IJABR Vol. 14(1): 97 - 110 (2023)

Original article

BIODEGRADATION POTENTIAL OF SOME BACTERIA ISOLATED FROM ABATTOIR EFFLUENTS WITHIN KADUNA METROPOLIS

***Kureh, D., Aliyu, A. M., Maiangwa, J., Idris, S., and Philemon, D.**

Department of Microbiology, Faculty of Life Sciences, Kaduna State University PMB 2339, Kaduna, Nigeria.

Submitted: January, 2023; Accepted: June, 2023; Published: June, 2023

ABSTRACT

An abattoir is a place meant for the killing of animals and processing of meat for human use and consumption. Bioremediation potentials of some bacteria isolated from abattoir wastewater located within Kaduna metropolis, Nigeria were determined. The wastewater was collected and serially diluted, plated on nutrient agar for bacterial isolation using the pour plate isolation method. The isolates were identified according to their morphological, cultural and biochemical characteristics. The identified organisms included *Escherichia coli, Bacillus*, *Pseudomonas*, *Klebsiella and Salmonella spp*. The isolates were screened for biodegradation potential using the Mineral Salt Medium (MSM) for five days. Spectrophotometry was used to determine the optical density of the bacterial growth during the biodegradation analysis. *Bacillus* and *Salmonella* species were used separately, in addition to the consortium of *Salmonella*, *Escherichia coli* and *Klebsiella spp* for bioremediation of the wastewater. The physical and chemical parameters of abattoir effluents such as Biochemical Oxygen Demand (BOD), Total Dissolved Solids (TDS), Electrical Conductivity (EC), temperature, pH, Nitrate and Phosphate concentrations were used in accessing the extend of the effluent's degradation using standard laboratory procedures. *Bacillus spp* reduced TDS of the wastewater from 1996.0 mg/l to 430.7 mg/l, EC 2.56 mg/l to 0.671 mg/l, Nitrate 64.5 mg/l to 47.3 mg/l, BOD 947.7 mg/l to 514 mg/l. The consortium of the bacteria reduced TDS 446.3 mg/l to 430.7 mg/l, EC 0.678 mg/l to 0.671 mg/l, Nitrate 44.9 mg/l to 39.9 mg/l, BOD 858.7 mg/l to 473.6 mg/l, Bacillus reduced the pH 7.87 to7. 20, while the consortium reduced the pH 6.77 to 6.16 after 21 days of inoculation and treatment. The results revealed a significant difference ($p < 0.05$) among the parameters during the period of biodegradation. The results indicated that *Bacillus* and the consortium of bacteria are promising microorganisms for industrial application of abattoir wastewater.

Keywords: Abattoir wastewater, biodegradation, bioremediation, physicochemical parameters, spectrophotometry

***Corresponding author's email**: kurehdan@gmail.com. Tel. 07039346206

INTRODUCTION

An abattoir is a place where animals are slaughtered or killed for human consumption [1]. The most commonly slaughtered animals for food are cattle, sheep, pigs, goats, and fowls, for poultry meat. The practice of slaughtering livestock and its resultant meat supply also provides very useful by-products such as skin and leather [2]. Abattoirs act as the starting point of the meat processing industry where stock comes from the market or farms to enter the food chain. The abattoir industry is an important component of the livestock industry in Nigeria, providing domestic meat supplies to over 150 million people and employment opportunities for the teeming population [3].

Abattoir waste encompasses solid wastes, which include inedible animal tissues such as condemned undigested ingesta as well as other forms of waste including meat/organ, ligaments, tendons bones, horns, hairs and aborted fetuses [4]. Abattoir wastewater, also called Slaughterhouse Waste Waters (SWWs) contains high amounts of biodegradable organic matter, suspended and colloidal matter such as fats, proteins and cellulose [5]. Biodegradable organic matter in receiving waters creates high competition for oxygen within the ecosystem leading to high levels of biochemical oxygen demand (BOD) and a reduction in dissolved oxygen, which is detrimental to aquatic life. Nutrients (nitrogen and phosphorus) enrichment in receiving sensitive bodies of water can cause eutrophication by stimulating the growth of algae (called an algal bloom). Blooming and finally the collapse of algae may lead to hypoxia/anoxia and hence mass mortality of benthic invertebrates and fish over large areas due to aquatic dissolved oxygen depletion. These effects entail a negative impact on biodiversity, sensitive species may be eliminated, major changes in the ecosystem and a number of serious human health hazards may occur [6].

In Nigeria, the abattoir industry is an important component of the livestock industry providing domestic meat supply to over 150 million people and employment opportunities for teaming population [7]. They are usually situated near aquatic environment where different untreated waste streams are discharged [8] and constitute public health concerns to the authorities. The impact of wastewater effluents on the quality of receiving water bodies is manifold and depends on the volume of the discharge, chemical and microbiological concentration/composition of the effluents [9]. Ever since humans tied down their health and well-being to the quality of their environment, sanitation which ought to have been one of the determinants of the quality of life has been neglected [10]. In addition, environmental sanitation practices that characterize some of these abattoir houses in developing countries call for attention. Environmental sanitation is an intervention to reduce peoples exposure to diseases by providing a clean environment to live in and with measures to break the cycle of disease. This includes hygienic management of human and animal excreta, refuse and wastewater and control of disease vectors and all the factors in the physical environment that may have deleterious effects on man's mental, social, and physical wellbeing [11].

