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Research Article
Coliform Bacteria Contamination in Chlorine-treated Swimming Pool Sports Complex

[1]Carolyn Payus, [2]Imelda Geoffrey, [2]Khairul Amrie and [3]Alvin Oliver

[1]Water Research Unit, Faculty of Science and Natural Resources, Universiti Malaysia Sabah, Kota Kinabalu, 88400, Sabah, Malaysia
[2]Natural Disaster Research Centre, Universiti Malaysia Sabah, Kota Kinabalu, 88400, Sabah, Malaysia
[3]Faculty of Medicine and Health Sciences, Universiti Malaysia Sabah, Kota Kinabalu, 88400, Sabah, Malaysia

Abstract

Background and Objective: Sufficient amount of chlorine is needed to be maintained in the pool as not only the adult go for swimming but also children with more sensitive skin. This study was conducted to determine the presence of coliform group of bacteria which involved faecal coliform and *Escherichia coli* as microbial indicators for water quality contamination in the Sports Complex swimming pool water that is treated with chlorine disinfectant. **Materials and Methods:** Identification of faecal coliform and *Escherichia coli* were done through Membrane Filtration Method from APHA standard. The amount of free chlorine content in the swimming pool were also analyzed using HACH Spectrophotometer in order to relate the reactions of the supplied free chlorine towards the number of the microbial colonies inside the swimming pool. **Results:** The result shows that the outdoor swimming pool has a higher concentration for both faecal coliform and *Escherichia coli* compare to the indoor swimming pool and the highest concentration of faecal coliform can reached 266±64.65 CFU 100 mL^{-1} and *Escherichia coli* up to 113±57.40 CFU 100 mL^{-1}. This showed that coliform bacteria still presence in the swimming pool at the sports complex although it has been treated with chlorine disinfectant. In a meantime, for the free chlorine content it showed that the average concentration in outdoor pool were recorded lower at 0.492±0.531 mg L^{-1} which was way below the minimum limit 1.0 mg L^{-1} of the permissible NSPF standard, whereas indoor pool were recorded at 1.069±0.585 mg L^{-1}. **Conclusion:** The microbial presence and chlorine content in indoor swimming pool can be said more hygienic and cleaner to swim compare to the outdoor.

Key words: Coliform bacteria, faecal coliform, *Escherichia coli*, free chlorine, HACH spectrophotometer, membrane filter method, swimming pool, water quality

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Corresponding Author: Carolyn Payus, Water Research Unit, Faculty of Science and Natural Resources, Universiti Malaysia Sabah, Kota Kinabalu, 88400, Sabah, Malaysia Tel: +6-088-320-000

Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Adding the right amount of chlorine in the swimming pool can be a tough balancing act as there is no proper standard or amount that can be followed by the pool operators. Regardless of how frequent and what type of pumping system that should be used also never been mentioned and recommended by any neither international nor national standards. Any higher concentration of chlorine in the swimming pool water will start to run the risk of red eyes and swimmers especially children with itchiness and skin rashes. Nevertheless lower concentration of chlorine will built up higher organic materials and bacteria in the swimming pool that can cause waterborne disease. Therefore, the important of this research finding are very relevant as it is to provide the information on the amount of free chlorine in the swimming pool and their effects towards the presence of the microbial coliform bacteria. Furthermore, the significance of the research study is to measure the effectiveness of chlorination of swimming pool water under varying conditions especially on consideration on what is the proper amount and type of chlorine need to be used on the swimming pool.

In a meantime, swimming pool sports complex is one of the main attractions to public use as a centre for recreational activity, sports and healthy lifestyle[1-3]. It provides swimming pools for public with affordable and cheaper entrance fee compare to swimming pools provided by others such as hotels and resorts which are way more expensive. Thus, many people tend to come and choose the Sports Complex swimming pool for swimming. Although physically the swimming pool at sports complex seems well maintained, but it does not ensure that the amount of chlorine in the pool is safe to be used and monitored properly. In addition, there are not only adult that go for swimming, but also the children. Children have more sensitive skin as their skin is still growing and young, thus need to be protected from harmful chemical like excessive chlorine[4-6]. Recent studies shows that amount of free chlorine in the swimming pool may give side effects to the swimmers due to the formation of chlorine by-product because of the chemical reaction from the chlorine with the water and other organic materials[7].

