

sedimentation basin averaging 0.20 log. Removal of aerobic spores, total particle counts, and turbidity all correlated well with removal of *Cryptosporidium* by sedimentation.

States *et al.* (1997) monitored *Cryptosporidium* removal at the Pittsburgh Drinking Water Treatment Plant (65–70 million gallons per day (MGD)). The clarification process included ferric chloride coagulation, flocculation, and settling in both a small primary basin and a 120 MG secondary sedimentation basin. Geometric mean *Cryptosporidium* levels in the raw and settled water were 31 and 12 oocysts/100 L, respectively, indicating a mean reduction of 0.41 log.

Edzwald and Kelly (1998) conducted a bench-scale study to determine the optimal coagulation conditions with different coagulants for removing *Cryptosporidium* oocysts from spiked raw waters. Under optimal coagulation conditions, the authors observed oocysts reductions through sedimentation ranging from 0.8 to 1.2 log.

Payment and Franco (1993) measured *Cryptosporidium* and other microorganisms in raw, settled, and filtered water samples from drinking water treatment plants in the Montreal area. The geometric mean of raw and settled water *Cryptosporidium* levels in one plant were 742 and 0.12 oocysts/100 L, respectively, suggesting a mean removal of 3.8 log. In a second plant, mean removal by sedimentation was reported as 0.7 log, with raw and settled water *Cryptosporidium* levels reported as <2 and <0.2 oocysts/L, respectively.

Kelley *et al.* (1995) monitored *Cryptosporidium* levels in the raw, settled, and filtered water of two water treatment plants (designated site A and B). Both plants included two-stage sedimentation. At site A, mean raw and settled water *Cryptosporidium* levels were 60 and 9.5 oocysts/100 L, respectively, suggesting a mean removal of 0.8 log by sedimentation. At site B, mean raw and settled water *Cryptosporidium* levels were 53 and 16 oocysts/100 L, respectively, for an average removal by sedimentation of 0.5 log. Well water was intermittently blended in the second stage of sedimentation at site B, which may have reduced settled and filtered water pathogen levels.

Patania *et al.* (1995) evaluated removal of *Cryptosporidium* in four pilot scale plants. Three of these were conventional and one used in-line filtration (rapid mix followed by filtration). *Cryptosporidium* removal was generally 1.4 to 1.8 log higher in the process trains with sedimentation compared to in-line filtration. While the

effectiveness of sedimentation for organism removal varied widely under the conditions tested, the median removal of *Cryptosporidium* by sedimentation was approximately 2.0 log.

ii. Data supplied by utilities on the removal of spores by presedimentation. Data on the removal of *Cryptosporidium* and spores (*Bacillus subtilis* and total aerobic spores) during operation of full-scale presedimentation basins were collected independently and reported by three utilities: St. Louis, MO, Kansas City, MO, and Cincinnati, OH. *Cryptosporidium* oocysts were not detected in raw water at these locations at levels sufficient to calculate log removals of oocysts directly. However, aerobic spores were present in the raw water of these utilities at high enough concentrations to measure log removals through presedimentation as a surrogate for *Cryptosporidium* removal. As noted earlier, data from Dugan *et al.* (2001) demonstrate a correlation between removal of aerobic spores and *Cryptosporidium* through sedimentation under optimal coagulation conditions. A summary of the spore removal data supplied by these utilities is shown in Table IV–11.

TABLE IV–11.—MEAN SPORE REMOVAL FOR FULL-SCALE PRESEDIMENTATION BASINS REPORTED BY THREE UTILITIES

Reporting utility	Mean spore removal
St. Louis Water Division.	1.1 log (<i>B. subtilis</i>).
Kansas City Water Services Department.	0.8 log (<i>B. subtilis</i>) (with coagulant). 0.46 log (<i>B. subtilis</i>) (without coagulant).
Cincinnati Water Works.	0.6 log (total aerobic spores).

The St. Louis Water Division operates four presedimentation basins at one facility. Coagulant addition prior to presedimentation includes polymer and occasional dosages of ferric sulfate. *Bacillus subtilis* spore samples were collected from June 1998 to September 2000. Reported mean spore concentrations in the raw water and following presedimentation were 108,326 and 8,132 cfu/100 mL, respectively, showing an average removal of 1.1 log by presedimentation.

The Kansas City Water Services Department collected *Bacillus subtilis* spore samples from January to November 2000 from locations before and after one of the facility's six presedimentation basins. Sludge

generated by the primary clarifier of a softening process was recycled to the head of the presedimentation basins during the entire study period. In addition, coagulant (polymer and/or ferric sulfate) was added prior to presedimentation when raw water turbidity was higher. During periods when coagulant was added, mean spore levels before and after presedimentation were 102,292 and 13,154 cfu/100 mL, respectively, demonstrating a mean removal of 0.9 log. When no ferric sulfate or polymer was used, mean presedimentation influent and effluent spore levels were 13,296 and 4,609 cfu/100 mL, respectively, for an average reduction of 0.46 log.

The Cincinnati Water Works operates a treatment plant using lamella plate settlers for presedimentation. Lamella plate settlers are inclined plates added to a sedimentation basin to significantly increase the surface area available for particle settling. Coagulant (alum and polymer) is added to the raw water prior to presedimentation. Total aerobic spore samples were collected from January 1998 through December 2000. The mean concentration of spores decreased from 20,494 cfu/100 mL in the raw water to 4,693 cfu/100 mL in the presedimentation effluent, indicating a mean spore removal of 0.64 log.

In conclusion, literature studies clearly establish that sedimentation basins are capable of achieving greater than 0.5 log reduction in *Cryptosporidium* levels. Further, the data supplied by utilities on reduction in aerobic spore counts across full scale presedimentation basins demonstrate that presedimentation can achieve mean reductions of greater than 0.5 log under routine operating conditions and over an extended time period. Thus, these data suggest that a 0.5 log presumptive credit for *Cryptosporidium* removal by presedimentation is appropriate under certain conditions.

With respect to the conditions under which the 0.5 log presumptive credit for presedimentation is appropriate, the data do not demonstrate that this level of removal can be achieved consistently without a coagulant. In addition, available data do not establish aerobic spores as an effective indicator of *Cryptosporidium* removal in the absence of a coagulant. Thus, supporting data are consistent with a requirement that systems apply a coagulant to be eligible for the presumptive 0.5 log presedimentation credit. Moreover, such a requirement is consistent with the Agreement in Principle, which recommends 0.5 log credit for presedimentation basins with a coagulant.