# AQUAPERL FILTER AIDS & SAND FILTERS

A range of studies have shown that the addition of AQUAPERL to sand filters has significant impact on the removal of Cryptosporidium-sized particles (i.e., the 5-µm microspheres).
James E. Amburgey, Ph.D in his technical paper Removal of Cryptosporidium-Sized Polystyrene Microspheres from Swimming Pool Water with a Sand Filter with and without Added Perlite Filter Media, found that perlite when added to a sand filter almost eliminated Cryptosporidium:

| FILTER TYPE | AVERAGE REMOVAL EFFICIENCY |
|---|---|
| Typical Sand Filter | 19 % @ 5 uM |
| Sand Filter + Aquaperl | 98 % @ 5 uM |

## ADDING AQUAPERL

- *Aquaperl should be added a rate of 1.2 kg per square metre of sand filter area.*
- For a typical home sand filter eg. 0.5m2, hence 0.6kg of AQUAPERL
- 0.6 kg is equivalent to 2.5 litres volume of AQUAPERL.

## METHOD

- Thoroughly back flush the sand filter free of debris
- Restart with filter operating normally and pump recirculating water through the filter.
- To the skimmer box add perlite powder at the recommended rate.

## PERFORMANCE

- Most pools will have a build up of fine dirt and debris.
- Expect to backflush the filter more frequently initially, as fine residue is rapidly removed from pool water.
- The particles that make water look dirty are often much smaller individually, than the naked eye can see.
- The human eye can only see down to 40uM.
- To make clear perfect water we need to filter to at least 5uM at very high efficiency.
- AQUAPERL will remove all significant solid debris from pool water, giving water a distinct sparkle.
- AQUAPER has a high affinity for organic lotions, oils and fats and will strip these substantially from the water.
- Very fine sub-micronic debris and oils may take a little longer tor remove but will improve water 'feel'.
- Water quality in most cases will improve visually very quickly.
- Some clients report reduced tannin discolouration in their water from gum tree debris also.
- Expect within several days, to enjoy a much improved silky sheen and feel to pool water.

## CRYPTOSPORIDIUM

- Chlorine at normal swimming dosage levels, with sand filtration only, will take over 20 days to kill or remove Cryptosporidium oocysts with any level of efficacy.
- AQUAPERL added to a sand filter can statistically remove Cryptosporidium at very high efficiency from pool water.
- Just one contamination by a swimmer may leave 10 million oocysts in the water. Contamination is typically treated by no swimming, super-chlorination for an extended period & filtration to remove debris.
- But what about oocyst contaminations that you don't see?
- Using AQUAPERL, contamination can be clarified in as little as 24 to 30 hours depending on pool recirculation rates with as few as 1 or 0 oocysts remaining, so family and friends can swim with greater confidence.

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Technical Note

# Removal of *Cryptosporidium*-Sized Polystyrene Microspheres from Swimming Pool Water with a Sand Filter with and without Added Perlite Filter Media

James E. Amburgey, Ph.D.[1]

**Abstract:** Waterborne disease outbreaks in U.S. swimming pools have been increasing in recent years, and the majority of the outbreaks are caused by *Cryptosporidium* oocysts. This research project evaluates sand filtration for swimming pools without and with an amendment, perlite. The evaluation was formed on the basis of removing 5-$\mu$m polystyrene microspheres, as a surrogate for *Cryptosporidium* oocyst, from simulated pool water stored in a 757 L (200 gal) tank. The results showed that a sand filter, without perlite, was not efficient at removing *Cryptosporidium*-sized particles (i.e., the 5-$\mu$m microspheres), with removals averaging 19% (or 0.09 log). The sand filter with a thin layer (1.2 kg/m$^2$ or 0.25 lbs/ft$^2$) of perlite media on top demonstrated removals of 98% (or 1.8 log). The filtration rate was maintained at 49 m/h (20 gpm/ft$^2$) in all experiments. These results indicate that perlite may hold promise in reducing the likelihood of outbreaks of cryptosporidiosis associated with swimming pools. **DOI: 10.1061/(ASCE)EE.1943-7870.0000445.** © *2011 American Society of Civil Engineers.*

