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Development of recreational water spray ground design regulations in New York State, an engineering approach

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ABSTRACT

The New York State Department of Health developed regulations for the design and operation of spray grounds to address the potential for recreational water illnesses associated with this type of venue. The water treatment component of the new regulation was based on a first-principles approach to address the unique challenges of spray grounds. The regulation departs from traditional recreational water treatment methods by requiring a novel filtration approach and the installation of UV disinfection. The water treatment system was also required to incorporate automatic control systems to ensure the water quality is maintained with a minimum of operator involvement. The treatment process specifications were based on pathogen and contaminant loadings that are likely to be encountered at spray grounds. The regulation was finalized in 2007, giving New York State a reliable means of protecting the health of spray ground patrons.

Key words | cryptosporidiosis, design regulation, recreational water, spray ground, ultraviolet disinfection

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NOMENCLATURE

Variables and parameters

- f Post filter fraction of turbidity
- Q Water flow rate, gpm
- Q_1 Filter flow rate for bypass treatment system, gpm
- Q_2 Feature flow rate for bypass treatment system, gpm
- S Ratio of feature to filter flow rates
- T Turbidity, NTU
- T_A Turbidity added value, NTU
- $\bar{t}$ Mean residence time, V/Q
- V Volume of water, gallons

INTRODUCTION

Spray grounds have gained popularity because they provide significant entertainment value and present a limited, or no, drowning hazard. In 2004, approximately 30 (and increasing) spray grounds existed in New York State at various lifecycle stages. New York State Department of Health (NYSDOH) recognized potential problems as existing pool and spa regulations failed to capture the unique treatment requirements of spray grounds. The literature at the time substantiated the concerns based on reported recreational water illness data and epidemiology.

Published statistics demonstrated an increasing frequency of recreational water-associated outbreaks between the years 1978 and 2002 (Blackburn *et al.* 2004). Of the 65 documented outbreaks between 2001 and 2002 (the highest frequency to date), 44 (68%) involved treated-water venues (e.g., pool, spas, spray grounds). The data demonstrated cryptosporidiosis outbreaks were becoming more frequent in recreational treated-water venues. Although cryptosporidiosis was associated with a modest fraction of all

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recreational water outbreaks, the number of individuals affected was disproportionately large. For example, during the period 2001–2002, only 14% of all outbreaks associated with treated-water venues involved cryptosporidiosis, however, at least 58% of all individuals affected by recreational water outbreaks were affected by *Cryptosporidium*. A single outbreak involving a spray ground in New York State in 2005 resulted in 2,307 documented cases of illness attributed to cryptosporidiosis (Yoder *et al.* 2008). The literature also documented several outbreaks caused by chlorine-sensitive organisms such as *Escherichia coli* and *Shigella* species, which were the result of poor facility maintenance and could have been prevented by greater diligence in operation and maintenance procedures (Blackburn *et al.* 2004).

To ensure public health would be protected, NYSDOH initiated a process to develop regulations for the design and operation of spray grounds with the final regulation taking effect on March 28, 2007. To address the unique characteristics of spray grounds, a proactive approach based on modeling and process engineering methods was introduced into the regulation development cycle. The focus of this work is to provide the public health community with the rationale underlying the development of the water treatment portion of the spray ground regulation, Subpart 6-3 of the New York State Sanitary Code (NYSSC) (NYSDOH 2007). Subsequent to the development and promulgation of Subpart 6-3, all spray grounds in New York State were required to conform to the new regulation. In the years since the regulation was enacted, spray grounds have been designed, approved for construction and used by patrons of New York State. The engineering plan review for both proposed and existing facilities, and eventual approval of these projects, provided valuable feedback that confirmed the regulation was well developed from engineering and regulatory perspectives.

DEVELOPMENT OF WATER TREATMENT REQUIREMENTS OF THE SPRAY GROUND REGULATIONS

Spray grounds are recreational water venues that spray water through features onto a play area and are attractive to a wide age range of patrons from very young children to adults seeking relief from heat. The typical design of spray grounds includes a hard play surface (spray pad) which may be constructed of brushed or polymer coated concrete. The spray pad has water features installed on it and a means of collecting the sprayed water for recycling. Modern spray grounds incorporate a variety of spray feature types including jets, fountains, dumping buckets, water cannons, and water falls. By definition, in New York State, a spray pad does not impound any water above grade so as to reduce the drowning hazard with respect to that of a pool. Spray pads may be scaled from very small (100 ft^2) to much larger with surface areas measuring approximately 10,000 ft^2. As a result, spray pads have been placed in a variety of locations such as shopping malls, theme and municipal parks, and both indoor and outdoor recreational water complexes. Spray pads have also been proposed as serving dual duty by becoming decorative fountains during non-recreational hours.

