

Report as of FY2007 for 2005CO117B: "Occurrence and Fate of Organic Wastewater Contaminants in Onsite Wastewater Systems and Implications for Water Quality Management"

Publications

- Other Publications:
 - Conn, Kathleen, Robert Siegrist, and Larry Barber, 2007, Colorado School of Mines (CSM) research regarding occurrence and fate of organic wastewater contaminants during onsite wastewater treatment, Colorado Water Newsletter of the Water Center of Colorado State University, August/September 2007, 12-14 pp.

Report Follows



Colorado School of Mines (CSM) research regarding occurrence and fate of organic wastewater contaminants during onsite wastewater treatment

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Organic wastewater contaminants (OWCs) such as pharmaceuticals and personal care products have received increasing attention in the last decade due to their possible adverse effects on ecosystems and human health. Several studies have identified wastewater as a primary contributing source of OWCs to the environment, but few have quantified their occurrence and fate in onsite wastewater treatment systems and associated receiving environments. A substantial portion of the wastewater generated in the U.S. is processed by onsite wastewater treatment systems before discharge to the environment. For example, in Colorado there are over 600,000 onsite systems in operation serving approximately 25% of the State's population and 7,000 to 10,000 new systems are being installed each year. As a result, over 100 billion liters of wastewater are being processed by onsite systems and then discharged to the environment every year in Colorado alone. A research project was initiated by the Colorado School of Mines (CSM) in collaboration with the U.S. Geological Survey (USGS) to (1) determine the occurrence of OWCs in wastewaters produced from varying sources and by different types of onsite wastewater treatment units, (2) to assess the treatment of OWCs in confined treatment units such as septic tanks and packed bed biofilters, (3) to assess the fate and transport of OWCs in soil treatment units prior to groundwater and surface water recharge, and (4) to assess the potential for OWCs to impact receiving waters.

Between 2002 and 2005, the CSM/USGS research team quantified the occurrence of OWCs in 30 Colorado onsite wastewater treatment systems serving different homes, businesses, and institutions, and varied types of confined treatment units (Conn *et al.* 2006). Of the 24 OWCs studied 21 were identified in at least one onsite system effluent, and six compounds- caffeine, the sterols cholesterol and coprostanol, the metal-chelating agent EDTA, the disinfectant 4-methylphenol, and the surfactant metabolite group 4-nonylphenolethoxycarboxylates- were identified in every residential septic tank effluent. Wastewater concentrations of OWCs were highly variable, ranging from less than 1 g/L to greater than 500 g/L. Differences in wastewater compositions regarding OWCs may be due to differences in water- and chemical-using activities at the source. For example, residential systems receive wastewater from a number of indoor activities, including toilets, kitchen and bathroom faucets, dishwashers, clothes washers, and showers. Onsite system wastewaters from residential sources were composed of a diluted mix of biogenic and anthropogenic compounds. Wastewater treated by onsite systems

serving veterinary hospitals, on the other hand, originates mostly from cleaning activities such as disinfecting and washing practices. The OWC composition from veterinary hospitals was composed of high concentrations of surfactant metabolites and other cleaning product chemicals. In contrast, most of the wastewater entering an onsite system serving convenience stores originates from public restrooms. The highest concentrations of 14 pharmaceuticals and antibiotics were found in convenience store wastewater, reflecting the large and diverse population visiting the stores each day.

To understand the fate of OWCs during onsite wastewater treatment, wastewater samples from confined treatment units (e.g. septic tank, textile biofilter) were collected and analyzed for OWCs to identify potential removal during confined unit treatment. Concentrations of OWCs in effluents before and after septic tank treatment were usually similar, suggesting low to negligible removal of OWCs during septic tank treatment alone. Apparent removal efficiencies during textile biofilter treatment varied by compound. OWCs that have been shown to be aerobically biotransformed, such as caffeine, 4-methylphenol, and 1,4-dichlorobenzene, had apparent removal efficiencies of greater than 90% during textile biofilter treatment. Other compounds such as EDTA that are resistant to the removal mechanisms employed during aerobic biofilter treatment (e.g. biotransformation, sorption, and volatilization) showed similar concentrations in effluents before and after the biofilter unit. Concentrations of compounds that are the degradation products of biotransformed OWCs, such as the surfactant metabolites nonylphenoethoxycarboxylates, increased during textile biofilter treatment. Therefore, concentrations of some OWCs were higher in the effluent from a confined treatment unit and which might be applied to the soil treatment unit than in the wastewater entering the onsite system. Additional sampling of confined treatment unit influent and effluent is underway at the Mines Park Test Site on the CSM campus (Figures 1 and 2) to better quantify expected removal efficiencies by accounting for temporal variability and hydraulic detention time within the treatment units.

