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Physicochemical Quality of Public Swimming Pools in Yenagoa Metropolis, Bayelsa State, Nigeria

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Abstract

The quality of water in public swimming pools is essential to the wellbeing of tourist and visitors who patronize them. When standard of treatment is compromised it become a threat to the swimmers. This study assessed the levels of heavy metals in 6 randomly selected public swimming pools in Yenagoa Metropolis, Bayelsa State. The sampling and analysis was carried out following standard protocols. Results on were reported for; Temperature (26.16 – 29.82 ^{o}C), pH (6.33 – 6.87), residual chlorine (0.44 – 4.14 mg/l), Total dissolved solid (36.18 – 81.44 mg/l), Turbidity (3.49 – 7.17 NTU), and Conductivity (70.22 – 177.94 mg/l). All values recorded were with the WHO permissible limit for recreational water. This study concludes that there is need to formulate the standardization and compliance monitoring as well as operational standards of public swimming pools in order to mitigate potential adverse effects and may arise from standard compromise.

Keywords: Physicochemistry; Pollution; Swimming pool; Yengoa; Water quality.

1. Introduction

The physicochemical characteristic of water such as pH, dissolved oxygen, chemical oxygen demand, biochemical oxygen demand, temperature, turbidity and residual chlorine levels within the swimming pool water are of significance as the parameters have serious influence on the biochemical reactions that occur within the water and aiding microbiological content and also determine the level of water deterioration [1-3] WHO, 2011.

Water is vital for life. However, it also serves as the commonest route of transmission of number of infectious diseases. Inadequate sanitation, surveillance and treatment of water accounts for 80% of all illnesses [4]. The recreational and environmental use of water is increasing in terms of activities being undertaken and the number of users. Public swimming pools are usually opened for public usage where it can accommodate several hundreds of people for water based recreational activities. One of the areas of major concern to environmentalist is water pollution and water requires continuous assessment [5]. The risk of infections and illness associated with swimming pool water has a very high probability of becoming a transmitter of water born disease among users.

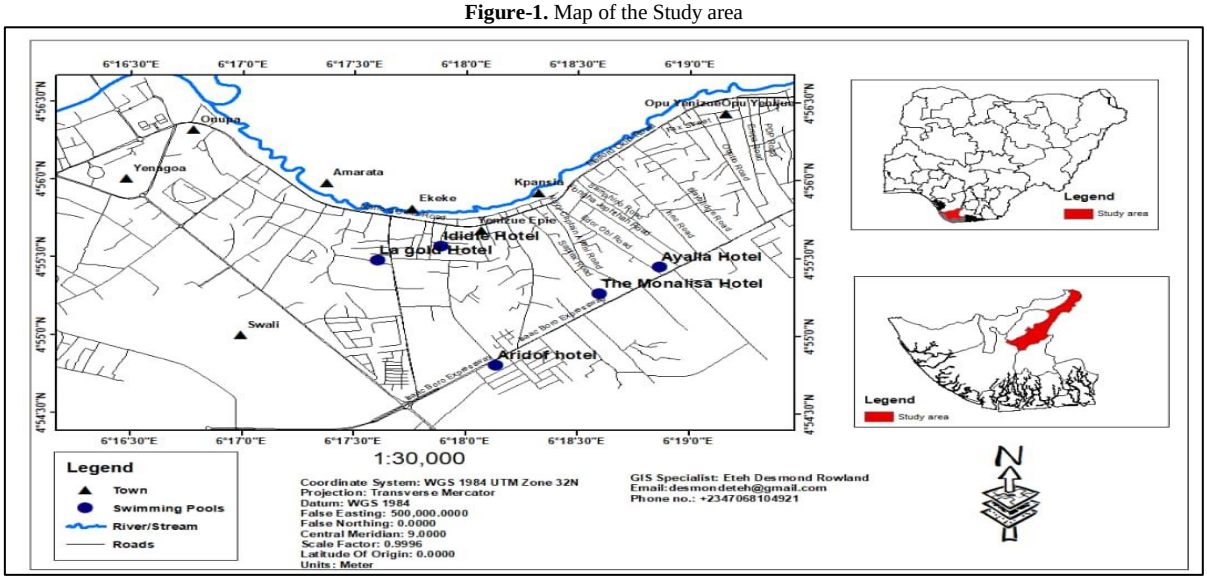
Swimming pool is one of the recreational facilities patronized by different classes of people for leisure, sports or pleasure in most of the hostels in Yenagoa metropolis. The potential health hazard associated with swimming pools is a major challenge. Furthermore, high rate of system breakdown, high maintenance cost, negligence and ignorance poses a high health risk to the swimming pool users [5]. There is paucity of information on the water quality and health risk assessment of public swimming pools in Yenagoa metropolis, in the Southern part of Nigeria.

2. Materials and Method

2.1. Study Area

Yenagoa metropolis is the capital city in Bayelsa State, Nigeria which is located in the Southernmost part of Nigeria (Figure 1). According to the National population census-NPC [6], it has 8 Local Government Areas (LGA), with population strength of over 300,000. It is a wetland forming part of the oil-rich Niger Delta Region. Additionally, it is a wetland with one of the largest mangrove, and many rivers systems channeled to the River Nun [7].

Figure-1. Map of the Study area



2.2. Sampling

Water samples were collected from six randomly selected public swimming pools including a control station. The sampling stations were represented with the sampling codes; LA, LB, LC, LD, LE and LX for the control station (Figure 1). The sampling was carried out in the evening of the second Saturday of the month around 4 pm. Sampling took place in the months of January, April, July and October.

2.3. Physicochemical Analysis

In situ measurement of physicochemical properties was carried out. Water temperature, pH, conductivity, and turbidity was measured *in-situ* using portable EXTECH Multi- probe (DO-700) meter. At the sampling point, the measuring probe were lowered into the water and allowed to settle for 1-2 minutes before the reading were taken. The turbidity, and residual chlorine were measured using HANNA Turbidimeter (HI93414). Prior to analysis, all meters were calibrated with the appropriate standards to ensure accuracy. Total dissolved solids of the water samples were measured using EXTECH probe (DO-700) meter. Three buttons on the meter were pressed on and the sensor in the total dissolved meter was inserted 2cm above waster sample level. Then reading was taken when it was stabilized.

2.4. Statistical Analysis

Data were subjected Analysis of Variance (ANOVA) for mean separation. The level of significance was established using Duncan as the Post Hoc at $p = 0.05$. The 2016 version of Microsoft excel was used for the computation of mean values and the plotting of graphs.