Bioremediation is the use of living organisms, or part of it, or their

metabolites, for the recovery or cleaning up of a contaminated medium such as soil, sediment, or liquid/water [12,13]. Under suitable conditions, microorganisms conduct their metabolic processes quickly and with extraordinary precision, facilitated by their broad enzyme-mediated responses. Detailed discovery of natural microbial ecology to uncover enzymes has contributed to the development of an enzyme solution as an alternative to harsh chemical technologies [14]. The transformation of solid and liquid abattoir wastes by microorganisms, or their metabolites is a novel trend; new microorganisms with proper biodegradation systems are necessary to meet the ever-increasing pile-up of abattoir wastes, especially in waste management and degradation [15]. The aim of this research was to determine the biodegradation potential of some bacteria isolated from abattoir effluents within Kaduna metropolis.

MATERIALS AND METHODS

Sample collection

Wastewater samples were collected from Sabon Tasha, Ungwan Rimi and Tudun Wada abattoirs all located within Kaduna metropolis according to the method of Adesemoye et al. [16]. Sterile 2.0 liters sampling bottles were used to aseptically draw 500 ml of the abattoir wastewater. The wastewater samples were collected from each abattoir as the wastewater was running off the drainage system (grab method). A total of 12 samples were collected from the 3 abattoirs. Two (2) samples were collected from each abattoir in every visit. Samples were collected from the point source and exit points. Samples were collected between the months of June and September 2021. Control samples were collected from water stored in buckets used for washing meat and utensils in the abattoirs. The samples were placed in a cooler containing ice blocks and were transported immediately to the laboratory within 4 to 6 hours after collection for analysis. The samples were collected in the early hours of morning when activities in the abattoir are usually high.

Preparation of culture media

The media used for this study were: Nutrient agar, Nutrient broth, Plate Count Agar (PCA), MacConkey agar, Mannitol Salt agar, Cetrimide agar, Eosin Methylene Blue (EMB) agar, Mineral Salts Medium and Salmonella Shigella agar, all of which were prepared according to manufacturer's instructions.

Bacterial analysis

A serial dilution of 1:10 was carried out on the abattoir wastewater. From the dilutions 0.1 ml aliquot taken from 10^{-3} and 10^{-5} was transferred aseptically into freshly prepared agar plates (MacConkey agar, MRS, Cetrimide agar, Salmonella Shigella agar, Nutrient agar and EMB agar) and spread evenly on the medium in duplicates. The inoculated plates were incubated at 37°C for 24 hours, after which, plates were examined for growth. Representative colonies of bacteria were picked from different plates after the incubation period. *Pseudomonas* cetrimide selective agar was used for the isolation of *Pseudomonas aeruginosa*, MacConkey agar for the isolation of *Klebsiella* spp, MRS for the isolation of *Bacillus spp, Salmonella Shigella* agar for the isolation of *Salmonella spp* and Eosin methylene blue agar for the isolation of *Escherichia coli and Klebsiella spp*. Pure cultures of bacteria were obtained by aseptically streaking representative colonies of different morphological types on to freshly

prepared selective media agar plates. Discrete bacterial colonies which developed on the plates, were used for subsequent characterization tests in accordance with the schemes of the Bergey's Manual of Determinative Bacteriology [17]. Nutrient agar was used as agar slant for storage of bacteria isolated while plate count agar was used for total bacterial count [18].

Characterization and identification

The isolates were characterized and identified on the basis of cultural appearance of colony, morphology, differential and selective media and by conventional biochemical tests [19]. Gram staining and conventional biochemical tests (urease, indole, citrate utilization, coagulase, oxidase and sugar fermentation tests) were carried out.

Determination of physico chemical characteristics

The physico-chemical properties determined were pH, temperature, conductivity, total dissolved solid, biochemical oxygen demand, temperature, phosphate and nitrate using the methods according to the methods of Ademoroti [20].

Screening of isolates for biodegradation potential

A 0.1 ml each of the broth cultures of the bacterial isolates (Bacillus*, Klebsiella, Pseudomonas, E coli and Salmonella)* plus 5ml each of MSM broth was mixed with 0.1ml of sterile abattoir wastewater in separate test tubes. The mixed sterile abattoir wastewater and MSM plus broth bacterial cultures were incubated at 37°C for 5 days. Spectrophotometer was used to determine the optical density at wavelength 550 nm. The isolates with the best potential were used for the bioremediation of abattoir wastewater [21].