Identification of unique water treatment needs for a spray ground

The water treatment challenges that are unique to spray grounds (compared to pools) include: (1) high patron-to-water volume ratio (spray grounds have approximately 80–150 gallons of water per patron where pools may have approximately 400–500 gallons per patron); (2) high water–air interface that can impact water chemistry and quality with increased rates of evaporation; and (3) underground water storage limiting the ability for supervisory staff to make visual observations and decisions concerning the water quality.

The concept of how spray grounds fit into the recreational water environment was still being developed in 2005. The idea that a recreational water venue could meet patron needs by providing significant entertainment value without a drowning hazard was attractive to facility owners and planners. As a result, spray grounds were being proposed at an unprecedented rate in New York State. Swimming pools had been in use for decades, providing designers and operators with a large amount of empirical data with which to refine future designs. However, spray ground treatment design criteria were not yet developed. To address this, NYSDOH decided to develop a new regulation before the industry proceeded much further. To facilitate the time constraints, a first-principles approach was used to develop design requirements that would provide the basis for a predictable and scalable water treatment process. During the development of the design component of the regulation, industry experts and design professionals were consulted to ensure the new regulation would be tenable from an industry perspective.

Spray pad design

The spray pad is the portion of a spray ground where the water is exposed to patrons and the environment, thereby collecting contaminants. To address this exposure route, several design requirements were built into the regulation to provide barriers to limit particulate and microbiological contamination by patrons and from the environment. A 'deck' at least 5 feet in width surrounding, and sloping away from, the spray pad was required to provide a buffer zone between the environment (e.g., grassy areas) and the wetted play surface. This prevents contaminated runoff water from draining onto the spray pad surface and leaving residual materials. Because spray pads are often located in landscaped playgrounds, foot showers were required at the entrance to provide patrons with a means of washing their feet. This requirement may be waived when spray pads are located in hardscaped locations such as theme parks. Finally, to protect the water in the treatment tank during non-use periods (e.g., nights, rainy days) valving in the main drain system was required to allow water to be diverted from the treatment tank and to the wastewater disposal system (see Figure 1, item 14). A means of diverting water to waste