Swimming pool is a huge artificial basins or large paved holes containing water for swimming. According to Edzwald[8], the swimming pool water should follow the potable water standard by being transparent, odorless and tasteless liquid having a freezing point of 0°C and boiling point of 100°C. In previous research stating that people with infections of any kind should not be allowed entry into the pool[9]. The quality of swimming pool water can be contrived by the transmission of contagious diseases. The infections from swimming pool can be presence due to poor and lack of cleaning of the swimming pool. It is reported that a swimming pool can be infected with pathogenic microorganisms infiltrating the pool either directly or indirectly by contaminated air, soil, dust, rain water, sewage, human or animal excrement and individual bathers[10]. Unless the water is sufficiently treated, contamination may lead to outburst of diseases, such as skin ulcers, gastroenteritis, conjunctivitis, trachoma, ear infection such as otitis media, cholera, dysentery, eczema and skin rashes[11]. In spite of these, operations should ensure an optimum water quality and maintenance of good hygiene by the use of disinfectant such as chlorine. According to Yue *et al.*[12], chlorination is the most well-liked method as it is cost effective and relatively reliable. Swimming pool is open for public usage where it can accommodate more than hundreds of people makes it as a good transmission tool for infectious disease[13]. Faecal matter was introduced into the swimming pool when an individual has an accidental faecal release or when residual faecal material on the swimmers body is washed into the pool and also when the pool treatment system having a leakage. Whilst non-faecal human shedding likes vomit, mucus, saliva or skin in the swimming pool is also a potential source of pathogenic organisms[14]. The presence of *Escherichia coli* (*E. coli*) in swimming pool water is a signal that faecal material has infiltrate the pool water from contaminated skin or from faecal material that has been accidentally or knowingly released. It also indicates that the treatment has failed to remove this contamination. Microbiological evaluation which involving a test of indicator bacteria has been the most reliable method in quality control and assessment of swimming pools[15]. As indicators of faecal pollution, their existence is a strong indication of the presence of enteric pathogenic bacteria, such as *Salmonella typhi*, *Salmonella paratyphi*, *Shigella dysenteriae*, *Vibrio cholerae* and parasites in the pool. Therefore, the aim of this study it is necessary to monitor the level of microbial quality in the pool as it is the most crucial for public health.

MATERIALS AND METHODS

Study area: Sports complex L that chosen involved the indoor and outdoor swimming pools which is open for public use. The indoor pool is with olympic size standard swimming pool, approximately 50 m length and width of 25 m with 1.8 m of depth. Whereas for the outdoor pool, the length is 29 m and the width is 11 m with depth of 0.6-1.8 m which is mainly for children as shown in Fig. 1-3.

