sediments as a result of the turbulence caused by runoff inflow and rain drops impacts.

3.2. Chemical parameters

3.2.1. Dissolved Oxygen

The results for dissolved oxygen levels within the study period are presented in Figure 7 below.

From Figure 7, there is a peak experienced for the last three months of the study period. This could be as a result of the absence of the runoff component of organic matter from the catchments, lower temperatures as a result of harmattan fog as well as wind-induced mixing due to increased wind speed within the period. The sag in the dissolved oxygen in September is attributable to the fact that samples collection was carried out under rain, samples may have included bottom sediments as a result of the turbulence caused by runoff inflow and rain drops impacts.

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3.2.3. Chemical Oxygen Demand

The COD values obtained from the tests are presented in Figure 9 below.
The COD values are higher in magnitude than their corresponding BOD5 counterpart because they measure wastes which are both biodegradable and non-biodegradable, hence covering a broader spectrum [25]. COD showed a similar pattern of variation as BOD5. The reasons for such variation are the same with those advanced for BOD5.

3.2.4. Nitrate-nitrogen

Figure 10 below presents the variation of nitrate-N during the study period. The nitrate-N concentrations for samples collected at the discharge point (TADP) peaked in September, lowered sharply in October and November and then began to increase again in December.

The peak in September could be due to two reasons: samples were collected under heavy rain when the sites were troubled and could have included bottom sediments, and the surface runoff inflow to the sites brought with it organic matter-laden wastewater from the catchments which may have increased the nitrate-N concentration at the sites. The propensity for this movement is higher when the moisture holding capacity of the soil is greatly exceeded, and this could have been the case in this area in August and September. Nitrate-N concentrations at all the sites in the study period were well over the 11mg/L WHO recommended limits for drinking water [23]. Nitrate has been linked with methemoglobinemia or ‘blue baby syndrome’ at concentrations above 50 mg/L [26] and stomach cancer in humans. Other effects include nitrate poisoning in animals and great increase of phytoplankton in a water body due to increased nutrient levels (eutrophication) which damages the ecosystem in the water body [27]. Eutrophication also increases water treatment costs. In addition, the degradation of nutrients may deplete the oxygen in the water. Moreover, the denitrification process in water produces nitrous oxide (N₂O) which is a greenhouse gas [28].

3.2.5. Ammonia-nitrogen

Figure 11 below presents the variation of ammonia-nitrogen during the study period. Ammonia-N concentration showed no regular pattern except that TADP and TADS experienced peaks in November. The concentration of ammonia-N at the upstream sample point (TAUS) was less than the other values throughout the study period. This indicates that the increased ammonia-N in the water is due to the abattoir wastewater discharged into the river. The elevated levels of ammonia-N in September and November are an indication of recent organic pollution. The WHO thresholds for odour and taste concentrations for ammonia are 1.5 mg/L (in alkaline pH), and 35 mg/L respectively. During water treatment, the presence of ammonia-N is an issue as it reacts with chlorine to reduce free chlorine and to form chloramines which are less effective disinfectants. In water bodies, ammonia is also known to be toxic to fish [29].

3.2.6. Total Nitrogen

Figure 12 below presents the variation of total nitrogen during the study period.

Total nitrogen exhibited an increasing concentration from month to month up to October then TAUS and TADP dropped in November. This could be attributed to runoff inflow from the catchment area during the rainy season and the receding volume of water in the drier months which still received a considerable amount of nitrogen compounds from the abattoir wastewater. This indicates that the livestock activities (production, marketing and processing) have negatively impacted the water sources in the area. This can lead to eutrophication in the river.

3.2.7. Total Phosphorus

Figure 13 below presents the variation of total phosphorus during the study period.

The concentration of total phosphorus increased progressively throughout the period of the study for all the samples. The increment in phosphorus concentration from October to December is attributable to less dilution in the river due the cessation of rainfall. The concentrations of
phosphorus in the downstream samples were higher than the upstream samples indicating that the discharge has an impact on the river water. Phosphorus is one of the nutrients that cause eutrophication in water bodies.

This indicates that livestock activities around the sites had no influence on the surface water due to zinc.

3.2.8. Iron

The variation of the concentration of iron is presented in Figure 14 below.

Iron exhibited a decreasing trend from September to December. This is attributable to the combined contribution of iron compounds from municipal runoff in the rainy season. The presence of iron may be due to the littering of livestock wastes around the study area. The iron may have come from animal waste since iron is an essential macro nutrient for the normal functioning of all living organisms. Though iron is beneficial in human diet at low concentrations [30], elevated concentrations produce objectionable reddish-brown colour in the water due to the oxidation of ferrous iron to ferric iron. The presence of iron at concentration above 0.3 mg/L causes staining of laundry and plumbing fixtures [23]. The levels of iron present in the river water were well above 20 mg/L and the downstream concentrations were higher than iron levels upstream, indicating an impact of the waste discharge in the water body.

3.2.10. Lead

The concentration of lead in all the samples was 0 mg/L except for TADP in November (40 mg/L) and December (10mg/L). The reasons for the sudden high values in November and December at TADP may be due to the presence of lead in the rumen contents of cows that grazed along the highways. An earlier study found that lead compounds were present in high concentrations in grasses and shrubs that grew along the highways [31].

3.2.11. Cadmium

Cadmium concentrations in the samples are presented in Figure 16 below.

Cadmium was not detected in any sample until September. The appearance of cadmium can be attributed to the reduction in the dilution due to the reduced rainfall. WHO maximum allowable concentration of cadmium in drinking water is 0.003 mg/L [23]. This value was exceeded in all the samples when it started appearing.

4. Conclusions

The effects of abattoir wastewater discharge into river Kaduna on its water quality were assessed through water quality monitoring. Findings from this research indicate that livestock processing and marketing activities at Tudunwada Abattoir have impacted river Kaduna water quality. Concentrations of BOD₅, COD, nitrate-nitrogen, ammonia-nitrogen, total nitrogen and total phosphorus were in excess of normal levels for river water. The
downstream levels of these parameters were higher than their corresponding upstream values, indicating that the discharge of the abattoir wastewater into the river has negatively impacted the river water. The dilution of the high-strength abattoir wastewater in the river water was not enough to reduce them to acceptable levels. Although high-strength abattoir wastewater in the river water negatively impacted the river water. The dilution of the all members of staff of the Public Health Engineering Laboratory, Department of Water Resources and Environmental Engineering, Ahmadu Bello University, Zaria for their immense contributions to the success of this study.

This water quality data and pollution source information will be useful in identifying water quality problem areas and planning of engineering interventions. The findings can also be used as basis for legislation.

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Statement of Competing Interests

The authors have no competing interests.

List of Abbreviations

| Abbreviation | Description |
|--------------|-------------|
| BOD          | biochemical oxygen demand |
| BODs         | 5-day biochemical oxygen demand |
| COD          | chemical oxygen demand |
| DO           | dissolved oxygen |
| TADP         | Tudun Wada Abattoir discharged point |
| TADS         | Tudun Wada Abattoir downstream |
| TAUS         | Tudun Wada Abattoir upstream |
| TDS          | total dissolved solids |
| TSS          | total suspended solids |
| WHO          | World Health Organization |

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