

Cryptosporidium oocyst removal among them. These results indicate that bag and cartridge filters may be capable of achieving removal of oocysts in excess of 3 log; however, performance can vary significantly among products and there appears to be no correlation between pore size rating and removal efficiency.

Based on available data, specific design criteria that correlate to removal efficiency cannot be derived for bag and cartridge filters. Furthermore, the removal efficiency of these proprietary devices can be impacted by product variability, increasing pressure drop over the filtration cycle, flow rate, and other operating conditions. The data in Table IV-18 were generated from studies performed under a variety of operating conditions, many of which could not be considered conservative (or worst-case) operation. These considerations lead to the proposed challenge testing requirements which are intended to establish a product-specific removal efficiency.

The proposed challenge testing is product-specific and not site-specific since the intent of this testing is to demonstrate the removal capabilities of the filtration device rather than evaluate the feasibility of implementing the technology at a specific plant. Challenge testing must be conducted using full-scale filter elements in order to evaluate the performance of the entire unit, including the filtration media, seals, filter housing and other components integral to the filtration system. This will improve the applicability of challenge test results to full-scale performance. Multiple filters of the same type can be tested to provide a better statistical basis for estimating removal efficiency.

Either *Cryptosporidium* oocysts or a suitable surrogate could be used as the challenge particulate during the test. Challenge testing with *Cryptosporidium* provides direct verification of removal efficiency; however, some studies have demonstrated that surrogates, such as polystyrene microspheres, can provide an accurate or conservative measure of removal efficiency (Long 1983, Li *et al.* 1997). Furthermore, the National Sanitation Foundation (NSF) Environmental Technology Verification (ETV) protocol for verification testing for physical removal of microbiological and particulate contaminants specifies the use of polymeric microspheres of a known size distribution (NSF 2002b). Guidance on selection of an appropriate surrogate for establishing a removal efficiency for *Cryptosporidium* during challenge testing is presented in the Membrane Filtration Guidance Manual (USEPA 2003e).

In order to demonstrate a removal efficiency of at least 2 or 3 log for bag or cartridge filters, respectively, it will likely be necessary to seed the challenge particulate into the test solution. A criticism of published studies that use this approach is that the seeded levels are orders of magnitude higher than those encountered in natural waters and this could potentially lead to artificially high estimates of removal efficiency. To address this issue, the feed concentration applied to the filter during challenge studies is capped at a level that will allow the demonstration of a removal efficiency up to 4.5 log for cartridge filters and 3.5 log for bag filters if the challenge particulate is removed to the detection level.

The removal efficiency of some bag and cartridge filtration devices has been shown to decrease over the course of a filtration cycle due to the accumulation of solids and resulting increase in pressure drop. As an example, Li *et al.* (1997) observed that the removal of 4.5 μ m microspheres by a bag filter decreased from 3.4 log to 1.3 log over the course of a filtration cycle. Studies evaluating bag and cartridge filtration under the NSF ETV program have also shown a degradation in removal efficiency over the course of the filtration cycle (NSF 2001a and 2001b). In order to evaluate this potential variability, the challenge studies are designed to assess removal efficiency during three periods of a filtration cycle: within two hours of startup following installation of a new filter, between 45% and 55% of terminal pressure drop, and at the end of the run after 100% of terminal pressure drop is realized.

Although challenge testing can provide an estimate of removal efficiency for a bag or cartridge filtration process, it is not feasible to conduct a challenge test on every production filter. This, coupled with variability within a product line, could result in some production filters that do not meet the removal efficiency demonstrated during challenge testing. For membrane filtration processes, this problem is addressed through the use of a quality control release value established for a non-destructive test, such as a bubble point test or pressure hold test, that is correlated to removal efficiency. Since the non-destructive test can be applied to all production membrane modules, this provides a feasible means of verifying the performance of every membrane module used by a PWS. However, the non-destructive tests applied to membrane filtration processes cannot be applied to most bag and cartridge filtration devices, and EPA is not aware of an alternative non-

destructive test that can be used with these devices.

Typical process monitoring for bag and cartridge filtration systems includes turbidity and pressure drop to determine when filters must be replaced. However, the applicability of either of these process monitoring parameters as tools for verifying removal of *Cryptosporidium* has not been demonstrated. Only a few bag or cartridge filtration studies have attempted to correlate turbidity removal with removal of *Cryptosporidium* oocysts or surrogates. Li *et al.* (1997) found that the removal efficiency for turbidity was consistently lower than removal efficiency for oocysts or microspheres for the three bag filters evaluated. Furthermore, none of the filters was capable of consistently producing a filtered water turbidity below 0.3 NTU for the waters evaluated. The contribution to turbidity from particles much smaller than *Cryptosporidium* oocysts, and much smaller than the mesh size of the filter, make it difficult to correlate removal of turbidity with removal of *Cryptosporidium*. Consequently, EPA is proposing a 1 log factor of safety to be applied to challenge test results in awarding treatment credit to bag and cartridge filters, and is not proposing integrity monitoring requirements for these devices.

c. *Request for comment.* EPA requests comment on the following issues concerning bag and cartridge filters:

- The performance of bag and cartridge filters in removing *Cryptosporidium* through all differential pressure ranges in a filter run—EPA requests laboratory and field data, along with associated quality assurance and quality control information, that will support a determination of the appropriate level of *Cryptosporidium* removal credit to award to these technologies.

- The performance of bag and cartridge filters in removing *Cryptosporidium* when used in series with other bag or cartridge filters—EPA requests laboratory and field data, along with associated quality assurance and quality control information, that will support a determination of the appropriate level of *Cryptosporidium* removal credit to award to these technologies when used in series.

- Appropriate surrogates, or the characteristics of appropriate surrogates, for use in challenge testing bag and cartridge filters—EPA requests data or information demonstrating the correlation between removal of a proposed surrogate and removal of *Cryptosporidium* oocysts.