3. RESULT AND DISCUSSION

3.1. Temperatures of the Swimming Pools

Results of the swimming Pool temperatures and their statistical inferences is presented in Table 1. In location LA, the temperatures ranged from 25.99 - 27.15 ^{O}C, with no significant difference ($p>0.05$) except for the month of January. In addition, the lowest and highest temperatures in LA were reported during the months of July and January respectively. Results of temperatures in location LB ranges 26.16 - 29.58 ^{O}C with significant differences ($p<0.05$), also the lowest and highest values in the months of January and October respectively.

The temperatures of location LC (27.58 - 28.35 ^{O}C) had no significant difference ($p>0.05$) apart from the months of January and July. Also, January and October had the lowest and highest values respectively (Table 1). Location LD (29.19 - 29.82 ^{O}C) had temperatures ($p<0.05$) apart from July and October, with highest (January) and lowest (July) temperatures. In location LE (26.05 – 28.25 ^{O}C) there was significant difference ($p<0.05$) in temperature apart from January and April. Also, the lowest (January) and highest (October) temperatures were observed (Table 1). Generally, significantly lower temperatures values were observed in the control station (LX) as presented in Table 1.

Table-1. Temperature for the swimming Pools location

Locations	January	April	July	October
LA	27.15±0.036d	26.34±0.150c	25.99±0.095c	26.16±0.101c
LB	29.58±0.132j	29.14±0.240hi	26.16±0.036c	28.78±0.086h
LC	28.35±0.214g	27.73±0.694f	28.29±0.163g	27.58±0.189ef
LD	29.19±0.185i	29.52±0.107ij	29.82±0.108j	29.66±0.115j
LE	26.05±0.020c	26.07±0.032c	27.22±0.110dc	28.25±0.062g
LX	25.12±0.150b	25.07±0.032b	24.62±0.600a	25.18±0.057b

Results of the mean temperature values across the different Pools is presented in Figure 2. Results showed mean temperature values ranging from 26.41 – 29.55 ^{o}C, with Pools LA and LD having the lowest and highest values respectively (Figure 2). In addition, it was observed that the control site recorded a lower temperature (Figure 2).

Figure-2. Mean temperatures across different pools

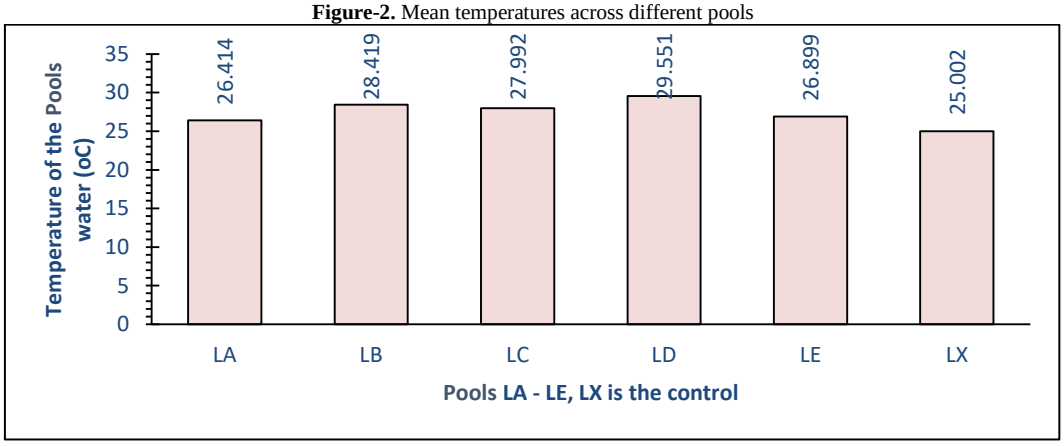
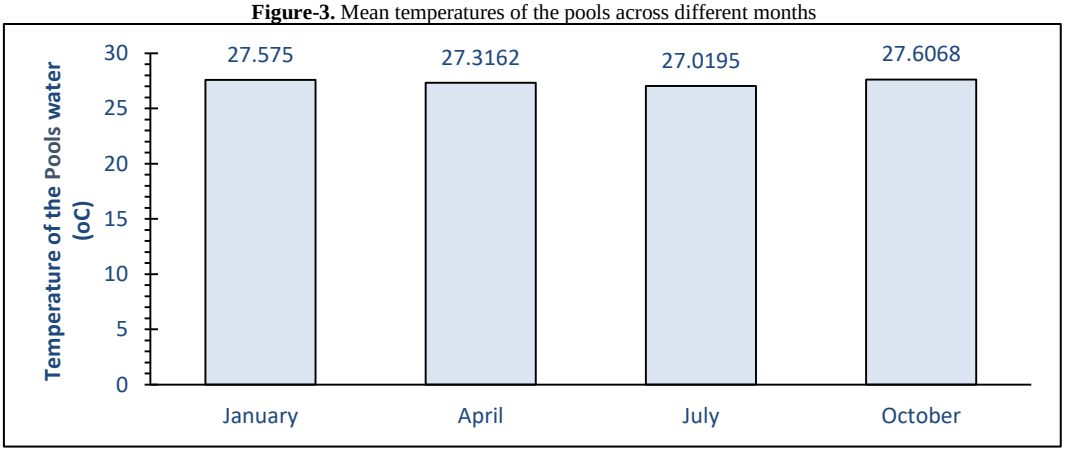


Figure-3. Mean temperatures of the pools across different months



Results on the mean temperature value across the different months is presented in Figure 3. Results showed values ranging from 27.01 – 27.60 ^{o}C as presented in Figure 3. Results on mean temperature values also showed that the months of July recorded the lowest mean temperature value, while the month of October had the highest mean temperature value (Figure 3).

Most of the temperature values obtained for this study were above threshold temperatures of 22 – 29 ^{o}C recommended by World Health Organization for swimming pools [8]. Although, this agreed with the studies of Onifade, *et al.* [9], Ajadi, *et al.* [10], and Yedeme, *et al.* [11]. On the other hand, it was not in agreement with the studies of Clark, *et al.* [12], Edimeh, *et al.* [13], and Onifade, *et al.* [14]. High temperature values have been attributed to the prevailing weather condition [14, 15]. The increase in temperature of the swimming pools aids the growth of bacteria [16]. The physicochemical parameter like temperature can influence biochemical reactions that leading to the proliferation of microbes that affects the quality of swimming pool water [1, 10]. Increase in swimming Pools water temperatures beyond 27^{o}C have been reported to increase bacterial growth [16, 17].

