Bacterial Profile of Livestock Farms in South-East Nigeria
I. I. Nwosu1, J. N. Ogbulie2, C. I. Chikwendu2, E.E. Mike Anosike2

ABSTRACT
The unregulated practice of livestock production has endangered the public health sector through the multiplication and spread of bacterial pathogens. This study investigated the bacterial profiles of livestock farms in Aba, Umuahia, Okigwe and Mbaise in the Southeastern part of Nigeria. Air was sampled with passive sedimentation technique; water samples were collected randomly from the farm water sources while hand swabs from the farmers and feeds were collected with sterile swab sticks and containers respectively. Total heterotrophic bacterial count (THBC) was analyzed by pour plate method; total coliform count (TCC) was determined by membrane filter technique while total potential pathogenic bacterial count (TPPBC) was examined by growing the samples in some selective agar media. Of the four cities studied, Aba had the highest THBC (28.43±0.3×10⁵, 26.70±0.7×10⁵, 26.26±0.5×10⁵ CFU/ml), TPPBC (17.47±0.5×10⁵ CFU/ml and 20.02±0.5×10⁵ CFU/ml) and TCC (24.06±0.4×10⁵, 17.93±0.6×10⁵ and 22.36±0.4×10⁵ CFU/ml) for pig, cow and poultry farms respectively while Mbaise had the least value. A total of thirteen (13) bacterial species were isolated in the study but, only Escherichia coli, Staphylococcus aureus, Klebsiella sp., Salmonella sp., Proteus mirabilis and Bacillus subtilis were commonly distributed in the four cities. Bacillus subtilis, Salmonella sp. and Staphylococcus aureus were isolated more in Okigwe, Abu and Umuahia respectively than Mbaise. Salmonella sp. (60.00%) had the highest occurrence followed by Staphylococcus aureus (55.33%) while Proteus mirabilis (45.00%) had the lowest occurrence. High bacterial loads were obtained in the study especially in Aba. Livestock farmers should consider proper hygienic measures in order to limit the spread of pathogenic bacteria among surrounding communities.

INTRODUCTION
Livestock farming is currently one of the leading agricultural practices in developing countries that is economically viable and performed both in urban and rural areas (Thornton, 2010). Urban livestock is a farming activity that is practiced within the urban centers. It is an important aspect that develops the urban areas. Apart from the economic impact on cities, urban livestock also produces negative effects for instance, increased health failure, environmental contamination and spread of diseases (Asadu et al., 2021). Livestock farming contributes to climate change which consequently affects the distribution of bacteria and other unhealthy chemical substances (Grossi et al., 2015). Livestock farms are agents of bacterial transmission and animal-related pathogens, especially the antibiotic-resistant strains. Livestock diseases are very significant worldwide based on their effects on the environment and inhabitants. These diseases produce direct effects on human and animal health and negatively affect the economy and food supply (Thornton, 2010; Gebreyes et al., 2020).

Nigeria is geopolitically grouped into six zones including the South-East which is made up of Enugu, Anambra, Imo, Abia, and Ebonyi States. The occupation of the southeasterners is mainly trading, crop production and livestock farming (Nwanta et al., 2011). The zone has so many urban towns with growing populations such as Aba, Umuahia, Okigwe and Mbaise. A lot of urban agricultural activities take place in these towns especially rearing of sheep, goats and pig (Asadu et al., 2021). They are managed in both intensive and semi-intensive systems. Livestock farming generate animal protein for consumers and revenue to the sellers (Nwanta et al., 2011). Most livestock farmers largely venture into pig farming while 65% included poultry, and 31% indulge in goat and sheep production (Nwanta et al., 2011). These animals are sources of direct and indirect disease spread. Microbial pathogens are transmitted via excreta, urine and flesh of animal hosts. They can also be isolated from feeds, drinking water, rain splashes, feeding troughs and hands of farmers (Alegbeleye et al., 2018).

Microorganisms are microscopic living organisms that survive either in their natural environment or in the body of both animals and humans. They are an important part of atmospheric particulate matter, water bodies, soil and are closely associated with human health. The growth and spread of these microbes are dependent on the available nutrients, hosts and locations (Köhl et al., 2019). Bacteria are the most highly bountiful microbes in livestock farms. Their ubiquity and survival mechanisms within and outside of the hosts make them most successful in disease transmission among other pathogens. They are distributed through mediums such as urine, faeces and hides of livestock and from their aerosols (Klous et al., 2016). Several strains of pathogenic bacteria such as Escherichia coli, Vibrio sp., Shigella sp. and Salmonella sp and

1 Department of Medical Laboratory Sciences, Abia State College of Health Sciences and Management Technology, Aba, Abia State, Nigeria.
2 Department of Microbiology, School of Science, Federal University of Technology Owerri, Imo State, Nigeria
3 Corresponding author's e-mail: jjaylin2007@yahoo.com
some non-pathogenic bacteria have been isolated from air, water and soil (Ugbogu et al., 2016). Through human and animal activities, these bacteria are spread thereby resulting in infectious diseases (Ali et al., 2021). This study is aimed at determining the bacterial species that are predominant in the livestock farms in four cities of the southeast.

