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Microbiological, Physical and Chemical Quality of Swimming Water with Emphasize Bacteriological Quality

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A quality of swimming water takes into account physical, chemical and microbiological quality information and shall be maintained these water quality standards at all times. Pool water clarity must be maintained in a clean, clear condition so that a 150 mm diameter matt contrasts with the color of the bottom of the swimming pool, is clearly visible when viewed through the pool water at the deepest part of the swimming pool. There must have a minimum chemical criterion by which a swimming pool should be operated to minimize health risks to bathers to acceptable levels. The microbiological quality of water must not present risk to the health of bathers.

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A variety of microorganisms can be found in swimming pools, which may be introduced in the pool water in a number of ways. In many cases, the risk of illness or infection has been linked to fecal contamination of the water, due to feces released by bathers or contaminated source water or, in outdoor pools, may be the result of direct animal contamination. If swimming pool is not managed properly, bathers acquire bacterial, viral, parasitological and fungal infection. To minimize/avoid these risks of infection a variety of disinfection techniques are used. Disinfection methods include filtration to remove pollutants, disinfection to kill infectious microorganisms, swimmer hygiene to minimize the introduction of contaminants into pool water, and regular testing of pool water, including chlorine and pH levels. Re-circulating pool water is disinfected during the treatment process, and the entire water body is disinfected by application of a disinfectant residual, which inactivates agents added to the pool by bathers.

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I. Introduction

Recreational use of inland and marine water is increasing in many countries. It is estimated that foreign and local tourists together spend around two billion days annually at coastal recreational resorts. The World Tourism Organization predicts that by 2026, 346 million tourists will visit Mediterranean destinations annually, representing about 22% of all arrivals worldwide. It has been estimated that 129 million people visited the beach or waterside in the United States of America between 2000 and 2001, an increase of 6% from 1995. In United Kingdom it is estimated that over 20 million people use British coast each year, in addition to inland waters and their surrounding areas, for a variety of reasons [1].

Swimming is generally considered to be a healthy leisure activity for both the young and old. Swimming is even often advised as the most appropriate sport for asthmatic children, mainly on the grounds that inhaling moist air is less conducive to trigger exercise-induced asthma [2]. The growing popularity of swimming and other “in-the-water” activities for sport, fitness, therapy or just enjoyable relaxation has led to the increased use of swimming pools and the establishment of a variety of specific-use pools such as spa pools, waterslides, and more recently, hydrotherapy and wave pools. These pools are used by a variety of people of various ages, health status and standards of hygiene [3]. Swimming pools may be supplied with fresh, marine or thermal water. Swimming pools may be located indoors, outdoors or both; they may be heated or unheated [4].

A variety of microorganisms can be found in swimming pools, which may be introduced in the pool water in a number of ways. Some of the various sources of bacteria and microbes in pool include people swimming in the pool, animals, dead wildlife and debris from around the property, such as leaves, grass and dust. In many cases, the risk of illness or infection has been linked to fecal contamination of the water, due to feces released by bathers or contaminated source water or, in outdoor pools, may be the result of direct animal contamination. Non-fecal human shedding (e.g. from vomit, mucus, saliva or skin) in swimming pool is also a potential source of pathogenic organisms [5].

Swimming pool sanitation refers to methods for ensuring healthy conditions in swimming pools, hot tubs, plunge pools and similar recreational water venues. Proper sanitation is needed to maintain the visual clarity of water and to prevent the transmission of infectious diseases. Sanitation methods include filtration to remove pollutants, disinfection to kill infectious microorganisms, swimmer hygiene to minimize the introduction of contaminants into pool water, and regular testing of pool water, including chlorine and pH levels [5]. Re-circulating pool water is disinfected during the treatment process, and the entire water body is disinfected by application of a disinfectant residual, which inactivates agents added to the pool by bathers. Effective swimming pool disinfection will take account of the need to inactivate any potential pathogens with the need to provide a pleasant swimming experience without adverse long term health effects [6, 7].

II. Type and Quality Standards for Swimming Water

The growing popularity of swimming and other "in-the-water" activities for sport, fitness, therapy or just enjoyable relaxation has led to the increased use of swimming pools and the establishment of a variety of specific-use pools such as spa pools, waterslides, and more recently, hydrotherapy and wave pools. These pools are used by a variety of people of various ages, health status and standards of hygiene. Swimming pools are a common feature in most middle to upper income bracket homes, with a strong design focus on outdoor living areas [3].