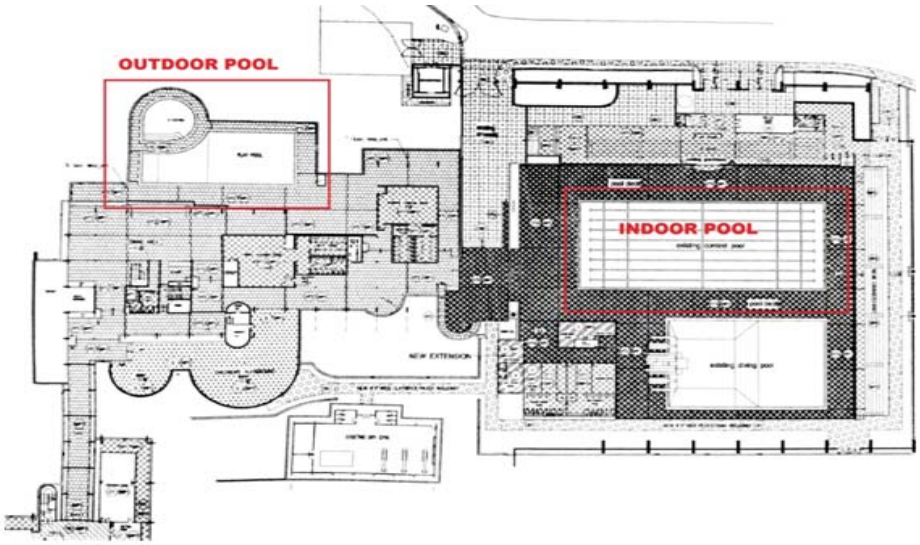

Fig. 1: Indoor and outdoor swimming pool at L sports complex
(Source: Ministry of Culture Youth and Sport Malaysia, 2017)

Fig. 2: Olympic standard indoor swimming pool

Coliform bacteria concentration analysis: The water samples of indoor and outdoor swimming pools were taken at 15-30 cm below the surface water[16] according to the depth of the sampling point involved at the pool. The sampling times were conducted both during morning and evening and sampled weekly on Sunday and Tuesday based on the chlorine and cleaning schedule of both pools, to see how the free chlorine can sustain and maintain in the swimming pool from morning till evening and after the cleaning on Monday and to see how chlorine content will affect the microbial concentrations in the pool. This research has more advance study and different compare to the studies done by Ekopai *et al.*[17] and Yedeme *et al.*[18], which both previous studies only conducted the sampling and measurement for the coliform colonies but not the chlorine concentrations measurement at the pool as this research does. Furthermore, unlike this research, in Ekopai *et al.*[17] and Yedeme *et al.*[18] sampling measurement is based on weekly basis (periodical sampling) and for this research is on time basis (time-scale sampling), where at this research the coliform colonies and

Fig. 3: Outdoor swimming pool for children

chlorine concentrations been measured twice a day during morning and evening to determine how the free chlorine can sustain and maintain in the swimming pool from morning till evening. Sampling in this research also conducted along with the existence of bathers or the swimmers in the pool unlike[17,18]. In this research it is also to identify the life span of the supplied chlorine inside the swimming pool and to relate their reactions towards the number of microbial colonies.

The method used in identification of faecal coliform and *E. coli* from the both indoor and outdoor swimming pools was the membrane filter technique standard method by APHA[19] which will give a total coliform of colony forming unit (CFU) per 100 mL of the sample[20]. The samples taken were analyzed with the membrane filter technique by the membrane filter unit which was wrapped with the aluminium foil and sterilized. The membrane which was used for the filtration was placed on the Membrane Lauryl Sulphate (MLS) media culture on the Petri dish which was then put into sterile. Then, the Petri dish was incubated for approximately at the temperature of 44±0.5°C for both faecal coliform and *E. coli*. After 24 h, colonies with yellow and pink colonies were counted by using colony counter and the formula is at the following:

$$\frac{\text{Faecal coliform}}{(\text{CFU/100 mL})} = \frac{\text{Number of coliform colonies count}}{\text{Volume of original sample filterd}(\text{mL})} \times 100 \quad (1)$$

Free chlorine content analysis: This study was carried out from 11 November, 2016 till 28 November, 2017. The water samples of indoor and outdoor swimming pools were taken for 4 months of samplings which were November, 2016, March, 2017, July, 2017 and November, 2017 based on alternate time range of sampling months and the research done for total period of 1 year. These samples were analyzed using the spectrophotometer Hach kit model HACH DR2800 using method 8021 with wavelength of 515 nm[21]. The samples taken from the pool were transferred to the cuvette about 10 mL and DPD free-chlorine powder pillow was added. The procedures of using the spectrophotometer were followed using the method in Fig. 4.

