National Collaborating Centre for Environmental Health

Centre de collaboration nationale en santé environnementale

JULY 2016

Float Tanks: Considerations for Environmental Public Health

Angela Eykelbosh[a] *and Shelley Beaudet*[b]

Key Messages

- Floatation refers to a meditative activity in which users float in a high-density Epsom salt solution in a dark, quiet environment.
- Because float tanks are distinct from swimming pools and other recreational water, questions have been raised regarding the need for and efficacy of various disinfection methods.
- Although direct evidence is lacking, pathogen kill assays and field studies from recreational water suggest the need for caution regarding H_2O_2+UV as a disinfection method.
- Float tanks do not appear to be risky in and of themselves; further research on floatation tanks under normal and worst-case operating conditions will help to inform best practices.

Background

The use of floatation tanks, or simply "floating," is a relaxation and meditation technique first popularized by neuroscientist John C. Lilly in the 1970s. The practice involves floating in a warm, shallow pool of a saturated solution of magnesium sulphate ($MgSO_4$, also known as Epsom salt) that renders the body extremely buoyant. Floatation derives, but is distinct from, earlier experiments in sensory deprivation, which involved full-body immersion.[1] Modern floatation tanks, which may also be known as float tanks, isolation tanks, or restricted environmental stimulation therapy (REST), are often commercialized within sports medicine and the alternative health and wellness industry. Currently, floating is experiencing a popular resurgence, with at least 220 floatation tanks in 88 centres worldwide, primarily within North America.[2]

Although floating is meant to improve physical and mental health, public health practitioners have questioned whether improperly operated float tanks may pose a health risk. Due to the cost of replacing the salt, the tank solution is typically only changed a few times per year and disinfection practice varies. Also, although there is a long history of regulation and management for pools and hot tubs, float tanks are currently unregulated in most jurisdictions and guidance on management is limited. The objective of this document is to review the academic and grey literature regarding the potential public health risks of float tank use (please see Appendix A for the detailed literature search strategy). Existing float tank guidance and regulation was also reviewed in the companion document to this paper, entitled *Float Tanks: Review of Current Guidance and Considerations for Public Health Inspectors*.[3]

Standard float tank design and use

Part of the difficulty in inspecting float tanks is the wide variety of designs and systems; the rapid growth of the industry is expected to drive even further technological change. Single-person designs include a fully enclosed pod or tank (Figure 1), a fully enclosed float chamber

[a]Environmental Health and Knowledge Translation Scientist (Ph.D.), National Collaborating Centre for Environmental Health (Vancouver, BC). For additional documents, please contact Angela.Eykelbosh@bccdc.ca

[b]Senior Environmental Health Officer (BSc, CPHI(C)), Vancouver Coastal Health (Vancouver, BC)

that allows the user to stand, or a shallow basin in a standard room. Two-person float designs include a fully enclosed chamber allowing the users to stand, or a shallow basin in a standard room. The units may be pre-fabricated or assembled from standard components. At present, only one commercial float system has sought and been granted NSF approval.[4] The units may be hard plumbed or manually filled and drained. In most commercial units, the tank solution is filtered using disposable or reusable cartridge filters, or bag-style cloth filters that filter to 1−10 microns.[5,6]

Figure 1. A pod- or tank-style floatation unit that is fully enclosed, but does not allow the user to stand. This is the most commonly encountered form in floatation facilities. Obtained from Wikimedia Commons.[7]

The solution in the floatation tank is maintained at a temperature of 34−35°C, a depth of 7–12”, and a specific gravity of 1.2–1.3 g/cm^3. For reasons mentioned, the $MgSO_4$ solution is replaced approximately every three months to a year, depending upon usage. Because float facilities generally seek to minimize client disruption due to noise, light, or vibration, the filtration/circulation system is typically shut off while a client is floating. However, specific sounds such as binaural beats or whale sounds and specific light frequencies such as blue light are sometimes used to enhance the meditative experience. When not in use, the filtration/circulation system can be run continuously to minimize the potential for microbes or biofilms to establish themselves, and to increase the likelihood of contact with UV light.[6]

Float tanks and human health risks

There are several aspects of float tanks and their typical user profile that may modify the risk of communicable disease compared to pools and hot tubs. Due to the high salinity and bitter taste of the solution, clients avoid ingestion or eye contact. Water is less likely to get in the ears as many facilities provide ear plugs, although some users prefer a plug-free experience. Clients are typically advised to protect small cuts with a barrier of petroleum jelly to prevent stinging, and are unlikely to float with open sores or wounds. Clients are also generally adults, thus reducing hygiene and fouling issues sometimes seen in other types of recreational water facilities caused by children with decreased bowel and bladder control, although it should be noted that some Canadian float facilities do not exclude (and in some cases market toward) children. Furthermore, total daily bather load in a float tank is low (8−12 individuals) and constant (1−2 people at a time), such that operators do not need to adjust disinfectant in response to changes in use. Clients are generally naked while floating, but there is no evidence as to whether swimwear significantly affects bacterial load or has any impact on urinary tract infections. Clients are asked or required to shower before using the tank, which reduces pathogen inputs, as well as organic contaminants that contribute to disinfection by-product formation and decreased disinfection efficiency. Finally, users shower after their sessions to remove the salt, which should help to reduce infection risk.

These aspects of float tank use decrease the likelihood of ingestion and eye contact as routes of transmission compared to recreational water facilities. Float tank users do remain potentially vulnerable to skin, genitourinary, and outer ear infections. Inhalation may represent another route of transmission, as some float tank models agitate the water vigorously between clients; it is unclear if this may lead to the formation of bioaerosols if pathogens are present in the water. Finally, the hydrodynamics of a float tank, specifically the stillness of both solution and client, may also positively or negatively affect the ability of pathogens to contact, adhere to, and invade the skin.[8] Thus, despite mitigating circumstances, a number of questions remain regarding disease transmission between clients in float facilities.

Pathogens in highly saline float tanks

In online marketing, some float facilities state that the high-concentration $MgSO_4$ solution is a natural disinfectant that creates an inhospitable (or even non-survivable) environment for pathogens. However, this overstates the ability of the $MgSO_4$ solution to control pathogens, as can be demonstrated through evidence directly and indirectly related to float tanks.

