

LT1ESWTR is described in the proposed rule (65 FR 59486, April 10, 2000) (USEPA 2000b). Pertinent information is summarized in the following paragraphs.

a. *Physical removal.* EPA evaluated eight studies on removal of *Cryptosporidium* by rapid granular filtration for the IESWTR. These were Patania *et al.* (1995), Nieminski and Ongerth (1995), Ongerth and Pecoraro (1995), LeChevallier and Norton (1992), LeChevallier *et al.* (1991), Foundation for Water Research (1994), Kelley *et al.* (1995), and West *et al.* (1994). These studies included both pilot and full scale plants.

Full scale plants in these studies typically demonstrated 2–3 log removal of *Cryptosporidium*, and pilot plants achieved up to almost 6 log removal under optimized conditions. In general, the degree of removal that can be quantified in full scale plants is limited because *Cryptosporidium* levels following filtration are often below the detection limit of the analytical method. Pilot scale studies overcome this limitation by seeding high concentrations of oocysts to the plant influent, but extrapolation of the performance of a pilot plant to the routine performance of full scale plants is uncertain.

Cryptosporidium removal efficiency in these studies was observed to depend on a number of factors including: water matrix, coagulant application, treatment optimization, filtered water turbidity, and the filtration cycle. The highest removal rates were observed in plants that achieved very low effluent turbidities.

EPA also evaluated studies of *Cryptosporidium* removal by slow sand (Schuler and Ghosh 1991, Timms *et al.* 1995) and DE filtration (Schuler and Gosh 1990) for the IESWTR. These studies indicated that a well designed and operated plant using these processes could achieve 3 log or greater removal of *Cryptosporidium*.

After considering these studies, EPA concluded that conventional and direct filtration plants in compliance with the effluent turbidity criteria of the IESWTR, and slow sand and DE plants in compliance with the effluent turbidity criteria established for these processes by the SWTR, would achieve at least 2 log removal of *Cryptosporidium*. Recognizing that many plants will achieve more than the minimum 2 log reduction, EPA estimated median *Cryptosporidium* removal among filtration plants as near 3 log (99.9%) for the purpose of assessing risk.

The LT1ESWTR proposal included summaries of additional studies of *Cryptosporidium* removal by conventional treatment (Dugan *et al.* 1999), direct filtration (Swertfeger *et al.* 1998), and DE filtration (Ongerth and Hutton 1997). These studies supported IESWTR conclusions stated previously regarding the performance of these processes. The LT1ESWTR proposal also summarized studies of membranes, bag filters, and cartridge filters (Jacangelo *et al.* 1995, Drozd and Scharzbrod 1997, Hirata and Hashimoto 1998, Goodrich *et al.* 1995, Collins *et al.* 1996, Lykins *et al.* 1994, Adham *et al.* 1998). This research demonstrated that these technologies may be capable of achieving 2 log or greater removal of *Cryptosporidium*. However, EPA concluded that variation in performance among different manufacturers and models necessitates that determinations of treatment credit be made on a technology-specific basis (65 FR 19065, April 10, 2000) (USEPA 2000b).

b. *Inactivation.* In the IESWTR NODA (62 FR 59486) (USEPA 1997a), EPA cited studies that demonstrated that chlorine is ineffective for inactivation of *Cryptosporidium* at doses practical for treatment plants (Korich *et al.* 1990, Ransome *et al.* 1993, Finch *et al.* 1997). The Agency also summarized studies of *Cryptosporidium* inactivation by UV, ozone, and chlorine dioxide. EPA evaluated these disinfectants to determine if sufficient data were available to develop prescriptive disinfection criteria for *Cryptosporidium*.

The studies of UV disinfection of *Cryptosporidium* that were available during IESWTR development were inconclusive due to methodological factors. These studies included: Lorenzo-Lorenzo *et al.* (1993), Ransome *et al.* (1993), Campbell *et al.* (1995), Finch *et al.* (1997), and Clancy *et al.* (1997). A common limitation among these studies was the use of in vitro assays, such as excystation and vital dye staining, to measure loss of infectivity. These assays subsequently were shown to overestimate the UV dose needed to inactivate protozoa (Clancy *et al.* 1998, Craik *et al.* 2000). In another case, a reactor vessel that blocked germicidal light was used (Finch *et al.* 1997).

EPA evaluated the following studies of ozone inactivation of *Cryptosporidium* for the IESWTR: Peeters *et al.* (1989), Korich *et al.* (1990), Parker *et al.* (1993), Ransome *et al.* (1993), Finch *et al.* (1997), Daniel *et al.* (1993), and Miltner *et al.* (1997). These studies demonstrated that ozone could achieve high levels of *Cryptosporidium*

inactivation, albeit at doses much higher than those required to inactivate *Giardia*. Results of these studies also exhibited significant variability due to factors like different infectivity assays and methods of dose calculation.

The status of chlorine dioxide inactivation of *Cryptosporidium* during IESWTR development was similar to that of ozone. EPA evaluated a number of studies that indicated that relatively high doses of chlorine dioxide could achieve significant inactivation of *Cryptosporidium* (Peeters *et al.* 1989, Korich *et al.* 1990, Ransome *et al.* 1993, Finch *et al.* 1995 and 1997, and LeChevallier *et al.* 1997). Data from these studies showed a high level of variability due to methodological differences, and the feasibility of high chlorine dioxide doses was uncertain due to the MCL for chlorite that was established by the Stage 1 DBPR.

After reviewing these studies, EPA and the Stage 1 Federal Advisory Committee concluded that available data were not adequate to award *Cryptosporidium* inactivation credit for UV, ozone, or chlorine dioxide.

3. New Information on Treatment for Control of *Cryptosporidium*

a. *Conventional filtration treatment and direct filtration.* This section provides brief descriptions of seven recent studies of *Cryptosporidium* removal by conventional treatment and direct filtration, followed by a summary of key points.

Dugan *et al.* (2001) evaluated the ability of conventional treatment to control *Cryptosporidium* under varying water quality and treatment conditions, and assessed turbidity, total particle counts (TPC), and aerobic endospores as indicators of *Cryptosporidium* removal. Fourteen runs were conducted on a small pilot scale plant that had been determined to provide equivalent performance to a larger plant. Under optimal coagulation conditions, oocyst removal across the sedimentation basin ranged from 0.6 to 1.8 log, averaging 1.3 log, and removal across the filters ranged from 2.9 to greater than 4.4 log, averaging greater than 3.7 log. Removal of aerobic spores, TPC, and turbidity all correlated with removal of *Cryptosporidium* by sedimentation, and these parameters were conservative indicators of *Cryptosporidium* removal across filtration. Sedimentation removal under optimal conditions related to raw water quality, with the lowest *Cryptosporidium* removals observed when raw water turbidity was low.

Suboptimal coagulation conditions (underdosed relative to jar test predictions) significantly reduced plant