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# Prevalence and antibiotic susceptibility patterns of *Escherichia coli* and *Staphylococcus aureus* isolated from bioaerosols of local markets located in Agulu, Anambara State

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## Abstract

There is a need for improved understanding of aerosol-acquired disease due to the increasing environmental load of antibiotic resistant bacteria. Multidrug-resistant *Escherichia coli* and *Staphylococcus aureus* are examples of bacteria for which the role of exposure to aerosolized organisms in disease transmission should be more closely evaluated globally. This study is aimed at evaluating the prevalence and antibiogram of *S. aureus* and *E. coli* present in market bioaerosols, located in Nwagu-Agulu, Anambra Nigeria. Impaction sample collection method was used to collect bioaerosol samples within the market using nutrient agar as the collection media, A combination of the cultural and microscopic features as well as selected biochemical tests were employed to identify the isolates. The Kirby-Bauer disk diffusion method was used to determine antibiotic resistance to selected commonly used antibiotics. A total of 76 *S. aureus* and 24 *E. coli* were isolated. Both organisms have been implicated in community-acquired infections. The most common bacteria isolated were *Staphylococcus aureus*. Varying levels of resistance were observed by these isolates to selected commonly use antibiotics. There is high prevalence of *S. aureus* and *E. coli* within Nwagu market Agulu, Anambra State, Eastern region of Nigeria. The organisms have very high rates of resistance to antibiotics (MDR) as reported by other workers. The government as well as Health professionals must play an important role in the prevention of community acquired infections via regular environmental monitoring of open markets bioaerosol and establishing a common permissible limits or concentration for bioaerosols within the markets.

**Keywords:** *S. aureus; E. coli*; Transmission; Bioaerosol; Nwagu market; Multidrug-resistance

## 1. Introduction

Microorganisms or their remains can be actively or inactively released into the air in reaction to climatological conditions [1] Many airborne pathogenic organisms can be spread great distances through air flow [2,3]. Bioaerosols are airborne particles derived from biological origins, including aerial suspensions of bacteria, viruses, fungi, enzymes,

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and pollen. It may be disseminated over large distances with possibly lethal results if carried by favourable air flow. Examples of bioaerosol organisms are *Staphylococcus aureus* and *Escherichia coli* [4-6].

*Staphylococcus aureus* is a gram positive and non-motile small round shaped organism that causes infections like hospital- and community-acquired bloodstream, lower respiratory, skin and soft tissue infection [7]. *Escherichia coli* a gram-negative bacillus is an enteric bacterium which colonizes the lower intestinal tract of mammals including humans and birds. It can cause intestinal and extra intestinal illnesses in humans. It infects ruminants, chickens and humans that are in close contact and share space [8]. It causes a spectrum of diseases ranging from mild, self-limited gastroenteritis to renal failure and septic shock [9]. It has been reported to be the most common pathogen associated with urinary tract infections in many countries causing both community- and hospital-acquired UTI [10,11]. It can lead to severe and life-threatening complications.

There is a need for improved understanding of aerosol-acquired disease due to the increasing environmental load of antibiotic resistant bacteria. *S. aureus* and *E. coli* are major challenge globally because of the presence of multiple drug resistant gene and air transmission has been identified as a major risk factor which influences the rapid spread of these pathogenic organisms [12,13]. Some people had reported on the increasing prevalence of multidrug-resistant *Staphylococcus aureus* (MDRSA) infections as well as ESBL-producing *E. coli* among community populations [13]. There is no data concerning the presence of *S. aureus* and *E. coli* in market bioaerosol. Because of the scarce data, huge variability in the potential health effects between different types of bioaerosols and for the fact that *Staphylococcus aureus* and *Escherichia coli have been* implicated in previous studies [12], it is important to determine prevalence of *S. aureus* and *E. coli* in this market bioaerosol as this can influence antibiotic-therapy decisions.

This study is aimed at evaluating the prevalence and antibiogram of *S. aureus* and *E. coli* present in market bioaerosols, located in Nwagu-Agulu, Anambra Nigeria.

## 2. Material and methods

### 2.1. Study Area

The study Area is a local market located at Nwagu-Agulu, Anambra state, Nigeria.

Nutrient agar, Mannitol salt agar, MacConkey agar, Citrate agar (Titan Biotech, India) were the agar media used. While the broth media used was Nutrient broth (Titan Biotech, India). They were strictly prepared according to the instructions of the manufacturers. The reagents employed in this work include Peptone water (Titan Biotech, India), immersion oil, Lugo's Iodine, acetone, ethanol, safranin stain, crystal violet stain, peptone pellets, tetramethyl-p-phenylenediamine powder (Merck, Germany), and Kovac's Indole Reagent (Qualikems fine Chemicals Pvt. Ltd).

Antimicrobial sensitivity discs containing amoxycillin-sulbactam (20µg), co-trimoxazole (25µg), cefotaxime (30µg), piperacillin/tazobactam (110µg), chloramphenicol (30µg), ciprofloxacin (5µg), ceftriaxone (30µg), tetracycline (30µg), ofloxacin (5µg), gentamicin (10µg), azithromycin (15 µg) levofloxacin (5 µg), erythromycin (15µg); streptomycin (10µg); roxithromycin (30µg) cloxacillin (5µg) (Life Save Biotech ,UK) were used to determine the susceptibility profile.

