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Recreational Water Quality Assessment of Some Selected Swimming Pools in the Asuogyaman District, Ghana

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Authors' contributions

This work was carried out in collaboration between all authors. Authors MGA and JT designed the study, performed the statistical analysis, wrote the protocol, and wrote the first draft of the manuscript. Author JAL managed the analyses of the study and the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

The aim of this study seeks to assess the quality of recreational waters in selected swimming pools in the Asuogyaman district in the Eastern Region, Ghana. Samples from three different swimming facilities, coded as VH, RS and SH were collected during the months of March 2018 through to August, 2018 and analyzed in the laboratory employing standard methods for physicochemical properties and microbiological load. Isolates of coliforms were identified by API20E. Mean residual chlorine was significantly higher in the VH pool (1.357±1.09, $P<0.001$) than the pools at SH and RS. The mornings recorded significantly higher mean turbidity values in all the pools (VH: 2.385±0.8, $P<0.001$; SH: 3.392±0.9, $P=0.010$; RS: 2.77±1.0, $P=0.007$). Coliforms were isolated in the morning at VH pool (1.375±3.3) and RS pool (0.583±1.38) and evening at the SH pool (64.00±66.35) even though they were within acceptable limits. With regards to the sampled place, the middle part had the most coliforms isolated with SH pool having the highest (49.46±59.72)

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isolates. Although there was no significant (P=0.05) association between total coliforms and the physicochemical parameters at the SH and RS pool, turbidity was associated directly with temperature and total dissolved solids (TDS), and indirectly with pH. Continued physicochemical and microbiological analysis of these pools will give an objective insight into pool hygiene and help to prevent infection outbreaks among pool users.

Keywords: Physicochemical; microbiological; parameters; coliforms; water quality.

1. INTRODUCTION

Contamination of recreational waters has remained common and persistent problem impacting public health, local and national economies. It is reported that, the presence of pathogenic agents, such as *E. coli*, Salmonella, Shigella and Campylobacter, can cause waterborne diseases in swimming pools worldwide [1]. Swimming, a popular pastime activity, creates fun and is active and a healthy way to relax and beat the heat in Africa. Swimming pools have therefore become one of the main side attractions in the marketing of tourism in Ghana, and are found in hotels, guest houses, restaurants, club houses and tertiary institutions, among others. Inhabitants along the Volta lake visit these sites during public holidays and other festive occasions to have fun. Swimmers and others who come into direct contact with swimming pools are therefore at risk of developing public health issues when there is bacterial contamination of the water [2].

Most Tourists who visit Ghana and for that matter the Asuogyaman district in the Eastern region and patronized these pools may be predisposed to the risk of contamination from these pools, which are not safeguarded from microbial and other water borne diseases. Risk of physical, microbiological or chemical nature is associated with recreational water system [3]. Swimming pool users with infections may pollute the pool water with micro-organisms, through secretions from the nose and throat, skin, mouth, urine, accidental faecal release or by contaminated objects and clothes, airborne contamination, incoming water from unsanitary source, and droppings from birds [4]. According to [5], Recreational Water Illnesses (RWIs) are caused by ingestion of contaminated water, inhalation of aerosols, and direct contact with contaminated water. Recreational water users would appreciate the benefits of protecting themselves from contracting infections whenever and wherever they patronize any recreational water body. However, there is no little or no available data on the quality of recreational waters in Ghana and for that matter, Asuogyaman district. Even though some studies have been conducted on some Asuogyaman swimming pools, most of them focused on the nutrient dynamics and environmental history of the lake and therefore failed to address the microbial and physicochemical recreational water quality of these pools. This study therefore seeks to assess the microbiological and physicochemical properties of swimming pools in the Asuogyaman district in the Eastern Region of Ghana. This will help policy makers to establish policies based on informed decisions to prevent disease outbreaks in recreational waters in the selected but well-patronized pools.