Swimming pools may be supplied with fresh, marine or thermal water. Swimming pools may be located indoors, outdoors or both; they may be heated or unheated. Swimming pools can be categorized as public, semi-public, and residential pools. A public pool is usually a larger pool (more than 1800 square feet) that is owned or operated by some legal entity and is made available to anyone who pays a small entry fee. Semi-public pool is similar to the public pool but has specific entry restrictions like that of a fitness center, country club, or hotel/motel pool. Residential pools are private pools that are not regulated by the health department or some other regulatory agency. Residential pools are not intended for commercial use and are not owned by more than three families. Public pools are usually inspected by a health official, whereas residential pools are not. More specifically, the basic components of a swimming pool and its circulation system include swimming pool basin, balancing tank, pump, hair and lint strainer, filter, heater and chemical disinfectant systems [4].

Essentially a swimming or spa pool that has balanced water meets the chemical criteria and should be relatively free from pathogenic organisms. Therefore, the potential risk of disease transmission for the pool is negligible [8]. The quality of swimming water takes into account epidemiology, microbiology and water quality information. The water in swimming pools shall be maintained at the following water quality standards at all times.

a) *Physical Quality*

Pool water clarity must be maintained in a clean, clear condition so that a 150 mm diameter matt black disc, or a 150 mm diameter disc that contrasts with the color of the bottom of the swimming pool, is clearly visible when viewed through the pool water at the deepest part of the swimming pool. The pool water shall be clear and clean. No scum or floating impurities shall be allowed to accumulate. The color of the water shall not exceed 5 Hazen units and the turbidity shall not exceed 5 NTU (nephelometric turbidity unit) [9].

b) *Bacteriological Quality*

The microbiological quality of water must not present risk to the health of bathers. When water samples are taken directly by pool operators, a copy of all results should be forwarded directly to the local health authority. Poor microbiological testing results will often mean immediate corrective action is needed as required by the health authority. The local health authority will assist in deciding on a routine sampling schedule sampling regime, and may require this as part of the conditions on an operating permit. Routine testing of water for bacteriological quality can provide evidence of the effectiveness of disinfection systems and sanitation schedules [9].

a. *E. coli* shall not be present in any 100 ml sample of water taken from the pool.
b. Not more than 10 coliform organisms shall be present in any 100 ml of water taken.
c. Not more than one out of five consecutive samples of the water, taken monthly, shall contain any coliform organisms in 100 ml of the water sample.
d. No sample shall contain more than 200 bacteria per ml as determined by the 24-hour plate count at 37 ° C or by the membrane filter method.

c) *Chemical Quality*

These specify the minimum chemical criteria by which a swimming pool should be operated to minimize the public health risks to bathers to acceptable levels. It is important for people responsible for pool operation to maintain their pools at a standard equal to or greater than these guidelines at all times the pool is open to the public. The level of one chemical parameter can adversely affect another that is if the pH is too high or too low the disinfectant properties of chlorine are decreased [8].

- A free chlorine residual of not less than 1.0 mg per liter and not more than 3.0 mg per liter shall be maintained in the pool.

- If copper sulfate is used as an algicidal agent, copper sulfate concentration of the water determined as copper shall not exceed 0.2 mg per liter.
- The pool water shall have a pH value of between 7.2 and 7.8.
- If cyanuric acid is used as a stabilizer for chlorine, its maximum concentration shall not exceed 100 mg/liter in the swimming pool water [10].

The first reviews of the incidence of disease associated with the use of recreational waters were undertaken by the American Public Health Association in the early 1920s. They investigated the link between bathing and illness. The findings concluded that there was an appreciably higher overall illness incidence rate in people who swam in Lake Michigan, the United States, in 1948 and on Ohio River at Dayton, United States, in 1949 compared with non-swimmers, regardless of the levels of coliform bacteria found in the water quality tests. It was concluded that, based upon the results of this study, the stricter bacterial quality requirements could be relaxed without a detrimental effect on the health of bathers. A study based on five years of investigation of 43 beaches in the United Kingdom and concluded that there was only a 'negligible risk to health' of bathing in sewage polluted sea water even when beaches were 'aesthetically very unsatisfactory' and that a serious risk would only exist if the water was so fouled as to be revolting to the senses. They insisted that pathogenic bacteria which were isolated from sewage contaminated sea water were more important as indicators of the disease in the population than as evidence of a health risk in the waters [1].