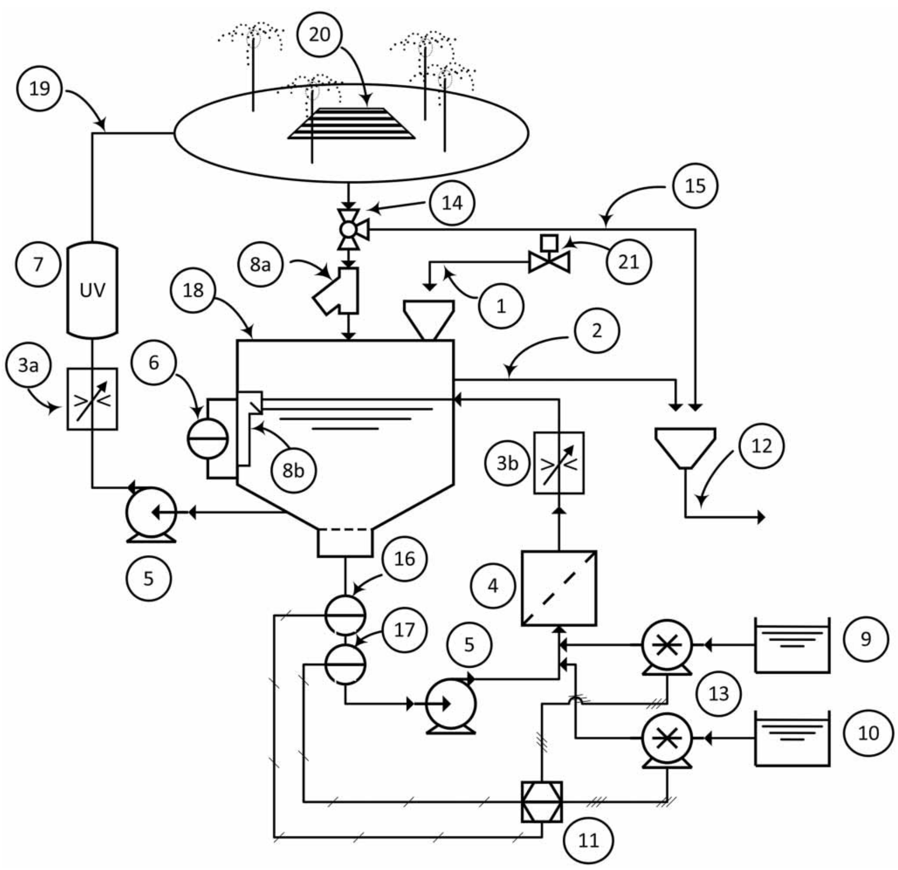


Figure 1 | Example of a spray ground water treatment process: (1) automated fill through an air gap, (2) treatment tank overflow pipe, (3a) flow controller for feature flow, (3b) flow controller for recirculation system, (4) filter, (5) recirculation pump, (6) level indicator, (7) UV reactor, (8a) strainer or (8b) pool skimmer, (9) disinfectant (NaOCl) feed tank, (10) acid tank for pH management, (11) pH and disinfectant controller, (12) wastewater system, (13) chemical feed pumps for disinfectant and acid, (14) rain/wash water diversion valve, (15) waste line to disposal system, (16) pH sensor probe, (17) disinfectant sensor probe, (18) treatment tank, (19) feature supply plumbing, (20) main drain, (21) automated control valve for fill pipe.

also allows the spray pad to be washed (with cleaning agents if necessary) without contamination of the spray ground water reservoir (treatment tank). Traffic barriers were also required to discourage pedestrians from traversing the spray pad when the facility is closed.

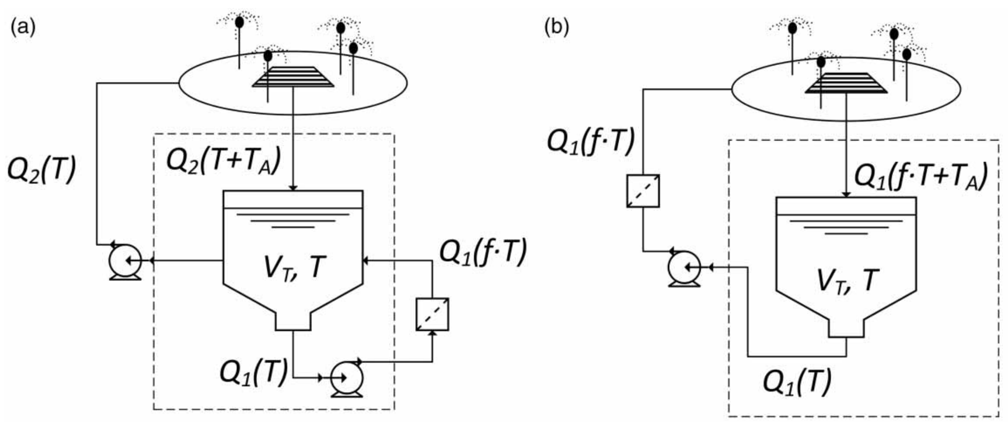
Treatment tank design

The treatment tank provides a vessel in which to maintain water chemistry, disinfect and store water that is provided to the features (see Figures 1 and 2). Frequently observed problems in recreational water venues include inadequate/excessive disinfectant concentration, incorrect pH, and improper water level. To address these issues, requirements were built into the regulation for automatic disinfectant and pH control systems and water level maintenance equipment. These automatic systems reduce the need for operator intervention and the likelihood of an outbreak due to the growth of chlorine/bromine sensitive organisms (Yoder *et al.* 2004). As treatment tanks are typically located underground, the regulation required a means of preventing/removing floating debris from collecting on the surface of the water. Pool skimmers installed at the normal operating level of the water in the treatment tank have been shown to be effective. A ready means for gaining access to the interior of the treatment tank was also required for inspection and maintenance operations. Large side-by-side type doors that facilitate a thorough inspection of the interior have been used successfully and provide greater safety when interior maintenance is required. Overflow plumbing with an outlet at the maximum permissible water level was required to convey excess water to waste through an air gap, which prevents the backflow of wastewater into the spray ground water. For more details concerning the treatment tank controls/specifications the reader is referred to Figure 1 and Paragraph 6-3.24 (f)(4) of the NYSSC (NYSDOH 2007).

Water treatment process design

Effective and efficient water treatment must remove particles and supply adequate disinfection. Particulate solids have the potential to shield organisms and consume disinfectant. The way interactive fountains/features distribute water over a play surface and the risk presented by *Cryptosporidium*-contaminated water warranted an examination of the methods used to develop and specify the treatment of spray ground water.