Biodegradability test

The experimental setup consisted of 200 ml of sterile wastewater with mineral salt medium and 1 ml of the 24 hours old culture of each isolated organism contained in 250 Erlenmeyer's flasks. Each flask contained sterile wastewater with mineral salt medium for each individual isolate (*Bacillus spp* or *Pseudomonas spp*) and consortium (*Escherichia coli*, *Klebsiella spp* and *Salmonella spp*). The flasks were all incubated at room temperature and were periodically shaken to ensure the oxygen was evenly distributed and circulated. The incubation period was at intervals of one week (7 days) for 21 days (3 weeks) after which the physicochemical analysis was carried out using the standard laboratory procedures. [22].

Data analysis

Statistical analysis including mean, standard deviation, one way analysis of variance (ANOVA), as well as the significant evaluation were performed using the SPSS windows

.

RESULTS

The results of the bacterial profile detected in all the abattoir wastewater samples analysed are presented in table 1.0. *Escherichia coli, Klebsiells sp, Pseudomonas sp, Salmonella sp and Bacillus sp* were detected in all the samples.

Table 1. Morphological and biochemical characteristics of isolates from selected points of Sabo, Tudun wada and Ungwan rimi abbatoirs

IC	GRAM	SHAPE	SPORES	MOT.	CAT.	COA.	IND.	CIT.	TSI	MR	UREASE	PROB. ORG.
EX 1	+	R	+	-	+	-	-	+		-	-	*Bacillus ap.*
EX 2	-	R	-	+	+	-	+	-		-	-	*Pseudomonas*
EX 3	-	R	-	+	+	-	+	-	A/A	+	-	*E. coli*
EX 4	_	R	+	-	+	-	-	+			+	*Bacillus sp.*
EX 5	_	R	-	+	+	-	+	+		+	+	*Pseudomonas*
EX 6	-	R	-	-	+	-	-	+	A/A	-	+	*Klebsiella sp.*
EX 7	+	R	+	-	+	-	-	+		+	+	*Bacillus sp.*
EX 8	+	R	+	-	+	-	-	+		+	+	*Bacillus sp.*
D1 S1	-	R	-	-	+	-	-	+	A/A	-	+	*Klebsiella sp.*
D1S2	-	R	-	+	+	-	+	-		+	-	*E. coli*
D1S3	-	R	-	+	+	-	+	-		-	+	*Pseudomonas*
D1S4	-	R	-	+	+	-	+	-		-	+	*Pseudomonas*
D1S5	+	R	+	-	+	-	-	+		+	+	*Bacillus sp.*
D1S6	-	R	-	+	+	-	-	-	A/A	+	-	*Salmonella sp.*
D1S7	-	R	-	+	+	-	-	-	A/A	+	-	*Salmonella sp.*
D1S8	-	R	-	+	+	-	-	-	A/A	+	-	*Salmonella sp.*

KEY: R – ROD, C – COCCUS, + POSSITIVE, - NEGATIVE, D- Discharge, EX-Exit

Growth Pattern of Isolates grown in mineral salt medium for Biodegradation Potentials

The isolates were grown in a mineral salt medium containing the sterile abattoir effluent for 5 days after which their growth pattern was monitored using spectrophotometer at 550nm. The highest growth was seen in *Bacillus spp* followed by *Pseudomonas spp. Escherichia coli* had the lowest growth among all the isolates as presented in Table 2

Table 2. Growth pattern of Isolates grown in Mineral Salt Medium

S/N	Isolates	Optical Density (OD)
1.	*Klebsiella spp*	1.207
2.	*Escherichia coli*	0.393
3.	*Salmonella spp*	1.359
4.	*Pseudomonas spp*	1.540
5.	*Bacillus spp*	1.728
6.	control	0.294

Effects of Bacteria on the Physicochemical parameters of wastewater samples

The initial temperature of the water samples collected at the sampling locations were between 27.3 and 27.4°C. Upon addition of the microorganism, either singly or as a consortium of organisms, it was observed that there were elevations in the mean water temperature with the different sampling intervals; however, the increase in the temperature was not statistically significant ($p > 0.05$). when compared with the W.H.O permissible limits for

water temperature, the results showed that the mean temperature of the water samples were below the acceptable limits (< 40°C). At each sampling interval, the temperature of the water samples collected at the various locations did not differ significantly ($P > 0.05$) between samples treated with either *Pseudomonas spp* or *Bacillus spp*. (Table 3).

The pH values of the water samples, both before and after the innoculation of microorganisms, were all with the W.H.O acceptable limits. However, the results indicated that lower pH values were recorded in water samples after the introduction of either *Pseudomonas* sp. or *Bacillus* sp. Furthermore, the decrease in pH of the water samples varied with time (Table 4).

The total dissolved solid values recorded in the water samples before and after the addition of the microorganisms were significantly higher than the W.H.O allowable limits for TDS of 2 mg/l. However, upon the introduction of microorganisms, either singly or as a consortium of organisms. A significant reduction in the TDS of the water samples was observed between the 7th and 21st day (Table 5).

The electrical conductivity values of the water samples prior to introduction of the microorganisms were higher than the WHO allowable limit of 1 mS/cm for water conductivity. Following the introduction of the remediating microbes, significantly lower values for electrical conductivity were recorded, with the values being lower than that of WHO permissible limit for electrical conductivity (Table 6).

