ASSESSMENT OF THE PHYSICOCHEMICAL AND MICROBIOLOGICAL QUALITIES OF SWIMMING POOLS IN SELECTED HOTELS IN OSOGBO METROPOLIS, SOUTHWESTERN NIGERIA.

Ajadi, F. A., Bakare, M. K. and Oyedeji, O.*
Department of Microbiology, Faculty of Science, Obafemi Awolowo University, Ile-Ife, Nigeria
*Corresponding Author's email: laoluoyedeji@gmail.com Phone Number: +234-8033745381
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ABSTRACT

Water is used for various human activities such as drinking, bathing, washing and recreation. The physico-chemical as well as microbiological qualities of water samples collected over a period of ten months from five swimming pools in five randomly-selected hotels in Osogbo metropolis, Southwestern Nigeria were assessed. The collection of the fifty water samples spanned the dry and rainy seasons and they were analysed for temperature, pH, turbidity, Dissolved Oxygen (DO), Biological Oxygen Demand (BOD), chemical Oxygen Demand (COD) and Residual Chlorine (RC), using standard procedure. The microbiological parameters studied were: Total Heterotrophic Bacteria Count (THBC), Total Coliform Bacteria Count (TCBC) and Total Heterotrophic Fungal Count (THF). The data showed variation in terms of swimming pools and seasons as follows: pH 4.48-7.70; temperature 23.3-28.8 ^{o}C; turbidity 0.22-12.61 NTU; conductivity 166.6-898.2 μS cm^{-1}; BOD 1.44-5.40 mg L^{-1}; DO 1.54-8.98 mg L^{-1}; COD 0.18-8.92 mg L^{-1}and RC 10.2-28.8 mg L^{-1}. THBC ranged between 23-520 CFU mL^{-1}, TCBC 2.0-110 100mL^{-1} and TFC 30-390 SFU mL^{-1}. The bacterial species isolated from the swimming pool samples included *Pseudomonas* sp., *Klebsiella* sp., *Shigella* sp. and *Staphylococcus aureus* while fungal species isolated were *Cephalosporium* sp., *Fusarium* sp., *Penicillium* sp. and *Trichophyton* sp. The concentrations of some of the physico-chemical parameters but all the microbial parameters exceeded recommended permissible limits of the World Health Organization for recreational water quality. The swimming pools therefore pose hazards to the health of swimmers without adequate treatment. The high microbial counts as well as presence of potentially-pathogenic microbes pose hazards of waterborne diseases hazards to swimmers, especially the immune-compromised individuals. There is therefore the need for improved management strategies of these water pools for compliance with standard safety regulations.

Keywords: Swimming Pools, Microbiological, Physico-chemical Quality, Waterborne diseases

INTRODUCTION

Water is very essential for the survival of humans and other life forms. It is required for human daily activities such as drinking, cooking, washing, bathing and also for agricultural, industrial and recreational purposes (Centre for Environmental Health, 2005). Although water is a basic requirement for human existence, it can serve as a medium for the transmission of pathogenic microorganisms, if not properly handled, leading to waterborne diseases such as cholera, typhoid fever and infectious hepatitis. The recreational and environmental use of water is increasing in terms of both the nature of the activities being undertaken, and the number of participants becoming involved (Barna and Kadar, 2012). Recreational and environmental waters include marine and fresh waters, as well as bathing and leisure pool waters which are frequently indoors and which often exhibit high bathing densities (Environment Agency, 2000). Swimming pools are concrete tanks, large artificial basins, or large paved holes containing water for swimming (Cairns and Dickson, 2003). They are facilities patronized by different classes of people for the purpose of leisure, pleasure or recreation in most hotels or other guest houses. Pool water and the surfaces of objects or materials at a swimming facility are exposed to contamination from body fat and human waste materials such as nasal secretions, saliva, sweat, faecal, urine and body lotions and creams (Saberianpour, 2015). Gastrointestinal, skin, eye and neurological disease conditions have all been reported to be associated with recreational and environmental water contact (Schets *et al.,* 2011). Opportunistic pathogens can also be shed from users and transmitted through surfaces and contaminated water. Some bacteria, mostly non-faecal derived may also accumulate into biofilms and present infection hazard (WHO, 2001). Swimming pools are often associated with outbreaks of waterborne infections (Dziuban *et al.*, 2006; Schets *et al.*, 2011). The infectious agents recovered from swimming pool waters include a variety of pathogens comprising bacteria, viruses, protozoa and fungi (Hilderbrand *et al.*, 1996; Papapetropoulou and Ventrarakis, 1998; Tate *et al.*, 2003; CDC, 2004; Schets *et al.*, 2004; WHO, 2006). Bacterial pathogens include *Shigella* species, *Salmonella* species, *Campylobacter* species and *Escherichia coli*, which are associated with gastrointestinal diseases; *Pseudomonas aeruginosa* which is associated with eye, skin and ear infections after contact with spa pool water (Hoebe *et al.*, 2004) and *Mycobacterium marinum* which has been associated with skin infections from pool water contact (Ang *et al.*, 2000). Protozoans *Cryptosporidium parvum*, *Giardia duodenalis*, *Acanthamoeba* species, *Hartmanella vermiformis* and *Naegleria fowleri* which are also implicated in gastrointestinal diseases. The small round structured viruses (SRSV) appear to be the most important cause of viral gastrointestinal diseases associated with recreational water contact (Hoebe *et al.*, 2004) Other human enteric viruses found in surface waters used for recreation include astroviruses and hepatitis A which causes diseases of the liver. The abrasive non-slip flooring that often surrounds pool waters has been associated with *Trichophyton* spp causing athlete's foot (Walsh and Dixon, 1996).

