4 Swimming and spa pools

4.1 Health concerns

Swimming pools and spas can present a number of risks to health. The most immediate danger arises from accidental drowning. Another source of harm is the injuries, potentially serious or even fatal, that can arise from slipping and tripping or from becoming snagged in ropes and fences or fittings such as ladders and drains. There have even been cases where swimmers have been thrown clear of the pool onto hard surfaces in heavy seas.

The very real and significant injury risks are not discussed in this chapter which is limited to consideration of risks associated with infectious disease and hazardous chemicals transmitted to humans *via* swimming and spa pools. A number of infectious diseases can be acquired in swimming and spa pools and cause diarrhoea or skin, ear, eye, and upper respiratory infections.

Faecal-oral pathogens have commonly been associated with swimming and spa pools and are caused by pathogens entering with sewage contamination or from contamination released directly by infected bathers. One of the most important such pathogens is *Cryptosporidium* which has infectious oocysts that are resistant to even the highest levels of chlorine that are generally used for maintaining residual disinfection in pools. Thousands of cases of swimming-associated cryptosporidiosis have been reported (Lemmon *et al* 1996, CDC 2001a) and public swimming pools can be temporarily shut down as a result. Where water quality and treatment has been inadequate, bacterial infections from *Shigella* (CDC 2001b) and *Escherichia coli* O157:H7 (CDC 1996) have been associated with swimming and spa pools.

Infections of surfaces such as skin and ears have been associated with spa pools where disinfection has been inadequate. These infections arise from opportunistic pathogens that are commonly present in water and soils. The swimming and spa pool environment is risky because it can both amplify the concentration of the hazard and facilitate exposure of humans to the hazard. *Pseudomonas aeruginosa* infection has been associated with a number of skin and ear infections arising from immersion in water with inadequate disinfection (Gustafson *et al* 1983, Ratnam *et al* 1986, CDC 2000). Symptoms have included outer ear and ear canal infections (“Swimmer’s Ear” or “Otitis Externa”) and skin infections such as dermatitis and folliculitis. *Legionella* infections causing outbreaks of legionnaire’s disease have been associated with spas including two of the outbreaks aboard ship reviewed by WHO (2001). More recently, mycobacterial infections have been associated with pneumonitis linked to exposure to aerosols from swimming and spa pools (Falkinham 2003).

In managing risk from microbial hazards using disinfectants, other risks can arise. For example, harm can result from excessive disinfectant chemical addition either directly or potentially through disinfection by-products. The disinfection by-products arise when chlorine reacts with organic matter, such as is found in sloughed skin, sweat and urine, and forms organohalide compounds, such as chloroform. Ozone can also react to produce a different set of by-products. These by-product compounds are of uncertain health significance at the low concentrations found but might be weakly associated with certain types of cancer or adverse pregnancy outcomes (WHO 2004a).

4.2 Guidelines relating to swimming and spa pool safety

The Guidelines for Safe Recreational Waters Volume 2 - Swimming Pools, Spas and Similar Recreational-water Environments (WHO 2004b) apply to the case of swimming and spa pools on ships.

4.3 Design and Construction

Of importance to the type of pool and its management is identification of how the pool will be used:

- The daily opening hours;
- The peak periods of use;
- The anticipated number of users; and
- Special requirements such as temperature, lanes and equipment.

Swimming and bathing pool water must be hygienically safe - free of unacceptable levels of pathogens and exhibiting no properties or constituents that may cause human health to be impaired. These water quality requirements can be met only through optimal matching of the following factors:

- Disinfection (to inactivate infectious microorganisms so that the water cannot transmit and propagate disease-causing microbiological agents);
- Pool hydraulics (to ensure optimal distribution of disinfectant throughout the pool);
- Appropriate treatment (to remove particulate pollutants and disinfectant-resistant microorganisms); and
- Addition of fresh water at frequent intervals (to dilute substances that cannot be removed from the water by treatment).

Pools and spa on ships should be of safe design, as with land pools. The source water may be either seawater or from the potable water supply for the ship. The hydraulic and circulation system of pool will necessitate a unique design, depending upon ship size and pool location. The filtration and disinfection systems will require adaptation to the water quality.

