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# Investigating the prevalence of bacterial contaminants in public swimming pools within Enugu metropolis

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## Abstract

Swimming pools are artificial bodies of water created for the purpose of human leisure and sports. However, various pathogenic microorganisms, including bacteria, fungi, viruses, and parasites, have been detected in swimming pools and similar recreational waters. The aim of this study is to assess the bacterial contamination of public swimming pools in Enugu Metropolis. In this cross-sectional experimental survey, 65 samples were assayed from various swimming pools across Enugu city. Upon culture and bacterial identification, 21 (32.31%) of the swimming pools showed positive bacterial contamination, whereas 44 (67.69%) showed no bacteria growth. The most common bacteria found in the samples were *Staphylococci* 8 (38.1%), followed by *E. coli* 6 (6%) and *Enterococcus species* 5 (23.81%). *Pseudomonas* and *Klebsiella*, were found in smaller amounts 1(4.76% each). The antibiogram of the bacteria isolates showed varying levels of susceptibility and resistance to the conventional antibiotics tested against. Gentamycin exhibited the highest sensitivity to the test isolates 10 (11.36%), this was followed by Ceftriaxone 7 (7.95%). Conversely, the least sensitivity was observed among Amoxiclav 1(3.23%), followed by Levofloxacin 2 (6.45%). The public health risk for the transmission of bacterial infections through swimming pools is significantly high as highlighted by the findings of this study. It is recommended that adequate and effective maintenance and regulation of swimming pools be ensured in order to promote and maintain public health and safety.

**Keywords:** Swimming Pools; Bacteria; Contamination; Antibiogram

## 1. Introduction

"The age-old adage, 'all work and no play makes Jack a dull boy,' resonates deeply with our inherent desire to strike a balance between personal and professional life. Recognizing the importance of relaxation and bonding, we often allocate time for vacations, seeking to rejuvenate our minds and bodies, and strengthen family ties. As we seek to bridge the gaps created by the demands of modern life, many families opt for destinations featuring swimming pools, offering a refreshing and enjoyable experience for all". Even though swimming and other recreational activities in swimming pools are considered healthy activities [1], it has potentials of exposing swimmers to adverse health challenges, including

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physical, chemical, and microbiological risks [2]. Children, old, pregnant women, and immunocompromised individuals are more liable to the health challenges associated with swimming pools.

Microbial contamination of swimming pools is influenced by several factors like; the number of people who use it, maintenance practices, and environmental conditions. Contaminants such as faecal matter, non-faecal human shedding, and even excrete of animals contribute to microbial contamination of swimming pools [3]. These contaminations increase the likelihood of infections of various categories, including acute respiratory, gastrointestinal, ocular, and cutaneous illnesses. Pathogens such as *Cryptosporidium*, Noroviruses, and *Escherichia coli* are known to cause diarrhoea, whereas others like *Pseudomonas aeruginosa* and *Staphylococcus aureus* are linked to skin infections [4]. According to reports, poor hygiene and inadequate maintenance have been identified as key contributors to microbial contamination of swimming pools. It was reported that in Port Harcourt, Nigeria, swimming pools with poor maintenance practices exhibited a higher prevalence of *Staphylococcus species* [3]. Similarly, another report [4] highlighted the presence of multiple pathogens, including *E. coli*, *Klebsiella pneumoniae*, and *Pseudomonas aeruginosa*, in swimming pool water samples. It was reported that at least, 208 outbreaks associated with recreational water occurred in the United States during 2015–2019 [5]. Most of these outbreaks were caused by *Cryptosporidium spp*., mainly in swimming pools, and by *Legionella*, mainly during the period from June to August [6].

This work, which studies the bacterial contamination of public swimming pools in Enugu state, Nigeria, is therefore a right step in the right direction. Information obtained will give informed concepts to policy issues and public health interventions necessary to make swimming pools a safe place for exercise, relaxation, recreational activities and fun.

## 2. Materials and methods

### 2.1. Study Design and Area

This is a cross-sectional study, conducted in Enugu Metropolis, Enugu State, Nigeria, covering public swimming pools in hotels, night clubs, and recreational centres.

### 2.2. Ethical considerations

Consent approvals in the form of signatures, were obtained from the owners of the swimming pools used, before sample collection. As well, ethical approval was obtained from the Research and Ethics Committee of The Enugu State University of Science and Technology Teaching Hospital to use their Microbiology Laboratory for the study.

### 2.3. Inclusion and Exclusion criteria

#### *2.3.1. Inclusion Criteria*

Public swimming pools within Enugu metropolis, Enugu State, Nigeria, that willingly provided consent to participate in the study were included.

