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Research Article

Assessment of Microbiological Quality of Some Recreational Waters in Port Harcourt Metropolis

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ABSTRACT

Recreational water users can be exposed to a range of disease-causing microorganisms and pose public health concerns. This study assesses the presence of different microorganisms in recreational waters in Port Harcourt. Samples were collected from six recreational waters of swimming pool and rivers and were used to test for the microbial water quality. Spread plate technique was used to enumerate the microbial distribution. Biochemical tests, biofilm and haemolysis tests were conducted to confirm the presence of microorganisms. The results of the total heterotrophic bacterial count ranged from 0.68±0.44 to 2.7±2.1×10^6 cfu/ml, total coliform count ranged from 0.00 ×10^3 to 2.0×10^5 CFU/ml, while total fungal count ranged from 1.0×10^3 to 11.0×10^3 CFU/ml. Bacterial isolates were identified as; *Streptococcus* sp, *Staphylococcus* sp, *Micrococcus* sp, *Proteus* sp, *Serratia* sp, *Bacillus* sp, *Pseudomonas* sp, *Klebsiella* sp, and *Escherichia coli*. While fungal isolates were identified as: *Candida* sp, *Aspergillus* sp, *Penicillium* sp and *Saccharomyces* sp. The frequency of occurrence for the isolates were 5.7%, 11.3%, 7.5%, 9.4%, 7.5%, 22.6%, 15.1%, 11.3%, and 9.4% respectively for the bacterial isolates and 25.7%, 34.3%, 22.9%, 17.1% for the fungal isolates respectively. Statistical analysis showed that there were no significant differences (P>0.05) in the microbial counts across the various recreational waters. The presence of these potential pathogenic microorganisms has been known to cause microbial diseases including: pneumonia, bloodstream infections, urinary tract infections, rashes, etc., suggests that there is need for constant monitoring of microbial quality of recreational waters.

Keywords: Recreational waters, public health, bacteria, potential pathogens, disease.

Introduction

Recreational water refers to rivers, lakes and coastal waters that are used for recreational purposes (USEPA, 2015). Recreational water include water in swimming pools, hot tubs, waterparks, interactive fountains, water play areas, lakes, rivers or oceans used for surfing, swimming, fishing, boating, etc. (Yoder *et al*., 2008). Recreational water can become contaminated with pathogens like bacteria, fungi and viruses from human sewage and animal manure.

The growth of several bacteria in contaminated water can make it injurious for our health and environment (Yoder *et al*., 2008). Other activities carried out around recreational waters include activities such as: hiking, nature viewing and hunting waterfowl (DENR, 2019).

Water quality can be described as combination of sanitary inspection and microbial water quality assessment. In developing countries, the quality of water is very essential to public health. Literatures have shown

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that there are numerous types of microbial pathogens found in the recreational areas (Hervio-Health *et al.*, 2002) and this can thus, serve as a vehicle for the transmission of microbial diseases to people by contact with contaminated water. The primary contact with recreational water involves activity such as swimming, windsurfing, and waterskiing and secondary contact involve boating and fishing. Contamination of water with fecal bacteria is a common and persistent problem impacting public health, local and national economies. Coffey *et al.*, (2014), stated clearly, that one of the major reasons for contamination of the recreational waters is the increasing number of population in the cities and metropolis as well as, the uncontrolled discharge of human waste, animal and industrial sewage and other various domestic wastes into the water bodies results to environmental damage and eutrophication of the recreational waters and its environments (Wade *et al.*, 2006). The presence of pathogenic agents, such as *E. coli, Salmonella, Shigella* and *Campylobacter* can cause waterborne diseases and it has been reported worldwide. The identification of the occurrence of diseases which may be transmitted by recreational water contact has also been reported (Russel and Walling, 2007). Pathogenic microorganisms are found among indigenous communities (e.g., cyanobacteria, protozoa, vibrios) and are introduced into waters in various ways (Carbral, 2010; Cayabo1 *et al*., 2021). Some of these infectious microorganisms are autochthonous to freshwater environments (*Aeromonas hydrophila*, *Naegleria fowleri*, *Legionella pneumophila*) and to marine and brackish waters (e.g., *Vibrio cholera*e and other vibrios, *Aeromonas* spp.) may represent natural reservoirs of many types of pathogenic microorganisms in recreational waters and their environments (Pandey *et al.*, 2014). Primarily, the bacteria like *Escherichia coli, Salmonella, Vibrio* and *Shigella* found in intestinal tracts of humans and warm-blooded animals can enter the water through feces thereby making the water fatal for consumption. Moreover, the intestinal tracts of warm-blooded animals carry viruses like rotavirus; enterovirus etc. which contaminates water and makes it unsafe for use (Gibson, 2014). These contaminants can gain entry into recreational waters through point source discharge; coming from single source like pipe and refuse and though non-point source pollution; where contaminants leach into a water source across a wider area (Barnett *et al.*, 2018). These recreational waters are mainly associated particularly with agricultural production (Harrington *et al.*, 1993). Fecal matter from livestock can get into waterways in several ways like: rainfall washing livestock effluent from the land into waterways, livestock defecating directly into waterways when they have access, and leaching into groundwater. Bacterial levels in waterways are often highest after rainfall, when fecal matter is carried from land into waterways (Ackerman and Weisberg, 2003).

