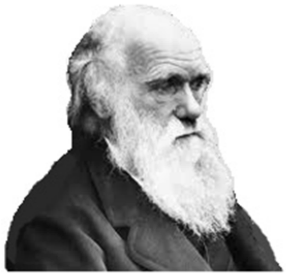
Available online at www.worldnewsnaturalsciences.com



World News of Natural Sciences

An International Scientific Journal

WNOFNS 59 (2025) 44-57 EISSN 2543-5426

Characterization of *Escherichia coli* Prevalence and Antibiotic Resistance in Abattoir Wastewaters in Calabar South, Nigeria

Charles Ayishie Agashi[1,*], Philip Effanga Ita[1], Emmanuel Solomon Daudu[1], Gift Tah Bankong[1], Abisola Mary Olaleye[2], Anointing Uyemuke Obuo[3], Ignatius Ashi Ikpang[1]

[1] Department of Microbiology, Faculty of Biological Sciences, University of Calabar, Calabar, Nigeria

[2] Department of Microbiology, Faculty of Sciences, Osun State Polytechnic, Iree, Nigeria

[3] Department of Biology, Faculty of Biological Sciences, Cross River State University of Technology, Calabar, Nigeria

*E-mail address: agashicharles07@gmail.com

ABSTRACT

Wastewaters are considered hotspots for antibiotic resistant bacteria and horizontal gene transfer among related and unrelated bacterial species. This study investigated the prevalence and antibiotic susceptibility pattern of *Escherichia coli* isolated from abattoir wastewaters in Calabar South, Nigeria. Seven hundred wastewater samples from three abattoirs: Uwanse (300), Mount Zion (250) and Amika Utuk (150) samples were analyzed. Standard microbiological procedures were followed in isolation and identification of the *E. coli* isolates. The antibiotic susceptibility test was done using the Kirby Bauer disk diffusion method. The results showed high prevalence of *E. coli* in the three abattoir locations; 202(67.3%) from Uwanse, 154 (61.6%) from Mount Zion and 81 (54%) from Amika Utuk. The antibiogram showed that the *E. coli* isolates were highly sensitive to Ofloxacin followed by Gentamicin in Uwanse (87.1% and 54.5%), Mount Zion (95.5% and 60.4%) and Amika Utuk (92.6% and 64.2%) respectively. The *E. coli* isolates were highly resistant to Ampicillin and Augumentin with both interchangeably topping the list in the three locations. Most isolates had Multiple Antibiotic Resistance (MAR) index greater than (>0.2). This result shows that the isolates are a public health threat since their contact with the environment might cause the spread of multidrug resistance organisms.

***Keywords*:** Wastewater, antibiotic, resistance, *Escherichia coli*, abattoir

(Received 03 December 2024; Accepted 07 January 2025; Date of Publication 10 January 2025)

1. INTRODUCTION

An abattoir is a facility specially designed and licensed for receiving, holding, slaughtering and inspecting meat, animals and meat products before release to the public (Alonge et al., 2005). 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 populations (Nafarnda et al., 2012). During slaughter and meat processing, wastewater is generated consisting of mainly intestinal contents, blood and water. Abattoir wastewater may therefore be defined as water that has been used in the cleaning up of slaughtered cattle, sheep, goat and pig carcasses, the floor of slaughter hall, personnel and slaughter equipment (Coker et al., 2001).

It is characterized by presence of high concentration of whole blood of the slaughtered food animals and suspended particles of semi-digested and undigested feeds within the stomach and intestine of slaughtered and dressed food animals. Abattoir effluents most often enter natural bodies of water like groundwater, streams, lakes, rivers and oceans as a result of natural drainage patterns and sequences (Madigan et al., 1997; Pelczar et al., 2002). Potential health risks from water-borne pathogens can exist in water contaminated by abattoir effluents (Nafarnda et al., 2012), and this could constitute significant environmental and public health hazards (World Bank, 1998; Coker et al., 2001; Nafarnda et al., 2006; Osibanjo and Adie, 2007).

Bacteria from abattoir waste discharged into water columns can be absorbed to sediments, and the bacteria released back into the water columns when the bottom stream is disturbed thus presenting long-term hazards (Sherer et al., 1992). Several studies have revealed that abattoirs in developing countries have an unhygienic environment (Adeyemo, 2002; Nwanta et al., 2010). The presence of pathogens that are known causes of diarrheal diseases and a possible hazard to human health in the abattoirs' wastewater and receiving water bodies have been detected in abattoirs (Benka-Coker and Ojior, 1996; Abiade-Paul et al., 2005).

This is as a result of meat production activities and failure in adhering to good manufacturing practices (GMP) and good health practices (GHP) (Adesemoye et al., 2006). Pathogens present in animal carcasses or shed in animal wastes may include *Bacillus* spp., *Cloistridium perfringes, Pseudomonas aeruginosa, Micrococcus luteus, Vibrio* spp., *Lactobacillus plantarum*, *Staphyloccus* spp, *Streptoccus* spp, *Escherichia coli*, *Salmonella* spp., *Mycobacterium bovis*, *Mycobacterium tuberculosis*, *Aspergillus niger*, *Mucor* spp., *Penicillium* spp., *Saccharomyces* spp. and *Fusarium* spp. (Yakubu et al., 2007; Narfanda et al., 2012).

The emergence of multi-drug resistance in bacterial human pathogens is one of the most serious challenges for healthcare globally.

Pathogens that earlier were sensitive to antibiotics are becoming resistant by mutations in their pre-existing DNA or by acquisition of DNA containing resistance genes (Martinez et al., 2009). Most of the antibiotic resistance genes carried by pathogens have their origins in environments other than the clinical world, and the normal bacteria floras of disparate environments are thought to be reservoirs of the resistance genes (Martinez, 2008; Allen et al., 2010; Forsberg et al., 2012; Finley et al., 2013; Wellington et al., 2013).