**METHODOLOGY**

**Study Area**

The study was conducted in the four most populated cities in Nigeria’s South-East region, namely Aba, Umunahia (Abia State) and Okigwe, Mbaise (Imo State). The selection of the cities was based on random sampling where livestock activities are predominant. The samples were collected from urban areas where livestock farming is vigorously practiced. These four cities stretch from latitude 4°50’ to 7°20’ N and longitude 6°51’ to 8°20’ E. It has common boundary with Benue State in the North, in the East it is bounded by Cross River and Akwa Ibom States, in the West by Delta State and River Niger (Kalu & Zakiora, 2019).

The zone has diverse ecological variations and land mass of 22,525 km² (Madu, 2006). Its annual rainfall is between March and October while the dry season starts from November and ends in February (Kalu & Zakiora, 2019). The study was conducted in the four most populated cities of the four states using scientific standards. Hand swabs of the livestock workers were also collected with sterile swab sticks in all the farms.

**Air Quality Sampling**

Passive air sampling was performed using settle plates. Freshly prepared nutrient agar (NA), blood agar (BA), Salmonella-Shigella agar (SSA), MacConkey (MCA) and Thiosulphate citrate bile salt sucrose (TCBS) plates were allowed to solidify and dry. The plates were exposed at the height of 1.5 m above the ground for 60 min at various locations in the poultry farm, cow ranches and pig farms. The samples were sealed, labeled appropriately, put inside sterile polythene bags, transported to the laboratory, and incubated at 30°C for 24 h for bacterial growth. The experiment was repeated in triplicate and expressed as CFU/plate/hour.

**Soil Quality Sampling**

Briefly, 2 kg of soil samples were collected in sterile polythene bags using soil auger at 30 cm depth (Bhat et al., 2011). The soil samples were collected from different locations in the pig farm, poultry farm and cow farm. Soil samples were placed on ice in a cooler box immediately after collection and transported to the laboratory for analysis.

**Hand Swab Sampling**

Hand swab samples were collected with sterile swab sticks from the hands of the livestock farmers and properly labeled. In the laboratory, 5 ml of normal saline was transferred into the swab sticks and allowed to stand for 10 min. Thereafter, ten-fold serial dilution (10⁻¹-10⁻⁶) was performed with the solution, and appropriate dilution inoculated on agar plates and incubated (Sampson et al., 2019).

**Heterotrophic Bacteria**

After ten-fold serial dilution, 1 ml from 10⁻⁴ was pipetted onto NA plates in triplicates. The discrete colonies in each NA plate were counted and recorded in CFU/ml for water, soil, hand swabs and feed samples and CFU/plate/hour for air sample. Plates with colonies between the ranges of 30-300 were counted. The heterotrophic bacterial count was recorded as total heterotrophic bacterial count (THBC).

**Total Coliform Bacterial Count**

**Water**

TCC was performed using membrane filter technique according to method described by Harley and Prescott (2002) with slight modification. Briefly, after serial dilution, 100 ml of the water sample from 10⁻⁴ dilution was transferred onto a membrane filter with pore size of 0.45 µm. After filtration, the absorbent paper was dried carefully on the MacConkey agar plate with sterile tweezers. The plates were incubated at 30°C for 24 h. After incubation, total coliform bacterial colonies were enumerated with the help of a magnifying glass.

**Soil**

Ten-fold serial dilution (10⁻¹-10⁻⁷) was performed according to the method described by Adhikari et al. (2007) with slight modifications. Briefly, 10 g of soil was suspended into 90 ml of distilled water and mixture shaken properly. After serial dilution, 50 ml filtrate from 10⁻⁴ was transferred onto a membrane filter (0.45 µm). The absorbent paper after filtration was transferred onto MacConkey agar plate and incubated for 24 h at 30°C. For confirmation, inoculum from the MacConkey agar plate were inoculated in tubes containing 10 ml of lactose bile broth. The mixture was incubated for 24 h at 30°C for fermentation to occur.

**Hand Swab**

A ten-fold serial dilution (10⁻¹-10⁻⁴) was conducted,
thereafter 1 ml from the 10^4 dilution was inoculated onto MAC plate using spread plate technique for 24 h at 37°C.

**Total Potential Pathogenic Bacteria**

TPPB was enumerated with selective media selected for potential pathogenic bacteria. SSA for *Salmonella* sp. and Shigella sp.; TCBS for *Vibrio cholerae* and *Vibrio parahaemolyticus;* EMB for *Escherichia coli* and *Enterobacter aerogenes;* MSA for *Staphylococcus aureus;* Blood agar for *Streptococcus pyogenes* and MCA for *Pseudomonas aeruginosa.* For air samples, each plate was exposed to air for 60 min; aliquots from water, soil and feeds were seeded onto the media plates while hand swabs were inoculated onto the plates. After incubation for 24 h at 30°C, the bacterial species were identified based on their colony appearances (Lama et al., 2013). The colonies on each plate were counted with magnifying glass.

