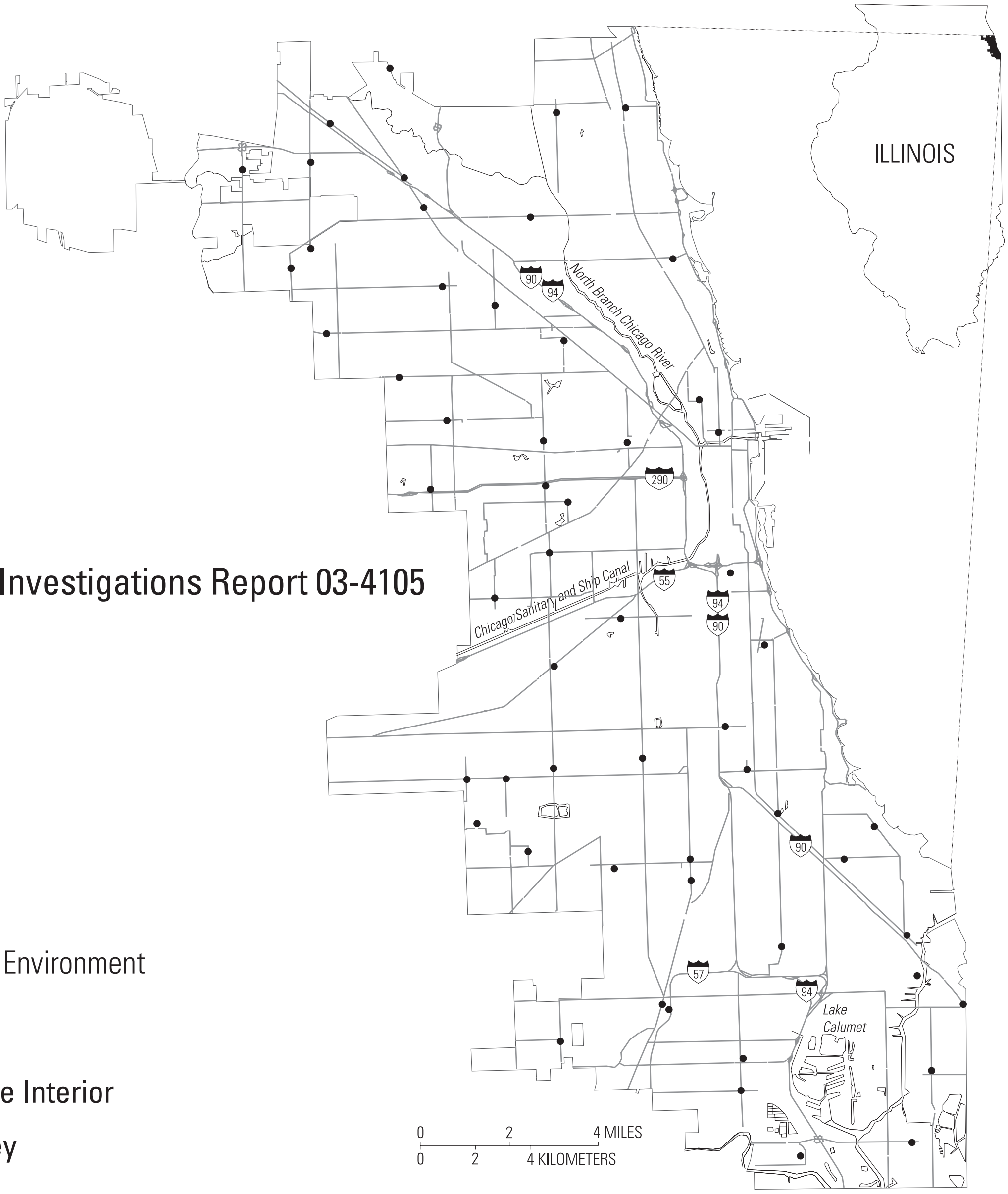
Concentrations of Polynuclear Aromatic Hydrocarbons and Inorganic Constituents in Ambient Surface Soils, Chicago, Illinois: 2001-02



Water-Resources Investigations Report 03-4105

In cooperation with the
Chicago Department of Environment

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

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By Robert T. Kay[1], Terri L. Arnold[1], William F. Cannon[1], David Graham[2], Eric Morton[3], and Raymond Bienert[3]

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[1] U.S. Geological Survey

[2] Chicago Department of Environment

[3] TetraTech EM, Inc.

U.S. DEPARTMENT OF THE INTERIOR
GALE A. NORTON, Secretary

U.S. GEOLOGICAL SURVEY
Charles G. Groat, Director

For additional information, write to:

District Chief
U.S. Geological Survey
221 N. Broadway Ave, Suite 101
Urbana, Illinois, 61801

Copies of this report can be purchased from:

U.S. Geological Survey
Branch of Information Services
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CONVERSION FACTORS AND ABBREVIATED SOIL- AND AIR-QUALITY UNITS

Multiply	By	To obtain
	Length	
inch (in.)	2.54	centimeter
foot (ft)	0.3048	meter
mile (mi)	1.609	kilometer
	Area	
acre	0.4047	hectare
square foot (ft^2)	0.09290	square meter
square mile (mi^2)	2.590	square kilometer
	Mass	
ounce, avoirdupois (oz)	28.35	gram

Temperature in degrees Celsius (°C) may be converted to degrees Fahrenheit (°F) as follows:

$$°F = (1.8 \times °C) + 32$$

Abbreviated soil- and air-quality units: Chemical concentration is given in metric units. Chemical concentration is given in micrograms per kilogram (µg/Kg) and in micrograms per cubic meter ($\mu g/m^3$). Micrograms per kilogram is a unit expressing the concentration of chemical constituents as weight (micrograms) of the constituent per unit mass (kilogram) of soil. One milligram equals 1,000 micrograms. Micrograms per cubic meter is a unit expressing the concentration of chemical constituents as weight (micrograms) of the constituent per unit volume (cubic meter) of air.