RESULTS AND DISCUSSION

As shown in Table 1 and 2 below show the results of bacterial count on faecal coliform and *E. coli* obtained using APHA standard method Membrane Filter Technique. Based on the National Water Quality Standards by the Malaysian Department of Environment (DOE), none of the monitored sampling points for both indoor and outdoor swimming pool fulfilled the requirement of Class I quality with coliform counts <10 CFU/100 mL although both pools are been treated and disinfectant by chlorine by the operator. However, overall the swimming pools of the sports complex were classified under Class IIB with faecal coliform<400 CFU/100 mL, that is suitable for recreational use with body and physical contacts but not for drinking purposes.

From the results, it showed the overall average concentration of faecal coliform and *E. coli* contents

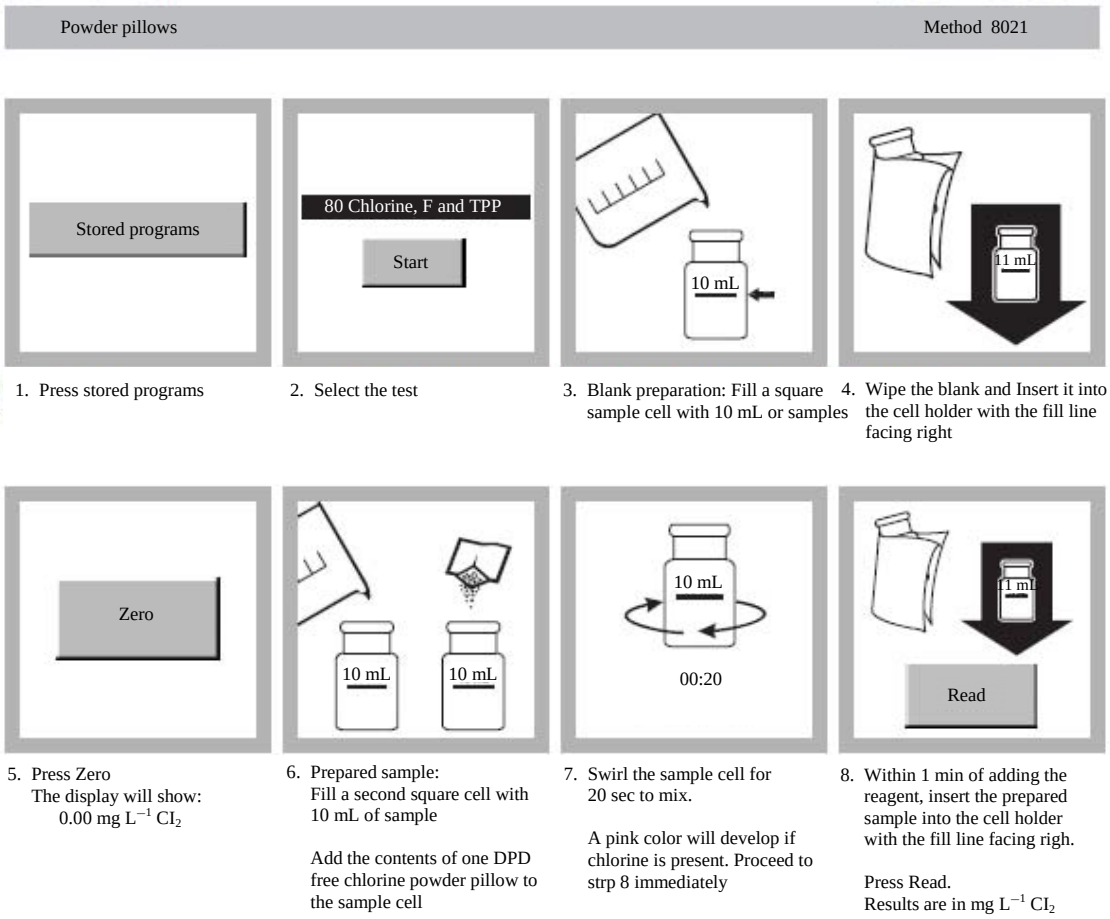

Fig. 4: Procedure of using spectrophotometer HACH DR2800
(Source: HACH DR2800 manual, 2017)