### 2.2. Collection of Samples

The labelled sterile nutrient agar plates containing 500 mg/L miconazole were strategically placed on the chairs and tables at the study area. Adopting the standardized method, each plate was positioned at a height of 1 m above floor level, and 1 m from items being sold. Plates were exposed for 3 hrs followed by incubating at 37℃ for 48 hrs in an inverted position. After incubation, the microbial contaminations of the sampled area were recorded [13,14]. Duplicate bioaerosol samples were collected from each sampling point.

### 2.3. Morphological Identification of Isolates

For the identification of the isolates, a single colony from the exposed nutrient agar plate was sub-cultured onto the selective media (Mannitol salt agar for *S. aureus*, and MacConkey agar for E. coli) containing 500 mg/L miconazole which enables the detection and differentiation of specific microorganism. The isolates were characterized by using the morphological appearance, Gram staining technique and biochemical tests: Indole, catalase, oxidase and citrate test [15-17]. The pure culture was stored in agar slants containing 500 mg/L miconazole at 4 ˚C. Prior to use, an aliquot of the test isolates was sub-cultured onto agar plate containing 500 mg/L miconazole and then incubated for 24 hrs at 37 ˚C for reactivation. Reactivated cultures were standardized by transferring distinct and separate colonies of the pure

culture of the test organism into 3 mL of sterile nutrient broth. The suspensions were incubated for 3 hours at 37°C to allow the growth of test organism till the density is equivalent to the turbidity of 0.5 McFarland.

### 2.4. Antibiotic Susceptibility Testing

The antibiogram study of the isolates with other antibiotics was determined using the Kirby-Bauer disc diffusion technique (described as follows). 0.1 ml of standardized cultures were dispensed unto dried agar plates. These were dispersed evenly onto the agar surface using sterile a swab stick to make a bacterial lawn. Inoculated plates were allowed to dry for 15 mins and the antibiotic discs were aseptically placed on the inoculated plates 15 mm away from the edge of the plates. The plates were allowed a further drying period of 30 mins and then incubated for 24 hrs at 37 ˚C [18]. After incubation, the zone of inhibition was observed and the diameter of the zone was measured, recorded and compared with a standard for each drug. The isolates were recorded as resistant based on the standard interpretative chart for each drug as described by the Clinical Laboratory Standard Institute [19].

## 3. Results and discussion

### 3.1. Isolation and Specie Identification of Test Micro-organisms.

A total of 100 samples were collected from the study area. Out of the 100, only 76 (27 Gram negative and 49 Gram positive) were isolated from the market bioaerosols and used for the study.

Figure I shows the culture of *E. coli* which are reddish, mucoid, opaque, convex colonies and *S. aureus* which appeared golden yellow, mucoid, opaque, convex colonies on nutruent agar. This is consistent with the result of [12] which stated the colony morphology of most S*. aureus* strains to be circular, smooth, convex, opaque and produces golden yellow pigment. While that of *E. co*li is circular, low convex, grayish white, moist, smooth, opaque or partially translucent colonies.

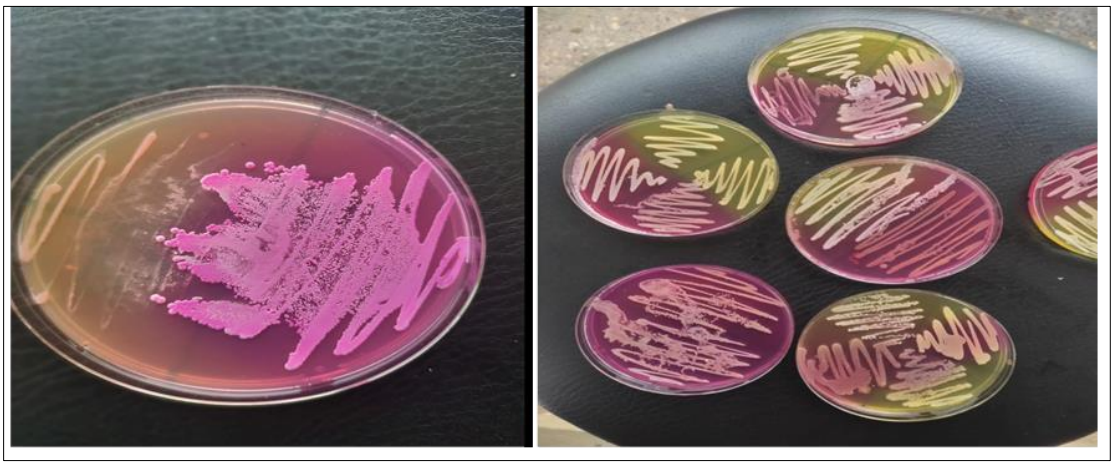

**Figure 1** Pure isolates of Escherichia coli and Staphylococcus aureus

The microscopic features of the isolated organisms showed that they are cocci in clusters for *S. aureus* and rods for *E. coli*. The morphological and biochemical tests (Table 1 and 2) confirmed them as *E. coli* and *S. aureus* respectively.