Abbreviations:

µg/L	micrograms per liter
mg/Kg	milligrams per kilogram

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Abstract

Polynuclear aromatic hydrocarbon (PAH) compounds are ubiquitous in ambient surface soils in the city of Chicago, Illinois. PAH concentrations in samples collected in June 2001 and January 2002 were typically in the following order from highest to lowest: fluoranthene, pyrene, benzo(b)fluoranthene, phenanthrene, benzo(a)pyrene, chrysene, benzo(a)anthracene, benzo(k)fluoranthene, indeno(1,2,3-cd)pyrene, benzo(g,h,i)perylene, dibenzo(a,h)anthracene, and anthracene. Naphthalene, acenaphthene, acenaphthylene, and fluorene were consistently at the lowest concentrations in each sample.

Concentrations of the PAH compounds showed variable correlation. Concentrations of PAH compounds with higher molecular weights typically show a higher degree of correlation with other PAH compounds of higher molecular weight, whereas PAH compounds with lower molecular weights tended to show a lower degree of correlation with all other PAH compounds. These differences indicate that high and low molecular-weight PAHs behave differently once released into the environment.

Concentrations of individual PAH compounds in soils typically varied by at least three orders of magnitude across the city and varied by more than an order of magnitude over a distance of about 1,000 feet. Concentrations of a given PAH in ambient surface soils are affected by a variety of site-specific factors, and may be affected by proximity to industrial areas. Concentrations of a given PAH in ambient surface soils did not appear to be affected by the organic carbon content of the soil, proximity to non-industrial land use, or proximity to a roadway.

The concentration of the different PAH compounds in ambient surface soils appears to be affected by the propensity for the PAH compound to be in the vapor or particulate phase in the atmosphere. Lower molecular-weight PAH compounds, which are primarily in the vapor phase in the atmosphere, were detected in lower concentrations in the surface soils. Higher molecular-weight PAH compounds, which are present primarily in the particulate phase in the atmosphere, tended to be in higher concentrations in the surface soils. The apparent effect of the PAH phase in the atmosphere on the concentration of a PAH in ambient surface soils indicates that atmospheric settling of particulate matter is an important source of the PAH compounds in ambient surface soils in Chicago.

The distribution of PAH compounds within the city was complex. Comparatively high concentrations were detected near Lake Michigan in the northern part of the city, in much of the western part of the city, and in isolated areas in the southern part of the city. Concentrations were lower in much of the northwestern, south-central, southwestern, and far southern parts of the city.

The arithmetic mean concentration of arsenic, mercury, calcium, magnesium, phosphorus, copper, molybdenum, zinc, and selenium was from 2 to 6 times higher in ambient surface soils in the city of Chicago than in soils from surrounding agricultural areas. The arithmetic mean concentration of lead in Chicago soils was about 20 times higher. Concentrations of calcium and magnesium above

those of surrounding agricultural areas appear to be related to the effects of dolomite bedrock on the chemical composition of the soil. Elevated concentrations of the remaining elements listed above indicate a potential anthropogenic source(s) of these elements in Chicago soils.