Table 1: Faecal coliform (CFU/100 mL) for indoor and outdoor swimming pool sports complex

	Faecal coliform count (CFU/100 mL)			
	Outdoor Pool		Indoor Pool	
Sampling months	Morning	Evening	Morning	Evening
1	266±64.65	92±38.89	86±01.41	65±28.99
2	98±38.18	191±67.70	187±82.23	73±43.13
3	47±36.65	43±14.85	29±14.14	18±55.15
4	39±27.58	15±07.78	6±04.24	26±02.82

Table 2: *Escherichia coli* (CFU/100 mL) for indoor and outdoor swimming pool sports complex

	E. coli count (CFU/100 mL)			
	Outdoor pool		Indoor pool	
Sampling months	Morning	Evening	Morning	Evening
1	113±57.40	24±03.54	32±07.07	24±08.49
2	43±18.38	82±19.80	69±41.22	30±29.70
3	29±24.04	11±12.73	2±03.54	5±55.86
4	9±16.26	0±00.00	0±00.00	4±06.36

in outdoor pool were recorded as follow 98.88±2.51 CFU/100 mL for faecal and 38.88±18.18 CFU/100 mL for *E. coli* which was under the Class IIB standard. Whereas indoor pool were recorded at 61.25±29.70 CFU/100 mL for faecal coliform and 20.75±2.73 CFU/100 mL still in the range of permissible limit.

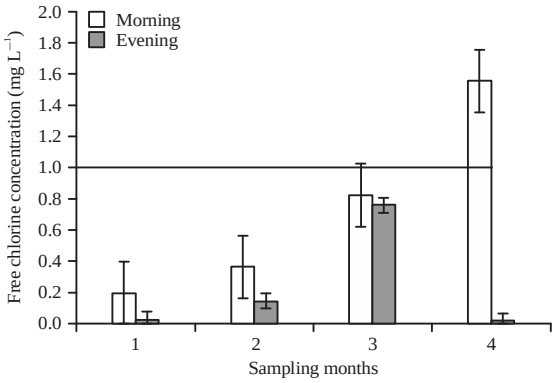

Fig. 5: Free chlorine concentrations in outdoor swimming pool (Mean±SE)

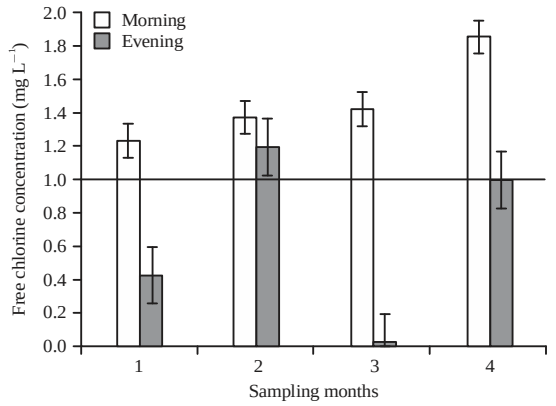

Fig. 6: Free chlorine concentrations in indoor swimming pool (Mean±SE)

It can be seen that the faecal coliform and *E. coli* contents are much higher in outdoor swimming pool compare to indoor pool. It is believe due to the free chlorine concentrations in outdoor swimming pool are low as shown in Fig. 5 and 6 and most of the readings are below the minimum permissible limit set by the National Swimming Pool Foundation (NSPF)[22] which must be above 1 mg L^{-1} have caused higher contaminations of faecal coliform and *E. coli* at the outdoor pool. It is recorded the overall average free chlorine concentrations in outdoor pool was at 0.49±0.13 mg L^{-1} and for indoor pool at 1.069±0.59 mg L^{-1}. This indicates that the chlorine contents in outdoor swimming pool were insufficient to disinfect microbial bacteria thus have caused higher bacteria coliform in the outdoor pool[23]. It can also be said that the outdoor pool is unhygienic which harmful bacteria, algae and other microbes can quickly multiply in water because of lack cleansing ability due to the lower concentrations of chlorine[24].