Table-2. pH of the swimming pool water from different location

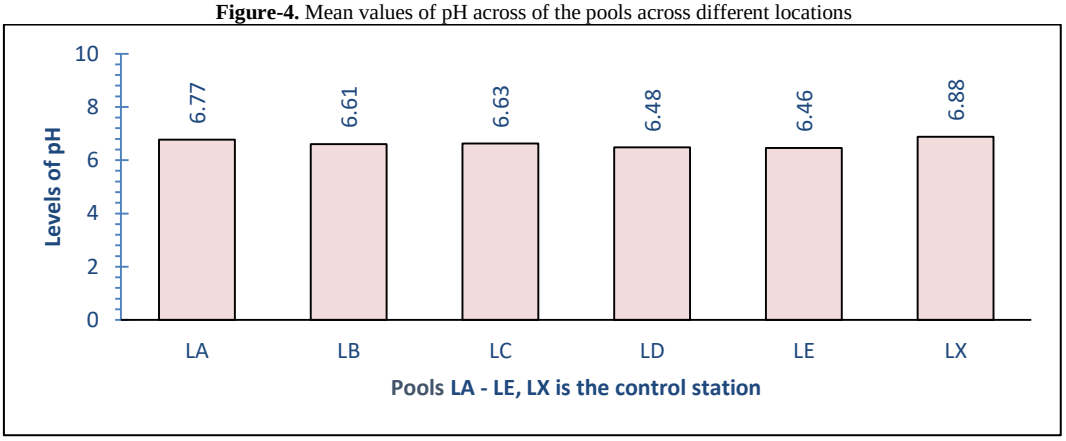
Locations	January	April	July	October
LA	6.64±0.087ef	6.80±0.030ghi	6.75±0.078fgh	6.87±0.025hij
LB	6.49±0.046bcd	6.56±0.032de	6.58±0.010de	6.74±0.115fgh
LC	6.43±0.035abc	6.62±0.045e	6.73±0.090fg	6.73±0.057fg
LD	6.37±0.032ab	6.54±0.031cde	6.46±0.092bcd	6.53±0.058cde
LE	6.33±0.006a	6.47±0.030bcd	6.48±0.130bcd	6.54±0.045cde
LX	6.84±0.046cde	6.94±0.031ghij	6.85±0.071j	6.89±0.051hij

3.2. pH of the Swimming Pools

Results of the pH values of the swimming pools and their statistical inferences are presented in Table 2. Results of pH quality in location LA ranges from 6.64 - 6.87 with no significant differences ($p>0.05$). The lowest pH value was reported during the month of January, while the highest pH value was reported in the month of October (Table 2). Results of pH quality in location LB ranges 6.49 - 6.74 with no significant differences ($p>0.05$). The lowest and highest pH values were reported in the months of January and October respectively (Table 2).

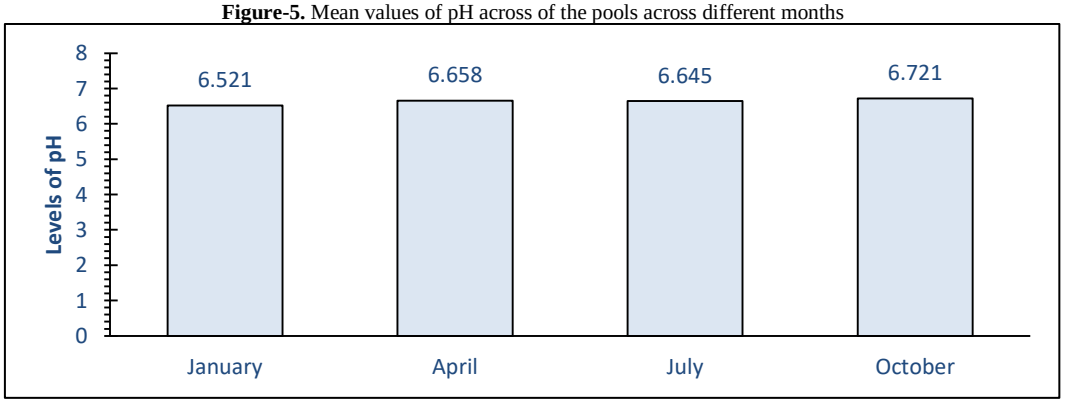
Furthermore, in location LC, pH values ranging from 6.43 - 6.73 was observed with no varying degrees of significance ($p>0.05$), the months of January and October having the lowest and highest values respectively (Table 2). Results of pH values in location LD ranged from 6.37 - 6.54 with no significant differences ($p>0.05$). The months of January and April recorded the lowest and highest pH values respectively. The pH values of location LE ranges from 6.33 – 6.54 with no significant differences $p>0.05$). It was also observed that the lowest was reported in the month of January, while the highest pH value was reported in the month of October (Table 2). It was observed that higher pH values were recorded in the control station (LX) as presented in Table 2.

Figure-4. Mean values of pH across of the pools across different locations



Results of the mean values of pH across the different pools is presented in Figure 4. Results showed pH values ranging from 6.46 – 6.88, with pools LE and LA having the lowest and highest values respectively (Figure 4). In addition, it was observed that higher pH value was in recorded in the control station (Figure 4). Results on the levels of pH across the different months is presented in Figure 5. Results showed values ranging from 6.521 – 6.721. Also, the month of January recorded the lowest pH value, while the month of October had the highest pH value (Figure 5).

Figure-5. Mean values of pH across of the pools across different months



Generally, it was also observed that significantly higher pH values ($p<0.05$) were reported in the control station (LX) than the other pools as presented in Figure 4. In addition, the pH values were significantly different across the months and Pools, with exception of the months of July and October in location LC (Figure 5). Also, with the exception of location LE, the mean pH values of all the pools (Figure 2) and months (Figure 3) were within the recommended threshold values (6.5 – 7.8) of the WHO standard for recreational water [8].

Notwithstanding, the higher pH values of this current study recorded in the month of October is typical of raining season, and similar to the study of Ajadi, *et al*. [10]. Some authors have reported values of pH range similar to this current study; 6.56 – 7.23, 6.20 - 7.10 [18]; others were slightly higher but within limits of WHO including; 7.20 – 7.80 [19], 7.20 – 7.80 [11]; also lower pH values have been reported by Ajadi *et al*., 2016 (4.58 – 6.69), and Nnabugwu, & Uchenna, 2019 (5.60 - 6.90).

The pH of swimming pools is very essential parameter that depicts level of contamination and disinfection [20]. Very high or low pH may cause adverse effects or irritation of the eyes and skin [21]. This may be due to the absence of trained pool operators, swimmers not adhering to swimming protocols like pre-swim showers or infrequent changing of the pool water [11]. Also, influx of swimmers may introduce microbes, organic matter and body oils, which can reduce the level of disinfection and reduce the pH level [19, 22]. As such the influx of swimmers should be checked more frequently [19].

