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Effects of Water Treatment on Microbial and Physicochemical Properties of Some Swimming Pool in Delta Central Senatorial District

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ABSTRACT

This study was aimed at investigating the effects of water treatment on microbial and physicochemical properties of swimming pools in Delta Central Senatorial district considering the great importance of the safety of recreational water. A total of 108 water samples were collected from three swimming pools before and after use from three hotels in Delta Central Senatorial District using sterile bottles with capacity of one liter for a period of three months, and were immediately transported to the laboratory for analyses using standard techniques to analyze for physico-chemical parameters and microbial parameters. The results obtained showed that the physico-chemical parameters were within the World Health Organization and Environmental Protection Agency recommended values before and after use with variation among sites 1, 2, and 3. The mean bacterial count ranged between 0.00cfu -2cfu before use and 0.00cfu-214cfu/100ml after use. Bacterial isolates were susceptible to calcium hypochlorite concentration at 0-5ppm,6-10ppm and 11-15ppm except Staphylococcus aureus which ensued at site 2 before use. The findings suggested that contamination of pool water can be minimized by promoting good hygiene, education, adequate disinfection of the pool and enforcement of recommended guidelines at regular intervals to ensure proper control of microbial and chemical conditions.

Keywords: *Disinfection, physicochemical properties, microbial parameters, recommended guidelines, membrane filter.*

1.0: INTRODUCTION

Swimming is acknowledged as one of the most valuable forms of exercise yet, yet recreational waters such as swimming pool present risks to health [1]. The prevalence of recreational water illness contacted through the use of swimming pool is a global public concern. Sources of contamination comprise microorganisms, infected bathers, body oil as well as sweat, makeup, suntan cream, urine, saliva, and fecal matter. For example, it was estimated that swimming pools contain an average of 30 to 80ml of urine from each individual during recreational activities [2]. The need for disinfection of water has long been recognized as paramount in industrialized society, and it can be implemented through multiple routes. These include chemical agents (e.g., chlorine, bromine, ozone, etc.), physical agents (e.g., heat, UV, and sound waves), mechanical means (e.g., filtration and sedimentation), and gamma rays from cobalt-60 isotopes, although irradiation from high-energy sources is neither practical nor commercially in use. Chlorination, in particular, is a common and effective disinfectant used for potable water, wastewater and swimming pools [3,4], as it provides multiple mechanisms of disinfection.

Microbial contamination of swimming pools can occur through faecal contaminated source water or direct defecation from swimmers, birds and animals usually faecal–oral [4, 5]. In addition, the interaction between disinfectants, pool water and impurities can yield a combination of chloramines and additional disinfection by-products [6].

Recreational waters comprise a mixture of pathogenic and non-pathogenic microorganisms as well as physico-chemical parameters which may be derived from sewage effluents and the recreational population using the water [7].

The upsurge in patronage has been recognized as posing some public health risk to users, owing to the uncleanness of the pool water. These contaminants can as well be introduced into the recreational water from pool filters or intermittently from deficiencies in pools engineering [8]. Several epidemiological studies have reported that health complications associated with the liver, reproductive system, kidney and central nervous system, increased the risk of cancer due to complication of water that contains (DBP) disinfection byproducts [9].

In swimming pools, combined chlorine is the most commonly identified ; it is very troublesome for bathers, as it is responsible for the so-called “irritation syndrome” in swimmers, dry skin, and irritations of mucous membranes. It also causes the unpleasant odor of swimming pool water and has mutagenic properties [5, 10]. The microbial safety of swimming pool water is highly questionable in countries with poor regulatory framework due to many existing possible microbial contaminant pathways. Microorganisms come in many forms and are sourced from land, humans and water bodies. Humans are the only recognized reservoir of *Staphylococcus aureus*, and it is found on the anterior nasal mucosa and skin as well as in the faeces of a substantial portion of healthy individuals. A variety of microorganisms can be found in swimming pools and similar recreational waters.

Non faecally derived contamination such as human shedding (e.g., from vomit, mucus, saliva, or skin) in the swimming pool is a potential source of pathogenic organisms. Opportunistic pathogens (notably bacteria) can also be shed from users and transmitted via surfaces and contaminated water [7,11].

Effectiveness of disinfection is often measured with the heterotrophic plate count (HPC). One major disadvantage of any cultivation method is its long period of time before results are known. In addition, only a very small fraction of the microbial population is culturable [12]. If bacteria could be cultivated, bacterial cells can, under certain conditions, reach a viable but non culturable state after chlorination. Indeed, fewer rates of respiratory or irritative problems are reported in swimming facilities that use alternative processes of disinfection, such as UV rays, oxygen, copper, and ozone [13]. Frequency of examination of swimming pool water depends on the size of the pool, in large indoor pools, microbiological analyses are performed one per month and chemical analyses are at least 2 times per year [13, 14]. It has been proposed that no single indicator microorganism is suitable, so faecal indicators and microorganisms from bathers should be considered concurrently in assessing the effect of chlorination and safety of pool water [15]. The use of many indicators and the necessity to evaluate the bather load to assess the quality of swimming pool water could be a constraint for the control of these waters mainly considering cost-benefit analysis and it is important that such a control could be less expensive and simple to be performed.

2.0: MATERIALS AND METHODS

2.1Methods of Laboratory Analysis

2.2 Sample collection

Samples were obtained from three different locations following [1] guidelines. Samples designated after use were collected during the peak of bathing periods and samples designated before use were collected after chlorination. A total of 108 samples were collected using sterile glass bottle with capacity of 1liter. All samples were obtained from a depth of 100cm at a point 50cm away from the edge and 1m away from the shore. Temperature, colour and transparency were determined at the point of sample collection and samples were conveyed to the laboratory in an ice cooler and were processed immediately.

2.3 Determination of Physicochemical properties of swimming pool water.

Physicochemical properties investigated include; pH, turbidity, chloride, nitrate, phosphorus, total dissolved solid, dissolved oxygen, and biochemical oxygen demand (BOD). The pH was measured using pH meter model Li.120 digital multimeter which gave the value of the pH. The turbidity of the water sample was determined using a meter by Elico model Li.120 digital meter. Chloride content was determined by titrating the sample against 0.02 sliver nitrate solution using potassium chromate indicator.

Nitrate content was determined spectrophotometric method at 328nm. Phosphorus content was assessed by the spectrophotometric method. Conductivity of the water sample was determined using conductivity meter Elico model C0.150 digital conductivity meter and the value was directly determined. Total dissolved solid of the sample was determined by weight difference. Dissolved oxygen was determined by the modified Winkler's method. Biochemical oxygen demand was done by measuring the amount of dissolved oxygen present in any given sample before and after incubation in the dark at 20°C for five days.

2.4 Bacteriological Analyses

Bacteriological analysis was done using membrane filtration technique with membrane filter with porous disc of 0.45µm. A 100 ml of the water sample was filtered through the membrane filter as the vacuum pump was switched on. After filtration, the membrane filter was inoculated on the media (m.endo agar, m-fc agar, m.enterococcus agar, salmonella shigella agar, eosin methylene blue agar, MacConkey agar, nutrient agar, centrimide agar), and was incubated at 37°C for 24hours to 48 hours.

2.5 Enumeration and Identification of bacterial isolates:

Isolates were characterized using standard tests which include; Gram reaction and shape, catalase, motility, bile solubility test, aerobic growth, anaerobic growth, coagulase, oxidase, hydrogen sulphide production, decarboxylase, Oxidation/Fermentation test, citrate utilization, urease, deoxyribonuclease, phenylalanine deaminase, indole, methyl red.

2.6 Data analysis

The differences in the bacterial population before and after use for physicochemical and microbial parameters with respect to their sources were analyzed by analysis of variance (ANOVA) [16].

3.0 RESULTS

Temperature of the swimming pool from the different site in Delta Central Senatorial District is presented as Table 3.1. The temperatures of the swimming pools in Site 1 during weeks 0-10 before use ranged between 22.50 ± 0.50^{a} and 23.67 ± 0.58^{a}, while after use ranged between 22.60 ± 0.12^{a} and 26.07 ± 0.12^{a}

The temperatures of the swimming pool in Site 2 during weeks 0 - 10 before use ranged between 21.67 ± 1.53 and 25.00 ± 1.00^{b} while after use ranged between 22.67 ± 0.58^{b} and 25.10 ± 0.10.

The temperature of the swimming pool in Site 3 during weeks 0-10 before use ranged between 22.67 ± 0.58^{a} and 26.00 ± 1.20^{b} while after use 24.00±1.74, week 2 before use 24.00±1.00, after use 25.13±0.12, week 4 before use was 22.67±0.58, after use ranged between 21.09 ± 0.25^{a} and 26.00 ± 0.53^{a}.

