

Full Length Research Paper

Studies on the physicochemical and bacteriological properties of some semi-public Swimming pools in Makurdi, Nigeria

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Recreational waters are routes of transmission for most water-related illnesses. In this study, the water quality of five selected swimming pools (SP) was examined after disinfection prior to bathing and after bathing by swimmers. SP sampling was carried out weekly for 4 weeks between August and September in Makurdi, Nigeria. Bacterial loads and physicochemical parameters were determined using standard and standard analytical methods, respectively. Most of the physicochemical parameters analyzed were within recommended limit except for residual chlorine, turbidity, dissolved oxygen and total dissolved solids exceeding the permissible limit in some SPs before and after bath. Total heterotrophic count before bath ranged from 2.1×10^7 to 10.9×10^7 cfu/ml and 4.2×10^7 to 17.6×10^7 cfu/ml after bath. Some SPs revealed Salmonella-Shigella spp. contamination before and after bath. Total coliforms (TC) ranged from 0-27 MPN/100 ml and 0-43 MPN/100 ml before and after bath respectively, while faecal coliforms (FC) ranged from 0-9 MPN/100 ml before bath and 0-21 MPN/100 ml after bath. Two of the studied SPs significantly increase in TC (150 and 86%) and FC (105 and 22%) after bath. The results suggest that the possible routes for pools contamination include source of water, inadequate disinfection process, faecal discharge and bather density.

Key words: Swimming pool, bacterial count, bath; physicochemical, standards, Makurdi, coliforms.

INTRODUCTION

Clean water still is a growing problem in the world today; and most communities lack access to portable water and some, if available, do not meet water quality standards for all types of drinking and recreational water. Recreational waters such as swimming pools are artificially formed water bodies for human recreational bathing

purposes with or without biological, chemical or other water treatments (Casanovas-Massana and Blanch, 2013). They may be domestic (private), semi-public (for example hotel, school, health club, housing complex, cruise ship) or public (for example municipal) (World Health organization; WHO, 2005). More so, the pools

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may be located outside (outdoor) or inside (indoor) or both. Pool water are usually supplied with fresh (surface or ground), marine or thermal water (that is, from natural hot springs) (WHO, 2005). Most often, the type, design and use of pools by bathers may predispose the user to certain health hazards, including pathogenic microorganisms.

The demand of hotels in every community of the world is increasing, especially in fast growing region and tourist attracted areas like river Benue in Northern Nigeria. This has resulted to large increase in hotel business in most part of the metropolis, and still the numbers are not commensurate with the populations.

In this part of the country, water demand remains a serious issue yearly especially during the peak of the dry season, hence most water is supplied by water distribution tankers either filled up directly from a water distribution board, river Benue or any available water source. This water shortage has led pool owners/managers to evacuate pool water for a long period after severally used by bathers.

Such unhygienic pools could likely harbour potentially accumulated harmful infective dose of microorganisms and organic matters. Meanwhile, for example, most outdoor pools (like those built in hostels) may be subject to higher bather-loads relative to the volume of water (WHO, 2006) and this could be a reservoir for difficult-to-treat pathogens especially the gastrointestinal tract infection. These associated microorganisms in water bodies are detected using specific microbes known as "Indicator organisms" which are used as principal water quality index. The indicator microorganisms used for comprehensive monitoring, evaluating and regulating pool water bodies and similar environments for microbial contamination include heterotrophic bacteria, faecal coliform (*E. coli*), total coliform (most members of the Enterobacteriaceae), *Pseudomonas aeruginosa* and *Staphylococcus aureus* (WHO, 2003; Eaton and Franson, 2005; Yedeme et al., 2017). Microorganisms can be found in swimming pools and similar recreational environment even though measures are put in place to ensure the biosafety and good hygiene quality of the swimming pool water.

Pathogenic organisms and environmental contaminants consistently enter pools directly or indirectly through contaminated air, soil, dust, rain water, sewage, human or animal excrement (especially from birds) (WHO, 2006). Additionally, disease-causing microbes could enter pools through contaminated body fluids such as saliva, blood, urine, vomit, hair, release of respiratory, digestive, genital and other harmful bacteria from the skin by bathers (WHO, 2006; Karami et al., 2015). More often, swimmers may accidentally ingest these non-faecal human materials into pool water.

Generally, pools are disinfected with chlorine, chloramines, ozone, and UV irradiation to reduce health hazard of bathers as well as deactivate potential pathogenic

organisms. This disinfection process determines to a large extent the microbiological safety and quality of any pool water. However, high concentration of this disinfecting agent could lead to toxic effects on bathers (Martinez and Long, 1995; Bernard et al., 2003). Apart from these disinfection compounds, other exogenous disinfectants and human inputs such as urine, sweat, hair and human care products (soap residues, cosmetics, suntan oil etc) are released into pool by bathers (WHO, 2006; Chowdhury et al., 2014). This may largely contribute to poor quality of pool water as well poses health threats to bathers resulting from the formation of highly toxic disinfection by-products (DBPS) which include chloramines, trihalomethanes (THMs) and haloacetic acids (HAAs) formed when disinfectants (such as chlorine etc) reacts with these exogenous chemicals and materials (Chowdhury et al., 2014).