A study in Iran showed that the mean of the physicochemical parameters, except in temperature, was standard in more than 60 % of the pools. Average temperature was higher than standard. The highest chlorine level was recorded in summer. Coliform bacteria were found to be positive in 3 % of the samples. Prevalence of saprophytic and opportunistic fungi was 27 %. Twelve species of fungi were isolated; the most common were *Aspergillus, Penicillium sp*, *Rhizopus sp*, and *Fusarium sp*, and the highest fungi pollution was observed in the summer. Prevalence of bacterial contamination was 9 %; bacteria isolate included *Staphylococcus epidermidis*, *Bacillus subtilis* and *Escherichia coli*. There was a significant association found between fungal and bacterial contamination with residual chlorine [11].

Quantitative microbial risk assessment (QMRA) is used to estimate the probability of becoming infected by a specific pathogen after an exposure. QMRA uses densities of particular pathogens, assumed rates of ingestion, and appropriate dose-response models for the exposed population to estimate the level of risk. QMRA can be useful in determining the risk of infection from the use of recreational water. QMRA and epidemiological studies provide complimentary information and should be used together to provide better overall estimates of risk. The process of QMRA produces a statistical estimate of adverse effects associated with exposure to particular hazards. The process consists of hazard identification, exposure assessment, dose-response assessment and risk characterization. One of the main problems with risk assessment is that a number of assumptions need to be made with respect to exposures. Assumptions need to be validated through research under similar conditions to those being modeled. Slight changes in for example, pathogen concentration or die-off may lead to widely varying results [1].

Water contact time is a prime factor influencing the amount of exposure to pathogens in water. The longer a person is in the water the more they can be exposed to pathogens in the water through ingestion, inhalation or penetration of the skin. Some activities are likely to pose greater risk of water ingestion than others. In most cases, monitoring for potential microbial hazards is done using indicator microorganisms which are easy to enumerate and would be expected to be present in greater numbers than pathogens. The traditional role of indicator parameters was to show the presence or absence of fecal pollution in water supplies. The indicator should be absent in unpolluted environments and present when the source of pathogenic microorganisms of concern is present [1].

- The indicator should not multiply in the environment
- The indicator should be present in greater numbers than the pathogenic microorganisms.
- The indicator should respond to natural environmental conditions and water treatment processes
- The indicator should be easy to isolate, identify and enumerate
- Indicator tests should be inexpensive, thereby permitting numerous samples to be taken

d) Microorganisms in swimming water

Microorganisms that are used to assess the microbial quality of swimming pool and similar environments include heterotrophic plate count (HPC) (a general measure of non-specific microbial levels), faecal indicators (such as thermotolerant coliforms, *E. coli*), *Pseudomonas aeruginosa*, *Staphylococcus aureus* and *Legionella* species. HPC, thermotolerant coliforms and *E. coli* are indicators in the strict sense of definition. As health risks in pools and similar environments may be faecal or non-faecal in origin, both faecal indicators and non-faecally-derived microorganisms (e.g. *P. aeruginosa*, *S. aureus* and *Legionella* spps) should be examined. Faecal indicators are used to monitor for the possible presence of fecal contamination; HPC,

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Pseudomonas aeruginosa and *Legionella* species can be used to examine growth, and *Staphylococcus aureus* can be used to determine non-fecal shedding. The absence of these organisms, however, does not guarantee safety, as some pathogens are more resistant to treatment than the indicators, and there is no perfect indicator organism [12].

Campylobacter jejuni is more likely to be found in recreational waters contaminated by animal and human waste. *Escherichia coli* O157 associated with food, a number of outbreaks have been reported from recreational use of waters, particularly in pools that are not adequately chlorinated. *Helicobacter pylori* have been implicated as one mode of transmission through swimming pools. *Legionella* species are a number of reports of Legionnaires' disease associated with the use of, and proximity to, hot tubs in particular. *Mycobacterium avium* complex is clear evidence for the association of *Mycobacterium avium* complex with recreational waters [1].

Shigella species exist with the association of recreational use of water and self-limiting infection with *Shigella* bacteria. The species responsible for the more severe illness, *Shigella dysenteriae,* is more common in tropical regions but no cases associated with recreational waters were found in the literature. The infective dose for *Shigella* species is usually between 10 and 100 organisms. *Vibrio vulnificus* bacterium commonly occurs in marine and estuarine environments. Evidence exists for the association of recreational use of water and infection with *V. vulnificus* where the user has a pre-existing open wound [12]. *Pseudomonas aeruginosa* is an organism that usually causes disease in immunecompromised individuals. These bacteria can live in many places and are common inhabitants of soil, water, plants, and animals in addition to swimming pools, whirlpools, and hot tubs [13, 14].