4.3.1 Types of pools and spas

Pools may be located either outdoors, indoors or both. A spa for the purposes of this guide is defined to include whirlpools. The following types of pools are considered:

- Fill and draw swimming pools are not recommended and should not be installed;
- Recirculating swimming pools should be equipped and operated to provide maximum health and safety protection for swimmers. Recirculating swimming pools should provide complete circulation of the water within the pool, with replacement of the water every 6 hours, or less during pool operation;

- The flow through swimming pool is the type most practicable for construction, installation and operation aboard ships. The pool and its water supply should be designed, constructed and operated to give maximum health and safety protection to the bathers; and

- Spa systems on passenger vessels should be designed to permit daily shock treatment or super halogenation and allow for routine visual inspection of granular filtration media. The type, design and use of the pool may predispose the user to certain hazards. Bubble pools or whirlpools, for example, may be subject to high bather loads relative to the volume of water. Where there are high water temperatures and rapid agitation of water, it may become difficult to maintain satisfactory pH, microbiological quality and disinfectant residuals. In any pool with concentrated bather loads, pollution can be high. In addition, some special provisions of pools, such as forced recirculation and aeration, may contribute to bacterial overgrowth

4.3.2 Circulation and hydraulics

The purpose of giving close attention to circulation and hydraulics is to ensure that the whole pool is adequately served. Treated water must get to all parts of the pool, and polluted water must be removed - especially from areas most used and most polluted by bathers. If not, even good water treatment may not give good water quality. The design and positioning of inlets, outlets and surface water withdrawal are crucial.

Circulation rate is related to turnover period, which is the time taken for a volume of water equivalent to the entire pool water volume to pass through the filters and treatment plant and back to the pool. In principle, the shorter the turnover period, the more frequent the pool water treatment. Turnover periods must, however, also suit the particular type of pool. Ideally, turnover can be designed to vary in different parts of the pool: longer periods in deep areas, shorter where it is shallow.

4.3.3 Bathing load

Bathing load is a measure of the number of people in the pool. All pools should identify and maintain a realistic relationship between bathing numbers and pool and treatment capacity. For a new pool, the bathing load should be estimated at the design stage.

The number of bathers that can use a swimming pool safely at one time and the total number that can use a pool during one day are governed by the area of the pool and the rate of replacement of its water by clean water. Therefore, the pool should be designed with special attention to the probable peak bathing load and the maximum space available for the construction of a pool. The many factors that determine the maximum bathing load for a pool include:

- Area of water - in terms of space for bathers to move around in and physical activity;

- Depth of water - the deeper the water, the more actual swimming there is and the more area a bather requires;

- Comfort; and

- Pool type and bathing activity.

4.3.4 Filtration

Filtration is crucial to good water quality. If filtration is poor, clarity will be affected. Water clarity is a key factor in ensuring the safety of swimmers. Disinfection will be compromised by reduced clarity, as particles associated with turbidity can surround microorganisms and shield them from the action of disinfectants. In addition, filtration is important for removing *Cryptosporidium* oocysts and *Giardia* cysts and some other protozoa that are relatively resistant to chlorine disinfection.

To remove *Cryptosporidium* oocysts, which are around 4 to 6 µm in diameter, granular media (e.g. sand) filtration needs to follow coagulation because the pore size of a pool sand filter can be as large as 100 µm. Membranes or fine-grade diatomaceous earth filtration can remove oocysts if the porosity of the filter is less than 4 µm.

Some of the factors that are important to consider in the design of a granular media (such as sand) filtration system include:

- Filtration rate: the higher the filtration rate, the lower the filtration efficiency. Some of the higher-rate granular filters do not handle particles and colloids as effectively as medium-rate filters and the cannot be used with coagulants;
- Bed depth: The correct sand bed depth is important for efficient filtration;
- Number of filters: pools will benefit greatly from the increased flexibility and safeguards of having more than one filter. In particular, pools can remain in use with a reduced turnover on one filter while the other one is being inspected or repaired. Filtered water from one filter can be used to backwash another; and
- Backwashing: the cleaning of a filter bed clogged with suspended solids is referred to as backwashing. It is accomplished by reversing the flow, fluidizing the sand and passing pool water back through the filters to waste. It should be initiated as recommended by the filter manufacturer, when the allowable turbidity value has been exceeded or when a certain length of time without backwashing has passed. The filter may take some time to settle once the flow is returned to normal and water should not be returned to the pool until it has.

