

**ORGANIC COMPOUNDS DOWNSTREAM  
FROM A TREATED-WASTEWATER  
DISCHARGE NEAR DALLAS,  
TEXAS, MARCH 1987**

**By Paul M. Buszka, Larry B. Barber, II, Michael P. Schroeder, and  
Larry D. Becker**

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## CONVERSION FACTORS, ABBREVIATED WATER-QUALITY UNITS, AND ABBREVIATIONS

Multiply	By	To obtain
cubic meter per second (m <sup>3</sup> /s)	35.31	cubic foot per second
cubic meter per day (m <sup>3</sup> /d)	35.31	cubic foot per day
gram (g)	0.0353	ounce, avoirdupois
kilometer (km)	0.6214	mile
kilometer squared (km <sup>2</sup> )	0.3861	mile squared
liter (L)	0.2642	gallon
liter per cubic meter (L/m <sup>3</sup> )	7.494 x 10 <sup>-3</sup>	gallon per cubic foot
meter (m)	3.281	foot
microgram (μg)	3.527 x 10 <sup>-8</sup>	ounce, avoirdupois
microgram per milliliter (μg/mL)	1.044 x 10 <sup>-3</sup>	ounce, avoirdupois per fluid ounce
microgram per liter (μg/L)	1.335 x 10 <sup>-7</sup>	ounce, avoirdupois per gallon
microgram per 100 grams of organic carbon (μg/100 g OC)	1 x 10 <sup>-8</sup>	ounce, avoirdupois per ounce, avoirdupois of organic carbon
microliter (μL)	3.38 x 10 <sup>-5</sup>	ounce, fluid
micrometer (μm)	3.94 x 10 <sup>-5</sup>	inch
milligram (mg)	3.527 x 10 <sup>-5</sup>	ounce, avoirdupois
milligram per second (mg/s)	3.527 x 10 <sup>-5</sup>	ounce, avoirdupois per second
milliliter (mL)	0.0338	ounce, fluid
<b>Temperature</b>		
degree Celsius (°C)	°F = 1.8 x (°C) + 32	degree Fahrenheit (°F)

**Abbreviated water-quality units:**

mg/μg, milligram per microgram  
 mg/L, milligram per liter

**Abbreviations:**

- BOD, biochemical oxygen demand, 5-day test
- C1, C2, C3, C4, C10, C11, C12, C13 or C14, number of carbon atoms per alkyl chain
- CLS, closed-loop stripping extraction
- CLS-LLE, sequential application of closed-loop stripping and liquid-liquid extraction
- DOC, dissolved organic carbon
- foc, fraction of organic carbon
- GC/MS, gas chromatography/mass spectrometry
- IF, instantaneous flux
- Koc, organic-carbon absorption coefficient
- Kow, octanol-water partition coefficient
- LLE, liquid-liquid extraction
- MBAS, methylene blue active substance
- MCL, maximum contaminant level
- OC, organic carbon
- PT, purge-and-trap extraction
- RMCL, recommended maximum contaminant level
- SOC, suspended organic carbon
- T, total
- USEPA, U.S. Environmental Protection Agency
- USGS, U.S. Geological Survey

# Organic Compounds Downstream from a Treated-Wastewater Discharge near Dallas, Texas, March 1987

By Paul M. Buszka, Larry B. Barber, II, Michael P. Schroeder, and Larry D. Becker

## ABSTRACT

Water and streambed-sediment samples were collected on March 9 and 10, 1987 from one site upstream and three sites downstream of the discharge from a municipal wastewater-treatment plant on Rowlett Creek near Dallas, Texas. To extract and separate organic compounds, purge-and-trap, closed-loop stripping, and pH-adjusted solvent extraction methods were used for water samples; and a Soxhlet-solvent extraction method was used for streambed sediment. These methods were combined with gas chromatography/mass spectrometry to identify organic compounds in Rowlett Creek. Results from this study confirm the persistence of many organic compounds in water as far as 13.5 kilometers downstream of the wastewater discharge. These include: (1) the volatile organic compounds chloroform, 1,2-dichlorobenzene, 1,4-dichlorobenzene, tetrachloroethene, and trichloroethene; (2) several linear alkylbenzene compounds, octyl phenol, and a tetramethylbutyl phenol isomer that are related to detergent use; (3) 9-phenyl-9H-carbazole, a compound related to coal tars and coal combustion residues; and (4) caffeine. The only compound present in water in concentrations greater than U.S. Environmental Protection Agency maximum contaminant levels for drinking water was tetrachloroethene (6.0 micrograms per liter) in a sample collected 13.5 kilometers downstream from the wastewater discharge. Compounds identified from the streambed-sediment samples include a xylene isomer at 7.7 kilometers downstream and chrysene, fluoranthene, pyrene, and a xylene isomer at 13.5 kilo-

meters downstream from the wastewater discharge.

Comparison of instantaneous flux values of selected organic compounds in water from downstream sites indicates: (1) the formation of chloroform in the stream following the discharge of the treated effluent, and that (2) instream biodegradation may be decreasing concentrations of linear alkylbenzene compounds in water. The relative persistence of many of the selected organic compounds in Rowlett Creek downstream from the municipal wastewater-treatment plant indicates that they could be transported into Lake Ray Hubbard, a source of municipal water supply.

## INTRODUCTION

Municipal-wastewater effluent is a major source of anthropogenic pollution to rivers (Sheldon and Hites, 1978) and estuaries (Barrick, 1982). Municipal-wastewater effluent is a mixed waste derived from a variety of industrial, commercial, and residential users. The waste typically is routed to a treatment plant through a common sanitary sewer system. Many treatment procedures may not effectively remove hazardous organic compounds. Treated-wastewater effluent which is chlorinated prior to discharge to receiving streams may contain trihalomethanes, a class of organic compounds including bromoform, chlorodibromomethane, chloroform, and dichlorobromomethane that are suspected carcinogens (Bull, 1986). Concentrations of these compounds above the RMCL or MCL's may prohibit use as a drinking-water source. Identifying the concentrations of compounds in surface water affected by the treated-wastewater effluent is necessary to assess their potential health hazards and to

devise effective water treatment and control procedures.

Many of the creeks and rivers in the Trinity River drainage area near Dallas receive large amounts of treated-wastewater effluent from wastewater-treatment plants (Davis and Bastian, 1988). Rowlett Creek, an effluent-dominated stream in a part of the Trinity River drainage area northeast of Dallas, empties into a municipal water-supply reservoir, Lake Ray Hubbard (fig. 1). Treated effluent discharged to Rowlett Creek from the wastewater-treatment plants of the North Texas Municipal Wastewater District at Plano (Plano plant) and at Garland have been the principal sources of nutrients to the lake (North Central Texas Council of Governments, 1977). Evaluating the types and concentrations of organic compounds contributed by treated-wastewater effluent to water in the creek is necessary to determine their potential effect on the water quality of Lake Ray Hubbard. Previous studies of organic compounds within the Trinity River basin near Dallas have concentrated on the polychlorinated biphenyl, pesticide, and fatty acid composition of surface water and bed sediment (Qasim and others, 1980; Davis and Bastian, 1988, 1990).

## Purpose and Scope

The purpose of this report is to present the results of a reconnaissance study conducted during March 1987 to determine if treated-wastewater effluent contributes anthropogenic-organic compounds to surface water. The study area covers an 18-km reach of Rowlett Creek, northeast of Dallas (fig. 1). The persistence of organic compounds in flow downstream from the Plano plant outfall was evaluated along a 13.5-km reach of Rowlett Creek.

## Description of the Study Area

Rowlett Creek is approximately 16 km northeast of Dallas, Texas and within the drainage basin of the East Fork Trinity River (fig. 1). The creek drains parts of the cities of Plano, Richardson, and Garland (Twidwell, 1985) and joins the East Fork Trinity River at Lake Ray Hubbard. The drainage area of Rowlett Creek above Lake Ray Hubbard is a 312-km<sup>2</sup> area. As of 1978, 75 percent of the land use in the basin was agricultural, supporting either cropland or grassland.

Since 1978, there has been substantial residential and commercial development in the area.