Table-3. Residual chlorine of the swimming pools (mg/l) in different locations

Locations	January	April	July	October
LA	1.28±0.26c	2.35±0.05de	2.14±0.16d	2.77±0.48f
LB	4.14±0.16j	3.28±0.26hi	3.22±0.02ghi	2.28±0.07de
LC	2.28±0.26de	2.88±0.41fgh	3.02±0.01ghi	2.45±0.21def
LD	2.15±0.13d	2.25±0.22d	3.22±0.19ghi	2.32±0.08de
LE	3.19±0.18ghi	3.46±0.11i	2.45±0.75def	2.01±0.01d
LX	1.00±0.00bc	0.44±0.11a	0.70±0.23ab	0.62±0.08ab

3.3. Residual chlorine of the Swimming Pools

Results of the residual chlorine concentrations in the swimming pools water and their statistical inferences are presented in Table 3. Results showed that residual chlorine concentration in location LA ranged from 1.28 – 2.77 mg/l ($p<0.05$), with lowest and highest values in January and October respectively (Table 3). In location LB (2.28 – 4.41 mg/l), apart from the months of April and July there was significant difference ($p<0.05$) in residual chlorine concentrations (Table 3). In addition, the months of January and October had the lowest and highest chorine value respectively.

Results of location LC (2.28 – 3.02 mg/l) showed that there was significant difference ($p<0.05$) in residual chlorine level, with lowest and highest values in the months of January and July respectively (Table 3). In location LD, residual chlorine level ranged from 2.15 – 3.22 mg/l ($p<0.05$), with the lowest value in the month of January and highest value in the month of July (Table 3). The residual chlorine concentrations in LE ranged from 2.01 – 3.19 mg/l ($p<0.05$), with the lowest value in the month of October and highest value in the month of January (Table 3). Generally, it was also observed that significantly ($p<0.05$) lower residual chlorine value was obtained from samples of the control station (LX) as presented in Table 3.

Results on mean concentrations of residual chlorine across the different pools showed values that ranged from 2.13 – 3.23 mg/l, with pools LA and LB having the lowest and highest values respectively (Figure 6). In addition, it was observed that the lowest residual chlorine value was in recorded in the control station (Figure 6).

Figure-6. Mean concentrations of residual chlorine across the different pools

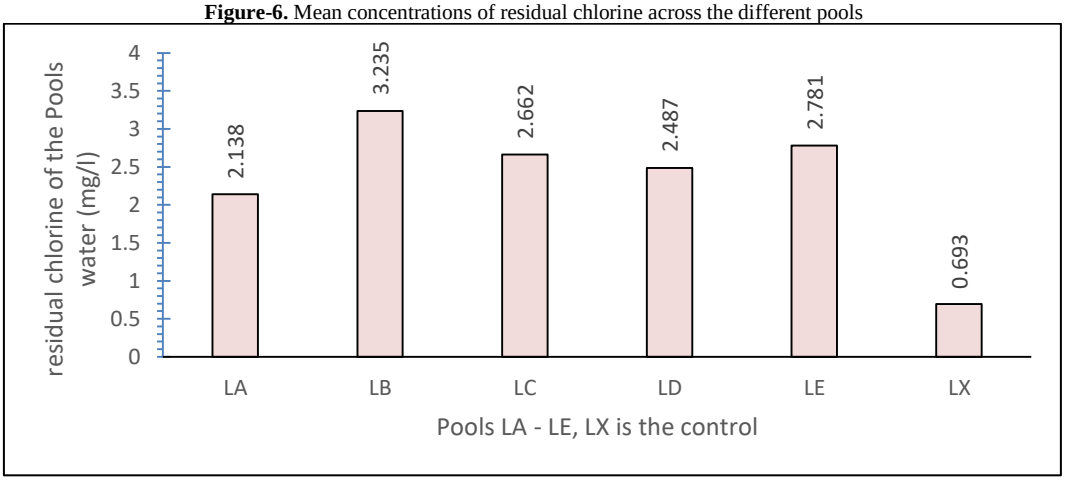
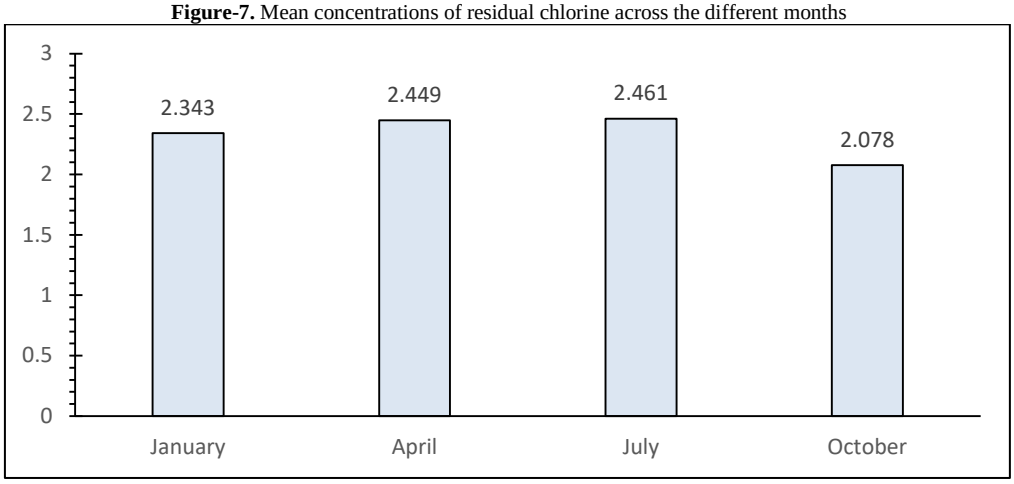


Figure-7. Mean concentrations of residual chlorine across the different months



Results on the mean concentrations of residual chlorine across the different months is presented in Figure 7. Results showed values that ranged from 2.07 – 2.46 mg/l. It was also observed that the month of October recorded the lowest concentration of residual chlorine, while the month of July recorded the highest concentration of residual chlorine value (Figure 7).

The detection of chlorine in swimming pool water indicates the efficacy of treatment provided its threshold concentration does not exceed 3.00 mg/l [14]. Values of free chlorine in this study agreed with earlier Studies of: Yedeme, *et al.* [11]; Yousefi-Mashouf, *et al.* [23]; Ali, *et al.* [24]; and Onifade, *et al.* [14]. But the study of Ajadi, *et al.* [10] reported a higher residual chlorine of 10.2 – 19.4 mg/l exceeding the recommended WHO limit of 5mg/l for recreational water.