These temperatures in the various Sites were observed to have conformed to the range of 22-26 as recommended by World Health Organization and Environmental Protection Agency standard for recreational water.

Table 3.1: Temperature values (oC) of swimming pool from the different Sites in Delta Central Senatorial District

	Site 1		Site 2		Site3 WHO and EPA Standard	
Period (Week)	BU	AU	BU	AU	BU	AU
0	23.20±0.26[b]	26.07±0.12[a]	21.67±1.53[a]	25.10±0.10[a]	26.00±1.20[b]	24.00±1.74[a] 22-26
2	23.20±0.26[a]	25.10±0.10[a]	22.67±0.58[a]	24.00±0.10[a]	24.00±1.00[b]	25.13±0.12[a]
4	22.07±0.26[a]	23.00±0.12[b]	25.00±1.00[b]	22.67±0.58[b]	22.67±0.58[a]	23.33±0.12[a]
6	23.67±0.58[a]	25.50±0.50[a]	23.33±0.58[a]	25.17±0.29[a]	24.43±0.51[b]	26.00±0.53[a]
8	23.23±0.29[a]	23.17±0.29[b]	24.23±0.15[a]	23.07±0.25[b]	25.23±0.12[b]	21.09±0.25[a]
10	22.50±0.50[a]	22.60±0.12[a]	24.27±0.25[a]	23.03±0.58[a]	23.03±0.58[a]	23.50±0.50[a]

Keys: BU-Before use, AU-After use
Values are represented as mean + standard deviation, of three replicates in all groups.
Values with different superscript are significantly different at (p<0.05).

The pH of the swimming pool sample is presented as Table 3.2 and was observed to conformed the recommended standard in Site 1 during weeks 0 – 10 before use ranged between was 7.04±0.06 and 7.40±0.10[a.] while after use from week 2-10 conformed the recommended standard, however, there was an increase after use beyond the recommended standard with value of 8.10±0.10 during weeks 0. The pH in Site 2 conformed with the recommended standard during weeks 0 -10 before use which ranged from 7.10±0.10 and 7.43±0.58, while after use it conformed with the recommended standard which ranged between 7.37±0.15[a] and 7.83±0.58[a] during weeks 0, 6, 8 and 10, after use an increase was observed during week 2 (8.03±0.58) and week 4 (8.10±0.10).
The pH in Site 3 conformed with the recommended standard during weeks 0 - 10 before use was which ranged between 7.03±0.58[a] and 7.17±0.35, 7.17±0.15, while after use it conformed with the recommended standard during weeks 0, 4,6 and 10, however an increase was observed after use during weeks 2 (8.10±0.10) and 8 (8.00±0.20[b]).

Table 3.2: pH values of swimming pool from the different Sites in Delta Central Senatorial District

	Site 1		Site 2		Site3		WHO and EPA Standard
Period (Week)	BU	AU	BU	AU	BU	AU	
0	7.04±0.06[a]	8.10±0.10[a]	7.10±0.10[a]	7.83±0.58[a]	7.12±0.15[a]	7.40±0.35[a]	7.0-7.8
2	7.03±0.58[a]	7.50±0.10[a]	7.17±0.15[a]	8.03±0.58[a]	7.17±0.15[a]	8.10±0.10[a]	
4	7.40±0.10[a]	7.50± 0.10[a]	7.43± 0.58[a]	8.10±0.10[a]	7.10±0.10[a]	7.60±0.10[a]	
6	7.20±0.40[a]	7.37±0.58[a]	7.30±0.10[a]	7.43±0.58[a]	7.10±0.10[a]	7.10±0.10[a]	
8	7.03±0.58[a]	7.33±0.15[a]	7.10 ±0.10[a]	7.50±0.10[a]	7.10±0.10[a]	8.00±0.20[b]	
10	7.16±0.15[a]	7.13±0.12[a]	7.20±0.20[a]	7.37±0.15[a]	7.03±0.58[a]	7.17±0.15[a]	

Keys: BU-Before use, AU-After use
Values are represented as mean + standard deviation, of three replicates in all groups.
Values with different superscript are significantly different at (p<0.05).

The turbidity of the swimming pool sample is presented as Table 3.3 was observed to conformed with the recommended standard in Site 1 during week 0 – 10 before use which ranged between 1.17±0.15[a] and 2.87±0.12[a], while after use during week 10 6.00±0.10[a] also conformed with the with the recommended standard. However, after use there was an increase beyond the recommended standard at weeks 0 with value of 6.30±0.26, 2 with value of 6.50±0.10, 4 with value of 6.83±0.10, 6 with value of 6.10±0.10.
The turbidity in Site 2 conformed with the recommended standard during week 0-10 before use which ranged between 1.17±0.15[b] and 2.10 ±0.66[a], and after use during week 0 (5.33±0.31[a]), 6 (4.70±0.10[a]) and 10 (6.00±0.20[a]). However, an increase was observed after use during weeks 2 (6.23±0.58[a]), 4 (6.27±0.58[a]) and 8 (6.07±0.12[a]).
The turbidity in Site 3 conform with the recommended standard during weeks 0 - 10 before use stayed between 2.47±0.58[b] and 3.40±0.20, and after use during weeks 2 (5.03±0.58[a]) 4 (4.47±0.58[a]), 8 (5.20±0.20[b]) and 10 (3.77±0.58[a]). However, after use an increase was observed during weeks 0 (6.50±0.10) and 6 (6.23±0.58).

Table 3.3: Turbidity values (mg/l) of swimming pool from the different Sites in Delta Central Senatorial District

	Site 1		Site 2		Site3		WHO and EPA Standard
Period (Week)	BU	AU	BU	AU	BU	AU	
0	2.10±0.50[a]	6.30± 0.26[b]	1.43± 0.40[b]	5.33±0.31[a]	3.10±0.10[a]	6.50±0.10[a]	≤6.0mg/l
2	1.17±0.15[a]	6.50±0.10[b]	1.17±0.15[b]	6.23±0.58[a]	3.10±0.10[b]	5.03±0.58[a]	
4	1.23±0.15	6.83±0.58[b]	1.30± 0.10[b]	6.27±0.58[a]	2.50±0.10[a]	4.47±0.58[a]	
6	2.40±0.40[a]	6.33±0.58[a]	1.27±0.25[a]	4.70±0.10[a]	3.40±0.20[a]	6.23±0.58[a]	
8	2.20±0.20[b]	6.10±0.10[b]	1.30±0.26[a]	6.07±0.12[a]	2.47±0.58[b]	5.20±0.20[b]	
10	2.87±0.12[a]	6.00±0.10[a]	2.10 ±0.66[a]	6.00±0.20[a]	2.87±0.37[a]	3.77±0.58[a]	

Keys: BU-Before use, AU-After use
Values are represented as mean + standard deviation, of three replicates in all groups.
Values with different superscript are significantly different at (p<0.05).

The chloride of the swimming pool sample is presented as Table 3.4, Site 1 was observed to conform to the recommended standard at week 0 before use was 2.17±0.50, there was a decrease after use below the recommended standard with value of 0.87±0.58, week 2 before use was 2.27±0.58, after use a decrease below the standard with value 0.80±0.10, at week 4 before use stayed at 2.40±0.10, while after use a decrease was observed with value of 0.90±0.10, week 6 before use was 2.63±0.15, while after use a decrease was noticed with value of 0.80±0.10, week 8 before use was 2.60±0.53, after use with value 1.43±0.40 and week 10 before use stayed at 2.87±0.12, while after use 0.80±0.12. Chloride at Site 2 conform to the recommended standard at week 0 before use was 2.50±0.10, and after use a decrease was observed with value of 0.90±0.10, week 2 before use 1.47±0.58, after use a decrease was observed with value of 0.57±0.50, week 4 before use 1.80±0.20, while a decrease was also observed after use with value of 0.97±0.21, week 6 before use 2.80±0.30 and after use decrease was also observed after use with value of 0.93±0.58, week 8 before use 2.50±0.30, after use decrease was also observed with value of 0.77±0.05, and week 10 before use 2.63±0.66, decrease was also observed after use with value of 0.80±0.20. Chloride in Site 3 conform with the recommended standard at week 0 before use stayed at 7.20±0.20, after use a decrease was observed with value of 0.87±0.58, week 2 before use 2.27±0.10, after use decrease was also observed with value of 0.87±0.58, week 4 before use was 3.00±0.20, after use 2.46±0.20, week 6 before use 2.83±0.15, after use after use a decrease was observed with value of 0.83±0.58, week 8 before use 2.50±0.44, after use decrease was also observed after use with value of 0.88±0.08, week 10 before use 2.77±0.37, after use a decrease was also observed with value of 0.77±0.58.