**Feed**

Total heterotrophic bacterial count, total potential pathogenic bacterial count and total coliform counts were performed according to the method described by Onyeagba (2015) and Adhikari et al. (2007) with slight modifications.

**Characterization and Identification of Bacterial Isolates**

The bacterial isolates were characterized based on their colonial/cultural characteristics, macroscopic and microscopic appearances including elevation, margin, colour, size and surface texture and afterwards, biochemical reactions. The isolates were further confirmed by culturing them in selective media. These approaches were done according to the method described by Buchanan and Gibons, 1974.

**Isolation and Maintenance of Pure Culture**

The representative bacterial colonies were sub-cultured on freshly prepared nutrient agar plates by streaking. The pure cultures were sub-cultured onto nutrient agar slants in bijou bottles and incubated at 30°C. After 24h, the slants were kept in the refrigerator at -4°C for storage until further processing.

**Statistical Analysis**

The results were expressed as mean± SD using graph pad prism graphical statistical package version 5. The student t-test at p<0.05 was applied to assess the difference between the mean for variables in triplicates and two-way analysis of variance (ANOVA) for more than two variables followed by Bonferreni post hoc test.

**RESULTS AND DISCUSSION:**

**Bacteria Profile of the Pig Farms in the Four Southeastern Cities**

The total heterotrophic bacteria count (THBC) from the pig farms varied between 6.13±0.6×10^5 and 28.43±0.3×10^6 CFU/ml while total potential pathogenic bacteria count (TPPB) ranged from 9.83±1.0×10^5 to 26.23±0.4×10^5 CFU/ml. The value obtained for total coliform bacteria count (TCC) was between 12.73±0.5×10^5 and 24.06±0.4×10^5 CFU/ml. Of the four cities, Aba (28.43±0.3×10^5, 24.06±0.4×10^5, 26.23±0.4×10^5 CFU/ml) had the highest values. THBC (TCC) were higher in soil samples while hand swabs of workers had higher TPPBC than other samples. Air samples had the least counts of bacteria. The THBC, TPPBC and TCBC of samples obtained from air, water, soil, feeds and hand swabs of farmers in pig farm are shown in Table 1.

**Bacteria Profile of the Cow Farms in the Four Southeastern Cities**

THBC of air, soil and hand swabs from the cow ranged from 10.50±0.6×10^5 to 26.70±0.7×10^5 CFU/ml; TPPBC had values between 9.26±0.5×10^5 and 17.47±0.5×10^5 CFU/ml. The values of TCC were between 9.03±0.6×10^5 and 18.33±0.5×10^5 CFU/ml. In Aba and Mbaise, the highest value for THBC and TPPBC (26.70±0.7×10^5 and 17.47±0.5×10^5 CFU/ml) respectively were obtained. Soil samples had the highest bacterial count (Table 2).

**Bacteria Profile of the Poultry Farm in the Four Southeastern Cities**

From Table 3, the THBC varied between 9.53±0.8×10^4 and 26.26±0.5×10^4 CFU/ml; TPPBC was within the range of 9.86±0.4×10^3 to 20.20±0.1×10^4 CFU/ml while the values 9.97±0.8×10^3 to 22.36±0.4×10^5 CFU/ml were for TCC. The highest counts of THBC (26.26±0.5×10^4 CFU/ml) were obtained in Aba and Mbaise. TPPBC and TCC were more only in Aba (20.20±0.5×10^4 and 22.36±0.4×10^5 CFU/ml) respectively. The hand swabs of workers produced the highest count for TPPBC while highest amount of THBC and TCC appeared more in soil samples. Result for the enumeration of bacteria in poultry farm is shown in Table 3.

**Distribution of Bacteria in Aba, Umuahia, Okigwe and Mbaise**

Of the thirteen different bacterial strains isolated from the four cities, only six, namely *Escherichia coli,* *Staphylococcus aureus,* *Klebsiella sp.,* *Salmonella sp.,* *Proteus mirabilis* and *Bacillus subtilis* were commonly distributed among the four cities (Table 4).

**Percentage Bacterial Occurrence in Aba, Umuahia, Okigwe and Mbaise**

*Salmonella* sp (60.00%) obtained from Aba were significantly higher (p<0.01) than those obtained from Umuahia (25.00%), Okigwe (18.33%) and Mbaise (32.33%). *Staphylococcus aureus* (55.33%) in Umuahia was appreciably higher (p<0.05) than others (50.00%, 15.67% and 8.33%) obtained. In Okigwe, *Bacillus subtilis* (38.33%)
obtained was significantly (p<0.01) higher than the other three cities 15.00% (Aba), 24.00% (Umuahia) and 19.00% (Mbaise). From the result, the livestock in Mbaise had the lowest percentage bacterial occurrence while Aba had the highest. *Proteus mirabilis* was the least isolated bacteria in all the cities while *Salmonella sp.*, *Klebsiella sp.* and *Escherichia coli* were predominantly isolated. Result for the percentage bacterial occurrence of bacteria commonly distributed in Aba, Umuahia, Okigwe and Mbaise is presented in Figure 1. Values with different numbers as superscripts within a row for the same parameter are significantly different (p<0.05; p<0.01; p<0.001; p<0.0001). Values with similar numbers as superscripts within a column are not significantly different (p>0.05). Each alphabet represents similar parameter within a column. 