3.4. Total Dissolved Solid (TDS)

Results of the total dissolved solid in the pools and their statistical inferences are presented in Table 4. Results showed that TDS in location LA ranged from 44.44 – 63.38 mg/l ($p<0.05$). The lowest TDS value was reported in the month of July, while the highest TDS value was reported in the month of October respectively (Table 4).

Table-4. Total Dissolved Solid in swimming pools (mg/l) at different locations

Locations	January	April	July	October
LA	55.12±0.92ef	62.60±0.65jk	44.44±0.55bc	63.38±1.82jk
LB	49.36±0.17cd	44.44±0.97bc	56.17±1.06ef	46.39±5.67bc
LC	58.59±0.02ij	45.59±1.51bc	36.18±2.93a	46.88±1.02bcd
LD	66.40±0.70k	81.44±2.49m	64.41±0.92k	41.48±2.56b
LE	43.03±0.27b	66.81±2.04k	51.65±2.85de	75.15±1.61l
LX	34.76±1.26a	31.48±2.57a	33.66±3.17a	31.56±3.29a

In location LB concentrations of TDS ranged from 44.44 – 56.17 mg/l with significant difference ($p<0.05$). Also, the months of April and July having the lowest and highest TDS values respectively in location LB (Table 4). The TDS values of location LC ranged from 36.18 – 58.59 mg/l ($p<0.05$), with lowest value in the month of July, and the highest value in the month of January (Table 4). In Location LD the TDS values ranged from 41.48 – 81.44 mg/l ($p<0.05$). The lowest TDS value of LD was reported in the month of October, while the highest TDS value was reported in the month of April (Table 4). In location LE the TDS values ranged from 43.03 – 75.15 mg/l ($p<0.05$), with lowest and highest TDS values in January and October respectively (Table 4). Generally, it was also observed that the concentrations of TDS were lowest ($p<0.05$) in the control station (LX) as presented in Table 4.

Figure-8. Mean concentrations of TDS across the different Pools

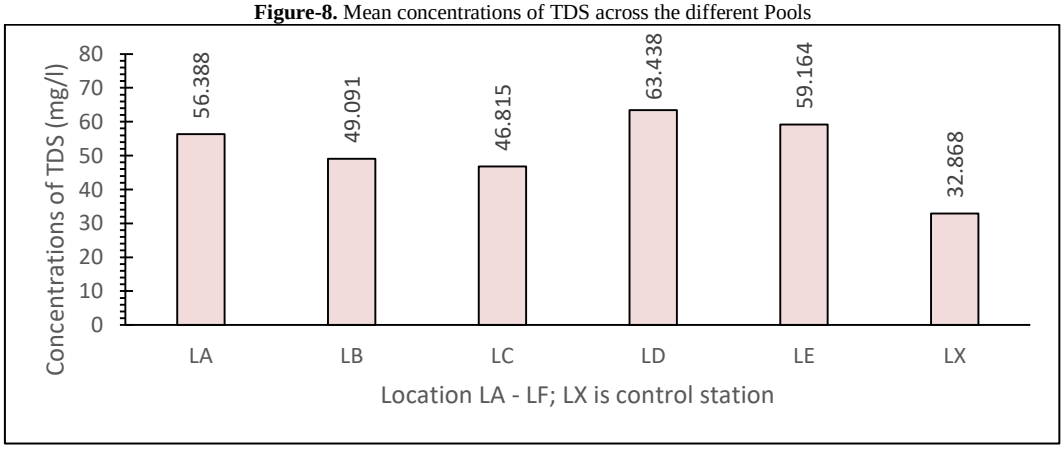
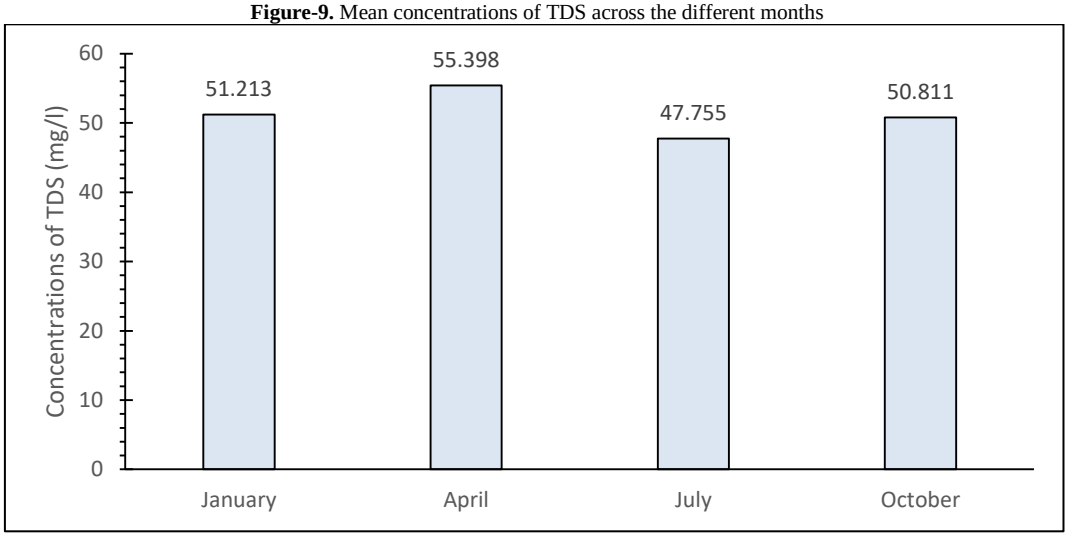


Figure-9. Mean concentrations of TDS across the different months



Results on mean concentrations of TDS across the different pools showed values that ranged from 46.81 – 63.43 mg/l, with pools LC and LD having the lowest and highest values respectively (Figure 8). In addition, it was observed that the lowest residual chlorine value was in recorded in the control station (Figure 8). Results on the mean concentrations of TDS across the different months is presented in Figure 9 showed values that ranged from 47.75 – 55.39 mg/l. It was also observed that the month of July recorded the lowest concentration of TDS, while the month of April recorded the highest concentration of residual chlorine value (Figure 9). Generally, it was observed that the mean concentrations of TDS in the control stations (LX) was lower as presented in Figure 9.

The values of total dissolved solids (TDS) recorded during the study fell within the acceptable value of 500 mg/l as recommended by the World Health Organization for recreational water. This is an indication that the TDS of the swimming pools in the study area were being monitored. Results of this study was also in agreement with the studies of; Esinulo and Ogbuagu [19]; Addo, *et al.* [25]; Aremu, *et al.* [26]; Onifade, *et al.* [14]. The levels of Total Dissolved Solid may be attributed to the contents of inorganic salts and other dissolved organic materials in the pool (EPA, 2007), as well as dissolved solids introduced by the Pools swimmers [19].