Properly managed and disinfected pool waters should not contain viable microrganisms. Modern swimming pools have a re-circulating system whereby water is filtered and disinfected effectively using chlorine compounds. However, recovery of chlorine-tolerant bacteria from pool water have been reported (Hingst *et al.*, 1995; Tate *et al.*, 2003; Lumb *et al.*, 2004; Reali *et al.*, 2004; Barben *et al.*, 2005). An important issue of public health is the reported antibiotic resistance of bacterial strains isolated from recreational waters, including those belonging to the natural aquatic environments (river, coastal, springs) (Okeke and Edelman, 2001; Tejedor Junco *et al.*, 2001; Tirodimos *et al.*, 2010; Lutz and Lee, 2011; Saba *et al.*, 2015). Natural waters are also the major sources of swimming pool water.

The physico-chemical conditions of the water such as pH, dissolved oxygen, chemical oxygen demand, biological oxygen demand, temperature, turbidity and residual chlorine levels within the pools are very important as these parameters have major influences on biochemical reactions that occur within the water affecting the recreation water and aiding microbiological content and the level of deterioration of water (Charles *et al.,* 1983; Bilajac *et al.*, 2012).

There is a dearth of information on the water quality of swimming pools in Osogbo metropolis, Southwestern Nigeria. The present study was therefore 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. Antibiotic resistance characteristics of the bacterial content of the pool water were also investigated.

MATERIALS AND METHODS

The Swimming Pools

Five swimming pools all located in different areas of Osogbo metropolis in southwestern Nigeria were randomly selected for assessment of their physicochemical and microbiological qualities (Figure 1).

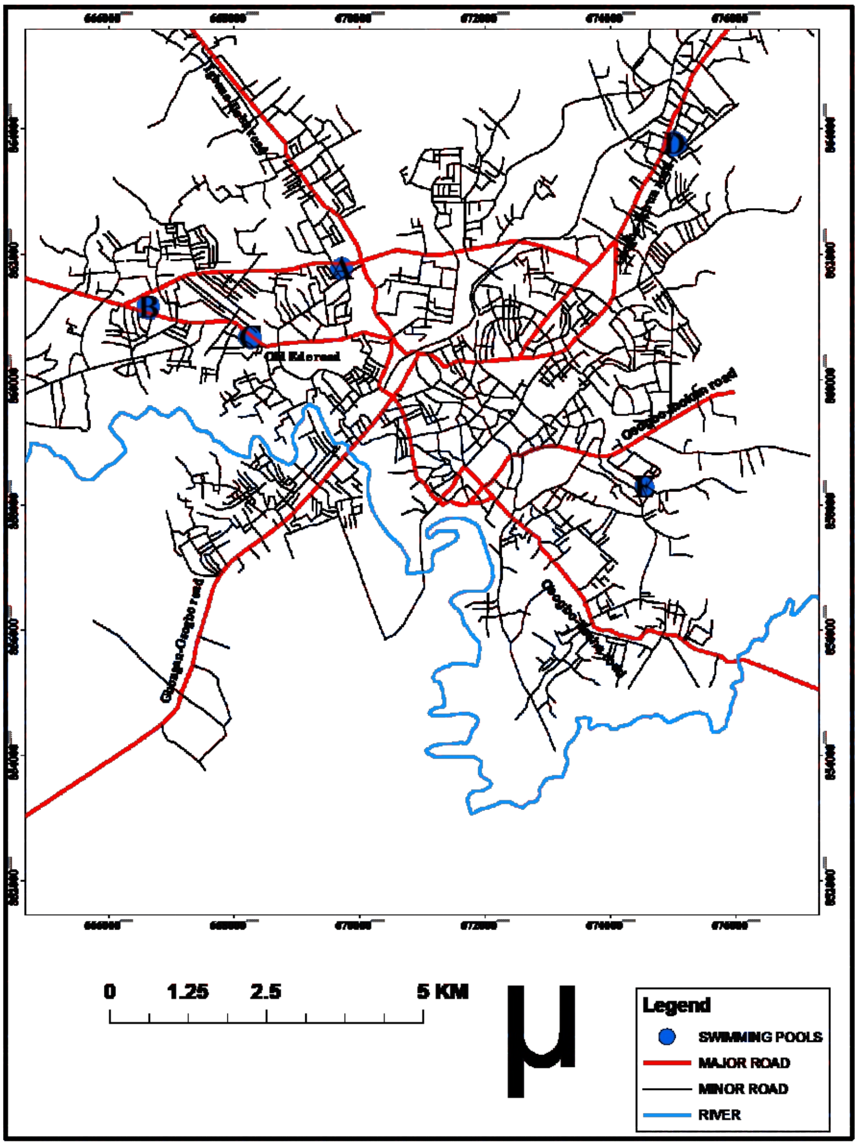

Figure 1 Map of Osogbo Metropolis, Southwestern Nigeria, Showing Swimming Pool Locations