**Table 1:** THBC, TPPBC and TCC of air, water soil, hand swabs and seed samples of pig farm in Aba, Umuahia, Okigwe and Mbaise.

|          | Aba   | Umuahia | Okigwe | Mbaise |
|-----------|-------|---------|--------|--------|
| Air       | THBC  | TPPBC   | TCC    | THBC   | TPPBC   | TCC    | THBC   | TPPBC   | TCC   |
| (CFU/plate/hour) | x10^6 | x10^6   | x10^6  | x10^6  | x10^6   | x10^6  | x10^6  | x10^6   | x10^6 |
| 18.96±0.4 a^1 | 21.33±0.4 b^1 | ND      | 11.36±0.4 a^2 | 20.23±0.4 b^2 | ND      | 12.20±0.3 a^3 | 17.50±0.5 b^3 | ND      | 13.20±0.3 a^4 | 19.00±0.3 b^4 | ND      |
| Water     | THBC  | TPPBC   | TCC    | THBC   | TPPBC   | TCC    | THBC   | TPPBC   | TCC   |
| (CFU/ml)  | x10^6 | x10^6   | x10^6  | x10^6  | x10^6   | x10^6  | x10^6  | x10^6   | x10^6 |
| 20.33±0.6 a^1 | 12.73±0.7 b^1 | 22.16±0.7 c^1 | 12.30±0.4 a^2 | 11.66±0.2 b^2 | 16.86±0.3 c^2 | 13.23±0.3 a^3 | 20.06±0.3 b^3 | 17.80±0.6 c^3 | 13.96±0.2a^4 | 12.30±0.5 b^1 | 21.00±0.4 c^4 |
| Soil      | THBC  | TPPBC   | TCC    | THBC   | TPPBC   | TCC    | THBC   | TPPBC   | TCC   |
| (CFU/ml)  | x10^6 | x10^6   | x10^6  | x10^6  | x10^6   | x10^6  | x10^6  | x10^6   | x10^6 |
| 28.43±0.3 a^1 | 23.10±0.3 b^1 | 23.26±0.4 c^1 | 22.06±0.2 b^2 | 21.16±0.4 c^2 | 23.33±0.3 a^3 | 20.33±0.5 b^3 | 19.20±0.4 a^3 | 28.16±0.5a^4 | 15.56±0.6 b^1 | 20.46±0.4 c^4 |
| Hand swabs| THBC  | TPPBC   | TCC    | THBC   | TPPBC   | TCC    | THBC   | TPPBC   | TCC   |
| (CFU/ml)  | x10^6 | x10^6   | x10^6  | x10^6  | x10^6   | x10^6  | x10^6  | x10^6   | x10^6 |
| 19.43±0.5 a^1 | 15.46±0.6 b^1 | 20.50±0.7 c^1 | 11.43±0.4 a^2 | 12.83±0.7 b^2 | 14.76±0.6 c^2 | 6.13±0.6 a^3 | 9.83±1.0 b^3 | 12.73±0.5c^3 | 11.46±0.5a^4 | 26.23±0.4 b^1 | 20.36±0.6c^4 |
| Feeds     | THBC  | TPPBC   | TCC    | THBC   | TPPBC   | TCC    | THBC   | TPPBC   | TCC   |
| (CFU/ml)  | x10^6 | x10^6   | x10^6  | x10^6  | x10^6   | x10^6  | x10^6  | x10^6   | x10^6 |
| 21.16±0.4 a^1 | 20.36±1.3 b^1 | 24.06±0.4 c^1 | 14.93±0.3 a^2 | 19.60±0.7 b^1 | 21.53±0.5 c^1 | 12.90±0.3a^3 | 17.56±0.5b^3 | 22.33±0.5c^3 | 14.60±0.5a^4 | 19.23±0.3 b^1 | 19.23±0.5 c^4 |

**Table 2:** THBC, TPPBC and TCC of air, water soil, hand swabs and seed samples of cow farm in Aba, Umuahia, Okigwe and Mbaise.

