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ASSESSMENT OF WATER QUALITY OF THE SELECTED RECREATIONAL SWIMMING POOLS IN UMUAHIA METROPOLIS, SOUTHEASTERN NIGERIA

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ABSTRACT

This Study was conducted on the selected public swimming pools in Umuahia for water quality assurance for recreation. Water samples were randomly taken from five swimming pools during October – December, 2020, from five hotels: Damgrete (SWP_1), Confidence (SWP_2), Villa Roy (SWP_3), Wiss Castle (SWP_4), and Benac Hotels (SWP_5), respectively. The study evaluated the physicochemical and microbial properties of the swimming pools. The media applied for the study were MacConkey agar, nutrient agar, Salmonella-Shigella agar, eosin methylene blue agar, Sabouraud dextrose agar, thiosulphate citrate bile salt sucrose agar for total aerobic plate count; coli form count, Escherichia coli count, Salmonella-Shigella count, Vibrio cholerae count and fungal count respectively. Bacterial isolates identified by using standard microbiological techniques to include Gram staining and biochemical tests. The fungal isolates identified using the needle mount technique. Data were analyzed using variance and mean separation by Duncan Multiple Range Test (DMRT) at P<0.05. From the results, the Average temperature for the pools in Umuahia was 24.75 ^{0}C. The average turbidity of the swimming pools was 3.0±0.08 turbidity >the 0.5–1.0 NTU world health (WHO) permissible limit. The mean pH of the swimming pools recorded 6.82±0.06-indicating moderate acidic against the pH 7.2-7.8 WHO limit for swimming pool. Total chlorine in some selected pools ranged between 3.15 ±0.21-3.25 ±0.07 mg/l above the <3 WHO limit. The percentage of bacteria prevalence in the selected swimming pools indicated 14% for P.aeruginosa, Bacillus sp, Citrobacter sp, Enterobacter sp each, 19% S.aureus, and 24% Klebsiella sp. Pseudomonas aeruginosa *was dominant in the swimming pools followed by Total faecal coli form, total aerobic plate count and Escherichia coli being the least and were below the WHO limits respectively. Regular monitoring and testing of the pool water chemistry will ensure a low-cost maintenance sparkling and clean swimming pool all the year round.*

KEYWORDS: *Swimming Pools, Microbiology, Physicochemical characteristics, Health risk assessment.*

1. INTRODUCTION

Recreational use of water is beneficial to health and well-being of humans but, with adverse health effects if the water quality is polluted or unsafe by pathogenic microorganisms (Indabawa and Muskhtar, 2015). In less developing countries of the world, there is no support for standards or regulatory framework to ensure that swimming pools are not hubs for pathogen infection or other dangers (Ekopai *et al.,* 2017). However, studies have reported the chemical, biological, physical contaminations in swimming pools in the world (Le *et al*., 2011; Abd El-Salam, 2012). Accordingly, there are several health risks associated with the swimming pools, which include risk of drowning, trauma and injuries, risk of microbiological, and physicochemical agents (WHO, 2006; Ajadi *et al*., 2016). Among these, microbial safety of swimming pool water is highly questionable in countries with poor regulatory framework due to the many existing possible microbial contaminant pathways. The infectious agents recovered from swimming pool waters include a variety of pathogens embracing bacteria, viruses, protozoa and fungi (Benkel *et al.,* 2000; Ali-Shtayel *et al*., 2002; Tate *et al*., 2003; Somekh *et al.,* 2003; Schets *et* al., 2004; Braue *et al.,* 2005; WHO, 2006). In addition to infections due to pathogens, infections due to opportunistic microorganisms (*M. fortiutum, M. chelonei, M marinum*) are reported too, which are able to cause mild-to-severe disease in immune competent and immune depressed (Sonia *et al*., 2015).

Microbial contamination of swimming pools can occur through: faecal contaminated source water or direct defecation from swimmers; birds, and animals (Papadopoulou *et al*., 2008; Kumar *et al*, 2014; Onichandran *et al.,,* 2014; Masoud *et al.,* 2016), nonfaecal human shedding from vomiting, sneezing, mucous, spitting, or skin, ; poor waste water disposal (WHO, 2008); microbial biofilm formation along piped water networks (Sente *et al.,* 2016) , contaminated air, dust, soil, or rainwater (El-Salam, 2012), and individuals with contagious diseases or infectious pathogens (Papadopoull *et al.,* 2008; WHO, 2008). Indeed, swimmers bring microorganisms and organic substances from saliva, sweat, cosmetics, sunscreen and urine alongside into the pool, which strongly contributes to water contamination (Sakkas *et al.,* 2003; Kanan and Karenfil, 2011; Keuten *et al.*, 2012; Uysal *et al*., 2017).

Swimming pools have become major recreation facilities for leisure and sports in cities across the world, but the standard guidelines, particularly in developing countries, are not adhered to because little is known about the contaminants in the pools and the possible health risks involved (Ekopai *et al.,* 2017; Ubuoh and Uchendu, 2018). Specifically, there is a dearth of information on the water quality of swimming pools in Abia State, especially Umuahia metropolis, Nigeria. Meanwhile, lack of proper quality control of the pool water can result in health risks for swimmers and staff and the spread of infections. The present study was carried out to determine the physicochemical and microbiological qualities of selected hotel swimming pools in the study area in order to assess their safety level.