3.5. Turbidity of the Pools

Results on the levels of turbidity of the pools water and their statistical inferences are presented in Table 5. Results showed that the Turbidity in location LA ranged from 4.69 – 6.88 NTU ($p<0.05$). The lowest turbidity value was recorded in the month of July, while the highest turbidity value was reported in the month of October (Table 5). The turbidity of location LB ranged from 3.49 – 5.45 NTU ($p<0.05$), with the lowest and highest values in the months of October and July respectively (Table 5).

In location LC the turbidity ranged from 3.54 – 5.34 NTU ($p<0.05$), with lowest and highest values in the months of July and of January respectively (Table 5). Location LD had turbidity values that ranged from 4.16 – 6.42 NTU ($p<0.05$), with the months of April and July having the lowest and highest values respectively (Table 5). In location LE turbidity values that ranged from 4.37 – 7.17 NTU ($p<0.05$) with lowest and highest values in the months of January and October respectively (Table 5).

Table-5. Turbidity of the swimming pools (NTU) from different locations

Locations	January	April	July	October
LA	4.92±0.37ef	6.30±0.06g	4.69±0.28cd	6.88±0.07h
LB	4.41±0.20bc	4.58±0.17bcd	5.45±0.03f	3.49±0.04a
LC	5.34±0.29fg	4.58±0.09bcd	3.54±0.08a	4.65±0.10bcd
LD	6.13±0.07g	4.16±0.14b	6.42±0.06g	4.19±0.21bc
LE	4.34±0.35bc	6.15±0.22g	5.36±0.04ff	7.17±0.26h
LX	3.48±0.10a	3.52±0.79a	5.30±0.08fg	3.55±0.15a

Results on mean the levels of turbidity across the different Pools showed values that ranged from 4.48 – 5.75 NTU. The lowest and highest turbidity values were reported in pools LB and LE respectively (Figure 10). In addition, it was observed that the control station (LX) recorded a lower mean turbidity value than the other Pools (Figure 10).

Figure-10. Mean turbidity levels of the pools across the pools

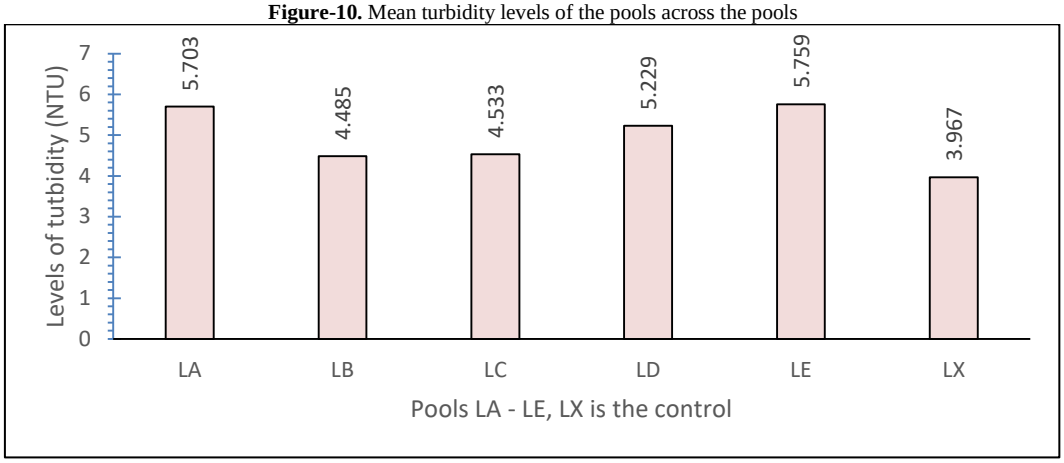
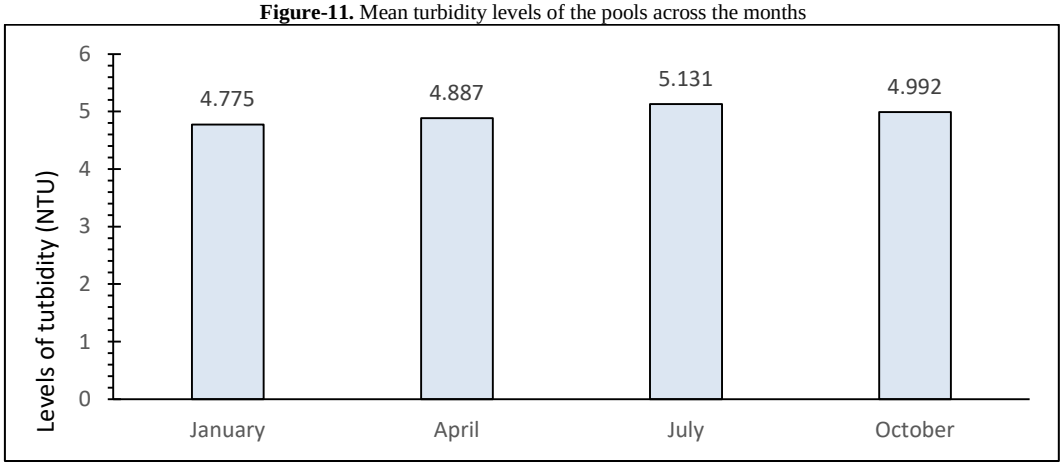


Figure-11. Mean turbidity levels of the pools across the months



Results on the mean turbidity levels across the different months is presented in Figure 11. Results showed values that ranged from 4.77 – 5.13 NTU. It was also observed that the month of January recorded the lowest mean turbidity value, while the month of July recorded the highest mean turbidity value (Figure 11). Incidentally, besides the control (LX) it was observed that the mean turbidity values of all pools were within the recommended by the WHO for recreational water quality standard [8].

This is an indication that the pools have some mild levels of contamination. This result agrees with the studies of Ajadi, *et al.* [10]; Onifade, *et al.* [14]; and Nnabugwu and Uchenna [27]. On the other hand, it disagreed with the study of Addo, *et al.* [25]. High turbidity values indicate contamination and reduce the patronage and aesthetic value of the pools, and can causes gastrointestinal diseases [30]. The high level of turbidity may be due to organic effluents, body colloids or organic matter introduced by the swimmers who did not comply with pre-swimming ethics like showering before swimming [14]. The influx of bathers and non-compliance to global best practices and safety measures can also cause elevated levels of turbidity [27].

