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Bacteriological physicochemical quality of recreational water bodies: Case studies from Addis Ababa and Oromiya region Ethiopia

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Waterborne diseases are common and major problem in developing countries. Considering the great importance of the safety of recreational waters, a cross-sectional study at Addis Ababa and Oromiya regional state was carried out over a three month period of time from May-July, 2008. A total of 72 water samples from two natural bathing lakes and six outdoor swimming pools were collected and analyzed for total and fecal coliforms, fecal streptococci, hetrotrophic bacteria, *Staphylococcus aureus*, pH, temperature, free chlorine and turbidity. The study demonstrated that from all the samples analyzed for microbiological water qaulity 52(96.3%) were found to be positive for *S. aureus*, 44 (81.5%) for total coliforms, 43 (79.6%) for total bacteria count, and 38 (70.4%) for fecal coliforms. All of the samples from the swimming pools do not have the required level of chlorination (1.0 mg l^{-1} (100%)). Moreover, 75.9% of the pool samples passed the required turbidity level and 33.3% of samples were alkaline in pH. All of the microbial analyses of the two natural bathing lakes were within guideline limit of bathing water regulations of United Kingdom. From these results it can be concluded that, except that of the natural bathing lakes, most of the bacteriological and physicochemical parameters measured from outdoor swimming pools were not in compliance with the reference values set out by WHO guideline. This is mainly due to lack of awareness, absence of monitoring, proper disinfection and/or lack of information or control over related parameters to efficient disinfection processes. The study findings suggest that the observed problems can be minimized by promoting good hygiene education and practices for swimmers, applying a better and strict supervision, providing training and education for operators, monitoring the biological and chemical conditions through guideline development of the pool at regular intervals.

Key words: Swimming pools, microbiological indicators, microbial water quality, recreational water quality.

INTRODUCTION

Recreational waters contain a mixture of pathogenic and non-pathogenic microorganisms, which may be derived from sewage effluents, the recreational population using the water, livestock, industrial processes, farming activities, domestic animals and wildlife (WHO, 2003). Now-adays, large numbers of people are taking up recreational

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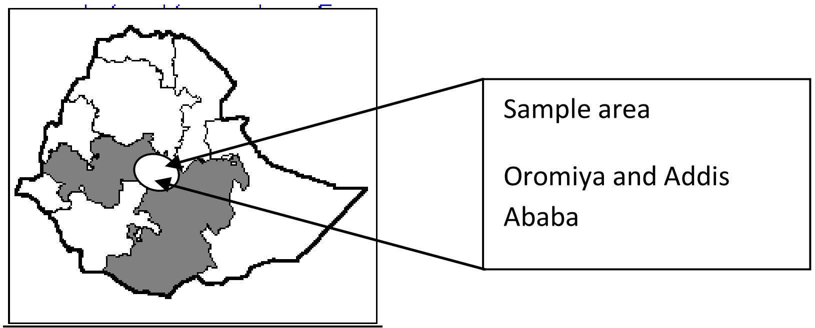

Figure 1. Sampling area.

activities in and around water, and these are becoming part of leisure and tourism around the world (WHO, 2006). Water based recreation (swimming), how-ever, can expose people to a variety of health risks. The hazards that are encountered in recreational water environ-ments vary from site to site, as do to the nature and extent of exposure, the type of water, geographical location and local conditions. Perhaps, the hazards are linked to physical, microbial and chemical agents, most available information relates to health outcomes arising from exposure through swimming and ingestion of water (WHO, 2003).

Recreational water illnesses (RWIs) are illnesses that are spread by swallowing, breathing, or having contact with contaminated water from swimming pools, spas, lakes, rivers, or the ocean. RWIs symptoms include intestinal, skin, ear, eye, respiratory and neurologic infec-tions. Currently, poor pool maintenance, the emergence of chlorine-resistant germs, and pool staff and swimmers that are illformed about RWIs is a challenge for the public health community and increases the complexity of any plan to prevent the spread of RWIs (CDC, 2008). Consequently, recreational water use is attracting the public, concerned professionals, regulatory agencies, and the tourist industry (WHO, 2006).

