Organic wastewater compounds in urban streams, Atlanta, Georgia

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Abstract

The Clean Water Atlanta (CWA) Program began a Long-Term Watershed Monitoring Program during December 2002 to evaluate the effects of proposed and ongoing wastewater treatment infrastructure upgrades on water quality. As part of this monitoring program, the U.S. Geological Survey collected and analyzed organic wastewater compounds (OWCs) samples from tributary streams in the City of Atlanta. Eighty-seven synoptic samples were collected from 43 sites during low- and high-baseflow conditions. An additional 20 sites on seven tributary streams were sampled more routinely (125 times) to better assess temporal changes in water quality and water-quality conditions across more diverse flow conditions. The OWC results from the CWA stream sampling were compared to 17 samples collected as part of the National Water-Quality Assessment Program on the Chattahoochee River upstream of the confluence with COA streams. Of the 64 OWCs analyzed, 57 were detected (excluding phenol and acetophenone because of detections in field blanks) with the number of OWCs detected in the 229 samples ranging from 1 to 43 compounds. Generally, the number of OWCs detected and the concentrations of OWCs detected increase at higher flows in basins with higher percentages of commercial and industrial land use. In contrast, fewer OWCs were detected and the number of OWCs tends to decrease with increasing flow in basins dominated by residential land use.

Introduction

In December 2002, the Clean Water Atlanta (CWA) Program began a Long-term Watershed Monitoring Program (LTWMP) to (1) evaluate the effects of proposed and ongoing wastewater treatment infrastructure upgrades on water quality, (2) replace or reduce the need for individual sewage overflow/spill monitoring, and (3) meet a state-mandated requirement to monitor stormwater quality and quantity. As part of the LTWMP, the U.S. Geological Survey (USGS) is responsible for collecting and analyzing streamflow and water-quality data to meet the program goals which include (1) assess baseline water-quality conditions, (2) identify sources of impairment, (3) determine trends in water-quality with respect to upgrades in wastewater infrastructure, and (4) provide information that can be used to make management decisions to improve water quality. Potential sources of wastewater to streams in the City of Atlanta (COA) include leaking or overflowing sanitary sewers, seven combined sewer overflows (CSOs, Figure 1), illegal discharges, runoff, and leachate from septic systems. There are no discharges of treated municipal wastewater effluent upstream from the CWA sampling sites.

As part of assessing baseline water-quality conditions and to begin to evaluate if a relatively recently developed laboratory method (Zaugg et al., 2002) can help identify sources of impairment to basins within COA, this paper provides a preliminary description of spatial and hydrologic-condition based variations in the occurrence in stream samples of a suite of 64 organic wastewater compounds (OWCs) typically found in domestic and industrial wastewater. The laboratory method focuses on the determination of compounds that are an indicator of wastewater or that were chosen on the basis of their endocrine-disruption potential or toxicity. OWCs measured include nonionic surfactants and their degradates antioxidants, food additives, fragrances, a fumigant, high-use domestic herbicides, an insect repellent, insecticides, nonprescription drugs, polycyclic aromatic hydrocarbons (PAHs), plasticizers and/or fire retardants, solvents, and steroids. Most of the OWCs analyzed have anthropogenic sources and a few also occur naturally. Each of the OWCs analyzed is used extensively, however, limited information about their occurrence in streams at a national (Kolpin et al., 2002) and local scale (Frick and Zaugg, 2003) and in similar urban settings (Wilkinson et al., 2002) are available.