|          | Aba   | Umuahia | Okigwe | Mbaise |
|-----------|-------|---------|--------|--------|
| Air       | THBC  | TPPBC   | TCC    | THBC   | TPPBC   | TCC    | THBC   | TPPBC   | TCC   |
| (CFU/plate/hour) | x10^6 | x10^6   | x10^6  | x10^6  | x10^6   | x10^6  | x10^6  | x10^6   | x10^6 |
| 18.56±0.3 a^1 | 11.70±0.4 b^1 | ND      | 10.50±0.6 a^2 | 10.33±0.5 b^2 | ND      | 10.66±0.5 a^3 | 10.86±0.3 b^3 | ND      | 11.46±0.5 a^4 | 10.66±0.3 b^4 | ND      |
| Water     | THBC  | TPPBC   | TCC    | THBC   | TPPBC   | TCC    | THBC   | TPPBC   | TCC   |
| (CFU/ml)  | x10^6 | x10^6   | x10^6  | x10^6  | x10^6   | x10^6  | x10^6  | x10^6   | x10^6 |
| ND        | ND     | ND      | ND     | ND     | ND      | ND     | ND     | ND      | ND     |
| Soil      | THBC  | TPPBC   | TCC    | THBC   | TPPBC   | TCC    | THBC   | TPPBC   | TCC   |
| (CFU/ml)  | x10^6 | x10^6   | x10^6  | x10^6  | x10^6   | x10^6  | x10^6  | x10^6   | x10^6 |
| 26.70±0.7 a^1 | 11.70±0.4 b^1 | 17.93±0.6 a^1 | 26.16±0.5 a^1 | 16.46±0.4 b^1 | 16.16±0.3 c^1 | 26.33±0.2 a^1 | 15.60±0.3 b^1 | 16.33±0.5 c^1 | 25.40±0.4 a^2 | 16.20±0.3 b^2 | 15.36±0.4 c^3 |
| Hand swabs| THBC  | TPPBC   | TCC    | THBC   | TPPBC   | TCC    | THBC   | TPPBC   | TCC   |
| (CFU/ml)  | x10^6 | x10^6   | x10^6  | x10^6  | x10^6   | x10^6  | x10^6  | x10^6   | x10^6 |
| 20.16±0.5 a^1 | 10.80±0.3 b^1 | 10.96±0.2 c^1 | 18.20±0.4 a^2 | 9.26±0.5 b^2 | 9.03±0.6 c^2 | 17.80±0.9 a^3 | 9.33±0.5 b^3 | 9.33±0.3 c^3 | 17.16±0.3 a^4 | 9.33±0.4 b^2 | 9.50±0.4 c^3 |
| Feeds     | THBC  | TPPBC   | TCC    | THBC   | TPPBC   | TCC    | THBC   | TPPBC   | TCC   |
| (CFU/ml)  | x10^6 | x10^6   | x10^6  | x10^6  | x10^6   | x10^6  | x10^6  | x10^6   | x10^6 |
| ND        | ND     | ND      | ND     | ND     | ND      | ND     | ND     | ND      | ND     |

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similar numbers as superscripts within a row for the same parameter are not significantly different (p>0.05). Each alphabet represents similar parameter within a column. Key; THBC-Total heterotrophic Bacteria Count; TPPBC-Total Potential Pathogenic Bacteria Count; TCC-Total Coliform Count; ND-Not determined.

Values with different numbers as superscripts within a row for the same parameter are significantly different (p<0.05; p<0.01; p<0.001; p<0.0001). Values with similar numbers as superscripts within a row for the same parameter are not significantly different (p>0.05). Each row for the same parameter are significantly different (p<0.05; p<0.01; p<0.001; p<0.0001). Values with similar numbers as superscripts within a row for the same parameter are not significantly different (p>0.05).

Table 3: THBC, TPPBC and TCC of air, water soil, hand swabs and feed samples of poultry farm in Aba, Umuahia, Okigwe and Mbaise

|          | Aba                      | Umuahia                  | Okigwe                   | Mbaise                   |
|----------|--------------------------|--------------------------|--------------------------|--------------------------|
| Air (CFU/plate/hour) | 15.20 ± 0.4a
| Water (CFU/ml) | 20.70 ± 0.6a
| Soil (CFU/ml) | 26.26 ± 0.4a
| Hand swabs (CFU/ml) | 19.06 ± 0.4a
| Feeds (CFU/ml) | 20.16 ± 0.6a

Table 4: Bacterial distribution in all the four cities

| Isolates               | Aba | Umuahia | Okigwe | Mbaise |
|------------------------|-----|---------|--------|--------|
| Escherichia coli       | +   | +       | +      | +      |
| Klebsiella sp.         | +   | +       | +      | +      |
| Staphylococcus aureus  | +   | +       | +      | +      |
| Enterobacter sp.       | +   | -       | +      | +      |
| Salmonella sp.         | +   | +       | +      | +      |
| Proteus mirabilis      | +   | +       | +      | +      |
| Pseudomonas sp.        | +   | +       | -      | +      |
| Shigella sp.           | +   | -       | +      | -      |
| Vibrio cholera         | +   | +       | -      | +      |
| Vibrio parahaemolyticus | +  | -       | +      | +      |
| Bacillus subtilis      | +   | +       | +      | +      |
| Streptococcus pyogenes | +   | -       | -      | +      |
| Chromobacterium violaceum | + | -       | +      | +      |