Although there are recreational water bodies which are regularly visited by people in Ethiopia, there is little, (if any) or no information available about their bacterio-logical quality, and there are no guidelines (standards) towards the safe use and quality control of recreational water. Under this circumstances, it is neither possible to know the gravity of the problem, nor simple to manage the possible health related risks that are associated with the use of recreational water bodies. It is therefore imperative to collect information about the microbial quality in recreational water bodies to assess the quality in relation between microbial contamination and health related problems. The obtained information would help to create awareness, develop guidelines in order to control or manage the possible health related problem.

The present work therefore, aims at evaluating the level of specific bacteriological indicator species (TC, FC, FS, *S. aureus* and HPC) as well as analyzing bacteriological related physiochemical quality parameter such as temperature, pH, turbidity and free chlorine residual from selected recreational water, 3) compare bacteriological quality of the selected recreational waters bodies in Addis Ababa and Oromiya Region in Ethiopia. The findings will serve as a baseline data for stakeholders and the public authorities to work in terms of better management of the recreational areas in the country.

MATERIALS AND METHODS

Description of the study area

The cross sectional study was conducted between May - July, 2008 from two natural lakes and six different outdoor swimming pools that are located at Addis Ababa and Oromiya regional state. Site one is located in Addis Ababa geographically located between 9° 0'19.4436"N and 38°45'48.9996''E with an elevation of 2356 a.s.l. Site two is geographyically located between 8°59'N37°51'E and 8°.983'N37.850°E with an elevation of 2101 at West Shewa zone of Oromiya region. Site three of the swimming pool is located at Bishoftu (Debre Zeyit) geographically located between 8°45'0N and 38°58'60E having an elevation of 1999 m a.s.l. The main swimming pool and teaching pools were constructed separately side by side and have different water system except that of site 2. Lake Hora and Babogaya are used as recreational water and the local inhabitants used it for washing and cooking. Both lakes are found at Debre Zeyit (Bishoftu) about 1 to 2 km apart from each other with an altitude 1860 m a.s.l and 8°50'N 39°E, respectively (Figure 1).

Sampling and sample collection

Recreational water bodies, which are frequently visited by most and those which are easily accessible for public and sample transport are randomly selected. Triplicate water samples were collected from each recreational sample site following on APHA (1998) and WHO (2006) guidelines. All samples were collected during the peak of bathing periods (weekends) by using a sterile glass bottles with capacity of 1 L containing sodium thio sulphate for complete neutralization of residual chlorine (1 ml of 10% $Na_2S_2O_3$). Free and total chlorine, pH and water temperature were determined on the spot at the time of sample collection. The samples were collected from a depth of 20 to 40 cm, at a point about 50 cm away from the pool edge and 1 m away of lake shore. Each sample site has three separate sampling points or location. A total of nine samples were systematically collected from each sample site at two weeks interval during the maximum bathing time and day (2:00 to 9:30 PM, Friday to Sunday), respectively, within the month of May to July 2008.

A total of 54 water samples, 18 samples from each site (sites1 to 3) were collected and transferred to Applied Microbiology laboratory, Addis Ababa, Ethiopia by keeping the samples at 4°C in ice box. Samples were processed immediately after arrival within 1 to 6 h from sample collection time to avoid the death and growth of organisms.

