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Comparative analysis of effluent water quality from a municipal treatment plant and two on-site wastewater treatment systems

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HIGHLIGHTS

- A novel facility was used for comparison of onsite and centralized effluent quality.
- Water quality was assessed by traditional measures, toxicity and steroid levels.
- Effluent quality from an aerobic onsite system was similar to a centralized system.
- Performance-based measures appear useful for evaluations of onsite effluent quality.

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ABSTRACT

Though decentralized on-site technologies are extensively employed for wastewater treatment around the globe, an understanding of effluent water quality impairments associated with these systems remain less understood than effluent discharges from centralized municipal wastewater treatment facilities. Using a unique experimental facility, a novel comparative analysis of effluent water quality was performed from model decentralized aerobic (ATS) and septic (STS) on-site wastewater treatment systems and a centralized municipal wastewater treatment plant (MTP). The ATS and STS units did not benefit from further soil treatment. Each system received common influent wastewater from the Waco, Texas, USA Metropolitan Area Regional Sewerage System. We tested the hypothesis that MTP effluent would exhibit higher water quality than on-site effluents, based on parameters selected for study. A tiered testing approach was employed to assess the three effluent discharges: select routine water quality parameters (Tier I), whole effluent toxicity (Tier II), and select endocrine-active compounds (Tier III). Contrary to our hypothesis, ATS effluent was not statistically different from MTP effluents, based on Tier I and III parameters, but reproductive responses of *Daphnia magna* were slightly more sensitive to ATS than MTP effluents. STS effluent water quality was identified as most degraded of the three wastewater treatment systems. Parameters used to assess centralized wastewater treatment plant effluent water quality such as whole effluent toxicity and endocrine active substances appear useful for water quality assessments of decentralized discharges. Aerobic on-site wastewater treatment systems may represent more robust options than traditional septic systems for on-site wastewater treatment in watersheds with appreciable groundwater – surface water exchange.

1. Introduction

Quantification of water quality impairment presents challenges to water resource managers because water quality is a term that is often poorly defined among aquatic scientists, engineers, managers, and policy makers (Parparov et al., 2006). In the United States, water quality of effluents released from centralized municipal and industrial wastewater treatment plants is regulated by the US Environmental Protection Agency's (US EPA) National Pollutant Discharge Elimination System program (Grothe et al., 1996). Under this program, water quality is evaluated by screening specific water quality parameters (e.g., metals, nutrients, pathogens, pesticides) against established criteria, and by whole effluent toxicity,

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which employ model organisms such as the cladoceran *Daphnia magna* to integrate chemical, physical, and biological conditions of an effluent through quantifiable biological responses (US EPA, 2002a).

US EPA reports that approximately 1 in 4 American households (an estimated 60 million people), up to a third of new homes, and over half of the mobile homes in the United States rely on on-site treatment systems to treat wastewater (US EPA, 2002b, 2005). Historically, septic treatment systems (STSs) have been most commonly used for decentralized on-site treatment of wastewater. Over half of these septic systems are more than 30 years old and at least 10% are estimated to be malfunctioning (US EPA, 2002b, 2005). Failure rates for on-site systems have been reported to be up to 70% in select areas (US EPA, 2002b). These failures can degrade water quality in watersheds, potentially impacting ecosystem or human health (US EPA, 2002b). An alternative to STS are aerobic treatment systems (ATSs), which represent a newer generation of on-site technologies with generally improved treatment capabilities (Jantrania and Gross, 2006). In fact, ATS are required by regulatory agencies in select regions experiencing high groundwater exchange with surface water bodies (Jantrania and Gross, 2006).

Potential ecological impacts of failing or poorly installed on-site wastewater treatment systems are varied, but often include nutrient-enhanced productivity and bacterial contamination of aquatic systems (US EPA, 2002b). More recently, several studies have identified endogenous and exogenous compounds with endocrine activity in on-site wastewater or groundwater influenced by on-site systems (Rudel et al., 1998; DeJong et al., 2004; Conn et al., 2006; Swartz et al., 2006; Stanford et al., 2010). Endocrine active substances and other contaminants of emerging concern present challenges for such historical approaches to assess wastewater quality (Brooks et al., 2009), particularly in regions influenced by municipal wastewater discharges (Brooks et al., 2006). Such introductions of these contaminants of emerging concern from diffuse decentralized effluents may be particularly relevant to aquatic systems located adjacent to areas with dense concentrations of on-site systems because endocrine active compounds such as endogenous steroids may impact the reproduction of aquatic vertebrates (Purdom et al., 1994; Huggett et al., 2003; Jobling et al., 2006; Dobbins et al., 2008).