2. MATERIALS AND METHODS

The Study Area

Abia State occupies about 5,833.77 sq.km with a population density of 450/km^2. The state is located on latitude 5^{o}25^{1}N and longitude 7^o 30^{1}E. By the projection of the National Bureau of statistics, based on the 1991 census figure of 1million, Abia state was expected to have a population of 3.51million. In 2006 the National Population Commission allocated 2,833,999 as the population of Abia State (NPC, 2006). The rainy season begins around the first of May and continues into September while the dry season runs from November to April. Rainfall reaches its highest monthly maximum of 300 – 400mm during the month of June through September and drop to 0.0-1.0mm in December and January.

Selection of Swimming Pools

For the study, swimming pools from five hotels were purposely selected for the assessment of their physicochemical and microbiological qualities, designated swimming pool sampling point (SWP_{1-5}), respectively, (Figure 1).

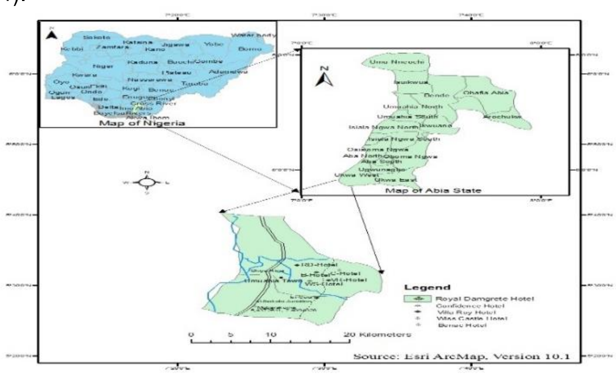

Fig 1. Map of Abia State showing Umuahia as the study location

Water sampling techniques for Swimming Pools Water Quality

Random selection of swimming pools in the Umuahia Metropolis was performed during October – December, 2020, from five hotels: Damgrete (SWP_1), Confidence (SWP_2), Villa Roy (SWP_3), Wiss Castle (SWP_4), and Benac Hotels (SWP_5). Commercial swimming pools were being sampled from five (5) randomly picked hotels designated SWP_{1-5} and the experiment was done with permission from the management of the hotels. Swimming pools water samples were collected at the time of swimming directly in pre-sterilized 750 mL bottles during dry season and duplicate each month at a selected sampling point for three consecutive months. Sampling was first done at the first and the last week of February till May 2020. At the pools, bottles were opened and held at their bases and submerged to a depth of about 20 cm with the mouth facing upwards, and water samples were taken by filling the bottles from the top to exclude air. The samples were taken to the laboratory in an ice chest/icebox containing ice cubes not more than three (3) hours after collection (Omoni *et al.,* 2019). The water samples for the Biological Oxygen Demand (BOD_5) were collected into sterile black BODbottles with stoppers. The samples were sent to the FISHARM'S Laboratory, Michael Okpara University of Agriculture for analyses.

Swimming Pool Water Quality Assessment

Swimming pool water sample analysis -Physical characteristics

The Absorptometric Method was applied in the determination of the turbidity. The method is based upon a comparison of the intensity of light scattered by the sample under defined conditions with the intensity of light scattered by a standard reference suspension. The higher the intensity of scattered light, the higher the turbidity. The Turbidimeter was calibrated using the 1000 NTU, 100 NTU and 10 NTU. Total dissolved solids in pool water were carried out as per methods described by APHA (1992). In Determination of Total Suspended Solids, the known volume of vigorously shaken pool water sample (50 ml) was filtered through a weighed standard glass fibre filter and the residue that is retained on the filter is dried to a constant weight at 103-105 ^{o} C. The increase in the weight of the filter determines the total suspended solids. Temperature was determined in situ using portable digital conductivity, pH meter (Beckman, Model 50), by immersion into the pool sample for a sufficient period of time (till the reading stabilized) and the reading taken. The turbidity of the water samples was determined by the turbidimetric method using a colorimeter (JENWAY, Model 6051).

Swimming pool water sample analysis -Chemical characteristics.

The swimming pool water sample was analyzed for determination of pH by atomic absorption spectroscopy described by the American Society for Testing Materials (APHA, 1998; ASTM, 2002). The conductivity was measured using Hanna instruments HI 9033 multi-range conductivity meter which uses a single probe to perform all conductivity readings in four ranges. Nitrate was by using a stock KNO_3 solution prepared by dissolving 0.7218 g KNO3 in 1L distilled water. The sulphate ion concentrations in the sampled pool water were determined by the Automated Methylthymol Blue Method. Ammonia (NH_4^+) was by Colorimetric method described by Hansen and Koroleff (Grasshoff *et al.*,1999; Kérouel and Aminot, 1997). Potassium concentrations was determined by flame atomic absorption spectrometry Total hardness by EDTA titrimetric method described by Owoso *et al*. (2000). Dissolved Oxygen (DO) and Biological Oxygen Demand (BOD_5) were analyzed through iodometric titrations using Winkler's reagent, suphuric acid, starch indicator and sodium thiosulphate. Chemical Oxygen Demand (COD) was determined using potassium dichromate digestion method. Free Chrorine was by Argentometric method, where a standard $AgNO_3$ solution was prepared and stored in brown amber bottle. A known volume (20 mL) of filtered sample was pipetted into a 250 mL conical flask to which 1 ml of K_2CrO_4 indicator was added to get light yellow colour.

Swimming pool water sample analysis - microbiological characteristics.

