

Bacteriological Safety of Swimming Pools Within and Around the University of Port Harcourt

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ABSTRACT

The swimming pool is an essential place of recreation. However, these pools can pose significant public hazard for swimmers, especially when contagious levels exceed those recommended by regulatory agencies. Five different swimming pools in and around the University of Port Harcourt, Choba, Rivers State, were investigated before and after usage for their microbial safety and susceptibility of bacterial isolates from the different swimming pools. Ten water samples from the swimming pools were serially diluted and dilution factors of up to 10^{-3} were cultured on the appropriate agar media, using the spread plate method. The mean coliform and fecal coliform counts ranged from <2 to 50MPN/100 ml and <2 to 17MPN/100 ml, respectively. The total heterotrophic bacterial count ranged from 3.80 to 4.76 \log_{10} cfu/ml. The resulting bacteria isolates were identified based on the morphological, physiological and biochemical characteristics as *Bacillus spp.* (36%), *Proteus spp.* (28%), *Citrobacter spp.* (12%), *Staphylococcus spp.* (4%), *Micrococcus spp.* (4%), *Providencia spp.* (4%), *Pseudomonas spp.* (4%), *Escherichia spp.* (4%) and *Salmonella spp.* (4%). The isolated bacteria have varying resistance against gentamycin, augmentin, amoxicillin, carbapenem, cefuroxime, ceftriaxone and cefixime. The presence of coliform, fecal coliform and antibiotic resistant bacteria revealed that the examined swimming pools have not met the World Health Organization (WHO) standard for recreational waters, thus necessitating prompt and effective intervention.

Keywords: Coliform, Most Probable Number (MPN), disinfectants, swimming pool.

Introduction

Water is one of the most basic needs of man, playing prominent roles in food production and processing, transportation, power generation, cooling industrial machines, irrigation, recreation amongst others (Mackereth *et al.*, 2003).

A swimming pool is an enclosed body of water of limited size contained in a holding structure, designed to enable swimming or other leisure activities such as sports or rehabilitative treatment (Amala and Aleru, 2016). Pools can be built into

the ground (in-ground pools) or built above ground; as a freestanding construction or as part of a building or other larger structures, aboard ocean-liners and cruise ships. The largest known pool is the Olympic-size swimming pool.

This water is generally of potable quality and is treated with additional disinfectants (chlorine compounds, ozone). Swimming pools have grown in popularity recently, and potential maintenance issues could have a negative impact on public health. Due to the numerous potential channels for

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microbial contamination, the microbiological safety of swimming pool water is seriously questioned in nations with lax regulatory frameworks. (Ekopai *et al.*, 2017).

Although modern swimming pools have a recirculating system so that the water can be filtered and disinfected effectively, relevant research studies, show that neither advanced technological systems nor disinfectants can prevent the colonization of the pool water with hazardous pathogens (Lumb *et al.*, 2004; Reali *et al.*, 2004; Barben *et al.*, 2005).

A wide range of microorganisms can be found in swimming pools, which may be introduced in the pool water in several ways. In many cases, the risk of illness or infection has been linked to faecal contamination of the water, from bathers or contaminated source water or, in outdoor pools, may be the result of direct animal contamination from birds and rodents (WHO, 2006; Nichols, 2006; Amala and Aleru, 2016). Faecal matter is unintentionally released into the swimming pool water when a person has an accidental faecal release (through the release of diarrheic stool into the water) or when residual faecal material on swimmers' bodies is washed into the pool (CDC, 2001). Non-faecal human excretion (e.g., from vomit, mucus, saliva or skin) in recreational water is also a potential source of pathogenic organisms. In addition, infected users can directly contaminate pool waters with pathogens (particularly viruses or fungi), which may lead to skin infections in other patrons, who come in contact with the contaminated water. 'Opportunistic pathogens' (mainly bacteria) can also be excreted by users and spread by tainted water. Some bacteria, particularly of non-faecal origin may be concentrated in biofilms and present an infection hazard. In addition, certain free-living aquatic bacteria and amoebae can grow in pool waters, in pool components or facilities (including heating, ventilation and air-conditioning systems) or on other wet surfaces within the facility to a point at which some of them may cause an assortment of

respiratory, dermal or central nervous system infections or diseases (WHO, 2006; Nichols, 2006).