#### *2.3.2. Exclusion Criteria*

Swimming pools that either gave their consents, but did not allow samples to be collected, or those that did not give their consents were excluded in the study. Also excluded in the study, were swimming pools that were used privately, and those that were located outside Enugu Metropolis.

### 2.4. Sample Size Determination

The target sample size for this study was 369, which was determined using the fisher's formula [7], with prevalence of the attribute under study (P), as 40% (0.4) from literature [3], but the actual sample size achieved was 77. Out of the 70 swimming pools selected for the study, only 65 gave their full consents.

#### *2.4.1. Sample Collection*

As part of the consent agreement, sample bottles (sterile universal container), were labelled 1 to 65, as the owners of the swimming pools did not allow their names be written on the bottles, though each number serves as a password for each of the swimming pools assessed. For the purpose of sample dichlorination (to avoid false negative results), 200mg of sodium thiosulphate (Na2S2O3, sodium thiosulphate pentahydrate, 106509, Merck KGaA, Darmstadt, Germany), was added into each of tubes before sample collection. 7 am to 9 am each day, before daily treatment procedures were carried out on the swimming pools, 1 ml each was collected from two different parts of each swimming pool (a total of

2 ml was sampled from each swimming pool). Samples were collected at a depth of about 200 mm below the surface, using a 10 ml sterile syringe, hands covered with sterile gloves. A total of 65 water samples were aseptically collected from the swimming pools. The samples were packed in a cooler (maintained at +2 to +6°C, using ice packs), and then transported within 1 hour of collection to the Microbiology Laboratory of The Enugu State University of Science and Technology Teaching Hospital for immediate processing.

#### *2.4.2. Microbial Analysis*

Samples were cultured on Sheep blood chocolate agar, Sheep blood agar, and MacConkey agar (Oxoid, UK) and incubated at 37°C, to isolate bacteria. Bacterial Isolates obtained were identified morphologically and biochemically (using Indole, Methyl red, Voges Proskauer, Citrate utilization, Urease, Oxidase, Catalase, and Bile esculin), and the results were tabulated.

#### *2.4.3. Antibiotic Susceptibility Testing*

Antibiotic susceptibility assay was performed using the Kirby Bauer disk diffusion method, in accordance with the CLSI guidelines of 2006 [8]. Resistance and sensitivity were interpreted according to the European Committee on Antimicrobial Susceptibility Testing (EUCAST) breakpoint tables, version 14.0, for the interpretation of MICs and zone diameters [9]. Antibiotic discs used were: Gentamycin (10 mg), Co-amoxiclav (20 mg), Ciprofloxacin (5 mg), Levofloxacin (5 mg), ceftazidime (10 mg), ceftriaxone (30 mg), and Clindamycin (2 mg).

### 2.5. Data Analysis

Results were analysed using descriptive statistics, and findings were presented in tables.

## 3. Results

### 3.1. Culture Results

- Total number of Swimming Pools selected for the study = 70
- Total number of swimming pools assessed = 65
- Total number of samples showing positive culture = 21
- Total number of samples showing negative result = 44
- Prevalence of positive culture = 32.31%
- Prevalence of Negative culture = 67.69%
- Total prevalence = 100%.

**Table 1** Distribution of Bacterial Organisms in the Swimming Pool Samples

| S/N | Name of Bacterial Isolate | Frequency | Prevalence (%) |
|---|---|---|---|
| 1 | *Staphylococci* | 8 | 38.10 |
| 2 | *Escherichia coli* | 6 | 28.57 |
| 3 | *Enterococcus specie* | 5 | 23.81 |
| 4 | *Pseudomonas* | 1 | 4.76 |
| 5 | *Klebsiella* | 1 | 4.76 |
| Total | | 21 | 100 |

Table1 above shows the distribution of the bacterial isolates in the swimming pool samples. *Staphylococcus specie* was the most prevalent isolate obtained with a prevalence of 38.1%, followed by *E. coli* with a prevalence of 28.57%. The least prevalence was observed in *Pseudomonas* and *Klebsiella*, with prevalence of 4.76% respectively.