2. MATERIALS AND METHODS

2.1 Water Sample Collection

A cross-sectional sampling was conducted during the months of March 2018 through to August, 2018 from three (3) different swimming facilities coded SH, RS and VR and located within the Asuogyaman district in the Eastern Region of Ghana. Water samples were collected on each study day from the three different swimming facilities in the community. For each of the selected pools, samples were collected from three different transects (bottom, middle and surface) perpendicular to the surface of each pool in triplicate. A representation of the sampling locations and additional details of the sampling protocol have been described previously [6].

All the chemicals and reagents used were of analytical grade, BDH Chemicals Limited, United Kingdom. Samples were collected in 300 ml capacity polythene bottle having doubly stopper. Prior to the collection, the well cleaned sample bottles were rinsed thoroughly with the sample water to be collected. Each sample bottle was clearly labelled and relevant details recorded. At each sampling site, three samples were collected into 300 ml sterilized bottles. These samples were stored in an ice chest containing ice cubes and transported to the Volta River Authority laboratory, Akosombo for analysis within 24 h.

2.2 Water Analysis

All the samples were analyzed in the laboratory employing standard methods for physicochemical parameters (pH, temperature, electrical conductivity (EC), total dissolved solids (TDS), turbidity, residual chlorine) and microbial properties (Total coliforms and *Escherichia coli*). EC, TDS, and pH were measured using potable Orion 5-star sensor multiparameter analyzer from Orion instruments (Model No. Orion 5-star, S/N: A03158). Turbidity was determined by nephelometric method (Turbidity meter with sample cell: HACH Model – 2100 P). Residual chlorine was determined by DPD method, and TSS and TDS by gravimetric method. The physical and chemical analysis of water samples were based on [7].

2.3 Isolation and Identification Microorganisms

The total viable bacterial counts (TVBCs) at 22°C and 37°C were determined using the spread-plate method. The number of total and faecal coliforms was determined using the most probable number (MPN) method Isolation of gram-negative bacteria in Damietta Branch water samples were performed using MacConkey agar supplemented with 0.001 g/L crystal violet. Isolates were subjected to identification by biochemical characteristics using API 20E strip system (BioMereux). Total and faecal coliforms and *E. coli* were enumerated as described by [8,9].

2.4 Statistical Analysis

Statistical analyses were carried out using AqQA (version 1.1.1) water-quality software and SAS (version 9.2), MINITAB (version 14) and Rockworks (version 15), respectively. Statistically significant level was put at P = 0.05. Analysis of Variance (ANOVA) was used to determine the differences in the Mean values of the parameters at the various sampling sites.

3. RESULTS

3.1 Physicochemical Parameters of Recreational Water Quality in Pools VH, RS and VH

A total of two hundred and sixteen (216) water samples were collected and analyzed from the three different swimming pools. The mean residual chlorine was significantly higher in the VH pool (1.357±1.09, P<0.001) than the pools at SH and RS. The pH of the pools at VH (4.119±0.25) and RS (4.117±0.31) were significantly lower than that of SH (7.355±1.07, p<.001). Even though SH recorded statistically significant (P<0.001) higher mean values in conductivity (802.7±28.42), total dissolved solids, TDS (399.5±18.46) and turbidity (3.04±0.92) (Table 1) respectively, they were all below the recommended standards of 300 µS/cm, 1500 ppm and 5.0 NTU for conductivity, TDS and turbidity respectively.

3.2 Variation of Mean Turbidity, Temperature, Residual Chlorine, pH, Electrical Conductivity, Total Dissolve Solids at Pools SH, RS and VH at different times of the Day

The mean turbidity values were significantly higher in the morning (VH: 2.39±0.8, P<0.001; SH: 3.39±0.9, P=0.010; RS: 2.77±1.0, P=0.007) than in the afternoon and evening at the pools (Table 2). Unstable mean temperatures were observed at SH and RS pools as the morning temperatures were statistically different (30.37±1.6, P<0.001 and 30.48±0.9, P<0.005 respectively) from that of the afternoon and evening. The mean residual chlorine was higher in mornings than in the afternoons and evenings but was statistically significant at RS pool whereas pH, conductivity and total dissolved solids (TDS) did not indicate any significant difference with respect to the time of day of the swimming pools (Table 2).