Microbiological assessment has, for decades, been the most important technique for hygienic and quality control of swimming pools, hence this investigation was carried out to ascertain the microbiological quality of swimming pools within and around the University of Port Harcourt, Nigeria and ascertain the possible health implications of using the swimming pools.

Materials and Methods

Study area

Water samples were obtained from five distinct swimming pools in and around the University of Port Harcourt.

Collection of samples

A total of 10 samples of swimming pool water were collected from five different swimming pools before bath (EBB, HBB, MBB, UBB, UCBB) and after bath (EAB, HAB, MAB, UAB and UCAB) into sterile 250 ml wide-mouth plastic containers at a depth of about 30 cm. The sampling periods were morning after swimming pool treatment with chlorine and evening after usage by pool patrons. The samples were taken to the laboratory for immediate bacteriological examination.

Presumptive Test

A series of fermentation tubes, the first roll containing MacConkey broth of double Strength, the second and third roll containing single strength concentration respectively. The first five tubes with double strength medium were inoculated with 10mls of water sample, the second five tubes received 1.0ml of sample and the last five tubes were inoculated with 0.1ml of sample. These tubes were incubated separately within 24-48 h at 37°C and 44.5°C for gas production and colour change. Based on the number of positive tubes, the results were compared with the Most Probable Number (MPN) statistical table.

Confirmed Test

The confirmed test was done using Eosin methylene blue agar (EMB). The medium was poured into Petri dishes. Over the surface of EMB agar medium, a loopful culture of the least positive tubes was streaked; plates were incubated at 37°C and observed after 24 h.

Completed Test

The last test, the completed test was performed to ascertain the consistency and ability of the Coliform to ferment lactose to yield forming acid and gas. From a positive confirmed test, the colony was transferred to nutrient agar plates. The plates were incubated at 37°C for 24 h. A Gram stain procedure was also performed as part of the completed test to show, Gram-negative, non-spore forming rods on the agar slant (Ugbong *et al.*, 2015).

Microbiological Analysis

A 10-fold serial dilution for each sample was made using sterile buffered peptone water (10ml of the water sample was diluted with 90ml of 0.1% sterile peptone water) up to 10^{-4} dilution and 0.1 ml of each sample were surface spread onto duplicate sterile Nutrient agar plate and Mannitol salt agar plates for enumeration of bacteria, incubated at 37°C for 24 h. Discreet colonies were counted and expressed as coliform forming units per milliliter (cfu/ml) while representative colonies were purified and preserved in slants pending confirmation.

Confirmation of Isolates

The conformation was based on isolates' cultural characteristics, physiology (Gram's reaction) and biochemical [catalase, citrate, coagulase, indole, motility, methyl-red, Voges-Proskauer, triple sugar iron, utilization of sugar (glucose, sucrose and lactose) tests (Cowan and Steel, 1985; Holt *et al.*, 2004).

Antibiotics Susceptibility Testing

Susceptibility tests were performed using the disk diffusion method (Bauer *et al.*, 1966). The selection of antimicrobial agents and interpretation of zones of inhibition was based on the Clinical and Laboratory Standards Institute (2013). The antimicrobial agents tested are of medical importance, including augmentin (30µg), erythromycin (15µg), gentamycin (10µg), carbapenem (10µg), ceftriaxone (30µg), cefixime (30µg), levofloxacin (10µg), ciprofloxacin (10µg), azithromycin (15µg), cefuroxime (20µg), amoxicillin (30µg), neomycin (10µg), cefotaxime (30µg), ofloxacin (10µg) and nalidixic acid (10µg).

Result

Total Heterotrophic Microbial Counts

The results of the microbial analysis showed significant bacteria growth across all the examined swimming pools (Table 1). The bacteria count ranged from 3.80 to 4.76 \log_{10} cfu/ml.

Coliform Counts

The total coliform and fecal coliform counts from the different sample locations are presented in Tables 2 and 3, respectively. The total coliform counts ranged from <2 to 50 MPN/100ml. Similarly, the fecal coliform counts ranged from <2 to 17 MPN/100ml.