Results from the reconnaissance survey of 30 onsite wastewater treatment systems suggest that OWCs are being applied to onsite system soil treatment units at environmentally-relevant concentrations. To help understand the fate of OWCs in wastewater effluents during soil treatment, a tracer test was conducted at the CSM Mines Park Test Site using a conservative tracer (potassium bromide) and a pharmaceutical surrogate (rhodamine WT). Known concentrations of both tracers were added to tap water dosed to 14 soil test cells for 22 days at hydraulic loading rates ranging from 2 to 8 cm/d. Soil solution at 60, 120, and 240 cm below the infiltrative surface of each test cell was collected using *in situ* soil suction lysimeters and analyzed for both tracers for 20 months. Results indicate significant retardation of the pharmaceutical surrogate relative to water movement, as indicated by the conservative tracer (Figure 3). Water travel times from the infiltrative surface to 60 cm below the infiltrative surface ranged from 5 to 25 days. The time required for 10 % of the added pharmaceutical surrogate to reach 60 cm below the infiltrative surface ranged from 35 to over 200 days between test cells. After 20 months, mass recovery of the pharmaceutical surrogate at 60 cm below the infiltrative surface varied between test cells, ranging from less than 1 % to approximately 100 % (average = 40 %) recovery of the total mass of pharmaceutical surrogate added. The differences in mass recovery are likely due to differences in hydraulic loading rates and inherent variability in the native soil properties between test cells. The results suggest that OWCs with similar properties

as the pharmaceutical surrogate may be retarded and/or removed during onsite system soil treatment depending on the site-specific soil characteristics.

To further elucidate the fate and transport of OWCs during onsite system soil treatment, soil solution is being collected from 60, 120, and 240 cm below the infiltrative surface of the Mines Park soil treatment test cells for analysis of a suite of conventional wastewater parameters and OWCs. The absence of ammonia, presence of nitrate, and low levels of dissolved organic carbon and phosphorus in the soil solution suggests that treatment processes such as nitrification and sorption are occurring in the vadose zone. Target OWCs have been identified that are amenable to analysis by the sample collection methods, which exclude some volatile and sorptive compounds. Results of the occurrence of OWCs in the soil solution compared to levels measured in the effluent being applied will provide information regarding expected removal efficiencies of select OWCs during vadose zone soil treatment prior to recharge of underlying groundwater.

The occurrence of endocrine disruptors such as surfactant metabolites in wastewater raises concerns about their adverse impacts on the environment following recharge of groundwater and potential recharge of surface waters. The U.S. Environmental Protection Agency has established a toxicity-based water quality criteria for the surfactant metabolite 4-nonylphenol with the 4-day average concentration in freshwater systems not to exceed 6.6 g/L. Twenty five of the 30 sites included in the study had detectable concentrations of 4-nonylphenol in their confined unit effluents and approximately half of those exceeded the water quality criteria, some by greater than ten times. The effect from multiple endocrine disruptors, such as the suite of alkylphenolic compounds studied here, is unknown but studies have indicated an additive effect. Understanding the additional treatment that occurs during soil infiltration and percolation through the vadose zone and within the groundwater and surface water receiving environments is critical to aid in defining potential adverse effects to ecosystem and human health due to OWCs being discharged from onsite wastewater treatment systems. Such information will also enable a comparison of onsite system performance relative to that associated with centralized systems. Laboratory and field research is ongoing at CSM along with modeling studies, the results of which will help guide wastewater facilities planning and design.

