

U.S. Department of the Interior
U.S. Geological Survey

A Review of Semivolatile and Volatile Organic Compounds in Highway Runoff and Urban Stormwater

Open-File Report 98-409

A Contribution to the
National Highway Runoff Data and Methodology Synthesis



U.S. Department
of Transportation



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By THOMAS J. LOPES and SHANNON G. DIONNE

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U.S. DEPARTMENT OF THE INTERIOR
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PREFACE

Knowledge of the characteristics of highway runoff (concentrations and loads of constituents and the physical and chemical processes which produce this runoff) is important for decision makers, planners, and highway engineers to assess and mitigate possible adverse-impacts of highway runoff on the Nation's receiving waters. In October, 1996, the Federal Highway Administration and the U.S. Geological Survey began the National Highway Runoff Data and Methodology Synthesis to provide a catalog of the pertinent information available; to define the necessary documentation to determine if data are valid (useful for intended purposes), current, and technically supportable; and to evaluate available sources in terms of current and foreseeable information needs. This paper is one contribution to the National Highway Runoff Data and Methodology Synthesis and is being made available as a U.S. Geological Survey Open-File Report pending its inclusion in a volume or series to be published by the Federal Highway Administration. More information about this project is available on the World Wide Web at <http://mass1.er.usgs.gov/fhwa/runwater.htm>

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SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

APPROXIMATE CONVERSIONS FROM SI UNITS

| Symbol | When You Know | Multiply By | To Find | Symbol | When You Know | Multiply By | To Find | Symbol |
|--|----------------------------|-------------------------|-----------------------------|-------------------|-----------------------------|-------------|----------------------------|---------------------|
| LENGTH | | | | | | | | |
| in | inches | 25.4 | millimeters | mm | millimeters | 0.039 | inches | in |
| ft | feet | 0.305 | meters | m | meters | 3.28 | feet | ft |
| yd | yards | 0.914 | meters | m | meters | 1.09 | yards | yd |
| mi | miles | 1.61 | kilometers | km | kilometers | 0.621 | miles | mi |
| AREA | | | | | | | | |
| in ² | square inches | 645.2 | square millimeters | mm ² | square millimeters | 0.0016 | square inches | in ² |
| ft ² | square feet | 0.093 | square meters | m ² | square meters | 10.764 | square feet | ft ² |
| yd ² | square yards | 0.836 | square meters | m ² | square meters | 1.195 | square yards | yd ² |
| ac | acres | 0.405 | hectares | ha | hectares | 2.47 | acres | ac |
| mi ² | square miles | 2.59 | square kilometers | km ² | square kilometers | 0.386 | square miles | mi ² |
| VOLUME | | | | | | | | |
| fl oz | fluid ounces | 29.57 | milliliters | mL | milliliters | 0.034 | fluid ounces | fl oz |
| gal | gallons | 3.785 | liters | L | liters | 0.264 | gallons | gal |
| ft ³ | cubic feet | 0.028 | cubic meters | m ³ | cubic meters | 35.71 | cubic feet | ft ³ |
| yd ³ | cubic yards | 0.765 | cubic meters | m ³ | cubic meters | 1.307 | cubic yards | yd ³ |
| NOTE: Volumes greater than 1000 L shall be shown in m ³ . | | | | | | | | |
| MASS | | | | | | | | |
| oz | ounces | 28.35 | grams | g | grams | 0.035 | ounces | oz |
| lb | pounds | 0.454 | kilograms | kg | kilograms | 2.202 | pounds | lb |
| T | short tons (2000 lb) | 0.907 | megagrams (or "metric ton") | Mg (or "t") | megagrams (or "metric ton") | 1.103 | short tons (2000 lb) | T |
| TEMPERATURE (exact) | | | | | | | | |
| °F | Fahrenheit temperature | 5(F-32)/9 or (F-32)/1.8 | Celsius temperature | °C | Celsius temperature | 1.8C + 32 | Fahrenheit temperature | °F |
| ILLUMINATION | | | | | | | | |
| fc | foot-candles | 10.76 | lux | lx | lux | 0.0929 | foot-candles | fc |
| fl | foot-Lamberts | 3.426 | candela/m ² | cd/m ² | candela/m ² | 0.2919 | foot-Lamberts | fl |
| FORCE and PRESSURE or STRESS | | | | | | | | |
| lbf | poundforce | 4.45 | newtons | N | newtons | 0.225 | poundforce | lbf |
| lbf/in ² | poundforce per square inch | 6.89 | kilopascals | kPa | kilopascals | 0.145 | poundforce per square inch | lbf/in ² |

* SI is the symbol for the International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380.

A Review of Semivolatile and Volatile Organic Compounds in Highway Runoff and Urban Stormwater

By Thomas J. Lopes *and* Shannon G. Dionne

Abstract

Many studies have been conducted since 1970 to characterize concentrations of semivolatile organic compounds (SVOCs) in highway runoff and urban stormwater. To a lesser extent, studies also have characterized concentrations of volatile organic compounds (VOCs), estimated loads of SVOCs, and assessed potential impacts of these contaminants on receiving streams. This review evaluates the quality of existing data on SVOCs and VOCs in highway runoff and urban stormwater and summarizes significant findings. Studies related to highways are emphasized when possible. The review included 44 articles and reports that focused primarily on SVOCs and VOCs. Only 17 of these publications are related to highways, and 5 of these 17 are themselves review papers. SVOCs in urban stormwater and sediments during the late 1970's to mid-1980's were the subject of most studies.

Criteria used to evaluate data quality included documentation of sampling protocols, analytical methods, minimum reporting limit (MRL) or method detection limit (MDL), quality-assurance protocols, and quality-control samples. The largest deficiency in documenting data quality was that only 10 percent of the studies described where water samples were collected in the stream cross section. About 80 percent of SVOCs in runoff are in the suspended solids. Because suspended solids can vary significantly even in narrow channels, concentrations from discrete point samples and contaminant loads estimated from those samples are questionable without information on sample location or how well

streamflow was mixed. Thirty percent or fewer of the studies documented the MRL, MDL, cleaning of samplers, or use of field quality-control samples. Comparing results of different studies and evaluating the quality of environmental data, especially for samples with low concentrations, is difficult without this information.

The most significant factor affecting SVOC concentrations in water is suspended solids concentration. In sediment, the most significant factors affecting SVOC concentrations are organic carbon content and distance from sources such as highways and power plants. Petroleum hydrocarbons, oil and grease, and polycyclic aromatic hydrocarbons (PAHs) in crankcase oil and vehicle emissions are the major SVOCs detected in highway runoff and urban stormwater.

The few loading factors and regression equations that were developed in the 1970's and 1980's have limited use in estimating current (1998) loads of SVOCs on a national scale. These factors and equations are based on few data and use inconsistent units, and some are independent of rainfall. Also, more cars on the road today have catalytic converters, and fuels that were used in 1998 are cleaner than when loading factors and regression equations were developed.

Comparisons to water-quality and sediment-quality criteria and guidelines indicate that PAHs, phenolic compounds, and phthalates in runoff and sediment exceeded U.S. Environmental Protection Agency drinking-water and aquatic-life standards and guidelines. PAHs in stream sediments adjacent to highways have the highest potential for adverse effects on receiving streams.

Few data exist on VOCs in highway runoff. VOCs were detected in precipitation adjacent to a highway in England, and chloromethane, toluene, xylenes, 1,2,4-trimethylbenzene, and 1,2,3-trichloropropane were detected in runoff from a highway in Texas. In urban stormwater, gasoline-related compounds were detected in as many as 23 percent of the samples. Land use could be the most significant factor affecting the occurrence of VOCs, with highest concentrations of VOCs found in industrial areas. Temperature is another factor affecting the occurrence and concentrations of VOCs. Urban land surfaces are the primary nonpoint source of VOCs in stormwater. However, the atmosphere is a potential source of hydrophilic VOCs in stormwater, especially during cold seasons when partitioning of VOCs from air into water is greatest. Tetrachloroethene, dichloromethane, and benzene were the only VOCs detected in stormwater that exceeded U.S. Environmental Protection Agency drinking-water standards.

INTRODUCTION

Runoff from highways and urban areas has long been recognized as a source of contaminants that could affect the Nation's water resources. Federal, State, and local agencies and universities have conducted or sponsored research since about 1970 to characterize runoff quality, estimate contaminant loads, and assess impacts on receiving streams. Sampling protocols, analytical methods and detection limits, and quality-assurance/quality-control (QA/QC) protocols have improved during this time. In addition, new contaminants are being released into the environment, more is known about their toxic effects, and water-quality criteria for contaminants have been established or changed. In light of these changes, highway-runoff and urban-stormwater studies need to be periodically reviewed for quality of data and whether the results address current water-quality issues.

Semivolatile organic compounds (SVOCs) and volatile organic compounds (VOCs) are two groups of contaminants that have been measured in runoff from highways and urban areas. SVOCs are operationally

defined as solvent-extractable organic compounds that can be determined by gas chromatography/mass spectrometry (GC/MS) (Furlong and others, 1996). Examples of SVOCs include phthalates, phenols, and polycyclic aromatic hydrocarbons (PAHs). Smith and others (1988) reviewed the sources of several types of SVOCs and processes affecting their fate and distribution in surface water. SVOCs are present in many products, including plastics, dyes, and disinfectants, and PAHs are produced by burning gasoline, oil, wood, and other fuels. SVOCs typically are hydrophobic and by definition have a moderate tendency to volatilize (Karickhoff and others, 1979; Lucius and others, 1989). These properties control how SVOCs are distributed among air, water, and soil when released into the environment. Because they are hydrophobic and moderately volatile, SVOCs preferentially distribute into organic phases, such as tissue and sediments containing organic carbon (Witkowski and others, 1987; Smith and others, 1988).

SVOCs are an environmentally significant group of contaminants because they may accumulate to concentrations that will adversely affect aquatic organisms. Benthic organisms that live in contaminated sediment are most affected because sediments have the largest fraction of SVOCs; however, organisms that feed on benthic species also may be affected. Adverse effects could include mortality, reduced fecundity, and inhibited or abnormal growth. Recently, scientists have become aware of compounds that disrupt the endocrine system and reproduction of fish, reptiles, and mammals (Colborn and others, 1993). Endocrine disruption occurs when a compound either mimics natural hormones or blocks their function. Certain phthalates and PAHs are among the organic compounds that cause endocrine disruption, although their effect is weaker than the effect of some pesticides. In a national survey, concentrations of phenols in bottom sediment were found to correlate with concentrations of 11-ketotestosterone in male carp at an alpha-level of 0.05, suggesting these SVOCs also could cause endocrine disruption (Goodbred and others, 1997).

VOCs are operationally defined as organic compounds that can be extracted from water by purging with an inert gas, then trapped and determined by GC/MS (Connor and others, 1998). VOCs are present in many products including fuels, solvents, refrigerants, paints, adhesives, and deodorants. VOCs

also are present in vehicle exhaust and chlorinated water. In contrast to SVOCs, VOCs can be either hydrophobic or hydrophilic, have a high tendency to volatilize, and distribute preferentially into air because of their volatility.

VOCs have low aquatic toxicity (Rowe and others, 1997). Except for spills, concentrations found in highway runoff and urban stormwater are too low to cause a toxic response in aquatic species. However, VOCs in highway runoff and urban stormwater could enter drinking-water supplies and have chronic effects on the consumers. For example, ground water in Tucson, Arizona, was contaminated with low concentrations of VOCs in urban stormwater (Pritt and others, 1996).

Objectives and Scope

The objectives of this review are to evaluate the quality of existing data on SVOCs and VOCs and to summarize significant findings. This is not an exhaustive review of all studies that contain information on SVOCs and VOCs, but a review of studies that focused primarily on SVOCs and VOCs in highway runoff, urban stormwater, precipitation, and sediments. Studies related to highway runoff are emphasized when possible. Measures of extractable organic compounds, such as petroleum hydrocarbons and oil and grease, are included in the discussion of SVOCs, but pesticides and polychlorinated biphenyls are not within the scope of this report.

A total of 44 articles and reports published between 1976 to 1998 were reviewed. Only 17 of these publications were related to highways, and 5 of these 17 are themselves review papers. SVOCs in urban stormwater and sediments were the subjects of most studies.

Criteria for Data Quality

Studies done since 1970 are useful if they were documented such that the quality, interpretations, and limits of the data can be qualified. Documentation should be able to answer several important questions, such as: Where, when, and how were samples collected? What analytical methods were used to identify and quantify contaminants, and what was the

minimum reporting limit (MRL) or method detection limit (MDL)? What QA/QC steps were taken to assure data are representative, accurate, and precise? These questions comprise the criteria for evaluating the quality of existing data.

MONITORING TRACE ORGANIC CHEMICALS

Because of their physical and chemical properties, different samplers and sampling procedures are needed for SVOCs and VOCs. SVOCs can be sampled using a variety of samplers because analyte loss during sampling is not a significant issue. The choice and use of a sampler depends on sampling objectives and logistical considerations. For example, discrete point samplers are adequate for obtaining occurrence data, but do not obtain accurate concentrations of SVOCs unless the stream is well mixed and suspended solids are evenly distributed in the stream cross section. The best techniques to obtain accurate data are equal-width-increment (EWI) and equal-discharge-increment (EDI) sampling using samplers that collect depth-integrated samples (Wells and others, 1990). However, these sampling techniques are difficult in flashy runoff from urban areas and highways, which is why automatic samplers commonly are used in stormwater studies. Regardless of the sampler type, the sampler should be made of noncontaminating materials. Generally, metal and glass are the best materials for sampling trace concentrations of organic compounds. Teflon is the preferred material when metal and glass cannot be used, such as for sampling lines for automatic samplers.

In contrast, analyte loss during sampling is a significant issue for VOCs because of their volatility. Three types of samplers and sampling techniques are used to collect VOC samples, all three of which collect discrete point samples. If point sources are not nearby, point sampling for VOCs is not as significant an issue as for SVOCs because VOCs are mostly in the dissolved phase and not sorbed to sediments (Rathbun, 1998). The two most common sampling techniques are to manually dip a 40-mL (milliliter) glass vial directly into the stream or to obtain a sample with another container and then transfer the water to a vial. Vials are then quickly sealed with a Teflon-lined septum cap.

Dipping a vial directly into the stream eliminates potential contamination from sampling equipment. However, this technique is limited to the length of the sampler's arm and can be hazardous during high-flow conditions. A stainless steel and copper sampler (Shelton, 1997) is more versatile and safer than dip sampling because it collects samples at greater depths and can be suspended from bridges. Sample water is collected directly into sample vials, which are sealed when the sampler is retrieved from the stream. Laboratory and field testing has shown that this sampler collects accurate data (Gregory Delzer, U.S. Geological Survey, written commun., 1997). VOCs should not be collected using automatic samplers with peristaltic pumps that do not quickly seal vials because the negative pressure created by the pumps and volatilization from open vials can bias sample results. Recently, ISCO Inc. developed the model 6100 automatic sampler for sampling VOCs in streams. This sampler uses a positive-displacement pump and quickly seals vials. Laboratory testing of this sampler indicates it produces accurate data with less than 2 µg/L (micrograms per liter) of carryover between samples (Gregory Delzer, written commun., 1997).

Preservation of water samples for analysis of SVOCs and VOCs depends on laboratory requirements. SVOC samples usually are chilled at 4°C. VOC samples usually are chilled and may be acidified to a pH of less than 2 using hydrochloric acid. Some laboratories require addition of ascorbic acid to VOC samples if free chlorine is present.

GC/MS is the most accurate method of identifying and quantifying most SVOCs and VOCs. Even if laboratories use the same analytical method, they may report varying MRLs and MDLs that can create difficulties in data interpretation (Cole and others, 1984). MRLs and MDLs can vary because of the sample matrix, study objectives require different values, and analytical methods improve with time. For example, MRLs and MDLs that meet current regulatory requirements may be satisfactory for compliance monitoring. However, organic compounds in stormwater commonly occur at concentrations below water-quality criteria (Makepeace and others, 1995), so regulatory requirements may be inadequate to determine if compounds are present, to estimate loads, to identify causal factors and emerging problems, and to use data in the future if water-quality criteria are lowered. The National Water-Quality Laboratory of the U.S. Geological Survey (USGS)

reports SVOCs in water as low as 5 µg/L (Fishman, 1993), SVOCs in sediment as low as 50 µg/Kg (micrograms per kilogram) (Furlong and others, 1996), and VOCs in water as low as 0.05 µg/L (Connor and others, 1998). Extraction and recovery efficiencies are lower for SVOCs than for VOCs, which is why SVOCs have higher MRLs and MDLs. Extraction and recovery efficiencies less than 90 percent are common for compounds that sorb to sediments (Furlong and others, 1996), whereas extraction and recoveries for most VOCs are 95 percent or greater (Connor and others, 1998).

Results of water-quality studies can form the basis of or alter agency policies and have significant economic and social implications. Studies should be supported by a QA/QC plan to ensure that these results are based on quality data. QA is the precautionary actions used to prevent systematic bias. Examples of QA are using noncontaminating materials and sample containers, cleaning equipment, preserving samples soon after collection, and shipping samples overnight. QC includes the steps used to check that QA is effective and to evaluate variability due to random error. Examples of QC are equipment blank samples to ensure that equipment is clean, replicates to assess sample variance and analytical precision, and samples spiked with analytes to evaluate analyte degradation and recovery. QC samples generally comprise 10 to 15 percent of all samples. The QA/QC plan usually is an unpublished document, but should be briefly described with study results. For large studies, the QA/QC plan often is a published document, such as that by Mueller and others (1997).

Sample Collection

Documentation of sample collection should include where, when, and how highway runoff and urban stormwater samples were collected. Documenting sample location is important so sampling can be repeated to evaluate apparent anomalies and to define changes with time. All studies answered the question of where samples were collected (table 1, at back of report), although the level of detail varied. Some studies provided maps showing precise sample locations; however, most studies included generalized maps or described sample locations. An extreme case of generalizing was Line and others (1997), who only stated that samples were collected in North Carolina.

Studies included in this review were conducted in the United States (fig. 1) and in Canada, Germany, Japan, Norway, Spain, Switzerland, and the United Kingdom. Most studies in the United States were conducted along the northeast coast and in southern states where population densities are greatest. Few studies have been conducted in the Great Lakes region and the central and western states.

Seventeen studies were related to SVOCs and VOCs in highway runoff or in rain, snow, and sediment near highways. Ten of the 17 studies related to highways were in the United States (Wiland and Malina, 1976; Zawlocki and others, 1980; Gupta, 1981; Hoffman and others, 1983, 1984, 1985; Hoffman and Quinn, 1987; Latimer and others, 1990; Barrett and others, 1993; Baldys and others, 1997); four were in England (Butler and others, 1984; Johnston and Harrison, 1984; Harrison and Johnston, 1985; Hewitt and Rashed, 1990); and one was in each of Canada (Boom and Marsalek, 1988), Norway (Gjessing and others, 1984), and Germany (Stotz, 1987). PAHs were the topic of most highway-related studies.

The priority pollutant monitoring project of the Nationwide Urban Runoff Program (NURP) had the widest geographic distribution and is the most

frequently cited study of organic contaminants in urban stormwater. The U.S. Environmental Protection Agency's (USEPA) priority pollutants, including SVOCs and VOCs, were monitored in 15 cities in 14 states (Cole and others, 1984). Concentrations of the priority pollutants were measured in 86 stormwater samples collected from drainage basins with residential, commercial, or industrial land use.

Marsalek and Schroeter (1988) conducted a study similar to NURP in 12 Canadian cities in the Great Lakes region. Up to 125 stormwater and sediment samples from 81 sites with residential, commercial, industrial, or transportation land use were analyzed for 50 priority pollutants, including PAHs and chlorinated benzenes.

A set of independent urban stormwater studies conducted by the USGS comprise another type of study with a wide geographic distribution. In 1991, USEPA required cities with a population of 100,000 or more to monitor stormwater quality and obtain municipal National Pollutant Discharge Elimination System (NPDES) permits. The USGS monitored stormwater from drainage basins with residential, commercial, or industrial land use in 16 of these cities in 11 states (Delzer and others, 1996). Most of these

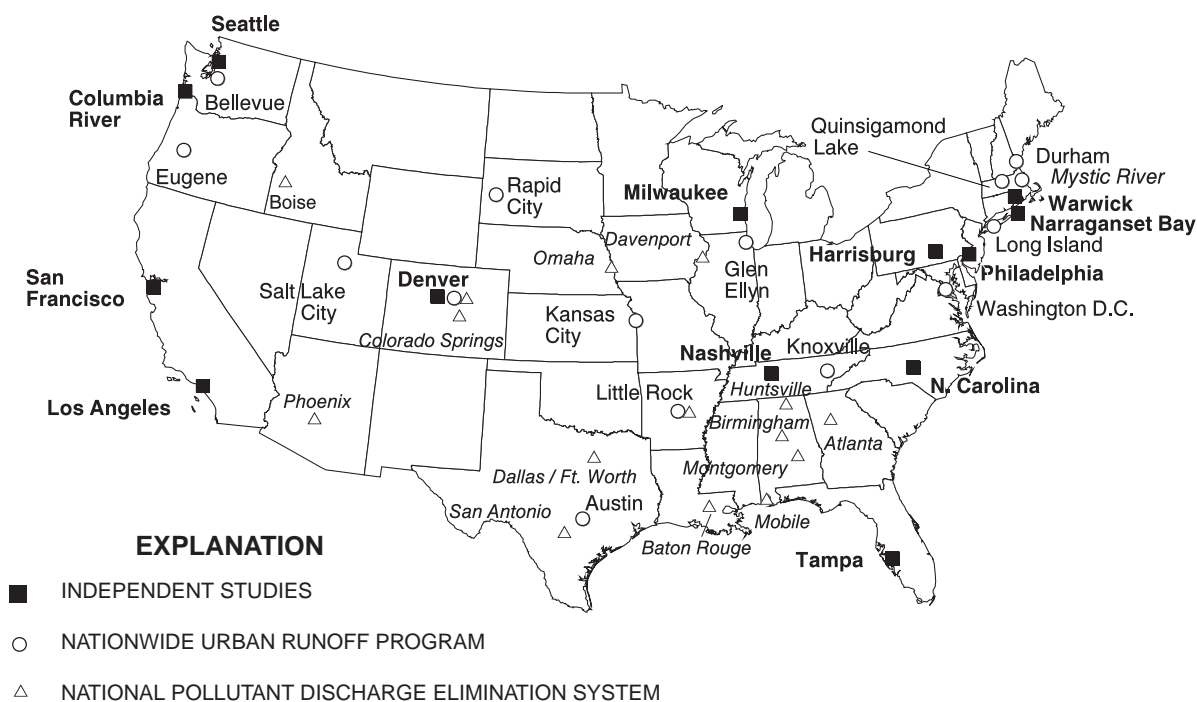


Figure 1. Cities in the United States where semivolatile and volatile organic compounds have been studied in highway runoff and urban stormwater.

cities are in southern and central states (fig. 1). A total of 642 stormwater samples were analyzed for up to 210 properties and constituents, including the priority pollutants. VOC data were compiled to characterize the occurrence of VOCs in stormwater (Delzer and others, 1996) and identify nonpoint sources (Lopes and Bender, 1998). Data on SVOCs and other contaminants that were measured in stormwater samples were not compiled.

Documenting when samples were collected is necessary to know if unusual weather occurred during the respective studies and to determine if state-of-the-art sampling and analytical methods were used. The question of when samples were collected was answered in about 84 percent of the studies. The majority of data were collected during the late 1970's to mid-1980's, including data related to highway runoff. Only 20 percent of studies, most of which were NPDES studies, collected data after 1990. Typically, the time between data collection and publication was about 2 to 4 years, although Latimer and others (1990) was published 10 years after data were collected. Studies that did not report when data were collected were published between 1982–91; therefore, data probably were collected prior to the mid-1980's.

The validity and comparability of data depend on several criteria, including documented sampling protocols. Description of the sampling protocol should include information on the type and material of the sampler; where in the stream cross section samples were collected; if discrete or composite samples were analyzed; and if whole water, suspended solids, or filtrates were analyzed. Most studies provided some, but none provided all information on the sampling protocol.

About 80 percent of studies reported the type of sampler. Water samples were collected with buckets, bottles, trays, cans, storage tanks, drums, and automatic samplers. Snow and sediment were sampled with corers, trowels, ponar samplers, jars, and lysimeters. Atmospheric deposition and rain were sampled with funnels. Line and others (1997) collected samples for VOCs with automatic samplers that were not designed for these contaminants; therefore, volatilization from sample water probably biased results.

About 60 percent of studies reported the sampler material. Most samplers were made of metal or glass, which are good materials to use for sampling organic contaminants. Studies that used flow splitters and samplers made of fiberglass and plastics included

Zawlocki and others (1980), Gjessing and others (1984), Johnston and Harrison (1984), and Harrison and Johnston (1985). Sorption to these materials may have biased the SVOC and VOC data of these studies. Hewitt and Rashed (1990) conducted a study in the same area as Johnston and Harrison (1984) and Harrison and Johnston (1985) and may have used the same equipment, but there is insufficient information to determine this from the article. Seven studies used automatic-pumping samplers. Three NPDES studies (Lopes and others, 1995; von Guerard and Weiss, 1995; and Baldys and others, 1998) noted that sampling lines were made of Teflon. The other studies did not document the sampler-line material.

The largest deficiency in documenting data quality was that only 10 percent of studies described where water samples were collected in the stream cross section, if streamflow was well mixed, or if equal-width increment or depth-integrated techniques were used. The representativeness of discrete point samples and interpretations based on those data, especially load estimates, are questionable without this information. Sample location could have affected results because SVOC concentrations depend on suspended solids concentrations (Hunter and others, 1979; Hoffman and Quinn, 1987; and Barrett and others, 1993). Suspended solids concentrations can have significant horizontal and vertical variations (Horowitz and others, 1989) even in channels less than 5 ft wide (Edwards and Glysson, 1986). Samplers do not need to be sophisticated devices like electronically activated point samplers to obtain representative samples. However, the water samplers used in these studies and lack of information on flow conditions suggest most studies sampled surficial streamflow along the streambank. Stream velocity and suspended sediment concentrations typically are lowest along the banks, so point samples collected along the streambanks may result in biased (low) contaminant concentrations and load estimates. This may not be a significant issue in stormwater drainages where streamflow usually is fast and shallow.