Gene exchange across bacterial species boundaries coupled with mobile genetic elements such as plasmids, transposons, integrons and genomic islands that harbor antibiotic resistance genes are important factors in the spread of acquired antibiotic resistance. (Marathe et al., 2013). Recent studies have shown that antibiotic resistance genes are ancient and were present in the environment long before the antibiotic era (D'Costa et al., 2011; Bhullar et al., 2012). The abuse of antibiotics has led to increased selection pressures even in the environment. Resistance genes may radically increase in abundance within the populations in bacterial communities exposed to sufficient selection pressure from exposure to antibiotics, (Barbosa and Levy, 2000; Dethlefsen et al., 2008; Kristiansson et al., 2011).

Such increases may also be accompanied by increased frequencies in genetic elements facilitating their mobility (Jernberg et al., 2010; Kristiansson et al., 2011). Thus, exposure to antibiotics is expected to increase the risk for the transfer of resistance between bacterial species. antibiotic contamination reaches the external environment. Environments exposed to hospital and agricultural waste typically contain both antibiotic resistance bacteria as well as moderately elevated levels of antibiotics, providing examples of ecosystems wherein antibiotics may exhibit the potential for selecting resistant strains (Segura et al., 2009; Gullberg et al., 2011). *Escherichia coli* is a normal inhabitant of the gastrointestinal tract of humans and warm-blooded animals (Von Baum and Marre, 2005).

Incidentally, it is an important cause of foodborne illnesses and a global public health threat (Awohr et al., 2019). The problem of antibiotic resistance in this widely studied bacterium makes it a double jeopardy in the health sector where it is known to cause a plethora of infections aside food related infections. Certain pathogenic strains such as Shiga-Toxin producing *E. coli* (STEC), Enterohemorrhagic *E. coli* (EHEC) and Enterotoxigenic *E. coli* (ETEC) have been associated with waterborne- disease outbreaks and mortality in humans (Ram et al., 2009). ETEC is commonly responsible for infectious diarrhea, vomiting, sunken eyes, massive dehydration and a collapse of the circulatory system due to poor sanitary conditions (Bhunia, 2008). STEC produce Shiga-like toxins (Stx1 and Stx2) after enteric infection that causes massive damage to kidney tubules, bloody urine and Hemorrhagic uremic syndrome (Laing et al., 2011). The gastro-intestinal tract serves as a reservoir for integron bearing *E. coli* strains (Vinué et al., 2008). Studies on farms have also shown an occurrence of multi antibiotic resistant *E. coli* after the chronic exposure to antibiotics (Von Baum and Marre, 2005). In Calabar South, there is no data on the prevalence and resistance of *E. coli* from the abattoir wastewaters to the current antibiotics used in the treatment of human bacterial infections hence the present study seeks to fill in this research gap with the objective of determining the prevalence and antibiotic susceptibility pattern of *Escherichia coli* isolated from abattoir wastewaters in Calabar South, Nigeria.

2. EXPERIMENTAL (MATERIALS AND METHODS)

2. 1. Collection of specimen/Sample collection

A total of seven hundred wastewater samples from three abattoirs (300 from Uwanse, 250 from Mount Zion and 150 from Amika Utuk in Calabar South, Cross River State, Nigeria were aseptically collected with sterile universal screw capped bottles. The samples were immediately transported to the laboratory for analysis.

2. 2. Isolation and identification

The abattoir wastewater samples were isolated in peptone water (Hi media, India) and incubated at 37 °C for 18-24h. The aliquots were then inoculated onto Eosin methylene blue Agar (Rapid Labs, UK) and incubated at 37 °C for 18-24h. Colonies with green metallic sheen were grown on Nutrient Agar (Rapid Labs, UK) to obtain pure colonies. The pure colonies were identified using Gram reaction, morphological and biochemical tests including motility test, catalase, oxidase, ONPG (Oxoid, UK), methyl red using MR-VP broth (Oxoid, UK) and API 20E (Biomerieux, France).The prevalence was calculated by dividing the number of positive *E. coli* isolates with the total number of samples

2. 3. Antimicrobial Susceptibility Test of the *Escherichia coli* isolates

The Kirby Bauer disc diffusion method was used (Kirby et al., 1966). Commercially impregnated discs containing 30 µg Ceftazidime (CAZ), 30 µg Cefuroxime (CRO), 10 µg Gentamicin (GEN), 5µg Ciprofloxacin (CPR), and 5 µg Ofloxacin (OFL), 10 µg Ampicillin (AMP), 30 µg Augmentin (AUG), 300 µg Nitrofurantoin (NIT), 30 µg Aztreonam (ATM), 30 µg Chloramphenicol (CHL), 10 µg Imipenem (IMP) and 25 µg Cotrimoxazole (COT) from Rapid Labs and Oxoid, UK were used. Overnight Pure cultures were emulsified in sterile normal saline and adjusted to 0.5 Mc Farland turbidity standard. This is uniformly plated on Muiller Hinton agar using sterile swabstick. The antibiotic discs were placed on the Mueller Hinton agar and allowed to stand faced up for about 30 mins for effective diffusion before incubating at 37 °C for 18-24h. The diameter zone of inhibition (including the diameter of the disc) was measured to the nearest millimeter and interpreted using Clinical Laboratory Standard Institute guide (CLSI, 2015). Multidrug resistance was defined as resistance to three or more classes of drug (Magiorakos et al., 2012). The multiple antibiotic resistance (MAR) index which is expressed in decimal ranging from 0.1 to 1.0 was determined using the method described by

Krumperman (1983) using the formula:

a/b,

with "**a**" being the number of tested antibiotics to which an organism is resistant to and "**b**" being the total number of antibiotics tested.