Microbiological analyses

Microbial indicators, total coliforms (TC), fecal coliforms (FC), fecal streptococcus (FS) were analyzed by membrane filtration (100 ml) technique by using 0.47 mm diameter, 0.45 µm pore size filters and absorbents (Gelman Sciences). For TC and FC membrane, lauryl sulfate (mLS) medium (PARK) was used and incubated at 35 and 44.5°C for 24 h, respectively; and all yellow colonies were counted as TC and FC. FS was detected using M Entrococcus agar which was prepared following APHA (1998); and all plates were incubated at 44°C for 24 to 48 h. All black colonies were counted as FS. Spread plate technique was used for *S. aureus* and heterotrophic plate count (HPC). From the original sample, 0.1 ml aliquots were spread- plated in duplicates on pre dried surface of manitol salt agar (MSA) (PARK) and incubated at 37°C for 24 to 72 h; golden yellow colonies were counted as *S. aureus*. Similarly for hetero-trophic plate count (HPC), plate count agar (PCA), (FLUKA) was used and incubated at 37°C for 24 to 48 h for all colony counting (WHO, 2006; APHA, 1998). All microbial analysis was done by following strict aseptic techniques of microbiology procedures.

Physicochemical analyses

Chlorine was determined by using the diethyl-p-phenylene diamine (DPD_1 and DPD_3) palin test, Wagtech international (0.1 to 1.0 mg/l) comparator disc-Wag-WE10210, Wag-WE10212 chlorine. Temperature and pH were also measured at the pool side by portable 370 pH meter JENWAY, EU. Turbidity was measured colorometrically using a spectrophotometer (DR/2010 HACH, Loveland, USA) at the laboratory following HACH instructions.

Statistical analysis

Statistical analysis of the data gotten was done by using SPSS version13 for windows and the data were compared with World Health Organization (WHO, 2006) guideline levels for outdoor swimming pools and British bathing water regulations of natural water bodies.

RESULTS AND DISCUSSIONS

Microbiological parameters

The highest mean TC (112.1±45.2) obtained from site 1A; not significantly different from site 1B) and the lowest mean TC (14.4±3.1) was obtained from site 3A). On other hand, the maximum mean FC (149.2 ± 72.8) was observed from site 2B and the lowest (7.9±3.4) from site 2A (Table 1). In addition to these, HPC was highest at site 3B while the least was from site 1B but, it is not significantly different from sites 1A, 3A and 2A (Table 1).

The high presence of total coliforms (TC) and fecal coliforms (FC) obtained might be as a result due to possible fecal accidental or deliberate contamination of the pools from the bathers and animals. Both are highly available in excreta of warm blooded animal. The presence of these organisms in the water sample indicates that recent fecal contamination of the pool water and the presence of inefficient treatment system (Al-Khatib and Salah, 2003). Weak controlling system observed on the related parameters (pH and turbidity) of swimming pools might be additional factor for the obtained results. For instance, weak disinfection process in the pool during sampling time, or the presence of turbidity by debris that serve as attachment sites reduce the efficiency of disin-fection process and may serve as source of nutrients for the growth of such microbes within the water system (Le Chevallier et al., 1981).

In addition, among the total 54 samples tested for indicator microbes, 81.5, 70.4, 79.6 and 96.3% were positive for total coliforms, fecal coliforms, heterotrophic plate count, and for *Staphylococcus aureus*, respectively (Table 2).

Samples from site 2 A main swimming pool and site 1B had relatively greater FC; this is might be due to high temperature from its source (thermal water) that favor the growth of FC since they can resist 44.4°C and the temperature is also comfortable for bathers (stay longer periods, may shade or discharge large amount of FC). Comparing the level of contaminants with the size of the pools, the teaching pools and the natural spa were relatively polluted than the main swimming pools. This might be associated with the size of teaching pool (smaller) and the large number of people (bather load) that hold at a time or per day than the main swimming pools plus the low awareness about hygiene in swimming. During sampling period, it was observed that all of the teaching pools and natural spa were relatively busy than that of the main. The pools were mostly occupied by people (trainees especially teenagers) with low level of swimming ability and experience. There is a consistent correlation between bather density and heterotrophic bacteria (Mood, 1977) and this can be related as, there is a possibility to drink and spit the water from the pool during their exercise of swimming; this will contribute a lot to discharge microbes from the body (body discharges like mucus from the nose, saliva, sweat, fecal matter and dead skin).