4.3.4.1 Coagulation

Coagulants (or flocculants) enhance the removal of dissolved, colloidal or suspended material by bringing this material out of solution or suspension as solids (coagulation), then clumping the solids together (flocculation), producing a floc, which is more easily trapped in the filter. Coagulants are particularly important in helping to remove the infective cysts and oocysts of *Cryptosporidium* and *Giardia*, which otherwise would pass through the filter. Coagulant efficiency is dependent upon pH which, therefore, needs to be controlled. Dosing pumps should be capable of accurately dosing the small quantities of coagulant required and adjusting to the requirements of the bathing load.

4.3.5 Disinfection

Disinfection is a process whereby pathogenic microorganisms are removed or inactivated by chemical (e.g. chlorination) or physical (e.g. filtration, UV radiation) means such that they represent no significant risk of infection. Recirculating pool water is disinfected using the treatment process, and the entire water body is disinfected by application of a disinfected residual, which inactivates agents added to the pool by bathers.

The choice of disinfectant depends on a variety of factors, including compatibility with the source water supply (hardness and alkalinity), bathing load, oxidation capacity, and margin between disinfectant action and adverse effects on human health. Chlorination is the most widely used pool water disinfection method, usually in the form of chlorine gas or sodium or calcium hypochlorite. Ozone in combination with chlorine or bromine is a very effective disinfection system but the use of ozone alone cannot ensure a residual disinfectant capacity throughout the swimming pool.

For disinfection to occur with any biocidal chemical the oxidant demand of the water being treated must be satisfied and sufficient chemical must remain to effect disinfection.

4.3.5.1 Choosing a disinfectant

Issues to be considered in the choice of a disinfectant and application system include:

- Safety;
- Compatibility with the source water supply;
- Type and size of pool (disinfectant may be more readily degraded or lost through evaporation in outdoor pools);
- Bathing load (sweat and urine from bathers will increase disinfectant demand); and
- Operation of the pool (i.e. supervision and management).

The choice of disinfectant used as part of swimming pool water treatment should ideally comply with the following criteria:

- Effective, rapid, inactivation of pathogenic microorganisms;
- Capacity for ongoing oxidation to assist control of contaminants during pool use;
- A wide margin between effective biocidal concentration and concentration resulting in adverse effect on human health;
- Availability of a quick and easy determination of the disinfectants concentration in pool water (simple analytical and test methods); and
- Potential to measure the disinfectant's concentration electrometrically to permit automatic control of disinfectant dosing and continuous recording of the values measured.

Commonly used disinfectants include:

- Chlorination is the most widely used pool water disinfection method, usually in the form of chlorine gas or sodium or calcium hypochlorite. Chlorine is inexpensive and relatively convenient to produce, store, transport and use. The chlorinated isocyanurate compounds are somewhat complex white crystalline compounds with slight chlorine-type odour that provide free chlorine when dissolved in water. They are an indirect source of chlorine, via an organic reserve (cyanuric acid). The relationship between the chlorine residual and the level of cyanuric acid is critical and can be difficult to maintain. Chlorinated isocyanurates are not suited to the variations in bathing loads usually found in large public pools. However, they are particularly useful in outdoor swimming pools exposed to direct sunlight where UV radiation rapidly degrades free chlorine.

- Ozone can be viewed as the most powerful oxidizing and disinfecting agent that is available for pool and spa water treatment. However, it is unsuitable for use as a residual disinfectant. It is most frequently used as a treatment step, followed by deozonation and addition of a residual disinfectant, such as chlorine. Excess ozone must be destroyed by an activated carbon filter because this toxic gas could settle, to be breathed by pool users and staff. Residual disinfectants would also be removed by the activated carbon filter and are, therefore, added after this step.