Table-6. Conductivity of the swimming pools (µS cm^{-1}) at different location

	January	April	July	October
LA	106.02±2.84de	126.60±1.31gh	85.01±1.016b	138.42±23.089hi
LB	100.42±1.22cde	88.11±1.23bc	119.63±5.381g	92.22±22.83bc
LC	118.39±1.68fg	93.49±5.13bcd	70.22±0.392a	97.02±1.16bcde
LD	135.84±1.61hi	177.94±2.72j	126.85±1.471gh	86.35±0.08b
LE	87.97±1.81bc	140.82±1.301h	106.72±2.023ef	158.82±4.72i
LX	68.98±0.08a	65.05±1.73a	69.33±0.837a	65.26±0.87a

3.6. Conductivity of the Swimming Pools

Results on the conductivities of the pools water and their statistical inferences are presented in Table 6. Results showed that the conductivity in pool LA ranged from 85.01 – 138.42 µS cm^{-1} ($p<0.05$). The lowest conductivity value in pool LA was recorded in the month of July, while the highest turbidity value was reported in the month of October (Table 6). The conductivities of pool LB ranged from 88.11 – 119.63 µS cm^{-1} ($p<0.05$), with the lowest (October) and highest (July) values respectively (Table 5).

In pool LC the conductivity ranged from 70.22 – 118.39 µS cm^{-1} ($p<0.05$), with lowest and highest values in the months of July and January respectively (Table 6). Location LD had conductivity values that ranged from 86.35 – 117.94 µS cm^{-1} ($p<0.05$), with the months of October and April having the lowest and highest values respectively

(Table 6). In location LE, the conductivity values that ranged from 87.97 – 158.81 µS cm^{-1} ($p<0.05$) with lowest and highest values in the months of January and October respectively (Table 6).

Figure-12. Mean conductivity levels of the pools across the locations

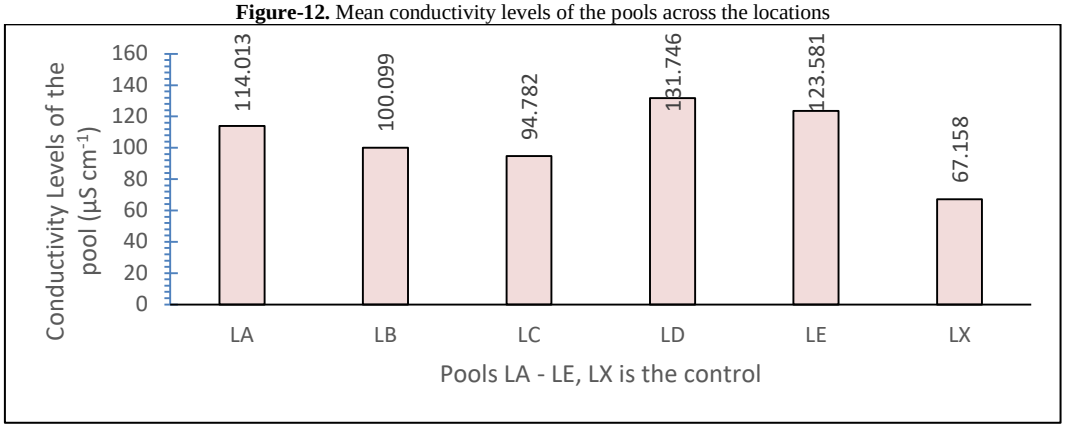
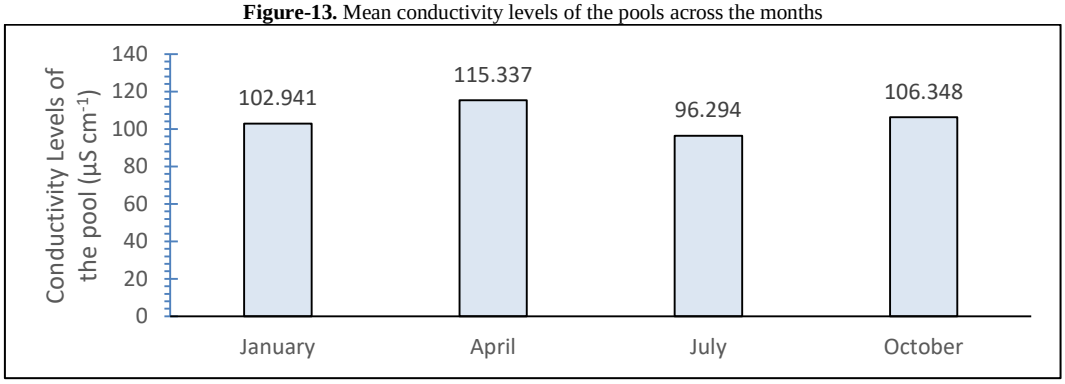


Figure-13. Mean conductivity levels of the pools across the months



Results on the mean levels of conductivity across the different pools showed values that ranged from 86.35 – 11.943 µS cm^{-1}. The lowest and highest turbidity values were reported in pools LB and LE respectively (Figure 12). Results on the mean turbidity levels across the different months (Figure 13) showed values that ranged from 86.35 – 117.94 µS cm^{-1}, January recorded the lowest mean value respectively (Figure 13). In addition, it was observed that the control station (LX) recorded a lower mean conductivity value than the other Pools (Figure 13).

The mean conductivity values of all pools were within the acceptable limit of not more 1000 µS cm^{-1} as recommended by the WHO standard for recreational water [8]. This is an indication that conductivity levels of the pool water in the current study were acceptable. This results of this of this current study agrees with the studies of Onifade, *et al.* [14], but was in disagreements with the studies of Ajadi, *et al.* [10], and Addo, *et al.* [25].

Conductivity levels in the swimming pool facility can be attributed to concentrations of dissolved ions from source of water Addo, *et al.* [25]. Also, the geology of groundwater in the area can be influence variation of soluble ions hence levels of conductivity Dharmappa, *et al.* [28]. Therefore, pool owners are advised to monitor conductivity level of their water. It will also be necessary to treat pool water before usage, this is because there is strong correlation between most physicochemical parameters that affects water quality [10, 29].

4. Conclusion

This study evaluated the physicochemical quality of selected public swimming pools in Yenagoa metropolis, Bayelsa State, Nigeria. Results showed spatial and monthly variation across the different pools. Incidentally, some of physicochemical parameters were within the acceptable WHO limit for recreational water. However, it is recommended that Government should formulate policies for the standardization and consistent monitoring of water quality in public swimming pools in order to reduce health hazard that may result from contaminated water.

References

[1] Bilajac, L., Lusic, D. V., Jelinic, J. D., and Rukavina, T., 2012. "Microbiological and chemical indicators of water quality in indoor swimming Pools before and after training of swimming Pools operators." *Journal of Water and Health*, vol. 10, pp. 108-115.