Cryptosporidium parvum fecal accidents are implicated in most of the cases as the cause of the outbreaks of cryptosporidiosis, which have primarily occurred in swimming pools. The risk of death and probability of developing long-term sequelae from this infection can be prolonged and moderately severe especially in immunocompromised persons. *Giardia lambilia* is a proven risk factor for infection in immunocompromised patients. *Naegeria fowleri* has been shown to colonize warm freshwater habitats, such as swimming pools and natural hot springs and there is a high risk of death in infected persons. *Schistosoma* species cause serious pathology associated with infection by *Schistosoma mansoni* occurs and can lead to long-term health issues. Schistosoma is only a potential hazard in certain geographic areas. Evidence shows that exposure to schistosomes is difficult to avoid but it has been shown that towel-drying after exposure to infested water can markedly reduce the risk of infection [12, 14].

Viral diseases transmission in recreational waters, primarily inadequately chlorinated swimming pools, has been documented via faecally-contaminated water and through droplets. Adenovirus and Hepatitis A virus has been isolated from surface waters which may be used for recreational purposes and a number of cases of HAV have been documented associated with recreational water users. Hepatitis E virus has been isolated from surface waters which may be used for recreational purposes [1].

e) Disinfection of swimming water

The importance of available chlorine and redox potential as indicators of the kill of *Escherichia coli* has previously been studied in laboratory experiments. Different chlorine compounds are tested in chlorine demand free water. The reduction of bacteria within 3 minutes is relatively well correlated with both available chlorine and redox potential for each pure chlorine compound, but the available chlorine needed for total kill is about 10 times higher for inorganic chloramines than for free available chlorine. The five keys to maintaining water quality in swimming pool include filtration, chlorination, pH level, total alkalinity and calcium hardness [15].

f) Filtration

The water in pool is pumped through a filter to remove debris and particles. How long you need to run the filter depends on the size of the swimming pool and the horsepower of the pool pump. Remember that even when you are filtering your pool according to specifications, about 35 percent of the water still won't be filtered. An electrically operated water pump is the prime motivator in re-circulating the water from the pool. Water is forced through a filter and then returned to the pool. Using the filtration method requires a constant electrical supply, with the typical pool pump using 500 watts to 2,000 watts. Coated mesh filters and sand filters are two basic types [16].

Coated mesh filters can be broken into two types - diatomaceous earth and cartridge filters. Diatomaceous earth is obtained from mining the skeletons of diatoms, minute creatures that lived millions of years ago. Diatomaceous Earth filters consist of a set of pads or filter elements that are coated with diatomaceous earth before use. After the filter becomes dirty the precoat, with the sediment, is backwashed to the drain. Cartridge filters come in various sizes to suit particular volumes of water. A cartridge filter usually consists of a container, which should include an automatic pressure bypass valve, and a manual release valve, in which a replaceable cartridge of porous material such as polyester or paper is fitted and sealed. Sand filters design is to secure maximum reduction in suspended and colloidal matter, long runs between backwashes, effective cleaning during the backwash cycle itself and a long life of the filter medium itself. This is achieved through careful selection of the sand, design of the washing equipment and under drainage system. Sand filters are generally available in three separate types the open gravity filter, pressure filter and hi-rate sand filter. Water is diffused, softening the water flow, in the filter over the top of the sand bed and through into the under drain in the bottom of the filter tank [17].

g) Chlorination

Chlorine is a chemical that disinfects the water and helps to remove debris. You should use a chlorine stabilizer to extend the chlorine's half-life. Generally, the longer the filtration cycle, the less chlorine you will need. Similarly, the more chlorine you use, the shorter the required filtration cycle. Chlorine requirements will be affected by a range of factors, including the pump and filter system, water temperature, water level, amount of debris and the number of swimmers in the pool [6]. Chloramination employs a mixture of ammonia and chlorine, the reaction products of both compounds are still active for killing microorganisms, but they are much less available for formation of disinfection by-products [16].

h) Free chlorine

A pool operated at a low free chlorine level is going to be a much healthier, non smelly pool for chloramine production is also minimized, and so too is the amount of chemicals used. Bathers want good clean water to swim in with no risk of cross-infection. The free chlorine residual should be at the lowest concentration that gives satisfactory microbiological quality; this should be possible at less than 1mg/l. The absolute minimum free chlorine level given that there needs to be a residual of active disinfectant to prevent the risk of cross infection is 0.5 mg/l. When operating at low free chlorine levels the pH value of the water must be around 7.2 to 7.4 to obtain the greatest disinfection effect [16].