About 90 percent of studies described whether samples were discrete or composite samples. About 70 percent of studies that described sampling methods manually collected discrete water samples. Eight studies composited stormwater samples, but two of these studies did not document whether these were time-weighted or flow-weighted composites. Composite samples were obtained using cone or churn

splitters (Lopes and others, 1995; von Guerard and Weiss, 1995) and a flow splitter (Zawlocki and others, 1980). Other studies did not describe how samples were composited. About 90 percent of studies described whether bottom-sediment samples were point samples or composites and the depth interval of bottom sediment that was sampled. Most samples were point samples collected from the upper 10 centimeters of bottom sediment. Ellis and others (1985) and Brown and others (1985) composited surficial bottom-sediment samples from several sites. Gavens and others (1982) and Butler and others (1984) sieved bottom sediment and Hoffman and others (1984) sieved suspended solids for a consistent grain size among samples. Comparing bottom-sediment concentrations is difficult because most studies did not analyze for organic carbon, which is the most common way of normalizing organic contaminant concentrations in sediments.

About 90 percent of studies described whether whole-water samples were analyzed or if suspended solids and filtrates were analyzed separately. Unless stated otherwise, it was assumed that whole-water samples were analyzed. About 30 percent of studies separated suspended solids and analyzed the filtrate, solids, or both. Separation was done by filtration with glass fiber filters or by centrifugation.

Analytical Methods and Minimum Reporting and Detection Limits

Documenting the analytical methods, MRLs, and MDLs is important to use data from different studies for a common objective. About 90 percent of studies described the analytical method for contaminant identification and quantitation. Gas chromatograph/flame-ionization detection (GC/FID) was the most commonly used analytical method. GC/MS was used to identify analytes or confirm GC/FID results in about 30 percent of the studies. About 30 percent of studies documented analytical precisions and recoveries. Generally, precision was less than 25 percent and recoveries were greater than 80 percent.

About 30 percent of studies, most of which were conducted in the 1990's, documented the MRL or MDL. The MRL is the lowest concentration that can accurately be quantified. The MDL is the lowest concentration that the method can detect. For studies

done in the 1980's, Brown and others (1985) reported an MRL of 1 µg/L for petroleum hydrocarbons, Schondorf and Herrmann (1987) reported MDLs ranging from 0.03 to 0.15 ng/L (nanograms per liter) for PAHs, Zawlocki and others (1980) reported an MRL of 100 µg/L for a variety of SVOCs, and Boom and Marsalek (1988) and Marsalek and Schroeter (1988) reported an MRL of 0.05 µg/L for PAHs. Except for Zawlocki and others (1980), these limits compare well with current (1998) limits of the U.S. Geological Survey. The high MRLs ranging from 5 to 100 µg/L used by Line and others (1997) could explain why few SVOCs and VOCs were detected in stormwater from industrial sites.

Quality Assurance and Quality Control

The validity and use of data depend on documenting the procedures used to ensure that high-quality data were collected. Most studies described some precautionary action to ensure sample integrity, but few studies described thorough QA/QC procedures. Only Cole and others (1984) described a QA/QC plan, although they were unable to evaluate the effectiveness of the plan for NURP.

As previously noted, about 60 percent of studies used noncontaminating materials such as glass and metal. However, only 30 percent of studies documented that equipment was cleaned before sampling or that samples were preserved. Chilling samples at 4°C was the most commonly used method for preserving samples. Infrequently described precautionary steps included use of Teflon-lined or metal lids, covering jars with aluminum foil, homogenizing samples before splitting into equal portions, slowly melting snow samples to minimize volatilization, sampling in well-mixed parts of a storm drain, shipping samples overnight, and using nitrogen to filter samples for SVOCs. Studies that retrieved samples up to 2 weeks after collection without chilling were Johnston and Harrison (1984) and Harrison and Johnston (1985). Latimer and others (1990) left samples at room temperature for up to 2 days before analysis. Line and others (1997) used automatic samplers for VOCs and retrieved and chilled samples sometimes hours after they were collected.

Both laboratory and field QC samples are needed to evaluate sample and analytical quality. About 30 percent of studies reported analyzing laboratory QC samples and 15 percent analyzed field QC samples.

Laboratory QC samples included blanks, lab-split duplicates, surrogate recoveries, and performance-evaluation samples. Four studies reported using laboratory blanks and surrogate recoveries to correct environmental concentrations. The use of field QC samples became prevalent after most of the studies in this review were conducted. Except for NURP, the only studies that reported analyzing field QC samples were conducted in the 1990's. Field QC samples included equipment blanks, trip blanks, replicates, and spikes. Evaluating the quality of environmental data, especially low concentrations, is difficult because few studies collected QC data and documented that samplers were cleaned.

SUMMARY OF STUDY RESULTS

Most highway-runoff and urban-stormwater studies were conducted to address regional or local issues. However, results from all studies could provide useful qualitative information to answer some general questions of national importance. For example, do certain SVOCs and VOCs occur more frequently and at higher concentrations in particular regions of the country? If so, do factors such as climate affect occurrence and concentrations of these compounds? What are the sources of SVOCs and VOCs? Can loads of SVOCs be estimated on a national scale? Could SVOCs and VOCs have an adverse effect on water resources? These questions are the focus of this summary.

Semivolatile Organic Compounds

SVOCs were the subjects of most highway runoff and urban stormwater studies. Much has been learned about these compounds, especially the extractable organic compounds and polycyclic aromatic hydrocarbons (PAHs).

Occurrence

Characterizing the occurrence of SVOCs in highway runoff and urban stormwater for the entire United States is not possible because few studies reported detection frequencies or were conducted in the Great Lakes region and the central and western states. Studies that reported detection frequencies are Cole and others (1984), Boom and Marsalek (1988),

Marsalek and Schroeter (1988), Lopes and others (1995), von Guerard and Weiss (1995), and Baldys and others (1998). SVOC concentrations vary by several orders of magnitude, which is typical of stormwater quality (table 7 at back of report). Table 7 was compiled assuming that unknown sample types and samples described as sediment samples, but reported in milligrams per liter or nanograms per liter, were whole-water samples. Thirty SVOCs were measured but not detected in stormwater (table 2, at back of report).

Total oil and grease and hydrocarbon concentrations in runoff ranged from less than 1 to 480 milligrams per liter (mg/L) (table 7). In suspended sediment, bottom sediment, and soils, oil and grease and hydrocarbon concentrations ranged from 8 to 507,000 micrograms per gram ($\mu\text{g/g}$). The highest concentrations in water and solid phases were associated with highways and industrial land use.

Studies that analyzed petroleum hydrocarbons and oil and grease for the classes of organic compounds that comprise these measurements were Zawlocki and others (1980), Eganhouse and Kaplan (1981b), Brown and others (1985), Fam and others (1987), Hoffman and Quinn (1987), Marsalek and Schroeter (1988), and Barrett and others (1993). Comparing results is difficult because fractions were separated using non-standard procedures (Hoffman and Quinn, 1987). Most extractable organic compounds in stormwater are aliphatic compounds and, except for polar compounds, about 80 percent or more are in the solid phase. The high solubilities of polar compounds, such as phenols, ketones, and alcohols, explain the large percentages measured in filtrates. Generally, aromatic compounds, phenolic compounds, PAHs, alcohols, and ketones comprise less than 1 percent to about 15 percent of the extractable organic compounds.

Concentrations of individual PAHs in runoff ranged from less than 1 to 120 $\mu\text{g/L}$. Highest concentrations were associated with industrial land use; few data exist for individual PAHs in highway runoff. In solid phases, concentrations of individual PAHs ranged from less than 1 to 200 $\mu\text{g/g}$. Of the few studies that reported total PAH concentrations, the maximum concentrations were 18,210 $\mu\text{g/L}$ in whole water and 1,100 $\mu\text{g/g}$ in solid phases. The maximum detection frequency of PAHs in both urban stormwater and snow was 90 percent. Most PAHs were detected in less than 25 percent of samples (Cole and others, 1984;

Boom and Marsalak, 1988; Marsalek and Schroeter, 1988; Lopes and others, 1995; von Guerard and Weiss, 1995; and Baldys and others, 1998).

Johnston and Harrison (1984) tentatively identified 2-chlorophenol and 2,4-dichlorophenol in bulk deposition adjacent to a highway. Baldys and others (1997) detected phenolic compounds at concentrations between 1 and 16 µg/L in 90 percent of highway runoff samples. Phenolic compounds were detected in 15 percent or less of urban stormwater samples from NURP (Cole and others, 1984), 55 percent for urban stormwater samples from Phoenix (Lopes and others, 1995), and were not detected in urban stormwater samples from Colorado Springs (von Guerard and Weiss, 1995) and Dallas-Fort Worth (Baldys and others, 1998). When detected, concentrations of phenolic compounds in urban stormwater generally were less than 20 µg/L.

Related Factors

Of the factors that affect SVOC concentrations in water, the most significant is suspended solids concentration. About 80 percent or more of SVOCs in stormwater are associated with the solid phase due to the hydrophobic character of these contaminants (Hunter and others, 1979; Zawlocki and others, 1980; Eganhouse and Kaplan, 1981a; Brown and others, 1985; Hoffman and Quinn, 1987; and Barrett and others, 1993).

Organic carbon content is the most significant factor affecting SVOCs in the solid phase (Butler and others, 1984; Ellis and others, 1985; and Witkowski and others, 1987). Mineral particles are less effective at sorbing nonionic SVOCs (Witkowski and others, 1987), thus grain size does not appear to be a significant factor affecting SVOC concentrations in sediments unless small grains have an organic coating (Witkowski and others, 1987; Gavens and others, 1982). In contrast, trace-element concentrations in sediments are strongly correlated with grain size because ionic elements adsorb to small particles that have charged surfaces (Horowitz and Elrick, 1987).

Sorption of SVOCs to solids is reflected in the high concentration of SVOCs in the initial runoff from a storm and correlation between concentrations of solids and SVOCs throughout a storm (Hunter and others, 1979; Stenstrom and others, 1984; Brown and others, 1985; Hoffman and others, 1984, 1985; and Hoffman and Quinn, 1987). The initial runoff,

commonly called first flush, can have concentrations of suspended solids and sorbed SVOCs that are several factors higher than concentrations in composite samples. Suspended solids concentrations typically decrease during a storm due to flushing of particles that accumulated on the land surface (Novotny, 1995).

Land use also affects SVOC concentrations. Most studies found higher SVOC concentrations in runoff, snow, and bottom sediment from highways or industrial areas compared to residential and commercial areas (Hoffman and others, 1983, 1984; Hoffman and Quinn, 1987; Evans and others, 1990; Latimer and others, 1990; Bomboi and Hernandez, 1991; and Baldys and others, 1998). For example, PAH concentrations in snow near highways and a steel plant were similar, and PAHs were more frequently detected and concentrations were higher than NURP stormwater data (Boom and Marsalek, 1988). Gjessing and others (1984) found PAHs in snow up to 50 meters from a highway, the furthest of all contaminants they measured, and that PAHs were fractionated during atmospheric transport. Johnston and Harrison (1984) found PAHs in rain up to 70 meters from a highway and that concentrations decreased with distance. Butler and others (1984) found that PAH concentrations in bottom sediment decreased with distance from highways.

Storm characteristics, such as rainfall intensity and volume of runoff, are important factors affecting SVOC concentrations and loads in stormwater and sediments. As rainfall intensity increases, stream velocity and sediment-carrying capacity increase, resulting in increased SVOC concentrations in stormwater (Hoffman and Quinn, 1987; Barrett and others, 1993). In bottom sediment, Evans and others (1990) found that PAH concentrations weakly correlated with monthly rainfall and that concentrations increased about 4 to 30 days after a storm. Gupta (1981) observed higher concentrations of oil and grease in highway runoff and Prah and others (1984) observed higher PAH concentrations in atmospheric particulates during winter compared to summer months. Schondorf and Herrmann (1987) found that freezing can concentrate organic compounds in water. During thaws, soluble organic compounds elute in the first and last parts of the melt and that about 90 percent of PAHs elute with the particulates during the last 20 percent of the melt. These observations indicate that concentrations and loads of SVOCs could vary seasonally.

Not all studies found a relation between storm characteristics and SVOC concentrations and loads. Stenstrom and others (1984) found no correlation between oil and grease concentrations and streamflow rates, total rainfall, time since beginning of storm, rainfall intensity, or antecedent dry days. Hunter and others (1979), Herrmann (1981), and Hoffman and others (1984) found that SVOC concentrations did not correlate with antecedent conditions. Zawlocki and others (1980) found no correlation between SVOC loads and rainfall, traffic volume, or runoff volume, although they noted that traffic volume during the storm had a greater effect than rainfall.

Conclusions have been mixed whether highway surface type significantly affects SVOC concentrations (Barrett and others, 1993). Gupta (1981) measured oil and grease concentrations from paved surfaces that were 20 times greater than from grass-covered surfaces, but concluded that land use was the most important factor. Stenstrom and others (1984) measured oil and grease concentrations 25 times greater from parking lots compared to residential areas. Wakeham and others (1980) concluded that PAHs in street dust were from asphalt. Zawlocki and others (1980) noted that higher suspended solids concentrations occurred in highway runoff at a site with a median barrier and side railings compared to another site without these features. Other variables, such as traffic volume and drainage, may be more important factors affecting SVOC concentrations than surface type (Stotz, 1987; Barrett and others, 1993).

Sources

Crankcase oil and vehicle emissions were consistently identified as the primary source of SVOCs in stormwater (Hunter and others, 1979; Zawlocki and others, 1980; Stenstrom and others, 1984; Brown and others, 1985; Hoffman and Quinn, 1987; Fam and others, 1987; Yamane and others, 1990; Latimer and others, 1990; and Bomboi and Hernandez, 1991). The significance of PAHs in automobile emissions is indicated by concentrations in sediment, snow, and rain that decrease with distance from highways (Butler and others, 1984; Johnston and Harrison, 1984; Gjessing and others, 1984; Harrison and Johnston, 1985; and Hewitt and Rashed, 1990).

Emission of most PAHs from automobiles is directly related to their concentration in gasoline (Westerhold and others, 1988). Naphthalene and its

alkylated homologues comprise about 0.5 percent by weight of gasoline (Canadian Petroleum Institute, 1994); 13 other PAHs occur in gasoline at less than 0.01 to 54 mg/L (Westerhold and others, 1988). About 95 percent of PAHs in gasoline are decomposed during gasoline combustion. However, in gasoline with low PAH content, a large percentage of the PAHs emitted are formed during combustion, including 70 to 80 percent of cyclopenta[*cd*]pyrene and benzo[*b&k*]fluoranthene. Gasoline exhaust contains about 1 to 2 parts per million of phenol and o-cresol (Lucius and others, 1989) and is a possible source of phenolic compounds in stormwater.

Load Estimates

Estimates of SVOC loads and mass balances have been made on different scales to evaluate the relative importance of different sources and transport mechanisms. For example, Edwards (1983) estimated that forest and agricultural fires comprise 75 percent of the annual global release of PAHs. Hoffman and Quinn (1987) estimated 470,000 tons per year of petroleum hydrocarbons are released to waters of the United States and that up to 50 percent of this amount could be discharged in urban stormwater. Bjorseth and Ramdahl (1985) estimated that automobile emissions comprise one-third of the 6,000 tons of PAHs emitted each year in the United States. In contrast, Edwards (1983) estimated that automobiles, buses, and trucks comprise only 1.6 percent of benzo(a)pyrene emissions in the United States. The difference could be because Bjorseth and Ramdahl (1985) did not correct for catalytic converters, which were in about 50 percent of cars.

At a regional scale, Hoffman and others (1983, 1984) estimated hydrocarbon and PAH loads to Narraganset Bay, and Marsalek and Schroeter (1988) estimated SVOC loads to the Great Lakes. Estimates by Hewitt and Rashed (1990) and Stotz (1987) indicated that 30 percent or less of the PAHs emitted along highways is transported in runoff and the remainder is dispersed. Other estimates have been made at a local scale (Butler and others, 1984; Gjessing and others, 1984; Johnston and Harrison, 1984; Harrison and Johnston, 1985; Boom and Marsalek, 1988; and Hewitt and Rashed, 1990).

Few regression equations or loading factors have been developed for SVOCs compared to other constituents such as suspended solids and nutrients.

Most equations and factors were based on few data and have little statistical power and large uncertainties, especially for regional and national application. Also, studies reported loading factors with inconsistent units so comparisons are difficult or with units that limit their application (table 3, at back of report). For example, Hoffman and Quinn (1987), Stotz (1987), and Barrett and others (1993) report loading factors that are independent of rainfall and, therefore, apply only to areas with climates similar to their study areas. Gupta (1981) estimated loads from highways using regression equations for runoff, pollutant build-up and wash-off, and loads of suspended solids. Correlations between other contaminants and suspended solids were used to convert loads of suspended solids into loads of the other contaminants. However, conversion equations were developed for individual sites and have only site-specific application. Marsalek and Schroeter (1988) used a procedure similar to Gupta (1981) to estimate loads to the Great Lakes.

Using study results to develop equations and factors of SVOC loads and concentrations at a national level, particularly from highways, is not possible because ancillary information was not documented, raw data were rarely reported, laboratory reporting levels varied, and few studies were related to SVOCs from highways. In addition, vehicles emit fewer SVOCs and VOCs today than when most studies were conducted (U.S. Environment Protection Agency, 1996a). The lower emissions are probably due to catalytic converters and to the use of cleaner-burning fuels. Gasoline-powered cars without catalytic converters emit 25 times more total aerosol PAHs in comparison to cars with catalytic converters, and diesel trucks emit 7 times more PAHs than cars with catalytic converters (Rogge and others, 1993). Therefore, the few loading factors that are available in the literature probably have limited application for estimating current loads of SVOCs and VOCs.

Comparison to Water-Quality and Sediment-Quality Standards and Guidelines

The potential for SVOCs to adversely affect water resources can be made by comparing SVOC concentrations in urban stormwater, snowmelt, and sediment to water-quality and sediment-quality standards and guidelines. Makepeace and others (1995) and Boom and Marsalek (1988) concluded that certain

PAHs, phenol, *m*- and *p*-cresols, pentachlorophenol, and phthalates in stormwater were a concern for drinking water and aquatic life. Of the PAHs, total PAH, acenaphthene, fluoranthene, and benzo(a)pyrene in urban stormwater exceeded drinking-water standards of the United States, Canada, and World Health Organization (WHO). Concentrations of fluoranthene in stormwater exceeded acute and chronic aquatic regulation values of the United States.

For this report, SVOC concentrations in sediments were compared to recently developed sediment-quality guidelines (U.S. Environmental Protection Agency, 1996b) as another assessment of their potential adverse effects. No single set of sediment-quality guidelines is universally accepted in the United States. Therefore, the method of USEPA (1996b) was used to determine an upper threshold concentration for selected SVOCs above which there is a high probability of adverse effects on aquatic life. However, guidelines do not exist for all SVOCs detected in urban stormwater and upper threshold concentrations may be over- or under-protective depending on site-specific conditions.

Briefly, USEPA (1996b) used several sets of sediment-quality guidelines that were developed using different methods and have considerable inconsistencies among them. Rather than select one set of guidelines over another, USEPA (1996b) used all available sediment guidelines for a contaminant to classify sites into one of three tiers based on the probability of adverse effects on aquatic life. Tier 1 sites have a high probability of adverse effects on aquatic life, Tier 2 sites have an intermediate probability of adverse effects on aquatic life, and Tier 3 sites have no indication of adverse effects on aquatic life. USEPA (1996b) used lower threshold guidelines, above which adverse effects occasionally occur, to define the Tier 2/Tier 3 boundary, and upper threshold guidelines, above which effects may be frequent or severe, to define the Tier 1/Tier 2 boundary. For a site to be designated as Tier 1, the measured contaminant concentration at that site must exceed at least two of the upper threshold guidelines for that contaminant.

The guideline used in this comparison was the Tier 1/Tier 2 boundary concentration (table 4, at back of report). The upper threshold values used were (1) the effects range-median (Long and Morgan, 1991; Long and others, 1995); (2) the apparent effects threshold-high (Barrick and others, 1988); (3) the probable effect level used by the Florida Department of

Environmental Protection (1994); (4) the probable effect level used by the Canadian Council of Ministers of the Environment (1995); (5) the USEPA sediment-quality criterion (U.S. Environmental Protection Agency, 1996b); and (6) the USEPA sediment-quality advisory level (U.S. Environmental Protection Agency, 1996b).

In the future, guidelines for PAHs are likely to change to PAH mixtures because PAHs typically co-occur in the environment. Testing and modeling is being conducted to determine the toxicity of PAH mixtures in sediment, which will form the basis for sediment-quality criteria for PAH mixtures (U.S. Environmental Protection Agency, 1998).

About 70 percent of surface-soil samples near a highway exceeded upper threshold concentrations of benz(a)anthracene, benzo(a)pyrene, chrysene, or pyrene, or of more than one of these PAHs, indicating adverse effects are probable (Butler and others, 1984). About 60 percent of bottom sediments from an urban stream exceeded upper threshold concentrations of fluoranthene, anthracene, pyrene, or benzo(a)pyrene, or of more than one of these PAHs (Ellis and others, 1985). Other studies had samples that exceeded upper threshold values, but the percentage of exceedence is unknown. For example, particulates in vehicle emissions and in the atmosphere exceeded upper threshold concentrations of benzo(a)pyrene (Prah and others, 1984; Bjorseth and Ramdahl, 1985). Suspended sediments and street dust from highways and commercial areas exceeded upper threshold concentrations of fluoranthene, phenanthrene, pyrene, acenaphthylene, and benzo(a)pyrene (Hoffman and others, 1984 and 1985; Marsalek and Schroeter, 1988).

Volatile Organic Compounds

Few studies have been done on VOCs in highway runoff and urban stormwater. This summary of VOCs is mostly from the National Urban Runoff Program (NURP) and National Pollutant Discharge Elimination System (NPDES) studies.

Occurrence

Harrison and Johnston (1985) and Baldys and others (1997) were the only studies of VOCs in highway runoff. Harrison and Johnston (1985) sampled 2-week composites of atmospheric deposition at three

sites near a highway in England. A total of 48 compounds were identified and quantified on a relative basis. Toluene and C₂-alkylbenzene were the major components in atmospheric deposition. No variation with distance from the highway was observed. Twenty-one highway runoff samples were collected at four sites between 1992-94 and analyzed for VOCs and other contaminants in the Dallas-Fort Worth area (Baldys and others, 1997). Chloromethane, toluene, xylenes, 1,2,4-trimethylbenzene, and 1,2,3-trichloropropane were detected in about 5 to 28 percent of samples at concentrations between 0.2 and 4.0 µg/L.

Most of the data on VOCs were collected during the NURP and NPDES studies. Together, these studies provide information on the occurrence of VOCs in most regions of the United States. For the NURP, the most frequently detected VOCs were dichloromethane, naphthalene, and chloroform, detected in 10 to 12 percent of all samples (Cole and others, 1984). In contrast, the most frequently detected VOCs for NPDES studies were toluene, xylenes, chloroform, and trimethylbenzene, detected in 12 to 23 percent of all samples (table 5, at back of report) (Delzer and others, 1996). A lower MRL for the NPDES studies could account from the greater frequencies of detection. Comparing VOC detections among regions of the United States may be possible using the NURP and NPDES data, but would be difficult because of the different reporting limits. Most detected concentrations of VOCs in urban stormwater for the NURP and NPDES studies were less than 10 µg/L and ranged from 0.2 to 43 µg/L.

The prevalence of gasoline-related compounds in NPDES data compared to NURP data probably is because stormwater was sampled closer to its source at NPDES monitoring sites and because the NURP did not measure xylenes, trimethylbenzenes, methyl *tert*-butyl ether (MTBE). MTBE and other ether oxygenates are added to gasoline to reduce vehicle emissions and enhance octane ratings. MTBE usage as an octane enhancer started about 1979. The use of MTBE to produce cleaner burning gasoline increased considerably during the late 1980's. In 1996, 17.6 billion pounds of MTBE were produced, making it the VOC with the third highest production (Chemical and Engineering News, April 8, 1996). MTBE's widespread use, high solubility, and resistance to degradation (Squillace and others, 1997) could account

for its frequent occurrence in urban stormwater (Delzer and others, 1996) and in shallow urban ground water (Squillace and others, 1996).

Related Factors

Land use could be the most significant factor affecting the occurrence of VOCs. Lopes and Bender (1998) found that concentrations of gasoline-related and chlorinated VOCs were significantly higher in industrial areas as compared to commercial and residential areas and that MTBE was detected more frequently in commercial areas. Most VOCs have industrial applications (Pankow and Cherry, 1996), which probably is why concentrations were higher in industrial areas. The frequent detection of MTBE in commercial areas could be from spills at gas stations, which typically are located in commercial areas. Line and others (1997) infrequently detected VOCs in first-flush samples from industrial sites in North Carolina; sampling methods and high MRLs could account for the few detections.

Temperature is a significant factor affecting the occurrence of VOCs. A study by von Guerard and Weiss (1995) observed that more detections of VOCs occurred during snowmelt than during storm runoff. For all NPDES data, MTBE, benzene, xylenes, and 1,2,4-trimethylbenzene were detected more frequently during winter than summer (Delzer and others, 1996; Lopes and Bender, 1998). This higher detection of VOCs could be caused by the increased partitioning of VOCs from air into precipitation or slower volatilization from stormwater during cold months.

Sources

Lopes and Bender (1998) concluded that urban land surfaces are the primary nonpoint source of VOCs in stormwater. Most VOC concentrations in NPDES samples were higher than those in equilibrium with concentrations measured in urban air, indicating the atmosphere was not the source. VOCs associated with certain products, such as gasoline, frequently occurred together, and concentrations were significantly correlated and different among urban land uses. Model results indicated that VOC concentrations near the reporting limits evolved by volatilization. The primary source of VOCs probably was spills and VOCs sorbed

to organic particulates and impervious surfaces, although partitioning between precipitation and VOCs in the atmosphere could be a source for MTBE.

The seasonal detection of some VOCs suggests that the atmosphere could be a nonpoint source. Measurements by Kawamura and Kaplan (1983), Pankow and others (1984), Harrison and Johnston (1985), Ligocki and others (1985), and Adachi and Kobayashi (1994) support the hypothesis that the atmosphere near highways and urban areas is a source of VOCs, although concentrations in precipitation were less than or equal to 0.2 µg/L. Concentrations of MTBE in precipitation estimated from concentrations in air range from less than 1 to about 4 µg/L (Squillace and others, 1996). These estimated concentrations of MTBE are why Squillace and others (1996) hypothesized precipitation could be a major source of MTBE detected in shallow urban ground water. Pankow and others (1997) demonstrated that MTBE and other VOCs in the atmosphere can be transported in recharge into sandy aquifers.

Comparison to Water-Quality Standards

From the NURP data, Makepeace and others (1995) concluded that tetrachloroethene, dichloromethane, and benzene could be a concern if stormwater entered drinking-water supplies. For the NPDES data, Delzer and others (1996) found that concentrations of MTBE in urban stormwater were less than the lower limit of the USEPA draft lifetime health advisory of 20 µg/L. Other VOCs detected in NPDES samples were compared to drinking-water standards (U.S. Environmental Protection Agency, 1996c) in table 6 (at back of report) because VOCs have low aquatic toxicities (Rowe and others, 1997) and primarily are a threat to drinking-water supplies. Less than 0.5 percent of NPDES samples exceeded drinking-water standards of dichloromethane and tetrachloroethene, similar to the NURP study (Makepeace and others, 1995).