Laboratory and field studies have shown that pathogenic organisms are able to survive (but not thrive) for relatively short- to medium-term periods in float solution. For the purposes of this paper, we focused on pathogen survival over a 30-minute period (data permitting), which is roughly consistent with the time between float clients. In the US, NSF International has performed two time-kill assays using float water. In the first assay, a grab sample from an operating float tank was inoculated and incubated (without shaking) with five pathogenic indicator microorganisms (*Pseudomonas aeruginosa, Escherichia coli* bacteriophage MS2, *Enterococcus faecium*, *Aspergillus niger,* and *Candida albicans*). After one hour, *P. aeruginosa* showed only a small 0.61-log reduction, whereas the remaining indicator organisms showed little or no change.[9]

In a second assay, a laboratory-prepared $MgSO_4$ solution was inoculated and incubated (with shaking to simulate tank circulation) with *P. aeruginosa* and *E. faecium*. *P. aeruginosa* was again the most sensitive organism, showing a 2-log reduction in one hour, whereas *E. faecium* showed only a 0.01-log reduction.[10] Both assays showed larger reductions over the longer-term; after 24 hours, *P. aeruginosa* showed a > 5-log reduction with shaking and a 2.6-log reduction without, but the more resistant organisms showed no change.[9,10] Finally, float solution (salt only) was far less effective in eliminating or reducing microbes than the same solution containing 1 ppm bromine, which was assessed using a mixture of pathogenic and non-pathogenic microbes sampled directly from human skin (staphylococci, *Micrococcus* spp., total diptheroids, *Bacillus* spp., *Moraxella osloensis, Rhodotorula rubra,* and *Penicillium* spp.).[11]

These assays demonstrate that although highly saline float solution does prevent exponential growth of pathogens, it is insufficient to achieve a 3-log reduction[c] over an interval consistent with one client and the next. For further information, Public Health Ontario has recently published an evidence brief that examines additional literature on microbial risk and human pathogen survival in floatation tanks.[12]

In the field, Ontario public health inspectors detected *P. aeruginosa* (>100 CFU/100 mL), as well as presumptive staphylococci, in an operating float tank, which was attributed to improperly executed ozone (O_3) and hydrogen peroxide (H_2O_2) disinfection.[13] In Australia, a survey of 17 float tanks in nine facilities also identified issues with *P. aeruginosa*, presumptive staphylococci, and high heterotrophic colony counts due to insufficient disinfection.[5] These reports, although not deriving from the peer-reviewed literature, show that microbes have been found in highly saline float solution in actual facilities with sub-optimal management. The period over which these organisms had existed in the float solution and their population dynamics are unknown.

The presence of pathogens in poorly managed float tanks and the ability of these pathogens to survive over the short-term highlights the need for effective management, including client advice, general cleaning, and disinfection. This review did not find documentation of outbreaks or illness linked to float tanks. However, the potential for unrecognized or unreported disease remains. *P. aeruginosa* has been of particular interest because of its preference for warm-water environments and its well-characterized connection to conditions such as folliculitis and otitis externa.[14] However, *P. aeruginosa* is one of the more sensitive organisms of those analyzed to date. Additional studies are required to better understand the risk due to pathogens that were found to be more resistant to float solution (i.e*.,* fungi, yeasts, and viruses). Other starting-point considerations may include pathogens known to exist in recreational water,[15-17] especially those known to infect the skin (e.g*.,* *Mycobacteria marinum*), and those adapted to saline environments (e.g*.,* *Vibrio* spp*.,* *Staphylococcus aureus)*.[18]

Disinfection methods for float tanks

Very little direct evidence on disinfection efficacy in float tanks is available. Due to the lack of direct evidence (i.e*.,* float tank studies), the literature on recreational and other water was used to compare disinfection practices most commonly found in float tanks. These include the use of: 1) a halogen (chlorine or bromine), typically with ultraviolet (UV) light and/or ozone (O_3), 2) O_3 with UV or H_2O_2, or 3) H_2O_2 with UV. Although specific evidence for float tanks is lacking, the potential advantages or disadvantages of these strategies for float tanks are discussed.

Some jurisdictions have required float tanks to use a ***halogen disinfectant***, and in many facilities a halogen has been combined with UV irradiation and/or O_3. As in drinking water treatment, using a multi-barrier approach lessens the probability of a disinfection failure. For example, in float systems that use halogen disinfection with UV, the use of a residual disinfectant may help to control free-living and biofilm-associated microbes in the tank and circulation/filtration system, while the use of UV

[c]In recreational water, the common standard for disinfection efficacy is a 3-log or 99.9% reduction in the number of viable pathogens over the course of treatment.

may help to reduce halogen-resistant organisms such as *Cryptosporidium* and *Giardia.*[19,20] Combining chlorine with an advanced oxidation process, such as UV or O_3, may also help to reduce halogen-related disinfection by-products (DBPs)[21-23] either by destroying DBPs themselves or the organic contaminants that lead to their formation, and at the same time (theoretically) reducing halogen requirements.[d] However, the efficacy and reliability of these advanced oxidation processes are the subject of ongoing research, and currently there is no evidence using these combined systems in float tanks.

In one of the few available float tank studies, researchers examined the effect of float tank solution (48% w/v $MgSO_4$ with or without 1 ppm bromine) on the survival of human skin microflora.[11] It was found that bathing in float solution with 1 ppm bromine elicited no change in microbiota sampled directly from the axilla, ankle, or forearm. However, when the same microflora were suspended in solution, float solution with 1 ppm bromine or 1 ppm bromine in pure water were equally effective in immediately killing all organisms isolated, with the exception of the highly resistant *Bacillus* endospores, and a *Penicillium* species. In contrast, float solution without bromine (salt only) required 1 to 48 hours to kill all organisms present, with the exception of the *Bacillus* endospore, which again remained. These data point to the relative speed of bromine disinfection for some species compared to the salt solution, and suggest that although bromine in the float solution does not kill microbiota on skin, it should eliminate most organisms that are shed into the solution. This should theoretically reduce the risk of disease transmission, although it should be noted that this study is most representative of normal use and not a worst-case scenario (i.e., sick users or a fecal incident) involving pathogenic organisms. The inability to kill microbiota on skin was attributed to the microstructure of the skin surface, which in other work examining *Pseudomonas* infectivity has been shown to protect microbes even from vigorous towelling.[8]

Float tanks that combine ***O_3 with UV or H_2O_2*** are also available. The concern with these systems is that although O_3 is a powerful oxidizer, it is also a respiratory irritant. In public pools that use O_3, the pool water is withdrawn, treated, and then de-gassed before returning to the pool, which prevents or limits public exposure to residual O_3. However, because the returning water should have little or no remnant O_3, there is no residual disinfectant in the bulk water, which precludes O_3 from being used as a primary disinfectant in pools.[23] In contrast, in a float tank setting, ozonated water can be cycled through the empty tank during the filtration/circulation phase without risk of human exposure (provided adequate ventilation is in place to clear the room or the chamber before the client enters). Interestingly, the half-life of O_3 is approximately eight minutes in water at 35°C,[24] which is long enough to allow it to circulate through and disinfect the entire float system, but short enough that the gas can dissipate given a reasonable interval between clients.