2. 4. Statistical analysis

The data was analyzed using percentage, excel worksheet and bar chart.

3. RESULTS

3. 1. Prevalence of *Escherichia coli* isolates

Table 1 shows the prevalence of *E. coli* isolates from the three abattoirs sampled. *E. coli* had a prevalence of 202/300 (67.3%), 154/250 (61.6%) and 81/150 (54%) from Uwanse, Mount Zion and Amika Utuk abattoirs respectively. The overall prevalence of the *E. coli* isolates is 437/700 (62.4%).

3. 2. Antibiotic susceptibility pattern

The antibiotic susceptibility pattern of the *E. coli* isolates from the three abattoirs is presented in Table 2. The results show that the organisms were highly susceptible to Ofloxacin (87.1% in Uwanse, 95.5% in Mount Zion and 92.6% in Amika Utuk)and highly resistant to Ampicillin (96.5% in Uwanse, 96.1% in Mount Zion and 100% in Amika Utuk) while the highest intermediate reaction was recorded against Ciprofloxacin (57.4%, 61.7% and 77.8%) in Uwanse, Mount Zion and Amika Utuk abattoirs respectively.

3. 3. Multiple Antibiotic Resistance (MAR) Index

The percentage MAR index of the *E. coli* isolates was shown in Figure 1. Most of the isolates (30.2% from Uwanse, 32.5% from Mount Zion and 49.4% from Amika Utuk) were found to have a MAR index of 0.8 with as much as 3.5% of the Uwanse isolates being resistant to all the antibiotics tested.

Table 1. Prevalence of *E. coli* isolates from the three abattoirs in Calabar South.

Location	Total number of samples (%)	Positive isolates %
Uwanse	300	202(67.4)
Mount Zion	250	154(61.6)
Amika Utuk	150	81(54)
Total	700	437 (62.4)

Table 2. Antibiotic susceptibility profile of the *Escherichia coli* isolates from the three abattoirs in Calabar South.

Antibiotic	Uwanse N = 202			Mount Zion N = 154			Amika Utuk N = 81		
	Sensitive (%)	Intermediate (%)	Resistant (%)	Sensitive (%)	Intermediate (%)	Resistant (%)	Sensitive (%)	Intermediate (%)	Resistant (%)
Ceftazidime	19 (9.4)	24 (11.9)	159 (78.7)	24 (15.6)	4 (2.6)	126 (81.8)	5 (6.2)	5 (6.2)	71 (87.7)
Cefuroxime	15 (7.4)	11 (5.4)	176 (87.1)	14 (9.0)	12 (7.8)	118 (76.6)	0 (0.0)	2 (2.5)	79 (97.5)
Gentamicin	110 (54.5)	48 (23.8)	44 (21.8)	93 (60.4)	18 (11.7)	43 (27.9)	52 (64.2)	11 (13.6)	18 (22.2)
Ciprofloxacin	23 (11.4)	116 (57.4)	63 (31.2)	12 (7.8)	95 (61.7)	47 (30.5)	10 (12.4)	63 (77.8)	8 (9.9)
Ofloxacin	176 (87.1)	9 (4.5)	17 (8.4)	147 (95.5)	0 (0)	7 (4.5)	75 (92.6)	3 (3.7)	3 (3.7)
Ampicillin	4 (2.0)	3 (1.5)	195 (96.5)	2 (1.3)	4 (2.6)	148 (96.1)	0 (0.0)	0 (0)	81 (100)

Augmentin	3 (1.5)	8 (4.0)	191 (94.6)	0 (0)	1 (0.6)	153 (99.3)	0 (0.0)	0 (0)	81 (100)
Nitrofurantoin	61 (30.2)	28 (13.9)	113 (55.9)	73 (47.4)	23 (14.9)	58 (37.9)	10 (12.4)	2 (2.5)	69 (85.2)
Aztreonam	45 (22.3)	18 (8.9)	139 (68.8)	50 (32.5)	10 (6.5)	94 (61.0)	22 (27.2)	2 (2.5)	57 (70.4)
Chloramphenicol	22 (10.9)	19 (9.4)	161 (79.7)	8 (5.2)	12 (7.8)	134 (87.0)	9 (11.1)	7 (8.6)	65 (80.2)
Imipenem	23 (11.4)	8 (4.0)	171 (84.7)	17 (11.0)	10 (6.5)	127 (82.5)	23 (28.4)	2 (2.5)	56 (69.1)
Cotrimoxazole	24 (11.9)	17 (8.4)	161 (79.7)	6 (3.9)	5 (3.2)	143 (92.9)	5 (6.2)	0 (0)	76 (93.8)