Swimming pool water samples were tested for the presence of *E. coli*, intestinal *enterococci, P. aeruginosa and S. aureus*, by using membrane filtration of various volumes of the water samples (range 1–100 ml), and incubation of the membrane filters on selective culture media. For enumeration of E. coli, intestinal enterococci, *P. aeruginosa* and *S. aureus on Brilliance Staph* 24 Agar and Collorex™ Staph aureus, mixed cellulose ester membrane filters (Merck-Millipore, HAWG047S6) were used.Enumeration of *E. coli* was done according to ISO 9308- 1:2014, with a modified incubation procedure to enhance selectivity (Jozić et al., 2018).Heterotrophic plate count was determined by spread plate method using nutrient agaras directed in Section 9215 (APHA, 2005). The 5–tube multiple tube fermentation method (also known as the Most Probable Number (MPN) technique) containing MacConkey broth (Fisher scientific, UK) was used to estimate total and faecal coliforms (APHA, 2005). The fecal coliforms (*E. coli*) were incubated at 44 ± 0.5°C for 24–48 h while the total coliforms were incubated at 37°C for 24–48 h. The enterococcus group is a subgroup of the faecal streptococci that includes S. faecalis, *S. faecium, S.gallinarium* and *S. avium*. The enterococci are differentiated from other streptococci by their ability to grow in 6.5%sodium chloride, at pH 9.6, and at 10℃ and 45℃. S. aureus was isolated using Mannitol Salt Agar according to APHA (2005). *P.aeruginosa* was isolated by using King A medium. The medium was weighed according to manufactures procedure and autoclaved at 121℃ for 15 minutes. Pure cultures were obtained by carefully picking a well-isolated colony that gave a typical response on nutrient agar plate. Plates were incubated at 35°C for 24 hours. Pure cultures arestored in the fridge prior to characterization (Agbagwa and Young, 2012).

Statistical Analysis

Data were analyzed with the SPSS© v. 22.0 and MS Excel© 2007 software. Variation plots were used to represent mean levels of the quality parameters of the pools sampled. One-Way ANOVA was used to determine homogeneity in mean variance of the parameters across the sampling locations, and post-hoc mean separation done with the Duncan Multiple Range Test (DMRT) at P<0.0.5 (Steel and Torrie ,1980).

3. RESULTS AND DISCUSSIONS

The results of the physical characteristics of the studied swimming pools bathing after being used are represented in **Mean ± SD (**Table 1).

Table 1: Mean ± SD of the Physical characteristics of the selected swimming pool water samples in Umuahia

Physical Characteristics	Swimming Pool Study Locations					Mean	**WHO limits (2005;2006)**
	SWP_1	SWP_2	SWP_3	SWP_4	SWP_5		
Turbidity (NTU)	3.05 ± 0.07^a	3.00 ± 0.14^a	3.00 ± 0.00^a	2.85 ± 0.07^{as}	3.00 ± 0.14^a	3.0±0.08	0.5–1.0
TSS (mg/L)	3.25 ± 0.21^b	1.10 ± 0.14^a	4.35 ± 0.35^c	5.15 ± 0.07^d	3.55 ± 0.35^b	3.5±0.22	Nil
TDS(mg/L)	345 ± 7.07^c	322.50 ± 3.54^b	305.00 ± 7.07^a	295.00 ± 1.41^a	302.50 ± 2.12^a	314±4.2	500
Temperature (°C)	24.15 ± 0.07^a	25.05 ± 0.35^b	24.70 ± 0.57^{ab}	25.15 ± 0.21^{ab}	24.70 ± 0.28^{ab}	24.8±0.3	21-32

Mean ± Standard deviation with same superscripts is not significantly different at P ≤ 0.05.

Variations of the Physical characteristics of Swimming Pools

From the Table 1, turbidity ranged between 2.85±0.07 to3.05 ±0.07 nephelometric turbidity units (NTU), with the mean value of 3.0±0.08NTU less than 3.29±0.25 -5.14±0.53 NTU found in the selected swimming pools in Makurdi, Benue State (Omoni *et al.,* 2019). The mean value of turbidity is above the 0.5–1.0 NTU WHO limit for swimming pool, having no significant different among the selected pools at $P \leq 0.05$. The mean value of turbidity was higher than 0.22-12.61 NTU in swimming pool water obtained in Oshogbo metropolis (Ajadi *et al*. (2016), with SWP_1, SWP_2, SWP_3 and SWP_5 falling within the turbidity range in swimming pools obtained in Owerri (Eze *et al.*, 2015), lower than the 26.6±11.5 NTU swimming pools in Iran (Karami *et al.*, 2017), lower than 1±0.15 1- 85±0.25NTU in Swimming Pools at Shahrekord (Abdolmajid and Masoud, 2015). The result of turbidity is consistent with the finding of 2.312±0.89 - 3.04±0.92 NTU obtained in swimming pools in Ghana (Addo *et al*., 2018). The higher concentration of turbidity in pool water has compromised and may pose health risks to the users (Fadaei and Sadeghi, 2014). The study in Ghana reported that turbidity values in 28 pools were > 0.5 NTU (Saba and Tekpor, 2015). Similarly, a high turbidity value of >5.5 NTU were reported in pools in Abeokuta, Nigeria (Shittu *et al*., 2008). However, results from this study differs from similar work carried out In Ilorin, Nigeria where the turbidity in all selected swimming pools were within the permissible limit as stipulated by WHO (Onajobi *et al*., 2013). Total suspended solids (TSS) in swimming pools studied ranged between 1.10 ±0.14 to 5.15 ±0.07 mg/L, with the mean value of 3.5±0.22 mg/L., and were significantly different of TDS among the selected pools at $P \geq 0.05$. The result of TDS is in tandem with the finding of Eze *et al*. (2015) who reported that TSS in the selected swimming pools in Owerri ranged from 1.0 ± 0.01 to 5.0 ± 0.3 mg/L.

