Vadose Zone Soil Treatment of Nutrients and Bacteria from Secondary Municipal Wastewater Discharged through an At-Grade System

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Summary

An at-grade design for an onsite wastewater treatment system was used to discharge secondary treated municipal wastewater to the soil surface. A vadose zone monitoring system for pathogen indicators and nutrients was installed to monitor the changing quality of the pore water down the soil column to determine the treatment achieved by the unsaturated soil. The results show a five log removal of pathogen indicators by 60 cm, nitrification by 30 cm and varying levels of denitrification.

Introduction

Soil based tertiary treatment of municipal wastewater is common for many developments that have limited access to centralized treatment. While treatment fields are traditionally located sub-grade, or elevated as mounds, newer at-grade systems discharge on the native soil surface but their treatment performance has not been extensively tested in the field. In this study, an at-grade system was installed and monitored for a period of one year. Effluent from the Fish Creek Wastewater Treatment Plant in Calgary was discharged to the soil surface in volumes equivalent to a single family dwelling. A vadose zone monitoring system, consisting of suction lysimeters, tensiometers, TDR, thermistors, and soil vapor probes, was installed beneath the system to track the effluent through the soil column

Method and Results

Generic *E. coli* was selected as a pathogen indicator, and occurred in an average concentration of 47,000 MPN/100mL in the effluent. *E. coli* exhibited greater survivability during periods of colder soil temperatures than when the temperatures exceeded 17°C. Regardless of soil temperature, *E. coli* were non-detectable past 60cm depth, indicating up to a five log reduction in pathogen indicators over this same soil interval. Three soil excavation and sampling events also indicated non-detectable *E. coli* below 60 cm depths.

Chloride concentrations from soil water samples indicate that effluent reached 1.5 m depth after three weeks of dosing. While the NO_3-N concentrations in the effluent were often less than 1 mg/L, NH_3-N averaged 32.8 mg/L over the operational time. During the first months of discharge to the soil, NH_3-N concentrations frequently declined to non-detectable levels by 30 cm depth, while NO_3-N concentrations increased by 13.6 mg/L, indicating rapid nitrification of NH_3 within the top 30cm. During seasons of increased soil temperature (above 19°C), there is strong evidence that pockets of quasi-saturated soil caused by biological clogging also promoted denitrification, thereby reducing the concentration of NO_3 deeper in the soil column. Average inorganic nitrogen removal in the unsaturated zone by 60 cm deep was approximately 53%.

Orthophosphate concentrations in the pore water extractions frequently exceeded phosphate input from the wastewater. Increasing soil temperatures, which caused an increase in CO_2 concentrations in the soil atmosphere, may have resulted in dissolution of calcium and phosphate bearing minerals, causing increased soil phosphate and calcium concentrations in the top 30 cm of the soil. This is further supported by a similar increase in magnesium concentrations at the 90 cm and 150 cm sampling points, where cation exchange of the shallow calcium likely occurred with the magnesium at these depths.

Conclusions

Extensive monitoring of the vadose zone beneath the at-grade system demonstrated five log reductions in pathogen indicators and full nitrification of ammonia. There was also evidence for localized denitrification, although nitrate was still transported deeper in the soil. The results of this study are being used to evaluate the treatability of nutrients and pathogens in the vadose zone, specifically using the at-grade design, to assist in establishing regulatory design requirements that reduce environmental impacts and protect groundwater quality.

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