Table 3.4: Chloride values (mg/l) of swimming pool from the different Sites in Delta Central Senatorial District

	Site 1		Site 2		Site3		WHO and EPA Standard
Period (Week)	BU	AU	BU	AU	BU	AU	
0	2.17±0.15^a	0.87±0.58^a	2.50±0.10^a	0.90±0.10^a	1.20±0.20^b	0.87±0.58^a	1-3mg/l
2	2.27±0.58^a	0.80±0.10^a	2.57±0.58^a	1.47±0.50	2.27±0.58^a	0.87±0.58^a	
4	2.40±0.10^b	0.80±0.10^b	1.80±0.20^a	0.97±0.21^b	3.00±0.20^a	2.46±0.58^a	
6	2.63±0.15^a	0.80±0.10^a	2.80±0.30^b	0.93±0.58^b	2.83±0.15^b	0.83±0.58^b	
8	2.60±0.53^a	1.43±0.40^a	2.50±0.30^b	0.77±0.05^b	2.50±0.44^b	0.88±0.08^b	
10	2.87±0.12^a	0.60±0.10^a	2.10±0.66^a	0.80±0.20^a	2.87±0.37^a	0.77±0.58^a	

Keys: BU-Before use, AU-After use
Values are represented as mean + standard deviation, of three replicates in all groups.
Values with different superscript are significantly different at (p<0.05).

The nitrate level of the swimming pool sample is presented as Table 3.5, Site 1 was observed to conform to the recommended standard at week 0 before use was 2.23±0.32, there was a slight increase after use above the recommended standard with value of 5.20±0.20, week 2 before use was 2.02±0.58, after use an increase above the standard with value 6.47±0.58, at week 4 before use stayed at 2.17±0.20, while after use an increase was observed with value of 5.30±0.12, week 6 before use was 3.80±0.58, while after use an increase was noticed with value of 6.47±0.10, week 8 before use was 1.77±0.25, after use an increase was noticed with value of 5.70±0.10 and week 10 before use stayed at 2.37±0.40, while after use 4.40±0.10.
Nitrate at Site 2 conform to the recommended standard at week 0 before use was 2.50±0.10, and after use an increase was observed with value of 5.10±0.10, week 2 before use 2.03±0.58, after use an increase was observed with value of 5.20±0.58, week 4 before use 2.33±0.53, while after use 3.80±0.10, week 6 before use 1.60±0.53 and after use an increase was also observed with value of 5.20±0.10, week 8 before use 2.543±0.15, after use 4.60±0.10, and week 10 before use 2.43±0.40, after use 4.30±0.26.
Nitrate in Site 3 conform with the recommended standard at week 0 before use stayed at 3.53±0.58, after use an increase was observed with value of 6.73±0.12, week 2 before use 3.77±0.15, an increase was also observed after use with value of 6.53±0.58, week 4 before use was 2.23±0.40, an increase was also observed after use with value of 6.50±0.20, week 6 before use 3.77±0.40, after use an increase was observed with value of 6.53±0.10, week 8 before use 2.33±0.31, after use an increase was also observed with value of 6.10±0.10, week 10 before use 2.33±0.20, after use was 3.43±0.40.

Table 3.5: Nitrate values (mg/l) of swimming pool from the different Sites in Delta Central Senatorial District

	Site 1		Site 2		Site3		WHO and EPA Standard
Period (Week)	BU	AU	BU	AU	BU	AU	
0	2.23±0.32^b	5.20±0.20^a	2.50±0.10^b	5.10±0.10^b	3.53±0.58^b	6.73±0.12^b	1-5mg/l
2	2.03±0.58^a	6.47±0.58^a	2.03±0.58^a	5.20±0.10	3.77 ±0.15^a	6.53 ±0.58^a	
4	3.80±0.20^b	5.07±0.12^b	1.60 ±0.53^a	3.80±0.10^b	2.23 ± 0.40^a	6.50±0.10^a	
6	3.80±0.58^a	6.47±0.10^a	2.03±0.53^a	5.20±0.10^a	3.77± 0.40^a	6.53 ±0.10^a	
8	1.77±0.25^a	5.70±0.10^a	2.43±0.15^a	4.60±0.10^a	2.33± 0.31^a	6.10 ±0.10^a	
10	2.37±0.40^a	4.40±0.10^a	2.43±0.40^a	4.30±0.26^a	2.33± 0.20^a	3.43±0.40^a	

Keys: BU-Before use, AU-After use
Values are represented as mean + standard deviation, of three replicates in all groups.
Values with different superscript are significantly different at (p<0.05).

The phosphate level of the swimming pool sample is presented as Table 3.6 Site 1 was observed to conform with the recommended standard at week 0 before use was 2.03±0.06, there was a slight increase after use above the recommended standard with value of 10.20±0.10, week 2 before use was 2.10±0.10, after use an increase above the standard with value 10.40±0.10, at week 4 before use stayed at 2.50±0.10, while after use was 5.23±0.15, week 6 before use was 3.77±0.25, while after use an increase was noticed with value of 10.37±0.15, week 8 before use was 2.50±0.10, after use an increase was noticed with value of with value of 10.90±0.10 and week 10 before use stayed at 2.50±0.10, while after use an increase was noticed with value of with value of 10.47±0.42.

Phosphate level conform with the recommended standard at Site 2 during week 0 before use was 5.10±0.10, and after use an increase was observed with value of 10.17±0.06, week 2 before use 3.30±0.10, after use an increase was observed with value of 10.47±0.06, week 4 before use 3.47±0.42, while after use 5.80±0.20, week 6 before use 2.30±0.26 and after use was 3.73±0.58, week 8 before use 2.60±0.53, after use 7.10±0.10, and week 10 before use 3.20±0.20, after use 6.40±0.40.
Phosphate level conform with the recommended standard in Site 3 at week 0 before use stayed at 3.77±0.06, an increase was also observed after use with value of was 10.17±0.15, week 2 before use 3.10±0.10, an increase was also observed after use with value of 11.10±0.10, week 4 before use was 3.60±0.10, while after use was 4.83±0.74, week 6 before use 4.83±0.35, after use was 9.87±0.21, week 8 before use 2.47±0.36, after use 9.87±0.12, week 10 before use 3.43±0.40, and after use 4.50±0.30.

Table 3.6: Phosphate values (mg/l) of swimming pool from the different Sites in Delta Central Senatorial District

	Site 1		Site 2		Site3		WHO and EPA Standard
Period (Week)	BU	AU	BU	AU	BU	AU	
0	2.03±0.06^{b}	10.20±0.10^{b}	5.10±0.10^{a}	10.17±0.06^{b}	3.77±0.06^{b}	10.17±0.15^{a}	1-10mg/l
2	2.10±0.10^{b}	10.40±0.10^{b}	3.30±0.10^{a}	10.47±0.06^{b}	3.10±0.10^{b}	11.10±0.10^{b}	
4	2.50±0.10^{a}	5.23±0.15^{a}	3.47±0.42^{a}	5.80±0.20^{a}	3.60±0.10^{a}	4.83±0.74^{a}	
6	3.77±0.25^{a}	10.37±0.15^{a}	2.30±0.26^{a}	3.73±0.58^{a}	4.83±0.35^{a}	9.87±0.21^{a}	
8	2.03±0.25^{b}	10.90±0.10^{b}	2.60±0.53^{a}	7.10±0.10^{a}	2.70±0.36^{a}	11.73±0.12^{b}	
10	2.50±0.10^{a}	10.47±0.42	3.20±0.20^{a}	6.40±0.40^{a}	3.43±0.40^{a}	11.50±0.30^{a}	

Keys: BU-Before use, AU-After use
Values are represented as mean +standard deviation, of three replicates in all groups.
Values with different superscript are significantly different at (p<0.05).

The total dissolved solid level of the swimming pool sample presented as Table 3.7 Site 1 was observed to conform to the recommended standard at week 0 before use was 283.00±2.65, after use with value of 496.97±15.28, week 2 before use was 307.33±6.43, after use with value 123.00±2.65, at week 4 before use stayed at 252.00±2.00, while after use an increase was observed with value of 580.00±2.00,week 6 before use was 205.33±5.03, while after use an increase was observed with value of 503.33±4.16, week 8 before use was 81.67±5.03, after use an increase was observed with value of 516.67±15.28 and week 10 before use stayed at 120.67±1.15, while after use with value of 293.33±11.55.
The total dissolved solid level of the swimming pool sample conforms with the recommended standard in Site 2 during week 0 before use was 365.33±1.53, and after use with value of 455.33±5.03, week 2 before use 382.67±6.43, after use with value of 410.00±10.00, week 4 before use 305.00±5.00, while after use 456.30±6.10, week 6 before use 363.33±3.05 and after use was 434.00±3.65, week 8 before use 150.00±2.00, after use 322.33±2.08, and week 10 before use 206.30±5.20, after use 368.33±24.66.
The total dissolved solid level of the swimming pool sample conforms with the recommended standard in Site 3 at week 0 before use stayed at 405.00±5.50, after use with value of 498.7±7.64, week 2 before use 484.33±4.04, after use an increase was observed with value of 602.67±2.51, week 4 before use was 205.30±5.03, while after use an increase was observed with value of 649.67±1.53, week 6 before use 316.67±2.87, after use an increase was observed with value of 502.67±2.52, week 8 before use 404.33±4.04, after use an increase was observed with value of 514.00±12.17, week 10 before use 213.33±11.55, and after use 466.67±15.28.