**CE Database subject headings:** Recreational buildings; Sand filters; Pathogens; Water pollution.

**Author keywords:** Recreational facilities; Sand filters; Pathogens; Swimming pools; Perlite.

## Introduction

*Cryptosporidium* is a chlorine-resistant protozoan pathogen with free chlorine concentration times contact time (or Ct) values on the order of 15,300 mg/L · min (Shields et al. 2008b), which causes the majority of waterborne disease outbreaks in swimming pools in the United States (Yoder et al. 2008). Cryptosporidiosis lasts an average of 12 days (with rare instances lasting as long as four weeks) in immunocompetent individuals with symptoms that include: watery diarrhea, nausea, vomiting, fever, and abdominal cramping (Daniel 1996; Hoxie et al. 1997). Surveillance of cryptosporidiosis in the United States indicates that the reported incidence of infection has increased dramatically since 2004 (Yoder and Beach 2010). Both the number of reported cases and the number of individual outbreaks have shown overall upward trends since 2004 (Yoder et al. 2010). Although it is difficult and expensive to assess the prevalence of protozoan parasites in public pools during normal (nonoutbreak) conditions, a study of 160 filter backwash water samples from Atlanta, Georgia showed that 13 (8.1%) were positive for *Giardia* or *Cryptosporidium* or both (Shields et al. 2008a). In a study of 803 Oklahoma children, 58% of adolescents (ages 14 to 21) were seropositive for *C. parvum*, indicating prior infection by the pathogen (Ford 1999). The true burden of cryptosporidiosis is not known with certainty, but recent estimates have ranged from 300,000 to 748,000 cases annually in the United States (Yoder and Beach 2007; Beach 2011). Multiple sources have indicated that weaker subpopulations (e.g., very young children, elderly people, pregnant women, and the immunocompromised) could die from cryptosporidiosis (Daniel 1996; Hoxie et al. 1997; Ford 1999). A quantitative risk assessment model of *Cryptosporidium* in swimming pools recently confirmed there is a "significant public health risk" (Pintar et al. 2010). As in the drinking water industry, the burden for safety falls primarily on physical removal (i.e., filtration).

Swimming pools are complex systems wherein a body of water experiences variable mixing and fluctuating inputs of contaminants. The filtration and disinfection of the water in a pool typically occurs as the water is recirculated through a treatment area at regular intervals that could be as long as 4–8 h on average (via a system of interconnected inlets and outlets spaced around the pool). A target pH (e.g., 7.2 to 7.5) and free chlorine level (e.g., 1 to 4 mg/L) are typically maintained in the water (often by an automatic controller) to achieve some level of residual disinfection between treatment cycles. Automatic control systems for filters exist, but most swimming pool filters are still controlled and backwashed manually. The overall quality and safety of the pool water depends on many variables [e.g., bather inputs, mixing efficiency, length of treatment cycle, disinfection process type(s), and filtration efficiency], but this study focused solely on the efficiency of the filtration process for particles of only one size.

Recent research has shown that typical removals of *Cryptosporidium*-sized microspheres by high-rate (i.e., filtration velocity 25–49 m/h or 10–20 gpm/ft$^2$) swimming pool sand filters are less than 50% (Amburgey et al. 2007, 2008, 2009a, b; Croll et al. 2007). These levels of removal appear inadequate to prevent outbreaks of cryptosporidiosis, which is supported by surveillance data on U.S. outbreaks investigated each year. Precoat (e.g., perlite or diatomaceous earth) filters rely on the size-exclusion principle to prevent pathogens from passing through the tiny pores into the filtered water, and recent research suggests that precoat filters may be far more effective than sand filters in removing *Cryptosporidium* (Amburgey et al. 2009a).

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**Table 1.** Materials and Equipment Used for Research

| Item | Model | Manufacturer | Address |
|---|---|---|---|
| Sand filter | Triton II TR 40 | Pentair Water | Samford, NC |
| Centrifugal pump | Challenger 3 HP | Pentair Water | Samford, NC |
| Perlite | Tech-Flo 2000X/SwimBrite | IIG, LLC | Brunswick, GA |
| Flow meter | SEM-40 | FlowServe | Irving, TX |
| Peristaltic pumps | 505 Di | Watson Marlow | Wilmington, MA |
| Magnetic stirrer | Cimarec | Thermo Fisher | Waltham, MA |
| Microspheres | Fluoresbrite YG | Polysciences, Inc. | Warrington, PA |
| PCTE filters | K30CP02500 | GE Osmonics | Minnetonka, MN |
| Filter funnels | XX10 025 00 | Millipore, Inc. | Billerica, MA |
| Microscope | Standard 25 | Carl Zeiss | Oberkochen, Germany |