3.3 Variation of Mean Physicochemical Parameters of Recreational Water Quality in Pools VH, SH and RS at Different Depth

The mean physicochemical parameters of the recreational water quality in the selected swimming pools with regards to their s were statistically insignificant despite slight variations in temperature P=0.64) (Table 3). Variation in conductivity, turbidity, residual chlorine and pH at the pool surface, middle and bottom were all insignificant with P-values of 0.95, 0.38, 0.95 and 0.48 respectively (Table 3). Whilst conductivity [Surface: 799.8±29.4, Middle: 805.1±27.2, Bottom: 803.2±29.5), (P=0.81)] at SH; and conductivity [(Surface Surface: 344.7±67.1, Middle: 359.2±62.7, Bottom: 355.1±61.2), (P=0.72)], turbidity [(Surface: 2.39±1.0, Middle: 2.30±0.9, Bottom: 2.24±0.9), (P=0.83)] and residual chlorine at RS.

3.4 Mean Bacteria Isolate at Different Times of the Day and Different Depth of Pools VH, SH and RS

The results of the bacteriological analysis revealed significant differences in the isolation of total coliforms at different times of the day and at different depths. Table 4 shows significant coliforms ($P<0.001$) were isolated in the morning and in the evening at pool SH and RS. This trend was however different for pool VH which recorded maximum numbers in the morning and the afternoon with the evening recording the least microbial load. With regards to sample depth, the middle part of VH: 1.125±3.11, SH: 49.46±59.72, RS: 0.708±1.40 had the most coliforms isolated. The overall significant (P<0.001) mean CFU/ml ranged from 0.431±1.11 at RS pool, 0.9583±2.4 at VH pool and 44.93±57.62 at SH pool (Table 4). Of the faecal coliforms isolated, 7.3% were identified as *Escherichia coli* (Results not shown). Total coliforms isolated at the SH pool were slightly higher in the mornings and least in the afternoon.

4. DISCUSSION

Swimming pools are increasingly being patronized by people for leisure and recreational purposes hence possible failures with its maintenance would be a matter of public health significance [10]. The mean residual chlorine recorded was significantly higher in the VH pool (p<0.001) than samples from the SH and RS pools. The recorded values which ranged from 0.33- 1.47 mg/l were below the WHO recommended dose of 5 mg/L [11]. Our results contradict a similar work conducted in some pools in Nigeria, where excessive chlorine levels were observed in some swimming pools [10]. The relatively low residual chlorine at these pools could be as a result of ineffective treatment or bad management as initial data indicated that the SH facility does not have a medium for measuring how and when to chlorinate.

Apart from the mean pH values of water samples from the SH pool which were within the acceptable range of 7.0 to 7.8 recommended by [11], samples from RS and VH were slightly acidic in all cases of time of the day or depth. The low pH conditions recorded in RS and VH probably may be due to excessive chlorination. [12] report that low pH conditions have been associated with problems such as itching, chlorine loss, skin spots and sore eyes in swimmers.

One of the most important environmental factors which control the behavioural characteristics of microorganisms is temperature [13]. The highest and lowest temperatures of 30.4°C to 31.87°C were recorded in the afternoon and morning samples of pool SH respectively. These figures were above the recommendations of 22°C - 29°C [14] and may be attributed to the period and weather conditions of sample collection. [15] reported that temperature could be affected by the weather due to the different times of sampling from the pools. According to [16], pools with a temperature of more than 27°C are more likely to be contaminated than pools with a temperature of 22-27°C.

The SH pool recorded statistically significant (p<0.001) higher mean values in conductivity of 802.7 µS/cm which is above the WHO recommendation of 300 µS/cm for drinking water. High conductivity in this facility could be related to the high concentrations of dissolved ions in the swimming pools since the source of swimming pool water is ground water with dissolved salts. It could also be attributed to differences in geochemical conditions and soluble ions in the locations analysed [17]. On the other hand, the conductivity means r ecorded in the VH and RS pools were within the accepted recommendation by the World Health Organisation.