Confirmation and Characterization of Isolates

The cultural morphology, physiology and biochemical characteristics of the isolated bacteria isolates are presented in Table 4. The most occurring bacterial was *Bacillus* spp. (36%), followed by *Proteus* spp. (28%). Other isolates are *Citrobacter* spp. (12%), *Staphylococcus* spp. (4%), *Micrococcus* spp. (4%), *Providencia* spp. (4%), *Pseudomonas* spp. (4%), *Escherichia* spp. (4%) and *Salmonella* spp. (4%).

Percentage Occurrence of Bacteria Isolates

Figure 1 shows the percentage occurrence of the bacteria isolates from the swimming pool water samples examined. The most occurring bacteria were *Bacillus* spp. (36%), followed by *Proteus* spp. (28%), *Citrobacter* spp. (12%), with the least occurring bacteria being *Salmonella* spp., *Escherichia* spp., *Pseudomonas* spp., *Staphylococcus* spp., *Micrococcus* spp., and *Providencia* spp. (4%).

Distribution of Bacteria Isolates across Samples

Table 5 shows the distribution of the isolated bacteria across the swimming pool samples. All samples had at least one genera of bacteria isolated from it. Samples MBB, UBB, MAB and UCBB had three genera of bacteria each, samples HBB and EAB had two each, while samples HAB, EBB,

UAB and UCAB had just one genera of bacteria isolates.

Antibiotic Susceptibility Testing

Tables 6 and 7 show the antibiotic sensitivity for Gram-positive and Gram-negative bacteria, respectively. For the Gram-positive organisms, azithromycin was the most effective followed by ofloxacin while augmentin, gentamycin and cefuroxime were the least effective. The Gram-negative organisms were more resistant than the Gram-positive organisms, showing complete resistance against a number of the Gram-negative antibiotics. However, ofloxacin proved effective against all but one Gram-negative bacteria. For the Gram-negative bacteria, augmentin, amoxicillin, carbapenem, cefuroxime, ceftriaxone, and cefixime had no effect on any of the isolates.

Table 1: Total heterotrophic bacteria count of the swimming pools

Sample code	Average no of colonies	Dilution factor	cfu/ml	Log ₁₀ cfu/ml
HBB	83	10 ⁻²	8.3 x 10 ³	3.80
HAB	64	10 ⁻²	6.4 x 10 ³	3.91
EBB	82	10 ⁻²	8.2 x 10 ³	3.91
EAB	172	10 ⁻²	1.72 x 10 ⁴	4.23
MBB	66	10 ⁻²	6.6 x 10 ³	3.81
MAB	152	10 ⁻²	1.52 x 10 ⁴	4.10
UBB	124	10 ⁻²	1.24 x 10 ⁴	4.09
UAB	58	10 ⁻³	5.8 x 10 ⁴	4.76
UCBB	182	10 ⁻²	1.82 x 10 ⁴	4.15
UCAB	142	10 ⁻²	1.42 x 10 ⁴	4.25

Table 2: Total coliform counts from the different sample locations

Sample code	10ml	1ml	0.1ml	MPN/100ml
HBB	1	0	0	2
HAB	4	0	0	13
EBB	2	0	0	4
EAB	2	0	0	4
MBB	5	1	1	50
MAB	1	1	0	4
UBB	2	1	0	7
UAB	0	0	0	<2
UCBB	2	1	0	7
UCAB	1	1	0	4

Table 3: Fecal coliform counts from the different sample locations

Sample code	10 ml	1 ml	0.1 ml	MPN/100ml
HBB	0	0	0	<2
HAB	0	0	0	<2
EBB	0	0	0	<2
EAB	0	0	0	<2
MBB	4	1	0	17
MAB	2	1	0	7
UBB	1	1	0	4
UAB	0	0	0	<2
UCBB	1	0	0	2
UCAB	1	1	0	4