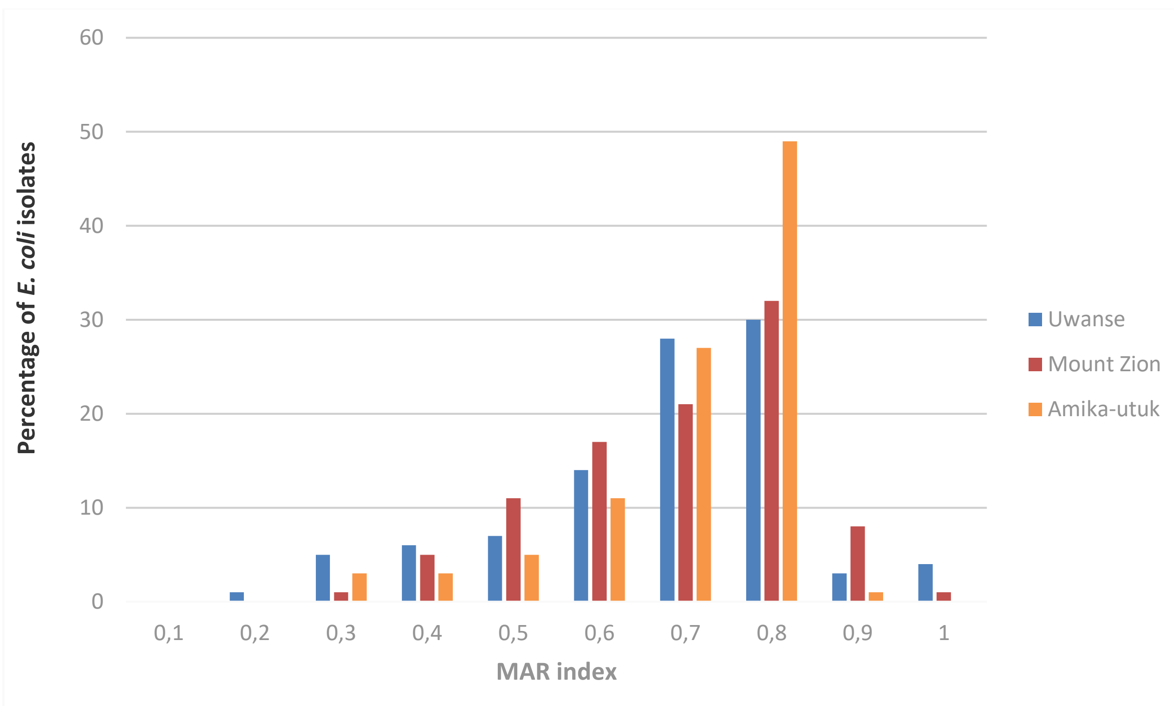


Figure 1. Percentage MAR index of the *E. coli* isolates from the three abattoirs

4. DISCUSSION

Escherichia coli had a high prevalence in this study with an average of 62.4% and a distribution of 67.3%, 61.6% and 54.0% for Uwanse, Mount Zion and Amika Utuk abattoirs respectively. The presence of *E. coli* indicates possible presence of other pathogenic organisms of public health importance (Atuanya et al., 2018). The variation in the results might be attributed to the impact of human activity in and around the abattoir environments on the bacteria isolates (Abu and Egenonu, 2008).

This result contrasted with the works of Aradhye et al.(2014), who recorded 48% *E. coli* isolates from beef cattle and slaughterhouse premise, Haberecht et al. (2019) who recorded 37% from sewer water, 22% from wastewater treatment plant influent, 14% from surface water and 2.4% from wastewater treatment plant effluent in Colorado and Omeregbe et al. (2017), who recorded 28.30% and 30.19% respectively for wastewater and sludge samples. Higher prevalence rate was recorded by Abraham et al. (2019) who reported 100%, Gautam et al. (2019) 100% and Tesfaye et al. (2019) 75%. In Wa abattoir, Ghana, *E. coli* from different anatomical sites had a prevalence rate of 98%, 92% and 88% (Adzitey, 2020).

This work was somehow similar to the works of Thanigaivel and Anandhan (2015), who had 70% prevalence. Cabral (2010) suggested that the huge difference between the results might be due to the use of contaminated water during washing, slaughtering and other handling processes and also the fact that *E. coli* is a common inhabitant of the human and animal gut. However since this study did not focus on the quality of the water used in washing and clean up processes in the abattoir, the water quality parameters were not studied. Most of the above studies reveal that *E. coli* was the most dominant organism and the public health importance of this organism cannot be over emphasized.

E. coli O157:H7 and 104:H4 both enterohaemorrhagic strains have been associated with many zoonotic outbreaks both in the US and Germany (NYSDH, 2000; Frank et al., 2011). Raw sewage and slaughter house effluent characteristics if untreated may cause dissemination of *E. coli* in the environment (Kabiu et al., 2015). Contamination with *E. coli* in abattoir remains a persistent problem which has negative impact on human health and natural environments (Camizalez-Roman et al., 2016).

The susceptibility pattern of *E. coli* from the various locations had almost the same pattern with only a slight variation. *E. coli* from Uwanse was highly susceptible to Ofloxacin (87.1%), Gentamicin (54.5%) and Nitrofurantoin (30.0%). *E. coli* from Mount Zion showed similar pattern with only a change in the percentage susceptibility of 95.5%, 60.4% and 47.4% respectively. *E. coli* isolates from Amika Utuk had a slight deviation with 92.6% susceptibility to Ofloxacin, 64.2% to Gentamicin and 28.4% to Imipenem while Nitrofurantoin and Ciprofloxacin had a sensitivity of 12.4% respectively. This showed that Ofloxacin and Gentamicin might be the only drugs that still have potential in the treatment of infections caused by these *E. coli* isolates.

The *E. coli* isolates were found to have high resistance to most of the antibiotics used in this study. *E. coli* from the three locations (Uwanse, Mount Zion and Amika Utuk) showed resistance to most of the antibiotics used with the isolates having less resistance (<50%) to only three or four antimicrobials as the case maybe according to the location. High resistance rate in *E. coli* was reported by Igwaran et al.(2018).

Similar results were also obtained by Tesfaye et al. (2019). However, this differs from a study on *E. coli*isolated from Amsterdam meat chickens which showed 63.1% susceptibility to tested antimicrobials (Abraham et al., 2019). The problem of antibiotic resistant bacteria occurring in the environment is the serious threat it poses to public health, the higher disease burden it adds and the fact that the antibiotics effectiveness is reduced leading to increased mortality rate (Amaya et al., 2012; Igwaran et al., 2018) The high resistance of *E. coli* isolates to Ampicillin (80%), Augmentin (66.7%), Cotrimoxazole (66.7%) is in agreement with Ahmed et al. (2013), Atuanya et al. (2018) and Gautam et al. (2019).