Table 3.7: Total dissolved solid values (mg/l) of swimming pool from the different Sites in Delta Central Senatorial District

	Site 1		Site 2		Site3		WHO and EPA Standard
Period (Week)	BU	AU	BU	AU	BU	AU	
0	283.00±2.65^{a}	496.67±15.28^{a}	365.33±1.53^{a}	455.33±5.03^{a}	405.00±5.00^{a}	498.33±7.64^{a}	500mg/l
2	307.33±6.43^{a}	123.00±2.65^{a}	382.67±6.43^{a}	410.00±10.00^{a}	484.33±4.04^{a}	602.67±2.51^{a}	
4	252.00±2.00^{a}	580.00±2.00^{a}	503.00 ±5.00^{a}	456.30±6.10	205.3±5.030^{a}	649.67±1.53^{a}	
6	205.33±5.03^{a}	503.33±4.16^{b}	363.33±3.05^{b}	434.00±3.65^{a}	316.67±2.87^{a}	502.67±2.52^{a}	
8	81.67±5.03^{a}	516.67±15.28^{b}	150.00±2.00^{a}	322.33±2.08^{a}	404.33±4.04^{b}	514.00±12.17^{b}	
10	120.67±1.15^{a}	293.33±11.55^{a}	206.30±5.20 ^{a}	368.33±24.66^{a}	213.33±11.55^{a}	466.67±15.28^{a}	

Keys: BU-Before use, AU-After use
Values are represented as mean +standard deviation, of three replicates in all groups.
Values with different superscript are significantly different at (p<0.05).

The dissolved oxygen level of the swimming pool sample in Table 3.8, Site 1 was observed to conforms to the recommended standard at week 0 before use which was 9.03±0.06, after use with value of 8.50±0.10, week 2 before use was 9.23±0.06, after use an increase was observed with value of 11.23±0.21, at week 4 before use stayed at 9.33±0.31, while after use a slight increase was observed with value of 10.30±0.10, week 6 before use was 8.47±0.42, while after use an increase was observed with value of 10.80±0.20, week 8 before use was 9.23±0.25, after use was 8.37±15.28 and week 10 before use stayed at 9.46±0.66, while after use with value of 8.37±0.15.
The dissolved oxygen level of the swimming pool sample conforms with the recommended standard in Site 2 during week 0 before use was 9.50±0.10, and after use with value of 9.63±0.15, week 2 before use 9.63±0.15, after use an increase was observed with value 10.77±0.15, week 4 before use 9.20±0.20, while after use an increase was observed with value of 10.63±0.15, week 6 before use 8.60±0.10 and after use was 9.67±0.32, week 8 before use 9.87±0.12, after use an increase was observed with value of 10.87±0.12, and week 10 before use 9.43±0.15, after use 9.73±0.12. The dissolved oxygen level of the swimming pool sample conforms with the recommended standard in Site 3 at week 0 before use stayed at 9.30±0.10, after use with value of 6.50±0.10, week 2 before use 9.27±0.31, after use an increase was observed with value of 11.10±0.10, week 4 before use was 9.37±0.32, while after use an increase was observed with value of 11.33±0.31, week 6 before use 9.67±0.32, after use an increase was observed with value of 10.87±2.52,

week 8 before use 9.10±0.10, after use an increase was observed with value of 12.77±0.25, week 10 before use 9.17±0.15, and after use 9.63±0.15.

Table 3.8: Dissolved oxygen values (mg/l) of swimming pools from the different sites Sites in Delta Central Senatorial District

	Site 1		Site 2		Site3		WHO and EPA Standard
Period (Week)	BU	AU	BU	AU	BU	AU	
0	9.03±0.06^a	8.50±0.10^a	9.50±0.10^a	9.63±0.15^a	9.50±0.10^a	6.50±0.10^a	9-10mg/l
2	9.23±0.06^b	11.23±0.21^a	9.63±0.15^a	10.77±0.15^a	9.27±0.31^b	11.10±0.10^a	
4	9.33±0.31^a	10.30±0.10^a	9.20±0.20^a	10.63±0.15^a	9.37±0.32	11.33±0.31^a	
6	8.47±0.42^b	10.80±0.20^b	9.50±0.10^a	8.60±0.10^a	9.67±0.32^b	10.87±0.12^b	
8	9.23±0.25^b	11.67±0.12^a	9.87±0.12^b	10.87±0.12^b	9.10±0.10^b	12.77±0.25^a	
10	9.46±0.06^a	8.37±0.15^a	9.43±0.15^a	9.73±0.12^a	9.17±0.15^a	9.63±0.15^a	

Keys: BU-Before use, AU-After use
Values are represented as mean +standard deviation, of three replicates in all groups.
Values without allotment of a superscript letter on the same column are significantly different at (p<0.05)

The biochemical oxygen demand level of the swimming pool sample is presented in Table 3.9, Site 1 was observed to conforms to the recommended standard at week 0 before use which was 2.00±0.06, after use with value of 1.10±0.10, week 2 before use was 1.80±0.10, after use an increase was observed with value of 2.03±0.06, at week 4 before use stayed at 1.60±0.53, while after use a slight increase was observed with value of 2.63±0.06,week 6 before use was 2.00±0.26, while after use an increase was observed with value of 3.50±0.50, week 8 before use was 1.67±0.15, while after use an increase was observed with value of 2.83±0.15 and week 10 before use stayed at 1.50±0.50, while after use an increase was observed with value of 2.83±0.25.

The biochemical oxygen demand level of the swimming pool sample conforms with the recommended standard in Site 2 during week 0 before use was 2.00±0.10, and while after use an increase was observed with value of 3.57±0.12, week 2 before use 1.60±0.10, after use value 1.53±0.15, week 4 before use 1.43±0.04, while after use an increase was observed with value of 3.27±0.25, week 6 before use 1.77±0.10 and after use was 1.67±0.15, week 8 before use 1.77±0.25, after use an increase was observed with value of 2.76±0.25, and week 10 before use 1.93±0.12, after use 1.77±0.25.

The biochemical oxygen demand level of the swimming pool sample conforms with the recommended standard in Site 3 at week 0 before use stayed at 2.00±0.10, after use with value of 6.07±0.12, week 2 before use 1.77±0.25, after use an increase was observed with value of 2.47±0.66, week 4 before use was 1.60±0.20, while after use an increase was observed with value of 3.27±0.25., week 6 before use 1.87±0.12, after use an increase was observed with value of 3.10±0.10, week 8 before use 1.93±0.40, after use an increase was observed with value of 2.23±0.21, week 10 before use 1.77±0.25, and after use 1.53±0.25.

Table 3.9: Biochemical oxygen demand values (mg/l) of swimming pool from the different Sites in Delta Central Senatorial District

	Site 1		Site 2		Site3		WHO and EPA Standard
Period (Week)	BU	AU	BU	AU	BU	AU	
0	2.00±0.06^b	1.10±0.10^a	2.00±0.15^b	3.57±0.12^a	2.00±0.10^b	2.07±0.12^a	1-2mg/l
2	1.80±0.10^b	2.03±0.06^b	1.60±0.10^a	1.53±0.06^b	1.77±0.25^b	2.47±0.06^b	
4	1.60±0.53^b	2.63±0.06^a	1.43±0.04^a	3.27±0.25^a	1.60±0.20^b	3.27±0.25^b	
6	2.00±0.26^b	3.50±0.50^b	1.77±0.25^b	1.67±0.15^a	1.87±0.12^b	3.10±0.10^a	
8	1.67±0.15^b	2.83±0.15^a	1.7±0.25^b	2.76±0.25^a	1.93±0.40^b	2.23±0.21^b	
10	1.50±0.50^a	2.83±0.25^a	1.93±0.12^a	1.77±0.25^a	1.77±0.25^a	1.53±0.25^a	

Keys: BU-Before use, AU-After use
Values are represented as mean +standard deviation, of three replicates in all groups.
Values with different superscript are significantly different at (p<0.05).