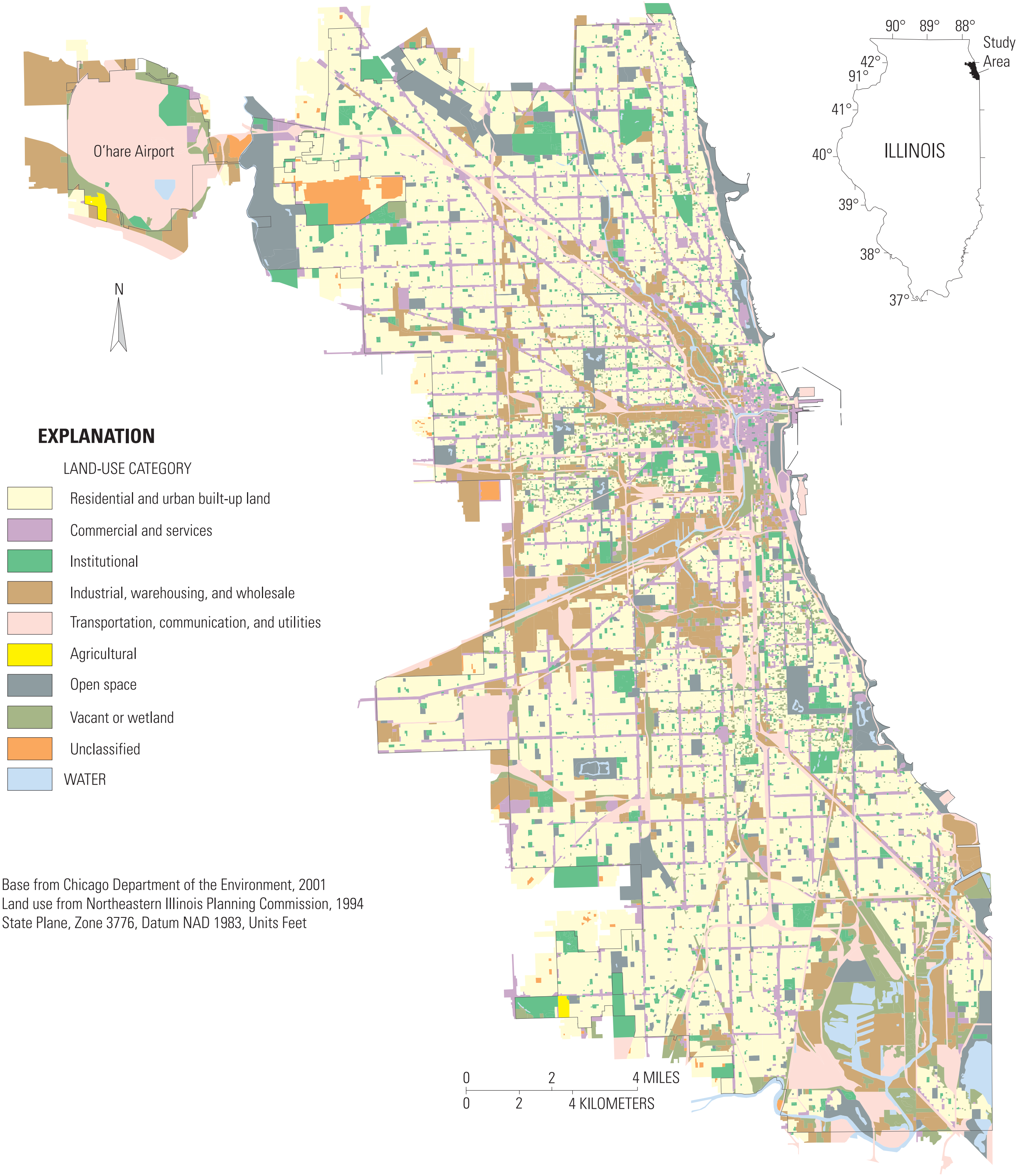
INTRODUCTION

Polynuclear aromatic hydrocarbon compounds (PAHs) are a family of fused ring hydrocarbon compounds derived primarily from the incomplete combustion of organic material including wood, coal, oil, gasoline, and garbage and from leaching from coal-tar products such as asphalt and roofing shingles. PAHs also are derived from natural sources such as forest fires and volcanic eruptions. However, the majority of PAHs released to the environment are derived from anthropogenic sources such as the operation of motor vehicles; burning coal, wood, or trash in a residential furnace; and industrial sources such as thermoelectric power generation and coking operations. There are more than 100 PAH compounds. However, the PAH compounds of interest for environmental investigations are acenaphthene, acenaphthylene, anthracene, benzo(a)anthracene, benzo(b)fluoranthene, benzo(k)fluoranthene, benzo(g,h,i)perylene, benzo(a)pyrene, chrysene, dibenzo(a,h)anthracene, fluoranthene, fluorene, indeno(1,2,3-cd)pyrene, naphthalene, phenanthrene, and pyrene.

PAH compounds are released to the environment largely from emissions to the atmosphere. PAHs in the atmosphere typically are in the vapor phase or attached to particulate matter and are capable of being transported long distances from their sources before deposition on the land surface during precipitation and particle settling. Additionally, PAH compounds can be emplaced in surface soils by routine operations or leaks from storage tanks and during waste-disposal activities such as the historical use of coal ash and debris from the Great Chicago Fire as fill material. Surface-fill material is common in the Chicago area (Kay and others, 1997). PAH compounds enter surface water and sediment primarily in discharges from industrial and wastewater-treatment plants, and roadside runoff. Although PAHs do not easily dissolve in water, given the proper conditions PAHs in soils, sediments, and surface water are capable of degrading ground-water quality. Because of their physical properties and methods of production and dispersal, PAHs typically occur as a mixture of compounds in environmental media.

As in all urban areas, substantial quantities of PAH compounds have been generated within the city of Chicago (fig. 1) as a result of incineration of wood, coal, and trash; construction of roads and parking lots; operation of motor vehicles; coking operations associated with steel manufacturing; production of electricity at manufactured gas facilities; use of creosote for wood preservation; and a variety of other processes (Simcik and others, 1997). As a result of current (2003) and historical production and disposal practices, PAH compounds have been detected in a number of environmental media within the city of Chicago. PAH compounds have been detected in soils at a number of residential, commercial, industrial, and waste-disposal sites (Ecology and Environment, Inc., 1990; Harza Engineering, Inc., 1994; Ecology and Environment, Inc., 2001; U.S. Army Corp of Engineers, 2001). An investigation of ground-water quality in the southern part of the city detected PAH compounds (Duwelius and others, 1996) that may have been derived from fill materials and road runoff. PAH compounds also have been detected in surface water and streambed sediment in the Chicago area (HydroQual Inc., 1985; U.S. Army Corp of Engineers, 1986, 2001; Sullivan and others, 1998) and in lake-bottom sediments in Lake Michigan (Simcik and others, 1996). PAH compounds in streambed sediments are at least partially derived from erosion of surface soils.

Many PAH compounds are suspected carcinogens or mutagens, and are deemed hazardous substances by the U.S. Environmental Protection Agency (USEPA). Consequently, cleanup of residential, commercial, industrial, and waste-disposal sites, including Resource Conservation and Recovery Act (RCRA), Superfund, and Brownfield sites, in the city of Chicago requires remediation of soils containing concentrations of PAH compounds above what is prescribed in the Illinois Environmental Protection Agency’s (IEPA) Tiered Approach to Cleanup Objectives (TACO) guidance (table 1). The TACO cleanup objectives vary with the intended future land use (industrial/commercial or residential) of the site, the route of exposure (ingestion, inhalation, and potential for migration



Base from Chicago Department of the Environment, 2001
Land use from Northeastern Illinois Planning Commission, 1994
State Plane, Zone 3776, Datum NAD 1983, Units Feet

Figure 1. Land use within the city of Chicago, Illinois.

to ground water), and the type of activity leading to the exposure (resident or site-construction worker). Because the city of Chicago derives its water supply entirely from Lake Michigan and city ordinances prohibit the use of ground water wells for potable water use, TACO remedial objectives pertaining to potential for migration to ground water will not be discussed in this report.