Table 4. Morphological and Biochemical Characteristics of Bacteria Isolates

Isolate code	Colonial morphology	Morphology	Gram stain	Catalase	Oxidase	Coagulase	Sucrose	Glucose	Lactose	TSA slant	TSA Butt	Gas	H ₂ S	Indole	MR	VP	Starch hydrolysis	Citrate	Motility	Most likely Genera
1	Orange, flat, shiny, round, curled	R	-	+	-	-	-	+	-	B	B	-	+	-	+	-	-	-	+	<i>Salmonella</i> sp.
2	Golden yellow, round, smooth, flat, entire	R	-	+	-	-	+	+	+	B	B	+	-	+	+	-	-	-	+	<i>Escherichia</i> sp.
3	White, flat, dry, round, entire	R	-	+	-	-	-	-	-	B	B	+	-	-	-	-	+	+	-	<i>Pseudomonas</i> sp.
4	Cream, round, mucal, raised, entire	C	+	+	-	+	+	+	+	B	B	-	-	-	+	+	+	+	-	<i>Staphylococcus</i> sp.
5	Cream, round, smooth, raised, entire	R	-	+	-	-	-	+	-	B	A	+	-	-	+	-	-	+	+	<i>Proteus</i> sp.
6	White, round, smooth, raised, entire	C	+	+	-	-	-	-	-	B	B	-	-	-	+	+	+	+	-	<i>Micrococcus</i> sp.
7	White, raised, dry, irregular, lobate	R	-	+	-	-	+	+	+	B	B	-	-	+	+	-	+	+	+	<i>Citrobacter</i> sp.
8	White, flat, dry, irregular, lobate	R	-	+	-	-	-	-	-	A	B	-	-	+	+	-	-	+	+	<i>Providencia</i> sp.
9	Cream, round, rough, flat, entire	R	+	+	+	-	+	+	-	B	B	-	-	-	-	+	-	+	+	<i>Bacillus</i> sp.

Key: + = Positive; - = Negative; VP = Voges Proskauer; MR = Methyl Red; B = Base; A = Acid; R = Rod; C = Cocci

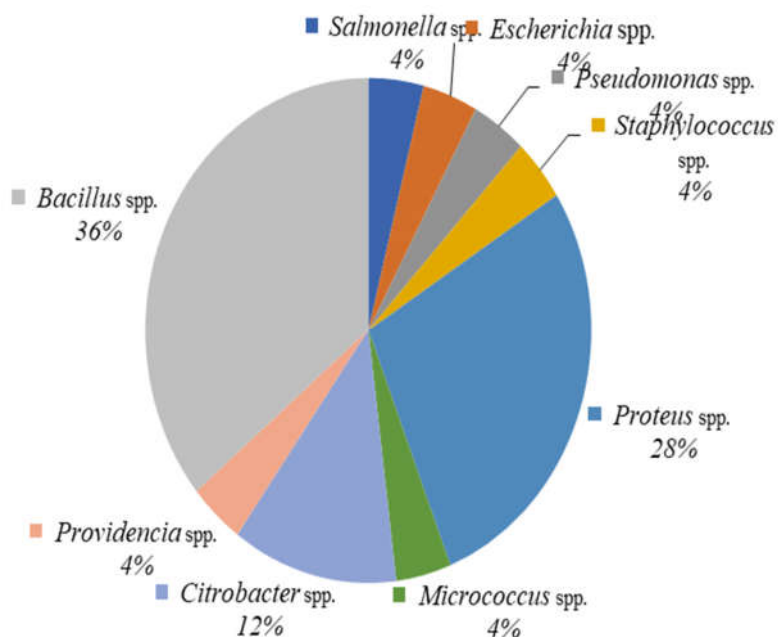


Figure 1: Frequency of occurrence of bacteria isolate

Table 5: Distribution of bacteria isolates among the swimming pool samples

Isolates	Samples										
	HBB	HAB	EBB	MBB	EAB	UAB	UBB	MAB	UCB	UCA	UCB
Salmonella sp.	-	-	-	-	-	-	+	-	-	-	-
Escherichia sp.	-	-	-	-	-	-	-	-	-	-	+
Pseudomonas sp.	-	-	-	-	-	-	-	+	-	-	-
Staphylococcus sp.	-	-	-	-	-	-	-	+	-	-	-
Proteus sp.	-	-	-	+	+	-	+	+	+	-	-
Micrococcus sp.	-	-	-	+	-	-	-	-	-	-	-
Citrobacter sp.	+	-	-	-	+	-	-	-	+	-	-
Providencia sp.	-	-	-	-	-	-	-	-	+	-	-
Bacillus sp.	+	+	+	+	-	+	+	-	-	-	-