This research project provides a preliminary performance evaluation of a plain sand filter compared to a sand filter with a thin layer of perlite added on top. The evaluation was in terms of removal of *Cryptosporidium*-sized microspheres (5-$\mu$m size) from simulated pool water. Normally, sand (or sand and gravel) are used in a sand filter. Although diatomaceous earth (DE) has reportedly been used as an amendment for sand filters, the practice does not appear to be widespread, and no research papers have been found in the literature describing the pathogen removal capabilities of a sand filter with either DE or perlite on top of the filter bed. The primary objective of this project was to evaluate the use of perlite for removal of 5-$\mu$m microspheres from simulated swimming pool water.

## Methods

### Experimental Setup

A 757 L (200 gal.) commercial hot tub was used at room temperature (20°C) to serve as the pool (or water tank) for this research. The original pump and filter were removed and replaced with a commercially available 2.2 kW centrifugal pump and a 0.18 $m^2$ (1.9 $ft^2$) sand filter (see Table 1 for equipment details) connected in series via a 51 mm (2-in.) diameter PVC pipe loop measuring approximately 6.5 m in length. A schematic of the experimental setup is shown in Fig. 1. The filter contained approximately 35 cm of sand (effective size of 0.49 mm and uniformity coefficient of 1.5), but only about 25 cm of the sand was necessarily used for filtration as the remainder was below the surface of the laterals. A cross-sectional drawing of the filter appears in Fig. 2. Only one type of precoat media (perlite) was used in this study. The perlite had a permeability of 3.21 $\mu m^2$ (3.25 Darcys), and the particle size range was approximately 2–200 $\mu$m with approximately 10% of the particles smaller than 8 $\mu$m and 10% larger than 60 $\mu$m. The flow was measured with a digital paddle-wheel flow meter and controlled with a 51 mm (2-in.) diameter PVC ball valve.

### Experimental Conditions

Water was pumped through the filter at 144 L/min (38 gpm) for a filter loading rate of 49 m/h (20 gpm/$ft^2$). Inline feed of the microsphere and perlite suspensions was made possible by a pair of digital peristaltic pumps feeding directly into the PVC pipe just upstream of the centrifugal pump. The microsphere suspensions were prepared in a 1-L glass erlenmeyer flask of simulated pool water, and stirred continuously with a magnetic stirrer and Teflon®-coated stir bar before and during the experiments. The perlite, when used, was similarly mixed and fed from a 1-L beaker. For the sand-perlite experiments, the perlite was added to the sand filter in the amount of 1.2 kg/$m^2$ (0.25 lbs/$ft^2$) of filter surface area.