**Table 1** Morphological, biochemical characterizations of *Escherichia coli* isolates

| Sample | Colony morphology | Gram- character | Microscopy | CAT | OXI | IND | CIT |
|---|---|---|---|---|---|---|---|
| E1 | Red, convex | Gram negative | Rods | + | - | + | - |
| E2 | Red, convex | Gram negative | Rods | + | - | + | - |
| E3 | Red, convex | Gram negative | Rods | + | - | + | - |
| E6 | Red, convex | Gram negative | Rods | + | - | + | - |
| E7 | Red, convex | Gram negative | Rods | + | - | + | - |
| E8 | Red, convex | Gram negative | Rods | + | - | + | - |
| E9 | Red, convex | Gram negative | Rods | + | - | + | - |
| E11 | Red, convex | Gram negative | Rods | + | - | + | - |
| E12 | Red, convex | Gram negative | Rods | + | - | + | - |
| E14 | Red, convex | Gram negative | Rods | + | - | + | - |
| E15 | Red, convex | Gram negative | Rods | + | - | + | - |
| E16 | Red, convex | Gram negative | Rods | + | - | + | - |
| E19 | Red, convex | Gram negative | Rods | + | - | + | - |
| E21 | Red, convex | Gram negative | Rods | + | - | + | - |
| E23 | Red, convex | Gram negative | Rods | + | - | + | - |
| E25 | Red, convex | Gram negative | Rods | + | - | + | - |
| E26 | Red, convex | Gram negative | Rods | + | - | + | - |
| E27 | Red, convex | Gram negative | Rods | + | - | + | - |

Key: E (*Escherichia coli*); CAT (catalase); OXI (oxidase); IND (indole); CIT (citrate) tests; + (positive reaction); - (negative reaction)

**Table 2** Morphological, biochemical characterizations of *Staphylococcus aureus* isolates

| Sample | Colony morphology | Gram- character | Microscopy | CAT | OXI | IND | CIT |
|---|---|---|---|---|---|---|---|
| S1 | Golden-brown | Gram positive | Cocci clusters | + | + | - | + |
| S2 | Golden-brown | Gram positive | Cocci clusters | + | + | - | + |
| S3 | Golden-brown | Gram positive | Cocci clusters | + | + | - | + |
| S4 | Golden-brown | Gram positive | Cocci clusters | + | + | - | + |
| S5 | Golden-brown | Gram positive | Cocci clusters | + | + | - | + |
| S6 | Golden-brown | Gram positive | Cocci clusters | + | + | - | + |
| S7 | Golden-brown | Gram positive | Cocci clusters | + | + | - | + |
| S8 | Golden-brown | Gram positive | Cocci clusters | + | + | - | + |
| S9 | Golden-brown | Gram positive | Cocci clusters | + | + | - | + |
| S10 | Golden-brown | Gram positive | Cocci clusters | + | + | - | + |
| S11 | Golden-brown | Gram positive | Cocci clusters | + | + | - | + |
| S12 | Golden-brown | Gram positive | Cocci clusters | + | + | - | + |
| S13 | Golden-brown | Gram positive | Cocci clusters | + | + | - | + |
| S14 | Golden-brown | Gram positive | Cocci clusters | + | + | - | + |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| S15 | Golden-brown | Gram positive | Cocci clusters | + | + | - | + |
| S16 | Golden-brown | Gram positive | Cocci clusters | + | + | - | + |
| S17 | Golden-brown | Gram positive | Cocci clusters | + | + | - | + |
| S18 | Golden-brown | Gram positive | Cocci clusters | + | + | - | + |
| S19 | Golden-brown | Gram positive | Cocci clusters | + | + | - | + |
| S20 | Golden-brown | Gram positive | Cocci clusters | + | + | - | + |
| S21 | Golden-brown | Gram positive | Cocci clusters | + | + | - | + |
| S22 | Golden-brown | Gram positive | Cocci clusters | + | + | - | + |
| S23 | Golden-brown | Gram positive | Cocci clusters | + | + | - | + |
| S24 | Golden-brown | Gram positive | Cocci clusters | + | + | - | + |
| S25 | Golden-brown | Gram positive | Cocci clusters | + | + | - | + |
| S26 | Golden-brown | Gram positive | Cocci clusters | + | + | - | + |
| S27 | Golden-brown | Gram positive | Cocci clusters | + | + | - | + |
| S28 | Golden-brown | Gram positive | Cocci clusters | + | + | - | + |
| S29 | Golden-brown | Gram positive | Cocci clusters | + | + | - | + |
| S30 | Golden-brown | Gram positive | Cocci clusters | + | + | - | + |
| S31 | Golden-brown | Gram positive | Cocci clusters | + | + | - | + |
| S32 | Golden-brown | Gram positive | Cocci clusters | + | + | - | + |
| S33 | Golden-brown | Gram positive | Cocci clusters | + | + | - | + |
| S34 | Golden-brown | Gram positive | Cocci clusters | + | + | - | + |
| S35 | Golden-brown | Gram positive | Cocci clusters | + | + | - | + |
| S36 | Golden-brown | Gram positive | Cocci clusters | + | + | - | + |
| S37 | Golden-brown | Gram positive | Cocci clusters | + | + | - | + |
| S38 | Golden-brown | Gram positive | Cocci clusters | + | + | - | + |
| S39 | Golden-brown | Gram positive | Cocci clusters | + | + | - | + |
| S40 | Golden-brown | Gram positive | Cocci clusters | + | + | - | + |
| S41 | Golden-brown | Gram positive | Cocci clusters | + | + | - | + |
| S42 | Golden-brown | Gram positive | Cocci clusters | + | + | - | + |
| S43 | Golden-brown | Gram positive | Cocci clusters | + | + | - | + |
| S44 | Golden-brown | Gram positive | Cocci clusters | + | + | - | + |
| S45 | Golden-brown | Gram positive | Cocci clusters | + | + | - | + |
| S46 | Golden-brown | Gram positive | Cocci clusters | + | + | - | + |
| S47 | Golden-brown | Gram positive | Cocci clusters | + | + | - | + |
| S48 | Golden-brown | Gram positive | Cocci clusters | + | + | - | + |
| S49 | Golden-brown | Gram positive | Cocci clusters | + | + | - | + |
| S50 | Golden-brown | Gram positive | Cocci clusters | + | + | - | + |