The results of total coliform load are presented as Table 3.10. The sampling points before use fulfilled the set standard by World Health Organization and Environmental Protection Agency with coliform counts <10 CFU/100 ml, although, the pools are being treated and disinfected using chlorine by the operator rendering them suitable for recreational use with body and physical contacts but not for drinking purposes. From the results, it showed the overall average concentration of total coliform contents in outdoor pool were recorded as follow; It was discovered that no growth of coliform ensued before use in Sites 1, 2 and 3 at week 0 to week 10 of sample collection. This conformed to the WHO and EPA standard for recreational water of <10cfu/100ml of sample. However, it was observed that total coliform load exceeded the WHO and EPA standard after use in Site 1 during week 0 with count of 83.30cfu±15.28, week 2 with count of 39.33cfu±10.67, week 4 with a count of 26.00cfu±3.61, week 6 with count of 77.70cfu±8.74, week 8 with count of 31.70cfu±7.23 as well as week 10 with count of 83.33cfu±15.28. It was also observed in Site 2 after use that total coliform count exceeded the WHO and EPA standard of < 10cfu /100ml of sample at Site 2 during weeks 0 with count of 40.00cfu±5.00, week 2 with count of 22.30cfu±2.51, week 4 with count of 15.00cfu±5.00, week 6 with count of 40.33cfu±6.81, week 8 with count of 28.00cfu±2.00 and 10 with count of 40.00cfu±5.00. It was also observed in Site 3 after use that total coliform exceeded the WHO & EPA recommended during week 0 with count of 50.00cfu±26.46, week 2 with count of 64.33cfu±6.03, week 4 with count of 41.70cfu±7.64, week 6 with count of 50.00cfu±15.00, week 8 with count of 27.33 cfu±3.06 and week 10 with count of 14.33cfu±26.46. These were significantly different at p<0.05 in Site 1 after use at week 6 with value of 77.70±8.74 and Site 3 after use at week 0 with value of 50.00±26.46.

Table 3.10: Total coliform load (cfu/100ml) for the various swimming pool from the different Sites in Delta Central Senatorial District using endo agar

	Site 1		Site 2		Site3		WHO and EPA Standard
Period (Week)	BU	AU	BU	AU	BU	AU	
0	0.00±0.00^a	83.30±15.28^a	0.00±0.00^a	40±5.00^a	0.00±0.00^a	50±26.46^b	≤10cfu/100ml
2	0.00±0.00^a	39.3± 10.67^a	0.00±0.00^a	22.3±2.52^a	0.00±0.00^a	64.3±6.03^b	
4	0.00±0.00^a	26±3.61^a	0.00±0.00^a	15±5.0^a	0.00±0.00^a	41.7±7.64^b	
6	0.00±0.00^a	77.70±8.74^b	0.00±0.00^a	40.3±6.81^a	0.00±0.00^a	50±15.00^b	
8	0.00±0.00^a	31.70±7.23^a	0.00±0.00^a	28±2.00^a	0.00±0.00^a	27.3±3.06^b	
10	0.00±0.00^a	83.33±15.28^a	0.00±0.00^a	40±5.00^a	0.00±0.00^a	14±26.46^a	

Keys: BU-Before use, AU-After use.
Values are represented as mean +standard deviation, of three replicates in all groups.
Values with different superscript are significantly different at (p<0.05).

Results of the fecal coliform load (cfu/100ml) for the various swimming pool is presented as Table 3.11. For a pool that is routinely disinfected, low fecal coliform counts were expected and isolated organisms should provide a qualitative assessment of fecal contamination making it suitable microbial parameters in the guidelines for safe recreational water. Nevertheless, studies have repeatedly shown that even true fecal indicators are unlikely to correlate with pathogen densities in water at low pollution levels. Additionally, fecal coliforms in pool waters present in sufficient densities, sensitive to chlorination and therefore reliable for assessing the efficiency of sanitary processes such as the disinfection of swimming pool waters, making them suitable indicators [17]. It was perceived results that no growth of fecal coliform was observed before use i.e. after chlorination in Site1, 2 and Site 3 at week 0 to week 10. These conformed to the WHO and EPA standard for recreational water of < 1cfu/100ml of sample. However, fecal coliform count exceeded the WHO and EPA recommended standard of < 1cfu/100ml for recreational water at Sites 1, 2 and 3 after use at weeks 1 to 10. However, at Site 1 week 2 after use fecal coliform count was found to be 3.33cfu±0.56, which was the lowest, and was found to be highest at Site 2 after use at week 2. These were significantly different at Sites 1 week 0 with count of 3.33±0.58, week 2 with value of 6.00±3.60, week 4 with count of 6.33cfu ±1.52 and week 8 8.00 cfu±2.00, Site 2 during week 2 with value of 6.00±3.60, week 6 with value of 21.00cfu±9.64, week 8 with value of 8.66cfu±1.15 and week 10 with value of 8.00cfu±2.00, and Site 3 during weeks 0 with value of 27.33cfu±6.42 and week 2 with value of 31.00cfu ±7.93. These were significantly different at p<0.05 in Site 1 after use at weeks 8 with value of 8.00cfu±2.00, Site 2 after use at weeks 6 with value of 21.00cfu ±9.64, week 8 with value of 8.70cfu ±1.15 and week 10 with value of 8.00cfu ±2.00 and Site 3 use at weeks 0 with value of 27.33cfu±26.46, 2 with value of 31.00cfu ±7.93 and 4.

Table 3.11: Fecal coliform load (cfu/100ml) for the various swimming pool in Delta Central Senatorial District using m-fc agar medium

	Site 1		Site 2		Site3		WHO and EPA Standard
Period (Week)	BU	AU	BU	AU	BU	AU	
0	0.00±0.00^a	3.33±0.58^b	0.00±0.00^a	20.00±15.00^a	0.00±0.00^a	27.3±6.42^b	≤1cfu/100ml
2	0.00±0.00^a	6.00 ±3.60^b	0.00±0.00^a	6.00±3.60^b	0.00±0.00^a	31.0±7.93^b	
4	0.00±0.00^a	6.33±1.52^b	0.00±0.00^a	5.67±3.78^a	0.00±0.00^a	21.33±3.51^a	
6	0.00±0.00^a	4.00±2.00^a	0.00±0.00^a	21.00±9.64^b	0.00±0.00^a	8.67±3.05^a	
8	0.00±0.00^a	8.00±2.00^b	0.00±0.00^a	8.66±1.15^b	0.00 ±0.00^a	7.67±2.51^a	
10	0.00±0.00^a	4.00±1.00^a	0.00±0.00^a	8.00±2.00^b	0.00 ±0.00^a	8.66±1.54^a	

Keys: BU-Before use, AU-After use
Values are represented as mean +standard deviation, of three replicates in all groups.
Values with different superscript are significantly different at (p<0.05).

Results of the fecal *Streptococci* per 100ml from the various swimming pools from the various Sites is presented as Table 3.12. It was detected that there was no *Streptococci* growth before use i.e after chlorination in Sites 1, 2 and 3 at weeks 0 to week 10. This conformed to the WHO and EPA standard of <40cfu/100ml for recreational water. It was also found that after use fecal *Streptococci* count were within WHO and EPA standard for recreational water in Site 1 during weeks 0 which was 7.00cfu±1.73, 2 with count of 15.70cfu±8.14, 4 with a count of 24.33cfu±12.09, 6 with count of 5.70cfu±0.58, 8 with count of 15.00cfu±3.00. It was also found to conformed to the WHO and EPA standard in Site 2 after use at weeks 0 with count of 25.00cfu±8.66, 2 with count of 16.00cfu±4.58 and 4 with count of 14.33cfu±4.04 and Site 3 after use at weeks 0 with count of 30.00cfu±5.00, 2 with count of 21.33cfu±1.53 and 6 with count of 18.33 cfu±7.64. However, it was observed that viable fecal *Streptococci* count exceeded the WHO and EPA recommended values of < 40cfu/100ml of sample for recreational water in Site 1 after use at week 10 with count of 42.70 cfu±2.52, Site 2 after use at weeks 6 with a count 48.70 cfu±9.02, 8 with count of 53.00cfu±2.65 and 10 with count of 47.33cfu±5.00. And lastly, it was detected that in Site 3 after use exceeded the WHO and EPA recommended values during weeks 6 with count of 56.33cfu±8.50, 8 with count of 40.33cfu±2.51 and with count 42.00cfu±12.17. The lowest fecal *Streptococci* count was observed in Site 1 during week 6 with count of 5.70cfu±0.58 and the highest in Site 3 during week 6 of sample collection with count of 56.33 cfu±8.50. These were significantly different at p<0.05 in Site 1 after use at weeks 0 with value of 7.00cfu±1.73, 2 with value of 15.70±8.14, 6 with value of 5.70±0.58
At Site 2 after use at weeks 0 with value of 25.00±8.66, 2 with value of 16.00cfu±4.58 and 4 with value of 14.33cfu±4.04 and at Site 3 after use at weeks 0 with value of 30.00cfu±5.00, 2 with value of 21.33cfu±1.53, 4 with value of 18.33cfu±7.64, 8 with value of 40.33cfu3±2.52 and 10 with value of 42.00±12.17.

