Report for 2002CO46G: Occurrence and Fate of Emerging Organic Chemicals in Onsite Wastewater Systems and Implications on Water Quality Management in the Rocky Mountain Region

Publications

- Other Publications:
    - DeJong, K., 2004, "Occurrence of emerging organic chemicals in wastewater system effluents," presented at the 4th International Conference on Pharmaceuticals and Endocrine Disrupting Compounds in Water, Minneapolis, MN.

Report Follows

Problem and Research Objectives

The Rocky Mountain region has experienced significant development during the past decade, much of which is occurring in suburban fringe and mountain resort settings. In these areas, wastewater management is commonly achieved by onsite wastewater treatment systems (OWS). While for many years, these onsite systems were viewed as temporary solutions until centralized treatment facilities became available, they are now an appropriate and necessary component of the wastewater infrastructure in the U.S. (USEPA 1997). Just like their big-city counterparts (i.e., the centralized, municipal wastewater treatment plants), small onsite systems can, and must, be designed, installed, operated and managed to be protective of public health and environmental quality (Siegrist 2001). At this time, nearly 25% of the U.S. population is served by decentralized wastewater systems and a substantial portion of all new development is being supported by such systems with thousands of new systems being installed each year.

Growth has led to rapid proliferation of onsite wastewater treatment systems throughout Colorado and other Rocky Mountain states. For example, in Colorado there are over 600,000 onsite systems in operation serving about 25% of the State s population and there are 7,000 to10,000 new systems installed each year. On an annual basis this amounts to over 30 billion gallons of wastewater effluent discharged to the environment. In Wyoming, Montana, and Utah, the situation is similar. Issues have been raised regarding potential water quality impacts from onsite systems and the adequacy of current efforts to minimize such impacts. To explore and begin to address these issues in Colorado, in 2001 Ms. Jane Norton, Executive Director of the Colorado Department of Public Health and Environment, established the Individual Sewage Disposal System (ISDS) Steering Committee, comprised of members with a wide range of expertise and interests related to OWS. Findings of this Colorado Committee revealed that water quality impacts are occurring, but the nature and magnitude of resulting problems often has not been verified or rigorously documented (Colorado 2002). Furthermore, the few water quality studies that have been completed have focused on nutrient loading and bacterial levels.

Emerging organic chemicals (EOCs), such as pharmaceuticals and personal care products (PPCPs), have received a great deal of attention in the last decade with several studies indicating the adverse effects of these chemicals on ecosystems and human health. While several studies have pointed to wastewater as a primary contributing source of EOCs in the water environment, only a few studies have quantified their occurrence and fate in wastewater and, most focused on the presence of EOCs in the influents and effluents of large municipal wastewater treatment plants. The results of these studies do not shed much light on the occurrence and fate of EOCs in onsite systems nor the fate of these EOCs during pretreatment operations (e.g., septic tank or sand filter) and percolation through soil before ground water and surface water recharge.

A preliminary literature review was completed at CSM to examine the occurrence and fate of EOCs in wastewater systems in general, and online systems in particular. In

addition, samples of septic tank effluent (STE) were collected from two separate multifamily residential sites in Colorado and analyzed by Dr. Larry Barber (USGS, Boulder) for 48 different EOCs. Some of the key constituents detected were: caffeine (~69000 ng/L), estrone (~355 ng/L), 17-estradiol (~800 ng/L), 17 –ethinylestradiol (~35 ng/L), 4-nonylphenol (~760 ng/L), and bisphenol A (~9000 ng/L). The results of this work were very preliminary, but serve as a motivation for proposing the research outlined herein. Further understanding regarding EOCs in onsite systems is critical to better management and long-term use of these systems. This is particularly true for mountain watersheds where onsite systems may recharge water supplies used as source waters for drinking water. For example, in Summit County, Colorado, over 1000 onsite systems contribute to the Blue River watershed, which feeds Lake Dillon, a surface water that provides 25% of the drinking water supply for the City of Denver. If EOCs are present in onsite wastewater system influents in appreciable concentrations and if they are ineffectively remove during treatment operations and soil percolation, they may reach groundwater and surface waters and present risks for human health and environmental quality.

The overall goal of the proposed research is to determine if EOCs are present in onsite wastewater effluents and to what extent key EOCs of concern are effectively removed during treatment in a septic tank or engineered filter unit (sand or textile filter) and soil percolation prior to release to receiving waters. The specific objectives of the proposed research are to: (1) quantify the occurrence of EOCs in onsite wastewater effluents, (2) evaluate the treatment efficiency of pretreatment units and sandy soil for removal of EOCs, (3) assess the potential for EOCs originating from onsite systems to reach receiving waters, particularly in Rocky Mountain watersheds, (4) educate and train students in experimental methods and scientific research, and (5) transfer the findings to the scientific community and decision-makers in Colorado and the nation.

Methodology

Monitoring efforts follow established protocols and methodologies (APHA 1998, Barber *et al.* 1998, USGS 1999, Van Cuyk *et al.* 2001). To preserve the sample integrity, proper sample handling procedures are employed from the time of sample collection through sample analysis during all monitoring tasks (USGS 1999). During monitoring, all samples are collected in containers of appropriate materials and closures to ensure integrity of the analyses and avoidance of artifacts due to extraneous contamination. Field parameters will be measured in situ or onsite ($_{o}$C, pH, D.O.). Samples are labeled with permanent, unique numbers and be logged into project notebooks. All samples are placed in coolers and stored at 4¡C until brought to CSM or the USGS laboratory for analysis. Conventional pollutants are analyzed at CSM (alkalinity, solids, TOC, COD, nutrients, anions and cations) using standard methods (APHA 1998). EOCs will be analyzed by CSM students following USGS established methods at Dr. Barber s USGS lab in Boulder, Colorado. On a subset of samples, analyses has been completed for additional analytes at the USGS NWQL following their Schedule 1433 (for 70 EOCs). QA/QC checks of sampling and analysis procedures will consist of field and laboratory

QA/QC samples (~10% of total samples collected). All quality data will be reported from the laboratory as mg or ug per liter (mg/L, ug/L).