Previous researches have reported that microbiological evaluation has, for many years, been the most significant method for sanitary and quality control of swimming pools (Papadopoulou et al., 2008; Onajobi et al., 2013; Karami et al., 2015). For effective quality control, a test for indicator bacteria is usually of primary importance (Itah and Ekpombok, 2004). Additionally, in some part of Nigeria, where water supply is adequate similar studies have been carried out to assess the microbial and chemical quality of pools (Agbagwa and Young-Harry, 2012; Ayandele et al., 2015; Itah and Ekpombok, 2004); however little information is available on the health risk associated with swimming pools especially in the Northern part of the country where water supply is scarce and inadequate for pool users, high density due to the terrain and extreme temperature experienced in most part of the season, thus could result to microbial proliferation in water.

Report from the literatures showed that there is no published work on pool water quality (physical, chemical and bacterial) in Makurdi, Nigeria. Therefore, this study was undertaken to evaluate the physicochemical properties and the bacterial loads of some selected swimming pools due to the large populace visiting them; assess and establish the possible sources of pool contamination, and their compliance to World Health organization (WHO) standards for swimming pools.

MATERIALS AND METHODS

Sample collection and processing

All studied swimming pools are made of glazed tile with different shapes (rectangular, circular and oval) and their sizes ranged from 500 to 1500 m². Water pools were disinfected with chlorine once a week if bathers' density is low and twice weekly when bather's density is high, however water was not evacuated regularly and replace with fresh water due to the cost of water supply to pools resulting from water scarcity. These swimming pools were chosen based on the frequency of swimmers visiting them. The average number of bathers per day was 90. During late raining season and early dry season (August - September), water samples from 5

randomly selected swimming pools (outdoor pools) in Makurdi metropolis of Benue state, Nigeria were collected weekly for a period of four weeks (two samples between Monday and Friday and two samples during the weekend) and totally 80 pool samples (16 samples from each pool). All pool water samples were collected by 6.45 am in the morning before bathing and 8.00 pm in the evening after bathing from surface (0.1 m) and 0.5 m water depth and mix together to form representative pool samples. Water samples were collected aseptically with reference to WHO sampling techniques (WHO, 2006, 2008). 2000 ml bottles were disinfected with concentrated acetone (allowed to volatilize for at least 2 h in a fumehood), rinsed off with distilled water and aseptically filled up with water samples from the five randomly selected pools. The water samples were collected before and after bathing by swimmers and were appropriately labeled A-E. 4 ml of 10% sodium thiosulphate solution was added to the water to neutralize any free chlorine residue in the water sample to prevent further disinfection effects on the microbial population. After collection, pool samples were transferred immediately to the laboratory and refrigerated at 4°C for bacteriological and physicochemical analyses. Water samples were analyzed soon after collection (before and after bath). Parameters such as temperature and pH values were taken at the site of sample collection.

Pool Locations and Depth; SW1: Flow through pool 9 ft at its deepest point; SW2: Fill and draw pool 8 ft at its deepest point; SW3: Flow through pool 9 ft at its deepest point; SW4: Fill and draw pool 6 ft at its deepest point; SW5: Fill and draw pool 7ft at its deepest point.

Physicochemical analysis

The physico-chemical parameters were measured using standard analytical procedures (American Public Health Association, APHA, 1998; Association of Official Analytical Chemists, AOAC, 2000). The water quality parameters examined included temperature and total dissolved solids (TDS) (measured using Garasa 2-in-1 water quality meter); pH, electrical conductivity (EC), salinity and dissolved oxygen (DO) were measured by HQ30D single channel meter (HACH), while turbidity was measured by turbidity meter, TB250 WL. Others include biochemical oxygen demand (BOD) measured using automated BOD analyzer (BD 600); chemical oxygen demand (COD) using portable COD colorimeter, MD200; and residual chlorine (RC) using Halosense chlorine analyzer. All samples were analyzed before and after bathing by swimmers.

Enumeration of total heterotrophic bacteria

The total heterotrophic bacterial count was carried out on pool water samples using the spread-plate method (Ibe and Okpleny, 2005) on plate count agar (Oxoid microbiological media, UK). A ten-fold serial dilution of each water sample was prepared aseptically in sterile physiological saline up to 10^{-6} and 0.1 ml aliquot of each dilution was plated on plate count agar plates (in triplicate). The inoculated plates were incubated at 37°C for 24 h. under aerobic conditions and cultured plates containing 30 to 300 colonies were counted. The mean number of viable bacteria present in each sample were expressed as colony-forming units per millimeter (cfu/ml) of pool water and calculated as follows:

CFU/ml= Average No. of colonies on culture plates x 1/dilution factor x 1/volume used (in ml).

Salmonella and Shigella species counts

The spread plate method (Ibe and Okpleny, 2005) was also

employed for the enumeration of Salmonella and Shigella species using Salmonella/Shigella agar (SSA) (Fisher scientific, UK) for the different pool water samples. Ten-fold serial dilution of each water sample was prepared aseptically in sterile physiological saline up to 10^{-3} and 0.1 ml aliquot of each dilution was plated on SSA plates in triplicate. The inoculated plates were incubated at 37°C for 24 h and cultured plates containing 30 to 300 colonies were counted and colonies were expressed as colony-forming units per millimeter (cfu/ml) of pool water.

Enumeration of total coliforms/faecal coliforms

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 (Ibe and Okpleny, 2005; APHA, 2005). The faecal coliforms (*E. coli*) were incubated at $44 \pm 0.5^\circ\text{C}$ for 24–48 h while the total coliforms were incubated at 37°C for 24–48 h. A confirmatory test on positive tubes from the MPN procedures were subcultured on Levine's eosin methylene blue (EMB) agar plates using the streak plate method in duplicate and incubated at 37°C for 24 h. Estimation of coliforms (MPN/100 ml) was based on MPN table.