Some data exist regarding the use of O_3 in float tanks. Currently, the only NSF-certified float tank uses O_3 with UV, which achieved a >5-log reduction in *E. faecium* and *P. aeruginosa* in 7.5 minutes during initial testing.[25] The amount of O_3 in solution did not exceed 0.01 ppm (maximum permitted = 0.1 ppm) during the filtration/circulation cycle.[25] After a 3000-hour life test, the period required for the minimum 3-log reduction increased to 20 minutes, which highlights the importance of understanding system wear and maintenance.[26] Furthermore, in the previously mentioned case of a problematic float tank in Ontario,[13] initiating O_3+H_2O_2 disinfection according to the manufacturer's recommendations resolved all bacteriological issues, and follow-up testing has shown that the tank remains problem-free after several years.[27] Additional data is required to understand whether this strategy is effective in different tank designs and for a range of pathogens. For example, although O_3 (2.5 mg L^{-1}) + H_2O_2 (1.5 mg L^{-1}) showed a 5−6-log reduction against indicator viruses and *E. coli* after 10 minutes (and dissipated quickly from solution), the combination appeared to be much less effective against highly resistant *Bacillus subtilis* spores, with a 1.4-log reduction.[28]

There is a strong desire within the float industry to allow the use of ***H_2O_2, with or without UV***. This appears to be related to air quality aesthetics (i.e., avoiding "chlorine smell") as well as the recent swelling of public concern over halogen-related DBPs,[29] which are discussed in greater detail in *Respiratory hazards.* The US industry-based Float Tank Association has developed a Float Tank Standard that recommends using H_2O_2 (with or without UV) at a level of 20−100 ppm (~0.002−0.010%).[30] However, without a catalyst to stimulate the production of hydroxyl free radicals ($^{\bullet}OH$), H_2O_2 is at best a moderate oxidizer of organic matter and does not have a long-lasting residual. It is not considered an acceptable disinfectant for recreational water under the Model Aquatic Health Code (MAHC).[23] In Canada, devices and products used to sanitize swimming pools and spas are regulated under the Pest

[d]DBP-related health hazards are discussed in *Respiratory hazards.*

Control Products Act, and must be reviewed and registered prior to sale, distribution, or use. Currently, H_2O_2 (with or without UV) is not approved for this use. Because of this apparent conflict, and the fact that guidance documents like the MAHC often cannot publish the detailed evidence for certain recommendations, public health inspectors may find it useful to have on hand some of the following primary evidence examining H_2O_2 with or without UV.

The literature on H_2O_2 and water disinfection includes laboratory pathogen-kill assays, as well as field studies in functioning pools, spas, and hydrotherapy facilities. Laboratory studies using cell suspension assays have found that H_2O_2 concentrations in the range of those used in float tanks (20−100 ppm, or ~0.002-0.010%) achieve little to no reduction in viable pathogens over a timeframe consistent with the interval between float clients (Table 1). In fact, much higher doses of H_2O_2 (up to 30,000 ppm) remain ineffective against organisms such as *Cryptosporidium parvum* and *Enterococcus faecalis.* In another study looking at artificial pool water dosed with organic matter (0.3 or 1.5 mg/L), sodium hypochlorite (1 ppm free chlorine) achieved a 3- or 4-log reduction for all pathogens studied (*P. aeruginosa, E. coli, Staphylococcus aureus, Legionella pneumophila,* and *Candida albicans*) in 30 minutes. In contrast, 150 ppm H_2O_2 with or without supplementary silver ions under a low organic load (0.3 mg/L) achieved log reductions in the range of 0 to 0.63 in 30 minutes. For comparison, log inactivations in response to chlorine can be viewed on the US CDC website.[31]

Table 1. Laboratory assays examining the efficacy of hydrogen peroxide against pathogens commonly found in recreational water. Short test durations (10−30 minutes) are presented here, as they best represent the interval between float tank clients.

Organism	Medium	Concentration H_2O_2 (ppm)	Log reduction	Test Duration (min)
Candida albicans	Artificial pool water[32]	150	0	30
Cryptosporidium parvum	Distilled water[33]	30,000	2.0	20
Cryptosporidium parvum	Distilled water[33]	60,000	> 3	20
*Enterococcus faecium**	Sterile tap water[34]	30,000	0.9	10
Enterococcus faecalis	Peptone water[35]	150	0.11	10
Escherichia coli	Artificial pool water[32]	150	0.13	30
Legionella pneumophila	Artificial pool water[32]	150	0.41	30
Legionella pneumophila	Buffer[36]	1,000	< 3	30
MS2 coliphage	Peptone water[35]	150	0.06	10
Pseudomonas aeruginosa	Artificial pool water[32]	150	0.16	30
Staphylococcus aureus	Artificial pool water[32]	150	0.33	30

*A vancomycin-resistant strain of *E. faecium* was used in this experiment.

Combining H_2O_2 with UV is often posed as a way to boost disinfection efficacy, due to the fact that the photolysis of H_2O_2 produces two strongly oxidizing $^{\bullet}OH$ radicals.[37] Indeed, H_2O_2+UV is much more effective than H_2O_2 alone and can achieve a 3-log reduction for *E. coli* even at low H_2O_2 concentrations (<20 ppm). [38,39] However, several issues remain. Firstly, in batch experiments, the entire volume of water required UV exposure for relatively long contact times,[38,39] which is not feasible in a flow-through float tank system. Second, H_2O_2+UV remains ineffective against organisms such as *E. faecalis* and the MS2 coliphage, even at high H_2O_2 concentrations (150 ppm).[35] Finally and most importantly, the

powerful oxidizer in this system, the hydroxyl free radical, is extremely short-lived and exists in solution for less than a microsecond.[40] Thus, although the water within the UV cell where the radical is continuously generated may be very well sanitized,[40] the tank and plumbing are exposed to predominantly H_2O_2 alone .