Collection of Pool Water Sample

Water samples were collected into sterile bottles with capacities of 250 ml with airtight stoppers. Samples were collected during the weekends when the largest numbers of swimmers were at the pool. Water sampling was conducted monthly for ten times spanning through the rainy and dry seasons. The sample bottles contain 0.25 ml of 3% solution of sodium thiosulphate ($Na_2S_2O_3$) to neutralize residual chlorine after sampling. The water samples for the Biological Oxygen Demand (BOD) were collected into sterile black BOD bottles with stoppers. All bottles containing the water samples were immersed in ice boxes and transported to the laboratory for analyses immediately on arrival.

Assessment of Physico-Chemical Parameters

The physico-chemical properties examined included pH, temperature, biological oxygen demand (BOD), chemical oxygen demand (COD), dissolved oxygen (DO), residual chlorine, turbidity and conductivity. The pH, conductivity and temperature were determined *in situ* using portable digital conductivity, pH meter (Beckman, Model 50) and thermometer respectively. The turbidity of the water samples were determined by the turbidimetric method using a colorimeter (JENWAY, Model 6051). Dissolved Oxygen and Biological Oxygen Demand (BOD_5) were analyzed through iodometric titrations using Winkler's reagent, suphuric acid, starch indicator and sodium thiosulphate.

$$\text{BOD (mg/L)} = DO_0 - DO_1$$

Where DO_0 = initial dissolved oxygen (immediately after sampling preparation)

DO_1 = final dissolved oxygen (after 5 days of incubation)

Chemical Oxygen Demand (COD) was determined using potassium dichromate digestion method. Organic substances in the samples were completely oxidized and the remaining dichromate was determined by titration with ferrous ammonium sulphate. Silver sulphate was added as a catalyst for the oxidation and mercuric sulphate was added to overcome chloride interference.

COD as mg O_2/L= (A-B) x M x 8000

Microbiological Analysis

The microbiological parameters determined included total heterotrophic bacteria count (THBC), total coliform bacteria count (TCBC) and total heterotrophic fungi count (THF), using serial dilution method and pour plate techniques. Streaking method was used to obtained pure bacterial isolates by sub-culturing a previously incubated plate onto a freshly prepared sterile plate while pure fungal isolates were obtained using cutting technique by subculturing a previously incubated plate onto a freshly prepared sterile plate. Evaluation of antibiotic susceptibility profile of the bacterial isolates was also carried out. The zones of inhibition from the antibiotic susceptibility profile of bacterial isolates were measured, compared with and interpreted using standard methods. The bacterial isolates were characterized using colonial, morphological and biochemical identification methods. They were further identified using Bergey's manual of Determinative Bacteriology. The microscopical and macroscopical characterization and identification of fungal isolates were carried out using standard methods.

Statistical Analysis

The data obtained were subjected to statistical analysis using ANOVA, linear correlations of software packages by Hammer *et al.*, (2001) and descriptive statistics. The level of significance was set at 5% to determine if there were significant differences between the results obtained for each parameter for dry and rainy season.

RESULTS

Physico-Chemical Parameters of the Swimming Pools

Temperature of the swimming pool water ranged from 23.3°C to 27.8°C throughout the period of study. The highest temperature was obtained during the dry season while the lowest temperature was observed during the rainy season. The mean values of water temperature and the standard error of the five swimming pools were significantly different ($p < 0.05$; Table 1).

Highest pH value of 7.7 was recorded during the rainy season while the lowest pH value of 6.46 was observed during the dry season (Table 1). The highest mean value (7.7 ± 0.22) of pH was recorded at Pool E during the rainy season, while the lowest mean value (5.04 ± 0.62) occurred at Pool D (5.04 ± 0.62) during the dry season. The mean pH of swimming pools were not significantly different but that of swimming Pool D was significantly different at $p < 0.05$.

Conductivity values of swimming pool water varied greatly during the period of study. The conductivity values ranged from 166.6 to 898.2 μS/cm during the dry season and from 366.4 to 513.2 μS/cm during the rainy season (Table 1). The highest mean value of conductivity occurred at Pool D (898.2 ± 40.8 $\mu S\ cm^{-1}$) during the dry season and the lowest value was at Pool A (166.60 ± 40.1$\mu S\ cm^{-1}$) during the dry season (Table 1). There was a significant difference between the mean values obtained for the pools at $p < 0.05$, except in Pool D.

Dissolved oxygen values observed in the swimming pools ranged from 1.12 to 9.20 mg/L in the dry season and from 3.29 to 7.40 mg/L in the rainy season (Table 1). The dissolved oxygen values varied significantly between the pools and seasons ($p < 0.05$).

Biological oxygen demand (BOD) observed in the swimming pool water varied from 3.10 to 5.40 mg/L in the dry season and from 1.44 to 2.66 mg/L in the rainy season (Table 1). Lower values were observed during the rainy season compared to the dry season (Table 1).