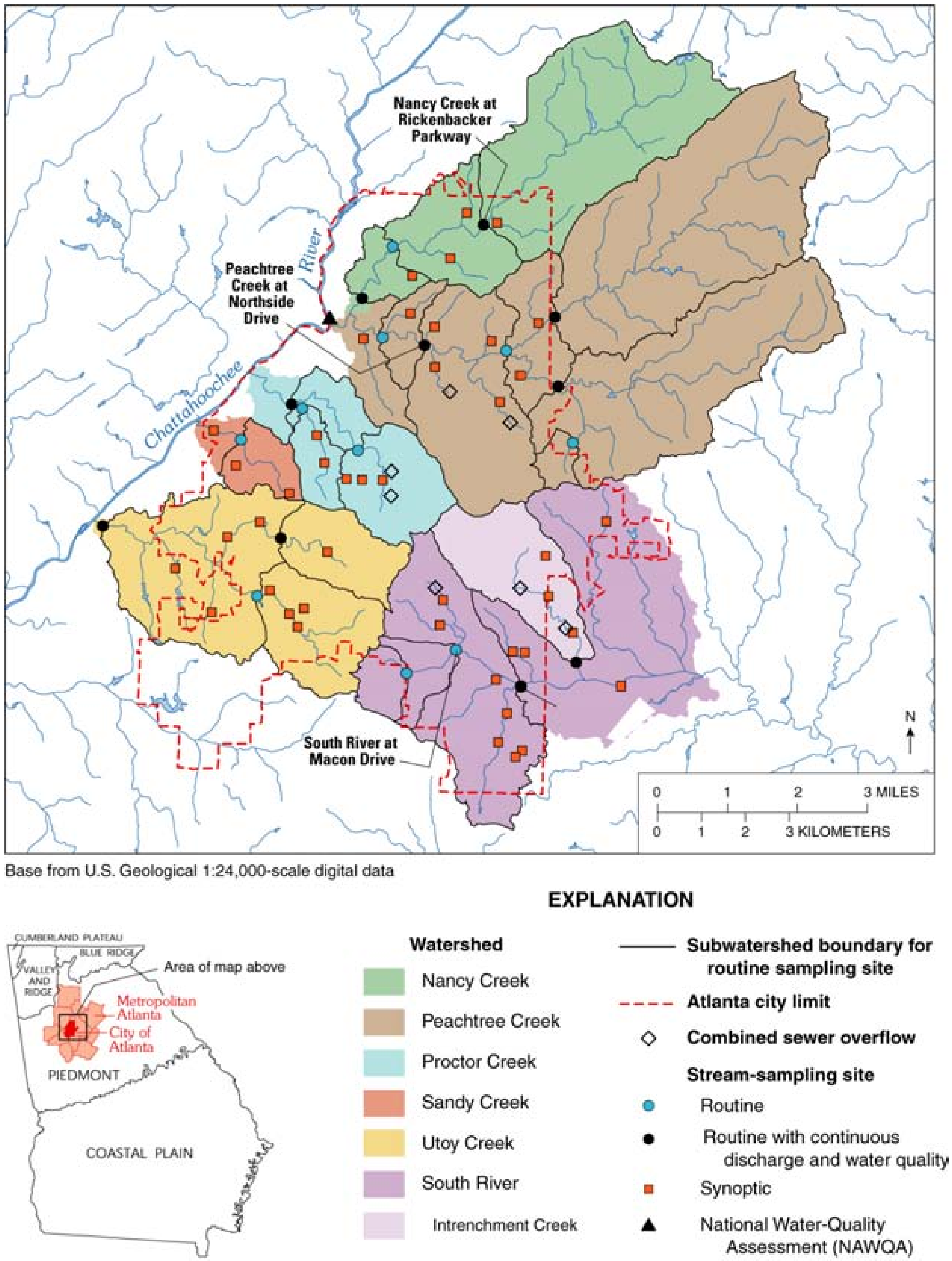

Figure 1. Stream-sampling sites, City of Atlanta, Georgia.

