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Occurrence of antibiotics in wastewater treatment facilities in Wisconsin, USA

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Abstract

Samples from several wastewater treatment facilities in Wisconsin were screened for the presence of 21 antibiotic compounds. These facilities spanned a range of community size served (average daily flow from 0.0212 to 23.6 million gallons/day), secondary treatment processes, geographic locations across the state, and they discharged the treated effluents to both surface and ground waters (for ground water after a soil passage). A total of six antibiotic compounds were detected (1–5 compounds per site), including two sulfonamides (sulfamethazine, sulfamethoxazole), one tetracycline (tetracycline), fluoroquinolone (ciprofloxacin), macrolide (erythromycin-H_2O) and trimethoprim. The frequency of detection of antibiotics was in the following order: tetracycline and trimethoprim (80%)>sulfamethoxazole (70%)>erythromycin-H_2O (45%)>ciprofloxacin (40%)>sulfamethazine (10%). However, the soluble concentrations were in the parts-per-billion (ppb) range (≤1.3 μg/L), and importantly were unaffected by the size of the wastewater treatment facility. The concentrations detected were within an order of magnitude of those reported for similar systems in Europe and Canada: they were within a factor of two in comparison to those reported for Canada but generally lower relative to those measured in wastewater systems in Europe. Only sulfamethoxazole and tetracycline were detected in groundwater monitoring wells adjacent to the treatment systems. Future intensive wastewater monitoring programs in Wisconsin may be limited to the six antibiotic compounds detected in this study.

Keywords: Antibiotics; Wastewater; Influent; Effluent; Tetracyclines; Sulfonamides; Fluoroquinolones; Macrolides; Trimethoprim

1. Introduction

Recent reports on the detection of pharmaceuticals in water bodies and waste streams in Europe, albeit at low concentrations, have raised some environmental concerns (Buser et al., 1998; Halling-Sorensen et al., 1998). There is an increasing interest among scientists, policy makers and industry personnel in the

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United States (U.S.) to survey the nation's water resources for human and veterinary pharmaceuticals, and steroidal hormones. The U.S. Geological Survey (USGS) is leading the efforts by collecting stream samples from several locations across the country to obtain base-line information regarding these *emerging contaminants* (Kolpin et al., 2002). Their efforts need to be augmented at the local level by systematically screening potential sources, such as effluents from wastewater treatment, animal waste lagoons, in addition to ground and surface waters, to obtain a better understanding of the transport pathways and environmental fate of pharmaceuticals.

Among a wide variety of pharmaceutical compounds, antibiotics assume special significance due to: i) their extensive use (>50,000,000 lbs produced annually in the US) in human therapy, veterinary medicine, and as husbandry growth promoters (Levy, 1998), ii) contributions from numerous sources (sewage treatment plants (STPs), confined animal feeding operations (CAFOs)), iii) their ability to alter microbial community structure facilitating the development of antibiotic-resistant human pathogens (Meyer et al., 2000), and iv) the potential to serve as indicators for the presence of resistant pathogens. Most of the antibiotics are poorly absorbed by humans and animals after intake, with about 25% to 75% of added compounds leaving the organisms unaltered via feces or urine (Chee-Sanford et al., 2001).

The concern with antibiotic residues in the environment is the inducement of resistance in bacterial strains. For example, fluoroquinolones use in poultry husbandry have promoted the evolution of fluoroquinolone-resistant *Campylobacter jejuni* (Gaunt and Piddock, 1996), an important human pathogen. Exposure to fluoroquinolones can result in a high fluoroquinolone minimal inhibitory concentration, for example of 4 mg/L for *C. jejuni*. Development of resistance to fluoroquinolones typically occurs within 2 years of their widespread application in veterinary medicine (Endtz et al., 1991).

Initial report on the presence of antibiotics in river water (micrograms per liter level of tetracycline and erythromycin) near a fish farm was provided by Watts et al. (1983). The past decade has witnessed more investigations related to antibiotics resulting in publications documenting their presence in ground and surface waters, landfill leachate, and liquid waste near animal operations. For example, sulfonamides have been detected in leachate from a Danish landfill (Holm et al., 1995), in Berlin drinking water wells for which 80% of the groundwater was bank-filtered surface water (Hartig and Jekel, 2001), and in groundwater in Germany (Sacher et al., 2001). Oxytetracycline concentrations ranging from 0.1–11 μg/g have been reported in sediments under a marine salmon farm (Coyne et al., 1994). Studies in the U.S. have identified antibiotics (sulfonamides and trimethoprim) in groundwater down-gradient from a landfill containing hospital waste (Eckel et al., 1993), in water supply wells in a Nebraska bank filtration site (Heberer et al., 2001) and in groundwater from Washington (Lindsey et al., 2001). In addition, tetracylines have been detected in groundwater samples collected near waste and wastewater lagoons (>1 μg/L, Thurman and Hostetler, 1999), and liquid hog lagoon samples (5 to 700 μg/L, Meyer et al., 2000). A screening study, using radioimmunoassay and immunoassay tests, conducted for different classes of antibiotics in liquid waste from CAFOs reported the following order in terms of frequency of detection: tetracyclines>sulfonamides>beta-lactams>macrolides (Meyer et al., 1999).

Studies focusing exclusively on wastewater treatment systems for the occurrence of antibiotics are somewhat limited. For these systems, more data is available from Europe. While Hirsch et al. (1999) and McArdell et al. (2003) reported on the presence of antibiotics in wastewater effluents in Germany and Switzerland, respectively, Golet et al. (2003) and Giger et al. (2003) evaluated reduction in concentrations after wastewater treatment for plants in Switzerland. As pointed out by Miao et al. (2004), for North America the available data is presently limited mainly to surface waters, while the studies reported earlier in this article provide information for groundwater, landfill leachate, and liquid animal waste. To our knowledge, results presented by Miao et al. (2004) are the first of their kind for wastewater treatment systems in North America.

The major goal of this study was, therefore, to determine the presence of antibiotics in the influent to and effluent from wastewater treatment systems. Samples were collected from municipal wastewater treatment facilities with a special focus on those with land-based effluent discharge systems. Specific