The BOD values were significantly higher than the WHO permissible limit of 20 mg/L for BOD in water sample; furthermore, the introduction of the microorganisms did not significantly alter the levels of BOD when compared to the pre-inoculation values (Table 7).

The nitrate concentration in water samples before bacterial treatment were higher than the WHO recommended limit of 45 mg/L. Addition of the remediating organisms was associated with decreasing nitrated concentrations in all the water samples collected with *Pseudomonas spp* and the consortium of microorganisms having the highest nitrate lowering effect by the 21stday of observation (Table 8)

Table 3: Changes in the temperature of water samples treated with *Pseudomonas* spp, consortium and *Bacillus* spp over four sampling intervals (in ℃)

Isolate	Abattoir	Day 0	Day 7	Day 14	Day 21	WHO[23]
Pseudomonas	U/rimi	27.3±0.35	28.7±0.75	29.9±0.15	32.0±0.2	< 40
	T/wada	27.4±0.40	28.7±0.36	29.6±0.61	32.0±0.4	
	Sabo	27.3±0.36	29.9±0.26	29.1±1.33	32.0±0.1	
Bacillus	U/rimi	27.3±0.35	28.8±0.43	28.2±1.24	32.0±0.1	
	T/wada	27.4±0.40	29.2±0.21	29.9±1.30	32.0±0.2	
	Sabo	27.3±0.36	29.2±0.31	28.9±1.10	32.0±0.6	
Consortium			28.9±0.56	30.2±0.21	30.2±0.21	
Control		26.8±0.60				

Key: T/wada: Tudun Wada, U/Rimi: Ungwan Rimi, W.H.O: World Health Organisation
Consortium*: Escherichia coli, Klebsiella* and *Salmonella spp*

Table 4: Changes in the pH of water samples treated with *Pseudomonas spp,* consortium and *Bacillus spp* over four sampling intervals.

Isolate	Abattoir	Day 0	Day 7	Day 14	Day 21	WHO[23]
Pseudomonas	U/rimi	7.87±0.03	7.25±0.06	7.25±0.08	7.15±0.03	6.5 – 9.5
	T/wada	7.57±0.09	7.46±0.09	7.31±0.04	7.40±0.12	
	Sabo	7.64±0.04	7.64±0.05	7.47±0.06	7.40±0.02	
Bacillus	U/rimi	7.87±0.03	7.25±0.06	7.25±0.05	7.20±0.08	
	T/wada	7.57±0.09	6.54±0.06	7.26±0.06	7.40±0.06	
	Sabo	7.64±0.04	7.73±0.03	7.63±0.06	7.50±0.04	
Consortium			6.77±0.11	7.16±0.03	7.16±0.03	
Control		5.82±0.14				

Key: T/wada: Tudun Wada, U/Rimi: Ungwan Rimi, W.H.O: World Health Organisation
Consortium*: Escherichia coli, Klebsiella* and *Salmonella spp*

Table 5: Changes in the total dissolved solids (TDS in mg/l) of water samples treated with *Pseudomonas spp*, consortium and *Bacillus spp* over four sampling intervals.

Isolate	Abattoir	Day 0	Day 7	Day 14	Day 21	WHO[23]
Pseudomonas	U/rimi	1666.0±7.20	357.6±10.2	476.0±11.7	463.1±6.42	1000
	T/wada	1533.6±11.2	405.3±5.03	417.3±3.06	455.4±1.48	
	Sabo	1966.3±14.3	427.3±3.78	384.0±13.7	502.6±3.26	
Bacillus	U/rimi	1666.0±7.20	427.0±4.58	429.3±1.52	430.8±4.89	
	T/wada	1533.6±11.2	384.6±3.51	428.3±4.51	490.6±1.12	
	Sabo	1966.3±14.3	446.7±12.9	443.3±4.51	511.3±9.65	
Consortium			446.3±8.50	430.7±9.86	430.7±9.86	
Control		81.7±3.06				

Key: T/wada: Tudun Wada, U/Rimi: Ungwan Rimi, W.H.O: World Health Organization
Consortium*: Escherichia coli, Klebsiella* and *Salmonella spp*

Table 6: Changes in the electrical conductivity (EC in µS/cm) of water samples treated with *Pseudomonas spp*, consortium and *Bacillus spp* over four sampling intervals.

Isolate	Abattoir	Day 0	Day 7	Day 14	Day 21	WHO[23]
Pseudomon	U/rimi	2.56±0.03	0.561±0.010	0.731±0.080	0.723±0.011	1
	T/wada	2.78±0.03	0.603±0.005	0.646±0.048	0.710±0.012	
	Sabo	2.61±0.02	0.666±0.006	0.620±0.007	0.784±0.011	
Bacillus	U/rimi	2.56±0.03	0.651±0.009	0.674±0.007	0.671±0.008	
	T/wada	2.78±0.03	0.627±0.008	0.662±0.021	0.765±0.004	
	Sabo	2.61±0.02	0.748±0.127	0.683±0.017	0.798±0.006	
Consortium			0.678±0.101	0.671±0.014	0.671±0.014	
Control		124.3±2.51				

Key: T/wada: Tudun Wada, U/Rimi: Ungwan Rimi, W.H.O: World Health Organization
Consortium*: Escherichia coli, Klebsiella* and *Salmonella spp*

Table 7: Changes in the biological oxygen demand (given in mg/l) in water samples treated with *Pseudomonas spp*, consortium and *Bacillus spp* over four sampling intervals.