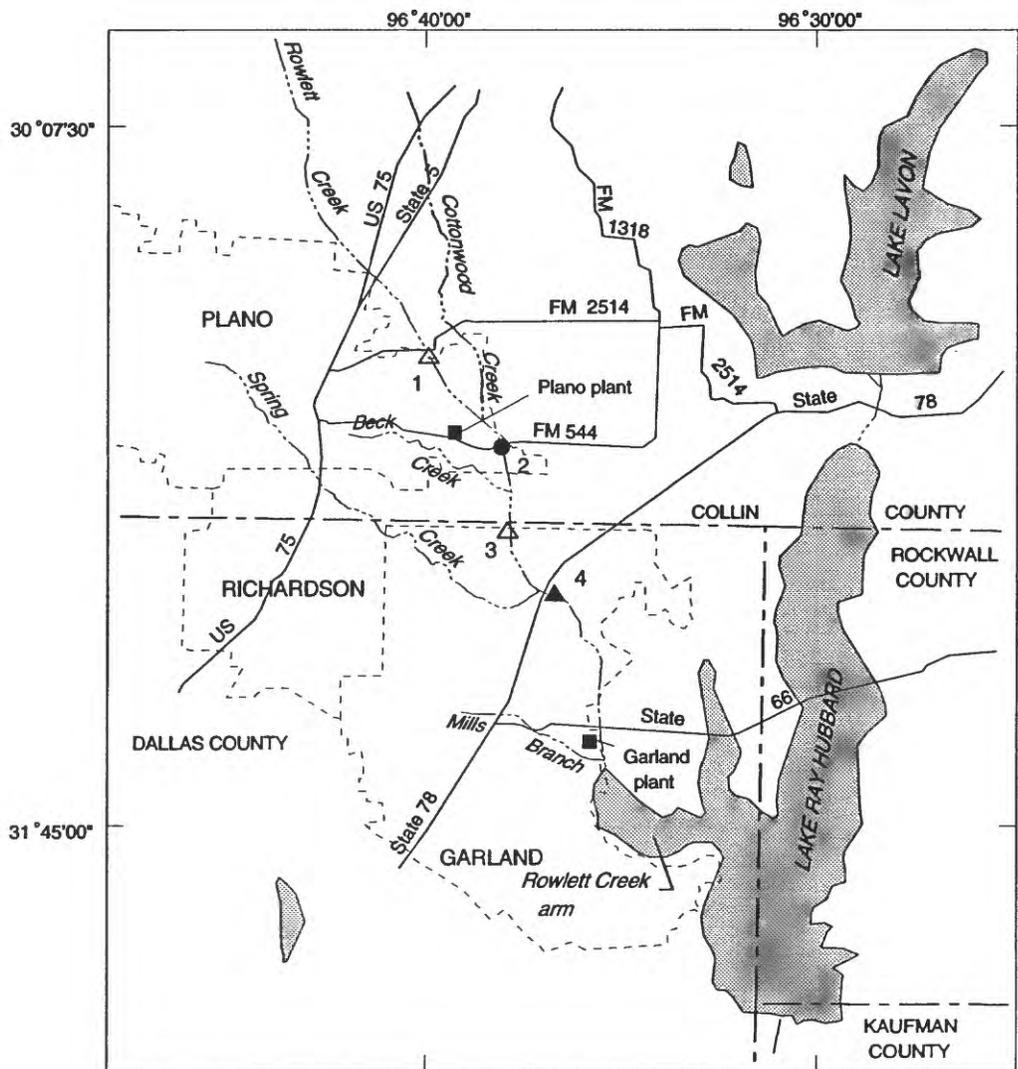
Rowlett Creek is intermittent above the Plano plant outfall (fig. 1) and is perennial below the plant. During the study, discharge in Rowlett Creek was 0.76 m<sup>3</sup>/s above the Plano plant and increased to 1.42 m<sup>3</sup>/s below the plant at its junction with Cottonwood Creek. Some of this increase reflects contributions from Cottonwood Creek. Discharges increased below the confluence of Rowlett Creek with Beck Creek (2.20 m<sup>3</sup>/s) and Spring Creek (2.61 m<sup>3</sup>/s).

About 79,500 m<sup>3</sup>/d of influent is treated at and discharged from the Plano plant into Rowlett Creek (Twidwell, 1985, p. 4). Treatment of the sewage includes screening, clarifying, aerobic bacterial digestion, filtration, and chlorination. Discharge from the plant fluctuates diurnally, and typically is greatest between about 1000 and 1400 hours (fig. 2). During normal flow conditions, time of travel for discharge from the plant to the junction with Spring Creek is 3 to 5 hours.

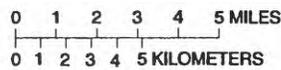
There was no observed precipitation at any of the precipitation gages near the Rowlett Creek drainage area the week before and during sample collection. At 1600 hours on March 9 a storm was inferred upstream from the junction with Spring Creek but below the junction with Beck Creek from a near doubling of discharge in Rowlett Creek downstream from the junction with Spring Creek (fig. 2). Normal flow resumed in Rowlett Creek about 12 hours prior to collection of water and sediment samples, providing ample time for water quality to once again become dominated by effluent.

## METHODS OF INVESTIGATION

During March 9 and 10, 1987, water samples were collected at 4 sites and streambed-sediment samples were collected at 3 sites along Rowlett Creek (fig. 1 and table 1). Site 1 is an upstream control site representing background conditions. Sites 2, 3, and 4 are downstream from the Plano plant discharge. The following discussion describes the methods used for sample collection and chemical analysis.

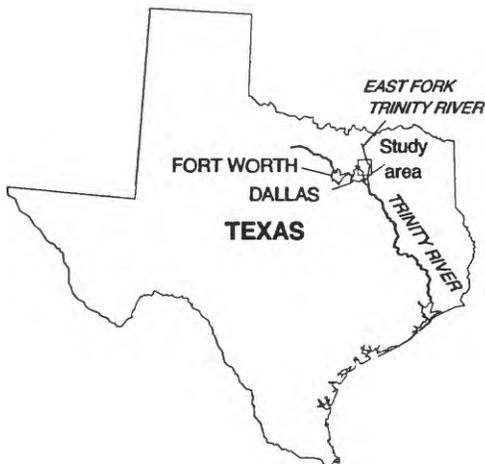


Base modified from Twidwell, 1985



**EXPLANATION**

- 2 ● SITE SAMPLED FOR WATER ANALYSES
- 1 △ SITE SAMPLED FOR WATER AND STREAMBED SEDIMENT ANALYSES
- 4 ▲ SITE WITH CONTINUOUS STREAM DISCHARGE RECORD SAMPLED FOR WATER AND STREAMBED SEDIMENT ANALYSES
- WASTEWATER TREATMENT PLANT



LOCATION MAP

Figure 1. Location of the study area and sampling sites.