Statistical analyses

The results were analyzed and compared using analysis of variance (ANOVA), while post-hoc test (tukey HSD) was used to determine significant differences between means of pool samples collected before and after bath. Data were presented as mean \pm standard error (SE) and $p < 0.05$ or $p > 0.05$. Microbial data for pools is presented in graphs.

RESULTS

Physicochemical variations in pool samples

The results of the physical and chemical properties of the studied swimming pools prior to bath and after bathing are represented in Table 1. Generally, the studied swimming pools were within the recommended range for temperature, pH, EC, BOD, and COD before and after bath for all water samples analyzed as stipulated by WHO. More so, there are no significant differences observed before and after bath for pH and temperature. Results of RC concentrations in pools before bath were higher in all sampled pools compared to samples collected after bath ($p < 0.05$). EC increased in water samples collected from 80% pools after bath ($p < 0.05$), but the values were within the stipulated WHO limit for EC in recreational water. Considering another parameter such as turbidity, 80% of all the sampled pools revealed higher values than the recommended standard of <1 NTU by WHO before and after bath with exception of SW4 with turbidity values of 0.82 to 0.87, NTU respectively. Notably, one of the pools (SW3) indicated higher turbidity compared to other pools before and after bath. The study revealed that 85% of all studied swimming pools before and after bath exceeded the recommended standard for dissolved oxygen by WHO. Two swimming pools (SW3

Table 1. The physicochemical properties of swimming pool samples (values are mean \pm standard error).

Parameter	Before bath					After bath					WHO limit (2005; 2006)
	SW1	SW2	SW3	SW4	SW5	SW1	SW2	SW3	SW4	SW5	
Temperature ($^{\circ}$ C)	26.40 \pm 0.40 ^a	26.40 \pm 0.50 ^a	25.8 \pm 0.31 ^a	26.30 \pm 0.15 ^a	26.00 \pm 0.06 ^a	26.90 \pm 0.23 ^a	26.90 \pm 0.35 ^a	26.80 \pm 1.26 ^a	26.80 \pm 0.06 ^a	27.00 \pm 0.15 ^a	21–32
pH	6.73 \pm 0.36 ^a	6.66 \pm 0.90 ^a	6.01 \pm 0.21 ^a	6.95 \pm 0.18 ^a	6.81 \pm 0.02 ^a	7.13 \pm 0.03 ^a	7.16 \pm 0.09 ^a	7.71 \pm 0.23 ^a	7.45 \pm 0.30 ^a	7.21 \pm 0.30 ^a	6.5–8.5
R. Chlorine (mg/L)	0.40 \pm 0.10 ^{cd}	0.68 \pm 0.07 ^{ab}	0.61 \pm 0.05 ^{abc}	0.56 \pm 0.01 ^{bc}	0.83 \pm 0.02 ^a	0.14 \pm 0.01 ^e	0.22 \pm 0.02 ^{de}	0.18 \pm 0.02 ^{de}	0.20 \pm 0.01 ^{de}	0.25 \pm 0.02 ^{de}	< 3
Conductivity(μ S/cm)	88.20 \pm 1.74 ^d	96.60 \pm 0.62 ^c	95.40 \pm 1.57 ^c	85.60 \pm 0.77 ^d	88.30 \pm 1.00 ^d	95.00 \pm 1.55 ^e	99.60 \pm 0.47 ^c	120.40 \pm 1.32 ^a	111.40 \pm 1.60 ^b	96.50 \pm 1.10 ^c	150
Salinity (mg/L)	0.10 \pm 0.00 ^b	1.20 \pm 0.11 ^a	0.80 \pm 0.05 ^{ab}	0.90 \pm 0.02 ^{ab}	1.00 \pm 0.21 ^a	0.90 \pm 0.03 ^{ab}	1.00 \pm 0.15 ^{ab}	0.80 \pm 0.04 ^{ab}	1.20 \pm 0.50 ^a	1.10 \pm 0.42 ^a	NA
Turbidity (mg/L)	3.24 \pm 0.15 ^b	2.88 \pm 0.27 ^b	3.64 \pm 0.25 ^b	0.82 \pm 0.06 ^c	3.07 \pm 0.21 ^b	3.29 \pm 0.25 ^b	3.38 \pm 0.15 ^b	5.14 \pm 0.53 ^a	0.87 \pm 0.09 ^c	3.77 \pm 0.08 ^b	0.5–1.0
DO (mg/L)	8.90 \pm 0.44 ^b	4.60 \pm 0.13 ^d	7.70 \pm 0.26 ^b	8.20 \pm 0.18 ^b	5.30 \pm 0.12 ^{cd}	14.20 \pm 0.26 ^a	8.80 \pm 0.12 ^b	15.60 \pm 0.33 ^a	14.20 \pm 1.60 ^a	7.30 \pm 0.50 ^{bcd}	7.5
BOD (mg/L)	2.10 \pm 0.10 ^a	0.90 \pm 0.11 ^b	2.20 \pm 0.19 ^b	2.00 \pm 0.05 ^{ab}	2.10 \pm 0.06 ^a	2.60 \pm 0.31 ^a	2.40 \pm 1.10 ^a	2.60 \pm 0.07 ^a	2.60 \pm 0.26 ^a	2.80 \pm 0.50 ^a	3
COD (mg/L)	4.20 \pm 0.20 ^a	1.80 \pm 0.21 ^b	4.40 \pm 0.38 ^a	4.00 \pm 0.10 ^{ab}	4.20 \pm 0.12 ^a	5.30 \pm 0.63 ^a	4.80 \pm 0.47 ^a	5.20 \pm 0.14 ^a	5.20 \pm 0.53 ^a	5.60 \pm 1.00 ^a	40
TDS (mg/L)	179.0 \pm 7.20 ^c	115.0 \pm 4.04 ^d	570.0 \pm 10.6 ^a	577.0 \pm 4.50 ^a	194.0 \pm 7.57 ^c	183.0 \pm 2.08 ^c	120.0 \pm 1.51 ^d	584.0 \pm 8.34 ^a	586.0 \pm 3.77 ^a	240.0 \pm 3.79 ^b	500