**Table 2** Antibiogram of Antibiotics Against Test Organisms

| S/N | Sample code | Name of bacterial isolate | Diameter of Zones of Inhibition for each Antibiotic (mm) | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | GN | AMC | CIP | LV | CT | CD | CET |
| 1 | P2 | *E. coli* | 6.6 (R) | 0.00 (R) | 16.2 (R) | 13.0 (R) | 25.6 (S) | NA | 17.2 (R) |
| 2 | P3 | *Enterococcus spp* | 12.0 (S) | 6.0 (R) | 15.0 (S) | 12.0 (R) | NA | NA | NA |
| 3 | P6 | *Staphylococci* | 23.0 (S) | 8.0 (R) | 12.0 (R) | 10.0 (R) | 26.0 (S) | 25.0 (S) | NA |
| 4 | P10 | *E. coli* | 16.2 (R) | 15.2 (R) | 10.0 (R) | 15.0 (R) | 14.0 (R) | NA | 16.0 (R) |
| 5 | P13 | *Pseudomonas* | NA | NA | 19 (R) | 15 (R) | 23.0(S) | NA | NA |
| 6 | P14 | *Klebsiella spp* | 18.0 (S) | 12.0 (R) | 14.0 (R) | 18.0 (R) | 26.0 (S) | NA | 27.0 (S) |
| 7 | P17 | *Staphylococci* | 9.3 (R) | 0.00 (R) | 0.00 (R) | 0.00 (R) | 0.00 (R) | 0.00 (R) | NA |
| 8 | P20 | *Staphylococci* | 24.0 (S) | 0.00 (R) | 24.0 (S) | 6.0 (R) | 16.8 (R) | 24.0 (S) | NA |
| 9 | P22 | *Staphylococci* | 13.2 (R) | 10.0 (R) | 16.0 (R) | 11.0 (R) | 7.4 (R) | 18.0 (R) | NA |
| 10 | P23 | *Enterococcus spp* | 9.0 (S) | 0.00 (R) | 6.4 (R) | 0.00 (R) | NA | NA | NA |
| 11 | P25 | *E. coli* | 18.2 (S) | 0.00 (R) | 11.0 (R) | 8.4 (R) | 27.0 (S) | NA | 19.4 (S) |
| 12 | P30 | *Enterococcus spp* | 6.0 (R) | 0.00 (R) | 0.00 (R) | 0.00 (R) | NA | NA | NA |
| 13 | P33 | *E. coli* | 6.0 (R) | 8.00 (R) | 10.4 (R) | 18.4 (R) | 10.8 (R) | NA | 10.00 (R) |
| 14 | P34 | *Staphylococci* | 6.5 (R) | 14.8 (S) | 0.00 (R) | 10.0 (R) | 19.4 (R) | 16.0 (R) | NA |
| 15 | P37 | *E. coli* | 18.0 (S) | 5.8 (R) | 25.0 (S) | 20.0 (S) | 28.4 (S) | NA | 20.0 (S) |
| 16 | P41 | *Staphylococci* | 16.6 (R) | 6.6 (R) | 13.0 (R) | 6.0 (R) | 26.0 (S) | 23.4 (S) | NA |
| 17 | P46 | *Enterococcus spp* | 9.0 (S) | 0.00 (R) | 0.00 (R) | 0.00 (R) | NA | NA | NA |
| 18 | P52 | *Staphylococci* | 10.6 (S) | 6.4 (R) | 14.8 (R) | 7.4 (R) | 17.0 (R) | 22.2 (S) | NA |
| 19 | P59 | *Staphylococci* | 6.2 (R) | 0.00 (R) | 6.0 (R) | 5.4 (R) | 0.00 (R) | 9.0 (R) | NA |
| 20 | P61 | *E. coli* | 6.2 (R) | 0.00 (R) | 23.2 (S) | 7.8 (R) | 4.6 (R) | NA | 0.00 (R) |
| P21 | P63 | *Enterococcus specie* | 21.0 (S) | 0.00 (R) | 9.0 (R) | 14.0 (R) | NA | NA | NA |
| Total | | 21 | | | | | | | |

KEY: NA: means that its either there is insufficient evidence that the organism or group is a good target for the therapy with the Antibiotics, or that agent is not suitable for treatment so susceptibility testing is not recommended.

Table 2 shows the AST results of different antibiotics against the isolated bacteria samples. The samples showed varying level of susceptibility and resistance to the conventional antibiotics tested against.

**Table 3** Summary of Antibiogram of the Bacteria Isolates

| S/N | Name of Isolate | Freq. | Antibiotics | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | GN | | AMC | | CIP | | LV | | CT | | CD | | CET | |
| | | | Sens | Resis | Sens | Resis | Sens | Resis | Sens | Resis | Sens | Resis | Sens | Resis | Sens | Resis |
| 1 | *Pseudomonas* | 1 | NIL | 1 | NIL | 1 | NIL | 1 | NIL | 1 | 1 | NIL | NIL | 1 | NIL | 1 |
| 2 | *E. coli* | 6 | 2 | 4 | NIL | 6 | 2 | 4 | 2 | 4 | 3 | 3 | NA | NA | 2 | 4 |
| 3 | *Enterococcus* | 5 | 4 | 1 | NIL | 5 | 1 | 4 | NIL | 5 | NA | NA | NA | NA | NA | NA |
| 4 | *Staphylococcus* | 8 | 3 | 5 | 1 | 7 | 1 | 7 | NIL | 8 | 2 | 6 | 4 | 4 | NA | NA |
| 5 | *Klebsiella* | 1 | 1 | NIL | NIL | 1 | NIL | 1 | NIL | 1 | 1 | 1 | NA | NA | 1 | 1 |
| *Total* | *Sensitive* | | 10 | | 1 | | 4 | | 2 | | 7 | | 4 | | 3 | |
| | *Resistance* | | | 11 | | 20 | | 17 | | 19 | | 10 | | 5 | | 6 |
| | | 21 | | | | | | | | | | | | | | |