Recreational water illnesses are microbial diseases that people can contact through contaminated water they swim in and play in, like: pools, hot tubs, water playgrounds, oceans, lakes, and rivers. If the water is contaminated with germs, the most common symptoms are diarrhea, skin rashes, ear pain, cough or congestion, and eye pain (Pruss, 1998). For these reasons recreational waters must be monitored for microbial quality so that safety measure can be carried out to guarantee water quality in order to prevent or reduce the possibilities of disease outbreak so that there will be no risk for human and environmental health hazard (Coffey *et al*., 2014). Hence, the present study is aimed at determining the microbiological quality of some recreational water in Port Harcourt, where bacterial and fungal population in the recreational water samples were enumerated in order to evaluate the risk associated with the use of contaminated recreational water.

Materials and Methods

Description of Study Area

The study was carried out in different swimming pools and rivers of Port Harcourt, Rivers state, Nigeria. Conditions of the water were noted which includes when water was last used, when it was lasted treated and how often it is changed (for swimming pools), how often it is used and how often different age ranges use it (ASTM, 1999; Johnston *et al*., 2010). SP which is a hotel's swimming pool had children and adults playing in it at the time of water sample collection and the pool are one which was frequently used and water changed once or twice a week depending on the number of people that have used it. DR is a river where boating and swimming takes place and is located very close to a dumpsite. JP had few people playing in it before water sample collection and was the least frequently used. E&G is a pool and the water was changed few hours before the water sample was taken and has not been used at the

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time of collection. AR also is a river where boating, swimming and activities that had to do with oil take place. Individuals living around AR use the river as a way to dispose waste. TBR which is a beach at the time of water sample collection had people at the side resting from boating and swimming in the river (APHA, 2005; Johnston, *et al*., 2010).

The water samples were obtained from three swimming pools and three recreational rivers, with the following coordinate; N – 4°47'41.5176" E – 7°02'35.2644" for Somitel hotel's swimming pool (SP), N – 4°44'32.2692" E – 7°01'49.8792" for Duckyard River (DR), N – 4°47'27.6072" E – 7°02'34.8072" for Jacaranda hotel's swimming pool (JP2), N – 4°48'02.4084" E – 7°02'37.8024" for E&G hotel's swimming pool (E&G), N – 4°48'15.6636" E – 7°03'12.3804" for Azuabie River (AR) and N – 4°45'29.3868" E – 7°02'38.022" for Tourist-beach River (TBR).

Collection of Recreational Water Samples

Swimming pool and River water samples were collected from 6 different stations. Standard procedures were adopted in water sample collection and laboratory analysis in line with requirement specified by WHO, the American society for Testing and Materials (ASTM), United States Environmental Protection Agency (USEPA) and American Public Health Association (APHA). Using a grab sampling technique, small amount of water was taken from numerous horizontal sections across the swimming pool and river water, at regular intervals. The collected samples were placed in ice pack container (Sabino *et al*., 2014) and sent to the microbiology laboratory of the department of Microbiology, Rivers State University for analysis.