NA= not available; R=Residual; DO = Dissolved oxygen; BOD = Biochemical oxygen demand; COD = Chemical oxygen demand; TDS = Total dissolved solids; SW1: Flow through pool 9ft at its deepest point, SW2: Fill and draw pool 8ft at its deepest point, SW3: Flow through pool 9ft at its deepest point, SW4: Fill and draw pool 6ft at its deepest point, SW5: Fill and draw pool 7ft at its deepest point. *Data with the same alphabet are not statistically different at 95% confidence interval before and after bath; while data with different alphabets indicate significant differences before and after bath at 95% confidence interval.

and SW4) had the highest values of DO after bath while the least values were recorded for SW2 and SW5 respectively. All pools sampled were within the minimum WHO recommended limit for COD and BOD before and after bath, however statistically lower value was observed SW2 for both properties before bath as compared to other sampled pools. Moreover, 40% of pools sampled revealed high TDS before and after bath compared to WHO recommended limit. Two pools (SW3 and SW4) recorded significantly higher values of TDS before and after bath in comparison to other pools and were also above the recommended limit stipulated by WHO for recreational water.

Enumeration of bacteria in pool samples

The results of bacterial counts for the 5 selected swimming pools prior to and after bath are

presented in Figure 1 (A – E). Total culturable heterotrophic bacterial count ranged from 2.1×10^7 to 10.9×10^7 cfu/ml and 6.1×10^7 to 22.7×10^7 cfu/ml with average values of 4.2×10^7 cfu/ml and 17.6×10^7 cfu/ml, respectively. SW4 showed a significantly higher heterotrophic bacterial count after bath, while bacterial colonies were not detected in SW2 before bath, however after bath, there was an observed high heterotrophic bacterial count in SW2. Data showed that all sampled pools after bath showed significantly higher heterotrophic bacterial counts than before bath. The total heterotrophic bacterial counts of all investigated pools before and after bath were much higher than the WHO limit of $\leq 2 \times 10^2$ cfu/ml for pool water.

The concentrations of *Salmonella-Shigella* species count recorded for the swimming pools sampled before and after bath ranged from 0.0×10^3 - 3.0×10^3 cfu/ml and 0.0×10^3 - 17.0×10^3 cfu/ml for *Salmonella* spp. respectively, while

Shigella spp. ranged from 4.9×10^3 to 7.8×10^3 cfu/ml and 5×10^3 to 11×10^3 cfu/ml respectively as shown in the figure (B and C). Two sampled pools revealed significantly higher *Salmonella* counts before bath (SW3 and 4) and after bath (SW4 and 5); however, no detectable *Salmonella* colonies were observed for SW1, 2 and 5 before bath. But this was not the trend after bath as significantly high colonies were cultured from sampled collected from SW5 after bath. For *Shigella* spp. detected in pools, two pools (SW3 and SW4) showed higher CFUs than other pools before and after bath ($p < 0.05$); with no detectable *Shigella* colonies in other pool samples during the sampling period. Generally, two out of five pools showed presence of *Salmonella-Shigella* species contamination before and after bath by swimmers.

The MPN number per 100ml of water sampled for total and faecal coliforms in the swimming pools before and after bath are presented in Figure 1 (E and F). The MPN for TC ranged from

