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Microbiological and Physicochemical Characteristics of Swimming Pool Water in Owerri, Imo State, Nigeria

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Abstract This study was carried out to investigate the microbiological and physicochemical characteristics of swimming pool water in Owerri. A total of twenty (20) samples of swimming pool water from different locations were investigated for microbiological and physicochemical characteristics. The media used were nutrient agar, MacConkey agar, eosin methylene blue agar, *Salmonella-Shigella* agar, Sabouraud dextrose agar, thiosulphate citrate bile salt sucrose agar for total aerobic plate count, coliform count, *Escherichia coli* count, *Salmonella-Shigella* count, *Vibrio cholerae* count and fungal count respectively. The identification of the bacterial isolates was performed using standard microbiological techniques which included Gram staining and biochemical tests. The fungal isolates were identified using the needle mount technique. Data were subjected to analysis of variance. The mean total aerobic plate count ranged from $0.11 \pm 0.1 Log_{10}$ CFU/ml to $0.74 \pm 0.09 Log_{10}$ CFU/ml. The coliform count ranged from 0 ± 0.00 CFU/ml to $0.40 \pm 0.02 Log_{10}$ CFU/ml. The *Escherichia coli* count, *Salmonella-Shigella* count and *Vibrio cholerae* count had 0 ± 0.00 CFU/ml respectively. The fungal count ranged from 0 ± 0.00 CFU/ml to 0.30 ± 0.07 Log_{10} CFU/ml. The microorganisms isolated from the swimming pool samples were *Staphylococcus aureus*, *Klebsiella* spp *Pseudomonas aeruginosa* and *Aspergillus* spp. The physicochemical parameters analyzed were within WHO limit for drinking water quality except total dissolved solid with mean values of 380 ± 10.0mg/L and 275 ± 8.0 mg/L respectively. The result showed that the swimming pools investigated were not contaminated with pathogenic microorganisms.

Keywords: *swimming pool, microbiological, physicochemical, characteristics, Owerri, Nigeria*

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1. Introduction

Swimming pool, swimming bath, wading pool, paddling pool, or simply a pool, is a container filled with water intended for swimming or water-based recreation. There are many standard sizes Swimming pool of which the Olympic-sized swimming pool is the largest. A pool can be constructed either above or in the ground, using concrete materials. Pools that are used by the general public are called public pools while those used exclusively by a few people or in a home are called private pools. Many health clubs, fitness centers and private clubs have public pools used mostly for exercise. Many hotels have pools available for their guests. Hot tubs and spas are pools with hot water, used for relaxation or therapy and are common in homes, hotels, clubs and massage parlors. Swimming pools are also used for diving and other sports, as well as for the training of lifeguards and astronauts. Conceptually, swimming pools are pretty simple and are just big basins of water. But on a hot summer day, a swimming pool can seem like the greatest invention known to man. Swimming pools come in all shapes and sizes, but nearly all of them, from the backyard personal pool to the water park wave pool, work in the same basic way. They use a combination of filtration and chemical treatment to continually clean a large volume of water. Swimming is one of the best forms of exercise available and having a residential swimming pool also can provide much pleasure. Nevertheless, it takes a great deal of work and expense to make and keep the pool water clean and free of floating debris. Without a doubt, a properly maintained and operated pool is quite rewarding. Home pools, however, are sometimes referred to as attractive nuisances or hazards. It is essential to be able to evaluate the risks associated with a pool. The risks associated with pool drowning, impact injuries, physiological, infection and poisoning, toxicoses and other conditions that may arise from long-term chemical exposures, contact with, inhalation or ingestion of algal toxins and chemically contaminated air. Drowning involves swimmers under the influence of alcohol, poor swimming ability, no supervision and poor pool design and maintenance. Impact injuries result from impact against hard surfaces. These include diving, accidents arising from the use of water slides, collision, treading on broken glass and jagged metal especially in outdoor pool surrounding. The

physiological risk may be due to exposure to heat and ultraviolet radiation in sunlight, cumulative exposure to sun for outdoor pool users. This also involves exposure in the hot tubs or natural spas or cold exposure in plunge pools. The risk from infection includes ingestion and inhalation of or contact with pathogenic bacteria, viruses, fungi and protozoa, which may be present in water and pool surrounding. This may be as a result of faecal contamination carried by participants or animals using the water or naturally present [1,2]. A regulatory agent or consultant must understand the total engineered pool system and be capable of identifying all equipment, valves, and piping systems. The piping system for a pool should be color-coded to assist the pool operator or the owner to determine the correct way to operate the swimming pool. The specific goal is to protect the owners, their families, and others who may be attracted to a residential pool [3].