An 'order of magnitude' analysis was used to determine the appropriate water disinfection efficacy. For this analysis, the treatment tank volume was assumed to be 5,000 (of the order 10^3) gallons and the minimum infectious dose for cryptosporidiosis set at ten oocysts (Chappell *et al.* 2006).



Bypass filtration configuration scheme. Full-flow filtration configuration scheme.

Figure 2 | A mass balance performed on turbidity demonstrates what variables require field measurement: (a) shows schematically a bypass filtration configuration, which has a maximum predicted turbidity value of 3.0 NTU when using a feature to filter flow rate ratio of 3.0; (b) shows schematically a full-flow filtration configuration, which has a maximum predicted turbidity value of 1.0 NTU. The variable *T* represents the water turbidity, the parameter T_A represents the amount of turbidity added to the water on the spray pad, and *f* represents post filtration fraction of turbidity remaining in the water.

In addition to this information, an estimate of the maximum number of oocysts deposited by an ill patron was needed to make the calculation. Goodgame *et al.* (1993) measured the concentration of excreted oocysts in stool of AIDS patients with cryptosporidiosis while counting the diarrhea events and measuring the total volume of feces. A statistical analysis was performed on the data to provide the 99% confidence level, which was 4.6×10^8 oocysts in a single diarrheal event (of the order 10^8). Therefore, in the case of a fecal accident at a spray ground, the resulting maximum average concentration of oocysts in the water is of the order 10^5 per gallon. Using the minimum infectious dose of ten oocysts (Chappell *et al.* 2006), an individual could become ill by consuming less than 2.6×10^{-4} gallon (1 mL) of contaminated water. To reduce the probability of infection after a fecal (diarrheal) contamination event it was determined that a disinfection method would be required that could achieve at least four logs of inactivation of *Cryptosporidium* prior to the water being delivered to the spray pad for contact with patrons. Four logs of inactivation would result in a patron having to consume as much as a gallon of water (on average) to obtain ten oocysts immediately after a fecal accident. Consumption of this much spray ground water by a patron is unlikely.

Chemical disinfection methods were examined to determine their feasibility for this type of application. An analysis was performed assuming a hydraulically efficient treatment tank design (e.g., plug flow) and pseudo-first order disinfection kinetics to determine whether chemical disinfection could be adequate. The treatment tank was modeled as a chemical reactor to determine the volume and mean residence time ($\bar{t}$) that corresponds to 4-log reduction of viable *Cryptosporidium* oocysts. The analysis showed the volume would need to be unreasonably large (i.e., large $\bar{t}$) even for a hydraulically efficient treatment tank with elevated concentrations of disinfectant such as 10 ppm of free available chlorine (FAC). Ozone disinfection was considered as well; however, it was determined ozone disinfection had similar barriers to effective use as does chlorine. From this analysis it was determined chlorine-resistant organisms such as *Cryptosporidium* and *Giardia* (Korich *et al.* 1990) present a significant challenge to the use of chemical disinfection for their control. Clearly, alternative methods would need to be considered in order to meet the water treatment goals outlined previously.

Ultraviolet light disinfection

In 2005, the emerging ultraviolet light (UV) disinfection field held promise for providing the efficacy required to address the potential *Cryptosporidium* oocyst loadings at spray grounds. The method of applying UV would need to provide an adequate degree of disinfection to the water prior to it being delivered to the spray pad. Installing a UV reactor in the plumbing that provides water to the spray features, rather than in a bypass line (see Figures 1 and 2), would assure all water coming into contact with patrons would be disinfected to the target level. Figure 3 shows the modeled concentration of viable oocysts with respect to time after a fecal accident for a 1,000 gallon treatment tank with a 350 gpm flow rate through the UV reactor which has a 4-log inactivation rate. A comparison of treatment configurations was made by contrasting the potential exposure of patrons assuming full-flow and bypass UV treatment of spray ground water. The solid line in Figure 3