The lack of an effective oxidizer in the tank system has implications for water quality, as insufficient oxidation may lead to urea or other organic matter build-up over time. A simulated bather experiment found that although H_2O_2+UV was effective in reducing amino acids (and to a lesser extent creatinine), urea showed very little oxidation after 107 hours of operation.[40] H_2O_2 has been used to control biofilm in some water systems, but is effective only at concentrations >500 ppm.[41,42] Finally, without an effective residual disinfectant, there may be inadequate protection against more UV-resistant organisms, such as viruses.[43] In Australia, seven members of a junior football club contracted hepatitis A virus (HAV) after submerging themselves and spitting water in an H_2O_2+UV outdoor spa.[44] Oral contact was critical in this case and bather load was very different from a float tank. This example is provided to illustrate the vulnerability of H_2O_2+UV systems, and should not be taken as evidence that float tanks could transmit HAV.

Finally, although UV is a well-known, proven technology in drinking and recreational water treatment, it has important limitations. UV disinfection efficacy is dependent upon the system being able to deliver a sufficient UV dose or "fluence" (mJ/cm^2), which is a function of the lamp intensity and exposure time (related to flow rate) in the UV cell. In the literature, the fluence required to achieve a 3-log reduction varies widely amongst pathogens, and is >20 mJ/cm^2 for the majority of viruses tested.[43] Disinfection efficacy is also impacted by water quality changes that affect the ability of the UV radiation to penetrate the water (i.e., transmittance), as well as lamp aging and fouling of the quartz sleeve. Salinity also plays a role. The contact time required to achieve a 3-log reduction for *E. coli* using an H_2O_2+UV system is greatly increased in artificial seawater (~210 minutes) compared to pure water (~120 minutes).[39] If the UV lamp used in a float tank is insufficiently powerful or should fail to deliver an adequate UV fluence for any other reason, the lack of an effective "back-up" sanitizer means that an H_2O_2+UV system might have very limited ability to disinfect between one client and the next.

To illustrate this, one of the few available float tank studies showed that UV alone, at a fluence of 20 mJ/cm^2, reduced coliform counts by 88% in a functioning float tank that had been dosed with coliform bacteria, falling short of a log-3 (99.9%) reduction.[45] The study did not examine a viral indicator. In contrast, under normal use conditions (i.e., daily use by healthy individuals over an extended period), UV treatment was as effective as UV with bromine in controlling total and fecal coliforms. However, the extremely limited methodological detail in this paper makes it difficult to assess the validity of these results.

Field studies also provide some insight into the efficacy of H_2O_2+UV systems compared to other methods. Glazer et al.[46] sampled water and air from 18 hot tubs and warm-water therapy pools managed with halogen disinfection, H_2O_2+UV, or O_3+UV. Halogen-disinfected facilities showed significantly lower median numbers of non-tuberculous mycobacteria (NTM) in both the water and the air above the water, compared to non-halogen-disinfected facilities. Schafer et al.[47] detected NTM in the air and water (and associated change rooms) of three H_2O_2+UV whirlpools in a large aquatics facility in the US, whereas chlorinated (but also lower temperature) pools in the same facility tested negative. These results suggest that halogen disinfection provides greater protection than alternative non-residual strategies in pools, although it is of course recognized that halogenated pools also experience disinfection failures that can lead to outbreaks. These studies also highlight the potential role for bioaerosols as a route for transmission. In the US, an outbreak of *Mycobacterium avium*-related hypersensitivity pneumonitis was documented among employees exposed to aerosols while working in a warm-water hydrotherapy facility maintained with a state-of-the-art UV+H_20_2 (100 ppm) system.[48]

Although it is important to note that the efficacy of H_2O_2 (with or without UV) has not been examined in a float tank, the data above indicate the need for further consideration. Based on these data, consumer protection issues may arise if operators claim to use H_2O_2 as a disinfectant, as the term "disinfectant" can give the consumer a reasonable expectation of high-efficacy pathogen-killing power. However, further studies are required in which float tanks are tested under normal operating conditions while additional sanitation measures (high-salinity, filtration, UV, ozone, etc.) are also in effect. Other suggestions for

further study are presented in *Knowledge Gaps and Concluding Remarks.*

Risk of accidental death and injury

There are several physical hazards that should be considered when inspecting float tanks. The first is the ***risk of falls*** due to the extremely slippery nature of the float tank solution, which can be addressed through appropriate design considerations and instructions on safely entering and exiting the tank. There is also a potential ***suction or entrapment hazard***, as in other recreational water settings,[49] but this risk is minimized in float tanks as the recirculation system is turned off during use. An ***electrocution hazard*** may exist if the float tank is not properly grounded; in 2008, the US Consumer Product Safety Commission recalled a line of float tanks for this reason.[50] In general, highly saline water in contact with electrical equipment poses a fire hazard due to the ability of the solution to damage materials through infiltration and crystal swelling[51] and the conductive nature of the solution. Float tank equipment should be kept clean and electrical components or wiring should not come into contact with the salt solution.

Drug use has also led to ***accidental death*** in float tanks. John C. Lilly, who popularized floating in the 1980s, often used psychoactive drugs in conjunction with floating to explore dissociative states.[52] Interest in combining floatation with drug use remains readily apparent in online fora and in the work of high-profile float tank enthusiasts.[53] For these or other reasons, some users who come to commercial facilities may use substances to enhance the floating experience. This review found two accidental deaths related to float tanks and substance abuse. In the first, a healthy 30-year-old man took ketamine before his session in a commercial float facility and drowned.[54] In the second case, a healthy 50-year-old woman died due to environmental hyperthermia complicated by drug and alcohol use while using a private float tank.[55]

Death or injury may also occur during an emergency situation if clients cannot be alerted. In England, an elderly float client caught in a building fire was unable to hear the manager's shouts to evacuate, and did not attempt to escape until smoke began infiltrating her tank. The client was rescued and treated for smoke inhalation; the facility was closed and the proprietor received a large fine.[56] From the inquiry into this event, it appears that there was no other mechanism in place to warn of an emergency. These cases, although extremely rare, demonstrate the ways in which accidental death or injury may occur in float facilities.