Microbiological Analysis

The microbiological analysis of the samples involved enumeration and isolation of the bacteria and fungi present in the different samples. The properties of the swimming pools and rivers that were investigated include Total Heterotrophic Bacteria (THB), Total Coliform Count (TCC) and Total Fungi Count (TFC).

The microbial populations in the water samples were enumerated using the tenfold serial dilution of Harrigan and McCanc as described by Halliday and Gast, (2011). In this method, one milliliter of the water sample was transferred into test tube containing 9mL of prepared sterile saline. After which a step wise dilution was made by transferring 1mL from the previous dilution into another test tube containing 9mL sterile saline. This was done serially until a dilution of 10^{-6} was reached (Halliday and Gast, 2011).

Enumeration and Isolation of Bacteria and Fungi

After the serial dilutions, aliquots of 10^{-2}, 10^{-3} and 10^{-4} dilutions were seeded into prepared Nutrient agar, Eosine Methylene Blue Agar (EMB) and Sabouraud dextrose agar (SDA) which was fortified with tetracycline antibiotics for inhibition of bacterial growth. Plates were spread evenly using sterile glass bent rod and were incubated at 37 ºC for 24-48 hours for bacteria and 3-5days for fungi (SDA). After incubation, plates were observed for microbial growth. Counts were made for the respective plates and colonies were characterized morphologically and were subcultured on freshly prepared nutrient agar plates. The counts from the different plates were used in enumerating the microbial load present in the water samples.

Preservation of Isolates

Pure cultures of the bacterial isolates were preserved in bijou bottles containing 10% freshly prepared glycerol. Prior to storage, 5mL glycerol suspension were transferred into bijou bottles and were sterilized by autoclaving at 121ºC for 15 psi. The pure isolates were transferred into sterile, properly labeled bijou bottles containing the glycerol suspensions. After which, the bottles were kept frozen in the refrigerator. These were used for subsequent identification and analysis (Nobel and Weisberg, 2005).

Characterization and Identification of Bacterial Isolates

The morphological and biochemical characteristics of the bacterial and fungal isolates were determined using the method of Cheesbrough (2006). The morphological and biochemical test used for bacterial isolates include; Gram staining, motility, catalase, indole production, methyl red, citrate utilization, vogees proskauer test, blood haemolysis test and sugar fermentation (raffinose, arabinose, mannitol, glucose, lactose and sucrose).

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Sugar fermentation test

Sugar fermentation test is used to determine their ability of the microorganisms to ferment specific sugars. Five (5) sugars were used in this work which includes lactose, sucrose, mannitol, glucose and fructose. This was prepared according to Cheesebrough (2006). The sugars used include; arabinose, raffinose, glucose, sucrose, lactose and mannitol. One gram (1g) of sugar was weighed and put in a beaker, which contained 1.5 g of peptone and 80 ml of distilled water. Twenty millilitres (20 mL) of phenol red was added into the beaker. The sugar solution (9 mL) was dispensed into test tubes which were then autoclaved at 121^{o}C for 15minutes for sterilization. After sterilization, the test organisms were aseptically introduced into the test tube containing the sugar solution with the aid of a sterile wire loop and incubated at 37^{o}C for 24 hours. After 24 hours, colour change was checked. Positive results changed from red to yellow while negative results remained unchanged and retained the initial red colour.

Haemolysis Test

The test for haemolysis was carried out on the various water isolates to check if the isolates could haemolyze blood. Alpha, Beta and Gamma haemolysis were used to indicate incomplete haemolysis, total haemolysis and no haemolysis respectively. The test isolates were grown on a blood agar which had been prepared and dried. The inoculated plates were then incubated for 24 hours and zones of clearing were read after 24 hours (Nobel and Weisberg, 2005; Roldan *et al.,* 2013).

Biofilm Screening

Bacterial isolates obtained from the samples were tested for their biofilm producing capacity using the Congo red test method. Biofilm screening by Congo red agar method is a simple qualitative way to detect biofilm production among bacterial isolates (Rodney and Donlan, 2001). This method was used to determine the bacterial isolates that produce biofilms. In this regard, the test organisms were inoculated on Congo Red Agar and incubated at 37°C for 24 hours. The formation of black crystalline colonies marks a positive test for biofilm production. (Roldan *et al.,* 2013).

