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Perfluoroalkyl sulfonates and perfluorocarboxylates in two wastewater treatment facilities in Kentucky and Georgia

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ABSTRACT

Discharge of effluents from municipal wastewater treatment plants (WWTPs) is a route for the introduction of certain organic contaminants into aquatic environments. Earlier studies have reported the occurrence of perfluorochemicals in effluents from WWTPs. In this study, contamination profiles of perfluorinated compounds (PFCs), including perfluoroalkyl sulfonates (PFASs; PFOS, PFOSA, PFHxS) and perfluoroalkyl carboxylates (PFACs; PFOA, PFNA, PFDA, PFDoDA, PFUnDA), were determined in samples collected at various stages of wastewater treatment during different seasons. The two WWTPs selected for this study represent rural (Plant A, Kentucky) and urban (Plant B, Georgia) areas. PFOS was a major contaminant in samples from Plant A (8.2–990 ng/g dry wt in solid samples and 7.0–149 ng/L in aqueous samples), followed by PFOA (8.3–219 ng/g dry wt in solid samples and 22–334 ng/L in aqueous samples). PFOA was the predominant contaminant in samples from Plant B (7.0–130 ng/g dry wt in solid samples and 1–227 ng/L in aqueous samples), followed by PFOS (<2.5–77 ng/g dry wt in solid samples and 1.8–22 ng/L in aqueous samples). PFHxS, PFNA, PFDA, and PFOSA were detected in most of the samples, whereas PFUnDA and PFDoDA were detected in very few samples. Concentrations of some PFCs, particularly PFOA, were slightly higher in effluent than in influent, suggesting that biodegradation of some precursors contributes to the increase in PFOA concentrations in wastewater treatment processes. No large-magnitude seasonal variations in concentrations were found, although mass flow of PFCs was higher in winter than in summer. In general, samples from the rural plant in Kentucky contained greater concentrations of PFCs than did those from the urban plant in Georgia. Incineration of sludge reduced the PFC levels significantly. The mass flows of PFCs in these two plants were several hundreds of mg/day, comparable to flow values reported earlier.

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1. Introduction

Perfluorinated compounds (PFCs) have emerged as global environmental contaminants (Giesy and Kannan, 2001; Kannan et al., 2002, 2004). In particular, two groups of PFCs, namely perfluoroalkyl sulfonates (PFASs) and perfluoroalkyl carboxylates (PFACs), are of particular concern from environmental and public health significance (Hekster et al., 2003; Lehmler, 2005; Senthil Kumar, 2005). Despite their detection in biota collected from all over the world, little attention has been paid to these compounds' local sources of release into the environment. Because many of these PFCs are used in multiple consumer products, the compounds eventually reach wastewater treatment plants (WWTPs) (Boulanger et al., 2005a; Sinclair and Kannan, 2006; Schultz et al., 2006a, b). These studies have shown that the discharge of wastewater effluent is a significant source of PFCs to the environment. Despite the reported occurrence of PFCs in wastewater, seasonal variations in concentrations and differences in mass flows between urban and rural plants have not been characterized. Variations in concentrations of PFCs between WWTPs from urban and those in rural areas need to be assessed to enable estimation of the inventories of PFCs in the environment. Furthermore, very limited information is available on the levels of PFCs in WWTP samples collected at various stages of the treatment process, including sludge removal and disposal. In this study, we measured PFC concentrations in WWTP samples collected from a facility in western Kentucky (Plant A; rural area) and in coastal Georgia (Plant B; urban area). Plant A and Plant B treat, on average, 19.7 and 68.4 million liters, respectively, (corresponding to 5.22 and 18.1 million gallons/day [MGD] of wastewater) daily. These two WWTPs treat primarily domestic and commercial district wastewaters. The objective of our study was to determine the concentrations, composition, and seasonal variation of PFCs in solid and aqueous matrices collected from the two WWTPs. In Plant B, sludge samples are incinerated, and therefore samples collected before and after incineration were analyzed. The target analytes were perfluorohexane sulfonate (PFHxS), perfluorooctane sulfonate (PFOS), perfluorooctane sulfonamide (PFOSA), perfluorooctanoic acid (PFOA), perfluorononanoic acid (PFNA), perfluorodecanoic acid (PFDA), perfluoroundecanoic acid (PFUnDA), and perfluorododecanoic acid (PFDoDA). Mass flows were calculated by multiplying average concentrations in aqueous and solid matrices by the average total flow at that WWTP.