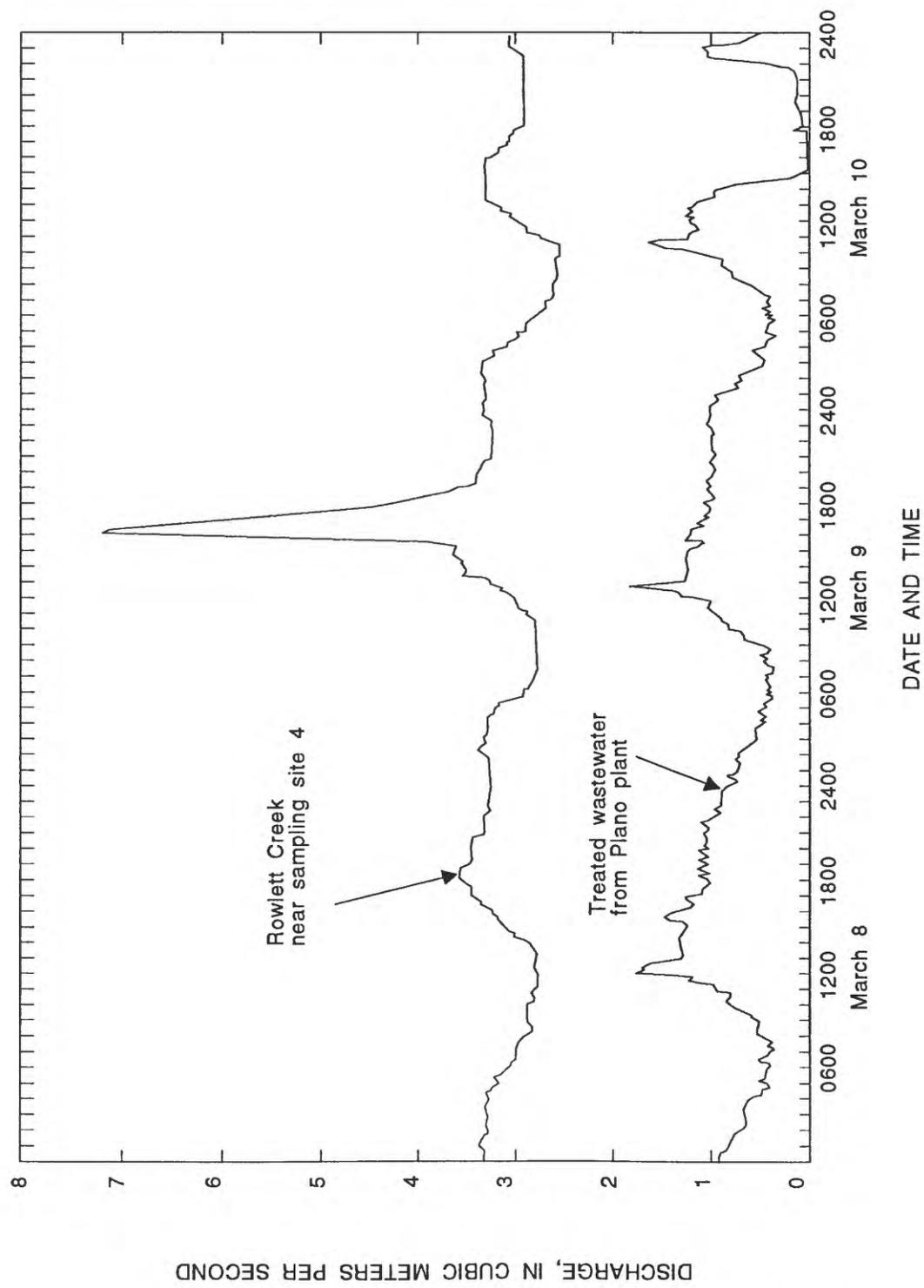


Figure 2. Streamflow at Rowlett Creek near sampling site 4 and treated-wastewater discharge from the Plano plant near Dallas, 1987.

**Table 1.** Description of sampling sites on Rowlett Creek near Plano, Texas

[--, not known]

Sampling site designation <sup>1</sup>	Distance from creek mouth (kilometers)	Creek channel width (meters)	Site location
1	35.0	--	Rowlett Creek at Farm Road 2514 bridge
Plano plant	30.5	5.05	Rowlett Creek at discharge point from the Plano plant
2	27.7	9.68	Rowlett Creek at State Highway 544 bridge
3	22.8	8.57	Rowlett Creek below confluence with Beck Creek
4	17.0	11.9	Rowlett Creek downstream from State Highway 78 bridge

<sup>1</sup> Maximum channel depth reported as 1 meter by Twidwell (1985, p. 19-20).

### Collection of Water and Streambed-Sediment Samples

Water samples for organic compound analyses were collected in amber glass bottles with Teflon-lined screw caps. At sites 1, 2, and 4, depth-integrated samples were collected by submerging the collection bottles and allowing them to fill completely. Because of the shallow depth, site 3 was sampled using a Teflon and stainless-steel equipped submersible pump. All samples were refrigerated until laboratory analysis. Specific conductance, pH, temperature, dissolved oxygen, and alkalinity measurements were made in the field. Water samples for nutrient, organic, and inorganic determinations were collected and preserved according to standard USGS procedures (Wells and others, 1990).

Streambed-sediment samples were collected at sites 1, 3, and 4 from a 0.3 m by 0.9 m sample grid using a stainless-steel dredge. Streambed-sediment samples were not collected at site 2 because of the rocky channel bottom. The sediment samples were composited in the field using a stainless steel bowl and subsampled for grain-size and organic-compound analyses. The subsamples were stored in 1-L wide-mouth glass bottles and preserved by refrigeration at 4 °C.

### Chemical Analyses of Water and Streambed Sediment

Water samples were analyzed for nutrients and boron using methods described by Fishman and Friedman (1985). Total, suspended and dissolved

organic carbon, detergents (as MBAS), and organic compounds (PT method) were determined by methods in Wershaw and others (1987). A 25-mL sample volume was used for the PT method to decrease the method-detection limit. BOD and residual chlorine analyses were made at the water-quality laboratory, USGS Subdistrict office, Fort Worth using methods described in Wells and others (1990, p. 73-77). Grain-size determinations for sediment samples were made at the USGS water-quality laboratory, USGS District office, Austin. All remaining analyses were performed at the National Water-Quality Laboratory, USGS, Arvada, Colorado.

The CLS method of Grob and Zurcher (1976), with some modification (Barber, 1985), was used to analyze water samples. Four-liter water samples were sparged for 2 hours. Organic compounds that were stripped from the water were trapped on a 1.5-mg activated carbon filter, and subsequently eluted with 20 µL of methylene chloride. An internal standard, 1-chlorooctane, was added to the methylene chloride extracts before GC/MS analysis.

Organic compounds were also extracted from a 4-L water sample from each site, using an LLE method described in Wershaw and others (1987). Two types of water samples were used for the extractions: (1) raw water (designated as LLE) and (2) water that was previously used for the CLS (designated as CLS-LLE). Organic compounds were then extracted from water samples using methylene chloride sequentially three times at pH 2 and three times at pH 11. The extracts were then combined and concentrated to a final volume of 1 mL using a Kuderna-Danish apparatus, followed by evaporation under dry nitrogen gas. Six

deuterated-aromatic compounds were added to each extract as internal standards before analysis.

Organic compounds were extracted from stream-bed-sediment samples using a Soxhlet method modified from Pereira and others (1988). Wet-sieved samples consisting of the less than 63- $\mu\text{m}$  grain-size fraction were extracted for 24 hours with methanol and methylene chloride. The resulting extracts were combined, then extracted with 900 mL of 2-percent sodium sulfate solution, and finally dried over anhydrous sodium sulfate. To enhance retention of the organic compounds during extract concentration, 2 mL of isooctane were added to the extracts. The extracts were then concentrated in a Kuderna-Danish apparatus before being evaporated to a volume of 1 mL under a stream of dry nitrogen gas.

Analysis of the CLS method extracts was performed on a Hewlett-Packard 5985 GC/MS system equipped with a capillary column (5-percent phenylmethyl silicone), using a helium carrier gas. The column temperature was 30 °C at injection and was held for 10 minutes, before being increased to 300 °C at a rate of 6 °C per minute, and then held at 300 °C for 5 minutes. Mass spectra were acquired from 45 to 450 atomic mass units at 2 scans per second. Analysis of the LLE, CLS-LLE, and Soxhlet method sediment extracts was performed on a Hewlett-Packard 5995 GC/MS system equipped with a capillary column (5-percent phenylmethyl silicone) and using a helium carrier gas. The column temperature was 50 °C at injection, and was held for 5 minutes, before being increased to 300 °C at a rate of 6 °C per minute, and then held at 300 °C for 9 minutes. Mass spectra were acquired from 50 to 450 atomic mass units at 2 scans per second. One  $\mu\text{L}$  of extract was injected for these analyses at a splitless injector temperature of 275 °C.

Tentative compound identification from GC/MS analyses was based on computer matching of sample-mass spectra with the National Bureau of Standards library. Identification of all compounds extracted by PT and other selected methods, and indicated with a (b) in the data tables, was confirmed by matching the mass spectrum and retention time of the sample with those of authentic standards.

Analyses of samples extracted by PT method were quantified using total ion peak areas relative to an internal standard with a known relative response factor. Concentrations were calculated for samples extracted by CLS, LLE, CLS-LLE, and Soxhlet methods using total ion peak areas relative to internal standards with

an assumed relative response factor of 1. Because of uncertainties in the variability of the relative response factors for compounds tentatively identified from CLS, LLE, CLS-LLE, and Soxhlet method extracts, concentrations determined for samples extracted by PT method are the most reliable values reported from this study.

## Analyses of Data

The IF of selected organic compounds were calculated to determine the effects of dilution by flow from unaffected tributary streams on concentrations of the compounds. IF is calculated using the following equation:

$$\text{IF (mg/s)} = [\text{concentration of compound } (\mu\text{g/L}) \times 0.001 \text{ (mg}/\mu\text{g)}] / [\text{stream discharge (m}^3/\text{s)} \times (\text{L}/\text{m}^3)], \quad (1)$$

where IF is instantaneous flux.