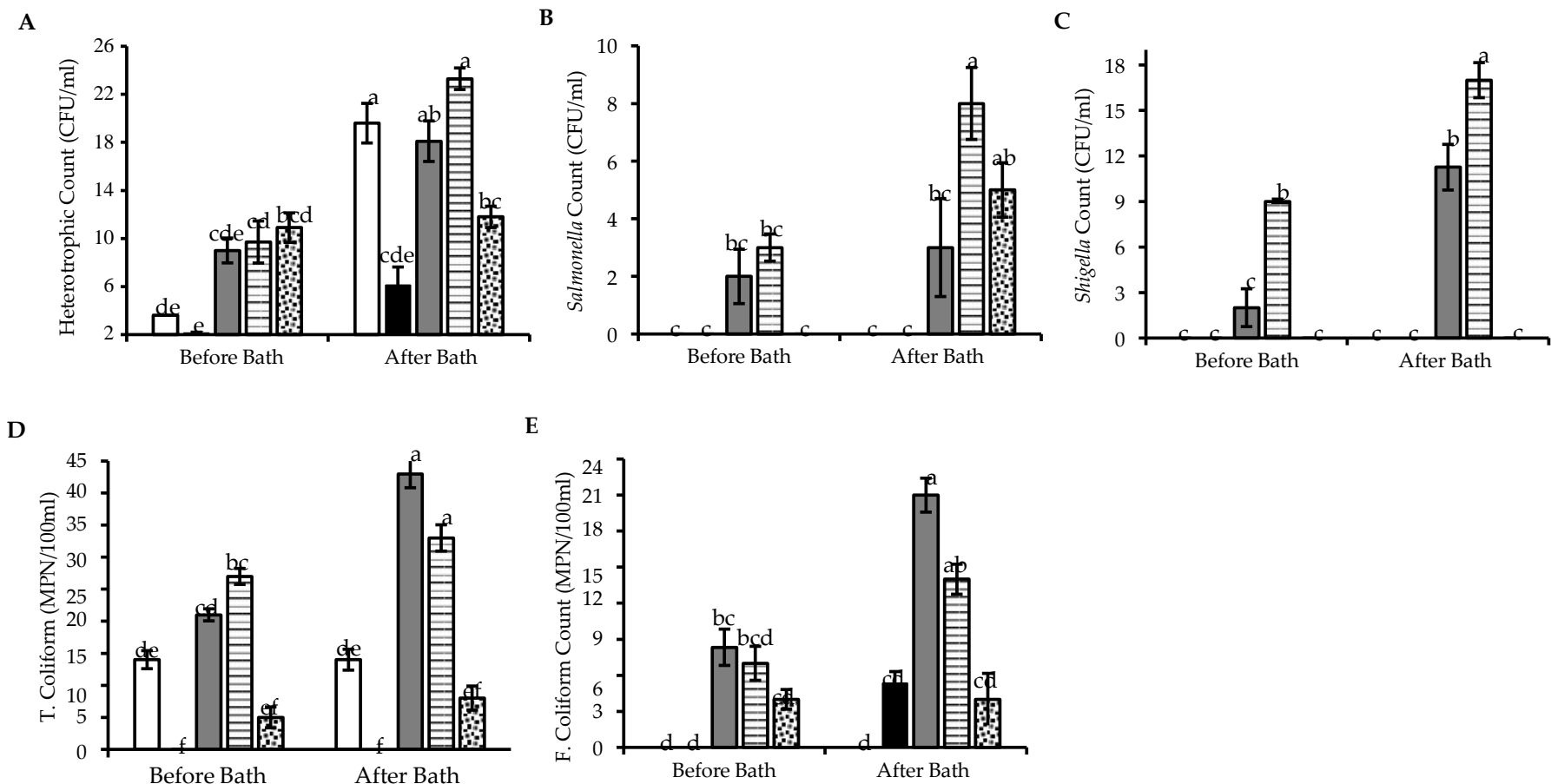


Figure 1. Bacterial counts in swimming pool samples before and after bath (a) Heterotrophic count, (b) *Salmonella* count, (c) *Shigella* count (d) Total (T) coliforms (e) Faecal (F) coliforms for pool 1 (□), pool 2 (■), pool 3 (■), pool 4 (▨), pool 5 (▩). *Data with the same alphabet are not statistically different at 95% confidence interval before and after bath; while data with different alphabets indicate significant differences before and after bath at 95% confidence interval.

0 – 27 MPN/100 ml before bathing and 0 – 43 MPN/100 ml after bath, while that of FC ranged from 0 – 9 MPN/100 ml and 0 – 21 MPN/100 ml before and after bath respectively. In comparison to other pools, two pools (SW3 and SW4) after bath showed significant increase of 150% and

86% for TC and 105 and 22% for FC respectively. At the same time, only one sampled pool had 0 CFU/ml colonies before and after bath for TC, whereas FCs were not detected in two pool samples after bath but this pattern changed in one pool after bathing by swimmers with 6 MPN

per 100 ml of pool water sampled. In general, 80% of pools recorded TC counts and 60% for FC counts respectively, with numbers exceeding the WHO standard for recreational waters ($\leq 1/100$ ml for TC and 0/100 ml for FC) before and after bath.

DISCUSSION

Several studies have been carried out around the world on the health safety and quality of swimming pool water and epidemiological risk of enteric and skin infections (Martins et al., 1995; Papadopoulou et al., 2008; Agbagwa and Young-Harry, 2012; Casanovas-Massana and Blanch, 2013; Saba and Tekpor, 2015). It is necessary for pools to maintain a high chemical and microbial quality and as such regarded as safe water due to the pathogenic and non-faecal contaminants that usually resulted in pools after use by swimmers. In our study, the swimming pools were within the recommended limit for temperature, pH, EC, BOD and residual chlorine as stipulated by World Health Organization (WHO, 2005; 2006). However, four key parameters such as RC, turbidity, DO and TDS in the studied pools did not meet WHO acceptable limit for swimming baths.

Residual level of chlorine and pH before and after bath in all pools were within the permissible limit recommended by WHO (WHO, 2005; 2006). The moderate pH values observed in all the pools in this study are possibly the amount of free available chlorine maintained in these pools. Also, a low pH may likely result to ineffectiveness and lower microbicidal potency of chlorine use in pools. Nonetheless, most bacteria grow optimally around neutral pH (6.5–7.0). These findings concurred with studies carried out in Ghana where reported pH of most of examined swimming pools were within pH recommended standard of 7.2 to 7.8 (Saba and Tekpor, 2015). Similar study has also reported pH values of pool water within the acceptable limit of 6.5 to 8.5 (Shittu et al., 2008). In addition, most studied pools have reported pH and RC not complying to WHO standard for pool water (Onajobi et al., 2013; Al-Khatib and Salah, 2003; Abd El-Salam, 2012). The mean temperatures obtained from the swimming pools were within the WHO acceptable standard temperature range of 21 to 32°C. Swimming pool waters with temperature more than 28°C (warm pool) could support and stimulate microbial growth and proliferation more likely than pools with a lower temperature range which could also be attributed to higher degree of water contamination. The findings also agree with results of pools studied in Ghana with temperature ranging from 22 to 27°C (Saba and Tekpor, 2015). However, microbial growth increases when there is an increase in swimming pool water temperature (Martins et al., 1995; Leoni et al., 2001).