Characterization and Isolation of Fungal Isolates

Isolates were identified using their morphological features such as colony, colour, shape, texture and size of colony followed by microscopic examination (conidial shape, arrangement of hyphae and type of spores) of their wet mounts prepared with lactophenol cotton blue and reference made to fungal identification manual (Cheessbrough, 2006).

Results

The result of the microbial counts (CFU/ml) of the water samples is presented in Table 1. Result showed that there were bacteria, fungi and coliform present in the different recreational waters analysed as follows: Azuabie River (AR), Duckyard River (DR), E&G pool(E&G), Jacaranda pool (JP) and Tourist Beach River (TBR) but there was no significant growth of coliform in Somitel hotel's pool (SP) but fungi and bacteria were present. Among the sampling points, AR was found to have the highest bacteria count followed by TBR, DR, SP, E&G while, JP had the lowest bacteria count. From the present study, AR had the highest counts of coliform that was too numerous, followed by DR, TBR, JP, E&G while, SP had no coliform found in it. From our study, DR had the highest fungal counts followed by TBR, SP, AR, E&G while, JP had the least fungal counts The following bacteria were isolated and includes result of the morphology and biochemical characterization of bacterial isolates showed that isolates 1 and 2 matched the morphological and biochemical characteristics of *Streptococcus sp.,* isolates 3 and 4 showed similar biochemical and microscopic characterization of *Staphylococcus sp.,* isolate 5 was similar to *Micrococcus sp.,* isolate 6 was similar to *Proteus sp.,* isolate 7 and 11 matched *Serratia sp.,* isolate 8 matched *Bacillus sp.,* isolates 9 and 12 showed same morphology and biochemical characterization as *Pseudomonas sp.,* isolate 10 was similar to *Klebsiella sp.,* and isolate 13 matched that of *E. coli.*

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Table 1. Microbial counts (cfu/ml) of the recreational water samples

Sample code	Total Heterotrophic Bacteria ($\times 10^6$)	Coliform count	Fungal count ($\times 10^3$)
AR	2.7±2.1 [a]	2.0×10^5 ±4.4[c]	4.0±2.2 [a]
DR	2.2±1.5 [a]	4.9×10^4 ±3.4[b]	11.0±2.1 [a]
E&G	0.77±0.45 [a]	1.2 $\times10^3$±2.5 [a]	3.0±2.5 [a]
JP	0.68±0.44 [a]	2.5×10^3±2.9 [ab]	1.0±2.0 [a]
SP	1.0±0.4 [a]	0.00×10^3±0.00[a]	5.5±0.6 [a]
TBR	2.4±0.4 [a]	8.5×10^3 ±1.0 [a]	5.7±4.9 [a]

*Means with similar superscript (alphabet) down the group show no significant difference ($P \leq 0.05$)

The percentage of occurrence of bacterial isolates is shown in Figure 1. From the present study, the percentage of occurrence of bacterial isolates were reported in decreasing order as follows: *Bacillus sp.* (22.6%) < *Pseudomonas sp.* (15.1%) < *Klebsiella sp.* and *Staphylococcus sp.* (11.3%) < *Proteus sp.* and *E. colin* (9.4%) < *Micrococcus sp. and Serratia sp.* (7.5%) < *Streptococcus* sp (5.7%). In all the samples analyzed, *Bacillus sp.* was the most occurring while, *Streptococcus* sp was the least occurring bacterial isolate.