INFORMATION NEEDS

This review has shown that highways can be major sources of SVOCs detected in water and sediment. However, there is insufficient information to determine if highways are sources of VOCs or to estimate loads and concentrations of SVOCs and VOCs from highways. Nationally consistent data are needed to (1) characterize the regional occurrence and

concentrations of SVOCs and VOCs in highway runoff, (2) determine which are the most important factors affecting runoff quality, (3) estimate contaminant loads and concentrations on regional and national scales, and (4) identify water resources that potentially are affected.

A strategy is needed so that the distribution of information adequately represents factors affecting highway runoff in the United States. This strategy should define regions that have different values of factors that are expected to significantly correlate with water and sediment quality. For example, streams in drainage basins with residential and commercial land use are being monitored in regions with significantly different climate (Lopes and Price, 1997) because urban stormwater quality is significantly correlated with mean annual precipitation (Driver and Tasker, 1990). Other factors, such as highway-surface type, drainage, and traffic load, could be incorporated into this plan to develop a similar strategy for highways.

Information that is needed includes chemical data on SVOCs and VOCs in runoff, precipitation, and sediment to characterize their occurrence and ranges in concentrations. PAHs, oil and grease, and petroleum hydrocarbons are the primary classes of SVOCs associated with highway runoff. However, phenolic compounds and VOCs are in vehicle exhaust and could also be in highway runoff, precipitation, and sediment along highways. Parameters that could be related to chemical concentration, such as pH, dissolved oxygen, and total organic carbon, should also be measured. These data should be collected using appropriate procedures and materials and documented in a QA/QC plan.

Factors that are significantly related to water quality need to be characterized to estimate contaminant loads and concentrations from unmonitored sites and to identify potentially affected water resources. Factors that clearly affect concentrations and loads of SVOCs in highway runoff include suspended solids and organic carbon concentrations, total rainfall, rainfall intensity, traffic loads, and how runoff is drained. It is unclear if the type of surface has a significant effect, how much temperature affects concentrations and loads of SVOCs, and if surrounding land use has an effect. These and other factors may affect VOCs in highway runoff and precipitation. Relations between water quality and significant factors can be characterized by statistical analysis of ancillary data associated with monitoring sites and storms. From these relations,

techniques similar to those of Driver and Tasker (1990) can be developed to estimate constituent loads and concentrations in highway runoff throughout the United States.

Geographic information on factors included in the estimation techniques can be used to obtain a national distribution of estimated contaminant loads and concentrations. These estimates and geographic information on water resources, including ground water, could then be used to determine which water resources could be adversely affected by highways. Ground water that is shallow and is used or has the potential of being used for drinking water could be affected by water-soluble compounds like MTBE.

Deterministic studies and modeling are also needed to understand the physical and chemical processes controlling highway-runoff quality, contaminant transport and fate, and impacts on biological and drinking-water resources. For example, Hewitt and Rashed (1990) and Stotz (1987) found that 70 percent of PAHs from highways are dispersed and 30 percent are transported in runoff. The majority of PAHs could be transported through the atmosphere into water-supply reservoirs. Modeling could help determine the transport and fate of dispersed PAHs and potentially affected waters.

SUMMARY

This review evaluated the quality and geographic distribution of existing data on SVOCs and VOCs, summarized significant findings, compared concentrations in highway runoff and urban stormwater with current (1998) water-quality criteria, and identified areas where additional information is needed. A total of 44 articles and reports were reviewed. Only 17 studies were related to highways, and 5 of these are review papers. Most of the data were collected during the late 1970's to mid-1980's. SVOCs in urban stormwater and sediments was the subjects of most studies.

Only 10 percent of studies described where in the stream cross section water samples were collected. This was the largest deficiency in documenting the sampling protocol. About 80 percent of SVOCs in runoff are in the suspended solids. Because suspended solids can vary significantly in the stream cross section even in narrow channels, the representativeness of discrete point samples and interpretations based on those data, especially load estimates, are questionable

without information regarding sample location, how samplers were used, or how well the streamflow was mixed.

Only 30 percent of studies documented the MRL or MDL of the analytical method and only 15 percent of studies used field quality-control samples. The lack of MRL and MDL documentation hinders the ability to compare stormwater quality from different parts of the country. Evaluating the quality of environmental data, especially low concentrations, is difficult because few studies collected QC data and documented that samplers were cleaned.

PAHs, petroleum hydrocarbons, and oil and grease are the major SVOCs in urban stormwater and highway runoff. Suspended solids concentrations is the most significant factor affecting SVOCs in water. In sediment, the most significant factors affecting SVOC concentrations are organic carbon content and distance from sources, such as highways and power plants. Rainfall intensity, storm volume, and land use also are important factors affecting concentrations and loads of SVOCs. The highest SVOC concentrations in runoff, snow, and bottom sediment were measured from highways and industrial areas. Crankcase oil and vehicle emissions are the primary sources of SVOCs. The few loading factors and regression equations that were developed in the 1970's and 1980's are inadequate to estimate current (1998) loads of SVOCs because they use inconsistent units, some are independent of rainfall and have limited application, and they are based on few data. Also, more cars have catalytic converters and fuels are cleaner than when loading factors and regression equations were developed. PAHs, phenolic compounds, and phthalates in runoff exceeded drinking-water and aquatic-life standards. PAHs exceeded upper threshold concentrations in sediments near highways, indicating adverse effects on receiving streams.

VOCs were detected in precipitation adjacent to a highway in England, and chloromethane, toluene, xylenes, 1,2,4-trimethylbenzene, and 1,2,3-trichloropropane were detected in runoff from a highway in Texas. VOCs were detected in as many as 23 percent of the urban stormwater samples; gasoline-related compounds were the most frequently detected VOCs. Land use could be the most significant factor affecting the occurrence of VOCs. The highest concentrations of VOCs were found in industrial areas, suggesting urban land surfaces are the primary nonpoint source of most VOCs. Temperature is another important factor affecting the occurrence of VOCs.

MTBE, benzene, xylenes, and 1,2,4-trimethylbenzene were detected more frequently during winter than summer. The seasonal detection could be due to the increased partitioning of VOCs in air into water at cold temperatures, suggesting that the atmosphere could be a nonpoint source of some VOCs. Tetrachloroethene, dichloromethane, and benzene were the only VOCs in stormwater that exceeded drinking-water standards.

Information deficiencies identified during the review included a need to determine if highways are a source of phenolic compounds and VOCs and if the occurrence and concentrations of SVOCs and VOCs vary regionally. A better understanding of the factors that affect SVOCs and VOCs is needed to estimate contaminant loads and concentrations at unmonitored sites and to identify potentially affected water resources. Deterministic studies and modeling also are needed to understand the physical and chemical processes controlling highway-runoff quality and contaminant transport and fate.

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TABLES 1–7

Table 1 . Documented quality criteria of data on semivolatile and volatile organic compounds in urban stormwater and highway runoff

[°C, degrees Celsius; cm, centimeters; m, meters; µg/L, micrograms per liter; mg/L, milligrams per liter; ng/L, nanograms per liter; ng/g, nanograms per gram; ppb, parts per billion; NA, not applicable; ND, not described; SS, stainless steel; O+G, oil and grease; GC/FID, gas chromatography/flame-ionization detector; GC-MS, gas chromatography-mass spectrometry; HCl, hydrochloric acid; HPLC, high performance liquid chromatography; IR, infrared spectrometry; EWI, equal-width increment; MRL, minimum reporting limit; NaCl, sodium chloride; NPDES, National Pollutant Discharge Elimination System; NURP, Nationwide Urban Runoff Program; %, percent; ~, approximate; ---, no comment]

| Reference | Where | Years data were collected | Water sampling protocol | | | | | Sediment and soil sampling protocol | | | | Comment |
|-----------------------------|-------------------------|---------------------------|-------------------------|----------------------|---------------------|-----------------------|-----------------------|-------------------------------------|----------|-----------------------|------------|---|
| | | | Sampler type | Material | Manual or automatic | Discrete or composite | Where in stream | Sampler type | Material | Discrete or composite | Depth (cm) | |
| Baldys and others, 1997 | Dallas–Ft. Worth, Texas | 1992–94 | auto-sampler + bottles | Teflon, steel, glass | both | both | ND | NA | NA | NA | NA | Flow-weighted composites; not known if splitter used. Sampled where storm drain well mixed. |
| Baldys and others, 1998 | Dallas–Ft. Worth, Texas | 1992–93 | auto-sampler + bottles | Teflon, steel, glass | both | both | ND | NA | NA | NA | NA | Flow-weighted composites; not known if splitter used. Sampled where storm drain well mixed. |
| Barrett and others, 1993 | Review paper | 1976–92 | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| Bjorseth and Ramdahl, 1985 | Review paper | 1775–84 | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| Bomboi and others, 1990 | Madrid, Spain | 1985–86 | tray | metal | manual | discrete | assume all flow | NA | NA | NA | NA | Simulated rain for runoff samples; extracted water, solids separately. |
| Bomboi and Hernandez, 1991 | Madrid, Spain | ND | tray | metal | manual | discrete | assume all flow | NA | NA | NA | NA | Same data as Bomboi and others, 1990. |
| Boom and Marsalek, 1988 | Ontario, Canada | 1986–87 | corer for snow | SS | manual | discrete | NA | NA | NA | NA | NA | NA |
| Brown and others, 1985 | Tampa | 1982–83 | ND | ND | ND | both | ND | ponar | ND | composite | 0–5 | Discrete samples of first flush, composite-type unknown; whole water and suspended solids analyzed. |
| Butler and others, 1984 | England | ND | NA | NA | NA | NA | NA | ND | ND | discrete | 0–4, 4–8 | Samples sieved to 18 mesh. |
| Cole and others, 1984 | 15 NURP cities | 1979–82 | ND | ND | ND | both | ND | NA | NA | NA | NA | Compilation of coordinated studies; low-weighted composites. |
| Delzer and others, 1996 | 16 NPDES cities | 1991–95 | vials | glass | manual | discrete | ND | NA | NA | NA | NA | Compilation of independent studies; sampling procedures varied. |
| Edwards, 1983 | Review paper | 1956–82 | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| Eganhouse and Kaplan, 1981a | Los Angeles, California | 1978 | ND | steel | manual | discrete | center, below surface | NA | NA | NA | NA | Whole and filtered water analyzed. |
| Eganhouse and Kaplan, 1981b | Los Angeles, California | 1978 | ND | steel | manual | discrete | center, below surface | NA | NA | NA | NA | Same data as Eganhouse and Kaplan, 1981a. |
| Ellis and others, 1985 | London, England | ND | NA | NA | NA | NA | NA | grab sampler | SS | composite | surface | NA |

Table 1 . Documented quality criteria of data on semivolatile and volatile organic compounds in urban stormwater and highway runoff—*Continued*

| Reference | Where | Years data were collected | Water sampling protocol | | | | | Sediment and soil sampling protocol | | | | Comment |
|-----------------------------|--|---------------------------|-------------------------|----------------|----------------------|-----------------------|-----------------|-------------------------------------|----------|-----------------------|--------------------|---|
| | | | Sampler type | Material | Manual or automatic | Discrete or composite | Where in stream | Sampler type | Material | Discrete or composite | Depth (cm) | |
| Evans and others, 1990 | United Kingdom | 1987–88 | NA | NA | NA | NA | NA | jars | glass | discrete | 0–10 | Collected bottom sediment monthly for 1 year. |
| Fam and others, 1987 | San Francisco, California | ND | bottles + buckets | glass + metal | manual | discrete | ND | NA | NA | NA | NA | Particulates and filtrate analyzed. |
| Gavens and others, 1982 | London, England | ND | ND | ND | ND | ND | ND | corer | SS | discrete | 0–10, 290–300 | Whole water analyzed; sediment samples sieved into several fractions. |
| Gjessing and others, 1984 | Norway | 1981–82 | cans | aluminum | manual | discrete | ND | gravity corer | acrylic | discrete | 0–2 | NA |
| Gupta, 1981 | Milwaukee, Harrisburg, Nashville, Denver | 1975–78 | ISCO | ND | both | both | ND | NA | NA | NA | NA | Oil and grease sampled manually; whole water analyzed. Flow-weighted composites. |
| Harrison and Johnston, 1985 | England | 1981–83 | funnel | plastic, glass | passive auto-sampler | composite | NA | NA | NA | NA | NA | Includes data from Johnston and Harrison, 1984. |
| Herrmann, 1981 | Germany | 1979 | auto-sampler | ND | auto | discrete | ND | pan | ND | NA | surface | Sampled stream, snow, street dust, bed load, rain. Mostly whole water analyzed. |
| Hewitt and Rashed, 1990 | England | ND | funnel, auto-samplers | ND | passive auto-sampler | discrete | NA | trowel | ND | discrete | 0–10, 10–20, 20–30 | Bulk deposition sampled; autosampler for SWRO. |
| Hoffman and others, 1983 | Narraganset Bay | 1979–81 | bucket | metal | manual | discrete | ND | NA | NA | NA | NA | Samples collected at about 30-minute intervals; suspended solids and filtrate analyzed. |
| Hoffman and others, 1984 | Narraganset Bay | 1979–81 | bucket | metal | manual | discrete | ND | NA | NA | NA | NA | Same data as Hoffman and others, 1983. |
| Hoffman and others, 1985 | Rhode Island | 1979–81 | bucket | metal | manual | discrete | ND | NA | NA | NA | NA | Samples collected at about 30-minute intervals; suspended solids and filtrate analyzed. |
| Hoffman and Quinn, 1987 | Review paper | 1969–87 | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| Hunter and others, 1979 | Philadelphia, Pennsylvania | 1974 | ND | ND | manual | both | ND | NA | NA | NA | NA | Flow-weighed composites; centrifuged water and particulates analyzed separately. |
| Johnston and Harrison, 1984 | England | 1982–83 | funnel | plastic | passive auto-sampler | composite | NA | NA | NA | NA | NA | Bulk deposition sampled biweekly. |
| Latimer and others, 1990 | Warwick, Rhode Island | 1979–81 | bucket | metal | manual | discrete | ND | trowel | SS | discrete | ND | Suspended solids and filtrate analyzed. Soil, vegetation, street dust sampled. |
| Line and others, 1997 | North Carolina | 1993–94 | auto-sampler | ND | auto-sampler | discrete | ND | NA | NA | NA | NA | Only first-flush samples. Samples iced after collection and preserved at lab. |

Table 1 . Documented quality criteria of data on semivolatile and volatile organic compounds in urban stormwater and highway runoff—*Continued*

| Reference | Where | Years data were collected | Water sampling protocol | | | | | Sediment and soil sampling protocol | | | | Comment |
|------------------------------|--|---------------------------|-------------------------|-------------------------------|-----------------------------------|-------------------------|---------------------------|-------------------------------------|----------|-----------------------|------------|---|
| | | | Sampler type | Material | Manual or automatic | Discrete or composite | Where in stream | Sampler type | Material | Discrete or composite | Depth (cm) | |
| Lopes and Bender, 1998 | 16 NPDES cities | 1991–95 | vials | glass | manual | discrete | ND | NA | NA | NA | NA | Includes data from Delzer and others, 1996. |
| Lopes and others, 1995 | Phoenix, Arizona | 1991–93 | auto-samplers | Teflon, steel, glass | both | both | ND, EWI for stream | NA | NA | NA | NA | Discrete manual samples for VOCs, phenols, O+G. Flow-weighted composites from churn splitter. |
| Makepeace and others, 1995 | Review paper | 1970–94 | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| Marsalek and Schroeter, 1988 | Canada, Great Lakes region | 1979–83 | auto-samplers | metal, glass | pumping and passive auto-samplers | flow-weight composite | bank, ND | filtered water | ND | ND | ND | Filtered at 5 micron due to high solids. Also collected street sediments. |
| Prahl and others, 1984 | Seattle, Washington and Columbia River | 1979–80 | pump | glass | manual | discrete | middle, 1–2 m deep | filtered water | NA | NA | NA | Only analyzed suspended sediment filtered from water using nitrogen. Also sampled air. |
| Schondorm and Herrmann, 1987 | Germany | 1986 | snow lysimeter | Aluminum foil covered plywood | manual | discrete | NA | NA | NA | NA | NA | NA |
| Stenstrom and others, 1984 | Richmond, California | 1980–81 | bottles | glass | manual | discrete | ND | NA | NA | NA | NA | Sampled at turbulent locations for uniform sample. |
| Stotz, 1987 | Germany | 1978–81 | ND | ND | ND | composite | ND | NA | NA | NA | NA | Whole water and centrifuged samples analyzed; unknown composite type. |
| von Guerard and Weiss, 1995 | Colorado Springs, Colorado | 1992 | auto-samplers | Teflon, glass | both | depth integrated manual | ND, flow turbulent, mixed | NA | NA | NA | NA | Discrete manual samples for VOCs, phenols, O+G. Flow-weighted composites from churn and cone splitter. |
| Wakeham and others, 1980 | Switzerland, Seattle, Washington | 1976–77 | NA | NA | NA | NA | NA | gravity, piston corers | ND | NA | max 6.4 m | Gravity cores for shallow (<1 m) cores, piston for deep cores. |
| Wiland and Malina, 1976 | Austin, Texas | 1976 | bottle | glass | manual | discrete | ND | NA | NA | NA | NA | Simulated rainfall for runoff |
| Yamane and others, 1990 | Tokyo, Japan | ND | bottle | glass | manual | discrete | ND | ND | ND | ND | ND | Whole water analyzed; sediment, street dust and highway dust analyzed. |
| Zawlocki and others, 1980 | Seattle, Washington | 1979–80 | tank, drum | poly-ethylene | automatic | composite | used flow-splitter | NA | NA | NA | NA | Samples taken from well-mixed tank, drum. Flume, flow splitter made of fiberglass, contamination assumed negligible. Filtrate, particulates analyzed. |

Table 1 . Documented quality criteria of data on semivolatile and volatile organic compounds in stormwater and highway runoff—*Continued*

| Reference | Laboratory methods | | | Quality assurance | | | | Quality control | | |
|-----------------------------|--------------------|--------------------|-------------------------|-------------------|-----------------|----------------|--|---|---|----------------------------------|
| | Instrument | MRL | Comment | Cleaned sampler? | Container | Preservation | Comment | Field QC | Lab QC | Comment |
| Baldys and others, 1997 | ND | mostly 0.2–10 mg/L | USGS analytical methods | ND | ND | ND | | equipment, trip blanks, matrix spikes, replicates | ND | QC data provided |
| Baldys and others, 1998 | ND | mostly 0.2–10 µg/L | USGS analytical methods | ND | ND | ND | --- | blanks, replicates, spikes | reference | No QC results discussed |
| Barrett and others, 1993 | NA | NA | --- | NA | NA | NA | --- | NA | NA | --- |
| Bjorseth and Ramdahl, 1985 | NA | NA | --- | NA | NA | NA | --- | NA | NA | --- |
| Bomboi and others, 1990 | GC-FID, GC-MS | ND | --- | ND | ND | ND | --- | ND | ND | --- |
| Bomboi and Hernandez, 1991 | GC-FID, GC-MS | ND | --- | ND | ND | ND | --- | ND | ND | --- |
| Boom and Marsalek, 1988 | GC-FID | 0.05 µg/L | --- | ND | stainless steel | ND | Slowly melted snow | ND | ND | --- |
| Brown and others, 1985 | GC-FID | ND | 1 µg/L | ND | glass | chilled 4°C | Teflon-lined lids | ND | all analyses duplicated, blanks, recovery samples | Teflon-lined lids |
| Butler and others, 1984 | GC-fluorescence | ND | --- | ND | ND | ND | --- | ND | ND | --- |
| Cole and others, 1984 | ND | varied | Many labs used | ND | ND | ND | Guidelines for consistent sample collection, but details not given | blanks, replicates, spikes | performance evaluation samples, surrogates | Summarized QC evaluation |
| Delzer and others, 1996 | GC-MS | 0.2–1 µg/L | USGS analytical methods | ND | glass | ND | --- | ND | ND | --- |
| Edwards, 1983 | NA | NA | --- | NA | NA | NA | --- | NA | NA | --- |
| Eganhouse and Kaplan, 1981a | gravimetric | ND | --- | ND | glass | ND | Samples shaken and split into 2 bottles | ND | ND | --- |
| Eganhouse and Kaplan, 1981b | gravimetric | ND | --- | ND | glass | ND | Samples shaken and split into 2 bottles | ND | ND | --- |
| Ellis and others, 1985 | GC-FID, GC-MS | ND | --- | yes | ND | ND | --- | ND | ND | --- |
| Evans and others, 1990 | HPLC, GS-MS | ND | Recovery 83–131% | yes | glass | chilled | Covered w/ foil, capped w/metal lid | ND | blanks, recovery samples | Blank, recovery corrections made |
| Fam and others, 1987 | GC-FID | ND | Standard methods | ND | glass | acidify, chill | --- | ND | ND | --- |

Table 1 . Documented quality criteria of data on semivolatile and volatile organic compounds in stormwater and highway runoff—*Continued*

| Reference | Laboratory methods | | | Quality assurance | | | | Quality control | | |
|-----------------------------|--------------------|---------------|-------------------------|-------------------|-----------|---------------------------|--|--------------------------|---|--|
| | Instrument | MRL | Comment | Cleaned sampler? | Container | Preservation | Comment | Field QC | Lab QC | Comment |
| Gavens and others, 1982 | GC-FID, GC-MS | ND | --- | yes | ND | sediment frozen; water ND | --- | ND | ND | Suggest naphthalene lost during workup |
| Gjessing and others, 1984 | GC-ND, reference | ND | --- | ND | ND | ND | --- | ND | ND | --- |
| Gupta, 1981 | Standard methods | ND | --- | ND | ND | chilled | Overnight shipping | ND | ND | --- |
| Harrison and Johnston, 1985 | HPLC, GC-MS | ND | --- | yes | glass | ND | Plastic samplers, 2 weeks w/o chilling | ND | blanks | Blank corrections made |
| Herrmann, 1981 | HPLC, fluorescence | ND | ND | ND | ND | ND | Snow, street dust frozen in polyethylene bags | ND | ND | --- |
| Hewitt and Rashed, 1990 | HPLC | ND | --- | ND | ND | ND | --- | ND | ND | --- |
| Hoffman and others, 1983 | GC-FID, GC-MS | ND | Precision ~15% | ND | glass | ND | Teflon-lined lids | ND | blanks | No blank corrections needed |
| Hoffman and others, 1984 | GC-FID, GC-MS | ND | Precision mostly 11–25% | ND | glass | ND | Teflon-lined lids | ND | blanks | --- |
| Hoffman and others, 1985 | GC-FID, GC-MS | ND | Precision mostly 11–25% | ND | glass | ND | Teflon-lined lids | ND | blanks | --- |
| Hoffman and Quinn, 1987 | NA | NA | --- | NA | NA | NA | --- | NA | NA | --- |
| Hunter and others, 1979 | GC-FID | ND | 85–95% recovery | ND | glass | ND | --- | ND | ND | --- |
| Johnston and Harrison, 1984 | HPLC | ND | | yes | glass | ND | Plastic samplers, 2 weeks w/o chilling | ND | ND | 43–87% recovery, corrections made |
| Latimer and others, 1990 | GC-FID | ND | Relative deviation <20% | yes | glass | none | --- | ND | blanks | Blank data given |
| Line and others, 1997 | Standard methods | 5 to 100 µg/L | --- | yes | ND | chilled | Sometimes hours before samples were retrieved, chilled; autosampler for VOCs | Automatic sampler blanks | lab-split duplicates, spikes for about 10% of samples | --- |

Table 1 . Documented quality criteria of data on semivolatile and volatile organic compounds in stormwater and highway runoff—*Continued*

| Reference | Laboratory methods | | | Quality assurance | | | | Quality control | | |
|------------------------------|---|---|--|-------------------|-----------|---|--|--|---|--|
| | Instrument | MRL | Comment | Cleaned sampler? | Container | Preservation | Comment | Field QC | Lab QC | Comment |
| Lopes and Bender, 1998 | GC-MS | 0.2–1 µg/L | USGS analytical methods | ND | glass | ND | --- | ND | ND | --- |
| Lopes and others, 1995 | ND | mostly 0.2–10 µg/L | USGS analytical methods | yes | ND | chilled | Autosampler checked with concurrent manual samples | Automatic sampler and trip blanks, matrix spikes, replicates | ND | Some compounds may degrade; blanks clean |
| Makepeace and others, 1995 | NA | NA | --- | NA | NA | NA | --- | NA | NA | --- |
| Marsalek and Schroeter, 1988 | GC/FID, ECD | water MDL 0.001–0.05 ppb. sediment 5–50 ppb | Recovery 60–110%, precision 12–83% | ND | reference | reference | --- | ND | ND, but done | --- |
| Prahl and others, 1984 | GC-FID air samples, HPLC sediment samples | ND | --- | yes | glass | air samples refrigerated, sediment frozen | Nitrogen used for filtering | ND | ND | GC, HPLC ± 15% |
| Schondorm and Herrmann, 1987 | HPLC, fluorescence | MDL 0.03–0.15ng/L | 85-90% recovery | ND | ND | ND | --- | ND | ND | --- |
| Stenstrom and others, 1984 | IR, GC-FID | ND | --- | yes | glass | ND | Sampled turbulent area for well mixed sample | ND | ND | --- |
| Stotz, 1987 | reference | ND | --- | ND | ND | ND | --- | ND | ND | --- |
| von Guerard and Weiss, 1995 | ND | mostly 0.2–10 µg/L | USGS analytical methods | yes | ND | chilled | Manual samples from turbulent, well-mixed flow | blanks, spikes | ND | Low spike recovery, blanks clean |
| Wakeham and others, 1980 | GC-FID | 1-2 ng/g | Reproducibility ± 25% | ND | ND | frozen or chilled at 4°C | Preservation for samples from 2 lakes not described | ND | blanks | Data blank and recovery corrected |
| Wiland and Malina, 1976 | IR | ND | --- | ND | glass | chilled at 4°C | Plastic sheet under truck used for simulated rain | ND | ND | --- |
| Yamane and others, 1990 | GC-FID, HPLC | ND | --- | ND | glass | NaCl, HCl pH<2.0 | Preserved on site | ND | ND | --- |
| Zawlocki and others, 1980 | GC/MS, Standard Methods | 100 µg/L for trace organics | Trace organics precision ± 50%, results summed into compound class | ND | glass | chilled | Samples well mixed, but don't know if they are of entire storm | ND | lab-split replicates, system blanks, recoveries | Particulate replicates ± 5%, total organic extracts within 20% |

