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Risk Assessment for Presence of Pathogens in Swimming Pools in Mumbai Suburban District

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Abstract: ***Swimming pools availability in modern residential complexes in Mumbai suburban district (MSD) has increased recently. The present paper attempts to assess the risk of swimmers' exposure to pathogens in ten pools in MSD. Pool water samples (30) were assessed for Total Heterotrophic Count (THC) and presence of pathogens. Results revealed THC did not comply with limits permitted in some pools. The pathogens isolated from pools included Salmonella paratyphi A, Pseudomonas aeruginosa, Staphylococcus aureus, etc. This study thus reveals the presence of potential pathogens and lack of public awareness among swimmers about risks associated with swimming in ill maintained pools.***

Keywords: MSD, pathogens, RWIs, swimming pools, THC

1.Introduction

A swimming pool is a construction of defined dimensions to hold water for swimming purposes or water related recreational activities. New residential projects are being constructed by modern reputed builders equipped with superior amenities like swimming pools, club house, Gym etc. in residential complexes in Mumbai Suburban District (MSD) regions, Maharashtra, India - like Ghatkopar, Mulund, Goregaon, Andheri, Kandivali, Borivali etc making these regions a sought-after residential destination in MSD.

The lifestyle of modern generation people in urban areas is stressful and with the increasing health consciousness amongst them, taking to swimming as a sport to keep fit has become extremely popular. Swimming is an excellent way to work out the entire body and cardiovascular system and can decrease the risk of chronic illnesses or lifestyle related illnesses like diabetes and heart disease. [**1]**

However, swimming in a pool also has few negative impacts. In many complexes in MSD, non-users refuse to pay the recurring cost of swimming pool maintenance which leads to improper maintenance of pools. Overcrowded pools are likely to harbour pathogens. Presence of organic material derived from bird droppings, rainwater, decaying leaves etc. can reduce the water quality further. . Accidental Fecal Release (AFR) can introduce pathogens in the pools due to uncontrolled defecation in the pool. Researchers have found that swimming diapers lack protection and can release microparticles as soon as a child takes to the water **[2].**

Disinfection of pool waters is most commonly done by chlorination. This may suggest safety in swimming in pools with excess chlorine. Chlorine when in excess can form disinfection by-products (DBPs) when combined with agents present in pool water like urine, saliva, perspiration, feces and even sunscreens and cosmetics. DBPs are absorbed via the skin and can be swallowed. As chemicals evaporate into air and are inhaled can lead to DNA damage. Studies report a rise in risk of cancer in humans exposed to DBPs [**3]**.

The findings of a survey undertaken by Maharashtra Pollution Control Board (MPCB) to evaluate the Residual Chlorine concentration in Swimming Pools during 30th May 2006 to 3rd June 2006 at various private clubs, hotels etc. in and around Mumbai reveal that of the 32 places checked by MPCB Central Laboratory, 27 places had excess Residual Chlorine than the limit of 0.2 -0.5ppm. [22]

Kids are at greater risk for suffering from respiratory illnesses by swimming in chlorinated pools A swimming pool in Germany might have ten times lesser chlorine compared to the United States **[4]**.In a study involving 800 teenagers from Belgium revealed that they were at greater risk to suffer from hay fever, asthma, and other allergies by swimming longer in chlorinated pools. However, this risk was greatly reduced in teens that swam in copper-silver solution disinfected pools **[5].**

With the lack of good personal hygiene or neglecting the need to shower before entering the pool, or continuing to swim even when suffering from gastrointestinal infections, swimming pools in MSD are increasingly becoming a potential source of infection to pool users. In fact, unclean infectious swimming pools have forced the closures (maybe temporarily) of many public swimming pools. Even with proper disinfection of pools, pathogens can survive in the water. So there is reason for concern about the potential risks that swimmers can be exposed to. This epidemiological study thus is an attempt to bring to light the problems associated with the increasing number of swimming pools and the lack of awareness amongst swimmers about the hygienic status of the pools thus rendering them prone to illnesses caused primarily by presence of pathogens in the pools besides the dangers of DBPs.