The significance of the study is that various microorganisms of public health importance are associated with swimming pool and similar recreational water environment. The risk of illness or infection emanating these microorganisms may be as a result of faecal contamination of the pool water. Some non-faecally derived bacteria may accumulate in biofilms and present an infection hazard. The monitoring for potential microbial hazards is important. This is therefore done using indicator microorganisms, which are easy to enumerate and are expected to be greater in numbers than pathogens. The monitoring helps in controlling water quality and prevents the transmission of infectious diseases in the swimming pools [4,5].

The aim of this study is to determine microbiological and physicochemical characteristics of swimming pool water in Owerri.

2. Materials and Methods

2.1. Collection of Materials

A total of 20 samples of swimming pool water were collected from different hotels in Owerri, Imo State, Nigeria. The hotels were Rock view, Juanita, Ideal suite, Concord, All seasons, Legend, Links, Lamond, The Ranch, and Owerri hotel plaza.

The samples for the microbial counts were collected in white sterile plastic containers, which were previously sterilized with 70% alcohol and rinsed with distilled water. At the swimming pool side, the containers were rinsed twice with the swimming pool water samples before being used to collect the samples. Samples for dissolved oxygen (DO) and biochemical oxygen demand (BOD) were collected with clean brown bottles. The samples for the other physiochemical parameters were collected with 500ml sterile plastic containers. They were transported to the laboratory in an ice packed cooler and immediately analyzed on reaching the laboratory.

2.2. Chemical Reagents

The chemical reagents used in the study were of analytical grade. They were products of BDH Chemicals, Poole's, England and Sigma Chemical Company, St. Louis Missouri, USA. The microbiological media used were products of Oxoid and Difco Laboratories, England. They were nutrient agar used for the estimation of total heterotrophic aerobic bacteria, purification and for stock culture; Sabouraud dextrose agar used for the isolation of fungi, *Salmonella-Shigella* agar for the isolation of *Salmonella* and *Shigella*, thiosulphate citrate bile salt sucrose agar for the isolation of *Vibrio cholerae*, eosin methylene blue agar for the isolation of *Escherichia coli* and MacConkey agar for coliform counts.

2.3. Enumeration of Total heterotrophic Bacteria and Fungi

Samples of the swimming pool water samples were serially diluted in ten folds. Total viable aerobic heterotrophic plate counts were determined using pour plate technique. Then the molten nutrient agar, Sabouraud dextrose agar, Salmonella-Shigella agar, thiosulphate citrate bile salt sucrose agar, eosin methylene blue agar and MacConkey agar at 45^0C were poured into the Petri dishes containing 1mL of the appropriate dilution for the isolation of the total heterotrophic bacteria and fungi, Salmonella-Shigella, Vibrio cholerae, Escherichia coli and coliform respectively. They were swirled to mix and colony counts were taken after incubating the plates at 30^oC for 48hrs and preserved by sub culturing the bacterial isolates into nutrient agar slants which were used for biochemical tests.

2.4. Characterization and Identification of Bacterial and Fungal Isolates

Bacterial isolates were characterized and identified after studying the Gram reaction as well as cell micro morphology. The other tests carried out were spore formation, motility, oxidase and catalase production; citrate utilization, oxidative/fermentation (O/F) utilization of glucose; indole and coagulase production, starch hydrolysis, sugar fermentation, methyl red-Voges Proskaur reaction and urease production. The tests were carried out according to the methods of [6,7,8]. Microbial identification was performed using the keys provided in the [9].

Fungal isolates were examined macroscopically and microscopically using the needle mounts technique. Their identification was performed according to the scheme of Barnett and Hunter and Larone [10,11].

2.5. Determination of Physicochemical Parameters

A number of physicochemical parameters of the stream water samples were determined. They included temperature, dissolved oxygen (DO), pH, total dissolved solids (TDS), total suspended solids (TSS), turbidity, alkalinity and others were nitrate, phosphate, sulphate, biochemical oxygen demand (BOD) and chemical oxygen demand (COD). The pH was measured *in-situ* using Hach pH meter (Model EC1O); temperature and total dissolved solids was measured *in-situ* using Hach conductivity meter (Model CO150). The dissolved oxygen was also measured *in-situ* using Hach DO meter (Model DO175). Sulphate was determined using Barium chloride (Turbidimetric) method. Nitrate was determined using Cadmium reduction method. Alkalinity and phosphate were measured using potentiometric titration and Ascorbic

acid methods respectively. Chemical oxygen demand and biochemical oxygen demand were determined using Walkley and Black dichromate reflux and Azide modification methods respectively. All analyses were in accordance with American Public Health Association (APHA) [12].