Whole effluent toxicity methodologies or other biological responses are often incorporated in evaluations of water quality from centralized effluent discharges (Grothe et al., 1996), but these approaches have not been employed to assess on-site effluent water quality. Unfortunately, the quality of on-site effluent discharges is often only quantified with basic measures of water quality such as Total Suspended Solids (TSSs) or Carbonaceous Biochemical Oxygen Demand (CBOD; TNRCC, 2002), which provide limited information on potential impacts of effluents to aquatic life. Further, even less is known about the magnitude, duration or frequency of exposure to endocrine active contaminants or whole effluent toxicity from various on-site system technologies.

Here we tested the hypothesis that a centralized MTP effluent discharge would exhibit higher water quality, based on selected parameters, than model on-site STS and ATS effluents. A critical component of our study was use of a unique experimental facility, which provided a globally unique setting to conduct such a study because common influent wastewater is diverted from a centralized wastewater treatment plant to model STS and ATS. We developed a tiered testing approach to assess the three effluent types, including select water quality parameters (Tier I), whole effluent toxicity (Tier II), and select endocrine-active compounds (Tier III). To our knowledge, this experimental facility provided for a novel assessment of effluent water quality from a centralized and two common decentralized treatment systems receiving a common wastewater influent.

2. Materials and methods

2.1. Study site description and experimental design

This study was performed at the Baylor Wastewater Research Program site (Fig. 1), located at the Waco Metropolitan Area Regional Sewerage System in Waco, Texas, USA, adjacent to the National Sanitation Foundation International's wastewater test facility for on-site systems. The Waco Metropolitan Area Regional Sewerage System is an activated sludge treatment plant (MTP) with a design capacity of approximately 151 ML per day and a mean daily load of about 95 ML per day. Influent from this facility is continuously diverted to the Baylor Wastewater Research Program and National Sanitation Foundation facilities, in which it is further partitioned to various on-site wastewater treatment technologies for study (Fig. 1). We selected an advanced aerobic treatment plant (ATS) and a typical STS as model systems for a comparative effluent water quality evaluation to the MTP. The ATS included a 5678 L multi-chambered system that was conceptually similar to the MTP because it contained an activated sludge process. The ATS used in this study also included a pretreatment tank, an aeration chamber and a final clarifier (HOOT Systems, Lake Charles, Louisiana, USA), but did not receive benefit from additional soil treatment. The STS was a basic, two-chambered 2800-l tank with no filter on the effluent discharge and also without benefit of a soil treatment unit, which may simulate a malfunctioning septic system scenario.

Hydrologic retention times of the MTP, ATS, and STS were considered in order to effectively compare effluent treated by the MTP to effluents treated by the ATS and STS. The MTP had a theoretical hydrologic retention time of approximately 8 h (Mike Jupe, City of Waco, pers. comm.), whereas the ATS and STS both had retention times of ~2.3 d based on dye tracer studies. Subsequently, 5 L of effluent from each treatment plant was collected on its corresponding sample day on six sampling dates over a three week period during summer conditions. Effluents were collected from the on-site systems prior to soil infiltration, which was intended to model worst case loadings to the environment with limited to no soil treatment. Because population demographics may influence

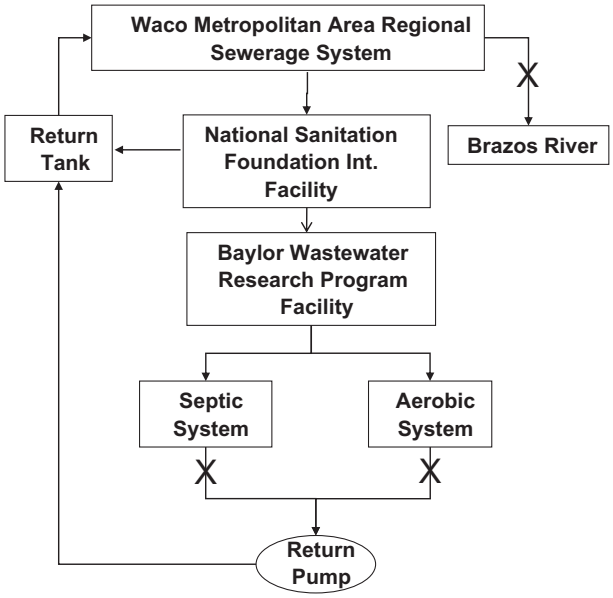

Fig. 1. Diagram of the Baylor Wastewater Research Program Facility located at the Waco Municipal Area Regional Sewerage System, Waco, Texas, USA. *X* denotes sample locations for this study.