Table 2 . Semivolatile and volatile organic compounds not detected in stormwater

[IUPAC, International Union of Pure and Applied Chemistry; NURP, Nationwide Urban Runoff Program; NR, not reported]

| IUPAC compound name (common name) | Minimum reporting limit (range), in micrograms per liter | Location | Reference |
|---------------------------------------|--|-----------------------|-----------------------------|
| Semivolatile organic compounds | | | |
| Benzidine | 40 | Maricopa County, AZ | Lopes and others, 1995 |
| | 40 | Colorado Springs, CO | von Guerard and Weiss, 1995 |
| | 40 | Dallas/Fort Worth, TX | Baldys and others, 1998 |
| 4-Bromophenyl phenyl ether | 5 | Maricopa County, AZ | Lopes and others, 1995 |
| | 5 | Colorado Springs, CO | von Guerard and Weiss, 1995 |
| | 5 | Dallas/Fort Worth, TX | Baldys and others, 1998 |
| | NR | Summary–NURP | Cole and others, 1984 |
| 0-Chlorobenzene | 5 | Colorado Springs, CO | von Guerard and Weiss, 1995 |
| 4-Chloro-3-methylphenol | 30 | Dallas/Fort Worth, TX | Baldys and others, 1998 |
| bis(2-Chloroethoxy)methane | 5 | Maricopa County, AZ | Lopes and others, 1995 |
| | 5 | Colorado Springs, CO | von Guerard and Weiss, 1995 |
| | 5 | Dallas/Fort Worth, TX | Baldys and others, 1998 |
| | NR | Summary–NURP | Cole and others, 1984 |
| bis(2-Chloroethyl)ether | 5 | Maricopa County, AZ | Lopes and others, 1995 |
| | 5 | Colorado Springs, CO | von Guerard and Weiss, 1995 |
| | 5 | Dallas/Fort Worth, TX | Baldys and others, 1998 |
| | NR | Summary–NURP | Cole and others, 1984 |
| bis(2-Chloroisopropyl)ether | 5 | Maricopa County, AZ | Lopes and others, 1995 |
| | 5 | Colorado Springs, CO | von Guerard and Weiss, 1995 |
| | 5 | Dallas/Fort Worth, TX | Baldys and others, 1998 |
| | NR | Summary–NURP | Cole and others, 1984 |
| 4-Chlorophenyl phenyl ether | 5 | Maricopa County, AZ | Lopes and others, 1995 |
| | 5 | Colorado Springs, CO | von Guerard and Weiss, 1995 |
| | 5 | Dallas/Fort Worth, TX | Baldys and others, 1998 |
| | NR | Summary–NURP | Cole and others, 1984 |
| 1,2,5,6-Dibenzanthracene | 10 | Colorado Springs, CO | von Guerard and Weiss, 1995 |
| 3, 3'-Dichlorobenzidine | 20 | Maricopa County, AZ | Lopes and others, 1995 |
| | 20 | Colorado Springs, CO | von Guerard and Weiss, 1995 |
| | 20 | Dallas/Fort Worth, TX | Baldys and others, 1998 |
| 2,4-Dichlorophenol | 5 | Maricopa County, AZ | Lopes and others, 1995 |
| | 5 | Colorado Springs, CO | von Guerard and Weiss, 1995 |
| | 5 | Dallas/Fort Worth, TX | Baldys and others, 1998 |
| | NR | Summary–NURP | Cole and others, 1984 |
| Dimethylphthalate | 5 | Maricopa County, AZ | Lopes and others, 1995 |
| | 5 | Colorado Springs, CO | von Guerard and Weiss, 1995 |
| | 5 | Dallas/Fort Worth, TX | Baldys and others, 1998 |
| | NR | Summary–NURP | Cole and others, 1984 |
| 4,6-Dinitro-2-methylphenol | 30 | Dallas/Fort Worth, TX | Baldys and others, 1998 |
| 4,6-Dinitro-ortho-cresol | 30 | Colorado Springs, CO | von Guerard and Weiss, 1995 |
| | NR | Summary–NURP | Cole and others, 1984 |
| 2,4-Dinitrophenol | 20 | Maricopa County, AZ | Lopes and others, 1995 |
| | 20 | Colorado Springs, CO | von Guerard and Weiss, 1995 |
| | 20 | Dallas/Fort Worth, TX | Baldys and others, 1998 |
| | NR | Summary–NURP | Cole and others, 1984 |
| 2,4-Dinitrotoluene | 5 | Maricopa County, AZ | Lopes and others, 1995 |
| | 5 | Colorado Springs, CO | von Guerard and Weiss, 1995 |
| | 5 | Dallas/Fort Worth, TX | Baldys and others, 1998 |
| 2,6-Dinitrotoluene | 5 | Maricopa County, AZ | Lopes and others, 1995 |
| | 5 | Colorado Springs, CO | von Guerard and Weiss, 1995 |
| | 5 | Dallas/Fort Worth, TX | Baldys and others, 1998 |
| 1,2-Diphenyl hydrazine | 5 | Colorado Springs, CO | von Guerard and Weiss, 1995 |
| | 5 | Dallas/Fort Worth, TX | Baldys and others, 1998 |

Table 2 . Semivolatile and volatile organic compounds not detected in stormwater—Continued

| IUPAC compound name (common name) | Minimum reporting limit (range), in micrograms per liter | Location | Reference |
|---|--|-----------------------|-----------------------------|
| Semivolatile organic compounds— | | | |
| <i>Continued</i> | | | |
| Hexachlorobutadiene | 5 | Maricopa County, AZ | Lopes and others, 1995 |
| | 5 | Colorado Springs, CO | von Guerard and Weiss, 1995 |
| | 0.2–10 | Dallas/Fort Worth, TX | Baldys and others, 1998 |
| Hexachlorocyclopentadiene | 5 | Maricopa County, AZ | Lopes and others, 1995 |
| | 5 | Dallas/Fort Worth, TX | Baldys and others, 1998 |
| Hexachloroethane | 5 | Maricopa County, AZ | Lopes and others, 1995 |
| | 5 | Colorado Springs, CO | von Guerard and Weiss, 1995 |
| | 5 | Dallas/Fort Worth, TX | Baldys and others, 1998 |
| Isophorone | 5 | Maricopa County, AZ | Lopes and others, 1995 |
| | 5 | Colorado Springs, CO | von Guerard and Weiss, 1995 |
| | 5 | Dallas/Fort Worth, TX | Baldys and others, 1998 |
| Nitrobenzene | 5 | Maricopa County, AZ | Lopes and others, 1995 |
| | 5 | Colorado Springs, CO | von Guerard and Weiss, 1995 |
| | 5 | Dallas/Fort Worth, TX | Baldys and others, 1998 |
| 2-Nitrophenol | 5 | Maricopa County, AZ | Lopes and others, 1995 |
| | 5 | Colorado Springs, CO | von Guerard and Weiss, 1995 |
| | 5 | Dallas/Fort Worth, TX | Baldys and others, 1998 |
| | NR | Summary–NURP | Cole and others, 1984 |
| n-nitrosodi-n-propylamine | 5 | Maricopa County, AZ | Lopes and others, 1995 |
| | 5 | Colorado Springs, CO | von Guerard and Weiss, 1995 |
| | 5 | Dallas/Fort Worth, TX | Baldys and others, 1998 |
| n-nitrosodiphenylamine | 5 | Maricopa County, AZ | Lopes and others, 1995 |
| | 5 | Colorado Springs, CO | von Guerard and Weiss, 1995 |
| | 5 | Dallas/Fort Worth, TX | Baldys and others, 1998 |
| n-nitrosodimethylamine | 5 | Maricopa County, AZ | Lopes and others, 1995 |
| | 5 | Colorado Springs, CO | von Guerard and Weiss, 1995 |
| | 5 | Dallas/Fort Worth, TX | Baldys and others, 1998 |
| Parachlorometacresol | 30 | Colorado Springs, CO | von Guerard and Weiss, 1995 |
| Phenol | 3 | Colorado Springs, CO | von Guerard and Weiss, 1995 |
| | 3 | Dallas/Fort Worth, TX | Baldys and others, 1998 |
| 2,4,6-Trichlorophenol | 20 | Maricopa County, AZ | Lopes and others, 1995 |
| | 20 | Colorado Springs, CO | von Guerard and Weiss, 1995 |
| | 20 | Dallas/Fort Worth, TX | Baldys and others, 1998 |
| | NR | Summary–NURP | Cole and others, 1984 |
| Volatile organic compounds | | | |
| Bromobenzene | 0.2 | Colorado Springs, CO | von Guerard and Weiss, 1995 |
| | 0.2 - 10 | Dallas/Fort Worth, TX | Baldys and others, 1998 |
| Bromochloromethane | 0.2 | Maricopa County, AZ | Lopes and others, 1995 |
| | 0.2 - 10 | Dallas/Fort Worth, TX | Baldys and others, 1998 |
| Bromomethane (Methyl bromide) | 0.2 | Maricopa County, AZ | Lopes and others, 1995 |
| | 0.2 | Colorado Springs, CO | von Guerard and Weiss, 1995 |
| | 0.2 - 10 | Dallas/Fort Worth, TX | Baldys and others, 1998 |
| Chloroethane | 0.2 | Maricopa County, AZ | Lopes and others, 1995 |
| | 0.2 | Colorado Springs, CO | von Guerard and Weiss, 1995 |
| | 0.2 - 10 | Dallas/Fort Worth, TX | Baldys and others, 1998 |
| | NR | Summary–NURP | Cole and others, 1995 |
| 2-Chloroethyl vinyl ether | 1.0 | Maricopa County, AZ | Lopes and others, 1995 |
| | 1.0 | Colorado Springs, CO | von Guerard and Weiss, 1995 |
| | 1.0 - 50 | Dallas/Fort Worth, TX | Baldys and others, 1998 |
| Chloromethane | 0.2 | Colorado Springs, CO | von Guerard and Weiss, 1995 |
| 1-Chloro-2-Methylbenzene (o-Chlorotoluene) | 0.2 | Maricopa County, AZ | Lopes and others, 1995 |
| | 0.2 | Colorado Springs, CO | von Guerard and Weiss, 1995 |

Table 2 . Semivolatile and volatile organic compounds not detected in stormwater—Continued

| IUPAC compound name (common name) | Minimum reporting limit (range), in micrograms per liter | Location | Reference |
|---|--|--|---|
| Volatile organic compounds— Continued | | | |
| 1,2-Dibromo-3-chloropropane (Dibromochloropropane) | 1.0 1.0 1.0 - 10 | Maricopa County, AZ Colorado Springs, CO Dallas/Fort Worth, TX | Lopes and others, 1995 von Guerard and Weiss, 1995 Baldys and others, 1998 |
| 1,2-Dibromoethane | 0.2 0.2 - 10 | Colorado Springs, CO Dallas/Fort Worth, TX | von Guerard and Weiss, 1995 Baldys and others, 1998 |
| 1,2-Dichlorobenzene | 0.2 0.2 - 10 NR | Colorado Springs, CO Dallas/Fort Worth, TX Summary–NURP | von Guerard and Weiss, 1995 Baldys and others, 1998 Cole and others, 1995 |
| 1,3-Dichlorobenzene | 0.2 0.2 - 10 NR | Colorado Springs, CO Dallas/Fort Worth, TX Summary–NURP | von Guerard and Weiss, 1995 Baldys and others, 1998 Cole and others, 1995 |
| 1,4-Dichlorobenzene | 0.2 0.2 - 10 NR | Colorado Springs, CO Dallas/Fort Worth, TX Summary–NURP | von Guerard and Weiss, 1995 Baldys and others, 1998 Cole and others, 1995 |
| Dichlorodifluoromethane | 0.2 0.2 0.2 - 10 NR | Maricopa County, AZ Colorado Springs, CO Dallas/Fort Worth, TX Summary–NURP | Lopes and others, 1995 von Guerard and Weiss, 1995 Baldys and others, 1998 Cole and others, 1995 |
| 1,3-Dichloropropane | 0.2 0.2 0.2 - 10 | Maricopa County, AZ Colorado Springs, CO Dallas/Fort Worth, TX | Lopes and others, 1995 von Guerard and Weiss, 1995 Baldys and others, 1998 |
| 2,2-Dichloropropane | 0.2 0.2 0.2 - 10 | Maricopa County, AZ Colorado Springs, CO Dallas/Fort Worth, TX | Lopes and others, 1995 von Guerard and Weiss, 1995 Baldys and others, 1998 |
| 1,1-Dichloropropene | 0.2 0.2 0.2 - 10 | Maricopa County, AZ Colorado Springs, CO Dallas/Fort Worth, TX | Lopes and others, 1995 von Guerard and Weiss, 1995 Baldys and others, 1998 |
| cis-1,3-Dichloropropene | 0.2 0.2 0.2 - 10 | Maricopa County, AZ Colorado Springs, CO Dallas/Fort Worth, TX | Lopes and others, 1995 von Guerard and Weiss, 1995 Baldys and others, 1998 |
| trans-1,3-Dichloropropene | 0.2 0.2 0.2 - 10 | Maricopa County, AZ Colorado Springs, CO Dallas/Fort Worth, TX | Lopes and others, 1995 von Guerard and Weiss, 1995 Baldys and others, 1998 |
| (1,1-Dimethylethyl)benzene (tert-Butylbenzene) | 0.2 0.2 0.2 - 10 | Maricopa County, AZ Colorado Springs, CO Dallas/Fort Worth, TX | Lopes and others, 1995 von Guerard and Weiss, 1995 Baldys and others, 1998 |
| 1,1,2,3,4,4-Hexachloro-1,3-butadiene (hexachlorobutadiene) | 0.2 0.2 - 10 NR | Colorado Springs, CO Dallas/Fort Worth, TX Summary–NURP | von Guerard and Weiss, 1995 Baldys and others, 1998 Cole and others, 1995 |
| (1-Methylpropyl)benzene (sec-Butylbenzene) | 0.2 0.2 0.2 - 10 | Maricopa County, AZ Colorado Springs, CO Dallas/Fort Worth, TX | Lopes and others, 1995 von Guerard and Weiss, 1995 Baldys and others, 1998 |
| Parachlorotoluene | 0.2 | Colorado Springs, CO | von Guerard and Weiss, 1995 |
| 2-Propenal (Acrolein) | 20 20 20 - 1000 | Maricopa County, AZ Colorado Springs, CO Dallas/Fort Worth, TX | Lopes and others, 1995 von Guerard and Weiss, 1995 Baldys and others, 1998 |
| 2-Propenenitrile (Acrylonitrile) | 20 20 20 - 1000 | Maricopa County, AZ Colorado Springs, CO Dallas/Fort Worth, TX | Lopes and others, 1995 von Guerard and Weiss, 1995 Baldys and others, 1998 |
| 1,1,1,2-Tetrachloroethane | 0.2 0.2 0.2 - 10 | Maricopa County, AZ Colorado Springs, CO Dallas/Fort Worth, TX | Lopes and others, 1995 von Guerard and Weiss, 1995 Baldys and others, 1998 |

Table 2 . Semivolatile and volatile organic compounds not detected in stormwater—*Continued*

| IUPAC compound name (common name) | Minimum reporting limit (range), in micrograms per liter | Location | Reference |
|---|--|-----------------------|-----------------------------|
| Volatile organic compounds— <i>Continued</i> | | | |
| 1,2,3-Trichlorobenzene | 0.2 | Maricopa County, AZ | Lopes and others, 1995 |
| | 0.2 | Colorado Springs, CO | von Guerard and Weiss, 1995 |
| | 0.2 - 10 | Dallas/Fort Worth, TX | Baldys and others, 1998 |
| 1,2,4-Trichlorobenzene | 0.2 | Maricopa County, AZ | Lopes and others, 1995 |
| | 0.2 | Colorado Springs, CO | von Guerard and Weiss, 1995 |
| | 0.2 - 10 | Dallas/Fort Worth, TX | Baldys and others, 1998 |
| | NR | Summary–NURP | Cole and others, 1995 |
| 1,2,3-Trichloropropane | 0.2 | Maricopa County, AZ | Lopes and others, 1995 |
| | 0.2 | Colorado Springs, CO | von Guerard and Weiss, 1995 |
| | 0.2 - 10 | Dallas/Fort Worth, TX | Baldys and others, 1998 |

Table 3 . Loading factors for semivolatile organic compounds as a function of land use

[kg, kilogram; km², square kilometer; km, kilometer; yr, year; cm, centimeter; m², square meter; PAHs, polycyclic aromatic hydrocarbons; µg, microgram; m, meter; hwy, highway; E-5, 10 to the exponent -5; --, factors were not estimated]

| Compound class | Residential | Commercial | Industrial | Highway | Bridges | Reference |
|------------------------|---|---|--|--|-----------|-----------------------------|
| Stormwater | | | | | | |
| Petroleum hydrocarbons | 180 (kg/km ²)/yr | 580 (kg/km ²)/yr | 14,000 (kg/km ²)/yr | 7,800 (kg/km ²)/yr | -- | Hoffman and Quinn, 1987 |
| | -- | -- | -- | 2.5E-5 (kg/vehicle)/km | -- | Hoffman and others, 1985 |
| | -- | -- | -- | 126 (kg/km ²)/cm rain | -- | Hoffman and others, 1985 |
| | 2,560 (kg/km ²)/yr | -- | -- | -- | -- | Hunter and others, 1979 |
| Oil and grease | -- | -- | -- | 485-76,700 (kg/km ²)/yr | 4.1 kg/yr | Barrett and others, 1993 |
| | -- | -- | -- | 9-16 (kg/km ²)/event | -- | Barrett and others, 1993 |
| | -- | -- | -- | 27-298 (kg/km ²)/cm rain | -- | Wiland and Malina, 1976 |
| | 9.8 (kg/km ²)/cm rain | 239 (kg/km ²)/cm rain | -- | -- | -- | Stenstrom and others, 1984 |
| PAHs | ¹ 0.009 (kg/km ²)/yr | ¹ 0.100 (kg/km ²)/yr | ¹ 2.42 (kg/km ²)/yr | ¹ 1.22 (kg/km ²)/yr | -- | Hoffman and Quinn, 1987 |
| | ² 0.258 (kg/km ²)/yr | ² 0.589 (kg/km ²)/yr | ² 3.97 (kg/km ²)/yr | ² 16.9 (kg/km ²)/yr | -- | Hoffman and Quinn, 1987 |
| | -- | -- | -- | 0.5-1.8 (kg/km ²)/yr | -- | Stotz, 1987 |
| | -- | -- | -- | 5.8E-8 (kg/vehicle)/km | -- | Hoffman and others, 1985 |
| | -- | -- | -- | 0.151 (kg/km ²)/cm rain | -- | Hoffman and others, 1985 |
| Bulk deposition | | | | | | |
| Petroleum hydrocarbons | 61.4 (summer) (µg/m ²)/day | -- | 1,130 (winter) 4,120 (summer) (µg/m ²)/day | -- | -- | Latimer and others, 1990 |
| Oil and grease | -- | -- | -- | -- | 8.1 kg/yr | Barrett and others, 1993 |
| PAHs | -- | -- | -- | ³ 15.6-48 µg/m of hwy/day | -- | Hewitt and Rashed, 1990 |
| | -- | -- | -- | 29-71 (µg/m ²)/yr | -- | Harrison and Johnston, 1985 |

¹Low-molecular-weight PAHs.

²High-molecular-weight PAHs.

³Within 50 meters of highway.

Table 4 . Upper threshold concentrations of selected semivolatile organic compounds in sediment

[CAS, Chemical Abstracts]

| Compound name | CAS number | Threshold concentration, in micrograms per kilogram of sediment |
|----------------------------|------------|---|
| Acenaphthene | 83-32-9 | ¹ 1,300 |
| Acenaphthylene | 208-96-8 | 640 |
| Anthracene | 120-12-7 | 1100 |
| Benz[a]anthracene | 218-00-9 | 693 |
| Benzo[a]pyrene | 50-32-8 | 782 |
| Bis(2-ethylhexyl)phthalate | 117-81-7 | 2,650 |
| Butylbenzylphthalate | 85-68-7 | 11,000 |
| Chrysene | 218-00-9 | 862 |
| Dibenz[a,h]anthracene | 53-70-3 | 260 |
| 1,2-Dichlorobenzene | 120-83-2 | 350 |
| 1,4-Dichlorobenzene | 95-50-1 | 340 |
| Diethylphthalate | 84-66-2 | 630 |
| Di-n-butylphthalate | 84-74-2 | 11,000 |
| Fluoranthene | 206-44-0 | ¹ 6,200 |
| Naphthalene | 91-20-3 | 470 |
| Phenanthrene | 85-01-8 | ¹ 1,800 |
| Pyrene | 129-00-0 | 1,398 |
| 1,2,4-Trichlorobenzene | 120-82-1 | 9,200 |

¹Assumes 1 percent sediment organic carbon.

Table 5 . Comparison of volatile organic compounds detected in the NURP and NPDES studies

[NURP, Nationwide Urban Runoff Program; NPDES, National Pollutant Discharge Elimination System; NA, not analyzed]

| Compound | Frequency of detection, in percent, NURP ¹ | Frequency of detection, in percent, NPDES ² |
|---------------------------------|---|--|
| Toluene | 2 | 23 |
| Xylenes | NA | 17.5 |
| Chloroform | 12 | 13 |
| Trimethylbenzene | NA | 12 |
| Tetrachloroethene | 5 | 8 |
| Naphthalene | 11 | 7 |
| methyl- <i>tert</i> butyl ether | NA | 7 |
| Dichloromethane | 10 | 6 |
| Bromodichloromethane | 1 | 6 |
| Ethylbenzene | 4 | 5 |

¹Cole and others, 1984.

²Delzer and others, 1996.

Table 6 . Comparison of volatile organic compounds in stormwater to drinking-water standards

[µg/L, micrograms per liter; IUPAC, International Union of Pure and Applied Chemistry; CAS, Chemical Abstracts; NPDES, National Pollutant Discharge Elimination System; MCL, maximum contaminant level; HAL, health advisory level (U.S. Environmental Protection Agency, 1996c)]

| IUPAC name | CAS number | Maximum concentration in NPDES samples | Standard, in µg/L | Type of standard |
|---------------------------------|------------|--|-------------------|------------------|
| Methylbenzene | 108-88-3 | 6.6 | 1,000 | MCL |
| Dimethylbenzenes | 1330-20-7 | 15 | 10,000 | MCL |
| Trichloromethane | 67-66-3 | 7.0 | ¹ 100 | MCL |
| Tetrachloroethene | 127-18-4 | 42 | 5 | MCL |
| Naphthalene | 91-20-3 | 5.1 | 20 | HAL |
| Methyl <i>tert</i> -butyl ether | 1634-04-4 | 8.7 | ² 20 | HAL |
| Dichloromethane | 75-09-2 | 13 | 5 | MCL |
| Bromodichloromethane | 75-27-4 | 2.8 | ¹ 100 | MCL |
| Ethylbenzene | 100-41-4 | 2.0 | 700 | MCL |
| Benzene | 71-43-2 | 0.8 | 5 | MCL |

¹Total for all trihalomethanes combined cannot exceed the 100 µg/L.

²Standard varies from 20 to 40 µg/L.

