

system was achieving 2 log removal of *Cryptosporidium*.

- For GWUDI systems where natural or alternative filtration (e.g. bank filtration or artificial recharge) is used in combination with a subsequent filtration barrier (e.g., bag or cartridge filters) to meet the 2 log *Cryptosporidium* removal requirement of the IESWTR or LT1ESWTR, how much *Cryptosporidium* removal credit has the State awarded (or is the State willing to grant if the bags/cartridges were found to be achieving < 2.0 logs) for the natural or alternative filtration process and how did the State determine this value?

- The proposed *Cryptosporidium* removal credit and associated design criteria, including any additional information related to this topic.

- Suitable separation distance(s) to be required between vertical or horizontal wells and adjacent surface water.

- Testing protocols and procedures for making site specific determinations of the appropriate level of *Cryptosporidium* removal credit to award to bank filtration processes.

- Information on the data and methods suitable for predicting *Cryptosporidium* removal based on the available data from surrogate and indicator measurements in water collection devices.

- The applicability of turbidity monitoring or other process monitoring procedures to indicate the ongoing performance of bank filtration processes.

7. Lime Softening

a. *What is EPA proposing today?* Lime softening is a drinking water treatment process that uses precipitation with lime and other chemicals to reduce hardness and enhance clarification prior to filtration. Lime softening can be categorized into two general types: (1) Single-stage softening, which is used to remove calcium hardness and (2) two-stage softening, which is used to remove magnesium hardness and greater levels of calcium hardness. A single-stage softening plant includes a primary clarifier and filtration components. A two-stage softening plant also includes a secondary clarifier located between the primary clarifier and filter. In some two-stage softening plants, a portion of the flow bypasses the first clarifier.

EPA has determined that lime softening plants in compliance with IESWTR or LT1ESWTR achieve a level of *Cryptosporidium* removal equivalent

to conventional treatment plants (i.e., average of 3 log). Consequently, lime softening plants that are placed in Bins 2–4 as a result of *Cryptosporidium* monitoring incur the same additional treatment requirements as conventional plants. However, EPA is proposing that two-stage softening plants be eligible for an additional 0.5 log *Cryptosporidium* treatment credit. To receive the 0.5 log credit, the plant must have a second clarification stage between the primary clarifier and filter that is operated continuously, and both clarification stages must treat 100% of the plant flow. In addition, a coagulant must be present in both clarifiers (may include metal salts, polymers, lime, or magnesium precipitation).

b. *How was this proposal developed?* The lime softening process is used to remove hardness, primarily calcium and magnesium, through chemical precipitation followed by sedimentation and filtration. The addition of lime increases pH, causing the metal ions to precipitate. Other contaminants can coalesce with the precipitates and be removed in the subsequent settling and filtration processes. While elevated pH has been shown to inactivate some microorganisms like viruses (Battigelli and Sobsey, 1993, Logsdon *et al.* 1994), current research indicates that *Cryptosporidium* and *Giardia* are not inactivated by high pH (Logsdon *et al.* 1994, Li *et al.* 2001). A two-stage lime softening plant has the potential for additional *Cryptosporidium* removal because of the additional sedimentation process.

Limited data are available on the removal of *Cryptosporidium* by the lime softening treatment process. EPA has evaluated data from a study by Logsdon *et al.* (1994), which investigated removal of *Giardia* and *Cryptosporidium* in full scale lime softening plants. In addition, the Agency has considered data provided by utilities on the removal of aerobic spores in softening plants. These data are summarized in the following paragraphs.

Logsdon *et al.* (1994) measured levels of *Cryptosporidium* and *Giardia* in the raw, settled, and filtered water of 13 surface water plants using lime softening. *Cryptosporidium* was detected in the raw water at 5 utilities: one single-stage plant and four two-stage plants. Using measured oocyst levels, *Cryptosporidium* removal by sedimentation was 1.0 log in the single-stage plant and 1.1 to 2.3 log in the two-

stage plants. *Cryptosporidium* was found in two filtered water samples of the single stage plant, leading to calculated removals from raw to filtered water of 0.6 and 2.2 log. None of the two-stage plants had *Cryptosporidium* detected in the filtered water. Based on detection limits, calculated *Cryptosporidium* removals from raw to filtered water in the two-stage plants ranged from >2.67 to >3.85 log.

Giardia removal across sedimentation was >0.9 log for a single-stage plant and ranged from 0.8 to 3.2 log for two-stage plants, based on measured cyst levels. Removal of *Giardia* from raw water through filtration was calculated using detection limits as >1.5 log in a single-stage plant and ranged from >0.9 to >3.3 log in two-stage plants.

While results from the Logsdon *et al.* study are constrained by sample number and method detection limits, they suggest that two-stage softening plants may achieve greater removal of *Cryptosporidium* than single-stage plants. The authors concluded that two stages of sedimentation, each preceded by effective flocculation of particulate matter, may increase removal of protozoa. Additionally, the authors stated that consistent achievement of flocculation that results in effective settling in each sedimentation basin is the key factor in this treatment process.

Removal of Aerobic Spores by Softening Plants

Additional information on the microbial removal efficiency of the lime softening process comes from data provided by softening plants on removal of aerobic spores. While few treatment plants have sufficient concentrations of oocysts to directly calculate a *Cryptosporidium* removal efficiency, some plants have high concentrations of aerobic spores in the raw water. Spores may serve as an indicator of *Cryptosporidium* removal by sedimentation and filtration (Dugan *et al.* 2001).

The following two-stage softening plants provided data on removal of aerobic spores: St. Louis, MO, Kansas City, MO, and Columbus, OH (2 plants). *Cryptosporidium* data were also collected at these utilities, but it was not possible to calculate oocyst removal due to low raw water detection rates. Data on removal of aerobic spores by these softening plants is summarized in Table IV–14.