Chemical oxygen demand (COD) values in the swimming pools ranged from 0.26 to 6.88 mg/L in the rainy season while it ranged from 0.18 to 0.65 in the dry season (Table 1). The highest mean value (6.88 ± 4.73 mg/L) occurred in pool D in the rainy season while the lowest mean value (0.18 ± 0.11 mg/L) occurred in pool C in the dry season.

Residual chlorine ranged from 24.8 to 28.8 mg/L during the rainy season and from 10.2 to 19.4 mg/L during the dry season (Table 1). The highest mean value (28.8 ± 0.71 mg/L) was observed in pool E during the dry season while the lowest mean value (10.2 ± 1.56 mg/L) was observed in Pool A during the dry season. There was significant difference between the mean values in the pools at $p < 0.05$ while for Pool E, there was significant difference at $p > 0.05$.

Turbidity values in the pool water ranged from 4.00 to 12.61 NTU in rainy season while it ranged from 0.64 to 2.59 NTU in the dry season (Table 1). The highest mean value (12.61 ± 0.72 NTU) was observed in Pool E in the rainy season while the lowest mean value (0.22 ± 0.11 NTU) was observed in Pool D in the dry season. There was significant difference between the turbidity values of swimming pools ($p < 0.05$).

Table 1 Physico-Chemical Parameters of the Swimming Pools

	Pools																		
	A				**B**				**C**			**D**				**E**			
Parameters	**Dry Season n=5**	**Rainy Season n=5**	**F**	**P**	**Dry Season n=5**	**Rainy Season n=5**	**F**	**P**	**Dry Season n=5**	**Rainy Season n=5**	**F**	**Dry Season n=5**	**Rainy Season n=5**	**F**	**P**	**Dry Season n=5**	**Rainy Season n=5**	**F**	**P**
Turbidity (NTU)	2.59 ±0.58	4.25 ±0.37	5.832	0.032	2.53 ±0.57	5.2 ±10.5	1.459	0.042	0.64 ±0.27	4.00 ±0.38	51.773	0.22 ±0.11	4.57 ±0.64	45.36	0.020	3.28 ±0.25	12.61 ±0.72	9.334	0.516
DO (mg/L)	7.74 ±0.56	8.98 ±0.27	3.902	0.084	3.60 ±0.54	5.68 ±0.33	10.92	0.011	2.80 ±0.31	6.25 ±0.42	43.986	1.54 ±0.44	4.35 ±0.47	19.24	0.002	2.79 ±0.30	4.94 ±0.58	10.827	0.011
BOD (mg/L)	3.10 ±0.61	1.99 ±0.13	3.165	0.113	4.63 ±0.77	2.62 ±0.36	5.548	0.046	4.22 ±0.54	1.44 ±0.39	17.089	5.40 ±0.74	1.44 ±0.39	22.56	0.001	4.49 ±0.48	2.48 ±0.22	14.620	0.005
COD (mg/L)	0.63 ±0.41	0.26 ±0.20	0.650	0.443	0.57 ±0.32	0.40 ±0.18	0.219	0.652	0.18 ±0.11	1.00 ±0.25	8.923	0.36 ±0.32	6.88 ±4.73	1.890	0.206	0.65 ±0.40	1.24 ±0.31	1.413	0.269
Residual Chlorine mg/L	10.2 ±1.56	25.2 ±6.33	5.297	0.050	12.6 ±1.63	26.8 ±3.85	11.52	0.009	11.2 ±1.36	25.6 ±3.12	17.876	11.4 ±1.75	24.8 ±1.83	28.06	0.001	19.4 ±0.87	28.8 ±6.97	1.109	0.323
pH	6.28 ±0.28	7.5 ±0.16	4.559	0.055	4.48 ±0.61	6.91 ±0.09	15.44	.004	6.46 ±0.52	6.66 ±0.35	3.729	5.04 ±0.62	5.46 ±0.48	0.291	0.604	6.09 ±1.04	7.7 ±0.22	7.231	0.028
Temperature (ºC)	27.2 ±0.76	24.7 ±0.79	5.006	0.056	29.3 ±0.73	23.6 ±0.85	6.142	.038	25.7 ±1.03	23.3 ±1.10	2.698	26.1 ±0.78	23.3 ±0.83	6.307	0.036	28.8 ±0.71	26.8 1.39	0.348	0.571
Conductivity (µS/cm)	166.6 ±40.1	491.4 ±66.5	17.51	0.003	664.2 ±64.8	513.2 ±32.3	6.142	.070	663.6 ±64.1	440.6 ±67.7	5.718	898.2 ±40.8	406.2 ±59.9	46.099	0.000	503.6 37.3	366.4 ±44.8	5.545	0.046

Microbiological Analysis of Swimming Pool Water

The Total Heterotrophic Bacterial Population

The total bacterial populations of the water samples were recorded as colony forming unit (cfu/ml). During the study period, it was observed that the bacterial population in Pool A ranged from 2.5 x 10^2 cfu/ml (Dry Season) to 3.2x10^2 cfu/ml (Rainy Season); Pool B values ranged from 2.2 x10^2 cfu /ml (Dry Season) to 2.9 x 10^2cfu/ml (Rainy season); Pool C values ranged from 1.7 x10^2 cfu/ml (Dry Season) to 3.6 x 10^2cfu/ml (Rainy Season); Pool D values ranged from 3.2 x 10^2cfu/ml (Dry Season) to 2.8 x 10^2cfu/ml (Rainy Season) and Pool E values ranged from 4.0 x 10^2cfu/ml (Dry Season) to 5.2 x 10^2 cfu/ml (Rainy Season) (Tables 2a and 2b). The bacterial load during the study period did not follow any particular trend with alternate increase and decrease in values observed, depending on the neatness of the water sample. Bacterial population was higher in the rainy season than in the dry season except in Pool D. Bacteria species isolated were *Klebsiella* spp., *Citrobacter* spp., *Shigella* spp., *Aeromonas* spp., *Pseudomonas* spp., *Proteus* spp. and *Staphylococcus aureus*.