- Ideally free chlorine should be no more than 1.5 – 2.0mg/l
- Free chlorine residuals above 2mg/l should not be used
- Free chlorine residuals above 3mg/l are unlikely to be necessary
- Above 5mg/l free chlorine, chlorination should be stopped immediately
- Above 10mg/l bathing should cease

i) Combined chlorine

The reactions between hypochlorite and nitrogenous matter or ammonia in the pool are complex and it is dangerous to over-simplify the meaning of test results. The combined chlorine residual should be as low as possible. It should always be at least half the free chlorine residual and never more than 1mg/l, where the pool water treatment is operating well.

j) PH level

For hypochlorite disinfectants to work properly, the pH value of the pool is critical. The pH level indicates how acidic or alkaline the water is at any given time. The pH value should be maintained between the acceptable range of 7.2 and 7.8; the bottom of the range should be the target, as disinfection will be more effective as may be coagulation. This is particularly important when operating at low levels of free chlorine. If, however, there is a "chlorine" smell or irritation, the pH value may have to be raised towards the upper part of the range and any bathing overload corrected. If the water pH is higher than 8, anyone who swims in the pool is at risk of skin rashes, while a pH of lower than 7 can sting the swimmers' eyes. Some of the many factors that can affect your pool's pH level include heavy rain, lots of swimmers and pool chemicals [16].

k) Total alkalinity (TA)

Total alkalinity means the sum of all alkaline chemicals in water. Total alkalinity is the measurement of the ability of pool water to resist changes in pH. Total alkalinity is the governor of pH. If TA is too low, the pH balance can become unstable. Concrete and painted pool surfaces will also deteriorate over time. TA and pH are interconnected. For example, raising the TA could also raise the pH. Make sure you don't disrupt your pool's pH when adjusting the TA and vice versa. The recommended range in public pools is 80 -120 ppm.

l) Calcium hardness

Calcium hardness refers to the amount of the mineral calcium dissolved in pool water. Low calcium levels will deteriorate pool surfaces, while high calcium levels will leave a 'scum' or scale on surfaces and equipment. The recommended range in public pools: 200 -300 ppm.

m) Bromine

Bromine has always been considered a disinfectant with similar properties to chlorine but in the context of swimming pool water treatment it is superior. In chlorine treated water, by-products are often formed which cause eye irritation and sometimes offensive odors. In bromine treated pools, although combined bromines are formed, the bromamines, eye irritation is virtually totally absent as these, unlike the chloramines, are good disinfectants with their activity almost being equal to free chlorine or free bromine. The use of elemental bromine however is very uncommon as it is a heavy red liquid which is very corrosive and gives off pungent fumes [17].

n) Ozone

Ozone is the most rapid disinfectant and most powerful oxidizing agent available for water treatment. It is a highly active gas which reacts immediately on contact with bacteria or other contaminants and impurities found in swimming pool water. Ozone is not a stable gas and it reverts quickly back to oxygen. This is why it has to be generated on-site and immediately introduced into the circulating pool water. The most efficient commercial production method is to pass dried air through a corona discharge ionizing field. Ozone's powerful oxidizing properties prevent the buildup of undesirable and odor producing by-products of the chlorination of human-based organic pollution [17].

o) UV Disinfection

UV is now a well-established method of swimming pool water treatment, from hydrotherapy spas to full-sized competition pools. This growth in popularity has been largely due to UV's reliability and ease of use. Another major factor is the reduced reliance on traditional chemical treatments it affords, particularly chlorine. UV is also highly effective at destroying chlorine-resistant microorganisms like *Cryptosporidium parvum* and *Giardia lambilia*. UV disinfection has many advantages over alternative methods. Unlike chemical treatment, UV does not introduce toxins or residues into process water and does not alter the chemical composition, taste, odor or pH of the fluid being disinfected. Another major benefit of UV is that it significantly reduces the need for backwashing and dilution, saving hundreds of pounds a month for pool operators [18].

p) Swimming water in Ethiopian

In Ethiopia, swimming water is rarely used, but there are some swimming pools in the country including both indoor and outdoor pools. Among the well known swimming pools Sheraton Addis, Ghion Hotel, Hilton Hotel, Intercontinental Addis Hotel, Elelly Hotel and Emibilta Hotel can be mentioned. Technical workers use different chemicals (HCl, Cl, $CuSO_4$, H_2SO_4, etc) to remove/inhibit microorganisms and as the same time the pools are supported by continuous pumping and filtration system [19]. Some of the managers supervising these pools do not have enough knowledge on about the physical, chemical and microbiological quality of their pools. For example, in Emibilta Hotel the technical worker disinfects the pool by simply adding un-weighted amount of HCl, H_2SO_4 i.e. without following WHO guidelines for swimming pools. From the interview I understand that they know nothing the proportion of disinfectant and volume of water in the well as well as the impact of disinfection by-products (DBP).