Increases in the IF of a compound along a downstream reach may indicate variation in effluent concentration from the Plano plant or the contribution of additional sources of the compound. Decreases in IF along the downstream reach may be related to decreases in the volume of plant effluent, decreases in the concentration of organic compounds in plant effluent, or to sorption and sedimentation, volatilization, biotransformation, or other physical, chemical, or microbial processes. Differences in IF of a compound among the downstream sites should be interpreted with caution because of the small number of samples and the possible variability of effluent quality and volume discharged from the Plano plant during the study.

The importance of suspended sediment to the transport of selected organic compounds was evaluated by estimating their sorption capacity. This evaluation was made to determine the potential for organic compounds to be transported downstream by suspended sediment into Lake Ray Hubbard. The concentrations of organic compounds in water for this study are presented as the total concentration of dissolved and suspended concentrations of each compound in the water column as shown below:

$$T = D + S, \quad (2)$$

where T is the total concentration of an organic compound, in mg/L;  
 D is the dissolved concentration of an organic compound, in mg/L;  
 and  
 S is the suspended concentration of an organic compound, in mg/L.

The S typically is related to the dissolved concentration, as represented by a modified version of the Freundlich equation (Lyman and others, 1982, p. 4-2):

$$S = ss \times X/m = K \times D^{(1/n)} \times ss, \quad (3)$$

where ss is the concentration of suspended sediment in 1 L of water, in mg/L;  
 X is the mass of an organic compound adsorbed, in micrograms;  
 m is the mass of suspended sediment, in grams;  
 K is the adsorption coefficient; and  
 n is a dimensionless parameter to account for the degree of nonlinearity in the relation between D and X/m.

Values of 1/n were assumed to equal 1.0, implying that the relation between dissolved and sorbed concentrations are linear.

The adsorption coefficient can be related to the organic-carbon adsorption coefficient by the fraction of organic carbon (dimensionless) in the suspended sediment (Lyman and others, 1982, p. 4-1).

$$K_{oc} = \frac{K}{foc}, \quad (4)$$

where  $K_{oc}$  is the organic-carbon adsorption coefficient in  $\mu\text{g adsorbed/g of organic carbon}/\mu\text{g dissolved/mL of solution}$ ; and

foc is fraction of organic carbon.

Sorption of neutrally-charged organic compounds by soils with an foc greater than 0.1 is strongly correlated with the organic-carbon content of these soils (Karickhoff, 1984). Therefore, the sorbing effect of suspended solids that contain organic and inorganic materials also can be represented by a single hypothetical reference sorbent that is 100 percent organic carbon. The suspended organic carbon in the water

column (in mg/L) similarly can be related to the suspended solids concentration:

$$ss = \frac{SOC}{foc}, \quad (5)$$

where SOC is suspended organic carbon, in mg/L.

By substituting equations 4 and 5 into equation 3, the values of S and D can be related to sorption onto the SOC:

$$S = K_{oc} \times D \times SOC, \quad (6)$$

Then by substituting the expression for S in equation 6 into the mass balance expression of equation 2, D can be estimated using laboratory determinations of T, SOC, and ss as presented in the data of this report and determinations of  $K_{oc}$  cited from published scientific literature:

$$D = \frac{T}{[1 + (K_{oc} \times SOC)]}, \quad (7)$$

The values of  $K_{oc}$  used by this study are derived from regression equation relations between the logarithms of the  $K_{oc}$  and the  $K_{ow}$ . The  $K_{ow}$  is an experimental determination of the tendency of a compound to partition into octanol, an organic solvent, or into water. The estimates of dissolved- and suspended-sediment concentrations of organic compounds can be used to evaluate the potential effect that sediment may have on the downstream occurrence of the compounds.

## ORGANIC COMPOUNDS AND RELATED SPECIES IN WATER AND STREAMBED SEDIMENT

### Nutrients, Organic Carbon, and Detergents

Many properties and constituents in water were found in larger values and concentrations at all sampling sites below the Plano plant outfall than above the outfall. These properties and constituents include BOD, all nitrogen species (except for dissolved and total nitrate), all dissolved and total phosphorus species, boron, dissolved and suspended organic carbon, and MBAS. Twidwell (1985) had previously concluded that the tributaries Cottonwood, Beck, and Spring Creeks were not substantial contributors of BOD, nitrogen, and phosphorus species to Rowlett

Creek. Dissolved-oxygen and nitrate concentrations were less at the sampling sites below the Plano plant outfall than at site 1, presumably because of the increased load of organic matter added to the stream in the treated effluent (tables 2 and 3).

Variability in the organic constituent load of treated effluent is indicated by variations in MBAS concentrations downstream from the Plano plant. In this reach of Rowlett Creek, MBAS concentrations were 0.16 mg/L at site 2, 0.59 mg/L at site 3, and 0.13 mg/L at site 4.

## Organic Compounds in Water

Several organic compounds, including halogenated saturated and unsaturated hydrocarbons and chlorinated and nonchlorinated alkylbenzene compounds, were detected in water downstream from the Plano plant discharge by PT method analysis (table 4). Volatile organic compounds that were detected in water in concentrations equal to or greater than 1 µg/L included: chloroform at sites 2, 3, and 4; tetrachloroethene at sites 2 and 4; and trichloroethene at site 4. Sheldon and Hites (1978); Schwarzenbach and Westall (1981); and Jungclaus and others detected compounds below municipal and industrial discharges similar to those identified in Rowlett Creek except for chlorodibromomethane; chloroform, 1,1-dichloroethane, 1,1,1-trichloroethane; and trichlorofluoromethane (table 4). Tom Collins (Dallas Water Utilities, Dallas, Texas, written commun., 1991), identified only dichlorobromomethane and a xylene isomer in a 1987 water sample from Lake Ray Hubbard (table 4). The total amount of organic compounds detected by PT method were 5.5 µg/L at site 2, 3.6 µg/L at site 3, and 13 µg/L at site 4 (table 4), representing less than 0.1 percent of the total organic carbon in water samples from Rowlett Creek (table 2). Organic compounds were not detected at site 1 by PT method.

All of the volatile compounds detected in this study have MCL's set by the USEPA. Concentrations of 1,4-dichlorobenzene, 1,1,1-trichloroethane, trichloroethene, and total trihalomethane compounds (expressed as the sum of chloroform, chlorodibromomethane, and dichlorobromomethane) were less than the MCL set by USEPA for public water systems (U.S. Environmental Protection Agency, 1990). The tetrachloroethene concentration at site 4, however, exceeded 5 µg/L MCL of the USEPA primary drink-

ing-water standards (U.S. Environmental Protection Agency, 1990).

A greater variety of compounds were detected in the samples extracted by CLS method than by PT method. These compounds include chlorinated and alkylated aromatic hydrocarbons; nitrogen, silicon, and oxygen heterocycles; alkyl phenols; chlorinated and unchlorinated aliphatic hydrocarbons; and polycyclic aromatic hydrocarbons (table 5). Most of the compounds identified using CLS method had anthropogenic origins. Compounds detected by CLS method that also have a USEPA-defined MCL include 1,2-dichlorobenzene, 1,4-dichlorobenzene, tetrachloroethene, toluene, trichloroethene, and a xylene isomer. Other dominant compounds detected include the C10-through C14-linear alkylbenzene isomers, octyl phenol, 9-phenyl-9H-carbazole, and 1,2,4-tributylbenzene.

Concentrations of all compounds with an MCL that were identified using the CLS method are all substantially less than the existing or proposed MCL's from the USEPA (U.S. Environmental Protection Agency, 1990). Concentrations of these compounds ranged from 0.01 µg/L of a xylene isomer to 0.55 µg/L of tetrachloroethene, both determined in samples from site 2. The concentration of 9-phenyl-9H-carbazole was the largest in all analyses, ranging from about 0.7 µg/L at site 3 to 1.1 µg/L at site 2. Nearly all other compounds were detected in concentrations ranging from 0.03 µg/L of several organic compounds at sites 2 and 3 to 0.46 µg/L of an unknown styrene compound at site 2 and a C3-alkyl benzene compound at site 4. Many of the compounds were detected in concentrations less than the lower limits of detection of either the PT (0.2 µg/L) or LLE (0.1 µg/L) methods. The total concentration of compounds extracted by CLS method were: 0.03 µg/L at site 1; 5.9 µg/L at site 2; 2.9 µg/L at site 3; and 3.0 µg/L at site 4. The proportion of CLS-method-extractable organic compounds, expressed as a percentage of DOC, is 0.002 percent at site 1 and ranges from 0.05 to 0.1 percent below the Plano plant. Concentrations and the number of organic compounds detected by CLS method were generally greater than those determined by other studies below wastewater discharges (table 5).