Table 7 . Concentrations of detected semivolatile and volatile organic compounds in stormwater, suspended sediment, and bottom material/soil

[NPDES, National Pollutant Discharge Elimination System; NURP, Nationwide Urban Runoff Program; NR, not reported; ND, not detected; <, less than reporting limit; --, no data]

| Compound name | Location | Land use | | | | | | | | | | | | | | | Reference |
|---|-------------------|----------|-----|------|-------------|-----|------|------------|-----|-------|------------|-----|------|-------------|-----|-------------------------|------------------------------|
| | | Highway | | | Residential | | | Commercial | | | Industrial | | | Unspecified | | | |
| | | Min | Max | Mean | Min | Max | Mean | Min | Max | Mean | Min | Max | Mean | Min | Max | Mean | |
| Semivolatile organic compounds, whole water, in micrograms per liter | | | | | | | | | | | | | | | | | |
| Acenaphthene | United States | | | | | | | | | | | | | | | | |
| | Arizona | | | | | | | | | | | | | | | | |
| | Maricopa County | -- | -- | -- | <5 | <5 | NR | <5 | <5 | NR | <5 | <5 | NR | -- | -- | -- | Lopes and others, 1995 |
| | Colorado | | | | | | | | | | | | | | | | |
| | Colorado Springs | -- | -- | -- | <5 | <5 | NR | <5 | <5 | NR | <5 | <5 | NR | -- | -- | -- | von Guerard and Weiss, 1995 |
| | Texas | | | | | | | | | | | | | | | | |
| | Dallas-Fort Worth | -- | -- | -- | <5 | <5 | NR | <5 | <5 | NR | <5 | <5 | NR | -- | -- | -- | Baldys and others, 1998 |
| | Canada | | | | | | | | | | | | | | | | |
| Canadian Great Lakes | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | NR | NR | 0.97 | Marsalek and Schroeter, 1988 |
| Sault Ste Marie | -- | -- | -- | -- | -- | -- | -- | -- | -- | <0.05 | 0.098 | NR | -- | -- | -- | Boom and Marsalek, 1988 | |
| Acenaphthylene | United States | | | | | | | | | | | | | | | | |
| | Arizona | | | | | | | | | | | | | | | | |
| | Maricopa County | -- | -- | -- | <5 | <5 | NR | <5 | <5 | NR | <5 | <5 | NR | -- | -- | NR | Lopes and others, 1995 |
| | Colorado | | | | | | | | | | | | | | | | |
| | Colorado Springs | -- | -- | -- | <5 | <5 | NR | <5 | <5 | NR | <5 | <5 | NR | -- | -- | NR | von Guerard and Weiss, 1995 |
| | Texas | | | | | | | | | | | | | | | | |
| | Dallas-Fort Worth | -- | -- | -- | <5 | <5 | NR | <5 | <5 | NR | <5 | <5 | NR | -- | -- | -- | Baldys and others, 1998 |
| | Canada | | | | | | | | | | | | | | | | |
| Canadian Great Lakes | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | NR | NR | 0.96 | Marsalek and Schroeter, 1988 |
| Sault Ste Marie | -- | -- | -- | -- | -- | -- | -- | -- | -- | <0.05 | 0.153 | NR | -- | -- | -- | Boom and Marsalek, 1988 | |
| Anthracene | United States | | | | | | | | | | | | | | | | |
| | Arizona | | | | | | | | | | | | | | | | |
| | Maricopa County | -- | -- | -- | <5 | <5 | NR | <5 | <5 | NR | <5 | <5 | NR | -- | -- | -- | Lopes and others, 1995 |
| | Colorado | | | | | | | | | | | | | | | | |
| | Colorado Springs | -- | -- | -- | <5 | <5 | NR | <5 | 9 | NR | <5 | 10 | NR | -- | -- | NR | von Guerard and Weiss, 1995 |
| | Texas | | | | | | | | | | | | | | | | |
| Dallas-Fort Worth | -- | -- | -- | <5 | <5 | NR | <5 | <5 | NR | <5 | 7 | NR | -- | -- | -- | Baldys and others, 1998 | |
| Summary-NURP | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 1 | 10 | -- | Cole and others, 1984 | |

Table 7 . Concentrations of detected semivolatile and volatile organic compounds in stormwater, suspended sediment, and bottom material/soil—*Continued*

| Compound name | Location | Land use | | | | | | | | | | | | | | | Reference | |
|---|---|----------|-------|------|-------------|-----|------|------------|-----|------|------------|-----|------|-------------|-------|------|-----------|---|
| | | Highway | | | Residential | | | Commercial | | | Industrial | | | Unspecified | | | | |
| | | Min | Max | Mean | Min | Max | Mean | Min | Max | Mean | Min | Max | Mean | Min | Max | Mean | | |
| <i>Semivolatile organic compounds, whole water, in micrograms per liter—Continued</i> | | | | | | | | | | | | | | | | | | |
| Anthracene | Summary | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 0.009 | 10 | NR | Makepeace and others, 1995 |
| | Norway Oslo | ND | 0.379 | NR | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | Gjessing and others, 1984 |
| Benz(a) anthracene | United States Arizona Maricopa County | -- | -- | -- | <10 | <10 | NR | <10 | <10 | NR | <10 | <10 | NR | -- | -- | -- | -- | Lopes and others, 1995 |
| | Colorado Colorado Springs | -- | -- | -- | <10 | <10 | NR | <10 | <10 | NR | <10 | 37 | NR | -- | -- | -- | -- | von Guerard and Weiss, 1995 |
| | Texas Dallas–Fort Worth | -- | -- | -- | <10 | <10 | NR | <10 | 13 | NR | <10 | 26 | NR | -- | -- | -- | -- | Baldys and others, 1998 |
| | Summary–NURP Summary | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 1 | 10 | NR | NR | Cole and others, 1984 Makepeace and others, 1995 |
| | Japan Tokyo | -- | -- | -- | NR | NR | 5 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | Yamane and others, 1990 |
| | Norway Oslo | ND | 0.677 | NR | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | Gjessing and others, 1984 |
| | Spain Madrid | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | NR | NR | 1.1 | | Bomboi and Hernandez, 1991 |
| Benzo(b) fluoranthene | United States Arizona Maricopa County | -- | -- | -- | <10 | <10 | NR | <10 | 19 | NR | <10 | <10 | NR | -- | -- | -- | -- | Lopes and others, 1995 |
| | Colorado Colorado Springs | -- | -- | -- | <10 | 15 | NR | <10 | 11 | -- | <10 | 73 | NR | -- | -- | -- | -- | von Guerard and Weiss, 1995 |
| | Texas Dallas–Fort Worth | -- | -- | -- | <10 | <10 | NR | <10 | 15 | NR | <10 | 23 | NR | -- | -- | -- | -- | Baldys and others, 1998 |
| | Summary–NURP Summary | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | NR | 2 | NR | NR | Cole and others, 1984 Makepeace and others, 1995 |
| | | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 0.0034 | 1.9 | NR | | |

Table 7 . Concentrations of detected semivolatile and volatile organic compounds in stormwater, suspended sediment, and bottom material/soil—*Continued*

| Compound name | Location | Land use | | | | | | | | | | | | | | | Reference | |
|---|---|-----------------|-------|------|-------------|-----|------|------------|-----|------|------------|-------|------|-------------|-----|------|-----------------------------|----------------------------|
| | | Highway | | | Residential | | | Commercial | | | Industrial | | | Unspecified | | | | |
| | | Min | Max | Mean | Min | Max | Mean | Min | Max | Mean | Min | Max | Mean | Min | Max | Mean | | |
| <i>Semivolatile organic compounds, whole water, in micrograms per liter—Continued</i> | | | | | | | | | | | | | | | | | | |
| Benzo(b) fluoranthene | Canada Sault Ste Marie | -- | -- | -- | -- | -- | -- | -- | -- | -- | <0.1 | 0.647 | NR | -- | -- | -- | Boom and Marsalek, 1988 | |
| | Norway Oslo | 1 | 1.171 | NR | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | Gjessing and others, 1984 | |
| Benzo(k) fluoranthene | United States Arizona Maricopa County | -- | -- | -- | <10 | <10 | NR | <10 | <10 | NR | <10 | <10 | NR | -- | -- | -- | Lopes and others, 1995 | |
| | Colorado Colorado Springs | -- | -- | -- | <10 | 14 | NR | <10 | <10 | NR | <10 | 90 | NR | -- | -- | -- | von Guerard and Weiss, 1995 | |
| | Texas Dallas–Fort Worth | -- | -- | -- | <10 | 28 | NR | <10 | 13 | NR | <10 | 22 | NR | -- | -- | -- | Baldys and others, 1998 | |
| | Summary–NURP Summary | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 4 | 10 | NR | Cole and others, 1984 | |
| | | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 0.0012 | 10 | NR | Makepeace and others, 1995 | |
| | Canada Sault Ste Marie | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | <0.1 | 0.99 | NR | -- | -- | -- | Boom and Marsalek, 1988 |
| | Japan Tokyo | -- | -- | -- | NR | NR | 5 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | Yamane and others, 1990 |
| | Norway Oslo | 1 | 1.171 | NR | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | Gjessing and others, 1984 |
| | Spain Madrid | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | NR | NR | 0.6 | Bomboi and Hernandez, 1991 |
| | Benzo(b) fluorene | Spain Madrid | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | NR | NR | 0.7 | Bomboi and Hernandez, 1991 |
| Benzo(ghi) perylene | United States Arizona Maricopa County | -- | -- | -- | <10 | <10 | NR | <10 | <10 | NR | <10 | 16 | NR | -- | -- | -- | Lopes and others, 1995 | |
| | Colorado Colorado Springs | -- | -- | -- | <10 | <10 | -- | <10 | 11 | NR | <10 | 31 | NR | -- | -- | -- | von Guerard and Weiss, 1995 | |

Table 7 . Concentrations of detected semivolatile and volatile organic compounds in stormwater, suspended sediment, and bottom material/soil—*Continued*

| Compound name | Location | Land use | | | | | | | | | | | | | | | Reference |
|---|---|----------|-------|------|-------------|-----|------|------------|-----|------|------------|-------|------|-------------|-----|------|-----------------------------|
| | | Highway | | | Residential | | | Commercial | | | Industrial | | | Unspecified | | | |
| | | Min | Max | Mean | Min | Max | Mean | Min | Max | Mean | Min | Max | Mean | Min | Max | Mean | |
| <i>Semivolatile organic compounds, whole water, in micrograms per liter—Continued</i> | | | | | | | | | | | | | | | | | |
| Benzo(<i>ghi</i>) perylene | Texas Dallas–Fort Worth | -- | -- | -- | <10 | <10 | NR | <10 | 15 | NR | <10 | 25 | NR | -- | -- | -- | Baldys and others, 1998 |
| | Summary | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 0.0024 | 1.5 | NR | Makepeace and others, 1995 |
| | Canada Sault Ste Marie | -- | -- | -- | -- | -- | -- | -- | -- | -- | <0.1 | 0.466 | NR | -- | -- | -- | Boom and Marsalek, 1988 |
| | Japan Tokyo | -- | -- | -- | NR | NR | 1.2 | -- | -- | -- | -- | -- | -- | -- | -- | -- | Yamane and others, 1990 |
| | Norway Oslo | ND | 0.551 | NR | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | Gjessing and others, 1984 |
| | Spain Madrid | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | NR | NR | 0.3 | Bomboi and Hernandez, 1991 |
| | United States Arizona Maricopa County | -- | -- | -- | <10 | <10 | NR | <10 | <10 | NR | <10 | <10 | NR | -- | -- | -- | Lopes and others, 1995 |
| Benzo(<i>a</i>) pyrene | Colorado Colorado Springs | -- | -- | -- | <10 | 11 | NR | <10 | <10 | NR | <10 | 46 | NR | -- | -- | -- | von Guerard and Weiss, 1995 |
| | Texas Dallas–Fort Worth | -- | -- | -- | <10 | <10 | NR | <10 | 11 | NR | <10 | 20 | NR | -- | -- | -- | Baldys and others, 1998 |
| | Summary–NURP | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 1 | 10 | NR | Cole and others, 1984 |
| | Summary | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 0.0025 | 10 | NR | Makepeace and others, 1995 |
| | Canada Sault Ste Marie | -- | -- | -- | -- | -- | -- | -- | -- | -- | <0.1 | 0.558 | NR | -- | -- | -- | Boom and Marsalek, 1988 |
| | Germany Bayreuth | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | NR | NR | 52 | Herrmann, 1981 |
| | Japan Tokyo | -- | -- | -- | NR | NR | NR | -- | -- | -- | -- | -- | -- | -- | -- | -- | Yamane and others, 1990 |
| | Norway Oslo | ND | 0.602 | NR | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | Gjessing and others, 1984 |

Table 7 . Concentrations of detected semivolatile and volatile organic compounds in stormwater, suspended sediment, and bottom material/soil—*Continued*

| Compound name | Location | Land use | | | | | | | | | | | | | | | Reference |
|---|----------------------|----------|-------|------|-------------|-----|------|------------|-----|------|------------|-----|------|-------------|-------|------|------------------------------|
| | | Highway | | | Residential | | | Commercial | | | Industrial | | | Unspecified | | | |
| | | Min | Max | Mean | Min | Max | Mean | Min | Max | Mean | Min | Max | Mean | Min | Max | Mean | |
| <i>Semivolatile organic compounds, whole water, in micrograms per liter—Continued</i> | | | | | | | | | | | | | | | | | |
| Benzo(a) pyrene | Spain | | | | | | | | | | | | | | | | |
| | Madrid | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | NR | NR | 1.1 |
| | Madrid | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | ND | 4.75 | NR | Bomboi and others, 1990 |
| Benzo(e) pyrene | Summary | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 0.4 | 0.609 | NR | Makepeace and others, 1995 |
| | Norway | | | | | | | | | | | | | | | | |
| | Oslo | ND | 0.609 | NR | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | Gjessing and others, 1984 |
| Butylbenzyl phthalate | United States | | | | | | | | | | | | | | | | |
| | Arizona | | | | | | | | | | | | | | | | |
| | Maricopa County | -- | -- | -- | <5 | <5 | NR | <5 | <5 | NR | <5 | <5 | NR | -- | -- | -- | Lopes and others, 1995 |
| | Colorado | | | | | | | | | | | | | | | | |
| | Colorado Springs | -- | -- | -- | <5 | <5 | NR | <5 | 11 | NR | <5 | <5 | NR | -- | -- | -- | von Guerard and Weiss, 1995 |
| | Texas | | | | | | | | | | | | | | | | |
| | Dallas–Fort Worth | -- | -- | -- | <5 | 10 | NR | <5 | 8 | NR | <5 | 14 | NR | -- | -- | -- | Baldys and others, 1998 |
| | Summary–NURP | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | NR | 10 | NR | Cole and others, 1984 |
| <i>p</i> -Chloro- <i>m</i> -cresol | Summary–NURP | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | NR | 1.5 | NR | Cole and others, 1984 |
| 2-Chloro naphthalene | United States | | | | | | | | | | | | | | | | |
| | Arizona | | | | | | | | | | | | | | | | |
| | Maricopa County | -- | -- | -- | <5 | <5 | NR | <5 | <5 | NR | <5 | <5 | NR | -- | -- | -- | Lopes and others, 1995 |
| | Colorado | | | | | | | | | | | | | | | | |
| | Colorado Springs | -- | -- | -- | <5 | <5 | NR | <5 | <5 | NR | <5 | <5 | NR | -- | -- | -- | von Guerard and Weiss, 1995 |
| | Texas | | | | | | | | | | | | | | | | |
| | Dallas–Fort Worth | -- | -- | -- | <5 | <5 | NR | <5 | <5 | NR | <5 | <5 | NR | -- | -- | -- | Baldys and others, 1998 |
| | Canada | | | | | | | | | | | | | | | | |
| | Sault Ste Marie | -- | -- | -- | -- | -- | -- | -- | -- | -- | <0.5 | 0.5 | NR | -- | -- | -- | Boom and Marsalek, 1988 |
| <i>B</i> -Chloro naphthalene | Canada | | | | | | | | | | | | | | | | |
| | Canadian Great Lakes | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | NR | NR | 0.97 | Marsalek and Schroeter, 1988 |
| 2-Chloro phenol | United States | | | | | | | | | | | | | | | | |
| | Arizona | | | | | | | | | | | | | | | | |
| | Maricopa County | -- | -- | -- | <5 | <5 | NR | <5 | <5 | NR | <5 | <5 | NR | -- | -- | -- | Lopes and others, 1995 |

Table 7 . Concentrations of detected semivolatile and volatile organic compounds in stormwater, suspended sediment, and bottom material/soil—*Continued*

| Compound name | Location | Land use | | | | | | | | | | | | | | | Reference | |
|---|---|----------|-------|------|-------------|-----|------|------------|-----|------|------------|-----|------|-------------|--------|------|-----------------------------|----------------------------|
| | | Highway | | | Residential | | | Commercial | | | Industrial | | | Unspecified | | | | |
| | | Min | Max | Mean | Min | Max | Mean | Min | Max | Mean | Min | Max | Mean | Min | Max | Mean | | |
| <i>Semivolatile organic compounds, whole water, in micrograms per liter—Continued</i> | | | | | | | | | | | | | | | | | | |
| 2-Chloro phenol | Colorado Colorado Springs | -- | -- | -- | <5 | <5 | NR | <5 | <5 | NR | <5 | <5 | NR | -- | -- | -- | von Guerard and Weiss, 1995 | |
| | Texas Dallas–Fort Worth | -- | -- | -- | <5 | <5 | NR | <5 | <5 | NR | <5 | <5 | NR | -- | -- | -- | Baldys and others, 1998 | |
| Chrysene | Summary–NURP United States | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | NR | 2 | NR | Cole and others, 1984 | |
| | Arizona Maricopa County | -- | -- | -- | <10 | <10 | NR | <10 | 17 | NR | <10 | <10 | NR | -- | -- | -- | Lopes and others, 1995 | |
| | Colorado Colorado Springs | -- | -- | -- | <10 | -- | NR | <10 | 12 | NR | <10 | 61 | NR | -- | -- | -- | von Guerard and Weiss, 1995 | |
| | Texas Dallas–Fort Worth | -- | -- | -- | <10 | <10 | NR | <10 | 23 | NR | <10 | 49 | 3.2 | -- | -- | -- | Baldys and others, 1998 | |
| | Summary–NURP Summary | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 0.6 | 10 | NR | Cole and others, 1984 |
| | Summary | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 0.0038 | 10 | NR | Makepeace and others, 1995 |
| | Norway Oslo | ND | 1.147 | NR | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | Gjessing and others, 1984 |
| Dibenzanthracene | Spain Madrid | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | NR | NR | 1.4 | Bomboi and Hernandez, 1991 | |
| | United States Texas Dallas–Fort Worth | -- | -- | -- | <10 | <10 | NR | <10 | <10 | NR | <10 | <10 | NR | -- | -- | -- | Baldys and others, 1998 | |
| Dibenz(<i>a,h</i>)anthracene | Norway Oslo | ND | 0.214 | NR | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | Gjessing and others, 1984 | |
| | Summary | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 0.0006 | 0.9 | NR | Makepeace and others, 1995 | |
| Dibenzofuran | Spain Madrid | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | NR | NR | 0.5 | Bomboi and Hernandez, 1991 | |
| | Norway Oslo | ND | 0.001 | NR | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | Gjessing and others, 1984 | |

Table 7 . Concentrations of detected semivolatile and volatile organic compounds in stormwater, suspended sediment, and bottom material/soil—*Continued*

| Compound name | Location | Land use | | | | | | | | | | | | | | | Reference |
|---|---|----------|-------|------|-------------|-----|------|------------|-----|------|------------|-----|------|-------------|-----|--------|---------------------------------|
| | | Highway | | | Residential | | | Commercial | | | Industrial | | | Unspecified | | | |
| | | Min | Max | Mean | Min | Max | Mean | Min | Max | Mean | Min | Max | Mean | Min | Max | Mean | |
| <i>Semivolatile organic compounds, whole water, in micrograms per liter—Continued</i> | | | | | | | | | | | | | | | | | |
| Dibenzothio- phene | Norway Oslo | ND | 0.136 | NR | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | Gjessing and others, 1984 |
| 1,2-Dichloro benzene | United States Colorado Colorado Springs | -- | -- | -- | <5 | <5 | NR | <5 | <5 | NR | <5 | <5 | NR | -- | -- | -- | von Guerard and Weiss, 1995 |
| | Texas Dallas–Fort Worth | -- | -- | -- | <0.2 | <5 | NR | <0.2 | <5 | NR | <0.2 | <10 | NR | -- | -- | -- | Baldys and others, 1998 |
| | Canada Canadian Great Lakes | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | NR | NR | 0.39 | Marsalek and Schroeter, 1988 |
| 1,3-Dichloro benzene | United States Arizona Maricopa County | -- | -- | -- | <5 | <5 | NR | <5 | <5 | NR | <5 | <5 | NR | -- | -- | -- | Lopes and others, 1995 |
| | Colorado Colorado Springs | -- | -- | -- | <5 | <5 | NR | <5 | <5 | NR | <5 | <5 | NR | -- | -- | -- | von Guerard and Weiss, 1995 |
| | Texas Dallas–Fort Worth | -- | -- | -- | <0.2 | <5 | NR | <0.2 | <5 | NR | <0.2 | <10 | NR | -- | -- | -- | Baldys and others, 1998 |
| 1,4-Dichloro benzene | Canada Canadian Great Lakes | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | NR | NR | 0.0074 | Marsalek and Schroeter, 1988 |
| | United States Arizona Maricopa County | -- | -- | -- | <5 | <5 | NR | <5 | <5 | NR | <5 | <5 | NR | -- | -- | -- | Lopes and others, 1995 |
| | Colorado Colorado Springs | -- | -- | -- | <5 | <5 | NR | <5 | <5 | NR | <5 | <5 | NR | -- | -- | -- | von Guerard and Weiss, 1995 |
| 1,4-Dichloro benzene | Texas Dallas–Fort Worth | -- | -- | -- | <0.2 | <5 | NR | <0.2 | <5 | NR | <0.2 | <10 | NR | -- | -- | -- | Baldys and others, 1998 |
| | Canada Canadian Great Lakes | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | NR | NR | 0.0089 | Marsalek and Schroeter, 1988 |

Table 7 . Concentrations of detected semivolatile and volatile organic compounds in stormwater, suspended sediment, and bottom material/soil—*Continued*

| Compound name | Location | Land use | | | | | | | | | | | | | | | Reference |
|---|-------------------|----------|-----|------|-------------|-----|------|------------|-----|------|------------|-----|------|-------------|-----|------|-----------------------------|
| | | Highway | | | Residential | | | Commercial | | | Industrial | | | Unspecified | | | |
| | | Min | Max | Mean | Min | Max | Mean | Min | Max | Mean | Min | Max | Mean | Min | Max | Mean | |
| <i>Semivolatile organic compounds, whole water, in micrograms per liter—Continued</i> | | | | | | | | | | | | | | | | | |
| Diethylphthalate | United States | | | | | | | | | | | | | | | | |
| | Arizona | | | | | | | | | | | | | | | | |
| | Maricopa County | -- | -- | -- | <5 | <5 | NR | <5 | <5 | NR | <5 | <5 | NR | -- | -- | -- | Lopes and others, 1995 |
| | Colorado | | | | | | | | | | | | | | | | |
| | Colorado Springs | -- | -- | -- | <5 | <5 | NR | <5 | <5 | NR | <5 | <5 | NR | -- | -- | -- | von Guerard and Weiss, 1995 |
| | Texas | | | | | | | | | | | | | | | | |
| | Dallas–Fort Worth | -- | -- | -- | <5 | <5 | NR | <5 | <5 | NR | <5 | <5 | NR | -- | -- | -- | Baldys and others, 1998 |
| | Summary–NURP | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 2 | 10 | NR | Cole and others, 1984 |
| | Summary | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 1 | 1.4 | NR | Makepeace and others, 1995 |
| 9,10-Dimethylanthracene | Spain | | | | | | | | | | | | | | | | |
| | Madrid | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | NR | NR | 1 | Bomboi and Hernandez, 1991 |
| 2,4-Dimethylphenol | United States | | | | | | | | | | | | | | | | |
| | Arizona | | | | | | | | | | | | | | | | |
| | Maricopa County | -- | -- | -- | <5 | <5 | NR | <5 | <5 | NR | <5 | <5 | NR | -- | -- | -- | Lopes and others, 1995 |
| | Colorado | | | | | | | | | | | | | | | | |
| | Colorado Springs | -- | -- | -- | <5 | <5 | NR | <5 | <5 | NR | <5 | <5 | NR | -- | -- | -- | von Guerard and Weiss, 1995 |
| | Texas | | | | | | | | | | | | | | | | |
| | Dallas–Fort Worth | -- | -- | -- | <5 | <5 | NR | <5 | <5 | NR | <5 | <5 | NR | -- | -- | -- | Baldys and others, 1998 |
| | Summary–NURP | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | NR | 10 | NR | Cole and others, 1984 |
| | United States | | | | | | | | | | | | | | | | |
| Di-n-butylphthalate | Arizona | | | | | | | | | | | | | | | | |
| | Maricopa County | -- | -- | -- | <5 | <5 | NR | <5 | <5 | NR | <5 | <5 | NR | -- | -- | -- | Lopes and others, 1995 |
| | Colorado | | | | | | | | | | | | | | | | |
| | Colorado Springs | -- | -- | -- | <5 | <5 | NR | <5 | 15 | NR | <5 | <5 | NR | -- | -- | -- | von Guerard and Weiss, 1995 |
| | Texas | | | | | | | | | | | | | | | | |
| | Dallas–Fort Worth | -- | -- | -- | <5 | <5 | NR | <5 | <5 | NR | <5 | <5 | NR | -- | -- | -- | Baldys and others, 1998 |
| Di-n-octylphthalate | Summary–NURP | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 0.5 | 11 | NR | Cole and others, 1984 |
| | United States | | | | | | | | | | | | | | | | |
| | Arizona | | | | | | | | | | | | | | | | |
| | Maricopa County | -- | -- | -- | <10 | <10 | NR | <10 | <10 | NR | <10 | <10 | NR | -- | -- | -- | Lopes and others, 1995 |

Table 7 . Concentrations of detected semivolatile and volatile organic compounds in stormwater, suspended sediment, and bottom material/soil—*Continued*

| Compound name | Location | Land use | | | | | | | | | | | | | | | Reference |
|---|----------------------|----------|-----|------|-------------|-----|------|------------|--------|------|------------|------|------|-------------|-----|-------|------------------------------|
| | | Highway | | | Residential | | | Commercial | | | Industrial | | | Unspecified | | | |
| | | Min | Max | Mean | Min | Max | Mean | Min | Max | Mean | Min | Max | Mean | Min | Max | Mean | |
| <i>Semivolatile organic compounds, whole water, in micrograms per liter—Continued</i> | | | | | | | | | | | | | | | | | |
| Di-n-octyl phthalate | Colorado | | | | | | | | | | | | | | | | |
| | Colorado Springs | -- | -- | -- | <10 | 11 | NR | <10 | 11 | NR | <10 | 11 | NR | -- | -- | -- | von Guerard and Weiss, 1995 |
| | Texas | | | | | | | | | | | | | | | | |
| | Dallas–Fort Worth | -- | -- | -- | <10 | <10 | NR | <10 | <10 | NR | <10 | <10 | NR | -- | -- | -- | Baldys and others, 1998 |
| bis(2-Ethyl hexyl) phthalate | Summary–NURP | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 0.4 | 1 | NR | Cole and others, 1984 |
| | United States | | | | | | | | | | | | | | | | |
| | Arizona | | | | | | | | | | | | | | | | |
| | Maricopa County | -- | -- | -- | <5 | <5 | NR | <5 | 8 | NR | <5 | 9 | NR | -- | -- | -- | Lopes and others, 1995 |
| | Colorado | | | | | | | | | | | | | | | | |
| | Colorado Springs | -- | -- | -- | 7 | 13 | NR | 11 | 100 | NR | 9 | 24 | NR | -- | -- | -- | von Guerard and Weiss, 1995 |
| | Texas | | | | | | | | | | | | | | | | |
| | Dallas–Fort Worth | -- | -- | -- | <5 | 24 | 5.7 | <5 | 20 | NR | <5 | 140 | 6.9 | -- | -- | -- | Baldys and others, 1998 |
| Fluoranthene | Summary–NURP | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 7 | 39 | NR | Cole and others, 1984 |
| | United States | | | | | | | | | | | | | | | | |
| | Arizona | | | | | | | | | | | | | | | | |
| | Maricopa County | -- | -- | -- | <5 | <5 | NR | <5 | 18 | NR | <5 | 7 | NR | -- | -- | -- | Lopes and others, 1995 |
| | Colorado | | | | | | | | | | | | | | | | |
| | Colorado Springs | -- | -- | -- | <5 | 32 | NR | 10 | 25 | NR | <5 | 120 | NR | -- | -- | -- | von Guerard and Weiss, 1995 |
| | Rhode Island | | | | | | | | | | | | | | | | |
| | Cranston | -- | -- | -- | -- | -- | -- | NR | 0.1609 | NR | -- | -- | -- | -- | -- | -- | Hoffman and others, 1984 |
| | Texas | | | | | | | | | | | | | | | | |
| | Dallas–Fort Worth | -- | -- | -- | <5 | 13 | NR | <5 | 23 | 3.6 | <5 | 52 | 6.5 | -- | -- | -- | Baldys and others, 1998 |
| | Summary–NURP | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 0.3 | 12 | NR | Cole and others, 1984 |
| | Summary | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 0.03 | 56 | NR | Makepeace and others, 1995 |
| | Canada | | | | | | | | | | | | | | | | |
| | Canadian Great Lakes | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | NR | NR | 1 | Marsalek and Schroeter, 1988 |
| | Sault Ste Marie | -- | -- | -- | -- | -- | -- | -- | -- | -- | <0.5 | 2.95 | NR | -- | -- | -- | Boom and Marsalek, 1988 |
| | Germany | | | | | | | | | | | | | | | | |
| | Bayreuth | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | NR | NR | 0.106 | Herrmann, 1981 |