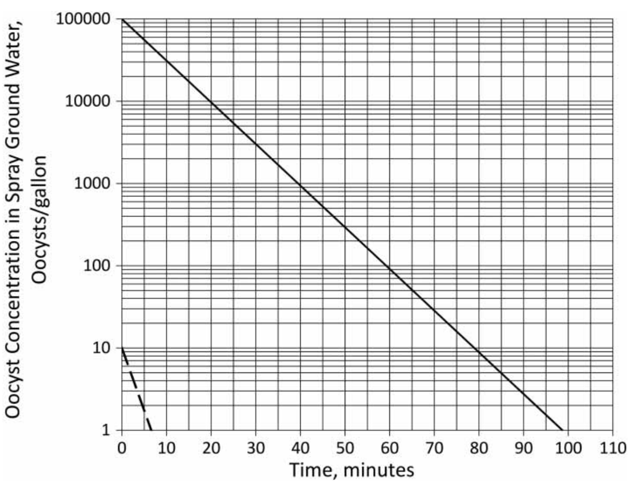


Figure 3 | Concentration of oocysts with respect to time for the water conveyed to the spray pad using two UV reactor placement configurations. With a UV reactor installed in a bypass (filter) loop, the patrons are exposed to the oocyst concentration (represented by the solid line) in the treatment tank water. In this configuration, the concentration of oocysts presents a significant level of exposure to patrons for over 60 minutes. With a UV reactor installed in the feature supply plumbing, the patrons are exposed to an oocyst concentration (represented by the dashed line) that is 10,000 times lower than in the treatment tank water. In this example, the treatment tank water volume is 1,000 gallons and the feature and filter flow rates are 350 gpm and 117 gpm, respectively.

represents the concentration of oocysts in the treatment tank and, therefore, in the water that comes into contact with patrons in instances where the UV reactor is installed in the bypass filter recirculation loop. Using this placement of the UV reactor and in this example, patrons would be exposed to a large concentration of oocysts for approximately 24 treatment tank turnovers over a period of at least 60 minutes. The dashed line (in Figure 3) represents the concentration of oocysts contained in the water that is discharged from the spray features and exposed to the patrons when a UV reactor is installed in the plumbing that supplies water to the spray pad. The oocyst concentration in the feature water immediately following a fecal accident (in this instance) would be on average ten per gallon, making it much less likely for a patron to contract cryptosporidiosis. In order to provide a conservative analysis, this model assumes the filter does not remove oocysts. The results from both treatment configurations show how a UV reactor installed in the spray feature supply plumbing affords better public health protection. Therefore, NYSDOH required the installation of a UV reactor in the spray feature supply plumbing.

The efficacy of UV disinfection is determined by the amount of ultraviolet radiation received by the water, which is measured as dose (in units of mJ/cm^2). Full scale UV reactor validation procedures determine the operating conditions required to achieve disinfection efficacy with respect to the reduction equivalent dose (RED) for specific organisms (USEPA 2006). At the time the spray ground regulations were being developed, a common RED to which UV reactors were being validated was 40 mJ/cm^2 using MS2 (bacteriophage) as the surrogate. For more information on UV reactor validation procedures, the reader is referred to Masschelein (2002) and the draft and final UV disinfection guidance manuals published by the United States Environmental Protection Agency (USEPA 2003, 2006). The analysis contained in the draft UV Disinfection Guidance Manual indicated a MS2 RED of 40 mJ/cm^2 is likely to produce 4-log inactivation of *Cryptosporidium*, which was determined to be protective of public health for spray ground water. The final UV Disinfection Guidance Manual (UVDGM) (USEPA 2006) includes additional data that indicated a MS2 RED of 40 mJ/cm^2 would likely produce 4-log inactivation on the condition the water had a UV transmissivity greater than or equal to 85% (see Appendix G of the UVDGM (USEPA 2006)). Measurements made by NYSDOH personnel at several recreational water facilities indicated spray ground water typically has $\geq$85% UV transmissivity. In the event the water transmissivity or lamp output becomes too low to produce the required UV intensity to deliver 40 mJ/cm^2, the regulation required the treatment system to automatically divert the water from the features to prohibit inadequately treated water from coming in contact with patrons. For more information regarding UV reactor installation guidance, the reader is referred to Chapters 3 and 4 of the UVDGM (USEPA 2006).

Chemical disinfection

UV disinfection is very effective for most microorganisms; however, it does not leave a residual in the water and therefore does not provide disinfection to the interior of the treatment tank, recirculation system plumbing, or the spray pad itself. Therefore, a requirement for chemical disinfection was included in the regulation. This requirement would provide a means for preventing the growth of biofilms on the interior wetted surfaces. It is important to maintain equipment free from biofilm because clusters of organisms can break free from surfaces and pass through the UV reactor without receiving adequate UV radiation to fully inactivate them. Halogen-based (chlorine or bromine) compounds have been determined to be effective for preventing the growth of biofilms and for inactivating many UV-resistant pathogens (in particular, some adenoviruses (Gerba *et al.* 2002)) at concentrations that had been approved for use in drinking water, and in then-current recreational water regulations (NYSDOH 2000). Additionally, chlorine and bromine compounds are effective at oxidizing organic materials that may otherwise accumulate in the water. The most commonly used disinfectants are liquid sodium hypochlorite solution applied using a chemical feed pump or pelletized calcium hypochlorite fed by an erosion feeder. Bromine compounds may also be used; however, the minimum residual is required to be 2.2 times the concentration required for chlorine (reported as Cl_2) in order to obtain the same disinfection efficacy. Bromine is fed to the spray ground water in stick form (bromochlorodimethylhydantoin) using an erosion feeder.