[2] Pavendan, P., Anbu, S. S., and Sebastian, R. C., 2011. "Pysico chemical and microbial assessment of drinking water from different water source of Tiruchirappalli District, South India." *European Journal of Experimental biology*, vol. 1, pp. 183-189.

[3] Shittu, O. B., Olaitan, J. O., and S., A. T., 2008. "Physico-chemical and bacteriological analyses of water used for drinking and swimming purpose in Abeokuta, Nigeria." *African Journal of Biomedical Research*, vol. 11, pp. 285-290.

[4] World Health Organization, 2004. *Guideline for drinking water quality*. 3rd ed. vol. 1. Recommendation. Geneva.
[5] Appah, E., 2023. *Physicochemical and microbiological quality of selected public swimming pools in yenagoa metropolis. Phd dissertation*. Niger Delta University.
[6] National population census-NPC, 2006. *National population Census*. Nigeria Census.
[7] Angaye, T. C. N., 2019. *Ecotoxicological assessment of municipal solid waste in yenagoa metropolis*. Bayelsa State, Nigeria.
[8] World Health Organization, 2021. "Guidelines on recreational water quality." vol. 1.
[9] Onifade, O. E., Faeji, C. O., Owoeye, J. A., and Onipede, T., 2018. "Physicochemical and bacteriological assessment of some drinking water sources around student hostel in Ekiti State University, Ado-Ekiti." *J. Chem. Bio. Phy. Sci. Sec. D.*, vol. 8, pp. 172-184.
[10] Ajadi, F. A., Bakare, M. K., and Oyedeji, O., 2016. "Assessment of physicochemical and microbial qualities of swimming pools in selected hotels in oshogbo metropolis, southwestern Nigeria." *Ife Journal of Science*, vol. 18, pp. 831 – 843.
[11] Yedeme, K., Legese, M. H., Gonfa, A., and Girma, S., 2017. "Assessment of physicochemical and microbial quality of public swimming pools in Addis Ababa, Ethopia."
[12] Clark, A., Turner, T., Dorathy, K. P., Goutham, J., Kalavati, C., and Rajanna, B., 2003. "Health hazards due to pollution of waters along the cost of visakhapatnam, east coast of India." *Ecotoxicology and Environmental Safety*, vol. 56, pp. 390 – 397.
[13] Edimeh, P. O., Eneji, I. S., Oketunde, O. F., and Sha'ato, R., 2011. "Physico-chemical parameters and some heavy metals content of Rivers Inachalo and Niger in Idah, Kogi State." *Journal Chemical Society Nigeria*, vol. 36, pp. 95-101.
[14] Onifade, O. E., Olowe, B. M., and Obasanmi, J., 2019. "Assessment of physicochemical and bacteriological quality of public swimming pools in selected hotel in ado-ekiti, Nigeria."
[15] Fritz, C., 2001. "Watershed information network, A watershed report and suggested framework for integrating water quality monitoring efforts." pp. 10 -2400.
[16] Leoni, E., Legani, P., Bucci, S. M. A., and Righi, F., 2001. "Prevalence of Legionnella in swimming Pools environment." *Pergamol*, vol. 35, pp. 3749-3753.
[17] Attah, R., Yousef, K., Ahmed, A., and Ashraf, A., 2007. "Sanitary conditions of public swimming pools in Amman, Jordan." *International Journal of Environmental. Research Public Health*, vol. 4, pp. 301-306.
[18] Nnaji, C. C., Agina, I., and Iloanya, I., 2011. "The ineffectiveness of manual treatment of swimming pools." *J. Appl. Sci. Environ. Manage*, vol. 15, pp. 517-522.
[19] Esinulo, A. C. and Ogbuagu, D. H., 2016. "Quality assessment of selected public swimming pools in owerri metropolis, Nigeria." *International Journal of Innovative Environmental Studies Research*, vol. 4, pp. 28-34.
[20] Thickett, K. M., Mccoach, J. S., Gerber, J. M., and Burge, P. S., 2002. "Occupational asthma caused by chloramines in indoor swimming-pools air." *European Respiratory Journal*, vol. 19, pp. 827-832.
[21] Agbagwa, O. E. and Young–Harry, W. M., 2012. "Health implications of some public swimming pools located in port harcourt, Nigeria." *Public Health Research*, vol. 2, pp. 190 – 196.
[22] Elizabeth, O. O., 2012. "Assessment of microbiological quality and sanitary status of swimming pools in ibadan, Nigeria." In *Keynote Conference*. pp. 1-6.
[23] Yousefi-Mashouf, R., Samarghandi, M. R., Rajabinegad, A., Ahmadi, M., and Nazarieh, F., 2011. "Microbial, pH and chlorine assessment of the swimming Pools water in hamadan city." *J. Res. Health Sci.*, vol. 3, pp. 10-14.
[24] Ali, I., Pentttin-Damdimopoulou, P. E., Makala, S. I., Berglund, M., Stenius, U., Akesson, A., H., Akanson, H., and Halldin, K., 2012. "Cadmium-induced effects on cellular signaling pathway in the liver of transgenic estrogen reporter mice." *Toxicological Science*, vol. 127, pp. 66 – 75.
[25] Addo, M. G., Tee1, J., and Larbi, J. A., 2018. "Recreational water quality assessment of some selected swimming pools in the asuogyaman district, Ghana." *MRJI*, vol. 26, pp. 1 - 8.
[26] Aremu, M. O., Olaofe, Ikokoh, P. P., and Yakubu, M. M., 2011. "Physicochemical characteristics of stream, well and borehole water sources in eggon, nasarawa state, Nigeria." *Journal of Chemical Society of Nigeria*, vol. 36, pp. 131-136.
[27] Nnabugwu, A. E. and Uchenna, A. P., 2019. "Swimming pools quality risk assessment for heavy metal deposition and intake via oral and dermal exposure." *Environmental Analysis Health and Toxicology*, vol. 34, p. e2019008.
[28] Dharmappa, H. B., Wingroove, K., Sivakuma, M., and Singh, R., 2000. "Wastewater and stremwater minimization in a cool mine." *Journal of Cleaner Production*, vol. 8, pp. 23- 34.
[29] Ohimain, E. I. and Angaye, T. C. N., 2014. "Iron levels, other selected physicochemical and microbiological Properties of earthen and concrete catfish ponds in central Niger Delta." *International Journal of Biological and Biomedical Sciences*, vol. 3, pp. 041-043.
[30] Mann, A. G., Tam, C. C., Higgins, C. D., and Rodrigues, L. C. (2007). The association between drinking water turbidity and gastrointestinal illness: a systematic review. *BMC Public Health*, 7(256), 1-7.