2. Materials and methods

2.1. Sampling sites

Grab sampling was performed during winter, spring, summer, and fall of 2005 in the plant in Kentucky (Plant A) and during winter, summer, and fall in the plant in Georgia (Plant B). Plants A and B serve populations of 15,000 and 130,000, respectively, and both plants employed an activated sludge treatment process. Schematic diagrams of the treatment processes employed at Plants A and B are shown in Figs. 1 and 2, respectively. At Plant A, influent, oxidation ditch water, oxidation ditch solids, clarifier water, effluent, reactivated liquid, reactivated sludge (also known as return activated sludge), and final solid waste were collected. For certain sampling periods, the final effluent was collected before and after chlorination. Dry solids from the drying pond and compressed dry cake were also analyzed. At Plant B, influent, primary, aeration supernatant, aeration-mixed liquid suspension solids (MLSS), reactivated sludge supernatant, reactivated sludge, effluent, ash basin water, and sludge cake (both

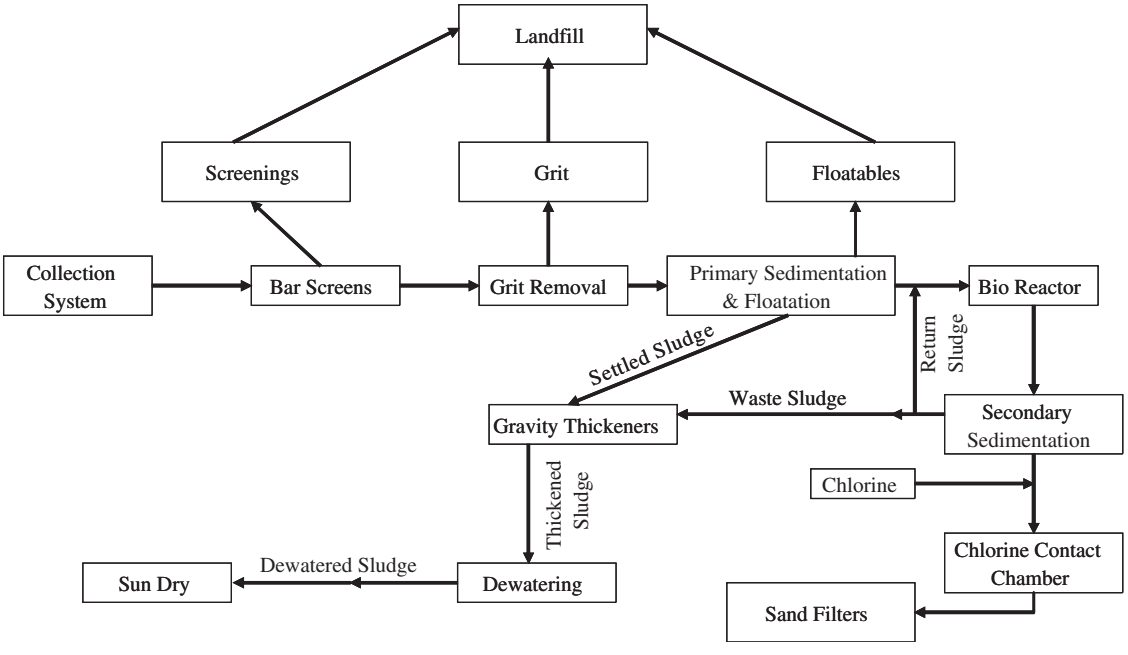

Fig. 1 – Schematic diagram of the treatment process at WWTP A in Kentucky.