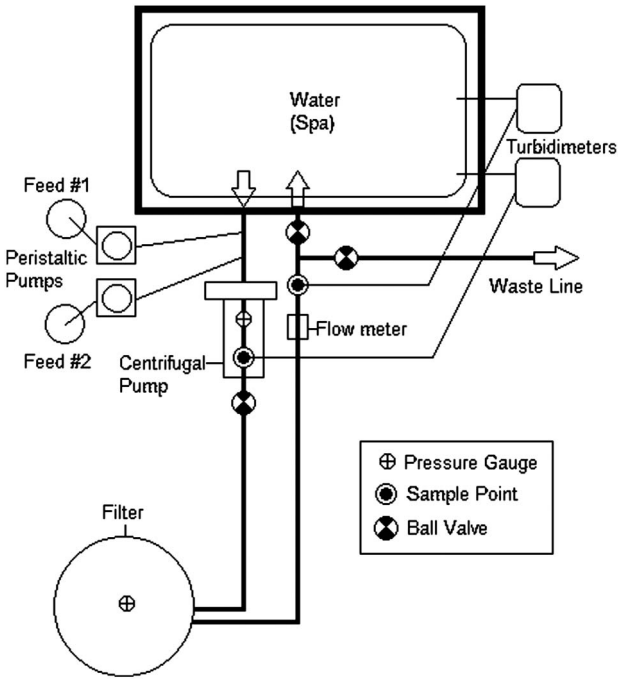


**Fig. 1.** Diagram of experimental setup

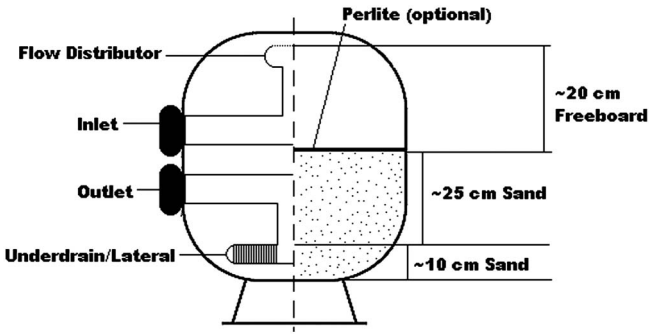


**Fig. 2.** Cross-sectional drawing of the filter

### Simulated Pool Water

Simulated pool water was created for each experiment from 757 L (200 gal.) of Charlotte, North Carolina, tap water supplemented with sodium bicarbonate to an alkalinity of 150 mg/L as $CaCO_3$, with calcium chloride to a hardness of 250 mg/L as $CaCO_3$, with sodium hypochlorite to a free chlorine concentration

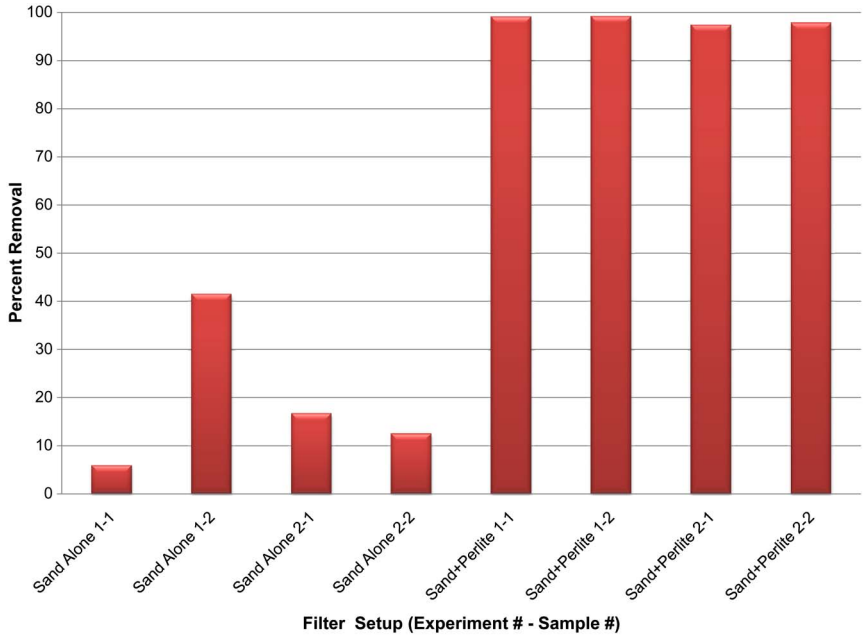


**Fig. 3.** Percent removal of *Cryptosporidium*-sized microspheres for individual sand filter experiments (with and without perlite)

of 2 mg/L, with hydrochloric acid to a pH of 7.5, and with a mixture of artificial sweat and urine to a final total organic carbon concentration of 20 mg/L as C.

### *Sample Collection*

Two experiments were performed for each set of conditions. For each experiment, duplicate samples were collected from the filter influent and effluent pipes; sampling was started approximately 2 min after the start of an experiment. The hydraulic detention time of the pipe loop from the point of microsphere injection through the pump and filter to filter effluent sample point was calculated to be 40 s at a flow rate of 138 L/min. Therefore, three hydraulic detention times passed before the collection of the first sample and between replicate sets of samples, and a delay of 40 s was used between collection of the influent and effluent paired samples. The hydraulic detention time of the system including the spa was only 6 min, so the duration of the microsphere seeding was limited to 5 min, to minimize any accumulation of microspheres in the spa that could potentially alter the filter influent concentration of microspheres between filter types because of removal efficiency. Approximately $2 \times 10^7$ fluorescent-green carboxylate-modified polystyrene microspheres (4.869 $\mu$m, standard deviation 0.246 $\mu$m) were used in each experiment. The 1 L microsphere suspension was fed in at 50 mL/min during the experiment to achieve a filter influent concentration of approximately 7 microspheres per mL of water. Influent samples of 50 mL were collected in sterile 50 mL conical-bottomed plastic centrifuge tubes, and the volume of the effluent samples varied from 50 mL to 500 mL, with the larger samples collected in glass media bottles.