Key: CAT (catalase); OXI (oxidase); IND (indole); CIT (citrate) tests

### 3.2. Prevalence

Market activities observed during the study showed an expected increased prevalence of bacteria resulting from increased transmission. Our results showed that both *E. coli* and *S. aureus* are the most frequently isolated microorganisms in the market, indicating that they have been implicated in community-acquired infections. The most common bacteria isolated were *Staphylococcus aureus*. This contradicts the findings of [20,21], which reported that *E. coli* was the most frequent isolated microorganism in both the community and hospital setting.

### 3.3. Antibiotic Susceptibility Testing of the Organisms

It is demonstrated from tables 3 and 4 that most of the isolates from the market bioaerosol were resistant to amoxycillin (4.1%), tetracycline (38.8%), ciprofloxacin (20.4%), ofloxacin (10.2%), and cloxacillin (100%). This indicates that MDR is very common within the study area. This could be because these antibiotics are commonly used for outpatient therapy. The percentage of MDR- *E. coli and S. aureus* causing community-acquired infections is 35.5% and 64.5 % respectively. This is the first study conducted in the study area. Our finding is an indication of a gradual change in the antibiotic status, where community-acquired organisms were more resistance to antimicrobial drugs tested.

**Table 3** Antibiotic Susceptibility Testing of *E. coli* isolated from the Market

| Isolate | Antibiotics (µg) / inhibition zone diameter (mm) | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **AS** | **BA** | **CTX** | **PT** | **C** | **CIP** | **CRO** | **TE** | **OF** | **GM** | **AT** | **LE** | **Antibiotic status** |
| *E1* | 0±0 | 0±0 | 0±0 | 0±0 | 13±0 | 15±0 | 10±0 | 15±0 | 17±0 | 0±0 | 0±0 | 0±0 | MDR |
| *E2* | 0±0 | 0±0 | 0±0 | 0±0 | 10±0 | 19±0 | 0±0 | 14±0 | 0±0 | 0±0 | 0±0 | 0±0 | MDR |
| *E3* | 0±0 | 0±0 | 0±0 | 0±0 | 23±0 | 26±0 | 0±0 | 0±0 | 0±0 | 0±0 | 0±0 | 0±0 | MDR |
| *E6* | 0±0 | 0±0 | 0±0 | 0±0 | 12±0 | 9±0 | 11±0 | 0±0 | 14±0 | 19±0 | 11±0 | 20±0 | MDR |
| *E7* | 0±0 | 0±0 | 0±0 | 0±0 | 20±0 | 28±0 | 10±0 | 15±0 | 30±0 | 0±0 | 20±0 | 32±0 | MDR |
| *E8* | 25±0 | 0±0 | 0±0 | 0±0 | 16±0 | 10±0 | 9±0 | 9±0 | 15±0 | 0±0 | 9±0 | 14±0 | MDR |
| *E9* | 0±0 | 17±0 | 0±0 | 0±0 | 30±0 | 24±0 | 0±0 | 13±0 | 26±0 | 0±0 | 24±0 | 26±0 | MDR |
| *E11* | 0±0 | 15±0 | 0±0 | 0±0 | 32±0 | 26±0 | 0±0 | 20±0 | 30±0 | 24±0 | 25±0 | 26±0 | MDR |
| *E12* | 0±0 | 0±0 | 0±0 | 0±0 | 11±0 | 16±0 | 0±0 | 0±0 | 15±0 | 0±0 | 11±0 | 20±0 | MDR |
| *E13* | 0±0 | 18±0 | 0±0 | 0±0 | 15±0 | 15±0 | 0±0 | 10±0 | 14±0 | 0±0 | 21±0 | 23±0 | MDR |
| *E14* | 0±0 | 0±0 | 0±0 | 0±0 | 0±0 | 26±0 | 0±0 | 10±0 | 18±0 | 0±0 | 22±0 | 27±0 | MDR |
| *E15* | 0±0 | 0±0 | 0±0 | 0±0 | 18±0 | 0±0 | 0±0 | 8±0 | 16±0 | 0±0 | 14±0 | 20±0 | MDR |
| *E16* | 0±0 | 0±0 | 0±0 | 0±0 | 17±0 | 12±0 | 0±0 | 15±0 | 22±0 | 0±0 | 20±0 | 25±0 | MDR |
| *E19* | 0±0 | 0±0 | 0±0 | 0±0 | 10±0 | 0±0 | 12±0 | 14±0 | 20±0 | 15±0 | 19±0 | 24±0 | MDR |
| *E20* | 0±0 | 0±0 | 0±0 | 0±0 | 22±0 | 0±0 | 0±0 | 0±0 | 17±0 | 0±0 | 26±0 | 22±0 | MDR |
| *E21* | 0±0 | 0±0 | 0±0 | 0±0 | 17±0 | 12±0 | 8±0 | 21±0 | 16±0 | 0±0 | 20±0 | 28±0 | MDR |
| *E23* | 0±0 | 0±0 | 0±0 | 0±0 | 22±0 | 14±0 | 0±0 | 16±0 | 21±0 | 0±0 | 12±0 | 22±0 | MDR |
| *E25* | 0±0 | 0±0 | 0±0 | 0±0 | 12±0 | 20±0 | 13±0 | 14±0 | 28±0 | 18±0 | 10±0 | 16±0 | MDR |
| *E26* | 0±0 | 0±0 | 0±0 | 0±0 | 30±0 | 25±0 | 11±0 | 14±0 | 16±0 | 23±0 | 20±0 | 25±0 | MDR |
| *E27* | 0±0 | 0±0 | 0±0 | 0±0 | 14±0 | 16±0 | 0±0 | 21±0 | 32±0 | 23±0 | 19±0 | 17±0 | MDR |