Furthermore, HPC also includes those microbes which are found in water as natural inhabitants, street and work place soil, dust, animal droppings, insects and others may contribute to the proliferation of heterotrophic microbes with in water body by serving as source of food and shelter. Overall high level of HPC>200 cfu/ml indicate that, the absence of proper pool monitoring and/or the result may also indicate failure of the

Table 1. Mean levels of TC, FC, FS, *S. aureus* and HPC counts of outdoor swimming pools ,2008 (n= 9 for each).

Parameter	Outdoor swimming pools					
	Site 1 (Addis Ababa)		Site 2 (Ambo)		Site 3 (Debre ziet)	
	Main A	Teach. B	Main A	Spa B	Main A	Teach. B
TC cfu /100 ml <10 cfu*	112.1±45.2^{a} HP	97.7± 34.2^{a} HP	43.8± 6.8^{b} P	46.2± 8.5^{b} P	14.4± 3.1^{c} LP	30.4± 16.1^{b} P
FC cfu /100 ml <1 cfu*	11.2± 4.2^{c} HP	13.1± 5.7^{c} HP	36.0± 8.1^{b} HP	149.9± 2.2^{a} VHP	7.9± 3.4^{c} HP	8.4± 3.0^{c} HP
FS cfu /100 ml <40 cfu*	3.22± 0.9^{c} S	4.1± 1.3^{c} S	9.1± 2.3^{a} S	11.7± 2.2^{a} S	6.6± 1.4^{b} S	4.0± 10^{c} S
S. aureus cfu /ml <1 cfu*	111.1±47.5^{b} VHP	231.1± 81.2^{a} VHP	62.2± 19.1^{b} VHP	226.7± 7.6^{a} VHP	26.8± 7.9^{c} P	24.6± 0.4^{c} P
HPC cfu/ml <200 cfu*	891.1±312.6^{c} P	497.7± 167.3 ^{c} P	943.3± 260.5^{c} P	1421.1± 352.6^{b} P	750± 215^{c} P	2261.1± 343.6^{a} HP
Total	16	16	14	16	12	14

*Standards of WHO; TC, total coliforms; FC, fecal coliforms; FS, fecal S*treptococcus*; HPC, hetrotrophic plate count; VHP, very highly polluted, value greater than 100x with the standard; HP, highly polluted, value greater than 10x and less than 100x from the standard; P, polluted, value greater than 3x but less than 10x from the standard; LP, least polluted, value between 1x-2x times greater form the standard; S, safe values relatively closer to the standard or less. Letters a, b, ab, c and d indicates their relative significance of the recorded values to the standard. Letter 'a' is highly significant than 'c'. Points are given for easy calculation VHP=5; HP=4; P=3; LP=2; S=0.

Table 2. Range values and frequencies of TC, FC, and FS, *S. aureus*, HPC of all swimming pools, 2008 (n=9 for each).

Bacteriological parameter	*Standard (WHO, 2006)								Total
	0*	>0	<10 cfu*	>10 cfu	<40 cfu*	>40 cfu	<200 cfu*	>200 cfu	54
FC/100 ml	16	38 (70.4%)							54
S. aureus/ml	2	52 (96.3%)							54
TC/100 ml			10	44 (81.5%)					54
FS/100 ml					54 (100%)				54
HPC/ml							11	43 (79.6%)	

*WHO, 2006 standards; TC, total coliforms; FC, fecal coliforms; FS, fecal *Streptococcus*; HPC, hetrotrophic plate count.

treatment process at the time of sampling (QGQH, 2004). This can be demonstrated by the 74.9% of the samples which were beyond the required level (HPC) and tell the poor hygienic condition of the environment. Low level of hygienic condition coupled with weak disinfection process was observed during sample collection. HPC measurements in water bodies are used to indicate the effectiveness of water treatment process, to measure number of regrowth organisms and to investigate aesthetic quality. Hence high level of HPC resulted due to the availability of nutrients, presence of optimum conditions like temperature and lack of sufficient level of free residual disinfectant and possible over growth of microbes (Table 3). Similar study in South America reveals that among the 60 swimming pools examined, 70.4% were positive for THC and it was observed positive relation among the levels of microorganisms, the bather load and the water temperature (Martin et al., 1992, 1995).