Key: GN: Gentamycin AMC: Amoxiclav CIP: Ciprofloxacin LV: Levofloxacin CT: Ceftriaxone CD: Clindamycin CET: Ceftazidime

*3.1.1. NA: Not applicable*

Table 3 shows that of all the antibiotics used, Gentamycin exhibited the highest sensitivity to the test isolates [10 (11.36%)], this was followed by Ceftriaxone [7 (7.95%)]. Conversely, the least sensitivity was observed among Amoxiclav [1(3.23%), followed by Levofloxacin [2 (6.45%)]

## 4. Discussion

This study assessed the microbial load of swimming pools in Enugu Metropolis, focusing on bacterial contamination levels, antibiotic resistance patterns, and public health implications. A total of 65 swimming pool water samples were analysed, and the findings revealed significant insights into microbial contamination and associated risks.

Microbial contamination Levels of the 65 samples collected were accessed, 21 (32.31%) tested positive for bacterial growth, while 44 (67.69%) showed no contamination. The most prevalent bacterial isolate was *Staphylococci* (38.1%), followed by *Escherichia coli* (28.57%) and then, *Enterococcus spp*. (23.81%). Smaller proportions of *Pseudomonas aeruginosa* and *Klebsiella species* were also detected, each accounting for 4.76% of the isolates. These findings align with similar studies, such as [3], which reported a 40% prevalence of bacterial contamination in swimming pools.

The antibiotic susceptibility testing revealed varying resistance and sensitivity levels among the bacterial isolates. Gentamycin exhibited the highest sensitivity (11.36%), followed by Ceftriaxone (7.95%). Conversely, Amoxiclav and Levofloxacin showed the least sensitivity, with rates of 3.23% and 6.45%, respectively. These findings echo global concerns about rising antibiotic resistance in environmental isolates. For instance, [10] reported a high prevalence of antibiotic-resistant bacteria in swimming pools, while [11] highlighted similar resistance patterns against multiple antibiotics.

The presence of coliform and faecal coliform bacteria, such as *E. coli*, in some swimming pools in this study, exceeds the World Health Organization standards for recreational water quality. Findings in this study indicate significant public health risks, including the potential transmission of gastrointestinal and cutaneous infections. The high antibiotic resistance observed in this study further complicates treatment options for infections acquired from contaminated pools, posing a dual challenge for public health management.

### 4.1. Recommendations

To address these risks, the following measures are recommended:

- **Enhanced Public Awareness:** Increase education on pool hygiene and proper usage practices to minimize contamination.
- **Regulatory Oversight:** Implement stricter regulations for routine inspection and maintenance of swimming pools to ensure compliance with safety standards.
- **Antibiotic Stewardship:** Investigate sources of environmental antibiotic contamination and promote strategies to curb antibiotic resistance in pool environments.

## 5. Conclusion

Recreational waters such as swimming pools are breeding ground for several microorganisms and the presence of coliform and fecal coliform bacteria in some pools in this study exceed the acceptable limits for microbiological water quality, posing a significant public health risk. The antibiotic susceptibility tests showed varying levels of sensitivity and resistance among the bacteria isolates, with Gentamycin exhibiting the highest sensitivity while some bacteria were resistant to most antibiotics tested. Hence the need to ensure adequate and effective maintenance and regulation of public recreational waters (swimming pools) in order to promote and maintain public health and safety.

## Compliance with ethical standards

### *Acknowledgments*

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### *Disclosure of conflict of interest*

The authors declare that they have no conflicts of interest.

### *Statement of informed consent*

Consent approvals were obtained from the owners of the swimming pools used, in the form of signatures before sample collection. As well, ethical approval was obtained from the Research and Ethics Committee of The Enugu State University of Science and Technology Teaching Hospital to use their Microbiology Laboratory for the study.

### *Authors' Contributions*

CCA is the principal investigator of the study and performed the design of the study, data management, study supervision, analysis, interpretation of data, and manuscript preparation, GCA, CNO, MCE, CEE, and QOA, were involved in the designing, supervision, acquisition of data, and critical review of the manuscript. Finally, all authors read and approved the final manuscript for publication.

### *Data Availability*

All the data supporting the conclusion of the study are included in the paper.

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