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HYDRAULIC AND PURIFICATION BEHAVIORS AND THEIR INTERACTIONS DURING WASTEWATER TREATMENT IN SOIL INFILTRATION SYSTEMS

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Abstract—Four three-dimensional lysimeters were established in a pilot laboratory with the same medium sand and either an aggregate-laden (AL) or aggregate-free (AF) infiltration surface and a 60- or 90-cm soil vadose zone depth to ground water. During 48 weeks of operation, each lysimeter was dosed 4 times daily with septic tank effluent (STE) at 5 cm/d (AL) or 8.4 cm/d (AF). Weekly monitoring was done to characterize the STE, percolate flow and composition, and water content distributions within the lysimeters. Bromide tracer tests were completed at weeks 0, 8, and 45 and during the latter two times, ice nucleating active (INA) bacteria and MS-2 and PRD-1 bacteriophages were used as bacterial and viral surrogates. After 48 weeks, soil cores were collected and analyzed for chemical and microbial properties. The observations made during this study revealed a dynamic, interactive behavior for hydraulic and purification processes that were similar for all four lysimeters. Media utilization and bromide retention times increased during the first two months of operation with the median bromide breakthrough exceeding one day at start-up and increasing to two days or more. Purification processes were gradually established over four months or longer, after which there were high removal efficiencies (>90%) for organic constituents, microorganisms, and virus, but only limited removal of nutrients. Soil core analyses revealed high biogeochemical activity within the infiltrative zone from 0 to 15 cm depth. All four lysimeters exhibited comparable behavior and there were no significant differences in performance attributable to infiltrative surface character or soil depth. It is speculated that the comparable performance is due to a similar and sufficient degree of soil clogging genesis coupled with bioprocesses that effectively purified the wastewater effluent given the adequate retention times and high volumetric utilization's of the sand media.

Key words—soil-aquifer treatment, soil clogging, pathogens, virus, nutrients

INTRODUCTION

Wastewater treatment for onsite and small community applications commonly relies on infiltration and percolation of primary effluent through soil to achieve purification prior to recharge to ground water (US EPA, 1978, 1980, 1997; Jenssen and Siegrist, 1990; Crites and Tchobanoglous, 1998) (Fig. 1). These systems can achieve high purification efficiencies due to the complex interactions of hydraulic and purification processes (Fig. 2) (Ausland, 1998). Extensive and lengthy contact between wastewater constituents and the soil matrix and associated biofilms, occurs during unsaturated flow achieved by intermittent dosing (e.g., 4–24 times/d) of daily loadings limited to a small fraction of the soil's saturated hydraulic conductivity (K_{sat}) (e.g., <5 cm/d) and by spatially uniform application. In addition, a clogging zone evolves at the soil infiltrative surface (Fig. 1) which leads to reduced permeability and more uniform infiltration and a concomitant unsaturated flow almost regardless of hydraulic loading. Moreover, wastewater-induced clogging increases the soil biogeochemical activity and can enhance sorption, biotransformation and die-off/inactivation processes (Siegrist, 1987; Siegrist *et al.*, 1991; Ausland, 1998). Clogging zone genesis has been described as a humification-like process and modeled as a function of the mass loading rates of wastewater suspended matter and bio-oxidizable substances (Siegrist, 1987; Siegrist and Boyle, 1987). In most wastewater soil infiltration systems, clogging zone genesis must occur to a balanced extent to foster the advanced purification required before ground water recharge without becoming hydraulically too restrictive. If clogging zone development is retarded or

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