The bacterial investigation includes the determination of viable bacteria (THC) and the isolation and identification

of potential bacterial pathogens from the swimming pool waters.

2.Materials and Methods

For investigating the health hazards and the emerging threat of swimming pools posing the risk of contracting infections termed broadly as Recreational water illnesses (RWIs), 10 swimming pools from Mumbai Suburban District were studied. From these pools, 30 samples were collected for analysis at random points during heavy bather load over different periods of time over two years.

0.2ml of 10% Sodium thiosulphate was added to the sample collection bottle of 250 ml capacity for de-chlorination of water. Sterile plastic bottles were dipped about 1 meter deep from the top to collect samples leaving ample air space (at least 2.5 cm) at the top for proper mixing. The samples were analysed in four hours of reaching the laboratory. In the event of any delay, samples were refrigerated till 18 hrs at the most till analysis.

Location of the pools: The ten pools selected for the study were located at residential complexes in Mumbai Suburban district over regions like Mulund, Ghatkopar, Chembur, Santacruz, Bandra, Oshiwara, Goregaon, Malad, Kandivali, Borivali The pools were coded as S 1 to S10.

Checking public awareness about pools: Survey carried out to check awareness amongst swimmers -Google forms were filled to check the responses of around 163 swimmers using the pools during the study period

Total Heterotrophic count (THC) - Determination of the total number of viable organisms (culturable) of the dechlorinated water samples was done. Representative samples were collected from each pool, in clean dry containers used to obtain dechlorinated (using Sodium thiosulphate) water separately, during the peak load periods from those areas of the pool where most of the bathers had congregated.

Plate Count Method using Sterile Glucose Yeast Extract Agar in triplicates was used to compare the THCs of dechlorinated water samples [**6] [7]**.

Isolation of Bacteria - Culturable bacteria were isolated from the water samples Sterile Trypticase Soya Agar and Sterile Nutrient Agar. Purified representative colonies were named 1 to 16 and maintained on Nutrient agar slants. Each isolate was further grown on various differential and selective media such as Sterile Pseudomonas Asparagine Broth, Sterile Cetrimide agar, Sterile Mac Conkey's agar and Sterile Salt Mannitol Agar (Hi -Media) to help in preliminary identification. **[8] [9]**

Biochemical analysis – Studies on the biochemical characteristics of the isolates were next done to identify the isolates. Sixteen representative bacterial isolates obtained from the pool water samples were identified by comparing the observed biochemical results with the standard biochemical results from Bergey's Manual of Systematic Bacteriology [**10]**.

3.Results and Discussion

Checking public awareness about the hygiene status of pools: Unfortunately, people are unaware of the potentially increasing risks that swimming pools can harbour especially when the quality of maintaining the pools is on the decline. In a survey conducted among the 163 swimmers using the above pools, the key findings were that 16% believe that pool water is safe , 46% of respondents believe they are likely to get ill from swimming in a pool, 56% were not taking a shower before entering the pool and 79% agree one should never swim when ill with diarrhea. These responses highlight the lack of public awareness of the risks associated with swimming in ill maintained pools and the possibility of presence of pathogens in the pools or the associated dangers of acquiring RWIs while swimming in such pools.

Bacteriological Assessment:

The Microbiological Guidelines and Standards for bathing water followed Worldwide (including India as per IS: 3328: 1993, Indian Standards) are provided in Table 1. Recommended frequency of microbiological sampling and analysis for swimming pool water is once in a month.

Table 1: Microbiological Guidelines and Standards for bathing water followed Worldwide (including India as per IS: 3328: 1993, Indian Standards **[11]**)

Parameter	Guide level	Target Level
Total Viable Count (THC)	≤ 100 per ml	

Determination of Total Heterotrophic count (THC)of Swimming pool water.