Table 7 . Concentrations of detected semivolatile and volatile organic compounds in stormwater, suspended sediment, and bottom material/soil—*Continued*

| Compound name | Location | Land use | | | | | | | | | | | | | | | Reference |
|---|---|---|-------|------|-------------|-----|------|------------|-----|------|------------|-------|------|-------------|-------|---------|------------------------------|
| | | Highway | | | Residential | | | Commercial | | | Industrial | | | Unspecified | | | |
| | | Min | Max | Mean | Min | Max | Mean | Min | Max | Mean | Min | Max | Mean | Min | Max | Mean | |
| <i>Semivolatile organic compounds, whole water, in micrograms per liter—Continued</i> | | | | | | | | | | | | | | | | | |
| Fluoranthene | Norway Oslo | 4 | 2.665 | NR | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | Gjessing and others, 1984 |
| | Spain Madrid | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | NR | NR | 2.7 | Bomboi and Hernandez, 1991 |
| | | Madrid | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 0.4 | 10.65 | NR | Bomboi and others, 1990 |
| Fluorene | United States Arizona Maricopa County | -- | -- | -- | <5 | <5 | NR | <5 | <5 | NR | <5 | <5 | NR | -- | -- | -- | Lopes and others, 1995 |
| | Colorado Colorado Springs | -- | -- | -- | <5 | <5 | NR | <5 | <5 | NR | <5 | <5 | NR | -- | -- | -- | von Guerard and Weiss, 1995 |
| | Texas Dallas–Fort Worth | -- | -- | -- | <5 | <5 | NR | <5 | <5 | NR | <5 | <5 | NR | -- | -- | -- | Baldys and others, 1998 |
| | Summary–NURP Summary | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | NR | 1 | NR | Cole and others, 1984 |
| | | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 0.096 | 1 | NR | Makepeace and others, 1995 |
| | Canada Sault Ste Marie | -- | -- | -- | -- | -- | -- | -- | -- | -- | <0.05 | 0.135 | NR | -- | -- | -- | Boom and Marsalek, 1988 |
| | Norway Oslo | ND | 0.96 | NR | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | Gjessing and others, 1984 |
| | Hexachloro benzene | United States Arizona Maricopa County | -- | -- | -- | <5 | <5 | NR | <5 | <5 | NR | <5 | <5 | NR | -- | -- | -- |
| Colorado Colorado Springs | | -- | -- | -- | <5 | <5 | NR | <5 | <5 | NR | <5 | <5 | NR | -- | -- | -- | von Guerard and Weiss, 1995 |
| Texas Dallas–Fort Worth | | -- | -- | -- | <5 | -- | NR | <5 | <5 | NR | <5 | <5 | NR | -- | -- | -- | Baldys and others, 1998 |
| Canada Canadian Great Lakes | | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | NR | NR | 0.00073 | Marsalek and Schroeter, 1988 |
| Indene Canada Sault Ste Marie | | -- | -- | -- | -- | -- | -- | -- | -- | -- | <0.05 | 0.05 | NR | -- | -- | -- | Boom and Marsalek, 1988 |

Table 7 . Concentrations of detected semivolatile and volatile organic compounds in stormwater, suspended sediment, and bottom material/soil—*Continued*

| Compound name | Location | Land use | | | | | | | | | | | | | | | Reference |
|---|-------------------|----------|-----|------|-------------|-----|------|------------|-----|-------|------------|-----|------|-------------|------|------------------------------|-----------------------------|
| | | Highway | | | Residential | | | Commercial | | | Industrial | | | Unspecified | | | |
| | | Min | Max | Mean | Min | Max | Mean | Min | Max | Mean | Min | Max | Mean | Min | Max | Mean | |
| <i>Semivolatile organic compounds, whole water, in micrograms per liter—Continued</i> | | | | | | | | | | | | | | | | | |
| Indeno (1,2,3-cd) pyrene | United States | | | | | | | | | | | | | | | | |
| | Arizona | | | | | | | | | | | | | | | | |
| | Maricopa County | -- | -- | -- | <10 | <10 | NR | <10 | <10 | NR | <10 | 27 | NR | -- | -- | -- | Lopes and others, 1995 |
| | Colorado | | | | | | | | | | | | | | | | |
| | Colorado Springs | -- | -- | -- | <10 | 11 | NR | <10 | 13 | NR | <10 | 38 | NR | -- | -- | -- | von Guerard and Weiss, 1995 |
| | Texas | | | | | | | | | | | | | | | | |
| | Dallas–Fort Worth | -- | -- | -- | <10 | <10 | NR | <10 | 15 | NR | <10 | 27 | NR | -- | -- | -- | Baldys and others, 1998 |
| Summary | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 0.31 | 0.5 | NR | Makepeace and others, 1995 | |
| Canada | | | | | | | | | | | | | | | | | |
| Sault Ste Marie | -- | -- | -- | -- | -- | -- | -- | -- | -- | <0.1 | 0.496 | NR | -- | -- | -- | Boom and Marsalek, 1988 | |
| Spain | | | | | | | | | | | | | | | | | |
| Madrid | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | NR | NR | 0.2 | Bomboi and Hernandez, 1991 | |
| 1-Methyl anthracene | Norway | | | | | | | | | | | | | | | | |
| Oslo | ND | 0.133 | NR | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | Gjessing and others, 1984 |
| 2-Methyl anthracene | Norway | | | | | | | | | | | | | | | | |
| Oslo | ND | 0.036 | NR | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | Gjessing and others, 1984 |
| Spain | | | | | | | | | | | | | | | | | |
| Madrid | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | NR | NR | 0.7 | Bomboi and Hernandez, 1991 | |
| 1-Methyl naphthalene | Canada | | | | | | | | | | | | | | | | |
| Sault Ste Marie | -- | -- | -- | -- | -- | -- | -- | -- | -- | <0.05 | 0.177 | NR | -- | -- | -- | Boom and Marsalek, 1988 | |
| Norway | | | | | | | | | | | | | | | | | |
| Oslo | ND | 0.045 | NR | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | Gjessing and others, 1984 |
| 2-Methyl naphthalene | Summary | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 0.01 | 1.6 | NR | Makepeace and others, 1995 | |
| Canada | | | | | | | | | | | | | | | | | |
| Canadian Great Lakes | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | NR | NR | 0.95 | Marsalek and Schroeter, 1988 | |
| Sault Ste Marie | -- | -- | -- | -- | -- | -- | -- | -- | -- | <0.05 | 0.251 | NR | -- | -- | -- | Boom and Marsalek, 1988 | |
| Norway | | | | | | | | | | | | | | | | | |
| Oslo | ND | 0.025 | NR | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | Gjessing and others, 1984 |

Table 7 . Concentrations of detected semivolatile and volatile organic compounds in stormwater, suspended sediment, and bottom material/soil—*Continued*

| Compound name | Location | Land use | | | | | | | | | | | | | | | Reference | |
|---|---|----------|-------|------|-------------|-----|------|------------|-----|------|------------|-----|------|-------------|-------|-----------------------------|-----------------------------|---------------------------|
| | | Highway | | | Residential | | | Commercial | | | Industrial | | | Unspecified | | | | |
| | | Min | Max | Mean | Min | Max | Mean | Min | Max | Mean | Min | Max | Mean | Min | Max | Mean | | |
| <i>Semivolatile organic compounds, whole water, in micrograms per liter—Continued</i> | | | | | | | | | | | | | | | | | | |
| Methylphenanthrene | Summary | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 2.9 | 3.4 | NR | Makepeace and others, 1995 | |
| | Spain Madrid | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | NR | NR | 2.9 | Bomboi and Hernandez, 1991 | |
| Naphthalene | United States Arizona Maricopa County | -- | -- | -- | <5 | <5 | NR | <5 | <5 | NR | <5 | <5 | NR | -- | -- | -- | Lopes and others, 1995 | |
| | Colorado Colorado Springs | -- | -- | -- | <5 | <5 | NR | <5 | <5 | NR | <5 | <5 | NR | -- | -- | -- | von Guerard and Weiss, 1995 | |
| | Texas Dallas–Fort Worth | -- | -- | -- | <0.2 | <5 | NR | <0.2 | <5 | NR | <0.2 | <5 | NR | -- | -- | -- | Baldys and others, 1998 | |
| | Summary–NURP | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 0.8 | 2.3 | NR | Cole and others, 1984 | |
| | Summary | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 0.036 | 2.3 | NR | Makepeace and others, 1995 | |
| | Norway Oslo | ND | 0.067 | NR | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | Gjessing and others, 1984 |
| | United States Arizona Maricopa County | -- | -- | -- | <30 | <30 | NR | <30 | <30 | NR | <30 | <30 | NR | -- | -- | -- | Lopes and others, 1995 | |
| Colorado Colorado Springs | -- | -- | -- | <30 | <30 | NR | <30 | <30 | NR | <30 | <30 | NR | -- | -- | -- | von Guerard and Weiss, 1995 | | |
| Texas Dallas–Fort Worth | -- | -- | -- | <30 | <30 | NR | <30 | <30 | NR | <30 | <30 | NR | -- | -- | -- | Baldys and others, 1998 | | |
| Summary–NURP | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 1 | 19 | NR | Cole and others, 1984 | | |
| PAH (total) | Summary | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 0.24 | 13 | NR | Makepeace and others, 1995 | |
| | Germany Obereisesheim | NR | NR | 2.97 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | Stoltz, 1987 | |
| | Pleidelsheim | NR | NR | 2.61 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | Stoltz, 1987 | |
| | Ulm | NR | NR | 2.51 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | Stoltz, 1987 | |
| | United Kingdom NW London | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 5830 | 18210 | NR | Gavens and others, 1983 | |

Table 7 . Concentrations of detected semivolatile and volatile organic compounds in stormwater, suspended sediment, and bottom material/soil—*Continued*

| Compound name | Location | Land use | | | | | | | | | | | | | | | Reference | |
|---|---|----------|-----|------|-------------|-----|------|------------|--------|------|------------|-------|------|-------------|-----|------|-----------------------------|------------------------------|
| | | Highway | | | Residential | | | Commercial | | | Industrial | | | Unspecified | | | | |
| | | Min | Max | Mean | Min | Max | Mean | Min | Max | Mean | Min | Max | Mean | Min | Max | Mean | | |
| <i>Semivolatile organic compounds, whole water, in micrograms per liter—Continued</i> | | | | | | | | | | | | | | | | | | |
| Pentachloro benzene | Canada Canadian Great Lakes | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | NR | NR | 0.001 | Marsalek and Schroeter, 1988 |
| Pentachloro phenol | United States Arizona Maricopa County | -- | -- | -- | <30 | <30 | NR | <30 | <30 | NR | <30 | <30 | NR | -- | -- | -- | Lopes and others, 1995 | |
| | Colorado Colorado Springs | -- | -- | -- | <30 | <30 | NR | <30 | <30 | NR | <30 | <30 | NR | -- | -- | -- | von Guerard and Weiss, 1995 | |
| | Texas Dallas–Fort Worth | -- | -- | -- | <30 | <30 | NR | <30 | <30 | NR | <30 | <30 | NR | -- | -- | -- | Baldys and others, 1998 | |
| Perylene | Summary–NURP | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 1 | 115 | NR | Cole and others, 1984 | |
| | Summary | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 0.05 | 0.5 | NR | Makepeace and others, 1995 | |
| | Spain Madrid | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | NR | NR | 0.5 | Bomboi and Hernandez, 1991 | |
| Phenanthrene | United States Arizona Maricopa County | -- | -- | -- | <5 | <5 | NR | <5 | <5 | NR | <5 | <5 | NR | -- | -- | -- | Lopes and others, 1995 | |
| | Colorado Colorado Springs | -- | -- | -- | <5 | 23 | NR | <5 | 14 | NR | <5 | 67 | NR | -- | -- | -- | von Guerard and Weiss, 1995 | |
| | Rhode Island Cranston | -- | -- | -- | -- | -- | -- | NR | 0.0906 | NR | -- | -- | -- | -- | -- | -- | Hoffman and others, 1984 | |
| | Texas Dallas–Fort Worth | -- | -- | -- | <5 | 10 | NR | <5 | 10 | NR | <5 | 33 | 3.6 | -- | -- | -- | Baldys and others, 1998 | |
| | Summary–NURP | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 0.3 | 10 | NR | Cole and others, 1984 | |
| | Summary | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 0.045 | 10 | NR | Makepeace and others, 1995 | |
| | Canada Sault Ste Marie | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | <0.05 | 3.56 | NR | -- | -- | -- | Boom and Marsalek, 1988 |
| Norway Oslo | 3 | 1.385 | NR | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | Gjessing and others, 1984 | |

Table 7 . Concentrations of detected semivolatile and volatile organic compounds in stormwater, suspended sediment, and bottom material/soil—*Continued*

| Compound name | Location | Land use | | | | | | | | | | | | | | | Reference |
|--|----------------------|----------|-------|------|-------------|-----|------|------------|--------|------|------------|-------|------|-------------|-----|------|------------------------------|
| | | Highway | | | Residential | | | Commercial | | | Industrial | | | Unspecified | | | |
| | | Min | Max | Mean | Min | Max | Mean | Min | Max | Mean | Min | Max | Mean | Min | Max | Mean | |
| Semivolatile organic compounds, whole water, in micrograms per liter— <i>Continued</i> | | | | | | | | | | | | | | | | | |
| Phenanthrene | Spain | | | | | | | | | | | | | | | | |
| | Madrid | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | NR | NR | 2.9 | Bomboi and Hernandez, 1991 |
| Phenol | Summary–NURP | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 3 | 10 | NR | Cole and others, 1984 |
| 0-Phenyl eneptyrene | Norway | | | | | | | | | | | | | | | | |
| | Oslo | ND | 0.432 | NR | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | Gjessing and others, 1984 |
| Pyrene | United States | | | | | | | | | | | | | | | | |
| | Arizona | | | | | | | | | | | | | | | | |
| | Maricopa County | -- | -- | -- | <5 | <5 | NR | <5 | 13 | NR | <5 | <5 | NR | -- | -- | -- | Lopes and others, 1995 |
| | Colorado | | | | | | | | | | | | | | | | |
| | Colorado Springs | -- | -- | -- | <5 | 24 | NR | 8 | 19 | NR | <5 | 94 | NR | -- | -- | -- | von Guerard and Weiss, 1995 |
| | Rhode Island | | | | | | | | | | | | | | | | |
| | Cranston | -- | -- | -- | -- | -- | -- | NR | 0.1367 | NR | -- | -- | -- | -- | -- | -- | Hoffman and others, 1984 |
| | Texas | | | | | | | | | | | | | | | | |
| | Dallas–Fort Worth | -- | -- | -- | <5 | 10 | NR | <5 | 18 | NR | <5 | 43 | 5.4 | -- | -- | -- | Baldys and others, 1998 |
| | Summary–NURP | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 0.3 | 10 | NR | Cole and others, 1984 |
| | Summary | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 0.045 | 10 | NR | Makepeace and others, 1995 |
| | Canada | | | | | | | | | | | | | | | | |
| | Canadian Great Lakes | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | NR | NR | 1 | Marsalek and Schroeter, 1988 |
| | Sault Ste Marie | -- | -- | -- | -- | -- | -- | -- | -- | -- | <0.05 | 3.75 | NR | -- | -- | -- | Boom and Marsalek, 1988 |
| | Norway | | | | | | | | | | | | | | | | |
| | Oslo | 5 | 2.002 | NR | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | Gjessing and others, 1984 |
| | Spain | | | | | | | | | | | | | | | | |
| | Madrid | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | NR | NR | 1.9 | Bomboi and Hernandez, 1991 |
| | Madrid | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 0.5 | 8.5 | NR | Bomboi and others, 1990 |
| Quinoline | Canada | | | | | | | | | | | | | | | | |
| | Sault Ste Marie | -- | -- | -- | -- | -- | -- | -- | -- | -- | <0.05 | 0.124 | NR | -- | -- | -- | Boom and Marsalek, 1988 |
| 1,2,3,4-Tetra hydronaphthalene | Canada | | | | | | | | | | | | | | | | |
| | Sault Ste Marie | -- | -- | -- | -- | -- | -- | -- | -- | -- | <0.05 | 0.05 | NR | -- | -- | -- | Boom and Marsalek, 1988 |

Table 7 . Concentrations of detected semivolatile and volatile organic compounds in stormwater, suspended sediment, and bottom material/soil—*Continued*

| Compound name | Location | Land use | | | | | | | | | | | | | | | Reference |
|--|----------------------|----------|-----|------|-------------|-----|------|------------|--------|------|------------|-----|------|-------------|------|---------|------------------------------|
| | | Highway | | | Residential | | | Commercial | | | Industrial | | | Unspecified | | | |
| | | Min | Max | Mean | Min | Max | Mean | Min | Max | Mean | Min | Max | Mean | Min | Max | Mean | |
| Semivolatile organic compounds, whole water, in micrograms per liter—<i>Continued</i> | | | | | | | | | | | | | | | | | |
| 1,2,4-Trichloro benzene | United States | | | | | | | | | | | | | | | | |
| | Colorado | | | | | | | | | | | | | | | | |
| | Colorado Springs | -- | -- | -- | <5 | <5 | NR | <5 | <5 | NR | <5 | <5 | NR | -- | -- | -- | von Guerard and Weiss, 1995 |
| | Texas | | | | | | | | | | | | | | | | |
| | Dallas–Fort Worth | -- | -- | -- | <0.2 | <5 | NR | <0.2 | <5 | NR | <0.2 | <10 | NR | -- | -- | -- | Baldys and others, 1998 |
| | Canada | | | | | | | | | | | | | | | | |
| | Canadian Great Lakes | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | NR | NR | 0.0015 | Marsalek and Schroeter, 1988 |
| 1,3,5,- Trichloro benzene | Canada | | | | | | | | | | | | | | | | |
| | Canadian Great Lakes | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | NR | NR | 0.00099 | Marsalek and Schroeter, 1988 |
| Semivolatile organic compounds, filtered/centrifuged water, in micrograms per liter | | | | | | | | | | | | | | | | | |
| Fluoranthrene | United States | | | | | | | | | | | | | | | | |
| | Rhode Island | | | | | | | | | | | | | | | | |
| | Cranston | -- | -- | -- | -- | -- | -- | NR | 0.0034 | NR | -- | -- | -- | -- | -- | -- | Hoffman and others, 1984 |
| Phenanthrene | United States | | | | | | | | | | | | | | | | |
| | Rhode Island | | | | | | | | | | | | | | | | |
| | Cranston | -- | -- | -- | -- | -- | -- | NR | 0.0263 | NR | -- | -- | -- | -- | -- | -- | Hoffman and others, 1984 |
| Pyrene | United States | | | | | | | | | | | | | | | | |
| | Rhode Island | | | | | | | | | | | | | | | | |
| | Cranston | -- | -- | -- | -- | -- | -- | NR | 0.0056 | NR | -- | -- | -- | -- | -- | -- | Hoffman and others, 1984 |
| Semivolatile organic compounds, suspended sediment, in micrograms per gram | | | | | | | | | | | | | | | | | |
| Acenaphthylene | Canada | | | | | | | | | | | | | | | | |
| | Canadian Great Lakes | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | NR | NR | 0.7 | Marsalek and Schroeter, 1988 |
| Benzo(b) fluoranthene | United States | | | | | | | | | | | | | | | | |
| | Washington | | | | | | | | | | | | | | | | |
| | Columbia River | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 0.021 | 0.35 | 0.07 | Prahl and others, 1984 |
| Benzo(k) fluorene | United States | | | | | | | | | | | | | | | | |
| | Washington | | | | | | | | | | | | | | | | |
| | Columbia River | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 0.008 | 0.14 | NR | Prahl and others, 1984 |

Table 7 . Concentrations of detected semivolatile and volatile organic compounds in stormwater, suspended sediment, and bottom material/soil—*Continued*

| Compound name | Location | Land use | | | | | | | | | | | | | | | Reference |
|---|---|----------|------|------|-------------|-----|------|------------|------|------|------------|-----|------|-------------|-------|-------|------------------------------|
| | | Highway | | | Residential | | | Commercial | | | Industrial | | | Unspecified | | | |
| | | Min | Max | Mean | Min | Max | Mean | Min | Max | Mean | Min | Max | Mean | Min | Max | Mean | |
| <i>Semivolatile organic compounds, suspended sediment, in micrograms per gram—Continued</i> | | | | | | | | | | | | | | | | | |
| Benzo(<i>ghi</i>) perylene | United States Washington Columbia River | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 0.007 | 0.15 | 0.019 | Prahl and others, 1984 |
| Benzo(<i>a</i>) pyrene | United States Rhode Island Cranston | 0.28 | 7.78 | 1.35 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | Hoffman and others, 1985 |
| | Washington Columbia River | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 0.005 | 0.097 | 0.016 | Prahl and others, 1984 |
| 1,2-Dichloro benzene | Canada Canadian Great Lakes | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | NR | NR | 0.12 | Marsalek and Schroeter, 1988 |
| 1,3-Dichloro benzene | Canada Canadian Great Lakes | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | NR | NR | 0.027 | Marsalek and Schroeter, 1988 |
| 1,4-Dichloro benzene | Canada Canadian Great Lakes | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | NR | NR | 0.4 | Marsalek and Schroeter, 1988 |
| Fluoranthene | United States Rhode Island Cranston | 3.2 | 45.7 | 12 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | Hoffman and others, 1985 |
| | Cranston | -- | -- | -- | -- | -- | -- | NR | 3.32 | NR | -- | -- | -- | -- | -- | -- | Hoffman and others, 1984 |
| | Washington Columbia River | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 0.025 | 0.38 | 0.052 | Prahl and others, 1984 |
| | Canada Canadian Great Lakes | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | NR | NR | 2.4 | Marsalek and Schroeter, 1988 |
| Hexachloro benzene | Canada Canadian Great Lakes | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | NR | NR | 0.075 | Marsalek and Schroeter, 1988 |
| Indene | Canada Canadian Great Lakes | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | NR | NR | 0.44 | Marsalek and Schroeter, 1988 |
| 2-Methylnaphthalene | Canada Canadian Great Lakes | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | NR | NR | 0.53 | Marsalek and Schroeter, 1988 |

Table 7 . Concentrations of detected semivolatile and volatile organic compounds in stormwater, suspended sediment, and bottom material/soil—*Continued*

| Compound name | Location | Land use | | | | | | | | | | | | | | | Reference |
|---|---|----------|-----|------|-------------|-----|------|------------|------|------|------------|-----|------|-------------|------|--------|------------------------------|
| | | Highway | | | Residential | | | Commercial | | | Industrial | | | Unspecified | | | |
| | | Min | Max | Mean | Min | Max | Mean | Min | Max | Mean | Min | Max | Mean | Min | Max | Mean | |
| <i>Semivolatile organic compounds, suspended sediment, in micrograms per gram—Continued</i> | | | | | | | | | | | | | | | | | |
| Pentachloro benzene | Canada Canadian Great Lakes | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | NR | NR | 0.0098 | Marsalek and Schroeter, 1988 |
| Perylene | United States Washington Columbia River | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 0.021 | 0.17 | 0.051 | Prahl and others, 1984 |
| Phenanthrene | United States Rhode Island Cranston | -- | -- | -- | -- | -- | -- | NR | 1.35 | NR | -- | -- | -- | -- | -- | -- | Hoffman and others, 1984 |
| Phenanthrene | Canada Canadian Great Lakes | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | NR | NR | 1.7 | Marsalek and Schroeter, 1988 |
| Pyrene | United States Rhode Island Cranston | -- | -- | -- | -- | -- | -- | NR | 2.76 | NR | -- | -- | -- | -- | -- | -- | Hoffman and others, 1984 |
| | Washington Columbia River | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 0.026 | 0.41 | 0.056 | Prahl and others, 1984 |
| | Canada Canadian Great Lakes | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | NR | NR | 2.2 | Marsalek and Schroeter, 1988 |
| 1,2,3,5-Tetra chloro benzene | Canada Canadian Great Lakes | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | NR | NR | 0.005 | Marsalek and Schroeter, 1988 |
| 1,2,3,4-Tetra chloro benzene | Canada Canadian Great Lakes | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | NR | NR | 0.0044 | Marsalek and Schroeter, 1988 |
| 1,2,4,5-Tetra chloro benzene | Canada Canadian Great Lakes | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | NR | NR | 0.005 | Marsalek and Schroeter, 1988 |
| 1,2,3-Trichloro benzene | Canada Canadian Great Lakes | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | NR | NR | 0.0076 | Marsalek and Schroeter, 1988 |
| 1,2,4-Trichloro benzene | Canada Canadian Great Lakes | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | NR | NR | 0.0085 | Marsalek and Schroeter, 1988 |
| 1,3,5-Trichloro benzene | Canada Canadian Great Lakes | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | NR | NR | 0.019 | Marsalek and Schroeter, 1988 |

Table 7 . Concentrations of detected semivolatile and volatile organic compounds in stormwater, suspended sediment, and bottom material/soil—*Continued*

| Compound name | Location | Land use | | | | | | | | | | | | | | | Reference |
|--|-------------------------------|----------|-------|-------|-------------|-----|-------|------------|-----|------|------------|--------|------|-------------|--------|------------------------|---------------------------|
| | | Highway | | | Residential | | | Commercial | | | Industrial | | | Unspecified | | | |
| | | Min | Max | Mean | Min | Max | Mean | Min | Max | Mean | Min | Max | Mean | Min | Max | Mean | |
| Semivolatile organic compounds, bottom material/soil, in micrograms per gram | | | | | | | | | | | | | | | | | |
| Anthracene | Norway Olso | ND | 0.16 | NR | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | Gjessing and others, 1984 |
| Benzo(a) anthracene | United Kingdom N.W. London | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 0.25 | 2.1 | NR | Ellis and others, 1985 |
| | Japan Tokyo | -- | -- | -- | NR | NR | 0.075 | -- | -- | -- | -- | -- | -- | -- | -- | -- | Yamane and others, 1990 |
| | United Kingdom Midlands | 0.169 | 2.97 | 1.165 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | Butler and others, 1984 |
| Benzo(b)fluor anthene | Norway Olso | 0.03 | 0.096 | NR | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | Gjessing and others, 1984 |
| | United Kingdom N.W. London | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 0.5 | 4 | NR | Ellis and others, 1985 |
| Benzo(k)fluor anthene | Japan Tokyo | -- | -- | -- | NR | NR | 0.14 | -- | -- | -- | -- | -- | -- | -- | -- | -- | Yamane and others, 1990 |
| | United Kingdom N.W. London | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 0.5 | 4 | NR | Ellis and others, 1985 |
| Benzo(ghi) perylene | Japan Tokyo | -- | -- | -- | NR | NR | 0.42 | -- | -- | -- | -- | -- | -- | -- | -- | -- | Yamane and others, 1990 |
| | United Kingdom N.W. London | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 0.1 | 4.5 | NR | Ellis and others, 1985 |
| Benzo(a) pyrene | US—summary | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 0.04 | 7 | NR | Edwards, 1983 |
| | Canada—summary | NR | 0.866 | NR | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | Edwards, 1983 |
| | Czechoslovakia— summary | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 0.0083 | 0.0421 | -- | Edwards, 1983 |
| | Germany—summary | -- | -- | -- | -- | -- | -- | -- | -- | -- | 0.8 | 650 | NR | 0.0015 | 0.004 | NR | Edwards, 1983 |
| | Japan Tokyo | -- | -- | -- | NR | NR | 0.08 | -- | -- | -- | -- | -- | -- | -- | -- | -- | Yamane and others, 1990 |
| | Russia Moscow—summary | -- | -- | -- | -- | -- | -- | -- | -- | -- | 0.058 | 0.2997 | NR | ND | 200 | -- | Edwards, 1983 |
| | Switzerland Greifensee | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | ND | 2 | NR | Wakeham and others, 1980 |
| United Kingdom N.W. London | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 0.2 | 2.9 | NR | Ellis and others, 1985 | |