The Total Heterotrophic Fungal Population

The total heterotrophic fungi counts were expressed as spore forming unit per milliliter (sfu/ml). The total heterotrophic fungi counts fluctuated throughout the study period. Fungal population was higher during the rainy season compared with the dry season. The highest value obtained for the fungal population during the dry season in the Pool A was 1.4 x 10^2 sfu/ml; Pool B 1.6 x 10^2 sfu/ml; Pool C 2.6 x 10^2 sfu/ml; Pool D 1.2 x 10^2 sfu/ml and Pool E 3.8 x10^2 sfu/ml; while the highest value obtained during the rainy season in the Pool A was 2.9 x10^2 sfu/ml; Pool B 2.0 x10^2

sfu/ml; Pool C 2.6 x10^2 sfu/ml; Pool D 1.4 x 10^2 sfu/ml and Pool E 3.9 x10^2 sfu/ml (Table 3a). The mean values obtained for the fungal population in the swimming Pool water A-E were compared statistically using the one way Analysis of Variance and it was observed that the difference in mean values were significant at $p < 0.05$ (Table 3b). The fungal species isolated were *Aspergillus, Fusarium, Schizophyta, Cladosporium, Trichophyton, Cephalosporium, Penicillium* and *Monotospora* species.

Table 2a Total heterotrophic bacterial count (cfu/ml) in swimming pool water.

	Sampling Periods									
	Dry Season						Rainy Season			
Pool	October	November	December	January	February	March	April	May	June	July
A	2.0 x10^1	5.0 x10^1	3.0 x10^1	2.5 x10^2	0.23 x10^2	0.4 x10^2	3.2 x10^2	0.9 x10^2	0.12 x10^2	0.38 x10^2
B	1.2 x10^2	1.7 x10^2	2.2 x10^2	1.9 x10^2	1.5 x10^2	2.8 x10^2	2.9 x10^2	2.0 x10^2	2.9x10^2	2.5 x10^2
C	1.7 x10^2	1.4 x10^2	1.0 x10^2	0.7 x10^2	1.2 x10^2	2.6 x10^2	3.2 x10^2	2.1 x10^2	2.0 x10^2	3.6 x10^2
D	2.2 x10^2	2.5 x10^2	3.2 x10^2	3.0 x10^2	1.6 x10^2	2.5 x10^2	2.2 x10^2	2.8 x10^2	1.9 x10^2	2.6 x10^2
E	3.9 x10^2	3.9 x10^2	2.2 x10^2	4.0 x10^2	3.8 x10^2	3.6 x10^2	4.2 x10^2	5.2 x10^2	4.6 x10^2	4.9 x10^2

Values represent mean of duplicate reading.

Table 2b Mean and standard deviation of total bacterial load of the swimming pool water samples for dry and rainy seasons

	Pools					F	P
	A	B	C	D	E		
(Dry Season) Mean Standard Error	3.5±0.04	3.57±0.04	3.45±0.06	3.40±0.05	3.73±0.06	3.456	0.027
(Rainy Season) Mean Standard Error	4.59±0.05	4.62±0.05	4.50±0.06	4.42±0.06	4.85±0.09	10.113	0.000

Values represent means for each of the parameters after $\log_{10}$ transformation for the period of dry and rainy
Mean values of each swimming pool are significantly different
Significant difference at $P < 0.05$

Table 3a The total heterotrophic fungal population in swimming pool water.

	Sampling Periods									
Pool	Dry Season						Rainy Season			
	October	November	December	January	February	March	April	May	June	July
A	1.8 x10^2	1.4 x10^2	1.4 x10^2	0.5 x10^2	1.2 x10^2	0.9 x10^2	2.2 x10^2	1.6 x10^2	1.8 x10^2	2.9 x10^2
B	1.6 x10^2	1.3 x10^2	0.9 x10^2	0.8 x10^2	1.2 x10^2	2.0 x10^2	1.5 x10^2	1.8 x10^2	1.1 x10^2	1.4 x10^2
C	0.7 x10^2	1.8 x10^2	2.5 x10^2	2.0 x10^2	2.4 x10^2	2.6 x10^2	1.7 x10^2	0.3 x10^2	0.9 x10^2	1.4 x10^2
D	0.6 x10^2	1.0 x10^2	0.6 x10^2	1.2 x10^2	1.2 x10^2	1.2 x10^2	0.8 x10^2	1.4 x10^2	1.1 x10^2	1.2 x10^2
E	3.2 x10^2	3.0 x10^2	3.8 x10^2	2.3 x10^2	2.8 x10^2	2.0 x10^2	3.9 x10^2	2.3 x10^2	3.5 x10^2	3.2 x10^2

Values represent mean of duplicate reading.