The LLE and CLS-LLE methods recovered the largest number of compounds among the methods used for water analysis. Compound types identified using LLE and CLS-LLE methods include saturated and unsaturated aliphatic hydrocarbons, alcohols

**Table 2.** Water-chemistry data for samples collected from Rowlett Creek

[D.M., reported values are diel mean of measurements made on day of sampling; m<sup>3</sup>/s, cubic meters per second; μS/cm, microsiemens per centimeter at 25 °C; °C, degree Celsius; mg/L, milligram per liter; <, less than; --, not detected or constituent not determined; μg/L, micrograms per liter; USGS, U.S. Geological Survey]

Constituent or property	Units	Rowlett Creek sampling sites; date and time collected				
		1	Plano plant <sup>1</sup>	2	3	4
		3/9/87 1500	4/25/84 D.M.	3/9/87 1500	3/9/87 1730	3/10/87 0800
Discharge, instantaneous, stream	m <sup>3</sup> /s	0.76	0.49	1.42	2.17	2.61
Specific conductance field	μS/cm	555	641	620	635	660
pH, field	units	7.8	6.8	7.5	7.5	7.7
Temperature, water <sup>2</sup> , field	°C	16.5	21.0	18.5	18.0	14.5
Dissolved oxygen, field	mg/L	9.9	8.7	8.5	7.5	7.4
Biochemical oxygen demand, 5-day at 20 °C	mg/L	1.0	7.5	8.1	8.6	8.6
Alkalinity, total, field as CaCO <sub>3</sub>	mg/L	217	790	226	218	225
Chlorine, total residue	mg/L	0	4.2	.8	5.2	6.0
Nitrate, total as N	mg/L	3.5	1.5	1.8	1.7	1.7
Nitrate, dissolved as N	mg/L	3.4	--	1.8	1.7	1.7
Nitrite, total as N	mg/L	.01	1.1	.15	.34	.33
Nitrite, dissolved as N	mg/L	<.01	--	.14	.33	.32
Nitrite plus nitrate, total as N	mg/L	3.5	2.7	1.9	2.0	2.0
Nitrite plus nitrate, dissolved as N	mg/L	3.4	--	1.9	2.0	2.0
Nitrogen, ammonia total as N	mg/L	.05	6.3	5.3	5.1	3.8
Nitrogen, ammonia dissolved as N	mg/L	.02	--	5.4	5.3	4.1
Nitrogen, total organic as N	mg/L	1.0	3.0	2.0	3.1	1.1
Nitrogen, dissolved organic as N	mg/L	1.0	--	1.5	2.7	.10
Nitrogen, ammonia + organic, total, 1 determination (N)	mg/L	1.1	9.3	7.3	8.2	4.9
Nitrogen, ammonia + organic, dissolved, 1 determination (N)	mg/L	1.0	--	6.9	8.0	4.2
Nitrogen, dissolved kjeldahl as N	mg/L	4.4	--	8.8	10	6.2
Nitrogen, total as N	mg/L	4.6	12	9.2	10	6.9
Phosphorus, total as P	mg/L	.01	7.4	1.5	2.0	.33
Phosphorus, dissolved as P	mg/L	.01	--	.26	1.7	.22
Phosphorus, total orthophosphate as P	mg/L	<.01	6.9	1.1	1.5	1.1
Phosphorus, dissolved orthophosphate as P	mg/L	<.01	--	1.1	1.1	1.0
Boron, dissolved as B	μg/L	30	--	100	100	90
Carbon, organic total as C	mg/L	1.5	--	11	5.8	9.9
Carbon, organic dissolved as C	mg/L	1.7	13	5.7	5.1	6.2
Carbon, inorganic total as C	mg/L	40	--	42	41	42
Carbon, inorganic dissolved as C	mg/L	39	--	40	39	39
Methylene blue active substances	mg/L	.05	--	.16	.59	.13

<sup>1</sup> Wastewater-treatment plant (Twidwell, 1985). The 1984 data are rounded to two significant figures to enable comparison with USGS data.

<sup>2</sup> Report to nearest 0.5 °C. Negative value to -1.0 °C may be reported.

**Table 3.** Suspended and streambed-sediment data for samples collected in 1987 from Rowlett Creek

[°C, degree Celsius; mg/L, milligrams per liter; --, not detected; N, nitrogen; g/Kg, gram per kilogram; C, carbon]

Constituent or property name	Units	Sampling sites			
		1	2	3	4
Dissolved solids, residue at 105 °C	mg/L	9	23	9	37
Suspended solids passing a 0.062-millimeter mesh sieve	percent	86	85	86	69
Streambed sediment passing a 0.062-micrometer mesh sieve	percent	1	--	1	1
Nitrogen, ammonia + organic, dissolved, 1 determination (N)	mg/L	--	.4	.2	.7
Carbon, organic bottom material as C	g/Kg	100	--	75	100
Carbon, organic suspended as C	mg/L	.04	4.0	2.0	2.1

(primarily fatty acids), alkynes, monocyclic aromatic hydrocarbons, and chlorinated and unchlorinated nitrogen and sulfur heterocycles. No compounds with an MCL set by the USEPA were detected in water using LLE and CLS-LLE methods. Simazine, an herbicide, was found below the confluence of Rowlett and Spring Creeks (site 4) in a concentration of 0.1 µg/L (table 6). Compounds detected in concentrations greater than 1 µg/L using LLE or CLS-LLE methods included caffeine at sites 2, 3, and 4, and cholestanol and 3.beta-coprostanol at site 2. The latter two compounds are common in human fecal waste (Davis and Bastian, 1988). Most of the compounds determined from the LLE method extracts were not found in the wastewater effluents from other studies cited in table 6. The total concentration of compounds recovered by the LLE method decreased from 15.6 µg/L at site 2 to 5.2 µg/L at site 4.

Compounds recovered using the PT method were the most volatile and lightest in molecular weight among all the compounds identified by the three methods. The CLS method recovered organic compounds that were generally less volatile and had greater molecular weights than those extracted by the PT method. For example, tetrachloroethene and trichloroethene were detected in larger concentrations by the PT method than by the CLS method. Larger and less volatile organic compounds such as the dichlorobenzene isomers, C10- through C14-linear alkylbenzene isomers, and octyl and nonyl phenols either were not detected or were found at fewer sites by the PT method than by the CLS method. Inclusion of all methods, however, provided more detections of organic compounds in surface water downstream from the Plano plant effluent discharge than any one or two of the methods alone.

### Organic Compounds in Streambed Sediment

Most of the organic compounds tentatively identified in streambed-sediment extracts upstream and downstream from the Plano plant effluent discharge were methyl esters of aliphatic acids (table 7). The total concentrations of the aliphatic-acid esters were greater at sites 3 and 4 than at site 1. Compounds extracted from streambed sediment whose concentrations are regulated by the USEPA in public drinking water supplies include dimethyl ester (dimethyl phthalate) at sites 3 and 4; a xylene isomer; and several polynuclear aromatic compounds including chrysene, fluoranthene, and pyrene at site 4. Concentrations of these compounds in streambed sediment from site 4 ranged from 0.8 µg/100 g OC of fluoranthene to 4.4 µg/100 g OC for the xylene isomer.