Respiratory hazards

A number of concerns have been raised regarding air quality within enclosed float tanks. These include the potential for mould or other bioaerosols, exposure to remnant O_3, and exposure to disinfection by-products (DBPs) in halogen-disinfected systems. Our literature review returned no information on any of these concerns within operating float tanks; here, we describe the primary concerns and how research might address knowledge gaps.

The high-humidity environment within a float tank may favour ***mould*** growth on the tank walls. The interior of the tank above the water line can be manually cleaned on a regular basis; however, not all hard-surface disinfectants are appropriate for this task.[e] There is no information regarding the growth of biofilms in other parts of the tank. ***Bioaerosols*** are an interesting consideration for float tanks, as the increased salinity, increased temperature, high humidity, and the enclosed pod are factors known to affect bioaerosol formation and exposure duration.[59,60] However, float tanks vary in the degree to which the float solution is agitated during the filtration/circulation cycle; it is unclear whether agitation in any given model is sufficient to eject bioaerosols, and if so, how long they persist. Air sampling during the filtration/circulation phase and at several time points thereafter would be necessary to characterize the effect of this warm, highly saline solution on aerosol formation and the potential for transmission.

Regarding O_3, concerns have been raised about adverse respiratory effects due to incomplete off-gassing and accumulation within enclosed tanks. The lowest observed adverse effects level (LOAEL) for a short-term O_3 exposure (four hours) is 0.120 ppm in air, and is associated with decreased lung function.[61] In the US, the only float system that is currently NSF-certified underwent extensive testing for residual O_3. The maximum O_3 concentration in the test water was 0.01 ppm.[25] Maximum O_3 in air would be expected to be yet lower, due to continual ventilation of the float

[e]Please see the NCCEH webpage for additional information on hard-surface disinfectants and sanitizers, as well as information on the efficacy of alternative antimicrobial agents.[57,58]

chamber while off-gassing. However, the potential for O_3 accumulation will vary according to a number of design considerations, including the ozone generator used, flow rate, additional treatment, and tank ventilation, and as such other tanks may not perform to the same standard.

DBP concerns derive from potential accumulation of these compounds in enclosed tanks, which may be exacerbated by the user breathing the air closest to the solution surface. Currently, there is no scientific literature exploring the formation of DBPs or related health risk in float tanks. In other literature, DBPs in chlorinated drinking water have been somewhat consistently (but not causally) associated with bladder cancer,[62] and DBPs in chlorinated pools have been linked to respiratory impacts in workers or elite swimmers with long-term exposure.[63,64] The duration and degree of exposure to DBPs is key and will depend on a number of factors, including: 1) the amount of time spent inside the tank, 2) the rate of ventilation, 3) the ability of the operator to maintain optimal halogen and low dissolved organic matter levels in the tank, and 4) the use of additional treatments such as O_3 or UV that destroy organic matter (including DBPs) through oxidation and photolysis.[22,37]

Air and water sampling for DBPs after successive floats and with different treatment systems may help to better understand DBP formation in halogenated float tanks. However, even with data in hand, assessing the overall health risk due to DBP exposure in float tanks is extremely challenging given the myriad ways in which humans are exposed to these compounds, including ingestion, inhalation, and dermal contact with chlorinated tap water, as well as internal generation.[65] Thus, although float clients may indeed be exposed to DBPs within a tank environment, it is unclear whether that exposure is significant compared to DBP exposure in daily life and how that might differ among individuals and over time.

Overall, respiratory risks from float tanks cannot be evaluated given the lack of air quality data under normal operating conditions. However, health and aesthetic concerns may be ameliorated through the installation and proper maintenance of the facility's HVAC system and improving tank ventilation.

Knowledge Gaps and Concluding Remarks

Float tanks do not appear to be "risky" in and of themselves; however, a poorly operated float tank, as with a poorly operated pool or personal service establishment, has the potential to negatively impact health. This document is not a call to regulation, but rather a knowledge tool to help EHOs in their inspection and review process and to assist decision-makers in policy development.

The development of new standards and guidelines, as discussed in our companion paper,[3] are important processes in the ongoing dialogue on the safe use of floatation tanks. However, the novelty of this practice means that significant knowledge gaps remain. This review did not find evidence of float tank-related outbreaks, but did find evidence of pathogen risk in float solution, poor air/water quality in similar recreational water settings under certain disinfection methods, and a rare but previously unrecognized risk of accidental death. Indirect evidence from laboratory and the recreational water literature highlights the need for further study as to whether H_2O_2+UV can sanitize effectively under the conditions currently recommended by the float industry.[30] Float tank design may also be a consideration, as the wide variety of designs available from the float industry means that results from one system may not be generalizable to others.

Direct evidence or float tank studies are necessary to resolve these knowledge gaps and to inform best practice for float tank design, operation, and inspection. Float tanks should be assessed holistically, with all components functioning normally, including cleaning, filtration, ventilation, and disinfection. Future float tank studies should analyze pathogen counts, tank air (bioaerosols, O_3, and DBPs), and biofilm growth in normally operating tanks under different disinfection methods. These parameters should be examined both over time (e.g., after zero floats, 100 floats, 1000 floats, etc.) and before and after being dosed with pathogenic species under controlled conditions over an appropriate interval (e.g., 15-30 minutes). Studies that use pathogen dosing or inoculation are key to understanding disinfection efficacy under worst-case conditions (e.g., an unreported, undetected fecal incident), and attempts should be made to include more- and less-resistant organisms. Due to the nature of the procedures required, collaboration between public health agencies, researchers,

industry, and standard developers will be required to obtain robust data. With this detailed information on float tanks, public health inspectors and regulators will be better positioned to assess public health risks and prioritize protective measures associated with this novel activity.

Acknowledgements

The authors would like to acknowledge the contributions of Michele Wiens (NCCEH) and input from Sean Jeon and Claudia Tien (Fraser Health), Amy Pavletic and Anne-Maria Quin (Middlesex London Health Unit), and Drs. Eleni Galanis, Jason Wong, and Troy Grennon (BC Centre for Disease Control). We also thank Float Lab (Venice Beach, California) for kindly sharing their NSF certification data. Finally, we thank our reviewers Nelson Fok (Concordia University of Edmonton), Esther Parker (BC Ministry of Health), Jason MacDonald (Alberta Health), Lynne Navratil (Alberta Health Services), Rich Martin (NSF International), Bob Vincent (Florida Department of Health), and Drs. Helen Ward and Lydia Ma (NCCEH).