Description of sampling networks

The CWA water-quality monitoring program consists of a synoptic network of 43 stream sites with watersheds ranging in size from 0.3 to 107 square kilometers (km^2) and a routine network of 20 regularly sampled stream sites with watersheds ranging in size from 3.5 to 232 km^2 (Figure 1). A broad suite of dissolved compounds including field parameters, nutrients, indicator bacteria, and OWCs and sediment-bound compounds such as trace elements and nutrients were analyzed. Each synoptic site was sampled twice—once during low-baseflow conditions in July 2003 and once during high-baseflow conditions from March to August 2003. Sites in the routine network were sampled for OWCs 4 to 12 times from July 2003 through March 2004 over a range of hydrologic conditions. Ten of the routine sampling sites were instrumented with real-time water-quality monitors for inorganic parameters. To monitor outflows from the COA, seven routine sites are located at the most downstream location of the seven major tributary watersheds shaded on Figure 1. To monitor inflows to the COA, three routine sites are located at the most upstream site within the COA on tributary streams with significant drainage areas outside of the city limits (Figure 1).

To provide an indication of the variability and occurrence of OWCs in the Chattahoochee River just upstream from the watersheds sampled as part of the CWA monitoring program, CWA sampling results were compared to results from samples collected at the Atlanta drinking-water intake on the Chattahoochee River as part of the USGS National Water-Quality Assessment Program (NAWQA) source-water assessment study (Gregory C. Delzer, USGS, written communication, 2004). Data collected from October 2002 through December 2003 at this NAWQA sampling site (Figure 1) represent regional water-quality conditions in a 3,780 km^2 watershed with streamflow regulated by a large upstream dam. Much of the northern Atlanta suburbs and urban areas are in the Chattahoochee River watershed for this NAWQA sampling site. The 77-km reach of the Chattahoochee River from the upstream dam to the NAWQA sampling site is influenced by multiple wastewater discharges and stormwater from a variety of land uses. Five of the seven tributary watersheds sampled as part of the CWA water-quality monitoring network drain into the Chattahooochee River downstream from the NAWQA sampling site on the Chattahoochee River. The South River and Intrenchment Creek watersheds drain southeastern Atlanta and drain into the Ocmulgee River Basin (not shown).

Characteristics of the Study Area

The 343 km^2 extent of COA is approximately centered within the 10-County Atlanta Regional Commission (ARC) planning area (4,780 km^2). All but four of the CWA sampling sites are within the COA boundary (Figure 1). Urban land use covers from 79 to 98 percent of the watersheds for the 20 routine sampling sites, with most of the remaining land use being forested (Atlanta Regional Commission, 2004). The 10-county Atlanta metropolitan area is a sprawling urbanized and suburbanized complex in which the population has increased from 1.1 million in 1960 to 3.67 million people in 2003 (Atlanta Regional Commission, 2003). The average population density for the 10-county metropolitan area is less than 800 people per km^2 compared to more than 1,250 people per km^2 within COA. The region is in the Piedmont Physiographic Province (Figure 1), which is hilly and is underlain by late Paleozoic crystalline and metamorphic rock.

On average, the study area receives 1,270 mm precipitation annually, which generally is distributed uniformly during the year (Carter and Stiles, 1983). During the spring and summer from April through September, rainstorms are convective (high intensity and short duration). During the remainder of the year, precipitation is dominated by synoptic-scale weather systems (low intensity and long duration). The runoff coefficient (RC; runoff as a fractional percentage of precipitation) of the watersheds ranges from approximately 30 to 40 percent with the highest RCs in watersheds with the highest percentages of impervious area (Rose and Peters, 2001). Stream baseflow varies seasonally with the lowest flows occurring during the summer growing season when evapotranspiration is the highest, and the highest baseflow occurring during winter when evapotranspiration is the lowest.

Results and Discussion

In the 229 stream samples collected (87 synoptic, 125 routine, and 17 from the NAWQA sampling site) a total of 59 of the 64 OWCs analyzed were detected. The most frequently detected OWCs were DEET (97 percent, insect repellent), caffeine (94 percent, stimulant), p-Cresol (65 percent, herbicide), and five organo-phosphate plasticizers and fire retardants—tributyl phosphate, tris(2-chloroethyl) phosphate, triphenyl phosphate, tris(dichloroisopropyl) phosphate, and tris(2-butoxyethyl) phosphate (58 percent to 67 percent). Few of the OWCs measured have drinking-water standards or other human or ecological health criteria (Kolpin et. al, 2002). Of those with standards, none of the concentrations in streams exceeded existing standards.