**key:** Amoxycillin-sulbactam (AS, 20 µg), Co-Trimoxazole (BA, 25 µg); cefotaxime (CTX, 30 µg), Piperacillin/Tazobactam (PT, 110 µg); Chloramphenicol (C, 30 µg); Ciprofloxacin (CIP, 5 µg), Ceftriaxone (CRO, 30 µg); Tetracycline (TE, 30 µg); Ofloxacin (OFX, 5 µg) Gentamicin (GM, 10 µg), Azithromycin (AT, 15 µg); Levofloxacin (LE, 5 µg)

**Table 4** Antibiotic Susceptibility Testing of the *S. aureus* isolated from the market

| Isolate code | S | AS | BA | E | TE | CTX | CIP | OF | RO | CX | GM | LE | Status |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ***S1*** | 20±0.4 | 0±0 | 14±0 | 22±5 | 0±0 | 0±0 | 0±0 | 0±0 | 10±0 | 0±0 | 24±0 | 14±0 | MDR |
| ***S2*** | 16±0.3 | 0±0 | 17±0 | 23±0.6 | 0±0 | 15±0.6 | 0±0 | 0±0 | 14±0 | 0±0 | 20±0 | 34±0 | MDR |
| ***S3*** | 20±0.5 | 0±0 | 12±0 | 23±0.6 | 15±0.3 | 17±0.3 | 0±0 | 0±0 | 19±0 | 0±0 | 18±0 | 28±0 | MDR |
| ***S4*** | 12±0.6 | 0±0 | 18±0 | 18±0.3 | 0±0 | 12±0.6 | 0±0 | 0±0 | 14±0 | 0±0 | 32±0 | 26±0 | MDR |
| ***S5*** | 11±0.4 | 0±0 | 21±0 | 0±0 | 0±0 | 0±0 | 0±0 | 0±0 | 17±0 | 0±0 | 19±0 | 32±0 | MDR |
| ***S6*** | 15±0.6 | 0±0 | 15±0 | 11±0.6 | 0±0 | 0±0 | 0±0 | 0±0 | 25±0 | 0±0 | 24±0 | 18±0 | MDR |
| ***S7*** | 27±0.5 | 0±0 | 17±0 | 20±0.6 | 13±0.3 | 15±0.6 | 0±0 | 0±0 | 10±0 | 0±0 | 17±0 | 19±0 | MDR |
| ***S8*** | 21±0.7 | 0±0 | 18±0 | 23±0.3 | 0±0 | 13±0.7 | 0±0 | 0±0 | 13±0 | 0±0 | 26±0 | 16±0 | MDR |
| ***S9*** | 33±0.4 | 0±0 | 20±0 | 25±0.3 | 0±0 | 16±0.6 | 0±0 | 20 | 22±0 | 0±0 | 19±0 | 35±0 | MDR |
| ***S10*** | 18±0.7 | 0±0 | 14±0 | 20±0.3 | 0±0 | 15±0.3 | 0±0 | 0±0 | 15±0 | 0±0 | 23±0 | 23±0 | MDR |
| ***S11*** | 28±0.4 | 0±0 | 16±0 | 21±0.3 | 0±0 | 15±0.5 | 0±0 | 0±0 | 14±0 | 0±0 | 12±0 | 24±0 | MDR |
| ***S12*** | 20±0.7 | 0±0 | 20±0 | 21±0.7 | 0±0 | 15±0.6 | 0±0 | 0±0 | 12±0 | 0±0 | 14±0 | 37±0 | MDR |
| ***S13*** | 19±0.5 | 0±0 | 18±0 | 15±0.3 | 0±0 | 16±0.3 | 0±0 | 0±0 | 18±0 | 0±0 | 22±0 | 20±0 | MDR |
| ***S14*** | 20±0.3 | 0±0 | 12±0 | 25±0.3 | 0±0 | 13±0.4 | 0±0 | 0±0 | 29±0 | 0±0 | 17±0 | 30±0 | MDR |
| ***S15*** | 0±0 | 20±0 | 19±0 | 0±0 | 0±0 | 0±0 | 0±0 | 20±0 | 24±0 | 0±0 | 26±0 | 18±0 | MDR |
| ***S16*** | 16±0.7 | 0±0 | 11±0 | 16±0.6 | 0±0 | 0±0 | 0±0 | 19±0 | 13±0 | 0±0 | 18±0 | 26±0 | MDR |