Total dissolved solids (TDS) ranged between 295.00±1.41 to 345 ±7.07 mg/L, with the mean value of 314±4.2 mg/L less than the 275 ± 8.03 to 380 ± 10.0 mg/L of TDS in Owerri Eze *et al*., 2015), which may be due to salt chlorinated in pools that constitutes the bulk of TDS in swimming pools (John, 2008).

Temperature varied between 24.15±0.07 to 25.15 ±0.21°C, with the mean value of 24.8±0.3°C within the 21-32°C WHO limit for recreational water and less than 25.83±0.74 - 25.5±0.74 °C in swimming pools in Shahrekord City (Abdolmajid and Masoud Amiri, 2014), and lower than 26.5 to 32.7 °C in public swimming pools in Tamale Metropolis, Ghana (Umar *et al.,* 2020). The result is inconsistent with the findings of Karami *et al*. (2017) *who* reported temperature ranges of: 28±0.6, 28±1, 28±0.5, 28.6±0.5 and 28±1 °C swimming pools in Iran, 26°C (Esinulo and Ogbuagu, 2016) in public swimming pools in Owerri Metropolis, Nigeria. The result is lower than 31.11±1.58 31.27±1.57 31.18±1.16°C obtained in swimming pools in Ghana (Addo *et al*., 2018). The mean temperature observed did not conform to the findings of Itah and Ekpombok (2004), Mwajuma (2010), Ubuoh *et al*. (2013) who reported an average temperature of approximately 26.7 °C. The temperature was the same at $P \leq 0.05$. Above all, swimming pools with temperature range of 22-27°C is less contaminated than one with temperature of 23.3 – 28.8°C. (Attah *et al*.,2007). Therefore, pools with a temperature of more than 27 °C are more likely to be contaminated than pools with a temperature of 22-27 C. Increase in temperature thus encourages the growth of bacteria (Leoni *et al*., 2001).

Table 2: Mean ± SD of the chemical characteristics of the selected swimming pool water

Chemical	SWP_1	SWP_2	SWP_3	SWP_4	SWP_5	Mean	WHOLimit (2004;2006)
pH	7.05 ±0.07^a	7.20 ±0.00^b	6.00 ±0.14^a	7.10 ±0.00^{ab}	6.95 ±0.07^a	6.82±0.06	7.2-7.8
NO_3^-(mg/L)	4.1 ±2.40^a	4.00 ±1.56^a	3.85 ±1.91^a	4.15 ±2.19^a	3.70 ±1.98^a	3.8±2.01	NA
EC (µS/cm)	93.8 ±2.26^a	105.55±0.21^c	100.45±0.35^b	102.60±0.14^b	101.65±0.21^b	100.8±0.63	150
SO_3(mg/L)	3.9 ±2.26^a	3.95 ±1.77^a	3.80 ±2.12^a	4.15 ±1.48^a	4.00 ±1.98^a	3.96±1.90	NA
NH_4^+(mg/L)	0.16 ±0.03^a	0.20 ±0.02^a	0.17 ±0.03^a	0.14 ±0.04^a	0.20 ±0.02^a	0.17±0.03	1
DO(mg/L)	7.70±0.25	8.31±0.33^a	12.31±0.24^b	7.75±0.61^a	8.51±0.62^a	8.92±0.41	7.5
BOD (mg/L)	0.875±0.05^a	1.68 ±0.06^c	1.01 ±0.01^b	0.93 ±0.04^{bc}	0.87 ±0.04^a	1.07±0.04	3
COD (mg/L)	1.44 ±0.04^a	2.07 ±0.07^{cd}	1.83 ±0.02^b	2.10 ±0.02^d	1.95 ±0.08^{bc}	1.88±0.05	40
PO_4^{3-}(mg/L)	0.14 ±0.01^a	0.61 ±0.72^a	0.09 ±0.02^a	0.10 ±0.01^a	0.11 ±0.01^a	0.21±0.15	NA
Total R. C(mg/L)	3.25 ±0.07^b	2.35 ±0.07^a	2.15 ±0.07^a	3.15 ±0.21^b	2.30 ±0.14^a	2.64±0.11	<3
$CaCO_3$ (mg/L)	9.5 ±0.71^a	9.00 ±0.00^a	9.00 ±1.41^a	10.00 ±1.41^a	8.50 ±2.12^a	9.2±1.13	NA