- Like ozone, UV radiation is a plant-room treatment that purifies the circulating water, inactivating microorganisms and to a certain extent breaking down some pollutants by photo-oxidation. This decreases the chlorine demand of the purified water but does not leave a disinfectant residual in the pool water. For UV to be most effective, the water must be pre-treated to remove turbidity-causing particulate matter that prevents the penetration of the UV radiation or absorbs the UV energy.

4.3.6 Dilution

Disinfectant and treatment will not remove all pollutants. The design of a swimming pool should recognize the need to dilute the pool water with fresh water. Dilution limits the build-up of pollutants from bathers (e.g., constituents of sweat and urine) and elsewhere, the by-products of disinfection and various other dissolved chemicals. Pool operators should replace pool water as a regular part of their water treatment regime. To some extent, dilution can be performed through the replacement of water run to waste during filter backwashing or by replacement of pool water used for pre-swim foot spas and other cleaning purposes.

4.3.7 Air quality

It is important to manage air quality as well as water quality in swimming pool, spa and similar recreational water environments. Rooms housing spa should be well ventilated to avoid an accumulation of *Legionella* in the indoor air. In addition, ventilation will help reduce exposure to disinfectant by-products in the air.

4.3.8 Showers and toilets

Pre-swim showers will remove traces of sweat, urine, faecal matter, cosmetics, suntan oil and other potential water contaminants. The result will be cleaner pool water, easier disinfection using a smaller amount of chemicals, and water that is more pleasant to swim in.

Pre-swim showers that are separate from post-swim showers are generally preferable. Pre-swim showers should be located en route from changing rooms to the swimming pool. They can be continuous to encourage use. Pre-swim showers must run to waste. Showers should be provided with water of drinking water quality as children and some adults may ingest the shower water.

Toilets should be provided where they can be conveniently used before entering the pool and after leaving the pool. All users should be encouraged to use the toilets before bathing to minimize urination in the pool and accidental faecal releases (AFRs). Babies should be encouraged to empty their bladders before they swim.

4.4 Operational management

The primary water and air quality health challenges to be dealt with are:

- Controlling clarity and other factors that minimize injury hazard;
- Controlling water quality to prevent transmission of infectious disease; and
- Controlling potential hazards from disinfection by-products.

This requires sound operational management of:

- Treatment (to remove particulates, pollutants and microorganisms):
- Disinfection (to destroy or remove infectious microorganisms as that the water cannot transmit disease-causing biological agents);
- Pool hydraulics (to ensure optimal distribution of disinfection throughout the pool); and
- Addition of fresh water at frequent intervals (to dilute substances that cannot be removed from the water by treatment).

4.4.1 Clarity

Controlling clarity involves adequate water treatment, usually involving filtration and coagulation. The control of pathogens is typically achieved by a combination of recirculation of pool water through treatment (typically involving some form of filtration plus disinfection) and the application of a residual disinfectant to inactivate microorganisms introduced to the pool by bathers.

4.4.2 Pool hygiene

As not all infectious agents are killed by the most frequently used residual disinfectants, and as removal in treatment is slow, it is necessary to minimize AFRs and vomitus and to respond effectively to them when they occur. The use of pre-swim showers is of use in minimizing the introduction of shed organisms. Therefore, all users should be encouraged to use toilets and showers before bathing to minimize contamination of the pool.

Where pre-swim showering is required, pool water is clearer, easier to disinfect with smaller amounts of chemicals and thus more pleasant to swim in. Operators should be satisfied that the water supplied for the showers is microbiologically satisfactory.

AFRs appear to occur relatively frequently, and it is likely that most go undetected. A pool operator faced with an AFR or vomitus in the pool water must act immediately.

If a faecal release is a solid stool, it should simply be retrieved quickly and discarded appropriately. The scoop used to retrieve it should be disinfected so that any bacteria and viruses adhering to it are inactivated and will not be returned to the pool the next time the scoop is used. As long as the pool is in other respects operating properly (disinfecting residuals, etc) no further action is necessary.