Key: + = present; - = absent

DISCUSSION

Livestock farming is a major contributor to small and medium scale enterprises and has been advocated for at both the state and federal levels. The spread of bacteria in livestock farms has been a major challenge in public health sector particularly in the South-East region. Total heterotrophic bacteria are the most multifaceted group of microorganisms with different nutritional and survival requirements. Some are primary colonizers while others are secondary invaders directly deriving their nutrients from the primary colonizers. The compositions of these microbes differ based on the location and nutrient available (Serves et al., 1996). According to World Health Organization (WHO, 2018), the standard bacterial count stipulated for drinking water is approximately 100 CFU/ml. Infectious diseases result when that quantity is exceeded. From this study, THBC was very significant in pig farm (Table 1) cow farm (Table 2) and poultry farm (Table 3) (28.43±0.5×10^3; 26.70±0.7×10^3 and 26.26±0.5×10^3 CFU/ml) respectively. The high values obtained could be attributed to water and soil pollution and improper disposal of waste generated from homes and industries (Ali et al., 2021). These wastes serve as
Figure 1: Percentage occurrence of bacteria in Aba, Umuahia, Okigwe and Mbaise.

breeding sites for bacteria (Agodo et al., 2016). During rainfall, splashes of water from these wastes percolate through underground water and affect the streams while the surrounding area becomes polluted.

THB, TC as well as the hand swabs of livestock keepers were assessed from Air, water, soil and livestock. THBC and TCC were appreciably higher in soil followed by water than air, feeds and hands of keepers. Soil and water support the multiplication of these microbes due to availability of nutrients. High values of THBC and TCC in soil samples is as a result of their ability to tap the available nutrients in soil sediments more than water (Adhikari et al., 2007). According to Adhikari et al. (2007), the availability of nutrient and water retaining capacity of soil bacteria tend to increase their survival rate. Air particles do not have enough resources to sustain microbes; the chemical preservatives used in producing feeds inhibit the survival of bacteria (Soriano, 2020). The TPPBC were seen to increase among hand swabs (26.23±0.4×10^5 and 20.20±0.5×10^5 CFU/ml) of pig and poultry keepers respectively while soil sample (17.47±0.5×10^5 CFU/ml) had the highest TPPBC for cow farm. These increased values could result from improper handling of the excreta, feeds and drinking water of the animals (McAllister and Toppt, 2012) and due to frequent close contact of livestock farmers with their livestock in our area (Klous et al., 2016). Most pathogenic bacteria which colonize the skins and excreta of host animals can be transmitted as zoonotic pathogens to humans (Klous et al., 2016).

Aba, from the results had the highest isolated THB, TC and TPPB. The increase in THBC, TCC and TPPBC in Aba can be attributed to the location of the pig and cow farms and the activities being performed. Aba River, where the research was conducted is a tributary of Imo River and all abattoir activities take place there. The river runs through two local governments in the State, and serve as sites for washing slaughtered animals and burning of hides (Ngozi and Humphrey, 2019). Of the sixteen bacteria isolated from the study (Table 4), only *Escherichia coli*, *Staphylococcus aureus*, *Klebsiella sp.*, *Salmonella sp.*, *Proteus mirabilis* and *Bacillus subtilis* were distributed in the four cities. The bacterial species isolated from the farms in the four cities were in agreement with Adogo et al. (2016).

Percentage occurrence of *Escherichia coli*, *Salmonella sp.*, *Klebsiella sp.*, *Staphylococcus aureus*, *Bacillus subtilis* and *Proteus mirabilis* is shown in Figure 1. *Salmonella sp.* have the highest occurrence at 60.00% while the least occurring bacteria was *Proteus mirabilis* (4.50%). *Bacillus subtilis* appeared more in Okigwe than in all the other cities. *Salmonella spp* are Gram negative rods in the family of Enterobacteriaceae and more than 2,500 serovars have been identified. They are ubiquitous bacteria that survive in dry environments and water bodies for a long time (WHO, 2018). The strains that inhabit the colons of pig and cow according to WHO, are invasive and life threatening to humans and become major concerns to public health. From the study, *Salmonella* species have the highest percentage occurrence especially in Aba. Due to lack of potable drinking water and good roads to assess it, the dwellers depend on the Aba River. They drink, bathe, cook and wash clothes with the water without proper treatment. These activities lead to increase in spread of *Salmonella spp* and *Escherichia coli* which subsequently cause waterborne diseases (Ali et al., 2021). The ability to survive in low moisture environments contributes to their widespread. They have high osmo-tolerant membranes, filamentous cells and strong metabolic process (Finn et al., 2013). In contrast, *Proteus mirabilis* recorded the lowest percentage occurrence. *Proteus mirabilis* is a motile bacterium that survives better in alkaline and urea-rich environments. It causes urinary tract infections, wound infections and kidney stones in humans (Zafar et al., 2019). Their low percentage values in all the four cities can be attributed to the fact that *P. mirabilis* is a human pathogen that is rarely transmitted and isolated in livestock except when a person comes in contact with poultry flesh and droppings (Nahar et al., 2014). The microbe has been reported to be transmitted through person-to-person contacts and food (Zafar et al., 2019).