Key: + = Present; - = Absent

Table 6: Percentage resistance of Gram-positive isolates

Isolate	No	AUG	ERY	GEN	IMP	CRO	ZEM	LBC	CIP	AZ N	CXM	OFX	CTX
<i>Bacillus</i> spp.	5	5(100%)	3 (60%)	5 (100%)	4 (80%)	4 (80%)	4 (80%)	1(20%)	1 (20%)	0	5 (100%)	0	4 (80%)
<i>Staphylococcus</i> sp.	1	1 (100%)	0	1 (100%)	1 (100%)	1 (100%)	1 (100%)	1 (100%)	1 (100%)	0	1 (100%)	1 (100%)	1 (100%)
<i>Micrococcus</i> sp.	1	1 (100%)	1 (100%)	1 (100%)	1 (100%)	0	1 (100%)	1 (100%)	1 (100%)	0	1 (100%)	0	1 (100%)

AUG= Augmentin; ERY= Erythromycin; GEN= Gentamycin; IMP= Carbapenem; CRO= Ceftriaxone; ZEM= Cefixime; LBC= Levofloxacin; CIP= Ciprofloxacin; AZN= Azithromycin; CXM= Cefuroxime; OFX= Ofloxacin and CTX= Cefotaxime.

Table 7: Percentage resistance of Gram-negative isolates

Isolate	No	AUG	AOX	IMP	NEF	CXM	CRO	CTX	ZEM	OFX	GEN	LBC	NXA
<i>Citrobacter</i> spp.	2	2 (100%)	2 (100%)	2 (100%)	2 (100%)	2 (100%)	2 (100%)	1 (50%)	2 (100%)	0	2 (100%)	1(50%)	1(50%)
<i>Proteus</i> spp.	2	2 (100%)	2 (100%)	2 (100%)	2 (100%)	2 (100%)	2 (100%)	2 (100%)	2 (100%)	1 (50%)	2 (100%)	2 (100%)	1 (50%)
<i>Salmonella</i> sp.	1	1 (100%)	1 (100%)	1 (100%)	1 (100%)	1 (100%)	1 (100%)	1 (100%)	1 (100%)	0	1 (100%)	0	1 (100%)
<i>Pseudomonas</i> sp.	1	1 (100%)	1 (100%)	1 (100%)	1 (100%)	1 (100%)	1 (100%)	1 (100%)	1 (100%)	0	0	1 (100%)	1 (100%)
<i>Escherichia coli</i>	1	1 (100%)	1 (100%)	1 (100%)	0	1 (100%)	1 (100%)	1 (100%)	1 (100%)	0	0	0	0

AUG= Augmentin; AOX= Amoxicillin; IMP= Carbapenem; NEF= Neomycin; CXM= Cefuroxime; CRO= Ceftriaxone; CTX= Cefotaxime ZEM= Cefixime; OFX= Ofloxacin; GEN= Gentamycin; LBC= Levofloxacin and NXA= Nalidixic acid.

Discussion

Swimming pools provide important recreational opportunities for individual or group swimming, relaxation for tourists, training in the sports of swimming and other social activities (Okwelle and Nwaokugha-Douglas, 2020). Recreational waters' microbiological quality has been extensively regulated using heterotrophic and coliform counts as a basis (Agbagwa and Young-Harry, 2012). The microbiological analyses of the swimming pools

showed a high prevalence of bacteria in majority of the swimming pools. The total heterotrophic bacteria count of the swimming pool samples before and after bath by patrons ranged from 3.80 to 4.15 and 3.81 to 4.76 log₁₀cfu/ml, respectively. The count from this study is less than the 7.32 to 8.04 and 7.62 to 8.25 log₁₀cfu/ml before and after bath reported by Omoni *et al.* (2019) in a somewhat public swimming pool in Makurdi, Nigeria. The finding of this study irrespective of the time of collection is within the range of 3.90 to