Table 3b Mean and Standard Deviation of Total Fungi Load of the Swimming Pool Water Samples For Dry and Rainy Season Respectively.

	Pools					F	P
	A	B	C	D	E		
(Dry Season) Mean Standard Error	2.27±0.29	2.06±0.16	2.3±1.22	1.96±0.13	2.58±0.17	15.856	0.000
(Rainy Season) Mean Standard Error	2.39±0.06	2.19±0.02	2.47±0.05	2.06±0.09	2.60±0.08	3.470	0.026

Values represent means for each of the parameters after $\log_{10}$ transformation a period of Dry and Rainy season
Mean values of each swimming pool are significantly different
Significant difference at $P < 0.05$

Most Probable Number of Coliforms in Swimming Pool Water

The results of the enumeration of the coliforms in the swimming pool water samples are shown in Tables 4a and 4b. The coliform count ranged from 0.4 x 10^1 to 3.1 x 10^1 MPN/100ml in Pool A, 0.2 x 10^1 to 1.3 x10^1 MPN/100ml in Pool B, 0.5 x 10^1 to 6.5 x 10^1 MPN/100ml in Pool C, 0.6 x 10^1 to 8.0 x 10^1 MPN/100ml in Pool D and 1.1 x 10^1 to 1.10 x 10^2 MPN/100ml in Pool E. It was observed that the coliform counts values were higher during the rainy season relative to counts obtained during the dry season in all the swimming pools A-E.

Interrelationship between Bacterial Population and Physicochemical Parameters of Swimming Pools

The heterotrophic bacteria count and physicochemical parameters observed for swimming pool water A to E were subjected to linear correlation analysis. A positive correlation was observed between the temperature, pH, turbidity, conductivity, residual chlorine, BOD, dissolved oxygen and bacteria count in Pool A (Table 5). However, an inversely weak correlation was observed between the chemical oxygen demand and bacteria count in the same pool. In Pool B, a positive correlation was observed with pH (r = 0.423), strong positive correlation with biological oxygen demand and weak correlation between residual chlorine and the bacteria count (Table 5). In Pool C, a strong positive correlation was observed with turbidity (r = 0.624), weak positive correlation with pH (r = 0.194) and no correlation with Biological Oxygen Demand (BOD) (r = 0.194) and no correlation with Biological Oxygen Demand (BOD) (r = 0.001). In Pool D, a strong positive correlation was observed with temperature (r = 0.767), strong inverse correlation with BOD (r = 0.618), no correlation with conductivity (r = 0.000) and bacteria counts. In Pool E, a strong positive correlation was observed between turbidity and dissolved oxygen and bacteria counts. However, a weak positive correlation was observed between temperature and BOD and bacterial counts (Table 5).

Table 4a Most probable number of coliforms in swimming pool water (MPN/100 ml)

Pools	Sampling Periods									
	Dry Season					Rainy Season				
	October	November	December	January	February	March	April	May	June	July
A	0.6×10^1	0.4×10^1	1.5×10^1	1.0× 10^1	2.5×10^1	0.6×10^1	2.7×10^1	3.1×10^1	2.7×10^1	0.7×10^1
B	0.2×10^1	1.0×10^1	1.4×10^1	1.0×10^1	1.3×10^1	0.4×10^1	1.0×10^1	0.5×10^1	0.7×10^1	0.9×10^1
C	0.5×10^1	1.4×10^1	2.5×10^1	1.7×10^1	0.8×10^1	0.6×10^1	2.5×10^1	0.7×10^1	2.2×10^1	6.5×10^1
D	0.8×10^1	0.6×10^1	1.4×10^1	1.1×10^1	1.7×10^1	0.9×10^1	2.3×10^1	1.7×10^1	5.0×10^1	8.0×10^1
E	2.0×10^1	1.1×10^1	2.0×10^1	1.4×10^1	2.5×10^1	4.6×10^1	6.2×10^1	2.3×10^1	1.1x 10^2	4.3×10^1

Table 4b Mean and standard deviation of coliform counts in the swimming pool water samples for dry and rainy seasons

	Pools					F	P
	A	**B**	**C**	**D**	**E**		
(Dry Season) Mean Standard error	1.08±0.57	1.53±0.29	1.14±0.55	1.05±0.17	1.26±0.39	1.036	0.413
(Rainy Season) Mean Standard error	1.64±0.98	1.82±0.07	2.04±0.58	1.93±0.41	2.22±0.82	1.654	0.200

Values represent means for each of the parameters after $\log_{10}$ transformation for the period of Dry and Rainy Season ± standard error.

Table 5. Correlation and regression analysis between bacteria counts and physicochemical parameters of swimming pool water.