*Data with the same alphabet are not statistically different at P>0.05 level

Variations of chemical characteristics of the selected swimming pools

From Table 2, mean pH in sampled pooled water ranged between 6.00 ±0.14 to 7.20 ±0.00, with the mean pH value of 6.8±0.01, less than The pH range of 4.58 - 6.69 observed in the pool water in selected hotels in Osogbo metropolis, Southwestern Nigeria (Ajadi *et al.,* 2016), less than 7.85-8.08 indoor swimming pools (Abdolmajid and Amiri, 2014), greater than acidity or alkalinity (pH) of the swimming pool water samples ranged from 3.86 ± 0.52 to 7.20 ± 0.62pH.The result agreed with the finding of Agbagwa and Young (2012) who reported pH 6.72 in swimming pools l in Port Harcourt . The result also disagreed with the finding of Addo et al. (2018) who observed pH values of 4.119±0.25, 7.355±1.07 and 4.117±0.31 in selected swimming pools in Ghana, lower than the findings of Wyczarska-Kokot (2009) in Poland, Eze *et al*. (2015), Esinulo and Ogbuagu (2016) who reported pH7.1 ± 0. to 7.68 in different pools respectively. Low pH conditions have been associated with problems such as itching, chlorine loss, skin spots and sore eyes in swimmers (Saberianpour *et al*., 2015). According to guidelines, the recommended pH for swimming pool water ranged from 7.2 to 8 (MHM, 2013). Health Protection, New South Wales Government (Health Protection NSW., 2013), and the Government of South Australia (2013) indicated that, if pH is below 7.2, there is the possibility of eye discomfort due to accelerated formation of chloramines, the rapid loss of chlorine, etching of exposed cement, and corrosion of metals. Above all, there was no significant different existing between pH in the selected pools at P≥0.05 level. The findings of Masoud *et al*. (2016) indicated that most swimming pools in Alexandria recorded a pH level of <7.2 or >7.8, with few being within 7.2–7.8. If pH is above 7.6, there is the possibility of reduction of chlorine disinfection efficiency, increased chlorine requirement, eye discomfort, drying of the skin, cloudy water, and scale formation (South Australia Health Commission., 2013). Levels of pH in pools should be maintained between 7.2 and 7.8 for chlorine disinfectants and between 7.2 and 8.0 for bromine-based and other nonchlorine processes. (Umar *et al*., 2020).

Nitrate ranged between 3.70 ±1.98 to 4.15 ±2.19 mg/L, with the mean value of 3.8±2.01 mg/L less than 12.75±3.13-13.26±2.14 mg/L of nitrate in swimming pools (Abdolmajid and Amiri, 2015); lower than 5.8 ± 0 mg/L obtained by Eze *et al*. (2015) in swimming pools. Nitrate concentration in the selected pools did not vary significantly at P≥0.05.

Electrical conductivity ranged between 93.8 ±2.26 to 105.55±0.21 µS/cm, with the mean value of 100.8±0.63 µS/cm lower than 150 µS/cm WHO acceptable recreational limit, less than Conductivity range of 32 to 7455 µS/cm that has been reported in swimming pools (Sila and Nzung', 2019). The result is consistent with the finding of Eze et *al,* (2015) who reported 95.2 ± 3.0 to 105.7 ± 5.0 µS/cm in swimming pools, less than 266.3±55.05, 802.7±28.42 and 353±63.09 µS/cm obtained in swimming pools in Asuogyaman district, Ghana (Addo *et al.*, 2018), 664.2µS/cm by Ajadi *et al.* (2015). Sulphate (SO_3) ranged between 3.80 ±2.12 to 4.15 ±1.48 mg/L with the mean value of 3.96±1.90 mg/L, less than 15.43±2.03 18.5±6.07 mg/L in Swimming Pools in Shahrekord (Abdolmajid and Amiri, 2015), and less than the finding of Eze *et al*. (2015) who reported 1.5 ± 0.01 to 2.0 ± 0.01 mg/L in swimming pools in Owerri. Ammonia (NH_4^+) in water that is an indicator of bacterial, fecal and animal wastes (Uysal *et al.,* 2017b). Pool water resources NH_4^+, the filling water, human origin (fecal and urine contamination) and is caused by biofilm formation (Güllüoglu, 2010; Uysal *et al.*, 2017). The NH_4^+(mg/L) ranged between 0.14 ±0.04 to 0.20 ±0.02 mg/L, with the mean value of 0.17±0.03 mg/L, less than 1mg/l limit value for pool by Uysal *et al*. (2017[a]). The result is consistent with the finding of Eze *et al*. (2015) that reported 0.14 ± 0.01 to 0.22 ± 0.01 mg/L in the selected swimming pools, and less than average summer results showed that NH_4+, concentrations varied between 0.003 and 0.999 mg/L (0.073±0.139 mgL^{-1} in water of swimming pools in Cana kale, Turkey (Uysal *et al*., 2017[b]). Dissolved oxygen (DO) ranged between 7.70±0.25 - 12.31±0.24 mg/L with the mean value of 8.92±0.41 mg/L greater than 8.38±0.69 7.28±0.78 mg/L (Abdolmajid and Amiri, 2015), and exceeded the 7.5 mg/L WHO standard for DO in pools (WHO, 2006). Meanwhile, a higher DO level indicates better water quality and how healthy the sampled pools. Depletion of dissolved oxygen in water could speed microbial conversion of nitrates to nitrites (WHO, 2008). Hence, the high DO values in pools could be the source of water supplied to the pools. The findings of the study agreed with the results reported from studied swimming pools in Ilorin (Onajobi *et al.,* 2013). Biological oxygen Demand (BOD_5) ranged between 0.87 ±0.04 to 1.68 ±0.06 mg/L, with the mean value of 1.07±0.04 mg/L less than 3.10 to 5.40mg/L BOD reported in the swimming pool water (Ajadi *et al*., 2016), and below the 3 mg/L WHO standard, but fall within 0.89 0.03 to 1.75 0.05 mg/L obtained in swimming pools by Eze *et al*. (2015). Chemical oxygen demand (COD_5) ranged between 1.44 ±0.04 to 2.10 ±0.02 (mg/L), with the mean value of 1.88±0.05 mg/L less than 0.26 to 6.88 mg/L in swimming pools (Ajadi *et al*., 2016) and below the 40mg/l WHO limit for pool. The result is in tandem with the finding of Eze *et al*. (2015) who reported the COD: 1.25 ± 0.02 to 2.55 ± 0.04 mg/L in swimming pools. Potassium (PO_4^{3-}) ranged between 0.09 ±0.02 to 0.61 ±0.72mg/l with the mean value of 0.21±0.15 mg/L greater than 0.07 ± 0.01 to 0.15 ± 0.02 mg/L observed in swimming pools by Eze *et al*. (2015). The range of the values obtained in this study agrees with the high to moderate levels of PO_4^{3-} in southern Nigeria, Rivers (Okeke and Adinna, 2013). The factor that could contribute to the input of PO_4^{3-}