Table 3.12: Fecal Streptococci (cfu/100ml) for the various swimming pool in Delta Central Senatorial District using m.enterococcus

	Site 1		Site 2		Site3		WHO and EPA Standard
Period (Week)	BU	AU	BU	AU	BU	AU	
0	0.00±0.00[a]	7.00±1.73[b]	0.00±0.00[a]	25.00±8.66[b]	0.00±0.00[a]	30.00±5.00[b]	≤40cfu/100ml
2	0.00±0.00[a]	15.70±8.14[b]	0.00 ±0.00[a]	16.00±4.58[b]	0.00±0.00[a]	21.33±1.53[b]	
4	0.00±0.00[a]	24.3±12.09[a]	0.00 ±0.00[a]	14.33±4.04[b]	0.00±0.00[a]	18.33±7.64[b]	
6	0.00±0.00[a]	5.70±0.58[b]	0.00±0.00[a]	48.70±9.02[a]	0.00±0.00[a]	56.33±8.50[a]	
8	0.00±0.00[a]	15.00±3.00[a]	0.00±0.00[a]	53.00±2.65[a]	0.00±0.00[a]	40.3±2.52[b]	
10	0.00±0.00[a]	42.70±2.52[a]	0.00±0.00[a]	47.33±5.03[a]	0.00±0.00[a]	42.00±12.17[b]	

Keys: BU-Before use, AU-After use
Values are represented as mean +standard deviation, of three replicates in all groups.
Values with different superscripts are significantly different at ($p<0.05$).

Results of *Staphylococcus aureus* per 100ml from the various swimming pools from the various Sites is presented in Table 3.13. *Staphylococcus aureus* was shown as the most predominant bacteria found to contaminate swimming pool water. The presence of *Staphylococcus aureus* in the pool water showed that the pool water contained fecal and non-fecal contaminations, and may be credited to the ecology of *Staphylococcus aureus* as a normal flora of man shed in the pool water during recreational activities. As the normal flora of the skin, it is frequently isolated from swimming pools which can cause severe infections in humans [18].

It was detected that there was no *Staphylococcus aureus* before use i.e after chlorination in Site 1 during weeks 0 to week 10. It was also observed in Site 3 before use that no *Staphylococcus aureus* growth occurred during weeks 0 to week 10 which conformed with the WHO and EPA recommended value of <1cfu/100ml for recreational water. However, it was detected that *Staphylococcus aureus* ensued in Site 2 before use at week 0 with count of 2cfu±0.00 which exceeded the WHO and EPA recommended values of < 1cfu/100ml. It was further observed that *Staphylococcus aureus* count exceeded the WHO and EPA recommended values of <1cfu/100ml for recreational water in Site 1 after use for the period of weeks 0 with count of 18.33cfu±7.64, 2 with count of 21.33cfu±10.26, 4 with count of 19.33cfu±9.02 , 6 with count of 16.70cfu±8.08 , 8 with count of 21.00cfu±3.61, and with count of 16.7cfu±7.64, Site 2 after use at weeks 0 with count of 55.00cfu+18.03, 2 with count of 27.70cfu±14.30, 4 with count of 14.33cfu±4.04 , 6 with count of 17.70cfu±6.81 , 8 with 20.00cfu±2.00, and with count of 21.70cfu±1.5, and Site 3 during weeks 0 with count of 58.00cfu±7.21, 2 with count of 17.33cfu±6.43, 4 with count of 20.70cfu±9.46, 6 with count of 54.33cfu±8.14, 8 with count of 16.70cfu±6.80 and 10 with count of 12.33cfu±0.58. These were significantly different at $p<0.05$ in Site 3 after use at weeks 0 with count of 58.00±7.21.

Table 3.13: Staphylococcus aureus load (cfu/ 100ml) for the various swimming pool in Delta Central Senatorial District using manitol salt

	Site 1		Site 2		Site3		WHO and EPA Standard
Period (Week)	BU	AU	BU	AU	BU	AU	
0	0.00±0.00[a]	18.3±7.64[a]	2.0±0.00[a]	55±18.03[a]	0.00±0.00[a]	58±7.21[b]	≤1cfu/100ml
2	0.00±0.00[a]	21.3±10.26[a]	0.00 ±0.00[a]	27.7±14.3[a]	0.00±0.00[a]	7.3 ±6.43[a]	
4	0.00±0.00[a]	19±9.02[a]	0.00±0.00[a]	14.3±4.04[a]	0.00±0.00[a]	20.7±9.46[a]	
6	0.00 ±0.00[a]	16.7±8.08[a]	0.00±0.00[a]	17.7±6.81[a]	0.00±0.00[a]	54.3±8.14[a]	
8	0.00±0.00[a]	21±3.61[a]	0.00±0.00[a]	20±2.00[a]	0.00±0.00[a]	16±6.81[a]	
10	0.00 ±0.00[a]	16.7±7.64[a]	0.00±0.00[a]	21.7±1.53[a]	0.00±0.00[a]	12.3±0.58[a]	

Keys: BU-Before use, AU-After use
Values are represented as mean +standard deviation, of three replicates in all groups.
Values with different superscript are significantly different at ($p<0.05$).

The results of the count of *E.coli* per 100ml of the samples from the various swimming pools from the various Sites is presented in Table 3.14. In settings with high rates of enteric infection and inadequate fecal waste management, *E. coli* in recreational water has often been associated with increased risk of illness. Similarly, the health risks of recreational uses of surface waters have been found to increase with *E.coli* density, but generally only at locations with known human fecal inputs or under high-risk conditions [19, 20].

It was detected that growth of *E.coli* was not detected before use i.e after chlorination in Sites 1, 2 and 3 at weeks 0 to 10. This conformed to the WHO and EPA standard of < 1cfu/100ml of samples for recreational water. However, it was detected that *E.coli* count exceeded the WHO and EPA standard of < 1 cfu/100ml for recreational water in Site 1 after use at week with count of 4.00cfu±1.00, 2 with count of 4.33cfu±1.53, 4 with count of 6.33cfu±1.00, 6 with count of 4.00cfu±1.00, 8 with count of 5.00cfu±1.00, and 10 with count of 7.70cfu±2.52.

Site 2 after use at weeks 0 with count of 12.33cfu±2.52, 2 with count of 9.00cfu±3.61, 4 with count of 5.70cfu±2.08, 6 with count of 11.70cfu±1.53, 8 with 7.00cfu±1.00 and 10 with count of 9.70cfu±2.08 and Site 3 after use at weeks 0 with count of 20.00cfu±5.00, 2 with count of 18.00cfu±3.00, 4 with count of 14.33cfu±4.04, 6 with count of 15.70cfu±8.14, 8 with 15.70cfu±4.04 and 10 with count of 10.70cfu±1.15. *E.coli* count was lowest in Site 1 week 0 with count of 4.00cfu±1.00 while it was highest in Site 3 week 0 with count of 20.00cfu±5.00. These were significantly different at $p<0.05$ in Site 1 after use at weeks 0 with value of 4.00cfu±1.00, 2 with value of 4.33cfu±1.52, 4 with value of 6.33cfu±1.00, 6 with value of 4.00cfu±1.00 and 8 with value of 5.00cfu±1.00. At Site 2 after use at weeks 0 with value of 12.33cfu±2.52, 2 with value of 9.00cfu±3.61, 6 with value of 11.70cfu±1.53 and 10 with value of 9.70cfu±2.08. At Site 3 after use at weeks 0 with value of 20.00cfu±5.00, 2 with value of 18.00cfu±3.00,4 with value of 14.33cfu±4.04, 6 with values of 15.70cfu±8.14, and 8 with value of 15.70cfu±3.06.

Table 3.14: E.coli load (cfu/100ml) for the various swimming pool in Delta Central Senatorial District using eosin methylene blue agar

	Site 1		Site 2		Site3		WHO and EPA Standard
Period (Week)	BU	AU	BU	AU	BU	AU	
0	0.00±0.00^a	4±1.00^b	0.00±0.00^a	12.3±2,52^b	0.00±0.00^a	20±5.00^b	≤1cfu/100ml
2	0.00±0.00^a	4.3±1.52^b	0.00±0.00^a	9±3.61^b	0.00±0.00^a	18±3.00^b	
4	0.00±0.00^a	6.3±1.00^b	0.00±0.00^a	5.7±2.08^a	0.00±0.00^a	14.3±4.04^b	
6	0.00±0.00^a	14.6±1.00^b	0.00±0.00^a	11.7±1.53^b	0.00±0.00^a	15.7±8.14^b	
8	0.00±0.00^a	5±1.00^b	0.00±0.00^a	7.0±1.00^a	0.00±0.00^a	4.04±3.06^b	
10	0.00±0.00^a	7.7±2.52^a	0.00±0.00^a	9.7±2.08^b	0.00±0.00^a	10.7±1.15^a	

Keys: BU-Before use, AU-After use
Values are represented as mean +standard deviation, of three replicates in all groups.
Values with different superscript are significantly different at (p<0.05).