| ***S17*** | 0±0 | 0±0 | 17±0.7 | 0±0 | 15±0.3 | 12±0 | 0±0 | 15±0 | 12±0 | 0±0 | 12±0 | 34±0 | MDR |
| ***S18*** | 20±0.7 | 0±0 | 15±0 | 24±0.6 | 0±0 | 13±0.6 | 0±0 | 0±0 | 11±0 | 0±0 | 32±0 | 12±0 | MDR |
| ***S19*** | 19±0.4 | 0±0 | 13±0 | 22±0.3 | 0±0 | 17±0.6 | 0±0 | 0±0 | 11±0 | 0±0 | 30±0 | 16±0 | MDR |
| ***S20*** | 21±0.3 | 0±0 | 10±0 | 22±0.4 | 0±0 | 11±0.6 | 0±0 | 0±0 | 14±0 | 0±0 | 26±0 | 25±0 | MDR |
| ***S21*** | 19±0.7 | 0±0 | 23±0 | 10±0.3 | 0±0 | 17±0.3 | 0±0 | 0±0 | 26±0 | 0±0 | 24±0 | 29±0 | MDR |
| ***S22*** | 14±0.4 | 0±0 | 17±0 | 20±0.7 | 0±0 | 15±0.7 | 0±0 | 0±0 | 22±0 | 0±0 | 25±0 | 34±0 | MDR |
| ***S23*** | 0±0 | 12±0 | 19±0 | 13±0.3 | 16±0 | 0±0 | 21±0 | 24±0 | 18±0 | 0±0 | 24±0 | 26±0 | MDR |
| ***S24*** | 15±0.5 | 0±0 | 11±0 | 21±0.5 | 0±0 | 10±0.6 | 0±0 | 0±0 | 12±0 | 0±0 | 27±0 | 28±0 | MDR |
| ***S25*** | 17±0.7 | 0±0 | 15±0 | 20±0.3 | 10±0.3 | 0±0 | 0±0 | 0±0 | 31±0 | 0±0 | 30±0 | 32±0 | MDR |
| ***S26*** | 33±0 | 0±0 | 22±0 | 23±0.3 | 0±0 | 22±0.3 | 0±0 | 0±0 | 19±0 | 0±0 | 32±0 | 37±0 | MDR |
| ***S27*** | 22±0.3 | 0±0 | 15±0 | 21±0.6 | 0±0 | 17±0.6 | 0±0 | 0±0 | 31±0 | 0±0 | 14±0 | 23±0 | MDR |
| ***S28*** | 14±0.2 | 0±0 | 11±0 | 14±0.3 | 0±0 | 11±0.3 | 0±0 | 0±0 | 23±0 | 0±0 | 18±0 | 18±0 | MDR |
| ***S29*** | 15±0.3 | 0±0 | 19±0 | 21±0.5 | 0±0 | 12±0.5 | 0±0 | 0±0 | 12±0 | 0±0 | 23±0 | 35±0 | MDR |
| ***S30*** | 0±0 | 0±0 | 22±0 | 0±0 | 0±0 | 0±0 | 0±0 | 0±0 | 10±0 | 0±0 | 12±0 | 14±0 | MDR |
| ***S31*** | 0±0 | 0±0 | 11±0 | 0±0 | 0±0 | 0±0 | 0±0 | 0±0 | 15±0 | 0±0 | 26±0 | 29±0 | MDR |
| ***S32*** | 25±0.3 | 0±0 | 18±0 | 24±0.3 | 13±0.3 | 0±0 | 0±0 | 0±0 | 18±0 | 0±0 | 23±0 | 16±0 | MDR |
| ***S33*** | 23±0.6 | 0±0 | 16±0 | 25±0.3 | 0±0 | 12±0.3 | 0±0 | 0±0 | 13±0 | 0±0 | 31±0 | 24±0 | MDR |
| ***S34*** | 25±0.6 | 0±0 | 13±0 | 0±0 | 20±0.4 | 0±0 | 15±0.6 | 0±0 | 10±0 | 0±0 | 26±0 | 27±0 | MDR |
| ***S35*** | 22±0.6 | 0±0 | 17±0 | 0±0 | 20±0.3 | 10±0.5 | 10±0.3 | 0±0 | 13±0 | 0±0 | 19±0 | 32±0 | MDR |
| ***S36*** | 25±0.3 | 0±0 | 15±0 | 0±0 | 20±0.7 | 10±0.3 | 10±0.7 | 0±0 | 14±0 | 0±0 | 21±0 | 14±0 | MDR |
| ***S37*** | 11±0.7 | 0±0 | 10±0 | 0±0 | 12±0.2 | 0±0 | 0±0 | 0±0 | 19±0 | 0±0 | 12±0 | 28±0 | MDR |
| ***S38*** | 10±0.3 | 0±0 | 16±0 | 0±0 | 20±0.3 | 0±0 | 0±0 | 0±0 | 32±0 | 0±0 | 14±0 | 35±0 | MDR |