Sanjukta et al. (2016) corroborated this work by reporting 74.5% resistance to Cefuroxime although they recorded 68.1% resistance to Gentamicin. Somda et al. (2018) in

Burkina Faso reported 100% sensitivity to Ciprofloxacin, Gentamicin and Chloramphenicol with 42.86% resistance in Ampicillin which contrasted with the current work. Partial agreement with this work was observed by Rahmen et al. (2017) who recorded 100% sensitivity to Ciprofloxacin and Gentamicin with 71.43% resistance to Azithromycin and Cotrimoxazole respectively. Varied results were obtained by Adzitey, (2020) who recorded 95.56% sensitivity to Ciprofloxacin, 82.22% sensitivity to Cotrimoxazole and 75.56%% sensitivity to Gentamicin. Similar results were also reported by Zhao et al. (2012) and Rasmussen et al. (2015) in Ghana and US.

Studies have shown a steady increase in the in the occurrence of highly resistant *E. coli* probably because of horizontal gene transfer (Fair and Tor, 2014). *E. coli* resistance is of great public health importance as they are the most common gram-negative bacterial infections in humans. Its resistance to ESBLs has been recorded to be on steady rise in Europe (EMA, 2009). Waterborne *E. coli* have been found to be a major reservoir of antimicrobial resistance including ESBL and K. pneumonia carbapenamase mechanism among others (Haberacht et al., 2019). It is worthy to note that ESBL positive strains in bacteramia have also shown increased cross resistance to fluoroquinolones (>80%) and Gentamicin (>40%) (Livermore et al., 2008).

Fluoroquinolone resistant *E. coli* have been isolated lately. (Rudolf et al., 2008; Fair and Tor, 2014). A high intermediate response was observed with Ciprofloxacin. *E. coli* isolates from Uwanse had 57.4% intermediate sensitivity to Ciprofloxacin, while Mount Zion and Amika Utuk recorded 61.7% and 77.8% intermediate sensitivity respectively. This shows that increased dosage of this drug is needed when in use for the treatment of associated *E. coli* infections.

Several studies have established high susceptibility of organisms to fluoroquinolones (Adanaike et al., 2013). However, some researchers associate intermediate response to resistance as the organisms might be in an intermediate process of acquiring resistance, a pointer to abuse or probable misuse of this drug in the treatment of both human and animal bacterial infections.

Most *E. coli* isolates from this study were found to be multidrug resistant (resistance to three or more classes of antimicrobials (Magiorakos et al., 2012)). Alvarez-Fernandoz et al. (2013) reported 91.7% multidrug resistant *E. coli* from poultry while Rahmen et al. (2017) recorded 76.0 % multidrug resistance from chicken meat and 57.14% from beef in Bangladesh.

According to Sharada et al. (2010), the varied antibiogram results indicate variation of antibiotic pattern with isolates time and multidrug resistance development among different *E. coli* isolates found to be related to transmissible R factor/plasmid. Multiple drug resistance was observed in *E. coli* from the three locations.

This finding is supported by Bekele et al. (2014), Adetunji et al. (2014) and Igwaran et al. (2018). The development of drug resistance in *E. coli* and other Gram negative bacteria can be linked to indiscriminate use of antibiotics in humans and food producing animals, selective pressure to extensive use of antibiotics in the animal industry and indiscriminate dumping of antibiotics in the environment.

Most of the *E. coli* (99.8%) isolates in this study had Multiple antibiotic resistance (MAR) index greater than (>) 0.2, with many of the *E. coli* isolates having MAR index of 0.8 in all the abattoirs investigated. MAR index is a measure of extent of resistance to antibacterial agent and gives an indirect suggestion of the probable source of the organism with MAR values >0.2 indicating isolates recovered from high risk sources where strict rules concerning antibiotic prescription and usage are lacking (Adenaike et al., 2013).

5. CONCLUSION

The result of this study showed high prevalence of *E. coli* in the three abattoir wastewaters investigated. This high prevalence is an indication of the unhygienic nature of the environment and production facilities, the water quality and processes in the abattoirs. The increased resistance of the isolates to the antibiotics used in this study shows that the discharge of the untreated abattoir wastewater into the environment (soil, water and vegetation) could not only increase the spread of antibiotic resistant *E. coli* but the spread of other antibiotic resistant bacteria which is possible through the various mechanisms of transfer of antibiotic resistance. This study demonstrates that the *E. coli* isolates from abattoir wastewaters are multidrug resistant hence they may pose serious public health threats. Observation of good hygiene practices in and around the abattoir environments, treatment of abattoir wastewaters before discharge into the environment and the active participation of State Environmental Protection Agency and Environmental Health officials in monitoring and enforcement of health and safety protocols are recommended in order to minimize the spread of antimicrobial resistance.

References

[1] Abiade Paul CU, Kene IC, Chah KF (2005). Occurrence and antibiogram of Salmonellae in effluents from Nsukka Municipal abattoir. *Nig Vet J.* 27(1): 48-53

[2] Abraham S, O'Dea M, Sahibzada S, Hewson K, Pavic A, Veltan T, Abraham R, Harris T, Trott DJ, Jordan D (2019). *Escherichia coli* and Salmonella spp isolated from Australian meat chickens remain susceptible to critically important antimicrobial agents. *Plos One,* 14(10): e0224281

[3] Abu GO, Egenonu C (2008). The current pollution studies of the new Calabar River in Niger Delta region of Southern Nigeria: A survey of antibiogram profiles of its bacterial isolates. *Afr. J. Environ. Sci. Technol.* 2: 134-141

[4] Adenaike O, Olonitola OS, Ameh JB, Whong CMZ, (2013). Incidence of Extended Spectrum -lactamase Producing Bacteria and Multidrug Resistance Strains from Processed Meat Suya Sold in a University Community. *Int. J. Eng. Sci.* 2(12), 1-6