The TACO cleanup objectives for a compound are based on assessment of the risk or hazard it poses to human health and the environment and do not automatically take its ambient concentration into account. The site-specific cleanup goals governed by the TACO guidance are intended to allow property remediation of hazardous compounds present as a result of historical operations, based on the site's future use, not to remove compounds present as a result of ambient (background) deposition. Therefore, the TACO guidance does allow for an interested party to calculate the background concentration of a compound in soil, which then can be used as the remediation objective.

Without an accurate determination of the ambient concentrations of PAH compounds in urban soils, it can be difficult to determine if concentrations of PAH compounds encountered in soils during site remediation are the result of contamination or ambient effects. Soil remediation may include excavation and disposal of contaminated soil to an appropriate waste-disposal facility or installation of an engineered barrier (clean soils, pavement, buildings) to prevent human contact. Often, excess soil removed during construction projects containing PAH compounds at concentrations similar to ambient concentrations but above site-remediation objectives must be disposed of in local landfills at additional cost. Therefore, the absence of values for the ambient concentrations of PAH compounds in surface soils in the city of Chicago may result in increased site-remediation costs associated with unnecessary soil excavation and disposal and installation and maintenance of unnecessary engineered barriers. Site-specific removal of soils containing ambient concentrations of PAH compounds also is unlikely to result in an improvement to human health and the environment. Development of a scientifically valid assessment of ambient concentrations of PAH compounds in surface soils and identification of the factors that affect PAH concentrations in surface soils has the potential to substantially help project managers and site investigators increase the effectiveness of remediation at waste-disposal sites in Chicago.

Potential receptors (with the exception of construction workers under some circumstances) are most likely to be exposed to PAHs through ingestion and direct contact with compounds in surficial soil, rather than to PAHs in soil at greater depths. As a consequence, it particularly is important to characterize surficial soils. For the purposes of conducting Tier 3 risk assessments under TACO, the IEPA requires that exposure point concentrations for soil ingestion be calculated based on analytical data for surface soil (typically 0 to 6 in. below ground surface) in addition to the requirement of evaluating the upper 3 ft of the soil.

The U.S. Geological Survey (USGS), in cooperation with the city of Chicago, Department of Environment, assessed the concentration of each of the regulated PAH compounds in ambient surface soils within the city. For the purposes of this report, ambient soils are those soils whose chemical composition is affected by ubiquitous natural and anthropogenic processes rather than the site-specific disposal of waste materials. This investigation did not include O'Hare Airport on the far northwestern part of the city. Samples were collected in June 2001 and January 2002 from areas near residential, commercial, and industrial land use. Based on discussions with IEPA personnel, analytical results from surficial soil samples, for the purposes of comparison, were considered applicable for all depths. This approach is consistent with the TACO guidelines, which recommend use of a single set of inorganic chemical background concentrations in surface soil for comparison to analytical results from site-specific soil samples collected at various depths (Illinois Pollution Control Board, 2002; Illinois Environmental Protection Agency, 1994).

In addition to PAH compounds, samples of surface soils were analyzed to characterize concentrations of a number of inorganic constituents, including metals and major elements. Analysis of the concentration of inorganic constituents was performed by the USGS as part of a program to chemically characterize surface soils in the United States.

Purpose and Scope

This report describes the results of an investigation that used stratified random sampling techniques and geographic information system (GIS) analysis to characterize the concentration of PAH compounds in ambient surface soils in the city of Chicago. In addition, a preliminary assessment is provided of the concentrations of inorganic constituents in these soils. This report presents the results of soil-quality sampling for PAHs and inorganic constituents at 57 randomly selected sites. It also presents statistical and GIS analysis of the soil PAH data. This report provides summary statistics of the concentrations of the PAH compounds, including the mean concentration of the individual PAH compounds. A summary of the concentrations of inorganic constituents is given. Potential sources of PAH compounds and inorganic constituents are identified, along with some of the factors that may affect the concentrations of these constituents in ambient soils.

Acknowledgments

The authors thank Commonwealth Edison for allowing access to their property for sample collection.

METHODS

This investigation required the selection of appropriate sampling sites, collection of representative samples, accurate measurement of concentrations of PAHs and inorganic constituents in the samples, and statistical analysis of PAH concentrations. Because sampling for inorganic constituents was designed to provide only a general assessment of the distribution and concentration of these compounds in Chicago and was not designed to meet regulatory needs, the inorganic data were not statistically analyzed.

Site Selection

A random site-selection computer program (Scott, 1990) was used with a GIS spatial data base to select 173 potential sampling sites in Chicago. Of these potential sampling sites, 60 were selected as primary sites and 113 were selected as alternate sites in the event that a primary site could not be sampled. For the purpose of site selection, the city of Chicago boundary was used as the boundary of the study area (fig. 1). Using the program, the study area was divided into 4,601 small square polygons (subareas), each of which was approximately 0.05 mi^2 (fig. 2a). These subareas later were aggregated to create equal-area cells from which sites were selected randomly. To create the cells from which the sites were selected, the subareas were accumulated into eight vertical strips (fig. 2b). The number of vertical strips was determined by taking the square root of the number of primary sites and rounding the result to the nearest whole number. The area of each vertical strip was approximately 30 mi^2. The number of cells created was equal to the number of primary sites (60), resulting in 60 equal-area cells (fig. 2c). Cells were created by aggregating each horizontal row of subareas within consecutive vertical strips, beginning in the lower left corner of the study area, until the desired area was obtained. The resulting cells had irregular shapes and were approximately 3.8 mi^2 in area.