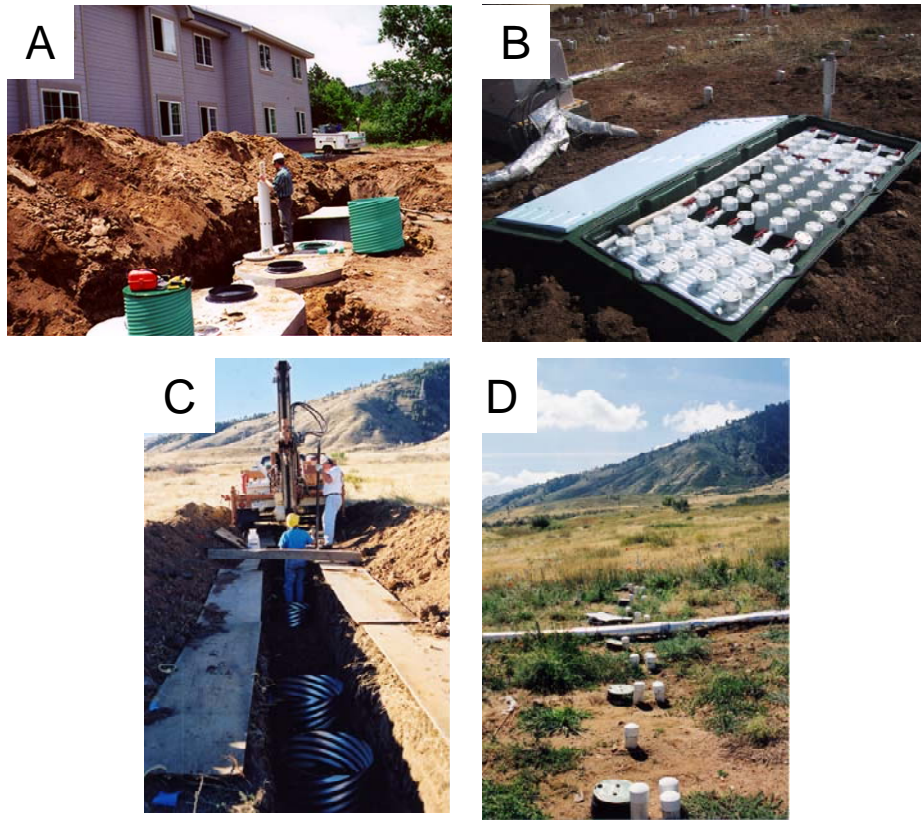


Figure 1. The fate of organic wastewater contaminants in onsite wastewater treatment systems is currently being investigated at the Mines Park Test Site where wastewater from a multifamily residence is intercepted (A) and managed using pilot-scale unit operations such as a textile biofilter (B) and in-ground soil test cells (C,D).

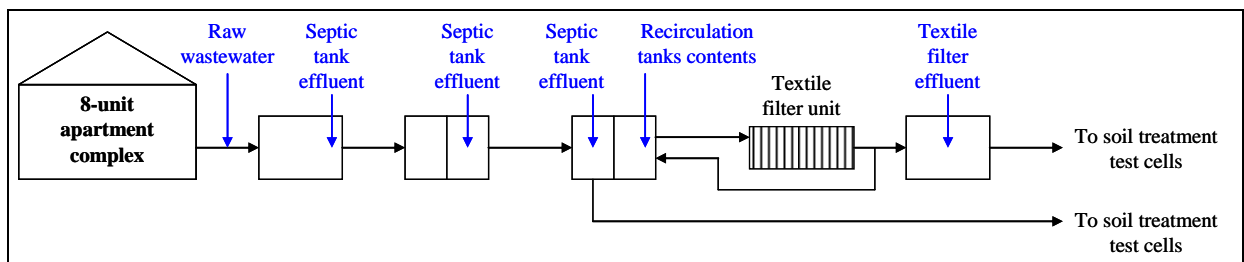


Figure 2. Schematic of the Mines Park Test Site confined treatment unit sampling locations.

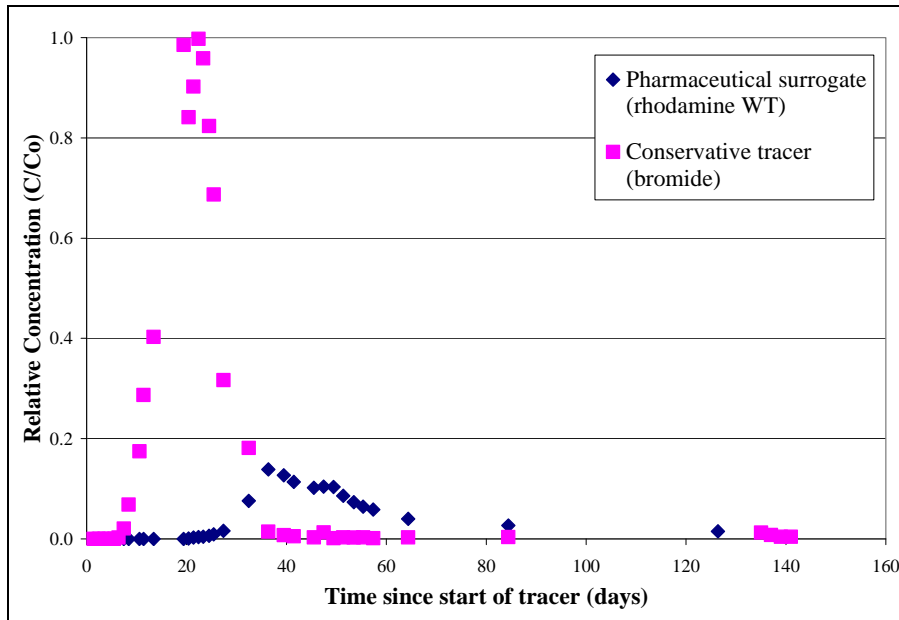


Figure 3. Comparison of the breakthrough curves at 60 cm below the infiltrative surface for a conservative tracer (bromide) and a pharmaceutical surrogate (rhodamine WT) added to an onsite system soil test cell.

Reference:

Conn, K.E.; Barber, L.B.; Brown, G.K.; and R.L. Siegrist. Occurrence and fate of organic contaminants during onsite wastewater treatment. *Environmental Science & Technology*, 2006, 40: 7358-7366.