References

1. Lilly JC. Mental effects of reduction of ordinary levels of physical stimuli on intact, healthy persons. Psychiatr Res Rep Am Psychiatr Assoc. 1956.

2. Float Tank Solutions. 2015 State of the float industry. Portland, OR: Float Tank Solutions. Available from: http://www.floattanksolutions.com/product/2015-state-of-the-float-industry-report/.

3. Beaudet S, Eykelbosh A. Float tanks: a review of current guidance and considerations for public health inspectors. Vancouver, BC: National Collaborating Centre for Environmental Health; 2016 Jul. http://www.ncceh.ca/documents/evidence-review/float-tanks-review-current-guidance-and-considerations-public-health

4. NSF International. NSF/ANSI 50 Equipment for swimming pools, spas, hot tubs and other recreational water facilities: floatation or sensory deprivation systems and related equipment (float lab). Ann Arbor, MI: NSF International. 2016 Jul. Available from: http://info.nsf.org/Certified/Pools/Listings.asp?Company=C0110845&Standard=050.

5. Lawrence K, Emanuel R, Knowles K. What is in your floatation tank? Environmental Health Australia (New South Wales) 2015 Meeting. Available from: http://www.ehansw.org.au/documents/item/776.

6. Alberta Health Services. Guidance document: inspection approach to floatation tanks (GD-SB(P)-16-03-006). Edmonton, AB: Alberta Health Services, Environmental Public Health; 2016.

7. Floatguru. i-sopod floatation tank in a spa setting. As created by Floatworks: Wikimedia Commons; 2012. Available from: https://commons.wikimedia.org/wiki/File%3AI-sopod_Flotation_Tank.jpg

8. Roser DJ, Van Den Akker RB, Boase S, Haas CN, Ashbolt NJ, Rice SA. Pseudomonas aeruginosa dose response and bathing water infection. Epidemiol Infect. 2014;142(03):449-62.

9. NSF International. Organism time kill in float lab water (J-00114729). Ann Arbor, MI: NSF International; 2012 Nov. Available from: http://floatlab.com/wp-content/uploads/2012/01/Organism-Time-Kill-in-Float-Lab-Water5.pdf.

10. NSF International. Organism viability testing in Epsom salt and control solution: NSF International; 2015 Oct. Available from: https://s3-us-west-2.amazonaws.com/floattanksolutions/NSF-Salt-Only-Tests_2015.pdf.

11. Malowitz R, Tortora GT, Lehmann CA. Effects of floating in a saturated Epsom-salt solution on the aerobic microbial flora of the skin. Clin Lab Sci. 1988;1(6):358-61.

12. Public Health Ontario, Nadolny E, MacDougall C. Evidence brief: risk of infection in the use of floatation tanks. Toronto, ON: Ontario Agency for Health Protection and Promotion; 2016 Jun. Available from: http://www.publichealthontario.ca/en/eRepository/EB_Floatation_Tanks_Infection_Risk.pdf.

13. Quin A-M, Pavletic A. Floatation tank investigation: Middlesex-London Health Unit [presentation slides]. CIPHI Ontario 2013 conference; Sep 17; London, ON: CIPHI; 2013. Available from: http://www.ciphi.on.ca/images/stories/pdf/resources/2013_Annual_Conference_Presentations/4_investigation_of_a_floatation_tank.pdf.

14. Public Health Agency of Canada. *Pseudomonas* spp. Ottawa, ON: PHAC; 2012 [updated 2012 Apr 30; cited 2016 Apr 15]; Available from: http://www.phac-aspc.gc.ca/lab-bio/res/psds-ftss/pseudomonas-spp-eng.php.

15. Barna Z, Kadar M. The risk of contracting infectious diseases in public swimming pools. A review. Ann Ist Super Sanita. 2012;48(4):374-86.

16. Jones F, Bartlett CLR. Infections associated with whirlpools and spas. J Appl Bacteriol. 1985;59:61S-6S.

17. La Rosa G, Della Libera S, Petricca S, Iaconelli M, Briancesco R, Paradiso R, et al. First detection of papillomaviruses and polyomaviruses in swimming pool waters: unrecognized recreational water-related pathogens? J Appl Microbiol. 2015;119(6):1683-91.

18. Tlougan BE, Podjasek JO, Adams BB. Review: aquatic sports dematoses. Part 2 – in the water: saltwater dermatoses. Int J Dermatol. 2010;49(9):994-1002.

19. Public Health Agency of Canada. *Cryptosporidium parvum*. Ottawa, ON: PHAC; 2014 [updated 2014 Sep 11; cited 2016 Apr 15]; Available from: http://www.phac-aspc.gc.ca/lab-bio/res/psds-ftss/msds48e-eng.php.

20. Public Health Agency of Canada. *Giardia lamblia*. Ottawa, ON: PHAC; 2012 [updated 2012 Apr 30; cited 2016 Apr 15]; Available from: http://www.phac-aspc.gc.ca/lab-bio/res/psds-ftss/giardia-lamblia-eng.php.

21. Lee J, Jun M-J, Lee M-H, Lee M-H, Eom S-W, Zoh K-D. Production of various disinfection byproducts in indoor swimming pool waters treated with different disinfection methods. Int J Hyg Environ Health. 2010;213(6):465-74.

22. Glauner T, Kunz F, Zwiener C, Frimmel FH. Elimination of swimming pool water disinfection by-products with Advanced Oxidation Processes (AOPs). Acta Hydrochimica et Hydrobiologica. 2005;33(6):585-94.

23. U.S. Centers for Disease Control and Prevention. The Model Aquatic Health Code (MAHC): an all-inclusive model public swimming pool and spa code. Atlanta, GA: CDC; 2014 Aug. Available from: http://www.cdc.gov/mahc/currentedition/index.html.

24. Lenntech. Ozone decomposition. Delft, the Netherlands: Lenntech [cited 2016 May 12]; Available

from: http://www.lenntech.com/library/ozone/decomposition/ozone-decomposition.htm.

25. NSF International. Qualification testing for float lab isolation floatation chamber (J-00119683). Ann Arbor, MI: NSF International; 2013 May.