A total of 374 properties owned by the city of Chicago and Commonwealth Edison (a local utility) were used as the population of potential sampling sites for this study (fig 3a). Properties owned by the city of Chicago including libraries, fire stations, and police stations and properties owned by Commonwealth Edison are located throughout the city. Point locations of these properties were combined into one layer using the GIS, with one point location representing each property. The density of the properties in the study area was about 0.5 of a point per square mile.

The modified GIS layer of properties owned by the city and Commonwealth Edison contained a total of 373 points (fig. 3b). These points were used as a fixed population of potential sites from which the site-selection program could choose randomly. From this fixed population of 373 points and the 60 equal-area cells, the site-selection program randomly selected 60 primary sites (one per cell), 58 secondary sites, and 55 tertiary sites (fig. 3c). The secondary and tertiary sites are alternate sites that could have been used if the primary site in a cell could not be

Figure 2. Locations of (A) subareas, (B) vertical strips, and (C) equal-area cells used for selection of random sample locations, Chicago, Illinois.

Figure 3. Locations of (A) properties owned by the city of Chicago and Commonwealth Edison, (B) final fixed population of potential sites used to randomly select sampling sites, and (C) randomly selected sampling sites, Chicago, Illinois.

sampled. Because of the distribution of potential sites, not every cell had enough points for the program to select two alternate sites from each cell.

Historical land use at each of the sample locations was evaluated by the Chicago Department of Environment (CDOE) to determine if PAH compounds derived from industrial activities or waste-disposal operations at the site might be present. Evaluation of historical land use consisted of reviewing available Sanborn Fire Insurance maps and aerial photographs. Within each cell, the primary location was the preferred sampling location unless it was deemed unsuitable based on the historical evaluation. For example, if the historical analysis indicated that land use at a particular location could have resulted in PAH contamination specific to the property, an alternative location within the cell was considered.

Following the historical review, the CDOE performed an inspection of the potential sampling sites. Sampling sites were rejected if there were indications of industrial sources of PAHs (electrical plants, steel mills, coke plants, gas stations, incinerators, and heating plants) at the site, if the property was paved entirely or contained structures so that soil samples could not be collected, or if stains or stressed vegetation were evident. If the site inspection indicated possible problems with the sampling site, the secondary or tertiary sampling locations were evaluated. Gravel areas that were not parking lots were considered for sampling if the gravel was less than 6 in. thick and could be scraped away to reveal soil.

Sample Collection and Analysis

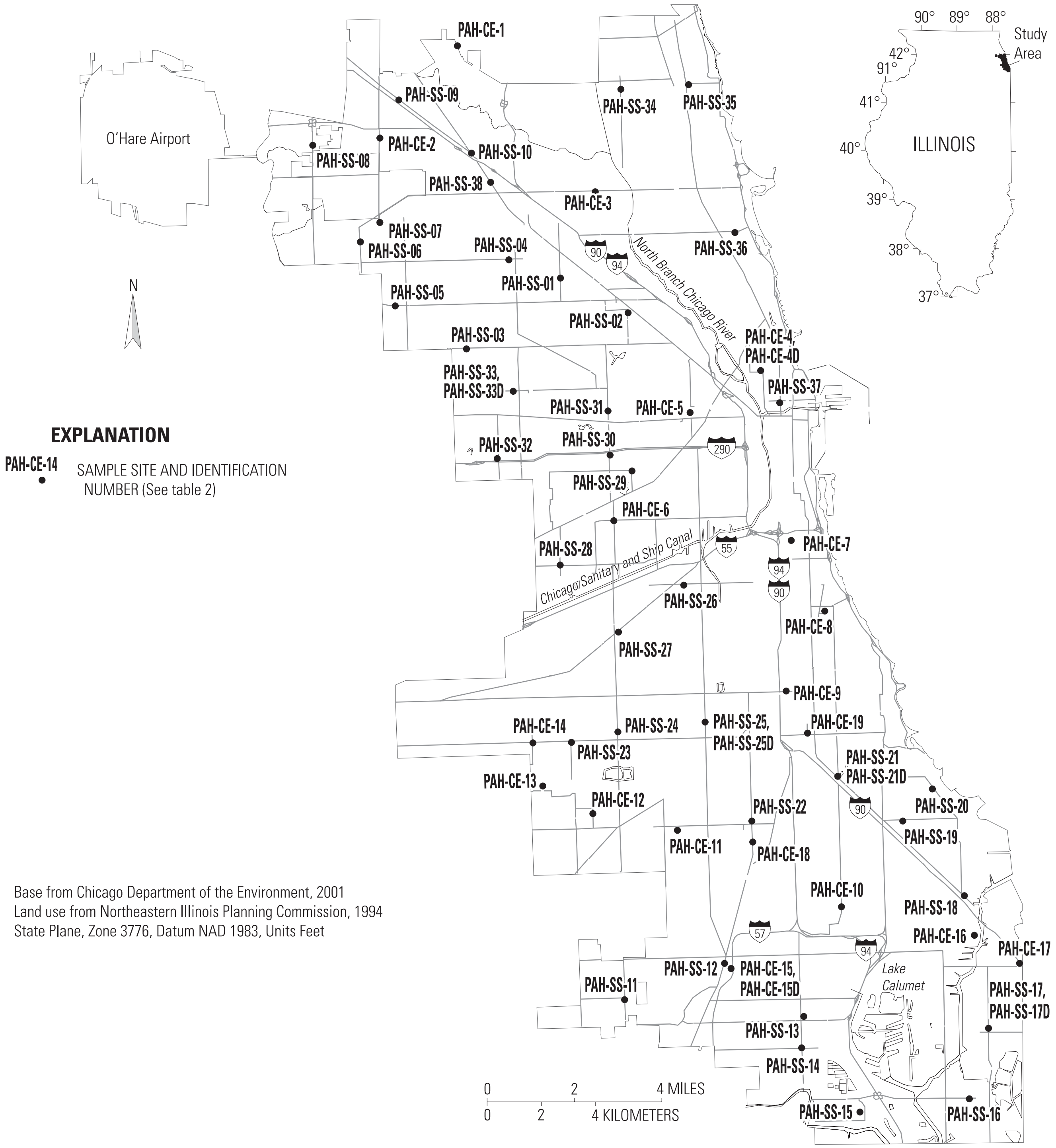
Soil samples were collected at 57 sites (table 2). Samples collected from properties owned by the city of Chicago are denoted by a SS prefix. Samples collected from properties owned by Commonwealth Edison are denoted by a CE prefix. Samples were collected in accordance with the IEPA approved field sampling plan, which is included in the IEPA approved quality-assurance project plan (QAPP) (TetraTech EM, Inc., 2001) (table 2, fig. 4). Inorganic samples were collected and analyzed in accordance with standard USGS procedures (Arbogast, 1996).