*Bacillus subtilis* is a spore forming bacterium that is air-borne. The formation of spores is a survival mechanism utilized by *B. subtilis* to thrive even in a challenging environment (Ravine, 2019). Only few literatures attributed *B. subtilis* to causing human diseases. They are reported to be beneficial in medicine as they can be used in producing probiotics, vaccines and enzymes (Piewngam and Otto, 2019; Sun et al., 2018). From the study, Okigwe had the highest percentage of *B. subtilis*. This could result from the economic activities carried out in the city. Livestock farming and crop production are major occupation of Fulani occupants; deliberate disposal of animal dungs, farm waste and pesticides could increase the spread of spores of *B. subtilis* (Jorgensen et al., 2015). Comparing the percentage of occurrence of bacteria in the four cities, it can be seen that Aba had the highest bacterial loads compared with Mbaise that had the least percentage. This could be attributed to the type of economic activity predominant in these two areas.
(Okoro and Ibe, 2017). Aba is a metropolitan city with large population of residents having diverse culture and business inclinations. It is the center for commercial activity in the South-east. As a center for Small and Medium Scale Enterprise (SME) in Nigeria (Agu et al., 2019), small businesses that involve waste generation and degradation of ecosystem usually take place which lead to increase in the spread of bacteria and infectious diseases (Wizor, 2019).

CONCLUSION

Livestock farming has remained one of the veritable means of improving the livelihood of the South-easterners. The challenge often experienced is the spread of pathogenic bacteria directly from the farm animals or the agents surrounding them such as air, water and soil. Of all the cities studied, Aba had the highest loads of bacteria. This calls for concerted effort by all stakeholders residing in the city and by extension the entire South-east as the disease resulting from the spread of these microbes from Aba could reach to other South-East States. Holistic hygienic practices should be promoted by livestock keepers as health workers should routinely conduct inspection on those farms and markets where these animals are reared and consumed respectively.

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REFERENCES

Adhikari, H., Barnes, D. L., Schiewer, S., & White, D. M. (2007). Total coliform survival characteristics in frozen soils. Journal of Environmental Engineering, 133(12), 1098-1105.

Agodo, L. Y., Ajiji, M. A., Anyanwu, N. C. J., & Ajide, B. (2016) Bacteriological and physicochemical analysis of borehole water in Auta Balefi community, Nasarawa State. British Microbiology Research Journal, 11(4), 1-7.

Agu, A. G., Onwuka, O. O., & Aruomah, O. (2019). Impact of taxation on the performance of small and medium enterprises in Aba, Abia State, Nigeria. Archives of Business Research, 7(3), 1-15.

Alegbeleye, O. O., Singleton, I., & Sant’Ana, A. S. (2018). Sources and contamination routes of microbial pathogens to fresh produce during field cultivation: A review. Food Microbiology, 73, 177-208.

Ali, A. I., Tanko, A. I., & Rilwanu, T. Y. (2021). Health impact of Aba River on riverine communities in Aba North local government area of Abia state. Zaria Geographer, 28(1), 24-34.

Asadu, A. N., Chah, J. M., Attamah, C. O., & Igbokwe, E. M. (2021). Knowledge of hazards associated with urban livestock farming in Southeast Nigeria. Frontiers in Veterinary Science, 8, 600299.

Bhat, M. M., Shankar, S., Shikha,Yunus, M., & Shukla, R. N. (2011). Remediation of hydrocarbon contaminated soil through microbial degradation-FTIR based prediction. Advances in Applied Sciences Research, 2(2), 321-326.

Buchanan, R. E., & Gibbons, N. E. (1974) Bergey’s Manual of Determinative Bacteriology (8th Edn.). Williams & Wilkins Co., Baltimore, USA.

Finn, S., Condell, O., McClure, P., Amexquita, A., & Fanning, S. (2013). Mechanisms of survival responses, and sources of Salmonella in low-moisture environments. Frontiers in Microbiology, 4(331).

Gebreyes, W. A., Jackwood, D., de Oliveira, C. J. B., Lee, C., Hoct, A. E., & Thaku, S. (2020). Molecular epidemiology of infectious zoonotic and livestock diseases. Microbiology Spectrum, 8(2), 1-11.

Grossi, G., Goglio, P., Vitali, A., & Williams, A. G. (2015). Livestock and climate change: impact of livestock on climate and mitigation strategies. Animal Frontiers, 9, 69-70.

Harley, J. P., & Prescott, L. M. (2002). Laboratory exercise in Microbiology. (5th edn.). McGraw Hill Company, USA. 291-297.

Jorgensen, J. H., Pfaller, M. A., Carrol, K. C., Funke, G., Landry, M. L., Richter, S. S., & Warrnock, D. W. (2015). Manual of Clinical Microbiology (11th edn.). ASM Press, Washington DC, USA.

Kalu, N. N., & Zakirova, Y. L. (2019). A review in Southeastern Nigeria: environmental problems and management solutions. Journal of Ecology and Life safety, 27(3), 231-240.

Kloos, G., Huss, A., Heederik, D. J. J., and Coutinho, R. A. (2016). Human-livestock contacts and their relationship to transmission of zoonotic pathogens, a systematic review of literature. One Health, 2, 65-76.