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|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ***S39*** | 11±0.6 | 0±0 | 12±0 | 0±0 | 22±0.6 | 0±0 | 15±0.3 | 0±0 | 27±0 | 0±0 | 19±0 | 32±0 | MDR |
| ***S40*** | 22±0.3 | 0±0 | 11±0 | 0±0 | 15±0.3 | 17±0.3 | 0±0 | 0±0 | 16±0 | 0±0 | 17±0 | 18±0 | MDR |
| ***S41*** | 11±0.3 | 0±0 | 17±0 | 0±0 | 17±0.5 | 13±0.7 | 0±0 | 0±0 | 13±0 | 0±0 | 25±0 | 26±0 | MDR |
| ***S42*** | 0±0 | 0±0 | 20±0 | 0±0 | 0±0 | 0±0 | 0±0 | 0±0 | 28±0 | 0±0 | 30±0 | 17±0 | MDR |
| ***S43*** | 0±0 | 0±0 | 11±0 | 0±0 | 0±0 | 0±0 | 0±0 | 0±0 | 14±0 | 0±0 | 18±0 | 22±0 | MDR |
| ***S44*** | 11±0.6 | 0±0 | 23±0 | 0±0 | 20±0.3 | 0±0 | 20±0.3 | 0±0 | 10±0 | 0±0 | 35±0 | 27±0 | MDR |
| ***S45*** | 8±0.3 | 0±0 | 16±0 | 0±0 | 17±0.4 | 0±0 | 11±0.6 | 0±0 | 12±0 | 0±0 | 32±0 | 29±0 | MDR |
| ***S46*** | 11±0.7 | 0±0 | 10±0 | 0±0 | 0±0 | 20 | 0±0 | 0±0 | 19±0 | 0±0 | 13±0 | 18±0 | MDR |
| ***S47*** | 25±0.3 | 0±0 | 18±0 | 0±0 | 25±0.7 | 0±0 | 15±0.4 | 0±0 | 30±0 | 0±0 | 22±0 | 23±0 | MDR |
| ***S48*** | 11±0.3 | 0±0 | 12±0 | 0±0 | 20±0.3 | 0±0 | 17±0.3 | 0±0 | 15±0 | 0±0 | 14±0 | 22±0 | MDR |
| ***S49*** | 8±0.4 | 0±0 | 14±0 | 0±0 | 23±0.3 | 0±0 | 13±0.7 | 0±0 | 19±0 | 0±0 | 17±0 | 24±0 | MDR |

Key: Amoxycillin-sulbactam (AS, 20 µg), Co-Trimoxazole (BA, 25 µg); Erythromycin (E, 15 µg); Tetracycline (TE, 30 µg); cefotaxime (CTX, 30 µg), Ciprofloxacin (CIP, 5 µg), Ofloxacin (OFX, 5 µg); Streptomycin (S, 10 µg); Roxithromycin (RO, 30 µg); Cloxacillin (CX, 5 µg); Gentamicin (GM, 10 µg), Levofloxacin (LE, 5 µg)

## 4. Conclusion

There is high prevalence of *S. aureus* and *E. coli* within Nwagu market Agulu, Anambra State, Eastern region of Nigeria. The organisms have very high rates of resistance to antibiotics (MDR) as reported by other workers. This requires drastic and urgent measures to curtail its spread and attendant healthcare challenges like outbreaks of infections and heightened healthcare delivery.

The government as well as Health professionals must play an important role in the prevention of community acquired infections via regular environmental monitoring of open markets.

Strict adherence to antibiotic policy and continuous surveillance is highly advocated since resistance is attributed to local epidemiology and uncontrolled use of antimicrobial agents.

Further research involving many open markets is needed in order to establish a common permissible limit or concentration for bioaerosols within markets.

## Compliance with ethical standards

### *Disclosure of conflict of interest*

The authors declare that there is no conflict of interest.

### *Authors Contributions*

MGUN and CIO conceptualized and designed the study; Data collection was done by CIO, Data Analysis was done by UAU, LNC and CME while writing, editing, and proofreading was done by MGUN, UAU, IPU and LNC. All the authors read and approved the manuscript.

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### *Review Board Statement*

This was not applicable as no samples were obtained from humans.