q) Laboratory assessment of swimming water

Poor microbiological testing results will often mean immediate corrective action is needed as required by the health authority. Routine testing of water for bacteriological quality can provide evidence of the effectiveness of disinfection systems and sanitation schedules. Pool water that is found to have poor microbiological quality could indicate there is a problem with the disinfection and recirculation system, or it could also indicate a health risk to patrons [9].

a. *E. coli* shall not be present in any 100 ml sample of water taken from the pool.
b. Not more than 10 coliform organisms shall be present in any 100 ml of water taken.
c. Not more than one out of five consecutive samples of the water, taken monthly, shall contain any coliform organisms in 100 ml of the water sample.
d. No sample shall contain more than 200 bacteria per ml as determined by the 24-hour plate count at 37 °C or by the membrane filter method.

For microbiological procedures, water samples are collected, when no bathers are in the pools. All samples are collected into sterile dark glass bottles with capacities 250, 500, 1000 and 2000 ml. Sufficient (100 mg/l) sodium thiosulfate pentahydrate is added to each bottle for de-chlorinization. The samples are collected from a depth of 30 cm, at a point about 40 cm away from the pool edge and they were transferred to the laboratory at 4°C within 1–2 h from collection, using appropriate insulated coolers and they are processed immediately after arrival at the laboratory. Bacteriological samples are analyzed by the membrane filter technique, using 0.47mm diameter, 0.45 mm pore size filters as specified in standard methods to determine the following parameters: Total heterotrophic plate counts (THC) per 1ml at 20 °C and 36°C [5].

r) Sample collection

- Sample collection for rapid methods is the same as for traditional methods
- Environmental/aquatic samples are complex; methods may have to be optimized for specific water types
- At low indicator bacteria numbers, detection limit for many methods becomes an issue
- Collection can include filtration, size fractionation, ultra-concentration, and enrichment in order to further, select/concentrate organisms of interest
- Filtration captures unwanted compounds that can inhibit detection of target organisms

Most detection technologies are based on measuring sample volumes less than 1 ml. The recommended marine bathing water standard is 35 *Enterococci* per 100 ml, which equates to less than one cell per ml. Thus, detectors measuring only a 1 ml volume, even if they are capable of detection of one cell per ml, will necessarily produce unacceptable sensitivity and poor precision at concentrations near the standard. There are two possible approaches to overcoming inadequate sensitivity. The first is to improve detector technology to allow measurement of larger volume samples. The preferred option at the present time is pre-concentration, which can enhance sensitivity several fold by increasing the number of target organisms per unit volume at a relatively modest cost [20].

s) Analytical techniques for indicator bacteria

The analytical techniques for indicator bacteria include membrane filtration, multiple tube fermentation and detection using chromogenic substances.

t) Membrane filtration

Indicator bacteria can be cultured on media which are specifically formulated to allow the growth of the species of interest and inhibit growth of other organisms. Typically, environmental water samples are filtered through membranes with small pore sizes and then the membrane is placed onto a selective agar. It is often necessary to vary the volume of water sample filtered in order to prevent too few or too many colonies from forming on a plate. Bacterial colonies can be counted after 24–48 hours depending on the type of bacteria. Counts are reported as colony forming units per 100 mL (cfu/100 mL) [20].

u) Multiple tube fermentation

Multiple tube fermentation technique is used to determine the presence of a member of the coliform group in ground water and surface water. The coliform group, as analyzed for in this procedure, is defined as all aerobic and facultative anaerobic, gram-negative, non-spore-forming, rod shaped bacteria that ferment lactose with gas formation within 48 hr at 35°C.

Presumptive Stage: A series of lauryl tryptose broth primary fermentation tubes are inoculated with graduated quantities of the sample to be tested. The inoculated tubes are incubated at 35 $\pm$ 0.5°C for 24 $\pm$ 2 hrs, at which time the tubes are examined for gas formation. For the tubes in which no gas is formed, continue incubation and examine for gas formation at the end of 48 $\pm$ 3 hrs. Formation of gas in any amount within 48 $\pm$ 3 hrs is a positive presumptive test.

Confirmed Stage: The confirmed stage is used on all primary fermentation tubes showing gas formation during 24 hrs and 48 hrs. Fermentation tubes containing brilliant green lactose bile broth are inoculated with medium from the tubes showing a positive result in the presumptive test. Inoculation should be performed as soon as possible after gas formation occurs. The inoculated tubes are incubated for 48 $\pm$ 3 hr at 35 $\pm$ 0.5°C. Formation of gas at any time in the tube indicates a positive confirmed test.