About 80% of all sampled pools showed higher turbidity than the recommended standard of <1 NTU by WHO before and after bath. Turbidity is a function of dissolved nutrients and solids in water bodies. High turbidity revealed in this study could suggest an indication of higher levels of disease-causing organisms owing to the likely nutrient present in pool water. This could have resulted from the source of water collection and the cloudiness of the water resulting from dissolved

substances. Increased turbidity in fresh water such as rivers may be contaminated from release of industrial and municipal wastewater, soil runoff (Schwartz et al., 2000; de-Bashan and Bashan, 2010). In a study of 28 swimming pools sampled in Ghana, turbidity values in pools were reported to be > 0.5 NTU (Saba and Tekpor, 2015). Similarly, a high turbidity value of >5.5 NTU were reported in pools sampled 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 recommended by WHO (Onajobi et al., 2013).

Dissolved oxygen is probably the most critical quality parameter in water. The dissolved oxygen level can be an indication of how polluted the water is and how well the water can support aquatic plant and animal life. Low DO levels may be found in areas where organic material (dead plant and animal matter) is decaying. Bacteria require oxygen to decompose organic waste, thus, deplete the water of oxygen. The study revealed that 85% of all studied swimming pools before and after bath exceeded the recommended standard for dissolved oxygen by WHO (WHO, 2006). Generally, a higher dissolved oxygen level indicates better water quality and how healthy the sampled pools. Depletion of dissolved oxygen in water could facilitate microbial conversion of nitrates to nitrites (WHO, 2008). Low level of DO in pool water may not be healthy to humans. Temperature has effect on the DO in water, however the temperatures were with recommended limit for all sampled pools. Thus, these high DO values maybe attributed to the source of water supplied to the pools. The findings in this study agree with the results reported from studied swimming pools in Ilorin (Onajobi et al., 2013). The authors reported that the dissolved oxygen level in pools were within WHO recommended limit while some pools exceeded the permissible standards of 7.5mg/l for recreational water.

The TDS values in our study concurred with results reported on some studied pools in another part of Nigeria and the data were within WHO limit except for some pools (Onajobi et al., 2013). This study suggested that the source of water supplied to the studied pools either could have been in contact with contaminated residual materials and chemicals or pool water were not properly treated before supplied to tanks, private home and hotels due to extreme water scarcity especially during the dry season (when these pools were sampled). Total dissolved solids have been associated with natural source, sewage from industrial operations, urban run-offs and chemical used in water treatment process and any other potential sources (Schwartz et al., 2000; Itah and Ekpombok, 2004; Abd El-Salam, 2012). Due to the terrain in this area, there is regular water scarcity almost all through the year; hence, most pool operators received their water supplied directly by moving tanks from the nearby accessible river.

The total heterotrophic bacterial counts (THBC) of all investigated pools before and after bath were much higher than the WHO limit of ≤ 200 cfu/ml for pool water. The result reveals marginal increase in heterotrophic bacterial count after bathing by swimmers. These high values can be attributed to the source of water supply to the pool, ineffective disinfection, other environmental contaminants and possible contamination from bathers. Bathers tend to shed bacteria from faecal and non-faecal materials that could result to high bacterial load in pool (Castor and Beach, 2004; Craun et al., 2005). This study revealed a higher heterotrophic bacterial count compared to the mean value of 3.0×10^6 to 6.6×10^7 cfu/ml reported in 20 different swimming pools examined in Lagos metropolis (Bello et al., 2012). Studies also showed THBC of 14×10^3 to 68×10^3 cfu/ml in pools much higher than the recommended permissible WHO limit in Kwara, Nigeria (Ayandele et al., 2015). In a similar study, 12.1% of studied semi-public pool (indoor and outdoor) swimming pools examined in Northwestern Greece exceeded WHO recommended limit for recreational water (Papadopoulos et al., 2008).

All pool samples revealed high *Salmonella-Shigella* species count before and after bath. The pool water samples showed higher *Shigella* species contamination to *Salmonella* species before and after bath. These results suggest potential water contamination from point source of water supply which could have been in contact with sewage and contaminated run-off as well as faecal matter release from human or animal sources into pool water. Non-human sources like birds and other wild life are likely source of emerging and re-emerging water borne zoonotic pathogens such as *Salmonella* but contamination through this route remain uncertain (Casanovas-Massana and Blanch, 2013).