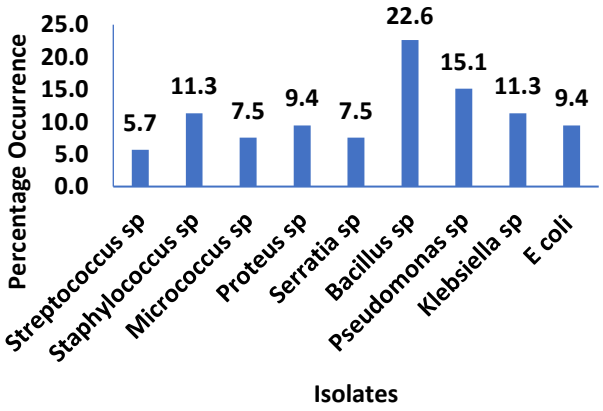

Fig. 1: Percentage occurrence of bacterial isolates from recreational waters

Figure 2 showed the percentage distribution of bacterial isolates across the samples. *Streptococcus sp, Staphylococcus sp, Micrococcus sp, Proteus sp, Bacillus sp, Klebsiella sp, Pseudomonas sp and E.coli* were detected in the sampling points bearing sample code: AR. *Streptococcus sp, Staphylococcus sp* and *Bacillus sp.* were seen in the sampling points bearing sample code: SP, *Staphylococcus sp, Micrococcus sp, Proteus sp* and *Bacillus sp.* were detected in the sampling point bearing sample code: JP. All the organisms with exemption of *Streptococcus sp.* were isolated from the sampling point bearing sample code: E&G. Sampling point bearing sample code: DR had *Serratia sp, Klebsiella sp, Bacillus sp, Pseudomonas sp.* and *E.coli* present. While, sampling point bearing sample code: TBR had all organisms also found in other recreational water samples except *Micrococcus sp.* and *Streptococcus* sp.

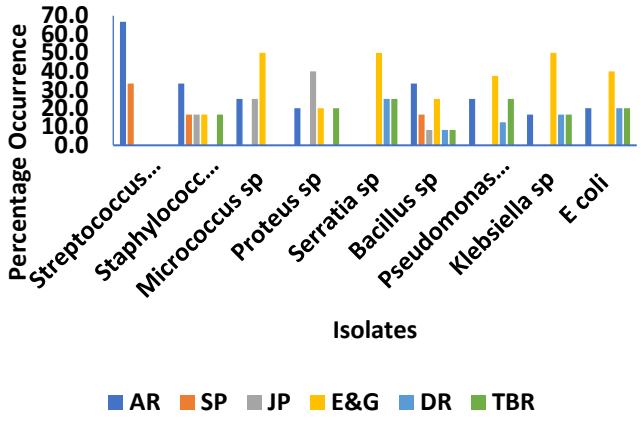

Fig. 2: Percentage distribution of bacterial isolates across the samples

The percentage occurrence of fungal isolates across the samples is presented in Figure 3. *Aspergillus* sp recorded the highest percentage of 34.3% which was followed by *Candida* sp (25.7%), *Penicillium* sp, and *Saccharomyces* sp (17.1%).

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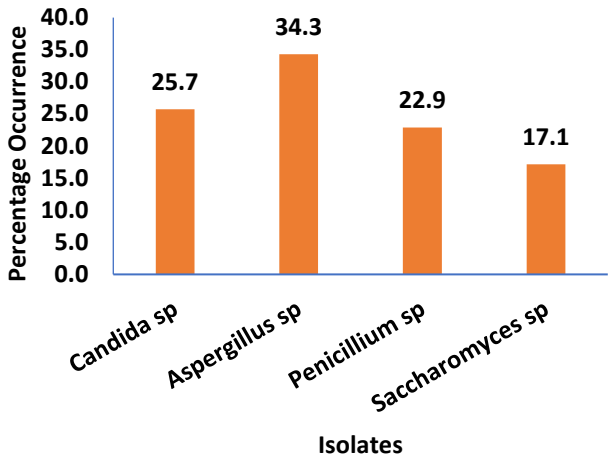

Fig. 3: Percentage occurrence of fungal isolates from recreational waters

The percentage distribution of fungal isolates across the samples is presented in Figure 4. Sample codes: TBR, JP and AR showed presence of *Candida sp.*, *Aspergillus sp.* and *Penicillium sp.*, sample codes: E&G and SP showed presence of *Candida sp.*, *Penicillium sp.* and *Saccharomyces sp.* while, sample code; DR showed all fungal isolates present in all samples analyzed except *Penicillium sp.*