Field and laboratory blank data were evaluated to verify that low concentrations of OWCs measured in stream samples are likely to be real rather than the result of contamination. Six compounds, including DEET, benzophenone, 3beta-coprostanol, cholesterol, menthol, and 4-nonylphenol, were detected at very low concentrations in one of seven field blanks. Phenol and acetophenone were excluded from analysis because they were detected in five of the seven field blanks, with some detections greater than the method reporting limit. Detections of phenol and acetophenone in one source solution blank sample accounted for 44 percent and 20 percent, respectively, of the concentrations measured in a companion field blank. OWCs were detected in 26 percent of the 14,198 possible detections (57 of 62 OWCs, i.e., excluding phenol and acetophenone). Of these detections, 222 (1.6 percent) were above the method reporting limits for 23 compounds. More than 40 of the OWCs have method reporting limits of 0.5 micro grams per liter (µg/L). The maximum method reporting limit was 5 µg/L for several of the detergent metabolites.

Because no streamflow data are available for the synoptic samples, a ratio of high to low baseflow was calculated to put the change in flow status in perspective for each pair of synoptic samples. This ratio is based on the streamflows at the time of sampling for each pair of synoptic samples from a long-term streamflow gauge on Peachtree Creek at Northside Drive. The high to low baseflow ratio for the 43 synoptic sites sampled ranged from 2.1 to 62. All the low-baseflow samples were collected during July 2003, when hydrologic conditions were fairly stable. Because of the relatively large range in the flow ratios among synoptic sites, some of the differences in the number of OWCs detected, which OWCs were detected, and the concentrations of OWCs detected during high-baseflow samples are more likely because of different high-baseflow conditions rather difference among OWC sources and land use upstream from the synoptic sites.

For the synoptic sampling, the largest number of OWCs were detected in samples collected during high-baseflow conditions in the Proctor Creek (16-26 compounds) and South River basins (12-40 compounds), which contain the highest percentage of commercial and industrial land uses compared to the other basins. The number of OWCs detected and concentrations of OWCs typically were lower for samples collected during low-baseflow conditions in July 2003 than for synoptic samples collected during high-baseflow conditions. For synoptic sites in the Proctor Creek basin, the number of detections increased from 5-8 during low-baseflow conditions to 16-26 during high-baseflow conditions. By contrast, in several of the synoptic and routine sites in basins containing more than 60 percent residential land use (Nancy, Utoy, and Peachtree Creek basins), the fewest number of OWC detections (3-5 compounds) were in samples collected during high-baseflow conditions.

For the synoptic sampling, the number of fragrance, herbicide, and insecticide compounds detected generally was higher in samples collected during high baseflow conditions. In contrast, the number of food additive, insect repellent, plasticizers, and fire retardants were lower in samples collected during high baseflow conditions. These patterns may be due to variations in source pathways among OWCs and changes in source contributions as affected by the hydrology, timing of source use, and relative contributions of leaking septic systems and sewer lines.

In the 17 samples collected at the NAWQA sampling site on the Chattahoochee River during a variety of flow conditions, the number of OWCs detected varied from 3 to 27. These detections do not correlate very well with the regulated streamflow in the Chattahoochee River; however, they do correlate with streamflow in Peachtree

Creek (Spearman Rank correlation coefficient r = 0.79). Peachtree Creek is the largest tributary drainage basin of the CWA monitoring program (Figure 1) and its streamflow is representative of runoff conditions in unregulated tributary streams with a high percentage of urban land use that are typical within the study area. The number of OWCs detected at the NAWQA sampling site increased from less than 5 in low-flow samples to more than 25 in high-flow samples (Figure 2). The result of more detections and at higher concentrations of OWCs in high-flow samples compared to low-flow samples is opposite the results observed upstream and downstream from 14 communities in Iowa reported by Kolpin et al. (2004). The Iowa communities had much lower populations (from 2,000 to 200,000 people) and probably had lower population densities and percentages of urban area that the Metropolitan Atlanta area, which may account for the different pattern in OWC detections and concentrations.