## References


[1] Jones AM, Harrison RM, The effects of meteorological factors on atmospheric bioaersol concentrations- a review. Science of the Total Environment. 2004; 326:151-180.

[2] Lee AKY, Lau APS, Cheng JYW, Fang M, Chan CK. Source identification analysis for the airborne bacteria and fungi using a biomarker approach. Atmos. Environ. 2007; 41:2831–2843.

[3] Brown JKM, Hovmoller MS. Aerial dispersal of pathogens on the global and continental scales and its impact on plant disease. Science. 2002; 297:537–541.

[4] Duan H, Chai T, Liu J, Zhang X, Qi C, Gao J, Wang Y, Cai Y, Miao Z, Yao M, Schlenker G (2009). Source identification of airborne *Escherichia coli* of swine house surroundings using ERIC-PCR and REP-PCR. Environ Res.

[5] Li X, Qiu Y, Yu A. et al. Characteristics of airborne *Staphylococcus aureus* (including MRSA) in Chinese public buildings. Aerobiologia. 2015; 31:11–19.

[6] Rajat N, Paul W, Bryan KM, O'Flaherty, V, Declan B, Owen F, Karl GR, Enda C. Risk assessment of *Escherichia coli* in bioaerosols generated following land application of farmyard slurry. The Science of the Total Environment. 2021; 791(148189):12

[7] Diekema DJ, Pfaller MA, Schmitz FJ, Smayevsky J, Bell J, Jones RN. Survey of infections due to Staphylococcus species: frequency of occurrence and antimicrobial susceptibility of isolates collected in the United States, Canada, Latin America, Europe, and the Western Pacific region for the Sentry Antimicrobial Surveillance Program, 1997–1999. Clin Infect Dis. 2001; 32, 114–132.

[8] Johnson JR. Molecular epidemiology and population genetics of extraintestinal pathogenic *Escherichia coli*. In Walk ST, Feng PCH (ed), Population genetics of bacteria: a tribute to Thomas S. Whittam. ASM Press, Washington, DC. 2011.

[9] Teny MJ. Epidemiology and Outcomes of Community-Acquired *Escherichia coli* Pneumonia, Open Forum Infectious Diseases. 2022; 9(1);597.

[10] Sabir S, Anjum AA, Ijaz T, Ali MA, Rehman MU, Nawaz M. Isolation and antibiotic susceptibility of *E. coli* from urinary tract infections in a tertiary care hospital. Pakistan Journal of Medical Sciences. 1969; 30(2):389–392.

[11] Gajdács M, Ábrók M, Lázár A, Burián K. Comparative epidemiology and resistance trends of common urinary pathogens in a tertiary-care hospital: a 10-year surveillance study. Medicina. 2019; 55(7).

[12] Gandara A, Mota LC, Flores C, Perez HR, Green CF, and Gibbs SG. Isolation of *Staphylococcus aureus* and Antibiotic-Resistant *Staphylococcus aureus* from Residential Indoor Bioaerosols. Environmental Health Perspectives 2006 Dec. 2006; 114(12): 1859–1864.

[13] Cimolai N. *Staphylococcus aureus* outbreaks among newborns: New frontiers in an old dilemma. Amer J Perinatol. 2003; 20, 125-136.

[14] Pumkaeo P, Iwahashi H. Bioaerosol Sources, Sampling Methods, and Major Categories: A Comprehensive Overview. Reviews in Agricultural Science. 2020; 8: 261–278.

[15] Smith AC, Hussey MA, Gram Stain Protocols. American Society for Microbiology. 2016; 3-4.

[16] El-Hadedy D, Abu El-Nour S. Identification of *Staphylococcus aureus* and *Escherichia coli* isolated from Egyptian food by conventional and molecular methods. Journal of Genetic Engineering and Biotechnology. 2012; 10(1): 129-135.

[17] Paramesh BN, Basavaraj A, Suryakanth P, Abhilash B, Revappayya M. Isolation and Biochemical Characterization of *Escherichia coli* from Bovine Mastitic Milk. Int.J.Curr.Microbiol.App.Sci. 2018; 7(07): 719-722.

[18] Nwaneri MGU, Anejionu OCD, Ugo UA. Investigation and mapping of the prevalence of "superbugs" Methicillin-resistant *Staphylococcus aureus* (MRSA) and antimicrobial susceptibility pattern in Enugu metropolis in Southeast Nigeria. GSC Biological and Pharmaceutical Sciences. 2023; 23(03), 245–254.

[19] CSLI Performance Standards for Antimicrobial Susceptibility Testing. 30th ed. CLSI supplement M100. 2020.

[20] Son JS, Song JH, Ko KS, Yeom JS, Ki HK, Kim SW. Bloodstream infections and clinical significance of health care associated bacteremia: a multicenter surveillance study in Korean hospitals. J Korean Med Sci. 2010; 25:992–8.

[21] Roula M, Souheil H, Rabih H, Wafaa B, Anne-Marie R, Pascale S, Epidemiology and microbiological profile comparison between community and hospital acquired infections: A multicenter retrospective study in Lebanon. Journal of Infection and Public Health. 2018; 11(3):405-411