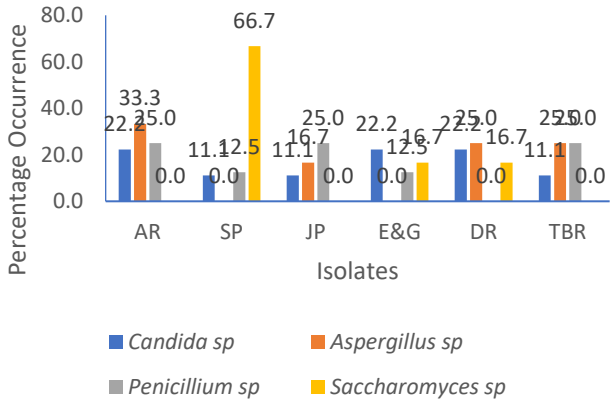

Fig. 4: Percentage distribution of fungal isolates across the sample

The result of biofilm and haemolysis test carried out on the bacterial isolates is presented in Table 2. *Streptococcus sp.*, *Staphylococcus sp.*, *Serratia sp.*, *Bacillus sp.*, and *Pseudomonas sp.*, showed positive result to both biofilm and haemolysis test. *Micrococcus sp.*, *Klebsiella sp.*, and *E. coli* showed negative result to biofilm and haemolysis test. *Proteus sp.* showed positive result to biofilm test and negative result to haemolysis test.

Table 2. Biofilm and coagulase formation of the bacterial isolates

Key: + = positive result; - = negative result

Discussion

Water–based recreation is of vital importance to human life. Nevertheless, literatures have recorded that mortality rate is twice among the non-swimmers than the active swimmers (Chase *et al.*, 2008; Anciaes *et al.*, 2020). Water–based recreation is always enjoyable when compared to non-water related adventures (Barnett *et al.*, 2018) and critical antidotes for several persistent ailments including arthritis through enhance utilization of affected bodily parts devoid of aggravating pains (Wade *et al.*, 2006). In spite of its usefulness, recreational water bodies in general, are always vulnerable to various forms of pollutants. Polluted water is not healthy for drinking, bathing, industry, agriculture (Boelee *et al.*, 2019) as well as its fitness for swimming and other recreational activities (Boelee *et al.*, 2019). Monitoring the number of indicator microorganisms such as fecal coliform and *E. coli* is a common approach to quantifying pathogenic microorganisms present in the surface waters (Cabral, 2010; Pandey *et al.*, 2014; Cimatu, 2020). The safety of recreational water is an important and timely issue when dealing with public health and sustainable water management (Ahmed, *et al.*, 2010). The results of this present study showed that recreational waters harbour many pathogenic microorganisms and most of these isolates were from rivers. This may be due to a number of factors including: the high number of different users, the various sources of water, discharge from municipal waste waters, contamination from bathers, discharge from onsite toilet facilities and boats etc. (Caruso *et al.*, 2002). The swimming pools having bacterial and fungal isolates were those facilities that are being frequently used, not changed and also not treated with purifying agents such as chorine Hellein *et al.*, 2011). This study highlights the potential health problems posed by waterborne microorganisms that are difficult to eradicate through conventional means of disinfecting. Among the list of such bacteria and fungi are; *Streptococcus* specie,

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Staphylococcus specie, *Serratia, Bacillus, Pseudomonas* specie, *Micrococcus* specie, *Klebsiella* specie, *Escherichia coli*, *Candida* specie, *Saccharomyces* specie, *Penicillium* specie and *Aspergillus* specie. Similar findings have been reported by researchers including; Mansoorian *et al.,* (2013); Hutcheson *et al.*, (2013). The study therefore shows the potential health risk associated with use of these water recreational facilities and that *Klebsiella* specie and *Pseudomonas* specie are the most frequently encountered isolates suggest that there is a need for monitoring of recreational waters because they are pathogenic organisms that could pose a lot of harm to humans who get in contact with them. This work is similar to work done by Bouzid, (2016) who isolated eight clinically important pathogenic bacteria including: *Escherichia coli, Proteus mirabilis, Klebsiella pneumoniae, Pseudomonas aeruginosa, Shigella* sp., *Salmonella* sp., *Vibrio parahaemolyticus* and *V. cholera* from contaminated recreational waters. They further emphasized that the presence of these bacteria in recreational water is alarming because the waterborne pathogens can cause illness with severe outbreak of microbial diseases when come in contact with to the average population (Franco, 2009; WHO 2015). In previous studies carried out by several researches like: Russel and Walling, (2007); Byappanahalli *et al*., (2012); USEPA, (2023); Boehm and Sassoubre, (2014); revealed that microorganisms associated with contaminated recreational waters included; bacteria, protozoa and viruses. Furthermore, Byappanahalli *et al*., (2012); Pandey *et al.,* (2014); USEPA, (2015); Bouzid (2016) reported clearly that, these pathogenic microorganisms have been identified as the primary source of microbiological water contamination and are usually responsible for waterborne microbial diseases such as typhoid fever, hepatitis, cholera and poses environmental and public health risk (Boehm and Sassoubre, 2014).