The results of the count of *Pseudomonas aeruginosa* count per 100ml of sample from the various swimming pools from the various Sites is presented as Table 3.15. *P. aeruginosa* is passed into the pool water from colonized health humans, through broken pool pluming, or from dust and fecal matter getting into the pool. Unfortunately, a warm, moist environment, particularly is an ideal environment for the growth of *P. aeruginosa*. It can grow in pool water and on pool surfaces and filters. *P. aeruginosa* can attach itself to surfaces by forming a biofilm layer that makes it resistant to disinfecting chemicals including chlorine [21, 22].
It was found that growth of *Pseudomonas aeruginosa* was not detected before use i.e after chlorination in Sites 1, 2and 3 at weeks 0 to 10. This conformed to the WHO and EPA standard of <1cfu/100ml of sample for recreational water. However, it was detected that viable *Pseudomonas aeruginosa* count exceeded the WHO and EPA recommended values for recreational water in Site 1 after use at weeks 0 with count of 190.00cfu±65.57, 2 with count of 58.33cfu±18.92, 4 with count of 52.00cfu±26.23, 6 with count of 52.70cfu±6.43, 8 with 95.33cfu±21.57, and 10 with count of 85.70cfu±8.14, Site 2 after use at weeks 0 with count of 21.70cfu±16.07, 2 with count of 100.00cfu±20.00, 4 with count of 116.70cfu±5.77, 6 with count of 12.70cfu±6.43, 8 with 107.00cfu+11.27, and 10 with count of 97.33cfu±16.17 and Site 3 during weeks 0 with count of 30.00cfu±10.00, 2 with count of 190.00±36.05, 4 with count of 38.00cfu+2.00, 6 with count of 61.70cfu±10.40, 8 with 78.70cfu±22.03, 10 with count of 45.00cfu±5.00. It was observed that *Pseudomonas aeruginosa* count was lowest in Site 2 after use at week 6 with count of 12.70cfu±6.43 while it was highest in Site 3 during week 2, with count of 190.00cfu±36.05 and Site 1 after use at week 0 with count of 190.00cfu+65 57. These were significantly different at p<0.05 in Site 2 after use at weeks 4 with value of 116.70cfu±5.77, 6 with value of 12.70cfu±6.43, at Site 3 after use at week 0 with count of 30.00cfu±10. 00, 4 with value of 38.00cfu±2.00 and 10 with value of 45.00cfu±5.00.

Table 3.15: Pseudomonas aeruginosa (load/ 100ml) for the various swimming pool in Delta Central Senatorial District using cetrimide agar

	Site 1		Site 2		Site3		WHO and EPA Standard
Period (Week)	BU	AU	BU	AU	BU	AU	
0	0.00±0.00^a	190.00±65.57^a	0.00 ±0.00^a	21.70±16.07^a	0.00±0.00^a	30.00±10.00^b	≤1cfu/100ml
2	0.00±0.00^a	58.33±18.92^a	0.00 ±0.00^a	100.00±20.00^a	0.00±0.00^a	190.00±36.05^a	
4	0.00±0.00^a	52.00±26.22^a	0.00±0.00^a	116.70±5.77^b	0.00±0.00^a	38.00±2.00^b	
6	0.00±0.00^a	52.70±6.43^a	0.00±0.00^a	12.70±6.43^b	0.00±0.00^a	61.00±10.40^a	
8	0.00±0.00^a	95.33±21.57^a	0.00±0.00^a	107.00±11.27^a	0.00±0.00^a	78.70±22.03^a	
10	0.00±0.00^a	85.70±8.14^a	0.00 ±0.00^a	97.33±16.17^a	0.00±0.00^a	45.00±5.00^b	

Keys: BU-Before use, AU-After use
Values are represented as mean +standard deviation, of three replicates in all groups.
Values with different superscript are significantly different at (p<0.05).

The results of *Proteus vulgaris* per 100ml of sample from the various swimming pools is presented as Table 3.16. It was observed that no growth of *Proteus vulgaris* was detected before use i.e. after chlorination in Sites 1, 2 and 3 at weeks 0 to 10. This conformed to the WHO and EPA standard of <1cfu/100ml of sample for recreational water. It was also found that after use no growth of *Proteus vulgaris* was observed in Site 1 after use at weeks 0 and 10 with count of 0.00 cfu±0.00 each, Site 2 after use at weeks 2, 4 and 10 with count of 0.00 cfu±0.00 and Site 3 after use at weeks 0, 2 and 4 with count of 0.00cfu±0.00 each, this also conformed with the WHO and EPA recommended values for recreational water. However, it was detected that viable *Proteus vulgaris* count exceeded the WHO and EPA recommended values of <1cfu/100ml of sample for recreational water in Site 1 after use at weeks 2 with count of 39.33cfu±4.04, 4 with count of 58.00cfu±9.17, 6 with count of 30.00cfu±9.65 and 8 with count of 95.33cfu±21.57. At Site 2 *Proteus vulgaris* count exceeded the WHO and EPA recommended values of <1cfu/100ml during weeks 0 with count of 10.00cfu±2.00, 6 with count of 46.70cfu±4.16 and 8 with count of 82.33cfu±8.74. At Site 3 *Proteus vulgaris* count exceeded the WHO and EPA standard at weeks 6 with count of 56.00cfu±6.93, 8 with count of 76.00cfu±14.00 and 10 with count of 24.33cfu±4.04. The lowest *Proteus vulgaris* count was observed in Site 2 week 0 with count of 10.00cfu±2.00 while it was highest in Site 1 week 8 with count of 95.33cfu±21.57.

Table 3.16: Proteus vulgaris load (cfu/ 100ml) for the various swimming pool in Delta Central Senatorial District using heart infusion agar supplemented with bile salt

	Site 1		Site 2		Site3		WHO and EPA Standard
Period (Week)	BU	AU	BU	AU	BU	AU	
0	0.00±0.00^a	0.00±0.00^a	0.00±0.00^a	10.00±2.00^a	0.00±0.00^a	0.00±0.00^a	≤1cfu/100ml
2	0.00±0.00^a	39.33±4.04^a	0.00±0.00^a	0.00±0.00^a	0.00±0.00^a	0.00±0.00^a	
4	0.00±0.00^a	58.00±9.17^a	0.00±0.00^a	0.00±0.00^a	0.00±0.00^a	0.00±0.00^a	
6	0.00±0.00^a	30.00±9.16^a	0.00±0.00^a	46.70±4.16^a	0.00±0.00^a	56.00±6.93^a	
8	0.00±0.00^a	95.33±21.57^a	0.00±0.00^a	82.33±8.74^a	0.00±0.00^a	76.00±14.00^a	
10	0.00±0.00^a	0.00±0.00^a	0.00±0.00^a	0.00±0.00^a	0.00±0.00^a	4.04±7.50^a	

Keys: BU-Before use, AU-After use
Values are represented as mean +standard deviation, of three replicates in all groups.
Values with different superscript are significantly different at (p<0.05).

Cultural, morphological, and biochemical, characteristics of six isolates were enumerated and identified which include *Staphylococcus aureus, Enterococcus faecalis, Escherichia coli, Pseudomonas aeruginosa, Proteus vulgaris* and as presented as Table 3.17. These groups were differentiated on the basis of several key reactions which included: the range of growth temperature, the production of catalase, the fermentation and utilization of sucrose, glucose and lactose, the ability to swarm on agar, the motility of the isolates, bile solubility, ability to grow aerobically, containing the enzyme cytochrome oxidase, possess the enzyme coagulase, hydrogen sulphide production, decarboxylase production, the ability to use citrate as its sole carbon source, production of the enzyme tryptophanase which can convert the amino acid and tryptophan to indole, the production of urease, phenylalanine deaminase and methyl. The separation of the groups on the basis of cultural and biochemical analyses was confirmed.