Analysis shows that for Fecal *Streptococcus* and *Enterococci, a*ll of the samples were containing less than 40 cfu/100 ml. High risk of infection might be resulted when the presence of FS in 100ml exceeds 40cfu (WHO, 2003; WHO, 2006).

In all the samples analyzed 96.3% of samples were found to be positive for *Staphylococcus aureus*

Table 3. Mean levels of physicochemical parameters of outdoor swimming pools and natural water bodies 2008 (n= 9 for each).

Physicochemical parameter	Outdoor swimming pools					
	Site 1 (Addis Ababa)		Site 2 (Ambo)		Site 3 (Debre Zeit)	
	Main A	Teach. B	Main A	Spa B	Main A	Teach. B
T°C	21.98±0.15[d]	22.89± 0.5[d]	30.4± 0.06[b]	35.2±1.1[a]	23.1± 0.6[d]	24.6±0.4[c]
pH	7.64± 0.22[c]	7.75±0.4[c]	6.8± 0.04[d]	6.5±0.08[c]	8.8± 0.03[a]	8.2±0.08[b]
Turbidity NTU	6.22± 1.5[b]	7.8± 2.12[ab]	9.9± 0.8[ab]	8.8±1.2[ab]	11± 0.8[a]	9.4±0.8[ab]
Free Cl_2 Mg/L	0.1± 0.0[c]	0.1±0.0[c]	0.1± 0.0[c]	0.1±0.0[c]	0.18± 0.02[a]	0.13± .02[b]

Letters a, b, ab, c, d indicates their relative significance of the recorded values to the WHO standard. Letter ‘a’ is highly significant than letter‘d’.

(Table 2). In this study, *S. aureus* count was relatively higher than fecal coliforms and fecal streptococci in all of the outdoor swimming pools. The result is supported from findings by Tosti and Volterra (1988). This shows that the presence of *S. aureus* and fecal indicators (FC and TC) in water shows that swimming pools examined contain both fecal and non-fecal contaminants. The higher percen-tage of isolation of *S. aureus* compared to fecal coliforms can be explained by the ecology of these bacteria as a normal inhabitant of the skin, nose, mouth and throat and its higher resistance to chlorine and environmental conditions (Croone and Tee, 1974; Alico and Dragonjiac, 1986; QGQH, 2004). Bathers can transport significant amounts of *S. aureus* to the water column, so this may indicate that bathers may not take proper shower (pre showering) before swimming to reduce the amount of bacteria that is shed per bather at a particular period of time (attributed to lack of hygiene of bathers before entering the water). The result shows the presence of incorrect management in swimming pools. Similar results have been reported by Esterman et al. (1984) in South Australia, Leoni et al. (1999) in Bologna, Italy; Marins et al. (1995), Hajjartabar (2004) in Iran and Rigas et al. (1998) in Greece.

The relative presence (amount) of *S. aureus,* in all of the tested outdoor pools shows that, site 1B is more polluted then followed by site 2b and site 1A. High FC count was obtained in the order from sites 2B, 2A and 1A, respectively. The least count was observed with low count in all except high HPC count in site 3B next site 2A and B. Specifically among the six pools, site 1A was highly polluted by TC. Among all tested microbial parameters, site 3A was least polluted, next to sites 3B and 2A. This might be due to the fact sites 3A and B pools uses filtration technique besides the disinfection processes hence this disinfection system might account for the low level of pollution (contamination) by microbes (Table 1).

Physicochemical parameters

Turbidity level in outdoor swimming pool samples was 75.9% which exceeds WHO guideline values (>5NTU) for turbidity. The sources of the observed turbidity may include presence of organic or/and inorganic suspended materials from street or working place soil, dust, pollen, microorganisms like algae etc. Since the pools are outdoor (exposed to every type of contaminants), particulate matters from the environment may easily fall or enter to the pools. Moreover the observed relatively high turbidity levels in the pool water might be the position of the pools which are near to the main road and the surrounding trees. The nature of source of water (ground water) may also contribute for higher value of turbidity besides the number of bathers. High level of turbidity levels might contribute for the shielding effect of microbes for proper disinfection (Table 3).