Furthermore, The result is similar to a research on: Bacteriological assessment of recreational waters carried out by Cayabo *et al*., (2021), the multiple fermentation (MTF) technique applied revealed that the water samples collected from eleven stations were all contaminated with coliform specifically, *E. coli*. From the present study, the presence of *Penicillium sp* in AR, SP, JP, E&G and TBR could be as a result of household wastes like: dried food stuffs dumped in the water, decay vegetations from the plants growing around the water, damaged parts of the pool or spores getting the surface of pools, *Aspergillus sp.* present in AR, DR and TBR must have been as a result of decaying plants and leaves found growing near the rivers, *Candida sp.* found in all the sampling site must have been as a result of constant swimming and bodily contacts made in the water. However, the study showed that bacteria isolates were well adapted to surviving in the recreational water facilities despite having being disinfected. Furthermore, previous study carried out by Rabi *et al.,* (2007) showed that, although chlorine treatment was done in the swimming pools, germs were not complete killed.

Biofilms are bacterial aggregates attached to various biotic and abiotic surfaces which can interact with each other and adapt themselves to environmental stressors (Mahapatra *et al.,* 2006). According to previous studies by Costerton *et al.,* (2000), biofilms tend to become more resistant to antibiotics and disinfectants thereby become a reservoir for spread of pathogenic organisms. Hemolysis on the other hand refers to the disruption of erythrocyte membranes that causes the release of hemoglobin which could result in decrease of erythrocyte life span (Harwood *et al.,* 2005; Franco, 2009).

From our study, the positive result obtained from the biofilm test indicates that these microorganisms were found present on the water surface and the positive result obtained from the haemolysis test indicates that these microorganisms are capable of lysing the red blood cells which is harmful to human. According to Carla and Maria, (2017), anthropogenic activities such as: land use and fecal pollution sources are the major causes of the presence of pathogenic microorganisms in recreational waters. These waterborne pathogenic organisms can occur ubiquitously in many aquatic habitats and humid soils and have been reported as important part of the biocoenosis in various substrates or water systems, especially in their preferred habitats, the biofilms (Boehm and Sassoubre, 2014).

Conclusion and Recommendations

Contaminated recreational water has been known to cause variety of microbial diseases because in one way or the other, recreational water finds its way into the body through the mouth. These diseases may include:

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gastrointestinal illnesses including the following: diarrhea (three or more loose stools in a 24-hour period), vomiting, nausea, stomachache, sore throat, cough, runny nose, cold, or fever, rashes or itchy skin, eye infection, upper respiratory illnesses (URI) etc. From this research, it is suspected that the high microbial count seen in recreational water samples including: AR and DR might be as a result of the household wastes disposed in the water. This is because household wastes mixed in garbage can result to environments that are naturally conducive for the multiplication of microorganisms. The safety of recreational waters is an important and timely issue especially as regards to public health sustainable water management. The number of hazardous microorganisms and their forms present in the recreational water is large and the regulatory agencies approach is guided by fecal contamination events. The quality of recreational water in many Nigerian cities cannot be neglected because of the risk and implications to human health. Hence, the prime motivation for carrying out this study is to assess the quality of recreational waters in order to ascertain the negative effects of the use of contaminated recreational water poses on human health. It is recommended that recreational water users should avoid swallowing water, regardless of the water quality, should take a shower immediately after swimming and also, should avoid swimming when they are sustained with open sores or wounds. Personnel kept in charge of all recreational waters should create public awareness in understanding water quality in order to reduce potential risk of swimmer illness or injury and provide information on expected risk associated with recreational water. Water quality assessment should be carried out regularly on recreational waters and the surrounding environments and monitored by the concerned regulatory bodies such as; Department of Environment and Natural Resources (DENR), Ministry for the Environment (MFE), World Health Organization (WHO).

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