9.12 and 1.48 to 5.81log₁₀cfu/ml previously reported by Agbagwa and Harry-Young (2012) and Ekopai *et al.* (2017) in pool in Port Harcourt metropolis, Nigeria and Kampala City in Uganda, respectively but less than the 6.48 to 7.82log₁₀cfu/ml reported by Bello *et al.* (2012) in swimming pool in Lagos metropolis. Onifade *et al.* (2019) in their study also reported that the total bacteria count of pool water samples was higher after use than before use. The heterotrophic bacteria count in swimming pools examined by Ndunuisi and Igwe (2019) ranged from 1.11 to 1.61log₁₀cfu/ml which was lower than the count in this study. This high bacterial count might be due to the constant usage of the pool by the students of the University of Port Harcourt. The heterotrophic bacterial counts for all the water samples were generally high, exceeding the limit of 5.0 x 10²cfu/ml by the National Water and Sewerage Corporation (NWSC) and World Health Organization (Ekopai *et al.*, 2017). The risk of illness or infection associated with swimming pools and similar recreational water environments has been connected to feces discharged by bathers or contaminated source water causing faecal contamination of the water. (NCR, 2004; APHA, 2005). The most probable number (MPN) for the presumptive total coliform count of the water samples ranged from <2 to 50 MPN/100ml, while the most probable number (MPN) for the presumptive fecal coliform count of the water samples ranged from <2 to 17 MPN/100ml. The coliform count obtained in this study is higher than the <2 to 20MPN/100ml previously reported by Agbagwa and Harry-Young (2012), while Amala and Aleru (2016) reported the inability to detect coliform and faecal coliform in 8 and 10 swimming pool, respectively in the pool within Port Harcourt metropolis. Bello *et al.* (2012) reported the non-detection of coliforms in 75% (15 or 20) of pools examined in Lagos metropolis. On their part, Ekopai *et al.* (2017) reported that the total coliform and *E. coli* tests yielded no positive results in a swimming pool in Kampala City,

Uganda. The absence of coliform and *E. coli* is an indication that faecal contamination of these pools was unlikely, since they are potent indicators of faecal contamination. It suggests that water from sample station MBB (MBL before bathing)) had the highest total coliform counts (50 MPN/100ml) while sample UAB had the least total coliform counts (<2 MPN/100ml). Similarly, sample MBB had the highest fecal coliform counts (17 MPN/100ml), while samples HBB, HAB, EBB, EAB and UAB had the least coliform counts of <2 MPN/100ml.

The results of this study indicate that microorganisms are present in the sampled swimming pools. The isolated bacteria are *Salmonella* spp., *Escherichia* spp., *Pseudomonas* spp., *Staphylococcus* spp., *Proteus* spp., *Micrococcus* spp., *Citrobacter* spp., *Providencia* spp., and *Bacillus* spp. These findings corroborate earlier reports of the presence of *Pseudomonas*, *Klebsiella*, *Enterobacter*, *Staphylococcus aureus*, *Staphylococcus epidermidis*, *Enterobacter faecalis*, *Klebsiella pneumoniae*, *Enterococcus faecalis*, *Clostridium perfringens*, *Bacillus cereus*, *E. coli*, *Micrococcus*, *Aeromonas*, *Citrobacter*, *Corynebacterium*, *Proteus vulgaris* and *Leuconostoc* spp. in swimming pool in Nigeria and other countries (Kiyohara *et al.*, 2006; Papadopoulou *et al.*, 2008; Sule *et al.*, 2010; Agbagwa and Harry-Young, 2012; Bello *et al.*, 2012; George *et al.*, 2014; Ajadi *et al.*, 2016; Amala and Aleru, 2016; Ndunuisi and Igwe, 2019; Okafor *et al.*, 2020). The findings of this study also corroborate the assertions that microbes associated with the skin, eye, ear and gastrointestinal tract infection were the most common infectious agents that can be transmitted by recreational waters (Wade *et al.*, 2003; Kiyohara *et al.*, 2010). The detection of pathogenic bacteria constitutes a public health hazard because swimmers can accidentally swallow contaminated pool water during swimming which can result in outbreaks of diseases like cholera, shigellosis, typhoid and paratyphoid fever, gastroenteritis and diarrhea.