### SOURCES AND DOWNSTREAM PERSISTENCE OF SELECTED ORGANIC COMPOUNDS

Several commonly detected compounds were selected to evaluate the relative persistence of wastewater-related organic compounds in Rowlett Creek. Chloroform, dichlorobromomethane, and dibromochloromethane are produced by the chlorination of naturally occurring and synthetic organic compounds in wastewater-treatment plants (Callahan and others, 1979). Trichloroethene and tetrachloroethene are used as degreasing solvents (Smith and others, 1987). Dichlorobenzene isomers (1,2 and 1,4) are components of toilet-bowl cleaners and other household and industrial products (Smith and others, 1987). Toluene and xylene are used as solvents, octane boosters in gasoline, and in the manufacture of petroleum-derived products (Smith and others, 1987). The C10- through

**Table 4.** Concentrations of organic compounds extracted from water samples from Rowlett Creek by purge-and-trap extraction method and analyzed by gas chromatography/mass spectrometry

[All compound identities were confirmed by matching sample mass spectra and retention indices with those of authentic standards. µg/L, microgram per liter; (a), selected anthropogenic organic compound; --, not detected; D, detected but not quantified; <, less than 0.2]

Compound	Concentrations from Rowlett Creek sampling sites, March 1987 (µg/L)				Concentration ranges determined in other studies (µg/L)			
	1	2	3	4	Delaware River below municipal wastewater discharge <sup>1</sup>	River Glatt below municipal wastewater discharges, Switzerland <sup>2</sup>	River below industrial wastewater discharge <sup>3</sup>	Lake Ray Hubbard at dam July, 1987 <sup>4</sup>
Chlorodibromomethane (a)	--	0.3	0.1	0.3	--	--	--	--
Chloroform (a)	--	2.2	1.9	3.8	D	--	--	--
1,4-dichlorobenzene (a)	--	<.2	--	.2	D	0.25	D	--
Dichlorobromomethane (a)	--	.6	.2	.7	--	--	--	0.38
1,1-dichloroethane	--	<.2	<.2	--	--	--	--	--
Tetrachloroethene (a)	--	1.7	.5	6.0	D	.6	D	--
Toluene (a)	--	.3	.4	.3	D	--	D	--
1,1,1-trichloroethane	--	<.2	--	.3	--	--	--	--
Trichloroethene (a)	--	.4	.3	1.0	D	.07	D	--
Trichlorofluoromethane	--	--	.2	.4	--	--	--	--
Total trihalomethane compounds <sup>5</sup>	--	3.1	2.2	4.8	--	--	--	.38
Xylene isomers (a)	--	--	--	<.2	D to 17	.25	D	1.1

<sup>1</sup> From Sheldon and Hites (1978).

<sup>2</sup> From Schwarzenbach and Westall (1981).

<sup>3</sup> From Jungclaus and others (1978).

<sup>4</sup> From Tom Collins (Dallas Water Utilities, Dallas, Texas, written commun., 1991).

<sup>5</sup> Sum of chlorodibromomethane, chloroform, and dichlorobromomethane concentrations.

C14-linear alkylbenzene isomers typically are residues from the use of commercial detergents that contain linear alkylbenzenesulfonate surfactants (Eganhouse and others, 1983). The source of 1,2,4-tributyl benzene in the Plano plant effluent is unknown. Presence of tetramethylbutyl-phenol in the effluent may be related to the aerobic biodegradation of alkylphenol-polyethoxylate, non-ionic surfactants or its use as an antioxidant (Barber and others, 1988). Octyl phenol commonly is associated with phenolic surfactant and antioxidant use. The compound 9-phenyl-9H-carbazole is a residue from coal combustion and is found in coal tars. Caffeine is a naturally occurring compound in coffee and tea and is added to many beverages.

The IF values of volatile organic compounds and of caffeine indicate that the effluent volume or quality from the Plano plant is variable. The IF values

of organic compounds, including chlorodibromomethane, chloroform, dichlorobromomethane, tetrachloroethene, toluene, trichloroethane, and caffeine, were about two or more times greater at site 4 than the values determined from site 1 (table 8). Downstream differences in the IF of volatile organic compounds between sites 3 and 4 may be caused by unknown compound contributions from Spring Creek. In-stream creation of the trihalomethane compounds chlorodibromomethane, chloroform, and dichlorobromomethane also is a possible explanation for some of the changes. This latter hypothesis is supported by downstream increases in concentrations of residual chlorine from 0.8 mg/L at site 2 to 6.0 mg/L at site 4 (table 2). By comparison, chlorination of water from the Rowlett Creek arm of Lake Ray Hubbard with 10 mg/L of free chlorine produced about 20 µg/L of

**Table 5.** Concentrations of organic compounds extracted from water samples from Rowlett Creek by closed-loop stripping method and analyzed by gas chromatography/mass spectrometry

[ $\mu\text{g/L}$ , microgram per liter; C3, number of carbon atoms per alkyl chain; --, not detected; D, detected but not quantified; (a), selected anthropogenic organic compound; (b), indicates compound identity confirmed by matching sample mass spectra and retention time with that of an authentic standard; c, compound not identified in sample]

Compound	Concentrations from Rowlett Creek sampling sites, March 1987 ( $\mu\text{g/L}$ )					Concentration ranges determined in other studies ( $\mu\text{g/L}$ )		
	1	2	3	3 (Duplicate)	4	Delaware River below municipal waste- water discharge <sup>1</sup>	River Glatt below municipal wastewater discharges, Switzerland <sup>2</sup>	River below industrial waste- water discharge <sup>3</sup>
C3 alkylbenzene compounds	--	--	--	--	0.46	D to 4	D	D
1,2 dichlorobenzene (a)(b)	--	0.28	0.14	0.11	.13	D	--	D
1,4 dichlorobenzene (a)(b)	--	.32	.19	.14	.16	D	0.25	D
Dimethyl trisulfide	--	.09	--	--	--	--	--	--
Di-tert-butyl-p-benzoquinone (b)	--	.05	--	--	--	--	--	1 to 11
C10 linear alkylbenzene isomers (a)	--	.07	.03	.03	.04	--	--	--
C11 linear alkylbenzene isomers (a)	--	.27	.12	.12	.06	--	--	--
C12 linear alkylbenzene isomers (a)	--	.22	.14	.09	.05	--	--	--
C13 linear alkylbenzene isomers (a)	--	.27	.14	.14	.09	--	--	--
C14 linear alkylbenzene isomers (a)	--	.04	--	.03	--	--	--	--
Total of C10-C14 linear alkylbenzene isomers	--	.87	.43	.41	.24	--	--	--
Nonyl phenol isomers (b)	--	.07	--	.05	.05	0.04 to 2	--	--
Octyl phenol	--	.42	.27	.23	.25	.4 to 2	--	--
Octamethyl-cyclotetrasiloxane (a)	--	.15	.04	.03	.04	--	--	--
9-phenyl-9H-carbazole (a)	--	1.1	.70	.74	.76	--	--	--
unknown alkane compounds	--	.41	.13	.07	--	c	c	c
unknown aromatic compound	--	.27	--	.03	--	c	c	c
unknown fluoromethoxy benzene isomer	--	.10	--	.06	.07	c	c	c
unknown naphthalene compounds	--	.21	.03	.03	.04	c	c	c
unknown oxirane compound	--	--	.09	.08	--	c	c	c
unknown propanoic acid compound	--	.05	--	.05	.06	c	c	c
unknown styrene compound	--	.46	.25	.23	.22	c	c	c
Tetrachloroethene (a)(b)	--	.55	.23	.19	.25	D	.6	D
Tetramethylbutyl phenol (a)	--	.09	.08	.05	.04	D to 2	--	--
Toluene (a)(b)	0.02	.15	.26	.14	--	D	D	D
1,2,4-tributyl-benzene (a)	--	.25	.17	.16	.14	--	--	--
Trichloroethene (b)	--	.03	--	--	--	D	D	--
Xylene isomer (a)	.01	--	--	.01	.12	D to 17	.25	D

<sup>1</sup> From Sheldon and Hites (1978).

<sup>2</sup> From Schwarzenbach and Westall (1981).

<sup>3</sup> From Jungclaus and others (1978).