Analysis for the presence of free chlorine level for disinfection revealed that all samples contained free chlorine which is much less than the required level. Chorine is used as disinfectant in all of the swimming pools and must be present continually and in sufficient concentrations in order to protect against survival of newly introduced pathogens, but the reasons might be using less amount and concentration of chlorine which may be incomparable to the volume of water, presence of high level of organic matter, microbial load, higher temperature (chlorine easily evaporate) and remains unavailable. Generally, physicochemical parameters of the water have strong influence on the efficiency of disinfection process. Factors like pH, turbidity of the water, concentration of chlorine and contact time, influence the efficiency of disinfection with chlorine (Al-Khatib and Salah, 2003; Galal-Gorchev, 1996). The observed pH in the pools occurred possibly from nature of water source surface or ground water. Variation in pH was due to the type of water they used for example; thermal hot spring water (site 1 and 2), municipal water (site 2) and non thermal ground water (site 3).

Moreover, since all of the swimming pools uses Chlo-rine for disinfection, to increase the efficiency of chlorine, WHO (2006) recommends the pH of pool water between 7.2 and 7.8. The bacterial loads of the two lakes are within the recommended level of bacteriological load and both can be considered as safe for the time being (Table 4). However both lakes are under increasing threat from habitat deterioration because of accelerated human impact

Table 4. Comparison of physicochemical microbiological levels of Two natural bathing Lakes at DZ, 2008 (n=9 for each) with limit values.

Site	Physicochemical parameter							
	TC	FC	FS	HPC	*S. aureus*	Temperature (°C)	pH	Turbidity NTU
Lake Babogaya	73.2±7.6	37.7±5.7	103.3±32.7	2618.8±377.6	53.6±17.1	24.2±0.07	8.9±0.1	17.4±2.63
Lake Hora	117.8±24.3	44.3±9.55	66.8±8.0	1793.3±378.5	51.4±16.8	24.0±0.31	8.83±0.022	21.2±4.02
Limit Value* cfu/100m/	≤500	≤100	≤100	NA	NA	NA	NA	NA
Status	S	S	S					

NA, Not available; TC, total coliforms; FC, fecal coliforms; FS, fecal *Streptococcus*; HPC, hetrotrophic plate count; Temp, temperature; NTU, nephelometric turbidity unit. * The Bathing Waters (Classification) Regulations 1991. Statutory Instrument 1991. No. 1597. London: HMSO, 1991.

in and around the area. Hotels and resorts have already been built around the rims with more to be constructed in the future. These lakes are used by local inhabitants other than recreation; sustainable waste management is highly required to safeguard the possible health hazard that may come as a result of recreation. Lake Babogaya is facing the possible danger of environmental degradation.

Conclusion

The bacteriological results of the outdoor swimming pools showed that most of the bacteriological parameters measured were not in harmony with the reference values set out by WHO (2006). Among the sample site, water samples from site 2B were very highly polluted. Moreover, the physicochemical parameters measured, free Chlorine, turbidity of the swimming pools were not in accordance with WHO limit values. The problem might result from the synergetic effect of absence of strict regulations, monitoring (supervision) and control system. This situation could result in health related hazards for the swimmers and the surrounding communities due to the spread of pathogenic microorganisms, including opportunistic pathogens.

The findings from this study indicates that since swimming pools and spas are expanding in the country, water use for recreational purpose should have to be enforced with quality control guidelines, standards and limit values. Moreover, users need to be properly trained and as well as provided with basic sanitation and hygienic protocols during swimming which will reduce the potential hazards that may mabe encountered during swimming.

In other to minimize the health risks, not only swimming water samples must constantly be checked for water but also further studies using advanced techniques are required on other recreational water bodies in the country.

Conflict of Interests

The author(s) have not declared any conflict of interests.

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