26. NSF International. Qualification testing for float lab isolation floatation chamber (J-00125267). Ann Arbor, MI: NSF International; 2013 May.

27. Pavletic A (Public Health Inspector with the Middlesex-London Health Unit), Quin A-M (Public Health Inspector with the Middlesex-London Health Unit). Follow-up to MLHU's experience with an improperly operated float tank: instituting O_3 + H_2O_2 treatment reduced or eliminated heterotrophic bacteria and *Pseudomonas*. Personal communication with Eykelbosh A (Environmental Health and Knowledge Translation Scientist at National Collaborating Centre for Environmental Health and the BC Centre for Disease Control). 2016 May 13.

28. Sommer R, Pribil W, Pfleger S, Haider T, Werderitsch M, Gehringer P. Microbicidal efficacy of an advanced oxidation process using ozone/hydrogen peroxide in water treatment. Water Sci Technol. 2004;50(1):159-64.

29. Driedger SM, Eyles J. Different frames, different fears: communicating about chlorinated drinking water and cancer in the Canadian media. Soc Sci Med. 2003;56(6):1279-93.

30. Jahromi A, Leibner S, Perry G, Talley G, Wasserman D. Float tank standard: Floatation Tank Association; n.d. Available from: http://www.floatation.org/resources/healthinfo/health-standard/.

31. U.S. Centers for Disease Control and Prevention. Effect of chlorination on inactivating selected pathogen. Atlanta, GA: CDC; [updated 2012 Mar 21; cited 2016 Jun 23]; Available from: http://www.cdc.gov/safewater/effectiveness-on-pathogens.html.

32. Borgmann-Strahsen R. Comparative assessment of different biocides in swimming pool water. Int Biodeterior Biodegrad. 2003;51(4):291-7.

33. Barbee SL, Weber DJ, Sobsey MD, Rutala WA. Inactivation of Cryptosporidium parvum oocyst infectivity by disinfection and sterilization processes. Gastrointest Endosc. 1999 May;49(5):605-11.

34. Saurina G, Landman D, Quale JM. Activity of disinfectants against vancomycin-resistant Enterococcus faecium. Infect Control Hosp Epidemiol. 1997 May;18(5):345-7.

35. Koivunen J, Heinonen-Tanski H. Inactivation of enteric microorganisms with chemical disinfectants, UV irradiation and combined chemical/UV treatments. Water Res. 2005;39(8):1519-26.

36. Domingue EL, Tyndall RL, Mayberry WR, Pancorbo OC. Effects of three oxidizing biocides on Legionella pneumophila serogroup 1. Appl Environ Microbiol. 1988;54(3):741-7.

37. Glaze WH, Kang J-W, Chapin DH. The chemistry of water treatment processes involving ozone, hydrogen peroxide and ultraviolet radiation. Ozone Sci Engineer. 1987;9(4):335-52.

38. Miranda AC, Lepretti M, Rizzo L, Caputo I, Vaiano V, Sacco O, et al. Surface water disinfection by chlorination and advanced oxidation processes: Inactivation of an antibiotic resistant E. coli strain and cytotoxicity evaluation. Sci Total Environ. 2016;554–555:1-6.

39. Rubio D, Nebot E, Casanueva JF, Pulgarin C. Comparative effect of simulated solar light, UV, UV/H2O2 and photo-Fenton treatment (UV–Vis/H2O2/Fe2+,3+) in the Escherichia coli inactivation in artificial seawater. Water Res. 2013;47(16):6367-79.

40. Wojtowicz J. Survey of swimming pool/spa sanitizers and sanitation systems. J Swim Pool Spa Ind. 2001;4(1):9-29.

41. Christensen BE, Trønnes HN, Vollan K, Smidsrød O, Bakke R. Biofilm removal by low concentrations of hydrogen peroxide. Biofouling. 1990;2(2):165-75.

42. Lin S-M, Svoboda KKH, Giletto A, Seibert J, Puttaiah R. Effects of hydrogen peroxide on dental unit biofilms and treatment water contamination. Euro J Dent. 2011;5(1):47-59.

43. Chevrefils G, Caron E, Wright H, Sakamoto G. UV dose required to achieve incremental log inactivation of bacteria, protozoa and viruses. IUVA News. 2006 Mar:38-45. Available from: http://iuva.org/sites/default/files/member/news/IUVA_news/Vol08/Issue1/CairnsArticleIUVANewsVol8No1.pdf.

44. Tallis G, Gregory J. An outbreak of hepatitis A associated with a spa pool. Commun Dis Intell. 1997 Dec 25;21(23):353-4.

45. Wong G, Suedfeld P. Ultraviolet light as a sterilization method in flotation tanks. J Clin Eng. 1986;11(1):69-72.

46. Glazer CS, Martyny JW, Lee B, Sanchez TL, Sells TM, Newman LS, et al. Nontuberculous mycobacteria in aerosol droplets and bulk water samples from therapy pools and hot tubs. J Occup Environ Hyg. 2007;4(11):831-40.

47. Schafer MP, Martinez KF, Mathews ES. Rapid detection and determination of the aerodynamic size range of airborne mycobacteria associated with whirlpools. Appl Occup Environ Hyg. 2003 Jan;18(1):41-50.

48. Angenent LT, Kelley ST, St Amand A, Pace NR, Hernandez MT. Molecular identification of potential pathogens in water and air of a hospital therapy pool. Proc Natl Acad Sci U S A. 2005 Mar 29;102(13):4860-5.

49. U.S. Consumer Product Safety Commission. 2008-2012 Reported circulation/suction entrapments associated with pools, spas, and whirlpool bathtubs, 2013 report. Bethesda, MD: CPSC; 2013. Available from: http://www.poolsafely.gov/wp-content/uploads/2013FinalCircsuctEntrapwStamp.pdf.

50. U.S. Consumer Product Safety Commission. Brian Smith recalls serene float tanks due to electrocution hazard. Bethesda, MD: CPSC; 2008 Jan 24. Available from: http://www.cpsc.gov/en/Recalls/2008/Brian-Smith-Recalls-Serene-Float-Tanks-Due-to-Electrocution-Hazard/.

51. Doehne E. Salt weathering: a selective review. Geological Society Special Publication: Natural Stone, Weathering Phenomena, Conservation Strategies and Case Studies. 2002;205:51-64.