3. Results

The results of the laboratory analysis of the water samples collected from swimming pool are shown in Table 1–Table 4.

Table 1 shows the mean counts of microorganisms isolated from the swimming pool water. The mean ranged as follows: total aerobic plate count 0.00 ± 0.00Log_{10} CFU/ml to 0.74 ± 0.09Log_{10} CFU/ml; coliform count, 0 ± 0.00 CFU/ml to 0.40 ± 0.02Log_{10} CFU/ml. The *Escherichia coli* count, *Salmonella* - *Shigella* count and *Vibrio cholerae* count had 0 ± 0.00 CFU/ml respectively. The fungal count ranged from 0 ± 0.00 CFU/ml to 0.30 ± 0.07 Log_{10} CFU/ml. The ANOVA, P>0.05 showed that there was no significant difference in the mean counts of the different among the different hotels.

Table 1. The mean counts of microorganisms isolated from the swimming pool water

Location	Log_{10}CF/ml TAPC	CC	ECC	FC	SSC	VC
Rock view	0.11 ± 0.1	0 ± 0.00	0 ± 0.00	0 ± 0.00	0 ± 0.00	0 ± 0.00
Juanita	0.52 ± 0.09	0.15 ± 0.4	0 ± 0.00	0 ± 0.00	0 ± 0.00	0 ± 0.00
Ideal suite	0.56 ± 0.09	0.30 ± 0.7	0 ± 0.00	0 ± 0.00	0 ± 0.00	0 ± 0.00
Concord	0.74 ± 0.09	0.40 ± 0.9	0 ± 0.00	0.30 ± 0.07	0 ± 0.00	0 ± 0.00
All seasons	0 ± 0.00	0 ± 0.00	0 ± 0.00	0 ± 0.00	0 ± 0.00	0 ± 0.00
Legend	0 ± 0.00	0 ± 0.00	0 ± 0.00	0 ± 0.00	0 ± 0.00	0 ± 0.00
Links	0 ± 0.00	0 ± 0.00	0 ± 0.00	0 ± 0.00	0 ± 0.00	0 ± 0.00
Lamond	0 ± 0.00	0 ± 0.00	0 ± 0.00	0 ± 0.00	0 ± 0.00	0 ± 0.00
The Ranch	0 ± 0.00	0 ± 0.00	0 ± 0.00	0 ± 0.00	0 ± 0.00	0 ± 0.00
Owerri hotel	0 ± 0.00	0 ± 0.00	0 ± 0.00	0 ± 0.00	0 ± 0.00	0 ± 0.00

Key: TAPC- Total aerobic plate count, CC- Coliform count, ECC- Escherichia coli count, FC- Fungal count.

The microorganisms isolated from the swimming pool water samples and their percentage occurrence is shown in Table 2 shows the bacterial species isolated and included *Klebsiella* spp, 28.57%; *Pseudomonas aeruginosa* 28.57% and *Staphylococcus aureus*, 42.86%). The fungus isolated was *Aspergillus* spp. These organisms were isolated from Rock View, Juanita, Ideal suite and Concord hotels. There were no microorganisms isolated in the water samples from the other hotels.

Table 2. Microorganisms isolated from the swimming pool water samples and their percentage occurrence

Isolate	RV	JU	IS	CC	AS	LG	LK	LM	TR	OH
Bacteria										
Staphylococcus aureus	0 (0)	1(33.3)	1(33.3)	1(33.3)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Klebsiella spp	1 (50)	0 (0)	0 (0)	1 (50)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Pseudomonas aeruginosa	0 (0)	0 (0)	1 (50)	1 (50)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Fungi										
Aspergillus spp	0 (0)	0 (0)	0 (0)	2 (100)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)

Key: RV - Rock view, JU- Juanita, IS –Ideal suite, CC –Concord, AS – All seasons, LG- Legends, LK- Links, LM- Lamond, TR – The Ranch, OH – Owerri Hotel.

Table 3 shows the physicochemical analysis of swimming pool water. There is no significant difference in the physicochemical properties of water isolated from two (2) samples.