Table 3.17: Cultural, morphological, and biochemical characteristics of bacterial isolates from the various swimming pool in Delta Central Senatorial District

Biochemical test	Isolates				
	A	B	C	D	E
Catalase test	+	+	+	+	-
Motility	-	+	+	-	-
Bile solubility test	+	-	-	-	-
Aerobic growth	+	+	+	+	+
Coagulase test	+	-	-	-	-
Anaerobic growth	-	-	-	-	-
Oxidase test	-	-	-	+	-
Hydrogen sulphide production	-	-	+	-	-
Decarboxylase test	-	+lysine	-	+Arginine	-
Citrate utilization test	-	+	-	+	-
Glucose fermentation test	+	+	-	-	+
Sucrose fermentation test	+	+	-	-	+
Indole test	-	+	+	-	-
Lactose fermentation test	+	+	+	-	+
Urease test	+		+	-	-
Phenylalanine Deaminase	-	-	+	-	-
Methyl red	+	+	-	-	-
Deoxyribonuclease	+ *S.aureus*	- *E.coli*	- *P.vulgaris*	- *P.aerogosa*	- *E.faecalis*

Key: + =Positive, - = Negative, S.*aureus* = *Staphylococcus aureus, E.coli=Escherichia .coli,*
P.vulgaris= Proteus vulgaris, P.aeroginosa =P*seudomonas aeruginosa,*
E.fecalis=*Enteroococcus faecalis*

5.0 DISCUSSION AND CONCLUTION

5.1 Physico-chemical parameters

This study revealed that temperatures of the swimming pools sampled before and after use was seen to have conformed to the WHO and EPA recommended values for recreational waters. Reports have shown that a decrease in dissolved oxygen and increase in the consumption of chlorine is attributed to high temperature [23, 24]. This study revealed that pH of most of the swimming pool conformed to WHO and EPA acceptable limit for recreational waters. However, there were remarkable increases after use. This may possibly be ascribed to the occurrence of contaminants. To this end regular adjustment of pH is necessary to maintain the pH within the recommended value of 7.0-7.8 by WHO and EPA.

The turbidity of the swimming pools recorded high values in Sites 1and 3 after use. This may possibly be accredited to an improper level of chlorine, imbalance pH, clogged filter, and growth of algae and the presence of debris in the pool [25]. Other factors include body lotion, shampoo and detergents used by bathers. It's necessary to keep chlorine and pH within the acceptable standard backwash filters or replace filtering agents; this will ensure healthy water for recreational activities. Keeping the water hygienic and pathogen-free, chlorination is crucial to getting the utmost delight obtainable from swimming pool. Reports showed that chloride stands as a degree of the effectiveness of chlorine as a disinfectant in swimming pools [1]. To this end regular dose cycling of chlorine is necessary to maintain chlorine within the set standards to guarantee a safe water for recreation activities. Nitrates and phosphates in pools repeatedly results in growth of algae and will drastically reduce the effectiveness of chlorine [26]. The study revealed that nitrate and phosphates remained within the recommended values before use, however, after use the values tended to increase beyond the acceptable limit. This may possibly be accredited to the occurrence of fecal matter, urine, shampoo, lotion, makeup, which could have been shed during recreational activities. [7] reported that with nitrate in the pool, algae and other contaminants won't respond to normal treatment. That nitrates lock up chlorine and that nitrate is a form of inorganic nitrogen which occurs in recreational water due to the occurrence of urine and faecal matters in the water, this is of public health significance. [1] reported that poor water quality and excessive chemical use are indicators of elevated phosphates. Regular chlorination is necessary to keep nitrates and phosphates within the acceptable limit to guarantee a safe water for recreational activities.

Total dissolved solid remains an amount of the dissolved combined content of the entire inorganic and organic substances existing in a liquid in molecular, ionize form. The overall dissolved solid (TDS) was detected within the recommended values before use in the three Sites but tended to increase in Sites 1 and 3 after use. This may have resulted from high number of users during the weekends and pose health risk to users. This could have produced decomposable organic and inorganic substances. Reports have shown that total dissolved is used as a suggestion of aesthetic features of swimming pool water and aggregate pointer of the occurrence of an array of chemical pollutants [25,27].

The dissolved oxygen (DO) is an essential factor of water quality and a guide of physical and biological processes going on in water body. This favored solubility of oxygen which is of great importance to all living organisms [28]. Reports have showed that dissolved oxygen solubility decreases as temperature and salt level increases. That colder and deeper waters have the capacity of holding greater concentrations of dissolved oxygen nevertheless owing to microbial decomposition dissolved oxygen may decrease. After use there were remarkable increase beyond the set standard, this may possibly be credited to the fact that temperature, salinity and hardness of the pools were within set standard, as such there was no depletion in dissolved oxygen. Biochemical oxygen demand determines the activity of bacteria for breaking down simpler substances, the decomposable organic matters, present in any water body. Therefore, the greater the decomposable matter present, the greater the oxygen demand and the greater the BOD5 value which was detected within the recommended values before use in all samples. However, there were minor upsurge above the recommended values after use.

This may possibly be credited to certain variables such as temperature, pH and depletion of free residual chlorine.

5.2 Microbial parameters.

The study revealed that microbial parameters of the various swimming pools sampled before use conformed to the WHO and EPA acceptable limits for recreational water rendering the swimming pool suitable for recreational activities. The low counts of bacteriological parameters before use may possibly be credited to the fact that water in these swimming pools were continuously clarified and chlorinated before use. The study revealed that microbial parameters of the various swimming pool after use exceeded WHO and EPA acceptable limits for recreational water, thus rendering the swimming pool waters unwholesome for swimmer [29].

They nevertheless varied markedly from one site to the other and during the different periods of sample collection. It was however found that total coliform count was higher in Site 1 after use during week 10 and lowest in Site 3. This variation may possibly be credited to the number, health status and hygiene status of swimmers that visited the swimming pool; these must have contaminated the pools thereby reducing the efficacy of chlorine in the pool.

Fecal *Streptococci* was observed to remain within the tolerable limit during sample collection, however, there was a remarkable increase beyond this limit after use in Site1 at week 10, Site 2 week 10 and Site 3 at weeks 6, 8 and 10, this may possibly be credited to the effectiveness of chlorine, the number of swimmers at the initial stage of recreational activities.

As the population increased, more contaminants were introduced which may have reduced the strength of chlorine hence the increase beyond the acceptable limit. It was further observed that fecal *Streptococci* was highest in Site 3 during week 2 of sample collection. *Escherichia coli* (an indicator of fecal contamination) exceeded the tolerable limit for recreational water.

However, the detection of fecal coliform bacteria, fecal *Streptococci* and *E. coli* in all the swimming pool water samples indicate fecal contamination. Thus, since the microbes serve as pointers of fecal contamination, there is the risk of contracting other pathogenic microorganisms in the swimming pool which may pose health hazard to users of the swimming pool [30].

The analysis revealed that *Staphylococcus aureus* obtained exceeded the WHO and EPA recommended values of < 1cfu/ml in in Site 2 during week 0 before use and Site 3 after use during week 4, this may have been as a result of the ecology of *Staphylococcus aureus* as a normal flora of the skin, nose and mouth which must have been shed during the process of changing and treating the water [31]. The high presence of *Staphylococcus aureus* and fecal contaminants in the pool water showed that the pool water contained fecal and non-fecal contaminations. It was detected that chlorination eliminated *Pseudomonas aeruginosa* before use which conformed to the WHO and EPA acceptable values of <1cfu/100ml for recreation water before use. However, it was observed that after use in all Sites, the counts exceeded the acceptable limit. The study revealed that *Proteus vulgaris* was within the acceptable values before use and after use in Site 1 during weeks 0 and 12, Site 2 during weeks 2, 6 and 10 and Site 3 during weeks 0, 2 and 4. This varying count of *Pseudomonas aeruginosa* and *Proteus vulgaris* may be credited to their occurrence in human and animals as opportunistic pathogens.

They rarely cause infection in healthy individuals nevertheless, immuno compromised persons are particularly at danger. Their occurrence repeatedly poses health challenges as being biofilm producers and can colonize drains and filters, grow within untreated water, can cause skin, ear and eye infections when present in large numbers. Out breaks of skin infections have been linked to swimming pools [32]. The increase in bacterial count after use by bathers could probably come from contamination by bathers, ineffectiveness of treatment process and possibly the hygiene status of bathers, this is in conformity with the work by [23] who reported that bathers tend to shed bacteria from fecal and nonfecal sources that increase the organic matters in the pool water.

5.3 CONCLUSION

From this research it can be established that to minimize the health risk of user's adequate disinfection of the pool and enforcement of recommended guidelines should be followed.

Moreover, users should be educated on the need for adequate personal hygiene before and during swimming which may reduce the potential hazard during swimming. There is urgent need for hotel management to seek the services of expert to ensure appropriate and high level of control of microorganisms associated with swimming pool and its environment.

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Conflict of Interest

The authors declare that there is no conflict of interest.

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