Appropriate care was taken while collecting samples for total heterotrophic count (THC) from the pools. To prevent the loss of thiosulfate during sample collection, it is recommended to follow normal analytical "resuscitation" procedures as the bacteria in pool water samples and especially those from disinfected pools might be "injured, ". However, resuscitation was not carried out.

The microbiological guidelines and standards of bathing water state that, the total viable count of swimming pool water should be less than 100 cfu/ml. **[12]**

The Samples S8 and S5 meet the microbiological guidelines and standards of bathing water followed worldwide for this parameter. In spite of resuscitation procedures not being carried out, the THC is highest for Sample S7 and lowest for Sample S8 as shown in Fig 1 . Of all the ten pools, eight of them failed to meet the standards put forth by WHO, thus indicating the poor hygiene status of these pools and poor pool management. Similar findings have been reported in a study conducted by comparing bacteriological assessment among pools in commercial and residential sectors in Mumbai. [**13]**

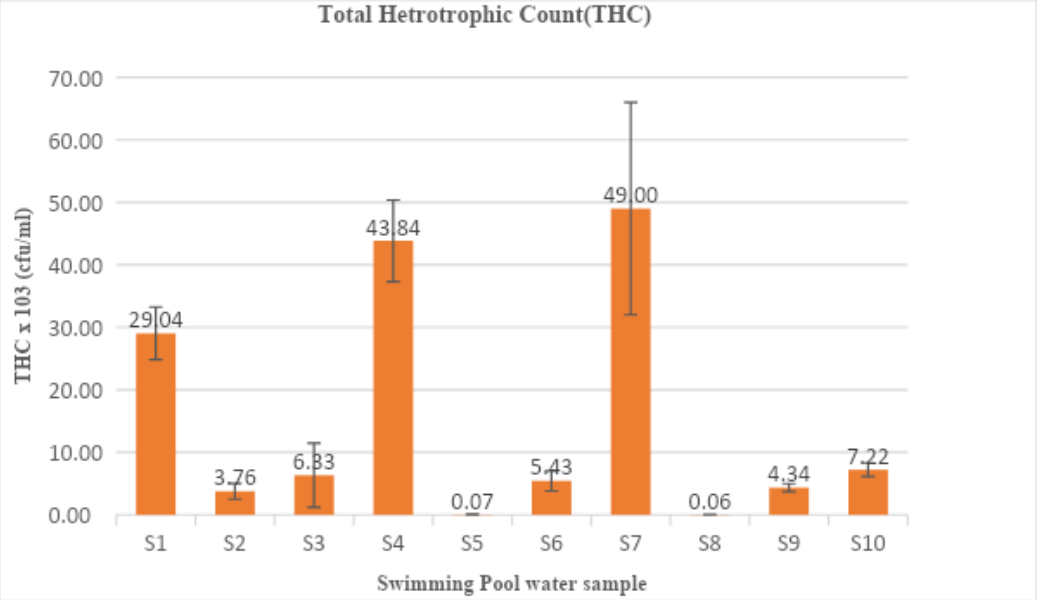

Figure 1: Total Heterotrophic Count (THC) of swimming pool water samples

4.Discussion

Microorganisms can be introduced from body secretions including sweat, cosmetics, sun screen lotion, urine, saliva, accidental vomit in the pool. It is also likely that organisms enter the pool via the swimmer's body from the bathroom, unclean swimming pool premises, damp lockers, floor etc. The problem is worsened when the bathers don't follow the guidelines of the swimming pool such as taking a shower before entering the pool, abstaining from swimming when suffering or recovering from infectious diseases etc.