Isolate	Abattoir	Day 0	Day 7	Day 14	Day 21	WHO[23]
Pseudomonas	U/rimi	726.0±2.64	862.7±21.0	748.0±11.2	894±2.48	20
	T/wada	947.7±5.68	630.3±4.93	868.6±20.0	1002±4.64	
	Sabo	822.7±2.51	537.0±13.1	628.0±3.60	642±1.33	
Bacillus	U/rimi	726.0±2.64	792.6±4.04	791.0±5.93	811±5.67	
	T/wada	947.7±5.68	646.0±7.00	836.7±5.68	989.0±6.38	
	Sabo	822.7±2.51	558.3±24.0	863.0±14.1	514±3.42	
Consortium			858.7±28.4	473.6±6.65	473.6±6.65	
Control		322.0±2.65				

Key: T/wada: Tudun Wada, U/Rimi: Ungwan Rimi, W.H.O: World Health Organization
Consortium*: Escherichia coli, Klebsiella* and *Salmonella spp*

Table 8: Changes in the NO_3^- (mg/l) content in water samples treated with *Pseudomonas spp,* consortium and *Bacillus spp* over four sampling intervals.

Isolate	Abattoir	Day 0	Day 7	Day 14	Day 21	WHO[23
Pseudomonas	U/rimi	64.5±0.52	48.8±0.62	40.4±1.75	31.5±1.42	45
	T/wada	71.8±0.87	42.4±0.72	47.6±3.23	47.3±4.48	
	Sabo	88.4±0.96	84.3±3.11	64.9±1.49	56.3±3.95	
Bacillus	U/rimi	64.5±0.52	49.2±0.31	37.6±1.13	47.3±1.43	
	T/wada	71.8±0.87	38.6±0.49	45.1±0.95	54.0±0.68	
	Sabo	88.4±0.96	66.8±1.94	67.8±4.55	56.3±2.04	
Consortium			44.9±1.15	39.9±1.35	39.9±1.35	
Control		31.0±0.78				

Key: T/wada: Tudun Wada, U/Rimi: Ungwan Rimi, W.H.O: World Health Organisation
Consortium*: Escherichia coli, Klebsiella* and *Salmonella spp*

DISCUSSION

The mean pH values obtained from this study were within the W.H.O tolerance limit of 6.5 to 9.5 for the discharge of wastewater into aquatic environments [24]. The basic pH that characterized the sample from this research contradicted the observation made by Oyinlola *et al*. [25] which recorded an acidic pH in the characteristics of sampled abattoir wastewater. This may be as a result of the ammonia released during the degradation that reacted with carbon dioxide produced during the anaerobic process resulting in ammonia bicarbonate which contributed to the increase in pH values compared to the control sample. This is as a result of the high concentration of organic compounds in the abattoir effluents that is composed mainly of proteins e.g blood [9]. There is statistically significant difference ($P < 0.05$) of pH values recorded by different abattoir effluents at 7 days interval for 21 days.

The total dissolved solids (TDS), obtained from Ungwan Rimi, Tudun Wada and Sabo abattoirs for day 0 in all the abattoirs were generally higher than the 1000 mg/l upper limit set by W.H.O [23]. The TDS values obtained were statistically significant from day 0 to day 7. However, the TDS values obtained for days 7, 14 and 21 fell within the limit. The reduction of the total dissolved solids during the experiment was an indication that the bacteria were using it to supply energy for their own metabolic processes and for biomass production. This result is in line with those observed by Moran*, et al*. [26].

The temperature values obtained were in compliance with the Federal Ministry of Environment (FMENV) effluent permissible limits of <40℃ and were similar to those obtained by Atuanya *et al*. [27]. Metabolic activities increased with a rise in temperature. A rise in temperature can produce conditions for the growth of disease-causing organisms. However, the increase in the temperature was not statistically significant ($P > 0.05$) when compared with the W.H.O permissible limit for water temperature (< 40℃). The mean Electrical Conductivity for day 0 in the abattoirs was above the W.H.O permissible limits of 1(one) [23]. However, conductivity after treating the abattoir wastewater fell within the limit set by FMENV/W.H.O. [23]. High values electrical conductivity showed that inorganic ions such as H^+, Na^+, $K^{+,}$ Mg^{2+}, Ca^{2+}, Cl^{2+}, SO_4^{2+} etc. Are present in reasonable concentration in the water. Such ions have major influence on the conductivity of water, [20]. There was a statistical significant difference ($P < 0.05$) among the pH values recorded at the different abattoir effluents at 7 days interval for 21 days. Total dissolved solids (TDS) and electrical conductivity (EC) exhibited similar characteristics/trend in all the abattoirs effluent samples, this may be as a result of the linear relationship that exists between the two parameters [28].