Physicochemical Parameter	Correlation Coefficient of Pool				
	A	B	C	D	E
Temperature	0.452	0.534	0.360	0.767	0.288
pH	0.505	0.423	0.194	0.009	0.499
Conductivity	0.522	0.000	0.417	0.000	0.381
Turbidity	0.423	0.207	0.624	0.698	0.601
Residual chlorine	0.409	0.350	0.363	0.408	0.350
Chemical oxygen demand	-0.212	0.187	0.526	0.459	0.445
Dissolved oxygen	0.400	0.472	0.490	0.653	0.611
Biological oxygen demand	0.511	0.630	0.001	-0.618	0.001

Interrelationship between Fungal Population and Physicochemical Parameters of Swimming Pools

In Pool A, there was a strong negative correlation between the fungal counts and temperature with a correlation coefficient (r = 0.518). BOD with a correlation coefficient (r = 0.396) and COD with a correlation coefficient (r = 0.382). It was observed that there was a weak positive relationship between fungal count and residual chlorine (r = 0.133), turbidity (r = 0.1201) and DO (r = 0.304). In Pool B, a positive correlation was observed between temperature and fungal count (r = 0.193) and the fungal count but an inverse correlation between COD (r = 0.169) and fungal count. In pool C, a strong positive correlation was observed with DO (r = 0.627) and weak correlation with temperature (r = 0.485). In Pool D, a positive correlation was observed with temperature, conductivity, residual chlorine and strong inverse correlation with temperature (r = 0.688). In Pool E, a positive correlation with turbidity, conductivity and inverse correlation with residual chlorine and fungal counts (Table 6).

Interrelationship between Coliform Counts and Physicochemical Parameters of Swimming Pools

In Pool A, it was observed that there was no correlation between coliform counts and the physicochemical parameters like temperature (r = 0.552) and BOD (r = 0.533) but positive correlation with turbidity (r = 0.587) (Table 7). In Pool B, a good positive correlation was observed between the coliform counts and pH (r = 0.6631) and inverse correlation between coliform counts and conductivity (r = 0.713) and temperature (r = 0.532). In Pool C, a strong correlation was observed between coliform counts and turbidity (r = 0.729) and inverse correlation in temperature (r = 0.44) and BOD (r = -0.532). In Pool D, there was a strong correlation between coliform counts and turbidity (r = 0.799), residual chlorine (r = 0.792), COD (r = 0.869) but an inverse correlation with BOD (r = -0.420). In Pool E, positive correlation was observed between the coliform counts and pH (r = 0.515), turbidity (r = 0.452), residual chlorine (r = 0.445) but inverse correlation was observed with COD (r = -0.186) and conductivity (r = -0.711) (Table 7).

Table 6. Correlation and regression analysis between fungal counts and physicochemical parameters of swimming pool water.

Physicochemical Parameter	Correlation coefficient of Pool A	B	C	D	E
Temperature	-0.518	0.193	-0.485	-0.688	0.015
pH	0.071	0.295	0.208	-0.248	0.059
Conductivity	0.001	0.344	0.260	0.492	0.349
Turbidity	0.120	0.174	0.581	0.403	0.490
Residual chlorine	0.133	0.260	0.258	0.488	-0.730
Chemical oxygen demand	-0.382	-0.169	0.197	0.543	0.057
Dissolved oxygen	0.304	0.333	0.627	0.555	0.100
Biological oxygen demand	-0.396	-0.419	0.315	0.307	0.168

Table 7. Correlation and regression analysis between coliform counts and physicochemical parameters of swimming pool water.

Physicochemical Parameter	Correlation coefficient of Pool A	B	C	D	E
Temperature	-0.552	-0.462	-0.441	-0.332	0.432
pH	0.274	0.663	0.283	-0.176	0.515
Conductivity	0.327	-0.713	-0.566	0.405	-0.711
Turbidity	0.587	0.364	0.729	0.799	0.452
Residual chlorine	0.438	0.424	0.364	0.792	0.445
Chemical oxygen demand	-0.341	0.198	0.539	0.869	-0.186
Dissolved oxygen	0.431	0.514	0.641	0.462	0.612
Biological oxygen demand	-0.533	-0.532	-0.508	-0.420	-0.386

DISCUSSION

Swimming pools are increasingly patronized by people for leisure and recreational purposes hence possible failures with its maintenance would be a matter of public health significance. All the swimming pools examined in this study were observed to fall below the microbiological quality standard specified by the World Health Organization (WHO, 2006).The results indicate high microbial counts (total heterotrophic bacteria count (THBC), total coliform bacteria count (TCBC) and total heterotrophic fungal count (THFC) exceeded quality standards for recreational water according to the world health regulatory body. These results underline the importance of continuous monitoring and good maintenance system of the swimming pools. Potential bacterial pathogens such as *Staphylococcus aureus*, *Pseudomonas* spp., *Aeromonas* spp., *Klebsiella* spp. and *Shigella* spp. were recovered from the pools. Some of these have been implicated in several human skin, intestinal and other diseases, especially in immune-compromised individuals. For instance, *Pseudomonas aeruginosa* is frequently present in small numbers in and around swimming pools and has been implicated in folliculitis outbreaks associated with swimming (Fiorilo *et al.*, 2001; Tate *et al.*, 2003). *S. aureus* , 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). The high microbial counts and potential pathogens observed in all the swimming pools could be due to use of contaminated water source, ineffective chlorination, poor hygienic conditions or the bathers shedding bacteria from faecal and non-faecal sources (Craun *et al.*, 2005; EPA, 2007). Bacterial contamination was significantly associated with the time of sample collection where there was a trend of increase in the prevalence of bacterial contamination during the weekends. This may reflect a cumulative effect of swimmers as a source of contamination. The numbers of swimmers were more at the time of sample collection and this may be associated with a high prevalence of contaminations. Martinys *et al.* (1995) reported that a significant association exists between water quality and the numbers of swimmers. In the examination of swimming pools in Iran, *P. aeruginosa* was found to grow in 63.6% of the water samples from eleven public swimming pools while 18.2% of the samples exhibited high rates of total heterotrophic bacteria counts and total coliform counts (Hajjartabar, 2004). Also, 32.9% of samples of swimming pool water studied in Greece did not conform to recommended microbiological standard regulations, with the samples found to be contaminated with *P. aeruginosa* and *Aeromonas hydrophila* (Papadopoulous *et al.*, 2008).