Maintenance of pH is important because it impacts the disinfection efficacy of chlorine (White 1992). A pH range of 7.2–7.8 was specified in the regulation to ensure chlorine efficacy while protecting the integrity of some spray pad surface finishes (e.g., plaster). At the upper pH limit of 7.8, the fraction of FAC that exists as hypochlorous acid, the more effective form (from a disinfection perspective), is less than 40% and decreasing (White 1992). The relatively small pH range was determined to be acceptable because automatic control systems can maintain the pH within limits.

The range of acceptable FAC concentrations was based on the need to maintain disinfection of the spray pad and other wetted surfaces. For example, an unnoticed fecal accident could leave large numbers of bacteria, viruses, and protozoa on the spray pad surface without the benefit of UV disinfection. Therefore, the minimum FAC concentration was set at 2.0 ppm. This is greater than the lower limit of 0.6 ppm required for swimming pools in New York State (NYSDOH 2000) because the patron-to-water volume ratio is much larger than for pools and the greater air–water interface could dissipate disinfectant in relatively short periods of time. The upper limit of the FAC concentration was set to 10 ppm, which represents a significant increase over the 5.0 ppm upper limit for pools and spas in New York State (NYSDOH 2000). An additional benefit of using elevated concentrations of FAC is that it allows a disinfectant residual to remain in the water for a longer period of time after the spray features are turned off. This helps minimize the growth of biofilms in the spray feature supply plumbing, which may develop in the absence of a disinfectant residual. The public health risk of biofilms was investigated by Rose *et al.* (1998), who demonstrated a link between plumbing biofilms and 'lifeguard lung' disease due to the inhalation of endotoxins from bacteria that may amplify in stagnant water and on pipe walls.

The upper concentration limit of 10 ppm can be justified by ocular and dermal studies performed by Gnemi (1991a, 1991b) that were subsequently reviewed by Bruch (2007). The ocular study examined the effect of placing 1,100 ppm FAC solution in the eyes of rabbits, which showed no effects during the subsequent 72 hours of observation. The dermal study entailed placing 1.1% (11,000 ppm) FAC on gauze in direct contact with shaved rat skin for 24 hours with a subsequent 14 day period of observation. The studies revealed no ill-effects in the test animals. A compilation of anecdotal incidences of the consumption of highly chlorinated water suggests drinking water with up to 50 ppm is not deleterious to humans (Muegge 1956). These studies suggest the upper limit could possibly be greater than 10 ppm; however, many commercially available test kits produce erroneous results at greater FAC concentrations because the chlorine begins to bleach the indicator dye.

Turbidity control

The control of particles in spray ground water is important because they can shield microorganisms and/or consume disinfectant. Modeling was employed to understand how spray grounds accumulate particulate materials. Pool water acquires particulate contaminants from patron use and atmospheric particles settling onto the water surface. The rate of particle accumulation is roughly proportional to the number of patrons that can fit in a pool which is limited by surface area. Spray grounds, however, distribute water over a play surface that may be disproportionately large compared to the volume of water stored in the treatment tank. This causes the water to become particle laden at a rate proportional to the spray feature flow rate, not the treatment tank volume. For example, consider two spray grounds both using a 5,000 gallon treatment tank to supply water to the features. The first spray ground has a feature flow rate (water provided to the spray pad) of 1,000 gallons per minute (gpm) as compared to another system, where the same volume of water is used to provide water to a spray pad at 100 gpm. The spray ground that has a feature flow rate of 1,000 gpm will expose the water to the environment at ten times the rate and therefore collect particles more rapidly as compared to the system with a 100 gpm feature flow rate. To address this problem, the water treatment process development effort applied modeling, filter equipment specifications (NSF/ANSI 50) and treatment standards to determine design and operation parameters (NSF International 2004).

