PERGAMON
www.elsevier.com/locate/watres

PII: S0043-1354(01)00181-6

Wat. Res. Vol. 35, No. 18, pp. 4359–4369, 2001

Printed in Great Britain
0043-1354/01/$ - see front matter

TRANSPORT AND FATE OF *CRYPTOSPORIDIUM PARVUM* OOCYSTS IN INTERMITTENT SAND FILTERS

ANDREW J. LOGAN[1,2]*, TOR KRISTIAN STEVIK[2], ROBERT L. SIEGRIST[1] and REGIN M. RØNN[3]

[1] Department of Environmental Science and Engineering, Colorado School of Mines, Golden, CO 80401, USA; [2] Department of Agricultural Engineering, Norwegian Agricultural University, Aas, Norway and [3] Department of Population Biology, Zoological Institute, University of Copenhagen, Universitetsparken 15, DK-2100, Denmark

(First received 1 November 1999; accepted in revised form 1 April 2001)

Abstract—The transport potential of *Cryptosporidium parvum* (*C. parvum*) through intermittent, unsaturated, sand filters used for water and wastewater treatment was investigated using a duplicated, 2^3 factorial design experiment performed in bench-scale, sand columns. Sixteen columns (dia = 15 cm, $L = 60$ cm) were dosed eight times daily for up to 61 days with 65,000 *C. parvum* oocysts per liter at 15°C. The effects of water quality, media grain size, and hydraulic loading rates were examined. Effluent samples were tested for pH, turbidity, and oocyst content. *C. parvum* effluent concentrations were determined by staining oocysts on polycarbonate filters and enumerating using epifluorescent microscopy. At completion, the columns were dismantled and sand samples were taken at discrete depths within the columns. These samples were washed in a surfactant solution and the oocysts were enumerated using immunomagnetic separation techniques.

The fine-grained sand columns ($d_{50} = 0.31$ mm) effectively removed oocysts under the variety of conditions examined with low concentrations of oocysts infrequently detected in the effluent. Coarse-grained media columns ($d_{50} = 1.40$ mm) yielded larger numbers of oocysts which were commonly observed in the effluent regardless of operating conditions. Factorial design analysis indicated that grain size was the variable which most affected the oocyst effluent concentrations in these intermittent filters. Loading rate had a significant effect when coarse-grained media was used and lesser effect with fine-grained media while the effect of feed composition was inconclusive. No correlations between turbidity, pH, and effluent oocyst concentrations were found. Pore-size calculations indicated that adequate space for oocyst transport existed in the filters. It was therefore concluded that processes other than physical straining mechanisms are mainly responsible for the removal of *C. parvum* oocysts from aqueous fluids in intermittent sand filters used under the conditions studied in this research.

Key words—microbes, transport, porous media, filtration, purification

INTRODUCTION

Cryptosporidium parvum (*C. parvum*) is a protozoan pathogen that is commonly present in surface water used for recreation, treated and untreated sewage and, less frequently, in raw drinking water and filtered drinking water supplies (Edwards, 1993; Haas and Rose, 1996; Roefer *et al.*, 1996; LeChevallier *et al.*, 1997; Richardson *et al.*, 1991). Ingestion of this pathogen results in a self-limiting infection in healthy adults, but can be fatal to the elderly, infants, and to persons with compromised immune systems (Dupont *et al.*, 1995). *C. parvum* completes its life-cycle within the intestine of the host and occurs in the environment as a robust oocyst capable of maintaining viability and potential infectivity during conventional drinking water and wastewater treatment (Hayes *et al.*, 1989; Richardson *et al.*, 1991; Roefer *et al.*, 1996) and under a variety of environmental conditions (Robertson *et al.*, 1992). These characteristics, coupled with the prevelance of land-based, wastewater treatment systems which have the potential to introduce *Cryptosporidium* to natural, granular media and groundwater environments, (Crites and Tchobanoglous, 1998) lead to questions concerning *C. parvum's* transport and fate in unsaturated, intermittent, granular-media filters used for water and wastewater treatment.

Previous research regarding the filtration of oocysts from contaminated water have included the use of slow sand and diatomaceous earth filters (Timms *et al.*, 1995; Schuler *et al.*, 1991; Chapman

*Author to whom all correspondence should be addressed. Department of Environmental Science and Engineering, Colorado School of Mines, Golden, CO 80401, USA. Tel.: +1-303-384-2219; fax: +1-303-273-3629; e-mail: alogan@mines.edu