Soil samples were collected from the upper 6 in. of the soil horizon (from 0 to 6 in. in an undisturbed soil horizon or from the upper 6 in. of a soil horizon where it may be covered by gravel) using a dedicated stainless-steel spoon or trowel. Samples were collected by personnel from Tetra Tech EM, Inc. and the CDOE. The soil type was characterized at the time of sample collection. Soil samples were placed in a disposable foil pan and homogenized by stirring the soil using the stainless-steel spoon or trowel. One 16-ounce and one 4-ounce sample jar were filled by spooning soil from the foil pan into the container. The latitude and longitude of the sample sites were determined with a global positioning system (GPS) unit (table 2).

Sampling activities were documented in the field. For each sample, all pertinent data including property address; cell number and whether primary, secondary, or tertiary property; sample number; date and time of sample collection; weather conditions; GPS coordinates; description of sample location; proximity to stained soil, stressed vegetation, asphalt, underground storage tanks, above-ground storage tanks, parking lots, or other distinguishing property characteristics, which could be a source of PAHs; soil characteristics; and sample depth were recorded. Samples were packaged, cooled to 4° C with ice, and shipped overnight to the laboratory for PAH analysis. Samples for inorganic analysis were stored at 4° C for as long as 7 days prior to shipment to the laboratory. Chain-of-custody procedures were followed for all samples collected for PAH analysis.

Soil samples were analyzed for PAHs in accordance with the approved QAPP (TetraTech EM, Inc., 2001). Soil samples used for PAH analysis were prepared according to SW-846 Method 3550 and analyzed by SW-846 Method 8270 SIM (U.S. Environmental Protection Agency, 1994a). All field and laboratory data were validated in accordance with accepted guidelines (U.S. Environmental Protection Agency, 1994b).

Analyses for inorganic constituents were performed using inductively coupled plasma-atomic emission spectrometry. Methods for handling and analysis of these samples are provided by Arbogast (1996). Samples were disaggregated and sieved to recover the minus 180 micrometer fraction for chemical analyses. Analyses were performed at Xral Laboratories in Toronto, Canada, using techniques developed by the USGS, and at USGS analytical laboratories in Lakewood, Colorado. Forty major, minor, and trace elements were determined by inductively coupled plasma-atomic emission



Base from Chicago Department of the Environment, 2001
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Figure 4. Locations of surface-soil sampling sites, Chicago, Illinois.

spectrometry (ICP-AES). The technique yields quantitative data for 28 elements (appendix 2); the remaining 12 have all or most analyses below the detection limit. In addition, total carbon was determined by an automated carbon analyzer and carbonate carbon was determined as carbon dioxide by coulometric titration. Organic carbon was calculated as the difference between total and carbonate carbon. Total sulfur was determined using an automated sulfur analyzer and mercury was determined by cold-vapor atomic absorption spectrometry. Arsenic and selenium were analyzed by hydride generation atomic absorption spectrometry.

Calibration of the inorganic samples was performed by standardizing with digested rock reference materials and a series of multi-element solution standards. Data were deemed acceptable if recovery for all was ±15 percent at five times the Lower Limit of Determination (LOD) and the calculated Relative Standard Deviation (RSD) of duplicate samples was no greater than 15 percent for all elements except mercury, arsenic, and selenium. For these elements, ±20 percent recovery and an RSD no greater than 20 percent was considered acceptable.

Field and internal laboratory quality controls were performed to determine the precision, accuracy, completeness, representativeness, and comparability of the data. To assist in this effort, one field duplicate sample was collected for every 10 investigative samples. One matrix spike/matrix spike duplicate PAH sample was collected for every 20 investigative samples. The laboratory prepared one PAH method blank sample for every 20 investigative samples. All data for both PAH and inorganic constituents were reviewed following quality-assurance/quality-control (QA/QC) procedures.