The most occurring bacteria was *Bacillus* spp. (36%), followed by *Proteus* spp. (28%) and *Citrobacter* spp. (12%), with the least occurring bacteria being *Salmonella* sp., *Escherichia* sp., *Pseudomonas* sp., *Staphylococcus* sp., *Micrococcus* sp., and *Providencia* sp. (4%). The results agree with reports by Ita and Ekpombok (2004) and Shittu *et al.* (2008), that approximately 40% of the microorganisms isolated from swimming pools are species of *Bacillus*. This is premised on the fact that *Bacillus* species are spore formers, which are resistant to common disinfectants like perchloride. In the present study, all samples had at least one genera of bacteria isolate and the presence of some human-associated and environmental organisms in high numbers in the pools may be attributed to the time of collection of the samples when pools are most heavily used or lack of or improper disinfection of the pools (Papadopoulou *et al.*, 2008). Barna and Kádár (2012) have however, reported water-borne disease outbreaks from 73.1 % of treated recreational pool, spa and similar facilities in the United States between 1999 and 2008.

Papadopoulou *et al.* (2008) have reported that pathogens that survived disinfectant or are tolerant might also be antibiotic resistant, a fact already documented for bacterial isolates from treated drinking water.

The results of the antibiotic sensitivity tests for the isolates showed that for the Gram-positive organisms, azithromycin was the most effective followed by ofloxacin while augmentin, gentamycin and cefuroxime were the least effective. The Gram-negative organisms showed greater resistance than the Gram-positive organisms, showing complete resistance against a number of the Gram-negative antibiotics. However, ofloxacin proved effective against all but one Gram-negative bacteria. For the Gram-negative bacteria, augmentin, amoxicillin, carbapenem, cefuroxime, ceftriaxone, and cefixime had no effect on the isolates.

The majority of antibiograms of swimming pool isolates in available literature centered on *Pseudomonas* species. In this study, the *Pseudomonas* sp. showed 83.33% (10 of 12) resistance against the tested antibiotics. This is comparable to the 81% reported by AiTuraifi *et al.* (2019). Lutz and Lee (2011) reported *Pseudomonas* resistance of 4, 9 and 29% against ceftriaxone, gentamycin and imipenem, respectively while Okafor *et al.* (2020) reported a resistance of 94.4, 93.1 and 87.4% against gentamycin, ciprofloxacin and erythromycin, respectively. According to Schiavano *et al.* (2017), the highest isolation rate of imipenem-resistant *P. aeruginosa* was observed in swimming pool water in a study examining water samples in central Italy. Tirodimos *et al.* (2010) also reported that the *P. aeruginosa* isolates in their research were highly resistant to antimicrobials which included: ceftazidime, ciprofloxacin, gentamycin and imipenem employed in this study. The resistance was attributed to the fact that the bacterium is naturally resistant to many antibiotics including those of first and second-cephalosporins, first-generation fluoroquinolones among a wide range of other antimicrobials because of their relatively impermeable membrane, constitutively expressed and inducible efflux systems and a chromosomally encoded inducible β -lactamase.

The resistance observed with other bacterial isolated in this study is consistent with the report of Okafor *et al.* (2020) who reported very high resistance of bacterial isolates from swimming pool against gentamycin, ciprofloxacin and erythromycin employed in this study respectively as follows: *Bacillus* spp. (90.8, 89.4 and 88.1%), *Staphylococcus* spp. (94.4, 93.1 and 87.4%), *Citrobacter* spp. (89.5, 98.5 and 87.2%), *Salmonella* spp. (89.8, 90.4 and 88.3%), *Proteus* spp. (90.1, 90.7 and 87.4%) and *Escherichia coli* (89.5, 93.7 and 89.5%). Ofloxacin was the most effective antibiotic in this study against the Gram-positive and Gram-negative bacteria; thereby corroborating an earlier report by Onifade *et al.*

(2020). These resistances imply that many bacterial illnesses that could be treated with the selected inexpensive antibiotics will now be more expensive to treat.

Conclusion

Pathogen transmission linked to swimming in freshwater is becoming well-established. According to the study's findings, several of the swimming pools within and around the University of Port Harcourt are not properly and regularly treated; necessitating the need for guidelines aimed at reducing the microbial load of swimming pools to the barest minimum. Pools patrons should be sensitized on the potential health risks associated with swimming pools judging from the antibiotic resistance observed in the examined pools; as this will alleviate the mismanagement of the pools by swimmers and managers. It is important to continuously test swimming pool water for presence of pathogens that pose public health risks to humans. There is the need to optimize water treatment methods to get the best-performing chemicals that can kill or reduce these pathogens to minimal or non-worrying levels.

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