If the stool is runny (diarrhoea) or if there is vomitus, the situation is potentially hazardous. Even though most disinfectants deal relatively well with many bacterial and viral agents in AFRs and vomitus, the possibility exists that the diarrhoea or vomitus is from someone infected with one of the protozoal parasites, *Cryptosporidium* and *Giardia*. The infectious stages (oocysts/cysts) are relatively resistant to chlorine disinfectants in the concentrations that are practical to use. The pool should therefore be cleared of bathers immediately.

The safest action, if the incident has occurred in a small pool, hot tub or whirlpool, is to empty and clean it before refilling and reopening. However, this may not be possible in larger pools.

If draining down is not possible, then the procedure given below - an imperfect solution that will only reduce but not remove risk - should be followed:

- The pool is cleared of people immediately;
- Disinfectant levels are maintained at the top of the recommended range;
- The pool is vacuumed and swept;
- Using a coagulant, the water is filtered for six turnover cycles. This could take up to a day and so might mean closing the pool until the next day;
- The filter is backwashed (and the water run to waste); and
- The pool can then be reopened.

There are a few practical actions pool operators can take to help prevent faecal release into the pools:

- No child (or adult) with a recent history of diarrhoea should swim;
- Parents should be encouraged to make sure their children use the toilet before they swim;
- Thorough pre-swim showering is a good idea and parents should encourage their children to do it;
- Young children should whenever possible be confined to pools small enough to drain in the event of an accidental release of faeces or vomitus; and
- Lifeguards should be made responsible for looking out for and acting on AFR/vomitus.

Microbial colonisation of surfaces can be a problem and is generally controlled through cleaning and disinfection such as shock dosing and cleaning.

4.4.3 Spa pools

Spa pools have different operating conditions and present a special set of problems to operators. The design and operation of these facilities make it difficult to achieve adequate disinfectant residuals. They may require higher disinfectant residuals because of higher bathing loads and higher temperatures, both of which lead to more rapid loss of disinfectant residual.

Hot tubs and whirlpools and associated equipment can create an ideal habitat for the proliferation of *Legionella* and *Mycobacteria*. In addition, *P. aeruginosa* is frequently present in whirlpools and skin infections have been reported when the pool design or management is poor.

A *P. aeruginosa* concentration of less than 1 per 100 ml should be readily achievable through good management practices. Risk management measures that can be taken to deal with these non-enteric bacteria include ventilation, cleaning of equipment and verifying the adequacy of disinfection.

Spa pools that do not use disinfection require alternative methods of water treatment to keep the water microbiologically safe. A very high rate of water exchange is necessary - even if not effective enough - if there is no other way of preventing microbial contamination.

In spa pools where the use of disinfectants is undesirable or where it is difficult to maintain an adequate disinfectant residual, superheating spa water to 70ºC on a daily basis during periods of non use may help control microbial proliferation.

To prevent overloading of spa pools, some countries recommend that clearly identifiable seats be installed for users combined with a minimum pool volume being defined for every seat, a minimum total pool volume and a maximum water depth.

Pools and spas on ships may use either seawater or potable water as the source water. The hydraulic and circulation system of the pool will necessitate a unique pool design, depending upon ship size and pool location. The filtration and disinfection systems will also require adaptation to the water quality. Flow through seawater pools on cruise ships may become contaminated by polluted water in harbour areas and risk contamination from sewage discharge

4.4.4 Monitoring

Parameters that are easy and inexpensive to measure and of immediate health relevance - that is, turbidity, disinfectant residual and pH - should be monitored most frequently and in all pool types.

4.4.4.1 Turbidity

The ability to see either a small child at the bottom of the pool or lane markings or other features on the pool bottom from the lifeguard position while the water surface is in movement, as in normal use, can be converted to turbidity equivalents and monitored routinely. The turbidity equivalents can be compared with 0.5 nephelometric turbidity units (NTU), which is a useful upper limit guideline for optimized water treatment. If these turbidity equivalents are higher than 0.5 NTU, the lower, more stringent guidelines of 0.5 NTU should be used.