The model used was simplified to focus on the important variables and parameters. Turbidity was used as a proxy variable for the concentration of particles to provide a ready means for relating the analysis to spray grounds in the field. A mass balance was used to model how turbidity accumulates in, and is removed from, spray ground water using bypass (Figure 2(a)) and full-flow (Figure 2(b)) filtration configurations. The model assumed a well-mixed treatment tank to obtain conservative results and treated the turbidity as if it was composed of particles of uniform size and therefore removed by the filter at a single rate $(1-f)$. The mass balance assumed particles are removed by filtration alone and that incoming water had no particles in it. The result of the modeling process is a first-order differential equation in time. The equation was solved for the steady state solution, as this would provide for the greatest value of turbidity in the treatment tank and therefore the worst case likely to be experienced. The modeling process resulted in the following two expressions for steady state turbidities of spray ground water with the bypass (Equation (1)) and full-flow (Equation (2)) water filtration configurations shown schematically in Figure 2(a) and 2(b), respectively:

$$T_{\text{Bypass system}} = \frac{ST_A}{1-f}; \; S = \frac{Q_2}{Q_1} \tag{1}$$

$$T_{\text{Full-flow system}} = \frac{T_A}{1-f} \tag{2}$$

where S is the ratio of feature (Q_2) to filter (Q_1) flow rates.

The amount of turbidity acquired by water (T_A) while it travels from the features toward the spray pad drain is a model parameter that was measured at an operating spray ground. The value of T_A was determined by measuring the turbidity of the water flowing down the main drain and subtracting the turbidity of the water discharging from a feature nozzle. The value was determined to be ~0.25 nephelometric turbidity units (NTU). The data used were collected on a breezy day when the air was laden with cottonwood seeds. Clearly, this model parameter may be a function of the type of features used and the population of patrons on the spray pad. Further measurements should be taken to confirm the value of T_A for high-use spray grounds.

The model (see Figure 2(a) and 2(b)) used to describe the accumulation and removal of turbidity from the water uses the parameter f which represents the fraction of turbidity remaining in the water after it passes through the filter. This value was assumed to be a constant to simplify the analysis and provide a parametric study. The instantaneous filter efficiency $(1-f)$ was determined to be 24% from the minimum filter performance required for listing by NSF International (2004). From Equation (1), the only remaining quantity needed to determine the maximum feature to filter flow rate ratio (S) is the permissible upper limit for turbidity.

The maximum turbidity of 3.0 NTU was obtained by comparing the prescribed limit for unfiltered drinking water and the results of UV disinfection research. The Surface Water Treatment Rule (SWTR) (USEPA 1989) referenced the work of LeChevallier *et al.* (1981) who suggested the upper turbidity limit of 5.0 NTU for unfiltered drinking water. UV disinfection research (Malley 2000) demonstrated, for certain types of turbidity-causing particles, the amount of power required to attain 2-log (99%) inactivation of MS2 bacteriophage increased significantly above 3.0 NTU. Based on this comparison, NYSDOH defaulted to the lower value of 3.0 NTU for spray ground water to assure effective UV disinfection. Using the permissible upper limit for turbidity of 3.0 NTU, the analysis resulted in a maximum feature to filter flow rate ratio of 3:1 for bypass systems (Figure 2(a)). Spray grounds that filter all the water prior to being conveyed to the spray pad (full-flow filtration) do not need to address the flow rate ratio as there is only one stream, and the maximum expected turbidity would be approximately 1.0 NTU (Figure 2(b)).

Basing the filtration flow rate on the flow provided to the spray features rather than the treatment tank volume represents a departure from traditional pool recirculation system designs that are focused on turnover time. As a result, the maximum flow rate ratio of 3:1 allows spray grounds to be scaled over a wide range of sizes with a ready means of determining the filter flow rate. The efficiency of the treatment process may be enhanced by considering treatment tank hydraulics that possess a smaller degree of mixing of newly arrived (from the spray pad drain and filter effluent) and existing water in the treatment tank.

Blended pool and spray ground treatment systems

During the rule-making process, NYSDOH became aware of several currently operating facilities that combined a spray ground and a pool on the same treatment system. The challenge to this treatment configuration is that fecal contamination of one venue affects the other, resulting in the potential for a larger outbreak. The water treatment portion of the regulation addressed shared-water venues using two options: (1) requiring all water drained from the spray pad to be treated with UV disinfection prior to combining/circulating with pool water (preferred) or (2) requiring UV disinfection to treat the combined recirculation flow rate of the pool and spray ground. It was recognized that the latter option would not be as protective as the design configuration for standard (stand-alone) spray grounds because, regardless of the recirculation rate, untreated water would remain in the pool due to mixing of recently treated and existing water (i.e., law of dilution). To address this, a treatment protocol was developed that would reduce an oocyst concentration over a 12-hour period to one that would be less likely to produce illness in patrons swimming in the pool or using the spray pad. The assumption was made that an oocyst seeding would deposit 100 million (10^8) oocysts in the pool water. Modeling the treatment system and assuming a level of disinfection efficacy that is lower than expected for 40 mJ/cm^2 (3-log/99.9% versus 4-log/99.99%) produced the following expression that gives the minimum flow rate of water required to be UV treated so that:

$$Q_{\text{minimum}} = \left(\frac{14.8 - ln(V)}{12 \times 60}\right)V \tag{3}$$

where Q_{minimum} (gpm) is the minimum flow rate through the UV reactor, and V (gallons) is the combined volume of the pool and spray ground water. The use of 3-log disinfection efficacy provided a conservative value for Q_{minimum} (i.e., it is greater than would be obtained by incorporating 4-log disinfection performance). This treatment scheme would reduce the concentration to one oocyst per 0.0264 gallon (0.1 L) within 12 hours. At this concentration, an individual would need to consume, on average, at least 0.26 gallon (1 L) of water to become ill with cryptosporidiosis. Consumption of this much water is not typical and, therefore, exposure to oocysts in adequate concentrations to continue an outbreak beyond 1 day is unlikely. The reality of swimming pool water treatment is that, because of the law of dilution, it is not possible to provide a venue in which there is absolutely no risk of infection in the period immediately following a diarrheal accident. Further work is needed to optimize the recirculation flow rate through a UV reactor for pools as a means of mitigating the effects of a fecal accident that contains *Cryptosporidium, Giardia* or other chlorine-resistant human pathogens.

Turbidity control for combined (pool–spray ground) systems was an issue that was addressed by incorporating both current design regulations for pools and the newly developed flow rate ratio concept for spray grounds. It was concluded from field observations that adherence to then-current regulations for pool recirculation rates maintained pool water in adequately clean conditions for public health purposes. Therefore, the minimum required filtration rate for a combined system is simply the filtration rate corresponding to the minimum turnover time for a pool plus one-third the feature flow rate so that:

$$Q_{\text{Minimum filtration rate}} = Q_{\text{Minimum pool turnover}} + \frac{Q_{\text{Feature}}}{3} \tag{4}$$

The result of addressing combined pool–spray ground systems using the methods described above provides a means for treating the water to significantly reduce the likelihood of a waterborne disease outbreak.

CONCLUSIONS

The NYSDOH recognized the need to develop a new regulation (Subpart 6-3) to address the design and operation parameters for spray grounds in order to protect public health. The unique character of spray grounds (compared to pools) warranted a more rigorous analysis to develop the specifications of a water treatment system. As a result, the design component of Subpart 6-3 is based on process engineering methods that utilized modeling and the scientific literature. Subpart 6-3 also stipulates process automation requirements to reduce the need for operator intervention and the potential for operational excursions such as inadequate/excessive disinfectant concentration or improper pH.

The requirement for UV treatment is based on the inability of traditional chemical methods to adequately inactivate chlorine-resistant organisms in a treatment tank of reasonable volume (or $\bar{t}$). The design and operation of UV reactors focused on RED instead of log inactivation of a specific organism to increase the likelihood the regulation would be protective of public health in the event of the discovery of an emerging pathogen that may be more resistant than the organisms that were of immediate concern. Focus on RED also eliminated the need to measure the UV transmissivity, which is required to determine the log inactivation using the validation procedures that were published in the UVDGM (USEPA 2006).

The most important requirements for spray ground system design include the following:

- UV treatment (RED = 40 mJ/cm^2) of all water provided to the features using a UV reactor installed in the spray feature supply plumbing.
- Chemical disinfection to maintain a biofilm-free system.
- Automatic control systems for treatment tank water level and chemistry (disinfectant and pH) maintenance.
- An automatic means of diverting water from the features in the event of a failure of the UV reactor to deliver at least 40 mJ/cm^2.
- A maximum feature to filter flow rate ratio (S) maintained by automatic flow control systems in the filter and feature supply plumbing.
- A means of diverting water to waste while the spray pad is not in use or undergoing cleaning.

Subpart 6-3 has been used as the standard for reviewing spray ground designs in New York State since the rule went into effect in 2006 and was finalized in 2007. During that time, the regulations have been shown to be defensible and readily applied to proposed designs. Future work on this code should include measurement of the maximum contamination burden for spray grounds to confirm the maximum value of the feature to filter flow rates (S). Further analysis of treatment tank design would also benefit particle removal and improve the overall process.

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