Statistical Analysis of Uncensored Polynuclear Aromatic Hydrocarbon Data

Benzo(a)anthracene, benzo(b)fluoranthene, benzo(k)fluoranthene, benzo(g,h,i)perylene, benzo(a)pyrene, chrysene, dibenzo(a,h)anthracene, fluoranthene, indeno(1,2,3-cd)pyrene, phenanthrene, and pyrene were detected in each of the samples collected (table 3). As a consequence, the actual reported concentrations were used in the statistical analysis for these compounds (uncensored data). For sites where duplicate samples were collected, the average value was used for all analyses. Concentrations of all of the PAH compounds in sample PAH-CE-19 except acenaphthylene were substantially higher than in the remaining samples (table 3). Because sampling location PAH-CE-19 was considered a potential outlier, most of the preliminary statistical analyses were performed both with and without this data point.

The sample location of PAH-CE-19 is adjacent to a Commonwealth Edison transfer station with no obvious source of atmospheric discharge. The property was grass covered and vacant with remnants of a former building foundation. Historical property use was residential, based on Sanborn Fire Insurance maps. Land use in the surrounding area was predominately residential according to the Northeastern Illinois Planning Commission (1994) maps. No obvious sources of PAHs were identified during site reconnaissance or sample collection.

The uncensored PAH data were analyzed statistically using standard parametric techniques as follows: test for two independent samples from the same population; graphical exploratory techniques; calculation of basic descriptive statistics; test for lognormal distribution; test for outliers; re-test for two independent samples from the same population without the outlier; re-test for lognormal distribution without the outlier; re-calculation of basic descriptive statistics without the outlier; calculation of the 95th percentile of the population, 95-percent confidence interval for the mean, and the mean; simple linear regressions of PAH concentration with percent land use and PAH concentration with mean distance to land use. Estimates of the actual values of the mean, standard deviation, and the 95th percentile of the lognormal distribution were estimated using techniques recommended by Gilbert (1987).

Population Tests

City of Chicago properties were sampled in the summer of 2001 and Commonwealth Edison properties were sampled in the winter of 2002. Because all of the data were not collected at the same time or on the same set of properties, there potentially were two separate data populations (city of Chicago properties and Commonwealth Edison properties) for each of the PAHs. A two-sided Wilcoxon-Rank-Sum test in S-Plus (MathSoft, 2000) was used to test if the one population contained larger or smaller values than the other. If the results of the test showed the populations likely were similar, then data from the city of Chicago and Commonwealth Edison properties could be combined into one dataset for further analysis. The null hypothesis was that the values in the two populations were similar and the alternate hypothesis was that the values from one population were larger or smaller than the other population. A 95-percent confidence interval (alpha of 0.05) was used for the Wilcoxon-Rank-Sum test. The Wilcoxon-Rank-Sum test was performed with and without sample PAH-CE-19.

Test for Lognormal Distribution

PAH concentrations were transformed in SAS (SAS Institute, Inc, 1999) by applying the natural logarithm (log transformation). The transformed data then were evaluated for lognormality using the Shapiro-Wilk test in SAS interactive data analysis with a significance level (alpha) of 0.1 as recommended by Helsel and Hirsch (1995) for normality tests. The Shapiro-Wilk test was performed with and without the data from sample PAH-CE-19.

Graphical Analysis

The raw uncensored data initially were investigated using graphical exploratory data techniques, including boxplots, histograms, and normal probability plots. Boxplots, histograms, and normal probability plots were graphed using Data Desk (Data Description, Inc., 1996). Natural-log transformed uncensored data also were explored using boxplots and normal probability plots graphed in Data Desk with and without the data from sample PAH-CE-19.

Descriptive Statistics

Standard descriptive statistics were calculated using interactive data analysis in SAS (SAS Institute, Inc, 1999). Descriptive statistics were calculated for raw and natural-log transformed data both with and without the data from sample PAH-CE-19. Calculated statistics (not all of which are presented in this report) include: mean, standard deviation, standard error, variance, number of observations, minimum, maximum, median, range of values, sum, corrected and uncorrected sum of squares, coefficient of variation, skewness, and kurtosis.

Outlier Test

A data point is classified as a mild outlier if the value is more than 1 step above the 75th percentile and classified as an extreme outlier if the value is more than 2 steps above the 75th percentile. A step is equal to 1.5 times the interquartile range (Helsel and Hirsch, 1995). To evaluate for an extreme outlier, the interquartile range and number of steps between the 75th percentile and the highest value were calculated. The interquartile range was calculated by subtracting the 25th percentile from the 75th percentile. The number of steps was calculated by subtracting the 75th percentile from the maximum value and dividing the result by 1.5 times the interquartile range. The outlier test was performed with the suspected outlier, PAH-CE-19, included.

To further determine if PAH-CE-19 is an outlier, the magnitude of the difference between the concentration of the PAH compound in this sample (the maximum value) and the next lowest value was examined using the number of standard deviations between them. The number of standard deviations between the maximum and next lowest value was calculated by subtracting the next lowest from the maximum value and dividing the result by the standard deviation.

95th Percentile, 95-Percent Confidence Interval For The Mean, and Geometric Mean

The 95th percentile and 95-percent confidence interval for the mean of the natural-log transformed data were calculated using interactive data analysis in SAS (SAS Institute, Inc, 1999). For natural-log transformed PAH concentrations, the geometric mean was calculated in Microsoft Excel (Microsoft Corporation, 2000) by taking the anti-log of the mean. The data from sample PAH-CE-19 were not included in these calculations.

Relation Between Polynuclear Aromatic Hydrocarbon Concentrations and Land Use

Various analyses were performed to determine if PAH concentrations in ambient surface soils were affected by nearby land use. For the purposes of this discussion, land use also includes the distance between the sampling point and the middle of the nearest roadway.