Completed Test: The completed test is performed on all samples showing a positive result in the confirmed test. It can also be used as a quality control measure on 20% of all samples analyzed. One or more plates of eosin methylene blue are streaked with sample to be analyzed. The streaked plates are incubated for 24 $\pm$ 2 hr at 35 $\pm$ 0.5°C. After incubation, transfer one or more typical colonies (nucleated, with or without metallic sheen) to a lauryl tryptose broth fermentation tube and a nutrient agar slant. The fermentation tubes and agar slants are incubated at 35 $\pm$ 0.5°C for 24 $\pm$ 2 hrs or for 48 $\pm$ 3 hrs if gas is not produced. From the agar slants corresponding to the fermentation tubes in which gas formation occurs, gram-stained samples are examined microscopically. The formation of gas in the fermentation tube and the presence of gram-negative, non-spore-forming, rod-shaped bacteria in the agar culture may be considered a satisfactorily completed test, demonstrating the positive presence of coliform bacteria in the analyzed sample.

v) Detections using chromogenic substances

One technique for detecting indicator organisms is the use of chromogenic compounds, which are added to conventional or newly devised media used for isolation of the indicator bacteria. These chromogenic compounds are modified to change color or fluorescence by the addition of either enzymes or specific bacterial metabolites. This enables for easy detection and avoids the need for isolation of pure cultures and confirmatory tests [20, 21].

w) Intervention for swimming water

Intervention is a deliberate entry into a situation or dispute in order to influence events or prevent undesirable consequences to improve a situation that are intended to relieve illness or injury. The most important intervention strategies include [22]:

- Increase public awareness about water safety
- Increase awareness and enforcement of pool and spa safety act requirements
- Address the role of swimming lessons as a layer of protection
- Familiarize technical workers/ the community how to disinfect swimming pools
- Increase public awareness that standard cardiovascular pulmonary recitation (CPR)
- Emphasize the importance of pool barriers as a layer of protection
- Expand statistical reporting throughout state

III. Conclusion

The growing popularity of swimming water activities for sport, fitness, therapy or just enjoyable relaxation has led the increased use of swimming pools and the establishment of a variety of specific-use pools such as spa pools, waterslides, and hydrotherapy. The difficulties associated with attributing an infection to recreational water use are numerous and the majority of research in this field has focused on infections. It is also increasingly apparent that a number of micro-organisms or their products are directly or indirectly associated with secondary health outcomes or sequelae and a number of these sequelae may result from waterborne infections.

Proper sanitation is needed to maintain the visual clarity of water and to prevent the transmission of infectious diseases. Sanitation methods include filtration

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to remove pollutants, disinfection to kill infectious microorganisms, swimmer hygiene to minimize the introduction of contaminants into pool water and regular testing of pool water, including chlorine and pH levels. The five keys to maintaining water quality in swimming pool include filtration, chlorination, pH level, total alkalinity and calcium hardness. The water in pool is pumped through a filter to remove debris and particles. Chlorine is a chemical that disinfects the water and helps to remove debris.

Microorganisms that are used to assess the microbial quality of swimming pool include heterotrophic plate count, faecal indicators, *Pseudomonas aeruginosa*, *Staphylococcus aureus* and *Legionella* species. The development of rapid microbial indicator methods is moving quickly and they will likely become available for use allowing managers to take action toward protecting swimmers from exposure to waterborne pathogens. Different intervention strategies are used to prevent undesirable consequences, increase public awareness about water safety, increase awareness and enforcement of pool activities.

IV. Recommendations

From the article review on microbiological and quality of swimming water, thereby would like to recommend some points to laboratory professionals, the concerned bodies and other stakeholders to investigate swimming pool in our country and apply the knowledge to improve the quality of swimming pool interms of physical, chemical and microbiological perspectives. It requires attention to minimize the risk of infection acquired through pools and the Government Issue policies, manuals and guidelines for appropriate/safe use of swimming pools at all levels from personal to public level at large. The population also should aware the merit/demerits of swimming pool and follow guidelines for safe swimming as well as strictly apply precautions. Since the impact of microorganisms and harmful residues of chemicals (disinfectant by products) is so devastating for health of the community, technical workers of swimming waters should be well trained about pool disinfection mechanisms.