Table 3. The mean values of the physicochemical parameters of the swimming pool water samples

Parameter	Location 1	Location 2	WHO Limit
pH	7.1 ± 0.1	6.8 ± 0.2	6.5 – 8.5
Conductivity (µS/cm)	95.2 ± 3.0	105.7 ± 5.0	
Turbidity (NTU)	3.0 ± 0.01	3.0 ± 0.01	
Hardness (mg/L)	10 ± 0.5	10 ± 0.3	50
Phosphate (mg/L)	0.15 ± 0.02	0.07 ± 0.01	200
Nitrate (mg/L)	5.8 ± 0.3	5.1 ± 0.1	45
Sulphate (mg/L)	1.5 ± 0.01	2.0 ± 0.01	250
Ammonia (mg/L)	0.14 ± 0.01	0.22 ± 0.01	
Chloride (mg/L)	294 ± 10.0	221 ± 6.0	
Total suspended solids (mg/L)	1.0 0.01	5.0 ± 0.3	50
Total dissolved solids (mg/L)	380 ± 10.0	275 ± 8.0	50
Biochemical oxygen demand (mg/L)	0.89 0.03	1.75 0.05	3.0
Chemical oxygen demand (mg/L)	1.25 ± 0.02	2.55 ± 0.04	
Total iron (mg/L)	0.3 ± 0.01	0.8 ± 0.01	3.0

4. Discussion

The organisms implicated were *Klebsiella* species, *Staphylococcus aureus*, coagulase negative Staphylococcus species, *Pseudomonas* species and *Aspergillus* species. Microbiological contamination of the pool water can result in pathogenic (disease producing) microorganisms causing infections to bathers. These microorganisms can be introduced into the swimming pool through various sources of contamination. These contaminants can be introduced into pool water from bathers, from the pool filters or occasionally from defects in pool engineering (e.g. that allow the water to be contaminated with sewage). Others are pet animals such as dogs that may like to paddle in the pool on hot days, dead wildlife such as frogs or lizards or insects that may occasionally drown in the pool and debris from around the property such as leaves, grass and dust can also find their way into the pool [13,14].

Pseudomonas aeruginosa is an opportunistic pathogen commonly found in water, soil and vegetation. It also can be found in human and animal faeces. It rarely causes infection in healthy people but can colonize damaged systems, such as burn wounds and damaged eyes. Immuno-compromised individuals are particularly at risk. *P. aeruginosa* can grow at the selective temperature of 41–42 °C, where most environmental microorganisms would not survive, allowing it to proliferate to high numbers and cause diseases like ear and eye infections and folliculitis. Although relatively resistant to a range of disinfectants, chlorination of swimming pools should be sufficient to kill the bacterium. However, in environments peculiar to spas such as water turbulence, elevated temperature and high bather loads, considerably greater care is needed to ensure their safe operation and eradication of the microorganism. The bacterium produces biofilms and colonizes drains and filter media [15,16,17,18,19]. *Pseudomonas aeruginosa* can grow within untreated waters and in biofilms. It 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.

The presence of *Staphylococcus aureus* may be from swimmers because it is a normal flora of the body and mucous membrane and most common aetiological agent of septic arthritis [20,21]. The consumer is at risk of acquiring food borne diseases. *Staphylococcus aureus* is the major cause of staphylococcal food poisoning. The poisoning is characterized by diarrhea and vomiting [21,22,23].

The physicochemical parameters analyzed except total dissolved solids were within the WHO limit for drinking water quality. Measures should therefore be taken to control total dissolved solids values from being out of range.

Swimming pool problems are a result of inadequate pool water maintenance. Regular monitoring and testing of the pool water chemistry will ensure a low-cost maintenance, sparkling and clean swimming pool all the year round. It will also save money on chemicals by preventing situations requiring expensive treatment such as chlorine shock treatment and the use of algaecide. The importance of monitoring the swimming pool water cannot be overemphasized as our health and the health of our families will at risk [24].

5. Conclusion

The results of the study have shown that the disinfection of swimming pool water around the vicinity varies. In order to ensure the safety of the health of swimming pool users and also to prevent the spread of pathogenic microorganisms, it is therefore appropriate that high-level of treatment through disinfection be carried out in hotel swimming pools before usage or during swimming period in other to maintain a clean swimming environment and also eliminate both natural swimming pool water organisms and those introduced unknowingly by swimming pool users.

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