Apart from the organisms isolated in the preliminary tests of this study there have been many studies carried out in the past which suggest that the range of organisms contaminating pool waters is very wide. In the period from 1997–2005, the susceptibility and microbiological quality of bacterial isolates derived from pool waters in North-western Greece were investigated. 462 water samples were collected from various sources. All water samples were assessed for the presence of protozoa, bacteria, and fungi and bacterial isolates were subjected to susceptibility tests. Sixty-seven percent of the samples complied with the microbiological standards while 32.9% failed to do so. Out of 107 bacterial isolates, 38 (35.5%) were resistant to antibiotics. Multi-drug resistant *Staphylococcus aureus, Pseudomonas alcaligenes*, *Leuconostoc* and *Staphylococcus wernerii*, *Chryseobacterium indologenes* and *Ochrobactrum anthropi*, *Pseudomonas aeruginosa*, *Pseudomonas fluorescens* as well as *Enterobacter cloacae*, *Aeromonas hydrophila*, *Klebsiella pneumoniae* and *S. aureus* (from hydrotherapy pool) and *A. hydrophila* (isolated from hotel pool) were detected. 12.1% of the samples was found to possess poorest microbiological quality (THC ≥500 cfu/ml), while in 6% of the samples *P. aeruginosa* count was ≤1500 cfu/100 ml and the hydrotherapy pool had highest prevalence of multi-drug resistant isolates (73.6%). [**14]**

Biochemical Identification of the isolated strains

By observing the morphological and cultural characteristics of the purified representative isolates on selective and differential media used viz. St. Pseudomonas Asparagine Broth, St. Cetrimide Agar (CA), St. MacConkey's Agar (MA), and St. Salt Mannitol Agar (SMA) and St. Nutrient Agar (NA) and on comparing the observed biochemical results with the standard biochemical results from Bergey's Manual [**15]**, the organisms were identified as follows as shown in Table 2:

Table 2: Identification of the isolated organisms

Water Sample No.	Isolate No.	Identified Bacterial isolate	Medium picked up from	Gram nature and morphology	Growth Characteristics on Nutrient Agar
S-1	1	*Staphylococcus aureus*	NA	Gram positive cocci in bunches	Golden yellow colonies
S-2	2	*Salmonella typhi*	MA	Gram negative bacilli	Pale colonies
S-3	3	*Enterobacter*	MA	Gram negative rods	pink colonies
	4	*Staphylococcus aureus*	SMA	Gram positive cocci in clusters	yellow colonies
S-4	5	*Pseudomonas fluorescens*	CA	Gram negative bacilli	Yellowish translucent colonies
S-5	6	*Pseudomonas aeruginosa*	CA	Gram negative rods	Translucent bluish colonies
	7	*Bacillus cereus*	NA	Gram positive rods	Creamish opaque colonies
S-6	8	*Staphylococcus epidermidis*	SMA	Gram positive cocci in bunches	Pink colonies

S-7	9	*Proteus mirabilis*	MA	Gram negative short rods	creamish colonies
	10	*Salmonella paratyphi A*	MA	Gram negative bacilli	Colorless translucent colonies
S-8	11	*Escherichia coli*	MA	Gram negative short rods	Pink colonies
	12	*Escherichia coli*	MA	Gram negative short rods	Pink colonies
S-9	13	*Proteus vulgaris*	NA	Gram negative short rods	Swarming creamish colonies
	14	*Pseudomonas aeruginosa*	CA	Gram negative rods	Bluish green colonies
S-10	15	*Klebsiella pneumoniae*	MA	Gram negative rods	Mucoid pink colonies
	16	*Proteus mirabilis*	MA	Gram negative short rods	Pale colonies

Note: All the obtained 16 isolates were maintained on NA slants for further investigations.

The detection of such pathogens makes swimming pools potential reservoirs of several infections **[16] [17]**. Most of the identified isolates have the potential to cause a variety of illnesses that could include opportunistic skin infections, pneumonia, chronic Broncho-pulmonary disease, urinary tract infection, wound infection, pyelonephritis, skin infections, boils, eye stye, eye infections and empyema, gastrointestinal and urinary tract infections, respiratory infections, otitis externa also known as Swimmer's ear, dermatitis, folliculitis, wound infection, corneal ulcers and various other skin infections, enteric fever, bacteraemia, skin and soft tissue infection, etc.