Table 1. Mean physicochemical parameters of recreational water quality in pools VH, SH and VH

Parameter/Units	VH	SH	RS	*P*-value
Residual Chlorine/(mg/L)	$1.357±1.09^a$	$0.353±0.45^b$	$0.950±0.93^c$	< 0.001
pH	$4.119±0.25^a$	$7.355±1.07^b$	$4.117±0.31^a$	< 0.001
Temperature/(ºC)	31.11±1.58	31.27±1.57	31.18±1.16	0.797
Conductivity/(µS/cm)	$266.3±55.05^a$	$802.7±28.42^b$	$353±63.09^c$	< 0.001
T. D. S/(mg/L)	$120.3±18.55^a$	$399.5±18.46^b$	$165.7±27.43^c$	< 0.001
Turbidity/(NTU)	$1.816±0.76^a$	$3.04±0.92^b$	$2.312±0.89^c$	< 0.001

Values with same superscripts along same rows are not significantly different at P=0.05

Table 2. Variation of mean physicochemical parameters of recreational water quality in pools VH, SH and RS at different times of the day

Parameter/Units	VH				SH				RS			
	Morning	**Afternoon**	**Evening**	***p*-value**	**Morning**	**Afternoon**	**Evening**	***p*-value**	**Morning**	**Afternoon**	**Evening**	***p*-value**
Residual Chlorine/(mg/L)	1.42±1.4	1.44±0.8	1.2±0.9	0.706	0.48±0.46	0.38±0.5	0.19±0.3	0.072	1.65±1.1^{a}	0.73±0.7^{b}	0.47±0.5^{b}	<0.000
pH	4.08±0.2	4.08±0.3	4.2±0.14	0.140	7.21±1.1	7.56±0.2	7.3±1.5	0.500	4.18±0.3	4.13±0.3	4.19±0.3	0.779
Temperature/(ºC)	30.67±1.2	31.17±2.2	31.48±1.0	0.197	30.4±1.6^{a}	31.87±1.5^{b}	31.58±1.2^{b}	0.001	30.48±0.9^{a}	31.7±1.1^{b}	31.35±1.1^{b}	0.000
Conductivity/(µS/cm)	265.4±61.1	270.5±57.1	263.1±48.4	0.896	794.9±30.9	802.8±22.5	810.4±30.2	0.169	350.9±67.7	358.1±66.8	350±56.7	0.891
T. D. S/(mg/L)	123.3±28.5	121.5±10.8	116.3±10.3	0.397	401.5±24.5	400.4±11.1	396.7±17.8	0.638	175.1±37.1	164.1±22.4	157.8±16.8	0.083
Turbidity/(NTU)	2.39±0.8^{a}	1.65±0.7^{b}	1.41±0.5^{b}	< 0.000	3.39±0.9^{a}	2.616±0.8^{b}	3.1±0.9a^{b}	0.010	2.77±1.0^{a}	2.1±0.8^{b}	2.06±0.7^{b}	0.007

Values with same superscripts along same rows are not significantly different at P=0.05

Table 3. Variation of mean physicochemical parameters of recreational water quality in pools VH, SH and RS at different depths

Parameter/Units	VH				SH				RS			
	Surface	**Middle**	**Bottom**	***p*-value**	**Surface**	**Middle**	**Bottom**	***p*-value**	**Surface**	**Middle**	**Bottom**	***p*-value**
Residual Chlorine/(mg/L)	1.29±1.1	1.47±1.2	1.32±1.1	0.837	0.37±0.4	0.35±0.4	0.33±0.5	0.949	0.958±0.9	0.91±1.0	0.98±0.9	0.967
pH	4.11±0.2	4.12±0.3	4.12±0.2	0.948	7.37±0.7	7.54±0.7	7.16±1.6	0.483	4.24±0.3	4.15±0.3	4.13±0.3	0.416
Temperature/(ºC)	31.3±1.7	30.86±1.4	31.18±1.7	0.638	31.05±1.6	31.25±1.5	31.5±1.6	0.609	31.27±1.2	31.09±1.1	31.2±1.2	0.865
Conductivity/(µS/cm)	266.9±56.5	268.5±54.9	263.6±56.0	0.953	799.8±29.4	805.1±27.2	803.2±29.5	0.809	344.7±67.1	359.2±62.7	355.1±61.2	0.719
T. D. S/(mg/L)	120.2±20.8	120.3±17.3	120.6±18.1	0.997	400.6±24.4	399.6±14.8	398.4±15.3	0.917	163±24.6	166.5±25.3	167.5±32.6	0.838
Turbidity/(NTU)	1.73±0.8	1.71±0.7	1.98±0.8	0.383	3.17±0.9	2.95±0.9	2.99±0.8	0.674	2.39±1.0	2.30±0.9	2.24±0.9	0.831