[5] Adesemoye AO, Opere BO, Makinde SCO (2006). Microbial content of abattoir wastewater and its contaminated soil in Lagos, Nigeria. *Afr J. Biotechnol,* 5 (20): 1963-1968

[6] Adetunji VO, Adesokan HK, Agada CA, Isola TO (2014) Bacterial load and antimicrobial profile of *Escherichia coli* and Listeria spp isolates from muscle tissues of slaughtered cattle at a major abattoir in Ibadan, South Western, Nigeria. *J. Basic Appl. Sci.* 10: 299-305

[7] Adeyemo OK (2002). Unhygienic operations of a city abattoir in South Western Nigeria: environmental implication. *Afr. J. Assess. Man.* 4(1): 23-28

[8] Adzitey F (2020). Incidence and antimicrobial susceptibility of *Escherichia coli* isolated from beef (meat muscle, liver and kidney) samples in Wa abattoir, Ghana. *Cogent food Agric.* 6(1), 1718269

[9] Allen HK, Donato J, Wang HH, Cloud-Hansen KA, Davies J, Handelsman J (2010). Call of the wild: Antibiotic resistance genes in natural environments. *Nat. Rev. Microbiol.* 8: 251-259

[10] Alvarez-Fernandez E, Cancelo A, Diaz-Vega C, Capita R, Alonso-Callega C (2013). Antimicrobial resistance in *E. coli* isolates from conventionally and organically reared poultry: A comparison of agar disc diffusion and sensi-test Gram negative methods. *Food Cont*. 30: 227-234

[11] Amaya E, Reyes D, Paniagua M, Calderon S, Rashid MU, Colque P, Kuhn I, Mollby R, Weintraub A, Nord CE (2012). Antibiotic resistance patterns of *Escherichia coli* isolates from different aquatic environmental sources in Leon, Nicaragua. *Clin. Microbiol. Infect.* 18: 347-354

[12] Aradhye AA, Kolhe RP, Bhong CD, Deshpande PD, LLokhande SD, Godse BN (2014). Prevalence of antimicrobial resistant pathotypes of Escherichia coli in beef cattle and slaughterhouse premise. *Afr. J. Microbiol. Res.* 8(3): 277-286

[13] Atuanya EI, Nwogu NA, Orah CU (2018). Antibiotic resistance and plasmid profiles of bacteria isolated from Abattoir effluents around Ikpoba river in Benin city. *Nigeria. J. Appl. Sci. Environ. Man.* 22(11): 1749-1755

[14] Aworh MK, Kwaga J, Okolocha E, Mba N, Thakur S (2019). Prevalence and risk factors for multi-drug resistant *Escherichia coli* among poultry workers in the Federal Capital Territory, Abuja, Nigeria. *Plos One*, 14(11): e0225379

[15] Barbosa TM, Levy SB (2000). The impact of antibiotic use on resistance development and persistence. *Drug. Resist. Updates,* 3: 303-311

[16] Bauer AW, Kirby MDK, Sherris JC, Turck M (1996) Antibiotic susceptibility testing by standard single disc diffusion method. *Am J. Clin. Pathol.* 45, 493

[17] Bekele T, Zewde G, Tefera, G, Feleke A, Zerom Z (2014). Escherichia coli O157:H7 in raw meat in Addis Ababa, Ethiopia: Prevalence at an abattoir and retailers and antimicrobial susceptibility. *Int. J. Food Cont.* 1(4): 1-8

[18] Benka-Coker M, Ojior O (1995). Effects of slaughter house waste on the water quality of Ikpoba river. Nigeria. *Biores. Technol.* 52(1): 5-12

[19] Bhullar K, Waglechner N, Pawlowski A, Koteva K, Banks ED, Johnston MD, Barton HA, Wright GD (2012). Antibiotic resistance is prevalent in an isolated cave microbiome. *Plos One*, 7(4): e34953

[20] Bhunia AK (2008). Food-borne microbial pathogens: Mechanisms and Pathogenesis. Springer New York, NY

[21] Cabral Joao, P. (2010). Water Microbiology: Bacterial pathogens and water. *Int. J. Environ. Res. Pub. Health*, 7 (10), 3657-3703

[22] Canizalez-Roman A, Flores-Villasenor HM, Gonzalez-Nunez E, Velazquez-Roman J, Vidal JE, Muro-Amador S, Alapizco-Castro,G, Diaz-Quinonez JA, Leon-Sicairos N (2016). Surveillance of diaaheagenic Escherichia coli strains isolated from diarrhea cases from children, adults and elderly at Northwest of Mexico. *Front. Microbiol*. 7: 1924

[23] D'Costa VM, King CE, Kalan L, Morar M, Sung WWL, Schwarz C, Frese D, Zazula G, Calmels F, Debruyne R, Golding GB, Poinar HN, Wright GD (2011). Antibiotic resistance is ancient. *Nature*, 447: 457-461

[24] Dethlefsen L, Huse S, Sogin ML, Relman DA (2008). The pervasive effects of an antibiotic on the human gutmicrobita, as revealed by deep 16S rRNA sequencing. *Plos Biology*, 6(11): e280. doi: 10.1371/journal.pbio.0060280

[25] Fair RJ, Tor Y (2014). Antibiotics and bacterial resistance in the 21st century. *Perspect Medicinal Med.* 6: 25-64

[26] Feng P, Weagant SD, Grant MA, Burkhardt W (2017). Bacteriological analytical manual (BAM), Enumeration of Eschrichia coli and the coliform bacteria. Retrieved from https://www.fdo.gov/food/laboratory-methods-foods/bam-4-enumeration-escherichia-coli-and-coliform-bactreia

[27] Finley RL, Collington P, Larsson DGJ, McEwen SA, Li XZ, Gaze HM, Reid-Smith R, Timinouni M, Graham DW, Topp E (2013).The scourge of antibiotic resistance: The important role of the environment. *Clin. Infect. Dis.* 57 (5): 704-710

[28] Forsberg KJ, Reyes A, Wang B, Selleck EM, Sommer MOA, Dantas G (2012). The shared antibiotic resistome of soil bacteria and human pathogens. *Sci.* 337: 1107-1111.