Biological Oxygen Demand (BOD) values recorded for all the abattoirs were greater than the permissible discharge limits of 20 mg/l by W.H.O. [23]. High Biological Oxygen Demand values could be attributed to the low Dissolved Oxygen level since low dissolved oxygen will result in high biochemical oxygen demand, which is an indication of pollution. The maximum reduction of BOD was observed at day 21 by the consortium of bacteria followed by *Bacillus* and *Pseudomonas spp* respectively. Similar results were observed by Shrivastava *et al.* (2013) and Prasad and Manjunath (2011) where it was found that *Bacillus* and *Pseudomonas spp* reduced BOD of Yamusa water and lipid rich wastewater. The BOD recorded were found to be higher, an indication of high organic matter. Higher BOD concentrations in all the abattoir samples were due to high blood volume. This agrees with the findings of Cao and Mehrvar, (2011). The reduction in BOD in the first seven (7) days is an indication of reduction of pollution level of abattoir effluent and the rise in the value of BOD in the third week of investigation is an indication that the microbial communities were getting old (Presscott, 2008).

The increase in BOD in the samples was statistically significant. The BOD and TDS are high as a result of the blood content and particulates respectively from the slaughter process, this agrees with the findings of Achi *et al*. (2014). The results obtained in this research is similar to the work of [32,33]. The Nitrate values recorded before treatment in all the abattoirs were above the W.H.O/USEPA permissible discharge limits of 45mg/l. However, nitrate maximum reduction in the research was recorded by *Pseudomonas spp* followed by the consortium of bacteria and *Bacillus spp* respectively. This result demonstrated that denitrification took place during treatment [34,35] reported that *Bacillus* and *Pseudomonas spp* were most efficient for nitrate reduction which is similar to work obtained in this research. However, the abattoirs effluents have Nitrate values that fell within the permissible limits after treatment for days 7, 14 and 21 respectively. The levels of Nitrate were higher in Sabo abattoir than from Tudun

Wada and Ungwan Rimi abattoirs. The difference may be attributed to the high fecal contents of the effluents. There was a statistically significant difference in the values of Nitrate recorded during the treatment of the waste abattoir water samples. Wastewater samples must have Nitrates not up to 50 Mg/l before discharging it into aquatic environment, [36]. Blood contributes significantly to the nitrogen content in the effluents. This is similar to the work ealier recorded by [37]. The result shows that there was a significant reduction of Nitrate concentration from day 0 to day 21. The overall result obtained from this study revealed that both the consortium and the individual bacteria effectively biodegraded the abattoir effluents. This means that the consortium collaborated in the degradation of a wide range of substrates under a short period of time [38].

In the biodegradation process, bacterial cellular metabolism, growth and development were feasible as a result of their utilization of organic compounds as substrates present in the wastewater [34]. The results obtained in this research is in agreement with the findings of Zhao *et al*. (2014). The overall results obtained from this study revealed that both the consortium and individual bacteria effectively biodegraded the abattoir effluents. This means that the consortium collaborated in the degradation of a wide range of substrates under a short period of time [38]. The efficacy in the reduction of BOD, TDS, EC, nitrates and phosphates as demonstrated by the test bacteria isolates indicates their ability to adapt and survive naturally in the presence of abattoir wastewater and possess degradative enzymes for the degradation of the wastewater.

CONCLUSION

From the results presented and their analysis, the following conclusions were made:
physical parameters like the pH and temperature of the samples were within the range 5.82 to 7.87, 26.8 to 32 .0 respectively. The pH and temperature of the samples fell within the guideline (Akan *et al.*,2010)

Biochemical oxygen demand detected in the sample after treatment were within the range 473.0 to 1002 mg/L, while the discharge limits showed 20.00 mg/L (W.H.O, 2011). The values from the samples showed increased BOD indicating pollution in the abattoirs.

Total dissolved solids (TDS) values obtained from the samples after treatment were within 411.0 to 511.0 mg/L. While the discharge limit guidelines show 1000mg/L (WHO, 2011). The TDS values obtained fall below the stipulated guidelines.

Enumeration of bacteria in the water samples obtained from three abattoirs in Kaduna metropolis shows that the bacterial load ranges from 1.025×10^7 to 9.35×10^6 (CFU/mL) s bacterial counts which is above the recommended level of 10×10^2 cfu/ml by EPA and WHO.

Wastewater discharged into the water body contains bacteria such as *Escherichia coli, Bacillus sp*, *Klebsiella sp, Salmonella sp* and *Pseudomonas sp.* There is a need to study the ecological implication of these bacteria.

For chemical parameters, concentration level of Nitrates (NO^-_3), phosphate (PO^-_4) in the abattoir wastewater samples were

above the WHO/USEPA tolerance limits for the discharged of wastewater into a river.