suggests detergents remnants of swimming wears. Total residual chlorine ranged between 2.15 ±0.07 to 3.15 ±0.21 mg/L, with the mean value of 2.64±0.11 mg/L 0.14±0.01 to 0.68±0.07 mg/L in some semi-public Swimming pools in Makurdi, Nigeria (Omoni *et al*., 2019), but below the <3 mg/L WHO limit (WHO,2008), and higher than standard of Iran (1–3mg/L) (Fadaei1 and Masoud, 2015), and agreed with Agbagwa and Young (2012) who observed the mean Cl^- of 2.51 mg/L in swimming pools. Above all, the present result of total residual chlorine is > residual chlorine with a standard density of 1.5 mg/L or higher level that is insufficient to destroy any parasites and free-living ameba within the swimming pools (Ondriska *et al.*, 2004; Shields *et al.*, 2008). Total hardness (mg/L $CaCO_3$) ranged between 8.50 ±2.12 to 10.00 ±1.41 mg/L with the mean value of 9.2±1.13 mg/L grossly less than $CaCO_3$ of 290.83±16.35 251±27.12 mg/L in Swimming Pools in Shahrekord City (Abdolmajid and Amiri, 2015)., less than 44.44 -61.41 mg/L total hardness in public swimming pools in Owerri Metropolis (Esinulo and Ogbuagu, 2016). The result is in consonant with the finding of Eze *et al*. (2015) who observed the total hardness in swimming pools that ranged between 10 ± 0.3 to 10 ± 0.5mg/L in Owerri, and less than the 65.46±10.32 to 74.32±11.36 mg/L in swimming pools in Iran (Abdolmajid and Masoud, 2013).

Table 3: Comparison of Physicochemical characteristics of swimming pool water with this study with the study of pool water of other authors.

This Study	**Turbidity**	**TSS**	**TDS**	**Temp.**	**pH**	**NO_3^-**	**EC**	**SO_3**	**NH_4^+**	**DO**	**BOD**	**COD**	**PO_4^{3-}**	**residual chlorine**	**$CaCO_3$**	**Locations**
	3.0	**3.5**	**314**	**24.8**	**6.82**	**3.8**	**100.8**	**3.96**	**0.17**	**8.92**	**1.07**	**1.88**	**0.21**	**2.64**	**9.2**	
Wyczarska *et al.* (2019)	0.48	-	-	-	7.3 – 7.6	10.00 -19.00	-	-	-	-	-	-	-	0.50–0.95	-	**Poland**
Courage and Saviour (2015)	1-1-1.7	-	-	22-27	6.2- 7.2	-	72-83	-	-	-	-	-	-	1.3- 1.9	-	**Tamale, Ghana**
Mustapha *et al* (2020)		-	-	30.8- 30.7	4.04 – 6.13	-	469 – 928		-	-	-	-	-	-	-	**Tamale, Ghana**
Omoni *et al.*(2019)	6.0-7.7	-	115- 586	25.8 -26.8	6.6- 7.71	-	85.6- 120.4	-	-	4.6- 5.6	0.9- 2.6	1.8- 5.6	-	-	-	**Makurdi, Nigeria**
Ajadi *et al*. (2016)	0.22- 12.61	-	-	23.3- 28.8	4.48- 7.70;	-	166.6- 898.2	-	-	1.54 - 8.98	1.44 - 5.40	0.1- 8.92	-	10.2-28.8	-	**Osogbo, Nigeria.**
Fadaei1 and Amiri (2015)	1-1.85	-	-	25.5- 25.8	7.85- 8.0	13.26- 12.75	-	15.4 - 18.5	-	-	-	-	-	0.58-0.63	251- 290.8	**Shahrekord, Iran**
Masoud, *et al* (2016)	-	-	-	-	7.2 – 7.8,	-	-	-	-	-	-	-		-	-	**Alexandria**
Uysal *et al*. (2017)	-	-	-	-	-	-	-	-	0.003- 0.99	-	-	-	-	-	-	**Canakkale, Turkey**
Schets *et al*., 2020	0.13-69		**-**	**20-24**	8.5- 7.4-	**-**	562- 596	**-**		**-**	**-**	**-**	**-**	**-**	**-**	Netherlands.

From Table 4 the occurrence of bacteria of the selected swimming pool water samples indicated, Staphylococcus aurous*(S.aureus)* recorded the mean value of 0.8, less than the count in (cfu/100 mL) of S. aureus observed in the swimming pool water sources ranged from zero (0) to 13 (cfu/100 mL) and from zero (0) to 65 in pools' respectively (Umar *et al*., 2020), *P.aeruginosa, Bacillus sp, Citrobacter sp*, and *Enterobacter sp* recorded mean of 0.6 (cfu/100 mL) respectively. Similarly, Ita and Ekpombok (2004), Lagerkvist *et al*. (2004) reported microorganisms isolated from swimming pools are species of *Bacillus*, with the reason is owing to the fact that the species contain spores, which are resistant to disinfectants, Accordingly *Pseudomonas aeruginosa* associated with *otitis* media in swimmers (WHO, 2004; Eze et al., 2015). Eze et al. (2015) explained that *pseudomonas aeruginosa* can grow within untreated waters and in biofilms, and can cause skin, ear and eye infections when present in large numbers and outbreaks of skin infections have been linked to swimming pools and spa pools. *Klebsiella sp* recorded mean value of 1.0 as a dominant factor.