Discussion

In a study conducted in Shahrekord, Iran, the average Chlorine levels and pH of the pools under the study were 1.62 mg/L and 7.8, respectively. The samples showed the presence of *Pseudomonas aeruginosa*, *Escherichia coli*, *Staphylococcus epidermidis* and *Staphylococcus aureus*. The study suggested that improvement in the environment and hygiene behavior of the swimmers can be effective in reducing the bacterial contamination of the pools. **[18]**.

In **Mumbai** itself, the swimming pools of commercial and residential sectors [(twenty samples (n=20)] were assessed bacteriologically for their THC, Coliform counts and to detect presence of pathogens especially *Pseudomonas aeruginosa*. Amongst commercial sector pools, THC ranged from 0.16 - 8.01 × 10^5 cfu/ml while for residential sector pools, THC ranged from 2.22 - 4.1 × 10^5 cfu/ml, which were high compared to WHO standards limits. *Pseudomonas aeruginosa* was found to be present with a greater frequency of occurrence (80%). This study thus drew attention for proper management of public swimming pools in an urban city like Mumbai. **[13]**

The source of the infection for folliculitis outbreak caused by *Pseudomonas aeruginosa* serotype O:7 among the guests of a hotel in St. John's, Newfoundland, Canada was traced to the hotel whirlpool. This outbreak was the foremost one which incriminated *P. aeruginosa* serotype O:7. **[19]**.

A similar study where bacteriological analysis of randomly selected pool waters in Kampala city, Uganda, showed that of the 13 pools studied 69.2% had high total (aerobic) plate count values of up to 6.35 x 10^5 cfu/ml and the lowest was 3 x 10^1 cfu/ml which failed to comply with the Ugandan standards. The study suggested the need to improve public awareness for hygiene amongst swimmers **[20]**.

Seasonal changes also have an impact on the bacterial load and level of pool water contamination. In Teheran, hundreds of people use many large and small public outdoor and indoor swimming pools, especially on hot summer days. Over a one-year period (2001-2002), the bacteriological quality of eleven public swimming pool waters was investigated to assess if these posed health risks to users and the exposed people were monitored. It was to be noted that *Pseudomonas aeruginosa* was isolated from nine (81.8%) of those pools and was able to thrive in seven (63.6%) of the swimming-pool water samples. In two (18.2%) other samples, in addition to *P. aeruginosa*, the total bacterial count, total number of coliform counts were also found to be very high. Ear swabs were collected from 179 users with a history of ear infections two weeks before swab collection. A control group was also considered of those who never used the investigated pools. *P. aeruginosa* was isolated from the ear swabs of 142 (79.3%) of the pool users, as well as from 4% of the controls. This showed a high indication that these pools were serving as reservoirs of the infection [**21**].

5.Conclusion

In the present study, only 20% of the swimming pool water samples with a viable count of 2x10^2 cfu/ml were within the standard set by WHO, while 80% with a viable count of up to 4.9 x 10^4 cfu/ml failed to meet the set standards which reflects a high incidence of non compliance to hygiene. Several authors all over the world have reported the lack of hygiene by microbiological analysis of the swimming pools over a specific season or area.

The results seen in the current study reveals the lack of educated pool operators, overcrowding of swimming pools at certain times, the casual attitude of bathers in failing to take pre-swim showers as well as less frequent changing of pool waters. Therefore, proper education, strict protocols for pool users and frequent analysis followed by regular changing of pool waters should be practiced. One of the social goals of this study is to help create awareness to the public about the potential threat of exposure to pathogens

and hence to contracting a variety of RWIs. Swimmers can be enlightened of the role they themselves can play to help reduce the level of contamination of pools by strictly adhering to hygienic practices that should be followed while using the pools.

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