The comparison between the growth of both faecal coliform and *E. coli* for morning and evening, where the morning has higher growths for both microbial bacteria for both indoor and outdoor pool with overall average of 94.75±0.35 CFU/100 mL for faecal coliform and 37.13±0.13 CFU/100 mL for *E. coli*, compared to the evening recorded at 65.38±0.67 CFU/100 mL for faecal coliform and 22.50±0.03 CFU/100 mL for *E. coli*. From the observation, in the morning both pools indoor and outdoor have higher swimmers compared to evening as the swimming lesson normally scheduled in the morning. In Osei-Adjei *et al.*[25] stating that a swimming pool may be infected with pathogenic microorganisms entering the pool either directly or indirectly through contaminated human or animal excrement such as feces and urine from the swimmers. At the same time, in the morning chlorine content is just starting to be pumped into the swimming pool causing their disinfectant reaction with the microbial bacteria slow compared to the evening. This explained the concentrations of free chlorine in the evening much lower compared in the morning as most of the chlorine has been used for disinfection reaction purposes causing the microbial bacteria counts decreases in the evening. Decreasing of free chlorine concentrations in the swimming pool can also be related to human body excretions that continuously accumulate in the pool that was decreased the chlorine in the evening compared to the morning[26,27] as shown in Fig. 5 and 6.

Higher number of swimmers means that the amount of contaminations introduced in water will increase due to the organic and inorganic material significantly increased with number of swimmers[28]. The reduction of free chlorine in evening can also be due to the demand of chlorine amount consumed by oxidation or substitution reactions with inorganic and organic materials, such as H_2S, Mn^{2+}, NH_3, amino acids, proteins and carbohydrates from surrounding. Besides Guidaa *et al.*[29] added that at the range of 0.094-16 mg L^{-1} of total organic compound (TOC) which is 99.4% is actually related to number of swimmers. High number of swimmers in the swimming pool causing higher amount of TOC in the water. In addition, it also reported that the swimming pool water contained higher levels of organic compounds compared to TOC in tap water, which is due to the human inputs[30]. The presence of high TOC levels in raw water supplies produce undesirable effect where it reacts with chlorine causing an in-effective for disinfection[31]. When the concentration of free chlorine is too low, the risk for bacterial growth and infection disease to swimmers will increase because the concentration of chlorine is not enough to eliminate the microorganisms in the pool. Based on Fig. 5 and 6, for both indoor and outdoor swimming pool, the reading obtained for free chlorine concentrations in the morning are above the minimum NSPF limit (1.0 mg L^{-1}) and still in the

range of permissible limit. However in evening, the free chlorine concentrations for most of the sampling months have decreased until below the minimum permissible limit.

CONCLUSION

It can be concluded that the concentration of both faecal coliform and *E. coli* were detected higher in outdoor swimming pool compared to indoor pool. Apart from that, there is a different in the microbial bacteria growth in the morning which is recorded higher compared to morning. Overall concentrations for both faecal coliform and *E. coli* in this study comply the Interim National Water Quality Standards for Malaysia under class IIB for Recreational use of body contact which only allowed 400 colonies per 100 mL. For the free chlorine content, it is found that the indoor swimming pool is more hygienic and cleaner to swim compared to the outdoor pool as the chlorine at outdoor pool recorded way lower than the minimum permissible limit by NSPF.

SIGNIFICANCE STATEMENTS

This study discovers the possible existence and life span of chlorine contents inside treated swimming pool sports complex that is used not only for adult but also for children. The data from this study is beneficial for developing database and the standard on how much exactly the amount of chlorine concentrations that need to be put inside the swimming pool by the operator as till now there is no right amount or no proper standard from the government or policy makers to avoid excessive chlorine thus higher bacteria in the swimming pool.

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