Authors Contribution

KD and MJS conceptualized the study. KD, MJS, AA, IS and PD designed the study. KD, MJS, and PD participated in fieldwork and data collection. KD, MSJ, AA, IS and PD performed the data analysis; KD, MJS, AA, IS and PD interpreted the data. KD prepared the first draft of the manuscript, reviewed by MJS, AA and IS. All authors contributed to the development of the final manuscript and approved its submission.

Disclosure of Conflict of Interest

None

Disclosure of Funding

The study did not receive any external funding.

REFERENCES

1. Bello Y. O. and Oyedemi D. T. A. (2009). "The impact of abattoir activities and management in residential neighbourhoods: A case study of Ogbomoso, Nigeria". *Journal of Social Sciences*, 19(2): 121-127.

2. Komba, E. V., Komba, E. V., Mkupasi, E. M., Mbyuzi, A. O., Mshamu, S., Mzula, A., & Luwumba, D. (2012). Sanitary practices and occurrence of zoonotic conditions in cattle at slaughter in Morogoro Municipality, Tanzania: implications for public health. *Tanzania Journal of Health Research*, *14*(2).

3. Ayoade, F., & Olayioye, E. O. (2016). Microbiological assessment of housekeeping practices and environmental impact of selected abattoirs in Lagos and Ogun States of Nigeria. *Journal of Applied Biosciences*, *99*, 9363-9372.

4. Franke-Whittle, I. H., & Insam, H. (2013). Treatment alternatives of slaughterhouse wastes, and their effect on the inactivation of different pathogens: A review. *Critical reviews in microbiology*, *39*(2), 139-151.

5. Caixeta, C. E. T., Cammarota, M. C. and Xavier, A. M. F. (2002). Slaughterhouse Wastewater Treatment: Evaluation of a New Three-phase Separation System in a UASB Reactor. *Bioresour. Technol*. 81:61-69.

6. Foroughi, M., Najafi, P., Toghiani, A. and Honarjoo, N. (2010). Analysis of Pollution Removal from Wastewater by *Ceratophyllum demersum*. *Afr.J. Biotechnol. 9* (14): 2125-2128.

7. Nafaranda, W. D., Ajayi, I. E., Shawulu, J. C., Kawe, M. S., Omeiza, G. K., Sani, N. A., Padilla-Gasca, E., López-López, A. and Gallardo-Valdez, J. (2011). Evaluation of Stability Factors in the Anaerobic Treatment of Slaughterhouse Wastewater. *J. Bioremed. Biodegrad* 2:1-5.

8. Adelegan, J. (2002). Environmental policy and slaughterhouse waste in Nigeria.

9. Ogbomida, E. T., Kubeyinje, B. and Ezemonye, L. I. (2016). Evaluation of Bacterial Profile and Biodegradation Potential of Abattoir Wastewater. *African Journal of*

Environmental Science and Technology, 10 (2), 50-57.

10. Burmamu, B. R., Law, P. L., Aliyu, H. H., & Ibrahim, Y. (2014). Environmental impacts and management strategies of solid waste disposal in Jimeta-Yola, Nigeria. *International Journal of Environmental Engineering Science and Technology Research*, *2*(3), 3-7.

11. Nwankwo, C. N., E Gobo, A., Israel-Cookey, C., & A Abere, S. (2020). Effects of hazardous waste discharge from the activities of oil and gas companies in Nigeria. *Central Asian Journal of Environmental Science and Technology Innovation*, *1*(2), 119-129.

12. Bosso, L., Scelza, R., Varlese, R., Meca, G., Testa, A., Rao, M. A. and Cristinzio, G. (2016). Assessing the Effectiveness of *Byssochlamys nivea* and *Scopulariopsis brumptii* in Pentachlorophenol Removal and Biological Control of two *Phytophthora* species. *Fungal Biol, 120*: 645–653.

13. Wang, W., Jiang, F. Y., Wu, F., Li, J. H., Ge, R., Li, J., Tan, G. Q., Pang, Y. L., Zhou, X. F. and Ren, X. J. (2019). Biodetection and Bioremediation of Copper Ions in Environmental Water Samples using a Temperature Controlled, Dual-Functional *Escherichia coli* cell. *Appl. Microbiol. Biotechnol, 103*. 6797–6807.

14. Shrivastava, J. N., Verma, S., & Kumar, V. (2013). Bioremediation of Yamuna water by mono and dual bacterial isolates. Indian Journal of Science Research and Technology, 1(1), 56-60.

15. Rathakrishnan, P., Nagarajan, P., and Kannan, R. R. (2012). Optimization of Process Parameters using a Statistical Approach for Protease Production by *Bacillus subtilis* using Cassava Waste, *Int. J. Chem. Tech. Res.*, 4: 749–760.

16. Adesemoye, A. O., Opere, B. O., & Makinde, S. C. O. (2006). Microbial content of abattoir wastewater and its contaminated soil in Lagos, Nigeria. *African Journal of Biotechnology*, *5*(20).

17. Holt, P., Barton, G., & Mitchell, C. (1999). Electrocoagulation as a wastewater treatment. *The third annual australian environmental engineering research event*, *1000*, 41-46.