Table 7 . Concentrations of detected semivolatile and volatile organic compounds in stormwater, suspended sediment, and bottom material/soil—*Continued*

| Compound name | Location | Land use | | | | | | | | | | | | | | | Reference |
|---|--|----------|-------|-------|-------------|-----|------|------------|-----|------|------------|-----|------|-------------|-------|------|---------------------------|
| | | Highway | | | Residential | | | Commercial | | | Industrial | | | Unspecified | | | |
| | | Min | Max | Mean | Min | Max | Mean | Min | Max | Mean | Min | Max | Mean | Min | Max | Mean | |
| <i>Semivolatile organic compounds, bottom material/soil, in micrograms per gram—Continued</i> | | | | | | | | | | | | | | | | | |
| Benzo(a) pyrene | Midlands | 0.165 | 3.196 | 0.781 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | Butler and others, 1984 |
| | Yugoslavia—summary | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 0.029 | 0.9 | -- | Edwards, 1983 |
| Benzo(e) pyrene | Norway Olso | ND | 0.8 | NR | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | Gjessing and others, 1984 |
| | United Kingdom Midlands | 0.164 | 2.293 | 0.731 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | Butler and others, 1984 |
| Chrysene | Norway Olso | 0.02 | 0.1 | NR | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | Gjessing and others, 1984 |
| | United Kingdom Midlands | 0.251 | 2.703 | 1.949 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | Butler and others, 1984 |
| Coronene | United Kingdom Midlands | 0.032 | 0.322 | 0.117 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | Butler and others, 1984 |
| Fluoranthene | Norway Olso | 0.066 | 0.248 | NR | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | Gjessing and others, 1984 |
| | Switzerland Greifensee | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | ND | 3.5 | NR | Wakeham and others, 1980 |
| | United Kingdom Midlands | 0.2 | 3.734 | 1.313 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | Butler and others, 1984 |
| Fluorene | United Kingdom N.W. London | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 0.3 | 3.9 | NR | Ellis and others, 1985 |
| PAH (total) | United States Washington Lake Washington | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 1 | 6.5 | NR | Wakeham and others, 1980 |
| | Canada—summary | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | NR | 1.109 | NR | Edwards, 1983 |
| | Switzerland Greifensee | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 0.3 | 6 | NR | Wakeham and others, 1980 |
| | Lake Lucerne | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 1 | 5.5 | NR | Wakeham and others, 1980 |
| | Lake Zurich | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 0.4 | 15 | NR | Wakeham and others, 1980 |

Table 7 . Concentrations of detected semivolatile and volatile organic compounds in stormwater, suspended sediment, and bottom material/soil—*Continued*

| Compound name | Location | Land use | | | | | | | | | | | | | | | Reference |
|--|-------------------|----------|-------|-------|-------------|------|------|------------|-------|-------|------------|--------|-------|-------------|-------|------|----------------------------|
| | | Highway | | | Residential | | | Commercial | | | Industrial | | | Unspecified | | | |
| | | Min | Max | Mean | Min | Max | Mean | Min | Max | Mean | Min | Max | Mean | Min | Max | Mean | |
| Semivolatile organic compounds, bottom material/soil, in micrograms per gram—<i>Continued</i> | | | | | | | | | | | | | | | | | |
| PAH (total) | Summary | 5 | 300 | NR | -- | -- | -- | -- | -- | -- | -- | -- | -- | 4 | 8 | NR | Edwards, 1983 |
| | United Kingdom | | | | | | | | | | | | | | | | |
| | Derwent River | 1.51 | 26.76 | 8.32 | 0.02 | 2.45 | 0.58 | 2.65 | 63.75 | 34.55 | 2.91 | 209.59 | 25.75 | -- | -- | -- | Evans and others, 1990 |
| | NW London | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 310 | 1100 | NR | Gavens and others, 1983 |
| Phenanthra-cene | Norway | | | | | | | | | | | | | | | | |
| | Olso | 0.07 | 0.18 | NR | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | Gjessing and others, 1984 |
| | Switzerland | | | | | | | | | | | | | | | | |
| | Greifensee | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | ND | 5 | NR | Wakeham and others, 1980 |
| Pyrene | Norway | | | | | | | | | | | | | | | | |
| | Olso | 0.11 | 0.122 | NR | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | Gjessing and others, 1984 |
| | United Kingdom | | | | | | | | | | | | | | | | |
| | N.W. London | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 0.1 | 3.3 | NR | Ellis and others, 1985 |
| | Midlands | 0.145 | 4.515 | 1.386 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | Butler and others, 1984 |
| Extractable organic compounds, whole water, in milligrams per liter | | | | | | | | | | | | | | | | | |
| Hydrocarbons | United States | | | | | | | | | | | | | | | | |
| | California | | | | | | | | | | | | | | | | |
| | Los Angeles | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 0.99 | 19.5 | NR | Eganhoues and Kaplan, 1981 |
| | San Francisco Bay | -- | -- | -- | -- | -- | -- | -- | -- | -- | 2.98 | 9.75 | NR | 1.606 | 10.83 | NR | Fam and others, 1987 |
| | Florida | | | | | | | | | | | | | | | | |
| | Tallahassee | -- | -- | -- | -- | -- | -- | 0.064 | 16.4 | 3.44 | -- | -- | -- | 0.17 | 1.35 | 0.58 | Hoffman and Quin, 1987 |
| | Pennsylvania | | | | | | | | | | | | | | | | |
| | Philadelphia | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 2.18 | 5.3 | 3.69 | Hunter and others, 1979 |
| | Rhode Island | 0.03 | 6.85 | 3.28 | 0.02 | 1.95 | 1.09 | 0.04 | 5.71 | 0.99 | 0.32 | 58.4 | 19.82 | -- | -- | -- | Hoffman and Quin, 1987 |
| | Cranston | 2 | 6 | NR | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | Hoffman and others, 1983 |
| | Cranston | -- | -- | -- | -- | -- | -- | -- | 1.14 | -- | -- | -- | -- | -- | -- | -- | Hoffman and others, 1984 |
| | Washington | | | | | | | | | | | | | | | | |
| | Seattle | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 6 | 24 | NR | Hoffman and Quin, 1987 |

Table 7 . Concentrations of detected semivolatile and volatile organic compounds in stormwater, suspended sediment, and bottom material/soil—*Continued*

| Compound name | Location | Land use | | | | | | | | | | | | | | | Reference |
|---|-------------------|----------|--------|--------|-------------|--------|--------|------------|--------|--------|------------|---------|---------|-------------|-------|----------------------|----------------------------|
| | | Highway | | | Residential | | | Commercial | | | Industrial | | | Unspecified | | | |
| | | Min | Max | Mean | Min | Max | Mean | Min | Max | Mean | Min | Max | Mean | Min | Max | Mean | |
| Extractable organic compounds, whole water, in milligrams per liter—Continued | | | | | | | | | | | | | | | | | |
| Hydrocarbons | Summary | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 0.64 | 19.71 | NR | Makepeace and others, 1995 |
| | Japan | | | | | | | | | | | | | | | | |
| | Tokyo | -- | -- | -- | NR | NR | 0.75 | -- | -- | -- | -- | -- | -- | -- | -- | -- | Yamane and others, 1990 |
| | Spain | | | | | | | | | | | | | | | | |
| | Madrid | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | NR | NR | 1.154 | Bomboi and Hernandez, 1991 |
| | Switzerland | 1.7 | 10 | 3.9 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | Hoffman and Quin, 1987 |
| | United Kingdom | | | | | | | | | | | | | | | | |
| | NW London | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 0.36 | 1.1 | NR | Gavens and others, 1983 |
| Extractable organic compounds, filtered/centrifuged water, in milligrams per liter | | | | | | | | | | | | | | | | | |
| | United States | | | | | | | | | | | | | | | | |
| | California | | | | | | | | | | | | | | | | |
| | Los Angeles | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 0.302 | 0.49 | NR | Eganhouse and Kaplan, 1981 |
| | San Francisco Bay | -- | -- | -- | -- | -- | -- | -- | -- | 1.29 | 4.32 | NR | 1.18 | 3.98 | NR | Fam and others, 1987 | |
| | Pennsylvania | | | | | | | | | | | | | | | | |
| | Philadelphia | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 0.67 | 0.16 | 0.4 | Hunter and others, 1979 |
| | Rhode Island | | | | | | | | | | | | | | | | |
| | Cranston | ND | 0.5 | NR | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | Hoffman and others, 1983 |
| | Cranston | -- | -- | -- | -- | -- | -- | -- | 0.0954 | -- | -- | -- | -- | -- | -- | -- | Hoffman and others, 1984 |
| Extractable organic compounds, suspended sediment, in micrograms per gram | | | | | | | | | | | | | | | | | |
| | United States | | | | | | | | | | | | | | | | |
| | Rhode Island | 8,750 | 51,800 | 24,800 | 15,700 | 59,800 | 42,000 | 16,400 | 34,000 | 24,800 | 61,900 | 507,000 | 211,000 | -- | -- | -- | Latimer and others, 1990 |
| | Cranston | -- | -- | -- | -- | -- | -- | -- | 21,900 | -- | -- | -- | -- | -- | -- | -- | Hoffman and others, 1984 |
| | Summary | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 8.75 | 507 | NR | Makepeace and others, 1995 |

Table 7 . Concentrations of detected semivolatile and volatile organic compounds in stormwater, suspended sediment, and bottom material/soil—*Continued*

| Compound name | Location | Land use | | | | | | | | | | | | | | | Reference | |
|--|--------------------|----------|-------|-------|-------------|-------|------|------------|-----|------|------------|-------|------|-------------|-------|------|-----------------------------|-------------------------|
| | | Highway | | | Residential | | | Commercial | | | Industrial | | | Unspecified | | | | |
| | | Min | Max | Mean | Min | Max | Mean | Min | Max | Mean | Min | Max | Mean | Min | Max | Mean | | |
| Extractable organic compounds, bottom material/soil, in micrograms per gram | | | | | | | | | | | | | | | | | | |
| Hydrocarbons | United States | | | | | | | | | | | | | | | | | |
| | Florida | | | | | | | | | | | | | | | | | |
| | Tampa | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 152 | 485 | 258 | Brown and others, 1985 | |
| Japan | Tokyo | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | NR | NR | 69 | Yamane and others, 1990 | |
| | United Kingdom | | | | | | | | | | | | | | | | | |
| | NW London | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 43 | 690 | NR | Gavens and others, 1983 | |
| Extractable organic compounds, whole water, in milligrams per liter | | | | | | | | | | | | | | | | | | |
| Oil and grease | United States | | | | | | | | | | | | | | | | | |
| | Arizona | | | | | | | | | | | | | | | | | |
| | Maricopa County | -- | -- | -- | <1 | 10 | NR | <1.0 | 5 | NR | <1 | 6 | NR | <1 | 8 | NR | Lopes and Fossum, 1995 | |
| | California | | | | | | | | | | | | | | | | | |
| | Richmond | 4.2 | 89.09 | 16.05 | 0.57 | 24.55 | 3.92 | 1.98 | -- | 10.9 | 1.49 | 21.11 | 7.26 | 2.1 | 71.97 | 7.87 | Stenstrom and others, 1984 | |
| | Colorado | | | | | | | | | | | | | | | | | |
| | Boulder | -- | -- | -- | 1.7 | 25.9 | NR | 8.9 | 155 | NR | -- | -- | -- | -- | -- | -- | Hoffman and Quin, 1987 | |
| | Colorado Springs | -- | -- | -- | <1 | 10 | NR | <1.0 | 10 | NR | <1 | 6 | NR | -- | -- | -- | von Guerard and Weiss, 1995 | |
| | Michigan | | | | | | | | | | | | | | | | | |
| | Southeast Michigan | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | ND | 0.28 | NR | Hoffman and Quin, 1987 | |
| | North Carolina | -- | -- | -- | -- | -- | -- | -- | -- | -- | <5 | 51 | 6 | -- | -- | -- | Line and others, 1997 | |
| | Texas | | | | | | | | | | | | | | | | | |
| | Austin | 1.4 | 7.8 | 3.65 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | Wiland and Malima, 1976 |
| | Dallas–Fort Worth | -- | -- | -- | <1 | 19 | 2.2 | <1.0 | 8 | 2.3 | 1 | 1.2 | 3.5 | -- | -- | -- | Baldys and others, 1998 | |
| | Washington | | | | | | | | | | | | | | | | | |
| Seattle | 146 | 480 | NR | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | Zawlocki and others, 1980 | |
| Wisconsin | | | | | | | | | | | | | | | | | | |
| Milwaukee | 1 | 20 | NR | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | Gupta, 1981 | |
| Summary | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 0.001 | 110 | NR | Makepeace and others, 1995 | |
| Summary | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 2.7 | 27 | NR | Barrett and others, 1993 | |

Table 7 . Concentrations of detected semivolatile and volatile organic compounds in stormwater, suspended sediment, and bottom material/soil—*Continued*

| Compound name | Location | Land use | | | | | | | | | | | | | | | Reference | |
|--|---|----------|-----|------|-------------|------|------|------------|------|------|------------|------|------|-------------|------|-------|-----------|-----------------------------|
| | | Highway | | | Residential | | | Commercial | | | Industrial | | | Unspecified | | | | |
| | | Min | Max | Mean | Min | Max | Mean | Min | Max | Mean | Min | Max | Mean | Min | Max | Mean | | |
| Extractable organic compounds, bottom material/soil, in micrograms per gram | | | | | | | | | | | | | | | | | | |
| Oil and grease | United States Arizona Maricopa County | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | <100 | 2,200 | NR | Lopes and Fossum, 1995 |
| Volatile organic compounds, whole water, in micrograms per liter | | | | | | | | | | | | | | | | | | |
| Benzene | United States Arizona Maricopa County | -- | -- | -- | <0.2 | <0.2 | NR | <0.2 | <0.2 | NR | <0.2 | <0.2 | NR | -- | -- | -- | -- | Lopes and others, 1995 |
| | Colorado Colorado Springs | -- | -- | -- | <0.2 | <0.2 | NR | <0.2 | 0.4 | NR | <0.2 | <0.2 | NR | -- | -- | -- | -- | von Guerard and Weiss, 1995 |
| | Texas Dallas–Fort Worth | -- | -- | -- | <0.2 | <0.2 | NR | <0.2 | 0.8 | 0.12 | <0.2 | 0.6 | NR | -- | -- | -- | -- | Baldys and others, 1998 |
| | Summary–NURP | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 3.5 | 13 | NR | -- | Cole and others, 1984 |
| Bromodi chloro methane | United States Colorado Colorado Springs | -- | -- | -- | <0.2 | <0.2 | NR | <0.2 | <0.2 | NR | <0.2 | <0.2 | NR | -- | -- | -- | -- | von Guerard and Weiss, 1995 |
| | Texas Dallas–Fort Worth | -- | -- | -- | <0.2 | 0.2 | NR | <0.2 | <10 | NR | <0.2 | 0.5 | NR | -- | -- | -- | -- | Baldys and others, 1998 |
| | Summary–NURP | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | NR | 2 | NR | -- | Cole and others, 1984 |
| | Summary–NPDES | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | <0.2 | 2.8 | NR | -- | Delzer and others, 1996 |
| <i>n</i> -Butyl benzene | United States Arizona Maricopa County | -- | -- | -- | <0.2 | <0.2 | NR | <0.2 | <0.2 | NR | <0.2 | <0.2 | NR | -- | -- | -- | -- | Lopes and others, 1995 |
| | Colorado Colorado Springs | -- | -- | -- | <0.2 | <0.2 | NR | <0.2 | 0.4 | NR | <0.2 | <0.2 | NR | -- | -- | -- | -- | von Guerard and Weiss, 1995 |
| | Texas Dallas–Fort Worth | -- | -- | -- | <0.2 | 0.2 | NR | <0.2 | <10 | NR | <0.2 | <10 | NR | -- | -- | -- | -- | Baldys and others, 1998 |
| Chlorobenzene | United States Arizona Maricopa County | -- | -- | -- | <0.2 | <0.2 | NR | <0.2 | <0.2 | NR | <0.2 | <0.2 | NR | -- | -- | -- | -- | Lopes and others, 1995 |

Table 7 . Concentrations of detected semivolatile and volatile organic compounds in stormwater, suspended sediment, and bottom material/soil—*Continued*

| Compound name | Location | Land use | | | | | | | | | | | | | | | Reference | |
|---|------------------|----------|-----|------|-------------|------|------|------------|------|------|------------|------|------|-------------|-----|------|-----------------------------|-----------------------------|
| | | Highway | | | Residential | | | Commercial | | | Industrial | | | Unspecified | | | | |
| | | Min | Max | Mean | Min | Max | Mean | Min | Max | Mean | Min | Max | Mean | Min | Max | Mean | | |
| <i>Volatile organic compounds, whole water, in micrograms per liter—Continued</i> | | | | | | | | | | | | | | | | | | |
| Chlorobenzene | Colorado | | | | | | | | | | | | | | | | von Guerard and Weiss, 1995 | |
| | Colorado Springs | -- | -- | -- | <0.2 | <0.2 | NR | <0.2 | <0.2 | NR | <0.2 | <0.2 | NR | -- | -- | -- | | |
| | Texas | | | | | | | | | | | | | | | | | Baldys and others, 1998 |
| Dallas–Fort Worth | -- | -- | -- | <0.2 | <5 | NR | <0.2 | <10 | NR | <0.2 | <10 | NR | -- | -- | -- | | | |
| | Summary–NURP | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 1 | 10 | NR | Cole and others, 1984 | |
| Chloroethene (vinyl chloride) | United States | | | | | | | | | | | | | | | | Lopes and others, 1995 | |
| | Arizona | | | | | | | | | | | | | | | | | |
| | Maricopa County | -- | -- | -- | <0.2 | <0.2 | NR | <0.2 | <0.2 | NR | <0.2 | <0.2 | NR | -- | -- | -- | | |
| | Colorado | | | | | | | | | | | | | | | | | von Guerard and Weiss, 1995 |
| Colorado Springs | -- | -- | -- | -- | -- | -- | <0.2 | <0.2 | NR | <0.2 | <0.2 | NR | -- | -- | -- | | | |
| | Texas | | | | | | | | | | | | | | | | Baldys and others, 1998 | |
| Dallas–Fort Worth | -- | -- | -- | <0.2 | <5 | NR | <0.2 | <10 | NR | <0.2 | 110 | NR | -- | -- | -- | | | |
| 1,2-Chloro toluene | United States | | | | | | | | | | | | | | | | Baldys and others, 1998 | |
| | Texas | | | | | | | | | | | | | | | | | |
| Dallas–Fort Worth | -- | -- | -- | <0.2 | <5 | NR | <0.2 | <10 | NR | <0.2 | 0.2 | NR | -- | -- | -- | | | |
| 1,4-Chloro toluene | United States | | | | | | | | | | | | | | | | Baldys and others, 1998 | |
| | Texas | | | | | | | | | | | | | | | | | |
| Dallas–Fort Worth | -- | -- | -- | <0.2 | <5 | NR | <0.2 | <10 | NR | <0.2 | 0.2 | NR | -- | -- | -- | | | |
| Dibromochloro-methane (chloro dibromo-methane) | United States | | | | | | | | | | | | | | | | Lopes and others, 1995 | |
| | Arizona | | | | | | | | | | | | | | | | | |
| | Maricopa County | -- | -- | -- | <0.2 | <0.2 | NR | <0.2 | <0.2 | NR | <0.2 | <0.2 | NR | -- | -- | -- | | |
| | Colorado | | | | | | | | | | | | | | | | | von Guerard and Weiss, 1995 |
| | Colorado Springs | -- | -- | -- | <0.2 | <0.2 | NR | <0.2 | <0.2 | NR | <0.2 | <0.2 | NR | -- | -- | -- | | |
| | Texas | | | | | | | | | | | | | | | | Baldys and others, 1998 | |
| Dallas–Fort Worth | -- | -- | -- | <0.2 | <0.2 | NR | <0.2 | <10 | NR | <0.2 | <10 | NR | -- | -- | -- | | | |
| | Summary–NURP | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 2 | 2 | NR | Cole and others, 1984 | |
| Dibromo methane | United States | | | | | | | | | | | | | | | | Lopes and others, 1995 | |
| | Arizona | | | | | | | | | | | | | | | | | |
| Maricopa County | -- | -- | -- | <0.2 | <0.2 | NR | <0.2 | <0.2 | NR | <0.2 | <0.2 | NR | -- | -- | -- | | | |

Table 7 . Concentrations of detected semivolatile and volatile organic compounds in stormwater, suspended sediment, and bottom material/soil—*Continued*

| Compound name | Location | Land use | | | | | | | | | | | | | | | Reference | |
|---|---|----------|-----|------|-------------|------|------|------------|------|------|------------|------|------|-------------|-----|------|-----------------------------|----------------------------|
| | | Highway | | | Residential | | | Commercial | | | Industrial | | | Unspecified | | | | |
| | | Min | Max | Mean | Min | Max | Mean | Min | Max | Mean | Min | Max | Mean | Min | Max | Mean | | |
| <i>Volatile organic compounds, whole water, in micrograms per liter—Continued</i> | | | | | | | | | | | | | | | | | | |
| Dibromo methane | Colorado Colorado Springs | -- | -- | -- | <0.2 | <0.2 | NR | <0.2 | <0.2 | NR | <0.2 | <0.2 | NR | -- | -- | -- | von Guerard and Weiss, 1995 | |
| | Texas Dallas–Fort Worth | -- | -- | -- | <0.2 | 0.2 | NR | <0.2 | 0.4 | NR | <0.2 | 0.7 | NR | -- | -- | -- | Baldys and others, 1998 | |
| 1,1-Dichloro ethane | United States Arizona Maricopa County | -- | -- | -- | <0.2 | <0.2 | NR | <0.2 | <0.2 | NR | <0.2 | <0.2 | NR | -- | -- | -- | Lopes and others, 1995 | |
| | Colorado Colorado Springs | -- | -- | -- | <0.2 | <0.2 | NR | <0.2 | <0.2 | NR | <0.2 | <0.2 | NR | -- | -- | -- | von Guerard and Weiss, 1995 | |
| | Texas Dallas–Fort Worth | -- | -- | -- | <0.2 | <5 | NR | <0.2 | <10 | NR | <0.2 | 8.3 | NR | -- | -- | -- | Baldys and others, 1998 | |
| | Summary–NURP | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 1.5 | 3 | NR | Cole and others, 1984 |
| 1,2-Dichloro ethane | United States Arizona Maricopa County | -- | -- | -- | <0.2 | <0.2 | NR | <0.2 | 0.2 | NR | <0.2 | <0.2 | NR | -- | -- | -- | Lopes and others, 1995 | |
| | Colorado Colorado Springs | -- | -- | -- | <0.2 | <0.2 | NR | <0.2 | 0.2 | NR | <0.2 | <0.2 | NR | -- | -- | -- | von Guerard and Weiss, 1995 | |
| | Texas Dallas–Fort Worth | -- | -- | -- | <0.2 | <5 | NR | <0.2 | <10 | NR | <0.2 | <10 | NR | -- | -- | -- | Baldys and others, 1998 | |
| | Summary–NURP | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | NR | 4 | NR | Cole and others, 1984 |
| 1,1-Dichloro ethene (1,1-Dichloro ethylene) | United States Arizona Maricopa County | -- | -- | -- | <0.2 | <0.2 | NR | <0.2 | <0.2 | NR | <0.2 | <0.2 | NR | -- | -- | -- | Lopes and others, 1995 | |
| | Colorado Colorado Springs | -- | -- | -- | <0.2 | <0.2 | NR | <0.2 | <0.2 | NR | <0.2 | <0.2 | NR | -- | -- | -- | von Guerard and Weiss, 1995 | |
| | Texas Dallas–Fort Worth | -- | -- | -- | <0.2 | 5.9 | NR | <0.2 | <10 | NR | <0.2 | 13 | NR | -- | -- | -- | Baldys and others, 1998 | |
| | Summary–NURP | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 1.5 | 4 | NR | Cole and others, 1984 |
| | Summary | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 1.5 | 4 | NR | Makepeace and others, 1995 |