### *Sample Analysis*

Samples were stored at 4°C after collection and before analysis. Sample volumes were adjusted to obtain between 10 and 150 oocysts and/or microspheres per sample. Samples were filtered through 3-$\mu$m polycarbonate track-etched (PCTE) filters in 25-mm glass microanalysis filter funnels by a regulated three-place vacuum manifold. The filters were mounted on glass micro slides with one drop of polyvinyl alcohol-DABCO solution (Freer 1984), and a 25-mm square glass cover slip for enumeration under epifluorescent microscope at 100× total magnification. The fluorescent filter set had a 450–490-nm excitation wavelength range, a 510-nm dichroic filter, and a 520-nm emission filter. The spa system was thoroughly cleaned between experiments with a minimum of three drain-and-fill rinses with recirculation at 227 L/min (60 gpm), and samples were collected prior to seeding in each experiment to measure any potential carryover between experiments. The experimental schedule was staggered between sand and sand-perlite experiments.

## Results

Filter removal percentages are shown in Fig. 3 for each experiment in this study; as noted, the filtration velocity was maintained at 49 m/h (20 gpm/ft$^2$). The results demonstrated that for a plain sand filter (i.e., without perlite), removals of the 5-$\mu$m microspheres ranged from 6 to 41% and had a mean of only 19%. The corresponding log-removals were 0.03 to 0.23 log, with a mean of 0.09 log. These values are in agreement with those reported previously in the literature for high-rate swimming pool sand filters (i.e., consistently less than 50%).

The same sand filter with a thin layer of perlite media on top demonstrated microsphere removals ranging from 97 to 99%, as shown in Fig. 3. The mean level of removal was 98%, and standard deviation ±0.9%. The corresponding log-removals for the perlite/sand filter ranged from 1.6 to 2.1 log, with a mean of 1.8 log. The removals were not corrected for analytical method losses because the same detection method was used on the influent and effluent samples. With similar losses on both influent and effluent samples (estimated to be less than 25%), the overall removals would not change by applying the same correction factor to all samples.

## Conclusions

The results showed that adding perlite in the amount of 1.2 kg/m$^2$ (0.25 lbs/ft$^2$) of filter surface area to a sand filter significantly improved the removal of the 5-$\mu$m microspheres. Previous research has established that these microspheres can serve as a reasonable

surrogate for *Cryptosporidium* oocysts in pool water (Amburgey et al. 2007, 2009a). Removals averaged less than 20% through sand filters without perlite, but the mean removal increased to 98% when perlite was added to the filter. Such a finding indicates that adding a perlite layer to a sand filter can reduce (by more than an order of magnitude) the concentrations of *Cryptosporidium* oocysts in filtered swimming pool water, which could significantly reduce the likelihood of cryptosporidiosis.

## Recommendations for Further Research

These preliminary results are promising and have implications for swimming pool filtration practice. However, many experimental and operational variables remain unexplored. The mass of perlite used was 1.2 $kg/m^2$ (0.25 $lbs/ft^2$), which could be optimized (on a cost-benefit basis) for filter pressure increases, particle removal efficiency, and media usage costs in future studies. Coarser and finer grades of perlite exist. The courser media would cause slower development of headloss, but the removal efficiency of 5-$\mu$m particles might decrease. The sand and sand/perlite filter loading rates remained constant in these experiments at 49 m/h (20 $gpm/ft^2$), which compares to 4.9 m/h (2.0 $gpm/ft^2$) for precoat filters as commonly operated in drinking water and swimming pool practice in the United States [Logsdon 2008; National Swimming Pool Foundation (NSPF) 2009]. The effects of filtration rates on microsphere removal and rate of headloss increase also should be investigated in future experiments. The rate of headloss increase and the associated "length-of-run" are important factors in practice and warrant further attention. Backwash cleaning efficiency also should be carefully assessed in a long-term full-scale pool trial because inefficient filter cleaning could lead to the failure of any filtration system.

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