18. Onuoha, P. C., Alum-Udensi, O., & Nwachukwu, I. I. (2018). Impacts of anthropogenic activities on water quality of the Onuimo Section of Imo River, Imo State, Nigeria. *International Journal of Agriculture and Earth Science*, *4*(4), 44-52.

19. Che Cheesbrough, M. (2005): District Laboratory Practice in Tropical Countries Part 2, UK, Cambridge University Press, Pp. 56, 64-65,69-70.

20. Ademoroti, C.M.A. (2012) Standard Methods for Water and Effluent Analysis. Foludex Press Ltd., Ibadan

21. Bandaw, T. and Herago, T. (2017).

Review on Abattoir Waste Management. *Global Veterinaria, 19*(2): 517-524.

22. Rice, E. W., Bair, R. B., Eaton, A. D. and Clesceri, L. S. (2012). *Standard Methods, for the Examination* of *Water* and *Wastewater*, (22nd edn). Published Jointly by American Public Health Association, American Water Works Association and Water Environment Federation.

23. WHO. (2011). Training Package for the Health Sector: Adverse Health Effects of Heavy Metals in Children. World Health Organization. Retrieve from http://www.who.int/ceh/capacity/heavy_metals.

24. Nasiru, A., Osakwe, C. E., Lawal, I. M., & Chinade, A. U. (2016). Assessment of physicochemical parameters and heavy metals in Gombe abattoir wastewater. *Am. J. Eng. Res*, *5*(3), 64-69.

25. Oyinlola, K. A., Odujebe, F. O., Ajibare, A. O., Oriolowo, D. K., Ogunleye, G. E., Odebunmi, E. O., & Kazeem, M. O. (2023). Assessment of the impact of wastewater from an abattoir in Oyo state on groundwater in Onidundu community, Nigeria. *Agricultural Science & Technology (1313-8820)*, *15*(2).

26. Liu, C., Gorby, Y. A., Zachara, J. M., Fredrickson, J. K., & Brown, C. F. (2002). Reduction kinetics of Fe (III), Co (III), U (VI), Cr (VI), and Tc (VII) in cultures of dissimilatory metal-reducing bacteria. *Biotechnology and bioengineering*, *80*(6), 637-649.

27. Atuanya, E. I., Nwogu, N. A., & Akpor, E. A. (2012). Effluent qualities of government and private abattoirs and their effects on Ikpoba River, Benin City, Edo State, Nigeria. *Advances in Biological Research*, *6*(5), 196-201.

28. Radojevic, M., & Bashkin, V. N. (1999). *Practical environmental analysis*. Royal Society of chemistry.

29. Cao, W., & Mehrvar, M. (2011). Slaughterhouse wastewater treatment by combined anaerobic baffled reactor and UV/H2O2 processes. *Chemical Engineering Research and Design*, *89*(7), 1136-1143.

30. Willey, J. M., Sherwood, L. M. and Woolverton, C. J. (2008) 'Prescott, Harley and Klein's Microbiology', *Climate Change 2013 - The Physical Science Basis*, pp. 1–1088.

31. Achi, C. G., Sridhar, M. K., & Coker, A. O. (2014). Performance evaluation of a water hyacinth based institutional wastewater treatment plant to mitigate aquatic macrophyte growths at Ibadan, Nigeria. *International Journal of Applied*, *4*(3).

32. Zhao, C., & Chen, W. (2019). A review for tannery wastewater treatment: some thoughts under stricter discharge requirements. *Environmental Science and Pollution Research*, *26*, 26102-26111.

33. Warade, A. R., Shinde, G. B., Gaikwad, R. W., Hakke, V. S., Sonawane, S. H., &

Lingayat, A. (2023). Intensification of pharmaceutical wastewater treatment using hydrodynamic cavitation process. *Materials Today: Proceedings*, *77*, 692-697.

34. Sonune, N., & Garode, A. (2018). Isolation, characterization and identification of extracellular enzyme producer Bacillus licheniformis from municipal wastewater and evaluation of their biodegradability. *Biotechnology Research and Innovation*, *2*(1), 37-44.

35. Sivaprakasam, S., Mahadevan, S., Sekar, S., & Rajakumar, S. (2008). Biological treatment of tannery wastewater by using salt-tolerant bacterial strains. *Microbial cell factories*, *7*(1), 1-7.

36. Chahinian, N., Bancon-Montigny, C., Caro, A., Got, P., Perrin, J. L., Rosain, D., ... & Tournoud, M. G. (2012). The role of river sediments in contamination storage downstream of a wastewater treatment plant in low flow conditions: Organotins, faecal indicator bacteria and nutrients. *Estuarine, Coastal and Shelf Science*, *114*, 70-81.

37. IJah, D. D. U. (2016). Physicochemical and microbiological qualities of the abattoir wastewater in part of Minna Niger State. *Advances in Life Science and Technology,* 21(1); 1-10.

38. Darshini, P. P., & Sharpudin, J. (2016). Bioremediation of industrial and municipal
wastewater using bacterial isolates *International Journal of Engineering Sciences & Technology*, *5*, 173-177