Table 7 . Concentrations of detected semivolatile and volatile organic compounds in stormwater, suspended sediment, and bottom material/soil—*Continued*

| Compound name | Location | Land use | | | | | | | | | | | | | | | Reference |
|---|-------------------|----------|-----|------|-------------|------|------|------------|------|------|------------|------|------|-------------|------|-------------------------|-----------------------------|
| | | Highway | | | Residential | | | Commercial | | | Industrial | | | Unspecified | | | |
| | | Min | Max | Mean | Min | Max | Mean | Min | Max | Mean | Min | Max | Mean | Min | Max | Mean | |
| <i>Volatile organic compounds, whole water, in micrograms per liter—Continued</i> | | | | | | | | | | | | | | | | | |
| <i>cis</i> -1,2-Dichloroethene | United States | | | | | | | | | | | | | | | | |
| | Arizona | | | | | | | | | | | | | | | | |
| | Maricopa County | -- | -- | -- | <0.2 | <0.2 | NR | <0.2 | <0.2 | NR | <0.2 | <0.2 | NR | -- | -- | -- | Lopes and others, 1995 |
| Colorado | Colorado Springs | -- | -- | -- | <0.2 | <0.2 | NR | <0.2 | <0.2 | NR | <0.2 | <0.2 | NR | -- | -- | -- | von Guerard and Weiss, 1995 |
| | Texas | | | | | | | | | | | | | | | | |
| | Dallas–Fort Worth | -- | -- | -- | <0.2 | <5 | NR | <0.2 | <10 | NR | <0.2 | 1200 | 25.7 | -- | -- | -- | Baldys and others, 1998 |
| <i>trans</i> -1,2-Dichloroethene (<i>trans</i> -1,2-Dichloroethylene) | United States | | | | | | | | | | | | | | | | |
| | Arizona | | | | | | | | | | | | | | | | |
| | Maricopa County | -- | -- | -- | <0.2 | <0.2 | NR | <0.2 | <0.2 | NR | <0.2 | <0.2 | NR | -- | -- | -- | Lopes and others, 1995 |
| | Colorado | | | | | | | | | | | | | | | | |
| | Colorado Springs | -- | -- | -- | <0.2 | <0.2 | NR | <0.2 | <0.2 | NR | <0.2 | <0.2 | NR | -- | -- | -- | von Guerard and Weiss, 1995 |
| | Texas | | | | | | | | | | | | | | | | |
| Dallas–Fort Worth | -- | -- | -- | <0.2 | <5 | NR | <0.2 | <10 | NR | <0.2 | 27 | NR | -- | -- | -- | Baldys and others, 1998 | |
| Summary–NURP | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 1 | 3 | NR | Cole and others, 1984 |
| Summary | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 1 | 3 | NR | Makepeace and others, 1995 |
| Dichloro methane (methylene chloride) | United States | | | | | | | | | | | | | | | | |
| | Arizona | | | | | | | | | | | | | | | | |
| | Maricopa County | -- | -- | -- | <0.2 | <0.2 | NR | <0.2 | <20 | NR | <0.2 | 0.2 | NR | -- | -- | -- | Lopes and others, 1995 |
| | Colorado | | | | | | | | | | | | | | | | |
| | Colorado Springs | -- | -- | -- | -- | -- | -- | <0.2 | <0.2 | NR | <0.2 | <0.2 | NR | -- | -- | -- | von Guerard and Weiss, 1995 |
| Texas | | | | | | | | | | | | | | | | | |
| Dallas–Fort Worth | -- | -- | -- | <0.2 | 0.8 | NR | <0.2 | <0.2 | NR | <0.2 | 0.09 | 0.09 | -- | -- | -- | Baldys and others, 1998 | |
| Summary–NURP | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 4 | 14.5 | NR | Cole and others, 1984 |
| Summary–NPDES | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | <0.2 | 13 | NR | Baldys and others, 1998 |
| 1,2-Dichloro propane | United States | | | | | | | | | | | | | | | | |
| | Arizona | | | | | | | | | | | | | | | | |
| Maricopa County | -- | -- | -- | <0.2 | <0.2 | NR | <0.2 | <0.2 | NR | <0.2 | <0.2 | NR | -- | -- | -- | Lopes and others, 1995 | |

Table 7 . Concentrations of detected semivolatile and volatile organic compounds in stormwater, suspended sediment, and bottom material/soil—*Continued*

| Compound name | Location | Land use | | | | | | | | | | | | | | | Reference |
|---|---|----------|-----|------|-------------|------|------|------------|------|------|------------|------|------|-------------|-----|------|-----------------------------|
| | | Highway | | | Residential | | | Commercial | | | Industrial | | | Unspecified | | | |
| | | Min | Max | Mean | Min | Max | Mean | Min | Max | Mean | Min | Max | Mean | Min | Max | Mean | |
| <i>Volatile organic compounds, whole water, in micrograms per liter—Continued</i> | | | | | | | | | | | | | | | | | |
| 1,2-Dichloro propane | Colorado Colorado Springs | -- | -- | -- | <0.2 | <0.2 | NR | <0.2 | <0.2 | NR | <0.2 | <0.2 | NR | -- | -- | -- | von Guerard and Weiss, 1995 |
| | Texas Dallas–Fort Worth | -- | -- | -- | <0.2 | <5 | NR | <0.2 | <10 | NR | <0.2 | <10 | NR | -- | -- | -- | Baldys and others, 1998 |
| 1,3-Dichloro propene (isomer not specified) | Summary–NPDES | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | NR | 3 | NR | Cole and others, 1984 |
| | Summary–NURP | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 1 | 2 | NR | Cole and others, 1984 |
| Ethenyl benzene (Styrene) | United States Arizona | -- | -- | -- | <0.2 | <0.2 | NR | <0.2 | <20 | NR | <0.2 | 0.5 | NR | -- | -- | -- | Lopes and others, 1995 |
| | Maricopa County Colorado Colorado Springs | -- | -- | -- | -- | -- | -- | <0.2 | <0.2 | NR | <0.2 | <0.2 | NR | -- | -- | -- | von Guerard and Weiss, 1995 |
| Ethylbenzene | Texas Dallas–Fort Worth | -- | -- | -- | <0.2 | <5 | NR | <0.2 | 0.6 | NR | <0.2 | <10 | NR | -- | -- | -- | Baldys and others, 1998 |
| | United States Arizona | -- | -- | -- | <0.2 | <0.2 | NR | <0.2 | <20 | NR | <0.2 | <0.2 | NR | -- | -- | -- | Lopes and others, 1995 |
| Isopropyl benzene | Maricopa County Colorado Colorado Springs | -- | -- | -- | <0.2 | <0.2 | NR | <0.2 | <0.2 | NR | <0.2 | <0.2 | NR | -- | -- | -- | von Guerard and Weiss, 1995 |
| | Texas Dallas–Fort Worth | -- | -- | -- | <0.2 | 0.6 | NR | <0.2 | 0.6 | NR | <0.2 | 1.5 | NR | -- | -- | -- | Baldys and others, 1998 |
| Isopropyl benzene | Summary–NURP | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 1 | 2 | NR | Cole and others, 1984 |
| | Summary–NPDES | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | <0.2 | 2 | NR | Delzer and others, 1996 |
| Isopropyl benzene | United States Arizona | -- | -- | -- | <0.2 | <0.2 | NR | <0.2 | <20 | NR | <0.2 | <0.2 | NR | -- | -- | -- | Lopes and others, 1995 |
| | Maricopa County Colorado Colorado Springs | -- | -- | -- | <0.2 | <0.2 | NR | <0.2 | <0.2 | NR | <0.2 | <0.2 | NR | -- | -- | -- | von Guerard and Weiss, 1995 |

Table 7 . Concentrations of detected semivolatile and volatile organic compounds in stormwater, suspended sediment, and bottom material/soil—*Continued*

| Compound name | Location | Land use | | | | | | | | | | | | | | | Reference | |
|---|--|--|-----|------|-------------|------|------|------------|-----|------|------------|------|------|-------------|------|------|-----------------------------|-------------------------|
| | | Highway | | | Residential | | | Commercial | | | Industrial | | | Unspecified | | | | |
| | | Min | Max | Mean | Min | Max | Mean | Min | Max | Mean | Min | Max | Mean | Min | Max | Mean | | |
| <i>Volatile organic compounds, whole water, in micrograms per liter—Continued</i> | | | | | | | | | | | | | | | | | | |
| Isopropyl benzene | Texas Dallas–Fort Worth | -- | -- | -- | <0.2 | -- | NR | <0.2 | <10 | NR | <0.2 | 4.6 | NR | -- | -- | -- | Baldys and others, 1998 | |
| 1-Isopropyl-4-methyl benzene (P-isopropyltoluene) | United States Arizona Maricopa County | -- | -- | -- | <0.2 | <0.2 | NR | <0.2 | <20 | NR | <0.2 | 0.7 | NR | -- | -- | -- | Lopes and others, 1995 | |
| | Colorado Colorado Springs | -- | -- | -- | <0.2 | <0.2 | NR | <0.2 | <10 | NR | <0.2 | <10 | NR | -- | -- | -- | von Guerard and Weiss, 1995 | |
| | Texas Dallas–Fort Worth | -- | -- | -- | <0.2 | <5 | NR | <0.2 | 0.9 | NR | <0.2 | 0.2 | NR | -- | -- | -- | Baldys and others, 1998 | |
| | United States Arizona Maricopa County | -- | -- | -- | <0.2 | <0.2 | NR | <1 | 0.2 | NR | <0.2 | 0.3 | NR | -- | -- | -- | Lopes and others, 1995 | |
| Methyl benzene (Toluene) | Colorado Colorado Springs | -- | -- | -- | <0.2 | 1.2 | NR | <0.2 | 1.7 | NR | <0.2 | 0.4 | NR | -- | -- | -- | von Guerard and Weiss, 1995 | |
| | Texas Dallas–Fort Worth | -- | -- | -- | <0.2 | 1.8 | 0.08 | <0.2 | 2.4 | 0.25 | <0.2 | 1.8 | 0.11 | -- | -- | -- | Baldys and others, 1998 | |
| | Summary–NURP | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 9 | 12 | NR | Cole and others, 1984 | |
| | Summary–NPDES | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | <0.2 | 6.6 | NR | Delzer and others, 1996 | |
| | 2-Methoxy-2-methyl-propane (Methyl tert-butyl ether) | United States Alabama Birmingham | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | <0.2 | 1.9 | NR | Delzer and others, 1996 |
| | | Arizona Maricopa County | -- | -- | -- | <0.2 | <0.2 | NR | <5 | 2.5 | NR | <0.2 | 0.3 | NR | -- | -- | -- | Lopes and others, 1995 |
| Phoenix | | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | <0.2 | 2.5 | NR | Delzer and others, 1996 | |
| Colorado Colorado Springs | | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | <0.2 | 3 | NR | Delzer and others, 1996 | |
| Denver | | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | <0.2 | 1.5 | NR | Delzer and others, 1996 | |

Table 7 . Concentrations of detected semivolatile and volatile organic compounds in stormwater, suspended sediment, and bottom material/soil—*Continued*

| Compound name | Location | Land use | | | | | | | | | | | | | | | Reference | |
|---|---|----------|-----|------|-------------|------|------|------------|------|------|------------|------|------|-------------|------|------|-----------|-----------------------------|
| | | Highway | | | Residential | | | Commercial | | | Industrial | | | Unspecified | | | | |
| | | Min | Max | Mean | Min | Max | Mean | Min | Max | Mean | Min | Max | Mean | Min | Max | Mean | | |
| <i>Volatile organic compounds, whole water, in micrograms per liter—Continued</i> | | | | | | | | | | | | | | | | | | |
| 2-Methoxy-2-methylpropane (Methyl <i>tert</i> -butyl ether) | Georgia Atlanta | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | <0.2 | 1.5 | NR | Delzer and others, 1996 |
| | Louisiana Baton Rouge | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | <0.2 | 0.4 | NR | Delzer and others, 1996 |
| | Texas Dallas–Fort Worth | -- | -- | -- | <1 | <25 | NR | <1 | 8.7 | 1.2 | <0.2 | 5.4 | NR | -- | -- | -- | -- | Baldys and others, 1998 |
| | San Antonio | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | <0.2 | 1.8 | NR | Delzer and others, 1996 |
| | Summary–NPDES | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | <0.2 | 8.7 | NR | Delzer and others, 1996 |
| Naphthalene | United States Colorado Colorado Springs | -- | -- | -- | <0.2 | 0.4 | NR | <0.2 | -- | NR | <0.2 | 1.1 | NR | -- | -- | -- | -- | von Guerard and Weiss, 1995 |
| | Texas Dallas–Fort Worth | -- | -- | -- | <0.2 | 0.6 | NR | <0.2 | <5 | NR | <0.2 | 1.3 | NR | -- | -- | -- | -- | Baldys and others, 1998 |
| | Summary–NPDES | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | <0.2 | 5.1 | NR | Delzer and others, 1996 |
| | United States Arizona Maricopa County | -- | -- | -- | <0.2 | <0.2 | NR | <0.2 | <0.2 | NR | <0.2 | <0.2 | NR | -- | -- | -- | -- | Lopes and others, 1995 |
| <i>n</i> -Propyl benzene | Colorado Colorado Springs | -- | -- | -- | -- | -- | -- | <0.2 | <0.2 | NR | <0.2 | <0.2 | NR | -- | -- | -- | -- | von Guerard and Weiss, 1995 |
| | Texas Dallas–Fort Worth | -- | -- | -- | <0.2 | <5 | NR | <0.2 | <10 | NR | <0.2 | 0.5 | NR | -- | -- | -- | -- | Baldys and others, 1998 |
| | United States Arizona Maricopa County | -- | -- | -- | <0.2 | <0.2 | NR | <0.2 | <0.2 | NR | <0.2 | <0.2 | NR | -- | -- | -- | -- | Lopes and others, 1995 |
| | Colorado Colorado Springs | -- | -- | -- | -- | -- | -- | <0.2 | <0.2 | NR | <0.2 | <0.2 | NR | -- | -- | -- | -- | von Guerard and Weiss, 1995 |
| 1,1,2,2-Tetrachloro ethane | United States Arizona Maricopa County | -- | -- | -- | <0.2 | <0.2 | NR | <0.2 | <0.2 | NR | <0.2 | <0.2 | NR | -- | -- | -- | -- | Lopes and others, 1995 |
| | Colorado Colorado Springs | -- | -- | -- | -- | -- | -- | <0.2 | <0.2 | NR | <0.2 | <0.2 | NR | -- | -- | -- | -- | von Guerard and Weiss, 1995 |
| | Texas Dallas–Fort Worth | -- | -- | -- | <0.2 | <5 | NR | <0.2 | <10 | NR | <0.2 | <01 | NR | -- | -- | -- | -- | Baldys and others, 1998 |
| | Summary–NURP | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 2 | 3 | NR | Cole and others, 1984 |

Table 7 . Concentrations of detected semivolatile and volatile organic compounds in stormwater, suspended sediment, and bottom material/soil—*Continued*

| Compound name | Location | Land use | | | | | | | | | | | | | | | Reference |
|---|------------------|----------|-----|------|-------------|------|------|------------|------|------|------------|------|------|-------------|-----|-----------------------------|-----------------------------|
| | | Highway | | | Residential | | | Commercial | | | Industrial | | | Unspecified | | | |
| | | Min | Max | Mean | Min | Max | Mean | Min | Max | Mean | Min | Max | Mean | Min | Max | Mean | |
| <i>Volatile organic compounds, whole water, in micrograms per liter—Continued</i> | | | | | | | | | | | | | | | | | |
| Tetrachloro ethene (Tetrachloroethylene) | United States | | | | | | | | | | | | | | | | |
| | Arizona | | | | | | | | | | | | | | | | |
| | Maricopa County | -- | -- | -- | <0.2 | <0.2 | NR | <0.2 | <0.2 | NR | <0.2 | <0.2 | NR | -- | -- | -- | Lopes and others, 1995 |
| | Colorado | | | | | | | | | | | | | | | | |
| | Colorado Springs | -- | -- | -- | -- | -- | -- | <0.2 | <0.2 | NR | <0.2 | <0.2 | NR | -- | -- | -- | von Guerard and Weiss, 1995 |
| | Texas | | | | | | | | | | | | | | | | |
| Dallas–Fort Worth | -- | -- | -- | <0.2 | <5 | NR | <0.2 | <10 | NR | <0.2 | 42 | 1.2 | -- | -- | -- | Baldys and others, 1998 | |
| | Summary–NURP | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 4.5 | 43 | NR | Cole and others, 1984 |
| | Summary–NPDES | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | <0.2 | 42 | NR | Delzer and others, 1996 |
| Tetrachloro methane (Carbon tetra chloride) | United States | | | | | | | | | | | | | | | | |
| | Arizona | | | | | | | | | | | | | | | | |
| | Maricopa County | -- | -- | -- | <0.2 | <0.2 | NR | <0.2 | <0.2 | NR | <0.2 | <0.2 | NR | -- | -- | -- | Lopes and others, 1995 |
| | Colorado | | | | | | | | | | | | | | | | |
| | Colorado Springs | -- | -- | -- | <0.2 | <0.2 | NR | <0.2 | <0.2 | NR | <0.2 | <0.2 | NR | -- | -- | -- | von Guerard and Weiss, 1995 |
| | Texas | | | | | | | | | | | | | | | | |
| Dallas–Fort Worth | -- | -- | -- | <0.2 | <5 | NR | <0.2 | <10 | NR | <0.2 | <10 | NR | -- | -- | -- | Baldys and others, 1998 | |
| | Summary–NURP | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 1 | 2 | NR | Cole and others, 1984 |
| Tribromo methane (Bromo form) | United States | | | | | | | | | | | | | | | | |
| | Arizona | | | | | | | | | | | | | | | | |
| | Maricopa County | -- | -- | -- | <0.2 | <0.2 | NR | <0.2 | <0.2 | NR | <0.2 | <0.2 | NR | -- | -- | -- | Lopes and others, 1995 |
| | Colorado | | | | | | | | | | | | | | | | |
| | Colorado Springs | -- | -- | -- | <0.2 | <0.2 | NR | <0.2 | <0.2 | NR | <0.2 | <0.2 | NR | -- | -- | -- | von Guerard and Weiss, 1995 |
| | Texas | | | | | | | | | | | | | | | | |
| Dallas–Fort Worth | -- | -- | -- | <0.2 | <5 | NR | <0.2 | <10 | NR | <0.2 | <10 | NR | -- | -- | -- | Baldys and others, 1998 | |
| | Summary–NURP | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | NR | 1 | NR | Cole and others, 1984 |
| 1,1,1-Trichloro ethane | United States | | | | | | | | | | | | | | | | |
| | Arizona | | | | | | | | | | | | | | | | |
| | Maricopa County | -- | -- | -- | <0.2 | <0.2 | NR | <0.2 | <0.2 | NR | <0.2 | <0.2 | NR | -- | -- | -- | Lopes and others, 1995 |
| Colorado | | | | | | | | | | | | | | | | | |
| Colorado Springs | -- | -- | -- | -- | -- | -- | <0.2 | 0.7 | NR | <0.2 | <0.2 | NR | -- | -- | -- | von Guerard and Weiss, 1995 | |

Table 7 . Concentrations of detected semivolatile and volatile organic compounds in stormwater, suspended sediment, and bottom material/soil—*Continued*

| Compound name | Location | Land use | | | | | | | | | | | | | | | Reference |
|---|-------------------|----------|-----|------|-------------|------|------|------------|------|------|------------|------|-------|-------------|------|-------------------------|-----------------------------|
| | | Highway | | | Residential | | | Commercial | | | Industrial | | | Unspecified | | | |
| | | Min | Max | Mean | Min | Max | Mean | Min | Max | Mean | Min | Max | Mean | Min | Max | Mean | |
| <i>Volatile organic compounds, whole water, in micrograms per liter—Continued</i> | | | | | | | | | | | | | | | | | |
| 1,1,1-Trichloroethane | Texas | | | | | | | | | | | | | | | | |
| | Dallas–Fort Worth | -- | -- | -- | <0.2 | <0.2 | NR | <0.2 | 0.2 | NR | <0.2 | 5.4 | <0.24 | -- | -- | -- | Baldys and others, 1998 |
| | Summary–NURP | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 1.6 | 10 | NR | Cole and others, 1984 |
| 1,1,2-Trichloroethane | United States | | | | | | | | | | | | | | | | |
| | Arizona | | | | | | | | | | | | | | | | |
| | Maricopa County | -- | -- | -- | <0.2 | <0.2 | NR | <0.2 | <0.2 | NR | <0.2 | <0.2 | NR | -- | -- | -- | Lopes and others, 1995 |
| | Colorado | | | | | | | | | | | | | | | | |
| | Colorado Springs | -- | -- | -- | -- | -- | -- | <0.2 | <0.2 | NR | <0.2 | <0.2 | NR | -- | -- | -- | von Guerard and Weiss, 1995 |
| | Texas | | | | | | | | | | | | | | | | |
| Dallas–Fort Worth | -- | -- | -- | <0.2 | <5 | NR | <0.2 | <10 | NR | <0.2 | <0.2 | NR | -- | -- | -- | Baldys and others, 1998 | |
| | Summary–NURP | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 2 | 3 | NR | Cole and others, 1984 |
| Trichloroethene (Trichloroethylene) | United States | | | | | | | | | | | | | | | | |
| | Arizona | | | | | | | | | | | | | | | | |
| | Maricopa County | -- | -- | -- | <0.2 | <0.2 | NR | <0.2 | <0.2 | NR | <0.2 | <0.2 | NR | -- | -- | -- | Lopes and others, 1995 |
| | Colorado | | | | | | | | | | | | | | | | |
| | Colorado Springs | -- | -- | -- | -- | -- | -- | <0.2 | <0.2 | NR | <0.2 | <0.2 | NR | -- | -- | -- | von Guerard and Weiss, 1995 |
| | Texas | | | | | | | | | | | | | | | | |
| Dallas–Fort Worth | -- | -- | -- | <0.2 | 0.2 | NR | <0.2 | <10 | NR | <0.2 | 28 | 1.3 | -- | -- | -- | Baldys and others, 1998 | |
| | Summary–NURP | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 0.3 | 10 | NR | Cole and others, 1984 |
| | Summary | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 0.3 | 10 | NR | Makepeace and others, 1995 |
| Trichloro fluoro methane | United States | | | | | | | | | | | | | | | | |
| | Arizona | | | | | | | | | | | | | | | | |
| | Maricopa County | -- | -- | -- | <0.2 | <0.2 | NR | <0.2 | <0.2 | NR | <0.2 | <0.2 | NR | -- | -- | -- | Lopes and others, 1995 |
| | Colorado | | | | | | | | | | | | | | | | |
| | Colorado Springs | -- | -- | -- | -- | -- | -- | <0.2 | <0.2 | NR | <0.2 | <0.2 | NR | -- | -- | -- | von Guerard and Weiss, 1995 |
| | Texas | | | | | | | | | | | | | | | | |
| Dallas–Fort Worth | -- | -- | -- | <0.5 | <13 | NR | <0.5 | <25 | NR | <0.2 | <25 | NR | -- | -- | -- | Baldys and others, 1998 | |
| | Summary–NURP | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 0.6 | 0.27 | NR | Cole and others, 1984 |

Table 7 . Concentrations of detected semivolatile and volatile organic compounds in stormwater, suspended sediment, and bottom material/soil—*Continued*

| Compound name | Location | Land use | | | | | | | | | | | | | | | Reference |
|---|------------------|----------|-----|------|-------------|------|------|------------|------|------|------------|------|------|-------------|-----|-----------------------------|-----------------------------|
| | | Highway | | | Residential | | | Commercial | | | Industrial | | | Unspecified | | | |
| | | Min | Max | Mean | Min | Max | Mean | Min | Max | Mean | Min | Max | Mean | Min | Max | Mean | |
| <i>Volatile organic compounds, whole water, in micrograms per liter—Continued</i> | | | | | | | | | | | | | | | | | |
| Trichloro methane Chloroform | United States | | | | | | | | | | | | | | | | |
| | Arizona | | | | | | | | | | | | | | | | |
| | Maricopa County | -- | -- | -- | <0.2 | <0.2 | NR | <0.2 | <0.2 | NR | <0.2 | <0.2 | NR | -- | -- | -- | Lopes and others, 1995 |
| | Colorado | | | | | | | | | | | | | | | | |
| | Colorado Springs | -- | -- | -- | <0.2 | <0.2 | NR | <0.2 | 2.1 | NR | <0.2 | <0.2 | NR | -- | -- | -- | von Guerard and Weiss, 1995 |
| | Texas | | | | | | | | | | | | | | | | |
| Dallas–Fort Worth | -- | -- | -- | <0.2 | 0.7 | 0.06 | <0.2 | 1.1 | NR | <0.2 | 0.7 | 0.15 | -- | -- | -- | Baldys and others, 1998 | |
| Summary–NURP | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 0.2 | 12 | NR | Cole and others, 1984 | |
| Summary–NPDES | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | <0.2 | 7 | NR | Delzer and others, 1996 | |
| 1,1,2-Trichloro-1,2,2-trifluoro ethane | United States | | | | | | | | | | | | | | | | |
| | Texas | | | | | | | | | | | | | | | | |
| Dallas–Fort Worth | -- | -- | -- | <0.2 | 0.4 | NR | <0.2 | <10 | NR | <0.2 | <0.2 | NR | -- | -- | -- | Baldys and others, 1998 | |
| 1,2,4-Trimethyl benzene | United States | | | | | | | | | | | | | | | | |
| | Colorado | | | | | | | | | | | | | | | | |
| | Colorado Springs | -- | -- | -- | <0.2 | 0.9 | NR | <0.2 | 2.8 | NR | <0.2 | 0.4 | NR | -- | -- | -- | von Guerard and Weiss, 1995 |
| Texas | | | | | | | | | | | | | | | | | |
| Dallas–Fort Worth | -- | -- | -- | <0.2 | 2 | NR | <0.2 | 0.4 | NR | <0.2 | 15 | NR | -- | -- | -- | Baldys and others, 1998 | |
| 1,3,5-Trimethyl benzene | United States | | | | | | | | | | | | | | | | |
| | Colorado | | | | | | | | | | | | | | | | |
| | Colorado Springs | -- | -- | -- | <0.2 | <0.2 | NR | <0.2 | 0.9 | NR | <0.2 | <0.2 | -- | -- | -- | von Guerard and Weiss, 1995 | |
| Texas | | | | | | | | | | | | | | | | | |
| Dallas–Fort Worth | -- | -- | -- | <0.2 | <0.2 | NR | <0.2 | <10 | NR | <0.2 | 6.3 | NR | -- | -- | -- | Baldys and others, 1998 | |
| Summary–NPDES | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | <0.2 | 15 | NR | Delzer and others, 1996 | |
| Trimethyl benzene | United States | | | | | | | | | | | | | | | | |
| | Arizona | | | | | | | | | | | | | | | | |
| | Maricopa County | -- | -- | -- | <0.2 | <0.2 | NR | <1 | 0.3 | NR | <0.2 | 0.2 | NR | -- | -- | -- | Lopes and others, 1995 |
| Colorado | | | | | | | | | | | | | | | | | |
| Colorado Springs | -- | -- | -- | <0.2 | 1.5 | NR | <0.2 | 4.4 | NR | <0.2 | 0.7 | NR | -- | -- | -- | von Guerard and Weiss, 1995 | |

Table 7 . Concentrations of detected semivolatile and volatile organic compounds in stormwater, suspended sediment, and bottom material/soil—*Continued*

| Compound name | Location | Land use | | | | | | | | | | | | | | | Reference |
|---|---|----------|-----|------|-------------|-----|------|------------|-----|------|------------|------|------|-------------|-------|------|----------------------------|
| | | Highway | | | Residential | | | Commercial | | | Industrial | | | Unspecified | | | |
| | | Min | Max | Mean | Min | Max | Mean | Min | Max | Mean | Min | Max | Mean | Min | Max | Mean | |
| <i>Volatile organic compounds, whole water, in micrograms per liter—Continued</i> | | | | | | | | | | | | | | | | | |
| Dimethyl benzene (total xylenes) (isomer not specified) | Texas Dallas–Fort Worth | -- | -- | -- | <0.2 | 3.7 | 0.12 | <0.2 | 1.9 | 0.23 | <0.2 | <0.2 | 0.43 | -- | -- | -- | Baldys and others, 1998 |
| | Summary–NPDES | -- | -- | -- | -- | -- | -- | -- | -- | -- | <0.2 | 10 | -- | <0.2 | 15 | NR | Delzer and others, 1996 |
| <i>Volatile organic compounds, suspended sediment, in micrograms per gram</i> | | | | | | | | | | | | | | | | | |
| Benzene | United States New York Love Canal | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | NR | 0.232 | NR | Makepeace and others, 1995 |

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