List of abbreviations

AFR: Accidental fecal release;
CFU: Colony-forming unit;
CPR: Cardiovascular pulmonary recitation;
DBAA: Dibromoacetic acid;
DBP: Disinfection by-products;
DCAA: Dichloroacetic acid;
DMH: Dimethylhydantoin;
HPC: Heterotrophic plate count;
HUS: Haemolytic uraemic syndrome;
ISO: International Organization for Standardization;
MCAA: Monochloroacetic acid;
NOEL: No-observed-effect level;
NTU: Nephelometric turbidity unit;
ORP: Oxidation–reduction potential;
PFU: Plaque-forming unit;
Ppm: Parts per million;
QMRA: Quantitative microbiological risk assessment;
TCAA: Trichloroacetic acid;
TCAN: Trichloroacetonitrile;
TDS: Total dissolved solids;
UV: Ultraviolet

Conflict of interest

The authors declare that they have no competing interests.

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References Références Referencias

1. Kathy Pond. Water Recreation and Disease: Plausibility of Associated Infections: Acute Effects, Sequelae and Mortality. WHO TJ International (Ltd), Padstow, Cornwall, UK.2005
2. Nemery B, Hoet PM and Nowak D. Indoor swimming pools, water chlorination and respiratory health. *Eur Respir J* 2002; 19: 790–793.
3. Public and Environmental Health Act of Government of Australia: Standard for the Operation of Swimming Pools and Spa Pools in South Australia. 1998.
4. Neuman CM, Scott RC, Beach MJ, Heath PJ and Wittstock G. The complete Swimming pool Reference. 2nd edition. Penn State University, Pennsylvania, 2003.
5. Papadopoulou C, Economou V, Sakkas H, Gousia P, Giannakopoulos X and Dontorou C. Microbiological quality of indoor and outdoor swimming pools in Greece: Investigation of the antibiotic resistance of the bacterial isolates. *Int. J. Hyg. Environ. Health* 2008; 385–397
6. Swimming pools and spa water quality and disinfection. Available from online at http://www.betterhealth.vic.gov.au/bhcv2/bhcarticles.nsf/ Assessed on May 6, 2016
7. Center for disease control and prevention (CDC): Fact sheet for pool staff. Available from online at http://www.cdc.gov/healthyswimming/fecal-response. Assessed on May 23, 2016
8. Queensland Health Swimming and Spa Pool Water Quality and Operational Guidelines. 2004
9. World Health Organization (WHO). Guidelines for safe recreational water environments. Volume 2, Swimming pools and similar environments. May, 2006.

10. Health Protection Branch Population Health and Wellness Division Ministry of Health: Guidelines for Swimming Pool Operations. April 2011
11. Rasti S, Assadi MA, Iranshahi L, Saffari M, Gilasi HR and Pourbabaee M. Assessment of Microbial Contamination and Physicochemical Condition of Public Swimming Pools in Kashan, Iran. *Jundishapur J Microbiol*. 2012; 5 (3):450-455.
12. Rabi A, Khader Y, Alkafajei A and Aqoulah AA. Sanitary Conditions of Public Swimming Pools in Amman, Jordan. *Int. J. Environ. Res. Public Health* 2008, 5(3) 152-157
13. Vesaluoma M, Kalso S, Jokipii L, Warhurst D, Ponka A and Tervo T. Microbiological quality in Finnish public swimming pools and whirlpools with special reference to free living amoebae: a risk factor for contact lens wearers? *BrJ Ophthalmol* 1995; 79: 178-181
14. Saskatchewan ministry of health. Pseudomonas aeruginosa: A bacteria found in swimming pools, fact sheet environmental health. 2010. Available from online at www.health.gov.sk.ca Assessed on June, 23, 2016
15. Katarina Victorin. A field study of some swimming-pool waters with regard to bacteria, available chlorine and redox potential. *J. Hyg., Camb.* 1999; (72) 101
16. Disinfection of pool water. Available online at www.isrm.co.uk. Assessed on June 2, 2016.
17. Münzberg R, Hesse EG and Ostermann M. Handbook of Swimming Pool and Spa Pool Water Treatment. Tintometer GmbH, Germany, 2009
18. UV disinfection technology, the applications just keep on growing. Available online from at http://halmapr.com/news/hanovia/. Assessed on June 25, 2016.
19. Swimming pool technical workers in Emibilta Hotel. Interview on January 22, 2016.
20. Noble RT and Weisberg SB. A review of technologies for rapid detection of bacteria in recreational waters. *Journal of Water and Health* 2005, 3 (4); 381-392
21. CDC. National Center for Emerging and Zoonotic Infectious Diseases. Facts about *Naegleria fowleri* and Primary Amebic Meningoencephalitis. 2005. www.cdc.gov/naegleria. Assessed on June, 26, 2016
22. Strategic Goals and Objectives: Unintentional Drowning. Coalition of Arizona. 2011