**Table 6.** Concentrations of organic compounds extracted from water samples from Rowlett Creek by liquid-liquid extraction method and sequential application of closed-loop stripping and liquid-liquid extraction methods, and analyzed by gas chromatography/mass spectrometry

[ $\mu\text{g/L}$ , microgram per liter; LLE, liquid-liquid extraction method; CLS-LLE, sequential application of closed-loop stripping and liquid-liquid extraction methods performed on water sample previously extracted by closed-loop stripping; --, not detected; C3, number of carbon atoms per alkyl chain; D, detected but not quantified; (a) selected anthropogenic organic compound; c, compound not identified in sample]

Compound	Concentrations from Rowlett Creek sampling sites, March 1987; extraction method ( $\mu\text{g/L}$ )							Concentrations determined in other studies ( $\mu\text{g/L}$ )		
	1 (LLE and CLS-LLE)	2 (CLS-LLE)	2 (LLE)	3 (CLS-LLE)	3 (CLS-LLE) (Duplicate)	4 (CLS-LLE)	4 (LLE)	Delaware River below municipal wastewater discharge <sup>1</sup>	River Glatt below municipal wastewater discharge, Switzerland <sup>2</sup>	River below industrial wastewater discharge <sup>3</sup>
Acetylbenzene	--	0.1	--	--	--	--	--	--	--	--
C3 alkylbenzene	--	--	--	0.1	--	--	--	D to 4	D	D
C4 alkylbenzene	--	--	--	--	--	--	0.1	D	D	D
Benzeneethanol	--	--	--	.1	0.1	--	--	--	--	--
Benzothiazole	--	.1	0.2	.2	.2	0.1	--	--	--	D
Caffeine (a)	--	1.3	2.1	2.4	2.4	1.7	3.2	D	--	--
5-chloro-1H-benzotriazole	--	.2	.3	--	--	--	.1	--	--	--
6-chloro-N,N'-diethyl-1,2,5-triazine-2,4-diamine (Simazine)	--	--	--	--	--	.1	.1	--	--	--
Chlorotoluene	--	.1	.5	--	--	--	--	D to 3	D	D
Cholesterol	--	--	2.7	--	--	--	--	1 to 9	--	--
3.beta-coprostanol	--	--	2.4	--	--	--	--	--	--	--
Dichlorobenzotriazole	--	--	.4	--	--	--	--	--	--	--
Dimethyl disulfide	--	--	.8	--	--	--	--	--	--	--
Dimethyl trisulfide	--	.1	--	--	--	--	--	--	--	--
Diphenyl methanone	--	--	--	.1	--	--	--	--	--	--
Dipropylene glycol isomer	--	--	--	.2	.3	--	--	--	--	--
C3 furandione isomer	--	.1	--	--	--	--	--	--	--	--
C11 linear alkylbenzene isomer (a)	--	--	.2	--	--	--	--	--	--	--
C12 linear alkylbenzene isomers (a)	--	.7	.8	--	.1	--	.2	--	--	--
C13 linear alkylbenzene isomers (a)	--	.6	.8	.1	--	--	.3	--	--	--
Total of C10-C14 linear alkylbenzene isomers	--	1.3	1.8	.1	.1	--	.5	--	--	--
1-(methylphenyl)-ethanone	--	--	--	--	--	--	.1	--	--	--
2-(methylthio)-benzothiazole	--	.2	.3	.1	.1	.5	.5	--	--	--

Footnotes at end of table.

**Table 6.** Concentrations of organic compounds extracted from water samples from Rowlett Creek by liquid-liquid extraction method and sequential application of closed-loop stripping and liquid-liquid extraction methods, and analyzed by gas chromatography/mass spectrometry--Continued

Compound	Concentrations from Rowlett Creek sampling sites, March 1987; extraction method (µg/L)							Concentrations determined in other studies (µg/L)		
	1 (LLE and CLS-LLE)	2 (CLS-LLE)	2 (LLE)	3 (CLS-LLE)	3 (CLS-LLE) (Duplicate)	4 (CLS-LLE)	4 (LLE)	Delaware River below municipal wastewater discharge <sup>1</sup>	River Glatt below municipal wastewater discharge, Switzerland <sup>2</sup>	River below industrial wastewater discharge <sup>3</sup>
Morpholine	--	--	0.2	--	--	--	0.1	--	--	--
Octyl phenol isomer	--	--	--	0.1	--	--	--	D to 2	--	--
1-propanol isomer	--	0.2	.2	.2	0.2	--	--	--	--	--
p-tert-butyl-phenol isomers	--	--	.3	--	--	--	.3	--	--	3
unknown alkane compounds	--	5.7	2.4	.3	--	--	.2	c	c	c
unknown aliphatic acid compounds	--	2.5	1.0	--	--	--	--	c	c	c
unknown cycloalkane compound	--	.1	--	--	--	--	--	c	c	c

<sup>1</sup> From Sheldon and Hites (1978).

<sup>2</sup> From Schwarzenbach and Westall (1981).

<sup>3</sup> From Jungclaus and others (1978).

chloroform (Kenneth J. DelRegno, Dallas Water Utilities, Dallas, Texas, written commun., 1987).

Losses of volatile organic compounds from surface water take place primarily by volatilization to the atmosphere (Smith and others, 1988). The smaller IF values of volatile organic compounds at site 3 relative to site 2 may reflect either changes in effluent concentration or volatilization of these compounds (table 8). Sorption of volatile organic compounds onto suspended sediment was estimated to account for less than 0.1 percent of their total concentration in the water column at site 4 (table 9). These estimates indicate that sorptive removal of the volatile organic compounds is small and does not limit their transport by streamflow.

Little difference in IF was apparent among sites 2, 3 and 4 for all the selected semivolatile organic compounds (table 8). Sorption of the semivolatile organic compounds onto suspended sediment was estimated to account for between 0.3 and 1.8 percent of their total concentration in the water column at site 4 (table 9). These data indicate that the effluent concentrations of these compounds did not change appreciably during

the period of sampling and that they were not removed from solution by physical, chemical, or biological processes.

Among the semivolatile organic compounds only the C11- and C12-linear alkylbenzene isomers had IF values that were appreciably less at site 4 than at site 2 (table 8). These compounds are sparingly soluble in water and may be removed from the water column (1) by sorption onto suspended sediment and subsequent sedimentation and (2) by biodegradation (Verschueren, 1983; Bayona and others, 1986). The estimated proportion of a C12-linear alkylbenzene compound that was sorbed onto suspended sediment at site 4, was 0.5 percent (table 9). The concentration of C12-linear alkylbenzene in the water column therefore is not affected substantially by sorption and sedimentation along the sampled reach of Rowlett Creek. The smaller IF values of C11- and C12-linear alkylbenzenes downstream from site 2 (table 8) indicate that selective biodegradation of the linear alkylbenzene compounds probably is occurring in the water column.

**Table 7.** Concentrations of organic compounds extracted from streambed-sediment samples from Rowlett Creek

[Concentrations are in micrograms per 100 grams of organic carbon. --, not detected; (a), selected organic compound; (b), compound identity confirmed by matching sample mass spectra and retention index with that of an authentic standard; C12, number of carbon atoms per alkyl chain]

Compound	Rowlett Creek site number		
	1	3	4
Benzaldehyde	0.3	0.5	--
1,2-benzenedicarboxylic acid, dimethyl ester (dimethyl phthalate)	--	.7	0.7
Caffeine (a)	--	1.2	--
Chloroisocyanato benzene	--	--	.7
Chrysene	--	--	2.2
Dimethyl ester, sulfurous acid	4.5	33	7.4
N-(1,1-dimethylethyl)-formamide	--	1.2	--
Fluoranthene (b)	--	--	.8
C12 linear alkylbenzene isomer	--	.8	--
Pyrene (b)	--	--	1.0
n-Undecene, n-methyl	.6	--	--
unknown alkane	.6	--	--
unknown aliphatic acid ester compounds	105	291	254
xylene isomers (a)	--	.8	4.4

A possible contribution of organic compounds from Spring Creek or an early-morning increase in effluent concentrations is indicated by the detections of toluene, xylene isomers and alkylbenzene compounds in water samples. For instance, toluene was detected in water from all sites below the Plano plant discharge (table 4). Detectable concentrations of xylene, however, were only observed at sites 3 and 4 and not at site 2 (table 5). C3-alkylbenzene compounds were only detected in water from site 4 (table 5).

Bed sediment was not an important sink for any of the selected compounds determined in the water analyses. The concentration of xylene isomers on sediment was less at site 3 than at site 4 (table 7), and the proportion of xylene isomers in water to xylene on sediment was greater at site 4 than at site 3 (table 8). This may indicate that the xylene in bed sediments at sites 3 and 4 is not in equilibrium with the xylene concentrations in water. The lack of sorbed anthropogenic organic compounds on bed sediments may relate to their relative lack of abundance in wastewater with respect to other compounds, the extraction efficiency of

the method used, and their affinity for the organic matter in suspended sediments.

It was not determined whether any of the organic compounds in the water column were transported downstream into Lake Ray Hubbard. Of the selected organic compounds, caffeine is the most likely to persist in the water column because of its great solubility and negligible volatility (Verschueren, 1983). Losses of volatile organic compounds by volatilization to the atmosphere are likely because of their elevated vapor pressures in water (Smith and others, 1988). Select semivolatile organic compounds may also persist in the water column because of their lesser volatility and lack of affinity for suspended sediment. Biotransformation of the C10- through C14-linear alkylbenzene isomers may result in further concentration decreases downstream from site 4. Despite the potential for volatilization and biodegradation in the sampled reach, quantifiable amounts of the organic compounds were determined at all three sites downstream from the Plano plant. Therefore, a measurable amount of these compounds may be transported into Lake Ray Hubbard.