52. Lilly JC. The center of the cyclone: an autobiography of inner space. New York: Julian Press; 1972.

53. Morris H. Tanks for the memories: an exploration of sensory deprivation tanks with Joe Rogan: VICE; 2013. Available from: http://www.vice.com/en_ca/video/tanks-for-the-memories-full-length.

54. Anonymous. Floatation tank victim took horse drug. The Reading Chronicle. 2008. Available from: http://www.readingchronicle.co.uk/news/13384212.Floatation_tank_victim_took_horse_drug/.

55. Lann MA, Martin A. An unusual death involving a sensory deprivation tank. J Forensic Sci. 2010 Nov;55(6):1638-40.

56. Dixon H. Woman left floating in isolation tank as building burned. The Telegraph. 2013 May 1. Available from: http://www.telegraph.co.uk/news/uknews/law-and-order/10030260/Woman-left-floating-in-isolation-tank-as-building-burned.html.

57. Gaulin C, Lê M-L, Shum M, Fong D. Disinfectants and sanitizers for use on food contact surfaces. Vancouver, BC: National Collaborating Centre for Environmental Health; 2014. Available from: http://www.ncceh.ca/sites/default/files/Food_Contact_Surface_Sanitizers_Aug_2011.pdf.

58. Fong D, Gaulin C, Lê M-L, Shum M. Effectiveness of alternative antimicrobial agents for disinfection of hard surfaces. Vancouver, BC: National Collaborating Centre for Environmental Health; 2014. Available from: http://www.ncceh.ca/sites/default/files/Alternative_Antimicrobial_Agents_Aug_2014.pdf.

59. Tyree CA, Hellion VM, Alexandrova OA, Allen JO. Foam droplets generated from natural and artificial seawaters. J Geophys Res Atmos. 2007;112(D12204).

60. Mårtensson EM, Nilsson ED, de Leeuw G, Cohen LH, Hansson HC. Laboratory simulations and parameterization of the primary marine aerosol production. J Geophys Res. 2003;108(D9):4297.

61. Health Canada. Residential indoor air quality guideline: ozone. Ottawa, ON: Government of Canada; 2010. Available from: http://healthycanadians.gc.ca/publications/healthy-living-vie-saine/ozone/index-eng.php.

62. Villanueva CM, Cordier S, Font-Ribera L, Salas LA, Levallois P. Overview of disinfection by-products and associated health effects. Curr Environ Health Rep. 2015;2(1):107-15.

63. Florentin A, Hautemanière A, Hartemann P. Health effects of disinfection by-products in chlorinated swimming pools. Int J Hyg Environ Health. 2011;214(6):461-9.

64. Goodman M, Hays S. Asthma and swimming: a meta-analysis. J Asthma. 2008;45(8):639-47.

65. Hrudey SE. Epidemiological inference and evidence on DBPs and human health. In: Hrudey SE, Charrois J, editors. Disinfection by-products and human health. London, UK: IWA Publishing; 2012.

Appendix A – Methods

This review was conducted in response to queries from public health practitioners seeking scientific evidence regarding: 1) the potential for pathogens to survive or thrive in a high-salinity environment; 2) the use of hydrogen peroxide (H_2O_2) with or without ultraviolet (UV) light as a means to control microbial growth in float tanks; 3) potential issues with water quality testing equipment in a high-salinity environment; and 4) the potential for air quality issues due to disinfection by-products or other agents. The information reviewed here includes peer-reviewed academic studies, as well as gray literature from reputable agencies and solicitation of expert opinions from a variety of public health professionals. EBSCO, Web of Science, and Google Scholar were used to execute the following search queries, which were designed to capture the broader context of the queries received from practitioners:

Table 2. Objectives and queries developed as part of the literature search protocol.

Objective	Search Query
Health risks due to float tanks	("float tank" OR "flotation tank" OR “floatation” OR "isolation tank" OR "float room" OR "sensory deprivation tank) AND ("health risk" OR "death" OR "pathogens")
Survival of human pathogens in a high-salinity environment	(“water”) AND (“pathogens”) AND (“halotoleran*” OR “halophilic” OR “high-salt” OR “high salinity” OR “salt stress”)
Efficacy of various disinfection strategies in water treatment	(“water disinfection” OR “water treatment”) AND (“pathogens” OR “viruses” OR “bacteria” OR “protozoa”) AND (“hydrogen peroxide” OR “ultraviolet” OR “halogen” OR “ozone”)
Pathogens in recreational water and their relationship to various disinfection strategies	(“pool” OR “hot tub” OR “spa”) AND (“pathogens” OR “viruses” OR “bacteria” OR “protozoa”) AND (“hydrogen peroxide” OR “ultraviolet” OR “halogen” OR “ozone”)
Illness or outbreaks in recreational water and their relationship to various disinfection strategies	(“pool” OR “hot tub” OR “spa”) AND (“pathog*” OR “outbreak” OR “illness”) AND (“hydrogen peroxide” OR “ultraviolet” OR “halogen” OR “ozone”)
Air quality concerns related to recreational water settings	(“pool” OR “hot tub” OR “spa”) AND (“air quality” OR “indoor air”) AND (“disinfection by-products” OR “bioaerosol” OR “ozone” OR “mould” OR “mold”)

These searches returned numerous hits, which were subjected to title/abstract review. Only documents in English were reviewed. Searches were not time-bounded and were repeated prior to publication. For disinfection research, studies related to relatively clean water were reviewed (e.g., recreational water, drinking water, and food processing water), whereas “dirty water” studies were excluded (e.g., sewage, ballast, and other effluents). Further targeted searches were performed for each objective as needed. In addition to database searches, documents relevant to the topic were solicited from public health and industry experts, and drawn from the citations of the documents reviewed. Google was also used to review the websites of more than 30 float centres across Canada to understand how and to whom floatation is marketed; however, individual facilities will not be named in this document.

This document was produced by the National Collaborating Centre for Environmental Health at the British Columbia Centre for Disease Control, July 2016.

Production of this document has been made possible through a financial contribution from the Public Health Agency of Canada through the National Collaborating Centre for Environmental Health.

ISBN: 978-1-988234-06-9

200 – 601 West Broadway
Vancouver, BC V5Z 4C2

Tel.: 604-829-2551
contact@ccnse.ca

National Collaborating Centre for Environmental Health

Centre de collaboration nationale en santé environnementale

To provide feedback on this document, please visit http://www.ncceh.ca/forms/feedback-form