Table 4. Mean total coliforms (CFU/100 mL) isolates at different times of the day and different depth of pools VH, SH and RS

	VH	SH	RS	p-value
Time of day				
Morning	1.375±3.36^{a}	52.75±64.87^{b}	0.583±1.38^{a}	< 0.001
Afternoon	0.792±1.84^{a}	18.04±20.94^{b}	0.25±0.74^{a}	< 0.001
Evening	0.708±1.68^{a}	64.00±66.35^{b}	0.458±1.14^{a}	< 0.001
Sampled location				
Surface	1.083±1.95^{a}	40.00±60.95^{b}	0.292±0.99^{a}	0.002
Middle	1.125±3.11^{a}	49.46±59.72^{b}	0.708±1.40^{a}	< 0.001
Bottom	0.667±2.04^{a}	45.33±54.03^{b}	0.292±0.86^{a}	< 0.001
Total mean	0.9583±2.4^{a}	44.93±57.62^{b}	0.431±1.11^{a}	< 0.001

Values with same superscripts along same rows are not significantly different at P=0.05

The mean values of total dissolved solids (TDS) recorded for all the swimming pools were within the acceptable range of 1000 mg/l recommended by WHO for drinking water and 1500 mg/l recommend for swimming water. However, samples from SH were generally higher than samples from VH and RS even though the differences were insignificant. Though the values recorded in these facilities are within the acceptable limits by the WHO, it contradicts what was reported by [18]. Mean turbidity values recorded in all the swimming pools were below and within the WHO recommended values of 5 NTU [19].

Recreational waters with significant numbers of coliforms is a strong indication that there is deficiency in the treatment of the pool water or the source of raw water is inadequately protected. The results of the bacteriological analysis revealed significant differences in the isolation of total coliforms at different times of the day and at different depths even though they were within acceptable limits. Of the total faecal coliforms isolated, 7.3% were identified as *Escherichia coli* (results not shown). The morning samples recorded more coliforms at both the VH and RS pools whilst the SH pool recorded highest in the evening samples. With regards to the sampled depth, the middle-sampled water had the most coliforms isolated with SH pool recording the highest (49.46±59.72) isolates. Even though there were detection of coliforms in all the swimming pools, they were all within the recommended threshold [20]. The presence of bacterial isolates in all the facilities may be due to the high temperatures recorded in all the pools. [21] reports that temperatures exceeding 27°C may be predisposed to contamination since a rise in temperature encourages bacteria growth. The high bacterial count at the SH pool could probably be due to contamination and poor water treatment. Other studies have also reported that, the occurrence of *E. coli* in pools also indicates poor pool management and lack of thorough disinfection of the pool and insufficient or lack of safeguarding measures of the raw water source [22]. In a similar study conducted in Greece, swimming pool water samples were found to be contaminated with *P. aeruginosa* and *Aeromonas hydrophila* [23].

5. CONCLUSION

Our study has provided information on the recreational water quality of some selected swimming pools in the Asuogyaman District, Ghana. The data obtained on the physicochemical water quality parameters, apart from samples from the SH pool, were all within permissible limits of WHO standards. However, the microbiological loads of all the swimming pool facilities examined were poor, with the water bodies being contaminated with different potentially-pathogenic microbes. Continued physicochemical and microbiological analysis of recreational waters will give an objective insight into pool hygiene and help to prevent infection outbreaks among pool users of these facilities.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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