The MPN results for TC and FC before and after bath revealed low microbiological quality in most of the sampled pools. About 80% of the pool waters were heavily contaminated with TC, while 60% showed contamination with FC before and after bath; and therefore, did not meet the permissible limit recommended by WHO for TC ($\leq 1/100$ ml) and FC (0/100ml) for swimming baths (WHO, 2006). In a similar study in Moscow, Russia; water sampled from 15 public indoor swimming pools showed that in 6 of the pools, the level of faecal contamination of the water did not meet acceptable standards, and coliform bacteria levels ranged from 10 to 57 cfu/100 ml in surface samples and 0 to 32 cfu/100 ml in deeper samples (Sinitsyna et al., 2012). In pool water samples analyzed in Egypt, total coliforms were >3 MPN/100ml in 43.3% of water samples and faecal coliforms was positive in 53.8% of water samples. Meanwhile, in Gaza strip, Palestine; 57% of the pool water samples collected were contaminated with total coliforms and 39% with faecal coliforms in the studied period of 2010 to 2013 when compared to WHO standards (Hilles et al., 2014). The presence of these

indicator organisms in two of the studied pools after bath suggest possible contamination from visiting infected humans shedding these organisms through accidental faecal 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 bathers. In addition, bather density could have caused the high bacterial numbers due to the low microbiological and sanitary quality of these pools. High density of swimmers may lead to transmission of pathogens and thus could result to faecal pollution (Bello et al., 2012; Castor and Beach, 2004). Mores so, most of these pools were visited more often during the dry season when the samples were collected. Some pools showed higher indicator bacteria counts before bath suggesting the likely sources of water contamination or poor disinfection process for water supply. Risk of infection caused by pathogenic and non-pathogenic enteric organisms in pools, spas and similar recreational environments have been attributed to the release of materials into water by bathers through human shedding these organisms in faeces, urine, skin, saliva or mucus discharges (APHA, 1998; Castor and Beach, 2004; Rabi et al., 2008). Inadequate residual of a halogen (like chlorine) based disinfectant in these studied pools, increased bathers loads, use of pools by infected persons and low balance in water chemistry, greatly increases the potential for human illnesses (Fleisher et al., 1996; Nnaji et al., 2011). Moreover, in a well-maintained pool, due to the frequency of faecal and non-faecal contamination, most microorganisms are not inactivated by chlorine disinfection leading to transmission of even more resistant strains present in bathing water (Casanovas-Massana and Blanch, 2013) and this poses health risk to bathers. Hence, the pool users should be protected by pool operators and water regulatory bodies by preventing illnesses and pathogens transmission outbreak in such pools through regular pool sampling for pool quality, good pool disinfection and hygienic practices to protect the health of bathers.

Conclusion

There is potentially high health risk of contamination in these studied pools and most did not meet the WHO standards for physicochemical and microbial quality for swimming pools. However, only a few pools comply with WHO permissible limits for recreational water. Water supply, bather density, disinfection processes and other environmental contaminants indicate possible routes of contamination. The pools could represent potential sources and route of transmission of disease-causing organisms if not monitored and regulated. And this could have negative health impact on pool users, especially the young, elderly and immunocompromised or suppressed swimmers. Therefore, it is pertinent for regulatory bodies

in Nigeria, carry out periodic checks on the risk-assessment on swimming pools through water quality (that is, source of water supply to pools), frequent environmental sanitation around pools, regular swimmer's education before entering pools and regular evacuation of water after bathing by swimmers. Specifically, stringent measures should be stipulated to ensuring that pool operators adhere to this information to reduce the public health risk.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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REFERENCES