In this study, fungi such as *Aspergillus, Fusarium, Schizophyta, Cladosporium, Trichophyton, Cephalosporium, Penicillium* and *Monotospora* species were isolated from the swimming pools. Some of these fungi can be hazardous in specific conditions especially in immunocompromised individuals and can cause infections such as keratinomycosis, otitis and allergy (Bolanos, 1991). In a study conducted in Palestine involving six swimming pools, 22 dermatophytes and other keratophilic fungi including *Trichophyton* spp., *Chrysosporium* spp., *Cladosporium* spp., *Aspergillus flavus*, *Fusarium* spp. and *Penicillium* spp. were recovered (Ali-Shtayeh *et al.*, 2002). Similar species such as *Penicillium* spp., *Rhizopus* spp. *Aspergillus niger*, *Fusarium* spp., *Trichophyton mentagrophytes*, *Mucor* spp. and *Absidia* spp. were recovered from swimming pools examined in the Southwestern parts of Nigeria (Itah and Ekponbok, 2004).

Also, the total heterotrophic bacterial population in the aquatic environment depends on the availability of growth supporting organic matter (Lakshmanaperumalsamy *et al.*, 1981). The high load of total bacterial population might have been due to the availability of micronutrients in the water samples.

The climatic and environmental conditions of the tropics favour the survival of many pathogenic microorganisms. Temperature is one of the most important environmental factors which control the behavioural characteristics of microorganisms and it varies from one organism to another (Dixit and Tiwari, 2008). It is a factor of great importance to the physiology of microorganisms as well as the chemical and physical characteristics of water (Delince, 1992). The recorded water temperature of the swimming Pool A-E ranged from 23.3°C to 28.8°C throughout the period of study. The highest temperature was obtained during the dry season while the lowest temperature was obtained during the rainy season. According to Attah *et al.* (2007), 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).

The mean pH values for the various swimming pool water samples showed that higher values were recorded during the rainy season for swimming pools A and E. The mean pH values in the water sample for the rainy season were within the acceptable range of 7.0 to 7.8 recommended by WHO (2008). The pH range of 4.58 - 6.69 observed in the pool water during the dry season fell below the recommended level and this probably indicates excessive chlorination. Low pH conditions have been associated with problems such as itching, chlorine loss, skin spots and sore eyes in swimmers (Saberianpour *et al.*, 2015).

The mean value of residual chlorine in the pool which ranged from 10.2-28.8 ppm was far above the WHO (2008) recommended dose of 5 ppm. The excessive chlorine level observed could come from super chlorination in order to cover for bad management or ineffective mixing of the pool water.

Dissolved oxygen is also one of the most important environmental parameters influencing the life of the coastal environment (Lester, 1975). The dissolved oxygen values recorded for the swimming pools A, B and E were above the value recommended by WHO while pools C and D fell short of the value recommended by WHO. This implied that the water columns were oxygenated and were adequate enough to support the growth of microorganisms. The value recorded was in line with the acceptable dissolved oxygen range by environment which proposed a range of 5.0 to 9.0 mg/l, except the swimming pools C and D that did not meet the standard. This may be attributed to decomposition of organic matter in the swimming pools C and D which is an oxygen consuming process.

Outbreaks of diseases due to use of contaminated swimming pools and recreational waters have been reported by various researchers (Papapetropoulou and Vantarakis, 1998; Fiorillo *et al*., 2001; Tate *et al*., 2003; Barben *et al.,* 2005). Public health education and adequate information on how to properly manage swimming pools should therefore be given to pool operators. Continuous and regular monitoring of water quality indicators should be undertaken by regulatory health authorities in order to ensure compliance with regulations. Also, swimmers should be enlightened on the need to exhibit good hygienic practices during the use of the facility.

CONCLUSIONS

The study has provided information on the water quality of selected swimming pools in Osogbo metropolis, Southwestern Nigeria. The data obtained on the selected physico-chemical water quality parameters, apart from a few exceptions, were within permissible limits of WHO standards. However, the microbiological qualities of all the swimming pools examined were poor, with the water bodies being contaminated with different potentially-pathogenic microbes. Increase in numbers of pool users therefore call for stricter surveillance measures by responsible health authorities for protection of swimmers' health. Continued chemical and microbiological water analysis will give an objective insight into pool hygiene and help to prevent infection outbreaks among pool users.

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