[29] Frank C, Werber D, Cramer JP, Askar M, Faber M, an der Heiden M, Bernard H, Fruth A, Prager R, Spode A, Wadl M, Zoufaly A, Jordan S, Kemper MJ, Follin P, Müller L, King LA, Rosner, B, Buchholz U, Stark K, Krause G, HUS Investigation Team (2011). Epidermic profile of shiga-toxin producing E. coli O104:H4 outbreak in Germany. *N. Engl, J. Med.* 365(19), 1771-1780

[30] Gautam N, Poudel R, Lekhak B, Upreti MK (2019). Antimicrobial susceptibility pattern of Gram negative bacterial isolates from raw chicken meat samples. *TUJM*, 6(1): 89-95

[31] Gullberg E, Cao S, Berg OG, Ilbäck C, Sandegren L, Hughes D, Andersson DI (2011). Selection of resistant bacteria at very low antibiotic concentrations. *Plos Pat.* 7(7): e1002158

[32] Haberecht HB, Nealon NJ, Gilliland JR, Holder AV, Runyan C, Oppel RC, Ibrahim HM, Mueller L, Schrupp F, Vilchez S, Antony L, Scaria J, Ryan EP (2019). Antimicrobial-resistant *Escherichia coli* from Environment waters in Nothern Colarado. *J. Environ. Pub. .Health*, 2019: 3862949

[33] Igwaran A, Iweriebor BC, Okoh AI (2018). Molecular characterization and antimicrobial resistance pattern of Escherichia coli recovered from wastewater treatment plants in Eastern Cape South Africa. *Int. J. Environ. Res. Pub. Health*, 15: 1237

[34] Jernberg C, Lofmark S, Edlund C, Jansson JK (2010). Long-term impacts of antibiotic exposure on the human intestinal microbiota. *Microbiol* 156: 3216-3223

[35] Kabiru LM, Bello MK, Junaid G, Laura MS (2015).Detection of pathogenic Escherichia coli in samples collected at an abattoir in Zaria, Nigeria and at different ppoints in the surrounding environment. *Int. J. Environ.Res. Pub. Health*, 12: 679-691

[36] Kristiansson E, Fick J, Janzon A, Grabic R, Rutgersson C, Weijdegård B, Söderström H, Larsson DGJ (2011). Pyrosequencing of antibiotic-contaminated river sediments reveals high levels of resistance and gene transfer elements. *Plos One* 6(2): e10738

[37] Krumperman PH (1983). Multiple antibiotis resistance indexing of E. coli to identify high risk sources of fecal contamination of foods. *Appl. Environ. Microbiol.* 46(1), 165-170

[38] Laing CR, Zhan Y, Gilmour MW, Allen V, Johnson R, Thomas JE, Gannon VP. (2011). A comparison of Shiga-toxin 2 bacteriophage from classical enterohemorrhagic Escherichia coli serotypes and the German E. coli O104: H4 outbreak strain. *Plos One*, 7(5): e37362

[39] Livermore DM, Hope R, Brick G, Lillie M, Reynolds R (2008). Non-susceptibility trends among Enterobacteriaceae from bacteramiae in the UK and Ireland 2001-. 06. *J. Antimicrob. Chem.* 62(2), 1141-1154

[40] Magiorakos AP, Srinivasan A, Carey RB, Carmeli Y, Falagas ME, Giske CG, Harbath S, Hindler JF, Kahlmeter G, Olsson Liljequist B, Paterson DL, Rice .B, Stelling J, Struelens MJ, Vatopoulos A Weber JT (2012). Multidrug-resistant, extensively drug resistant and pan drug resistant bacteria: an international expert proposal for interim standard definitions for acquired resistance. *Clin. Microbiol. Infect.* 18: 268-281

[41] Marathe NP, Regina VR, Walujkar SA, Charan SS, Moore ERB, Larsson DGJ, Shouche YS (2013). A treatment plant receiving wastewater from multiple bulk drug manufacturers is a reservoir for highly multi-drug resistant integron-bearing bacteria. *Plos One,* 8(10): e77310

[42] Martinez JL (2008). Antibiotics and antibiotic resistance genes in natural environments. *Sci.* 321: 365-367

[43] Martinez JL, Fajardo A, Garmendia L, Hernandez A, Linares JF, Martinez-Solano L, Sánchez M B (2009). A global view of antibiotic resistance. *FEMS Microbiol. Rev*. 3: 44-65

[44] Moawad AA, Hotzel H, Awad O, Tomaso H, Neubauer H, Hafez HM, El-Adawy H (2017). Occurrence of Salmonella enteric and Escherichia coli in raw chicken and beef meat in Nothern Egypt and dissemination of antibiotic resistance markers. *Gut Pat.* 9: 57-69

[45] Nafarnda WD, Ajayi IE, Shawul JC, Kawe MS, Omeiza, GK, Sani NA, Tenuche OZ, Dantong DD, Tags SZ. (2012). Bacteriological quality of abattoir effluents discharged into water bodies in Abuja, Nigeria. *ISRN Vet Sci* 2012: 515689. doi: 10.5402/2012/515689