- Abd El-Salam MM (2012). Assessment of water quality of some swimming pools: a case study in Alexandria, Egypt. *Environmental Monitoring and Assessment* 184:7395-7406.
- Agbagwa OE, Young -Harry WM (2012). Health implications of some public swimming pools located in Port Harcourt, Nigeria. *Public Health Research* 2:190-196.
- Al-Khatib I, Salah S (2003). Bacteriological and chemical quality of swimming pools water in developing countries: A case study in the West Bank of Palestine. *International Journal of Environmental Health Research* 13:17-22.
- American Public Health Association (APHA), American Water Works Association (AWWF), Water Environment Federation (WEF) (1998). Standard methods for the examination of water and wastewater, 20th edn.; Eaton AD, Clesceri LS, Greenberg AE, Franson MAH, eds. Washington, DC, USA
- American Public Health Association (APHA), American Water Works Association (AWWF) (2005). Standard methods for the examination of water and wastewater, 21th edn.; Eaton, AD, Clesceri LS, Eugene WS, Greenberg AE, Franson MAH, eds. Washington, DC, USA.
- Association of Official Analytical Chemists (AOAC) (2000). Official methods of analysis, 17th edn, Vol. 1. Association of Official Analytical Chemists Inc., Maryland, USA. ISBN: 0935584676 9780935584677.
- Ayandele AA, Adebayo EA, Oladipo EK (2015). Assessment of microbiological quality of outdoor swimming pools in Ilorin, Kwara State. *Journal Environmental Science, Toxicology and Food Technology* 9:25-30.
- Bello OO, Mabekoje OO, Egberongbe HO, Bello TK (2012). Microbial qualities of swimming pools in Lagos, Nigeria. *International Journal of Applied Science and Technology* 2:9-96.
- Bernard AC, Michel OS, Buchet JP, Hermans CG, Dumont XR, Doyle IJ (2003). Lung hyper-permeability and asthma prevalence in schoolchildren: unexpected associations with the attendance at chlorinated swimming pools. *Occupational and Environmental Medicine* 60:385-394.
- Casanovas-Massana A, Blanch AR (2013). Characterization of microbial populations associated with natural swimming pools. *International Journal of Hygiene and Environmental Health* 216:132-137.
- Castor ML, Beach M (2004). Prevention of recreational water illnesses: Is chlorination enough to ensure healthy swimming? *Infectious Disease in Children* 17:1-3.
- Chowdhury S, Alhooshani K, Karanfil T (2014). Disinfection byproducts in swimming pool: Occurrences, implications and future needs: A review. *Water Research* 53:68-109.
- Craun G, Calderon R, Craun M (2005). Outbreaks associated with recreational water in the United States. *International Journal of Environmental Health Research* 15:243-262.
- de-Bashan LE, Bashan Y (2010). Immobilized microalgae for removing pollutants: review of practical aspects. *Bioresource Technology* 101: 611-1627.
- Eaton AD, Franson MA (2005). Standard methods for the examination of water and wastewater (21st ed.). American Public Health Association. 1600 pp. ISBN 978-0-87553-047-5.
- Fleisher JM, Kay D, Salmon RL, Jones F, Wyer MD, Godfree AF (1996). Marine waters contaminated with domestic sewage: nonenteric illness associated with bather exposure in the United Kingdom. *American Journal Public Health* 86:1228-1234.
- Hilles AH, Sarsour A, Ramlawi A, Abed Y (2014). Assessment of sanitary conditions in the main swimming pools in Gaza strip (2010-2013): Palestine. *International Journal of Scientific Research in Environmental Sciences* 2:261-268.
- Ibe SN, Okpleny JI (2005). Bacteriological analysis of borehole water in Uli, Nigeria. *African Journal Applied Zoology and Environmental Biology* 7:116-119.
- Itah AY, Ekpombok MU (2004). Pollution status of swimming pools in south-south zone of south-eastern Nigeria using microbiological and physicochemical indices. *Southeast Asian Journal of Public Health* 35:488-493.
- Karami A, Mahvi AH, Sharafi K, Khosravi T, Moradi M (2015). Comparing and evaluating microbial and physicochemical parameters of water quality in men's and women's public swimming pools in Kermanshah, Iran: A case study. *International Journal Environmental Health and Engineering* 4:24.
- Leoni E, Legnani PP, Bucci Sabattini MA, Righi F (2001). Prevalence of *Legionella* spp. in swimming pool environment. *Water Research* 35:3749-3753.
- Martinez TT, Long C (1995). Explosion risk from swimming pool chlorinators and review of chlorine toxicity. *Clinical Toxicology* 33:349-354.
- Martins MT, Sato MIZ, Alves MN, Stoppe NC, Prado VM, Sanchez PS (1995). Assessment of microbiological quality for swimming pools in South America. *Water Research* 29:2417-2420.
- Nnaji CC, Agina I, Iloanya I (2011). The ineffectiveness of manual treatment of swimming pools. *Journal of Applied Science and Environmental Management* 15:517-522. ISSN: 1119-8362.
- Onajobi IB, Okerentugba PO, Okonko IO (2013). Physicochemical and bacteriological studies of selected swimming pool water in Ilorin metropolis, Kwara State, Nigeria. *Stem cell* 4:10-16.
- Papadopoulou C, Economou V, Sakkas H, Gousia P, Giannakopoulos X, Dontorou C, Filioussis G, Gessouli H, Karanis P, Leveidiotou S (2008). Microbiological quality of indoor and outdoor swimming pools in Greece: investigation of the antibiotic resistance of the bacterial isolates. *International Journal of Hygiene and Environmental Health* 211:385-397.
- Rabi A, Khader Y, Alkafajei A, Aqoulah AA (2008). Sanitary conditions of public swimming pools in Amman, Jordan. *International Journal of Environmental Research and Public Health* 5:152-157.
- Saba CKS, Tekpor SK (2015). Water quality assessment of swimming pools and risk of spreading infections in Ghana. *Research Journal Microbiology* 10:14-23.
- Schwartz J, Levin R, Goldstein R (2000). Drinking water turbidity and gastrointestinal illness in the elderly of Philadelphia. *Journal of Epidemiology and Community Health* 54:45-51.
- Shittu OB, Olaitan JO, Amusa TS (2008). Physicochemical and bacteriological analyses of water used in drinking and swimming purposes in Abeokuta, Nigeria. *African Journal of Biomedical*

- Research 11:285-290.
- Sinitsyna O, Zadiran A, Artemova T, Gipp E, Zagai nova A, Butorina N (2012). Evaluation of the informativity of sanitary-epidemiological safety indicators of swimming pools. *Gigiena I Sanitaria* 5: 84-87. PMID: 23243732
- World Health Organization (WHO) (2003). Guidelines for safe recreational-water environments: coastal and fresh-waters. 1:2-219. <https://apps.who.int/iris/bitstream/handle/10665/42591/9241545801.pdf?sequence=1>
- World Health Organization (WHO) (2005). Guidelines for safe recreational water environments. Swimming pools, spa and similar environments. 3rd ed. Vol. 2: recommendations. WHO press, Geneva, Switzerland. Available online: http://www.who.int/water_sanitation_health/bathing/srwe2full.pdf (accessed on 10 August 2017).
- World Health Organization (WHO) (2006). Guidelines for safe recreational water environments. Swimming pools and similar environments. 3rd ed. Vol. 1: recommendations. WHO press, Geneva, Switzerland. pp. 3-273. https://apps.who.int/iris/bitstream/handle/10665/43336/9241546808_eng.pdf?sequence=1&isAllowed=y
- World Health Organization (WHO) (2008). Guidelines for drinking water quality. Incorporating the first and second addenda (3rd ed.). World Health Organization (WHO) Press Geneva. Switzerland. https://apps.who.int/iris/bitstream/handle/10665/204411/9789241547611_eng.pdf?sequence=1.
- Yedeme K, Legese MH, Gonfa A, Girma S (2017). Assessment of physicochemical and microbiological quality of public swimming pools in Addis Ababa, Ethiopia. *The Open Microbiology Journal* 11:98-104.