Table 4: Percentage frequencies of bacteria prevalence in the selected swimming pool water samples in Umuahia.

Bacteria	SWP_1	SWP_2	SWP_3	SWP_4	SWP_5	Total	Mean
S.aureus	+	+	+	+	-	4 (19%)	0.8
P.aeruginosa	+	-	+	-	+	3 (14%)	0.6
Bacillus sp	-	+	-	+	+	3 (14%)	0.6
Citrobacter sp	+	-	+	-	+	3 (14%)	0.6
Klebsiella sp	+	+	+	+	+	5 (24%)	1.0
Enterobacter sp	-	+	-	+	+	3 (14%)	0.6
Total	4(19%)	4(19%)	4(19%)	4(19%)	5(23.8%)	21 (100%)	
Mean	**0.67**	**0.67**	**0.67**	**0.67**	**0.83**		

LEGEND -ve = absent, +ve = Present. P1= Damgrete, P2 = Confidence Hotel, P3=Villa Roy Hotel, P4 = Wiss Castel, P5= Benac Hotel.

Percentage of Bacteria prevalence in swimming pool

Studies have been performed around the world on the health safety and quality of swimming pool water and epidemiological risk of enteric and skin infections (Papadopoulou *et al*., 2008; Agbagwa and Young-Harry, 2012; Casanovas-Massana and Blanch, 2013; Saba and Tekpor, 2015). Selected swimming pools (SWP_1-SWP_4) contributed 19% of the bacteria in the study pools with mean value of 0.67 each while P_5 contributed 24% bacteria as the most bacterial occurring pools with the mean value of 0.83 (Fig. 3). The presence of these organisms may be attributed to the time of collection of the samples when pools are most heavily used, inadequate application of disinfection of pools and unhygienic environment (Papadopoulou, 2008).

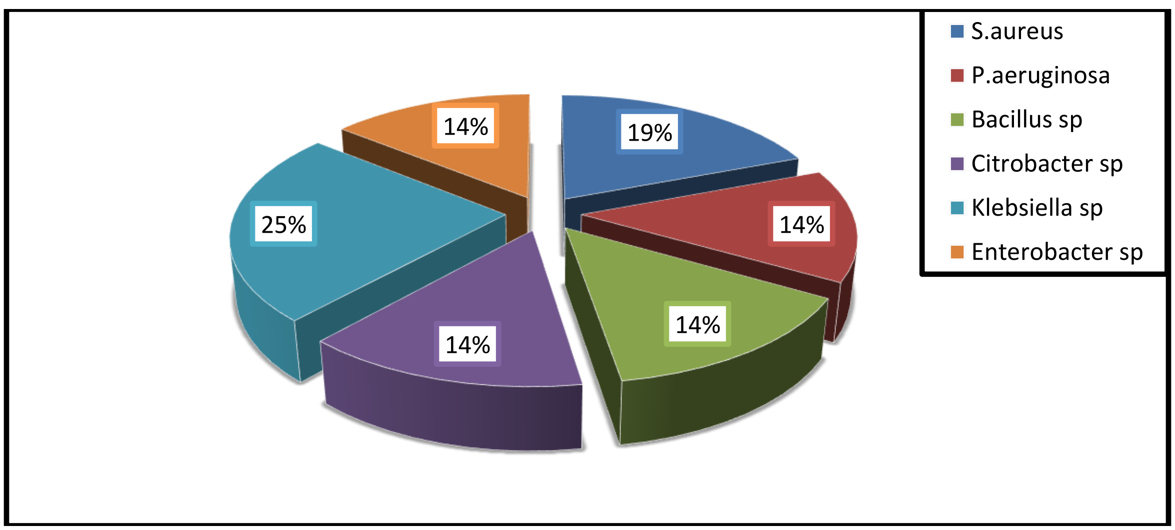

Fig.3: Percentage variations of bacterial in the selected swimming pools in Umuahia

TABLE 5: Microorganisms isolated from selected swimming pool water samples in Umuahia

Microbes	SWP_1	SWP_2	SWP_3	SWP_4	SWP_5	Mean	WHO Standards
TAPC/100 cfu/mL	0.21×10^{-1}	0.31×10^{1}	0.21×10^{-1}	0.00×10^{-1}	0.00×10^{-1}	0.15×10^{1}	≤5
*Pseudomonas aeruginosa*100ml	0.11×10^{-1}	0.32×10^{1}	0.00×10^{-1}	0.21×10^{-1}	0.31×10^{-1}	0.19×10^{-1}	<50
Total faecal coliform/100ml	0.00×10^{-1}	0.34×10^{1}	0.46×10^{-1}	0.00×10^{-1}	0.00×10^{-1}	0.16×10^{-1}	<1
***Escherichia coli*/100 ml**	0.00×10^{-1}	0.00×10^{1}	0.25×10^{-1}	0.00×10^{-1}	0.14×10^{-1}	0.08×10^{-1}	<1