Köhl, J., Kolnaar, R., & Ravensberg, W. J. (2019). Mode of action of microbial biological control agents against plant diseases: relevance beyond efficacy. Frontiers in Plant Science, 10, 845.

Lama, A., Bates, M., Covington, A. D., Allen, S. C., & Antunes, A. P. M. (2013). Methods of isolation and identification of pathogenic and potential pathogenic bacteria from skins and tannery effluents. Journal-American Leather Chemists Association, 108, 49-61.

Madu, I. A. (2006). Spatial inequality in Nigeria: the imperative of geographic perspectives in the development process. Journal of Social and Economic Development, 8(2), 105-120.

McAllister, T. A., & Toppt, E. (2012). Role of livestock in microbiological contamination of water: commonly the blame, but not always the source. Animal Frontiers, 2(2), 17-26.

Nahar, A., Siddiquee, M., Nahar, S., Anwar, K. S., Ali, S. I., & Islam, S. (2014). Multidrug resistant-Oroteus mirabilis isolated from chicken droppings in

https://journals.e-palli.com/home/index.php/ajaset
commercial poultry farms: bio-security concern and emergency public health threat in Bangladesh. *Journal of Health Education Research and Development, 2*(2), 1-2.

Ngozi, U. S., & Humphrey, E. (2019). Public health implications of Abu river pollution on communities in Aba North Abia State, Nigeria. *Taxila International Journal of Public Health, 7*(1).

Nwanta, J. A., Shoyinka, S. V. O., Chah, K. F., Onunkwo, J. I., Onyenwe, I. W., Eze, J. I., Iheagwam, C. N., Njoga, E. O., Onyema, I., Ogwu, K. I., Mwegbu, E. C., Nnadozie, P. N., Ibe, E. C., & Oladimeji, K. T. (2011). Production characteristics, disease prevalence, and herd-health management of pigs in Southeast Nigeria. *Journal of Swine Health Production, 19*(6), 331–339.

Okoro, U., & Ibe, C. O. (2017). Profiling socio-economic characteristics of citizens living around waste sites in Anambra, Nigeria. *Journal of Environmental Toxicological studies, 3*(2).

Onyeagba, R. A. (2015). Laboratory guide for Microbiology. Revised edition. Crystal Publisher. Okigwe, Imo State.

Piewngam, P., & Otto, M. (2019). Probiotics to prevent *Staphylococcus aureus* disease? *Gut Microbes, 103*, 4377-4392.

Ravine, J. J. (2019). Bacillus: an environmental contaminant or misunderstood pathogen? *Journal of Bacteriology and Mycology, 6*(6), 1117.

Sampson, T., A. P. Esheyigba. A. P., & Baridam, S. S. (2019). Bacteriological Assessment of Toilet Seats in a Nigerian University. *Journal of Advances in Microbiology, 19*(4), 1-11, 2019

Serves, A. M., Sora, S. & Ciferrri, O. (1996). The microbial colonization of oil paintings. Labaratory investigation. *International Biodeterioration and Biodegradation, 37*, 215-224.

Soriano, M. (2020). Animal feed preservatives: effect on feed's microbiological quality. Magazine of veterinary information, medicine and zootechnics specializes in poultry, pig ruminants. www.veterinaria digital.com.

Sun, H., Lin, Z., Zhao, H., Chan, T., Shang, M., Jiang, H., Tang, Z., Zhuo, X., Shi, M., Zhuo, L., Ren, P., Qu, H., Lin, J., Li, X., Xu, J., Huang, Y., & Yu, X. (2018). *Bacillus subtilis* spore with surface display of paramyosin from Clonorchis sinensis potentializes a promising oral vaccine candidate. *Parasites and Vectors, 11*, 156.

Thornton, P. K. (2010). Livestock production: recent trends, future prospects. Philosophical Transaction of the Royal Society of London B, Biological Sciences, *365*(1554), 2853-2867.

Ugbogu, O. C Onyeagba, R. A., Ugbogu, E. A., & Nwaugo, V. O. (2016). Heavy metal levels and potential pathogens of surface water sediments of two man-made lakes at Lokpa Umuchieze, Abia State, Nigeria. *International Journal of Environmental Biology, 6*(1), 4-10

Wizor, C. H. (2019). Impact of Ogbor hill waste dumpsite on socio-economic activities of urban dwellers in Aba metropolis, Abia state, Nigeria. *International Journal of Science and Research, 8*(7), 1206-1213.

World Health Organisation (WHO) (2018). *Salmonella (non-typhoidal). Fact sheet.* Retrieved July 2018.

Zafar, U., Taj, M. K., Nawaz, I., Hussain, A., Taj, I., Abideen, Z., Mengal, S., Panezai, M., Rind, N. A., Ali, A., Mohammad, G., Azam, S., & Samreen, Z. (2019). *Proteus mirabilis* as a pathogenic organism. *International Journal of Biosciences, 14*(3), 443-450.