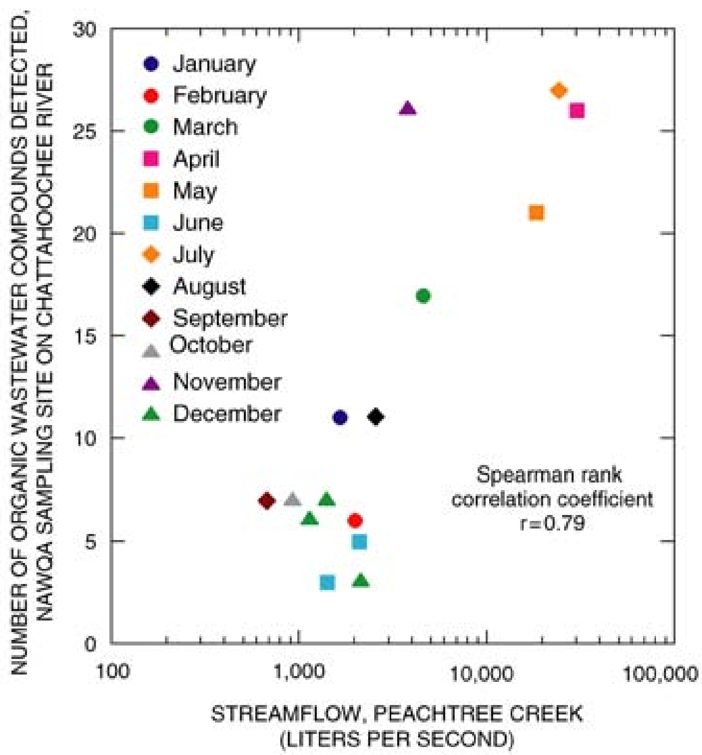

Figure 2. Relation between the number of organic wastewater compounds detected in samples collected at the National Water-Quality Assessment (NAWQA) sampling site on the Chattahoochee River (a highly regulated river) and the streamflow of Peachtree Creek (a free-flowing urban tributary watershed).

The largest number of OWC samples were collected at two routine sites with similar land-use characteristics—Nancy Creek at Rickenbacker Parkway (12 samples) and Peachtree Creek at Northside Drive (10 samples). Although the land-use characteristics of these two basins are very similar (approximately 60 percent residential, 27 percent industrial and commercial, and 4 percent transportation in both basins; Atlanta Regional Commission, 2004); but there are two CSOs upstream from the Peachtree Creek at Northside Drive sampling site. The number of OWCs detected at two routine sampling sites with the most samples varied markedly, ranging from 5 to 31 at the Nancy Creek site and from 4 to 41 OWCs at the Peachtree Creek site (Figure 1).

The routine site on the South River at Macon Drive (Figure 1) had a consistently high number of OWCs detected in the nine samples collected. From 16 to 34 OWCs were detected in the 9 samples collected and more than 30 OWCs were detected in 6 of the 9 samples. The South River basin at Macon Drive has a higher percentage of land use classified as commercial and industrial (37 percent) and transportation (8 percent) than some of the other sampling sites (Atlanta Regional Commission, 2004) and there is a CSO that discharges upstream from the sampling site, both of which may contribute to more OWC detections.

The Long-Term Watershed Monitoring Program is scheduled to continue collecting OWC and other water-quality samples through December 2005 at approximately 20 routine sampling sites. This extensive OWC data set will enable more thorough analyses of variations in OWCs with respect to temporal, seasonal, and hydrologic conditions at individual sampling sites and among sampling sites in watersheds with varying degrees of urbanization. If accurate data can be compiled on CSO releases, effluent spills, and wastewater infrastructure changes upstream from some of the sampling sites, then it may be possible to identify which OWCs are most useful to identify and quantify various sources of wastewater contributions to urban streams.

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