**Table 8.** Summary of instantaneous fluxes of selected organic compounds in water, Rowlett Creek, sites 2, 3, and 4

[m<sup>3</sup>/s, cubic meter per second; mg/s, milligram per second; \*, duplicate purge-and-trap sample not analyzed; C10, number of carbon atoms per alkyl chain; --, compound not detected in sample; µg/L, microgram per liter; mg/µg, milligram per microgram; L/m<sup>3</sup>, liters per cubic meter]

Compound	Sampling site			
	2	3	3 (Duplicate)	4
Stream discharge at site (m <sup>3</sup> /s)	1.42	2.14	2.14	21.95
Instantaneous fluxes <sup>1</sup> (mg/s)				
<u>Volatile-organic compounds, purge-and-trap extraction method:</u>				
Chlorodibromomethane	1.9	.96	*	4.0
Chloroform	14	18	*	50
Dichlorobromomethane	3.8	1.9	*	9.3
Tetrachloroethene	11	4.8	*	79
Toluene	1.9	3.8	*	4.0
Trichloroethene	2.6	2.9	*	13
<u>Semivolatile-organic compounds, closed-loop stripping extraction method:</u>				
1,2-dichlorobenzene	1.8	1.3	1.1	1.7
1,4-dichlorobenzene	2.0	1.8	1.3	2.1
C10 linear alkylbenzene isomers	.45	.29	.29	.53
C11 linear alkylbenzene isomers	1.7	1.2	1.2	.79
C12 linear alkylbenzene isomers	1.4	1.3	.86	.66
C13 linear alkylbenzene isomers	1.7	1.3	1.3	1.2
C14 linear alkylbenzene isomers	.26	--	.29	--
Total of C10-C14 linear alkylbenzene isomers	5.5	4.1	3.9	3.2
Octyl phenol	2.7	2.6	2.2	3.3
9-phenyl-9H-carbazole isomer	1.6	1.6	1.5	1.9
Tetrachloroethene	3.5	2.2	1.8	3.3
Tetramethylbutyl-phenol	.57	.77	.48	.53
Toluene	.96	2.5	1.3	--
1,2,4-tributyl-benzene	6.8	6.7	7.1	10
Xylene isomers	--	--	.10	1.6
<u>Nonvolatile-organic compound, liquid-liquid extraction method:</u>				
Caffeine	13	23	23	42

<sup>1</sup> Instantaneous fluxes (IF) are computed using the following formula:

$$IF \text{ (mg/s)} = \text{concentration (}\mu\text{g/L)} \times 0.001 \text{ (mg/}\mu\text{g)} \times \text{discharge (m}^3\text{/s)} \times 1,000 \text{ (L/m}^3\text{)}.$$

**Table 9.** Estimated proportions of selected organic compounds dissolved in water and sorbed onto suspended sediment, Rowlett Creek, site 4

[µg/L, micrograms per liter; g-OC/L, grams of organic carbon per liter of solution; C12, twelve carbon atoms per alkyl chain of compound]

Compound	Total concentration in water sample (µg/L)	Log octanol-water-partition coefficient <sup>1</sup> (dimensionless)	Log organic carbon-water-partition coefficient <sup>1</sup> (g-OC/L)	Concentration of organic compound, percentage of total	
				Dissolved in water	Sorbed onto suspended sediment
<u>Volatile-organic compounds, purge-and-trap extraction method:</u>					
Chloroform	3.8	<sup>2</sup> 1.97	<sup>3</sup> 1.88	99.98	0.02
1,2-Dichlorobenzene	.13	<sup>2</sup> 3.38	<sup>4</sup> 2.92	99.8	.2
1,4-Dichlorobenzene	.14	<sup>2</sup> 3.39	<sup>4</sup> 2.93	99.8	.2
Tetrachloroethene	6.0	<sup>2</sup> 2.88	<sup>3</sup> 2.71	99.9	.1
Toluene	.30	<sup>2</sup> 2.69	<sup>4</sup> 2.43	99.94	.06
Trichloroethene	1.0	<sup>2</sup> 2.29	<sup>3</sup> 2.17	99.97	.03
Xylene, o, m, and p isomers	.12	<sup>5</sup> 2.77	<sup>4</sup> 2.48	99.94	.06
<u>Semivolatile-organic compounds, closed-loop stripping extraction method:</u>					
C12 linear alkylbenzene isomers	.05	<sup>6</sup> 3.67	<sup>7</sup> 3.37	99.5	.5
Octyl phenol	.25	<sup>8</sup> 4.70	<sup>7</sup> 3.93	98.2	1.8
Tetramethylbutyl-phenol	.76	<sup>6</sup> 3.29	<sup>7</sup> 3.17	99.7	.3
9-Phenyl-9H-carbazole	.04	<sup>9</sup> 3.31	<sup>7</sup> 3.18	99.7	.3
1,2,4-Tributyl-benzene	.14	<sup>9</sup> 4.11	<sup>7</sup> 3.61	99.2	.8
<u>Nonvolatile-organic compound, liquid-liquid extraction method:</u>					
Caffeine	3.2	<sup>9</sup> 0.07	<sup>3</sup> 0.02	100	0

<sup>1</sup> An organic-carbon-absorption coefficient (log K<sub>oc</sub>) is estimated from an octanol-water-partition coefficient according to the following relation:

$$\log K_{oc} = a \times \log K_{ow} + b$$

where K<sub>oc</sub> is organic-carbon-absorption coefficient; a and b are constants;

and K<sub>ow</sub> is the octanol-water-partition coefficient (dimensionless).

The regression equations used to derive log K<sub>oc</sub> values are shown and referenced in footnotes 3, 4, and 5.

<sup>2</sup> From Callahan and others (1979).

<sup>3</sup> From Hassett and others (1983) (log K<sub>oc</sub> = 0.909 x log K<sub>ow</sub> + 0.088).

<sup>4</sup> From Schwarzenbach and Westall (1981) (log K<sub>oc</sub> = 0.72 log K<sub>ow</sub> + 0.49).

<sup>5</sup> From Smith and others (1987).

<sup>6</sup> From Leo and others (1971).

<sup>7</sup> From Kenaga and Goring (1980) (log K<sub>oc</sub> = 0.544 log K<sub>ow</sub> + 1.377).

<sup>8</sup> From Barber and others (1988).

<sup>9</sup> From Verschuere (1983) (for 1,2,4-tributyl-benzene, the octanol-water-partition coefficient for tert-butyl benzene was applied).

## SUMMARY AND CONCLUSIONS

During March 9 and 10, 1987, organic compounds attributed to treated-wastewater effluent from the Plano wastewater-treatment plant were measured in Rowlett Creek as far as 13.5 km downstream from the outfall. Anthropogenic compounds detected in downstream water samples include: (1) 1,2-dichlorobenzene, 1,4-dichlorobenzene, tetrachloroethene, 1,1,1-trichloroethane, trichloroethene, and several trihalomethane compounds, toluene, and xylene; (2) several C10- through C14-linear alkylbenzene isomers, octyl phenol, and an isomer of tetramethylbutyl phenol that was related to detergent use; (3) 9-phenyl-9H-carbazole, related to coal-combustion residues and coal tars; and (4) caffeine. Of the organic compounds detected in water from Rowlett Creek, only tetrachloroethane exceeded the USEPA MCL for public-drinking-water supplies. Xylene isomers were detected in streambed sediments sampled at two sites on the creek below the discharge. The polynuclear-aromatic compounds chrysene, fluoranthene, and pyrene and the pesticide simazine were detected in streambed sediments sampled immediately below the confluence of Rowlett and Spring Creeks. Consequently, flow from Spring Creek also may be a source of contaminants to Rowlett Creek.

Comparison of instantaneous-flux values of selected organic compounds in water samples collected at sites downstream from the plant indicates: (1) the formation of chloroform instream following discharge of the treated effluent and that (2) in-stream biodegradation may be decreasing concentrations of linear alkylbenzene compounds from stream water. The relative persistence of the selected organic compounds in the stream reach downstream from the Plano wastewater-treatment plant indicates that measurable amounts of many of these contaminants could be transported into Lake Ray Hubbard, a source of municipal water supply.

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