Variations of microorganisms isolated from selected swimming

The microbiological indicators include total faecal coli form, *Pseudomonas aeruginosa, Staphylococcus aurous*, *Legionalla*, and *Escherichia coli* (Schlegel, 2000; Rozporządzenie *et al*., 2007). Results in Table 5 showed that microbes such the total aerobic plate count (*TAPC) ranged from* 0.00×10^{-1} to 0.31×101 with the mean value of 0.15 ×101 less than the TPC within acceptable limits (≤5 × 10^2 cfu/ml) (Papadopoulou *et al*., 2008; Adjei et al., 2014; Masoud *et al*., 2016), *Pseudomonas aeruginosa* 0.00×10^{-1} to 0.32×10^{1} with the mean value of 0.19×10^{-1}. *Pseudomonas aeruginosa* can grow within untreated waters and in biofilms, that can cause skin, ear and eye infections when present in large numbers and outbreaks of skin infections have been linked to swimming pools. Total faecal coli form 0.00×10^{-1} to 0.46×10^{-1} with the mean value of 0.16×10^{-1} and Escherichia coli 0.00×10^{-1} to 0.25×10^{-1} having mean value of 0.08×10^{-1}. Accordingly, *Pseudomonas aeruginosa* was dominant in the swimming pools followed by Total faecal coli form, total aerobic plate count and Escherichia coli being the least. *Pseudomonas aeruginosa* 0.19×10^{-1} was below the WHO permissible limit of <50, Total faecal coli form and Escherichia coli at 0.16×10^{-1} and 0.08×10^{-1} were below the WHO permissible limit of <1 respectively (WHO, 2004,2006) (Table 6). Then, the bacteriological quality of water used in swimming pools should approximately to that of high purity drinking water (Indabawa, 2015). Although the MPN values for coli forms of the selected swimming pool water are within tolerable limits, and nevertheless differ markedly from one hotel to another. The pool water at sites appeared to be the least contaminated. This could be attributed to the fact that the water in these swimming pools is being continuously treated with chlorine, which is in tune with the finding of Indabawa (2015).

Table 6: This study and Global Environmental standards of Microbes in swimming pools

Indicators	**Iran guide lines (MHM**	**WHOguideli nes (MHRA)**	European Unionguideline s(EA	**Shahid Fazal pool** (Abdolmajid and Amiri, 2015)	**Shohada poo** (Abdolmajid and Amiri, 015**)**	This study
Total faecal coliform/100 ml	<1	<1	0	7.5±3.4	14.4±2.1	0.16×10^{-1}
Pesudomonad aeruginosa/100 ml	<1	<1	0	2.8±0.51	4.5±0.4	0.19×10^{-1}
Staphylococcus aurreus/100 ml	<50	<50	Not foreseen	1.5±0.44	3.1±0.8	**0.8**
Heterotrophic Plate Count/1 ml	<200	<200	0-100	220±18.5	250±20.1	Not foreseen
Legionalla/100 ml	<1	<1	Not foreseen	1.2±0.55	2.2±0.06	Not foreseen
Escherichia coli/100 ml	Not foreseen	<1	0	17.66±7.94	21.16±9.8	0.08×10^{-1}

Table 6 shows the results of microbiological analysis of swimming pools' water. The microbiological indicators, total faecal coli form, *Pseudomonas aeruginosa, Staphylococcus aurous*, *Legionalla*, and *Escherichia coli* per 100 ml of both swimming pools with a value of 7.5±3.4 and 14.4±2.1, 2.8±0.51 and 4.5±0.4, 1.5±0.44 and 3.1±0.8, 1.2±0.55 and 2.2±0.06, and 17.66±7.94 and21.16±9.8, respectively (Abdolmajid and Amiri, 2015). The result of Escherichia coli (0.08×10^{-1}) in the study is greater than the finding of Ekopai *et al*. (2017) who reported zero Escherichia coli in all the selected swimming pools in Kampala, Uganda. Other microbiological indicators were Heterotrophic Plate Count/1 ml 220±18.5 and 250±20.1, greater than total faecal coli form, *Pseudomonad aeruginosa*, *Staphylococcus aurous* and Escherichia coli of this study respectively. The results are against European Union guidelines (EA) who recommended zero value for total faecal coli form and Pseudomonad Aeruginosa respectively (WHO, 2004, 2006; Ekopai *et al*., 2017). The result in tandem with the report that, Pseudomonas *aeruginosa* is frequently present in small numbers in and around swimming pools has been associated with folliculated outbreaks (Fiorilo *et al*., 2001; Tate *et al*., 2003). *S. aurous,* found as part of the normal flora of the nasal mucosa and skin, is the cause of dermal and eye infections, exterior ear inflammation, uterine infections and impetigo (John and Petri, 2006).

4. CONCLUSION

From the result of the physicochemical characteristics of the selected swimming pools, turbidity was above the permissible limit, and the pH of the selected pools were below the permissible limit, might due to indiscriminate way of chlorine application leading to the formation of hypochlorous acid. Hence a reduction in pool water clarity, building up in the water creating algal bloom and cloudiness. The slightly pH values found in the selected pools are possibly the amount of total chlorine applied in these pools. Also, a low pH may likely result to ineffectiveness and lower microbial potency of chlorine use in pools. The presence of the indicator organisms in the selected recreational pools suggest possible contamination from infected humans shedding these organisms through accidental faucal discharge or likely non-faecal human materials around the environment in contact with pool water (Craun *et al.,* 2005), and could result to incidence and transmission of recreational water-borne illnesses among swimmer, if not monitored incessantly. This could have negative health impact, with the era of COVID 19 pandemic in the country swimmers. Above all, regulatory bodies in country should embark on periodic checks regarding the risk-assessment on swimming pools indicators like physicochemical parameters and microbial loads of the pools be examined constantly alongside environmental sanitation around pools, and regular swimmer's education before entering pools.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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