Principal Findings and Significance

Thirty OWS, 10 groundwater wells, and 9 surface waters in a Front Range region and Rocky Mountain region of Colorado were selected and sampled for conventional water and wastewater parameters and for a suite of OWCs. The OWS sites represented a range of sources: residential (single-family and multi-family homes), commercial (restaurants, convenience stores, and retail centers), and institutional (veterinary hospitals, schools, and churches). Ten groundwater wells and 9 surface water sites were selected to be representative of the sampling region and samples were collected in conjunction with the OWS sites.

The matrix of each OWS effluent, groundwater, and surface water sample collected has been characterized by general water and wastewater parameters. A wide range in concentrations has been measured for onsite system wastewater effluents, as would be expected from the diversity of wastewater sources sampled (e.g. ranging from single-family homes to large commercial and institutional establishments). The median values, though, are comparable to typical values reported for constituents in OWS effluents. For example, a typical effluent from an onsite system serving a residential source would be characterized by a carbonaceous biochemical oxygen demand (cBOD5) around 450 mg/L, total nitrogen of 100 mg/L, ammonia of 65 mg/L, and total phosphorus of 47 mg/L.

Each OWS effluent, groundwater, and surface water sample collected has also been analyzed for a suite of 25 organic wastewater contaminants. OWCs were identified frequently and at high concentrations in the wastewater effluents. Twenty three of the 25 compounds were identified in one or more of the wastewater effluents in concentrations ranging from less than the reporting level to greater than 1 mg/L. The number of compounds in each wastewater effluent sample ranged from 8 to 19, with the veterinary hospitals and convenience stores having the highest average number of compounds and the residential sources having the lowest average number of compounds.

The occurrence and concentrations of OWCs in OWS effluents can be related to the water use distribution at the wastewater source. For example, significantly higher concentrations of cholesterol, 3-β-coprostanol, caffeine, and triclosan were found in both convenience stores as compared to any other wastewater source included in the study. At convenience stores, approximately 90% of the water discharged to the onsite system originates from the public restrooms, i.e. from toilet and urinal flushing and sink faucets, therefore, higher concentrations of human-derived compounds (e.g. cholesterol, 3-β-coprostanol, and caffeine) and ingredients found in hand soaps such as triclosan are be expected in the wastewater effluent. Restaurants and veterinary hospitals that have a higher percentage of wastewater originating from clothes and dish washing reported elevated concentrations of EDTA, 4-methylphenol, and the surfactant metabolite and endocrine disruptor NPEC.

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. Concentrations of nonylphenol as low as 10 ug/L have been reported to induce production of the egg yolk precursor vitellogenin, an indicator of endocrine disruption, and significantly decrease the rate of growth of the testes in rainbow trout. In 2003 the U.S. Environmental Protection Agency proposed that the 4-day average concentration of nonylphenol in freshwater should not exceed 5.9 ug/L to ensure aquatic life water quality. Twenty five of the 30 sites included in the study had detectable concentrations of nonylphenol and approximately half of those exceeded the proposed value of 5.9 ug/L, 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. Significant treatment occurs during infiltration and percolation through the soil absorption system of OWS, though the removal rates and mechanisms of OWCs prior to recharge to the environment are currently unknown. Additionally, there is the potential for treatment failure, by preferential flow through the soil, or from hydraulic failure, such as a storm event, that would send untreated wastewater with pollutant concentrations seen here directly to ground or surface water. Currently, there are no established regulations for these compounds because little is still understood about the long-term reproductive effects of chronic exposure to pharmaceutically-active compounds at low concentrations such as those seen here.

Of the nine surface waters sampled in the study, very few OWCs were identified, and, if present, were in low concentrations. Cholesterol and 4-methylphenol were the only compounds identified in surface waters above the reporting level. The surface water sites are located in regions which rely heavily on OWS for wastewater treatment, but are not directly impacted by wastewater from municipal wastewater treatment plant discharge. Instead, treated OWS effluent percolates through the soil until it reaches the water table and recharges the groundwater which may, in turn, recharge the local surface water. Surface water may also be impacted by runoff from agriculture and development.

In the ten groundwater wells, there were more OWCs identified at higher concentrations than in the surface waters. Every groundwater well was contaminated with at least one and at most seven of the 25 OWCs included in this study. Nine of the sites are drinking water wells located up gradient on the same property as an OWS included in the study. In the OWS-reliant developments, contamination of these wells could indicate regional impacts to the groundwater from treated effluent recharge.

Due to the widespread and growing use of OWS as an appropriate method of wastewater treatment, understanding the potential impacts on the receiving environments to which they discharge is critical. Results of this study indicate OWCs are present in OWS effluent frequently and in variable concentrations. Treatment occurs in the septic tank, in additional pre-treatment units such as filters and wetlands, and during percolation through the soil absorption field prior to groundwater recharge. Controlled laboratory- and field-scale transport studies are underway to investigate the key mechanisms of removal during

soil treatment. OWCs have been identified in groundwater wells and, to a much lesser extent, in surface waters located in OWS-reliant regions. The results from the transport experiments in conjunction with the occurrence findings will aid in defining potential adverse effects to ecosystem and human health due to organic wastewater contaminants discharge from onsite wastewater treatment systems.