To exceed turbidity limits suggests both a significant deterioration in water quality and a significant health hazard. Such exceedance merits immediate investigation and may lead to facility closure pending remedial action.

4.4.4.2 Disinfectant and pH

For chlorine-based disinfectants, adequate routine disinfection should be achieved with a free chlorine residual level of at least 1 mg/litre throughout the pool. In a well-operated pool it is possible to achieve such a residual with maximum levels in any single point below 2 mg/litre for public pools and 3 mg/litre for semi-public pools. Lower residuals (0.5 mg/litre) will be acceptable in combination with the additional use of ozone, whereas higher levels (2-3 mg/litre) may be required for spa and hydrotherapy pools.

Disinfectant residuals should be checked by sampling the pool before it opens and after closing. The frequency of testing during swimming pool use depends upon the nature and use of the swimming pool. Samples should be taken at various parts of the pool, including the area of the pool where disinfectant residual is lowest. If the routine test results are outside the recommended ranges, the situation should be assessed and action taken.

The pH value of swimming pool water must be maintained within the recommended range to ensure optimal disinfection and coagulation. In order to do so, regular pH measurements are essential, and either continuous or intermittent adjustment is usually necessary. For heavily used pools, the pH value should be measured continuously and adjusted automatically. For less frequently used pools, it is sufficient to measure the pH manually.

The method of introducing disinfectants to the pool water influences their effectiveness. Individual disinfectants can have their own specific dosing requirements, but the following principles apply to all:

- Automatic dosing is preferable: electronic sensors monitor pH and residual disinfectant levels continuously and adjust the dosing correspondingly to maintain correct levels. Regular verification of the system (including manual tests on pool water samples) and good management are important;

- Hand dosing (i.e. putting chemicals directly into the pool) is rarely justified. Manual systems of dosing must be backed up by good management of operation and monitoring. It is important that the pool is empty of bathers until the chemical has dispersed;

- Trying to compensate for inadequacies in treatment by shock dosing is bad practice, because it can mask deficiencies in design or operation that may produce other problems and can generate unwelcome by-products;

- Dosing pumps should be designed to shut themselves off if the circulation system fails (although automatic dosing monitors should remain in operation) to ensure that chemical dispersion is interrupted;

- Residual disinfectants are generally dosed at the very end of the treatment process. The treatment methods of flocculation, filtration and ozonation serve to clarify the water, reduce the organic load and greatly reduce the microbial count, so that the post-treatment disinfectant can be more effective and the amount of disinfectant that must be used can be minimized;

- It is important that disinfectants and pH adjusting chemicals be well mixed with the water at the point of dosing; and

- Dosing systems, like circulation, should continue 24 h per day.

4.4.4.3 Disinfectant residuals

To avoid excessive disinfectant by-product or disinfectant irritation to mucosal surfaces, disinfectant residuals should be maintained at levels that are consistent with satisfactory microbiological quality but that are not unnecessarily excessive. Operators should attempt to maintain free chlorine residual levels below 5 mg/litre at all points in the pool or spa.

4.4.4.4 Microbiological quality

Microbiological monitoring at varying frequencies is often undertaken as a means of verification. Microbial quality should be checked before a pool is used for the first time, before it is put back into use after it has been shut down for repairs or cleaning and if there are difficulties with the treatment system or when contamination is suspected. Routine testing for *P. aeruginosa* in spa pools is also recommended.

4.4.4.5 Control of disinfection by-products.

The production of disinfection by-products can be controlled to a significant extent by minimizing the introduction of their organic precursors (compounds that react with the disinfectant to yield the by-products) through good hygienic practices (pre-swim showering), and maximizing their removal by well managed pool water treatment. The control of disinfectant by-products involves dilution, pre-swim showering, treatment and disinfection modification or optimization. Because of the presence of bromide ions in salt water, a common by-product formed in the water and air of seawater pools on ships will be bromoform which can result from either chlorine or ozone treatment.

It is inevitable that some volatile disinfectant by-products will be produced in the pool water and escape into the air. This hazard can be managed to some extent through good ventilation.

4.5 References

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