[46] Nafarnda WD, Yaji A, Kubkomawa HI (2006). Impact of abattoir waste on aquatic life: a case study of Yola. *Global J. Pure Appl. Sci.* 12 (1): 31-33

[47] Nwanta JA, Onunkwo JI, Ezenduka E (2010). Analysis of Nsukka metropolitan abattoir solid waste and its bacterial contents in South Eastern Nigeria: Public health implication. *Arc. Environ. Occ. Health*, 65(1): 21-26

[48] Omeregbe FB, Ebar EE, Nevkaa DN (2017). Antibiotic susceptibility and microbial analysis of Enterobacteriaceae from wastewater and sediments from abattoirs in Makurdi, Benue State, Nigeria. *Int. J. App. Microbiol. Biotechnol. Res.* 5 (2017): 103-109

[49] Osibanjo O, Adie GU (2007). Impact of effluent from Bodja abattoir on the physicochemical parameters of Oshunkaye stream in Ibadan City, Nigeria. *Afr. J. Biotechnol.* 6(15): 1806-1811

[50] Rahman MA, Rahman AKMA, Islam MA, Alam MM (2017). Antimicrobial resistance of Escherichia coli isolated from milk, beef and chicken meat in Bangladesh. *Bang, J. Vet. Med.* 15(2): 141-146

[51] Ram S, Vajpayee P, Singh RL, Shanker R (2009). Surface water of perennial river exhibits multi-antimicrobial resistant Shiga toxin and enterotoxin producing Escherichia coli. *Ectotoxicol Environ Safety,* 72: 490-495

[52] Ram, S., Vajpayee, P., Singh, R. L. and Shanker, R. (2009). Surface water of perennial river exhibits multi-antimicrobial resistant Shiga toxin and enterotoxin producing Escherichia coli. *Ecotoxicol. Environ. Safety*, 72: 490-495

[53] Rasmussen MM, Opintan JA, Frimodt-Moller N, Styrishave B (2015). Beta-lactamase producing Escherichia coli isolates in importedand locally produced chicken meat from Ghana. *Plos One,* 10: e0139706

[54] Rudolf AC, Leclercq R, Debbis EA, Canton R, Oppenheim BA Dowzicky MJ (2008). Comparative analysis of antimicrobial susceptibility among organisms from France, Germany, Italy, Spain and the UK as part of the Tigecycline evaluation and surveillance trial. *Clin. Microbiol. Infect.* 14(4): 307-314

[55] Sanjukta R, Dutta JB, Sen A, Shakuntala I, Ghatak S, Puro AK, Das S, Huidrom S, Dey TK, Purkait D, Dutta A, Das BC (2016). Characterization of multidrug-resistant Escherichia coli and Salmonella isolated from food producing animals in Northeastern India. *Int. J. Infect. Dis.* 45(1):114-115

[56] Segura PA, Francois M, Gagnon C, Sauve S (2009). Review of the occurrence of anti-infectives in contaminated wastewaters and natural and drinking waters. *Environ. Health Perspect.* 117: 675-684

[57] Sharada R, Wilfred RS, Thiyageeswaran M (2010). Isolation, characterization and antibiotic resistance pattern of Escherichia coli isolated from poultry. *Am-Eu J. Sci. Res.* 5: 18-22

[58] Sherer BM, Miner RJ, Moore JA, Buckhouse JC (1992). Indicator bacterial survival in stream sediments. *J. Environ. Quality*, 21(4): 591-595

[59] Somda NS, Bonkoungou OJ, Zongo C, Kagambèga A, Bassole IHN, Traore Y, Mahillon J, Scippo M, Hounhouigan JD, Savadogo A (2015). Safety of Ready-To-Eat Chicken in Burkina Faso: Microbiological Quality, Antibiotic Resistance, and Virulence Genes in Escherichia coli Isolated From Chicken Samples of Ouagadougou. *Food Sci. Nut.* 6(4): 1077-1084

[60] Tesfaye H, Alemayehu H, Desta AF, Eguale T (2019) Antimicrobial susceptibility profile of selected Enterobacteriaceae in wastewater samples from health facilities, abattoir, downstream rivers and a WWTP in Addis Ababa, Ethiopia. *Antimicrob. Resist. Infect. Cont.* 8: 13

[61] Thanigaivel G, Anandhan AS (2015). Isolation and characterization of microorganisms from raw meat obtained from different market places in and around Chennai. *J Pharm Chem Biol Sci.* 3(2): 295-301

[62] Vinué L, Saénz Y, Somalo S, Escudero E, Moreno M. A, Ruiz-Larrea F, Torres C (2008). Prevalence and diversity of integrons and associated resistance genes in fecal Escherichia coli isolates of healthy humans in Spain. *J. Antimicrob. Chem.* 62: 934-937

[63] Von Baum H, Marre R (2005). Antimicrobial resistance of Escherichia coli and therapeutic implications. *Int. J. Med. Microbiol.* 295: 503-511

[64] Wellington EM, Boxau AB, Cross P, Feil EJ, Gaze WH, Hawkey PM, Johnson-Rollings AS, Jones DL, Lee NM, Otten W, Thomas CM, Williams AP (2013). The role of the natural environment in the emergence of antibiotic resistance in gram-negative bacteria. *The Lancet Infect. Dis.* 13: 155-165

[65] Yakubu AA, Garba HS, Habibullah SA (2007). A microbial and chemical assessment of abattoir effluent used for vegetable irrigation in Sokoto, Nigeria. *Sahel J. Vet. Sci*. 6: 1-4

[66] Zhao S, Blickenstall K, Bodes-Jones S, Gaines SA, Tong E, McDermott PF (2015). Comparison of the prevalence and antimicrobial resistances of Escherichia coli isolates from different retail meats in the United States, 2004-2008. *Appl. Environ. Microbiol*. 78: 1701-1707