The Northeastern Illinois Planning Commission's 1990 land-use summary (Northeastern Illinois Planning Commission, 1994) was used to identify the current land use for each sample location. Chicago's land-use code is broadly classified as urban, built-up land (85 percent), agricultural (less than 1 percent), open space (7 percent), vacant and wetland (6 percent), water (less than 2 percent), and unclassified (less than 1 percent). Urban, built-up land is further subdivided as residential (47 percent), commercial services (10 percent), institutional (6 percent), industrial (11 percent), transportation, communication, and utility (11 percent). Therefore, about 15 percent of the land composing the city of Chicago is considered undeveloped and the majority of the land use is for residential purposes.

Simple Linear Regression

The mean distance from each sampling point to each type of land use in the area of the sampling point was calculated (table 4). Land use was classified as residential, commercial, institutional, industrial/warehousing/wholesale (hereafter referred to as industrial), transportation/communications/utilities (hereafter referred to as transportation), agriculture, open space, vacant/wetland (hereafter referred to as vacant), and water according to 1990 land-use spatial data obtained from the Northeastern Illinois Planning Commission (1994) (fig. 1).
To calculate the mean distance to each land-use category from each sampling point, ArcInfo GIS (Environmental Systems Research Institute, 2001a) was used with four raster data layers representing soil-sampling point locations, sampling-point zones, distance, and land use in 1990 (Northeastern Illinois Planning Commission, 1994). Cell size of raster data layers was 30 ft^2. Each sampling-point location was enclosed by Thiessen (also called proximal) polygons using a Euclidean allocation function, which created sampling-point zones. The Thiessen polygons formed a zone around each sampling point such that any location inside the zone was closer to that zone's sampling point than any other sampling point. Zones ranged in area from 1 mi^2 to 10 mi^2. The distance layer was created by calculating the Euclidean distance outward in every direction from each sampling point to the edge of the zone. The distance layer then was combined spatially with the land-use and sampling-point-zone layers to calculate the mean distance to each land use in the zone from the sampling point. Simple linear regressions of mean distance to each land use with natural-log transformed PAH concentrations were calculated using Data Desk (Data Description, Inc., 1996). The suspected outlier, PAH-CE-19, was not included in the regressions.

Land use surrounding the sampling site also was examined. Buffers of 0.25, 0.5, and 1 mi radius around the sampling site were created using ArcInfo GIS (Environmental Systems Research Institute, 2001a). The buffers were overlaid spatially with the land use layer (Northeastern Illinois Planning Commission, 1994) and the percent of land-use category within 0.25, 0.5, and 1 mi of the sampling point was calculated (table 5). Simple linear regressions of percent land use within a 0.25, 0.5, and 1 mi radius of the sample with natural-log transformed PAH concentrations were performed for all uncensored PAHs using Data Desk (Data Description, Inc., 1996). The data from sample PAH-CE-19 were not included in the regressions.

The distance between the sample location and the nearest roadway was estimated by use of an on-screen digitizer. The location of the sampling point was determined by GPS measurement, and the location of the nearest roadway was determined visually from a GIS coverage. The distance between the point and the road then was calculated by use of ArcInfo. Correlation between the natural-log transformed concentration of the PAH and the natural-log of the distance from the roadway then were estimated by simple linear regression in Microsoft Excel (Microsoft Corporation, 2000). The data from sample PAH-CE-19 were not included in the regressions.

Unbalanced One-Way Analysis of Variance

A spatial overlay of sampling locations and land use (Northeastern Illinois Planning Commission, 1994) was performed in ArcInfo GIS (Environmental Systems Research Institute, 2001a) to identify the land use at the sampling point. Sample locations were grouped into seven land-use categories: residential; commercial and service; institutional; industrial, warehousing, and wholesale; transportation, communication, and utilities; open space; and vacant and wetland (table 6). The Shapiro-Wilk test in S-Plus (MathSoft, 2000) was used to verify that the natural-log transformed PAH concentrations for those land uses with five or more samples (vacant and wetland; transportation, communication and utilities; commercial and service; industrial, warehousing, and wholesale; and residential) were normally distributed. To test if mean log-transformed PAH concentrations varied for different land uses, a one-way unbalanced analysis-of-variance (ANOVA) was performed for each uncensored PAH using S-Plus. The null hypothesis was that the mean natural-log transformed values statistically were the same for each land use. The alternate hypothesis was that at least one of the means differed with land use. An alpha value of 0.05 was used for the test. The data from sample PAH-CE-19 were not included in the ANOVA.

The distance between the sampling locations and the roadway were grouped into five categories: 10 ft or less (20 data points), 11 to 30 ft (15 data points), 31 to 50 ft (9 data points), 51 to 100 ft (6 data points), and greater than 100 ft (6 data points). The Shapiro-Wilk test in S-Plus was used to verify that the natural-log transformed PAH concentrations for distances were normally distributed. To test if mean log-transformed PAH concentrations varied with distance from the roadway, a one-way unbalanced ANOVA was performed for each uncensored PAH using S-Plus. The null hypothesis was that the mean natural-log transformed values statistically were the same for each distance category. The alternate hypothesis was that at least one of the means differed with distance. An alpha value of 0.05 was used for the test. The data from sample PAH-CE-19 were not included in the ANOVA.

Geospatial Analyses of Benzo(a)pyrene Concentrations

ArcMap Geostatistical Analyst, (Environmental Systems Research Institute, 2001b) was used to spatially evaluate variations in benzo(a)pyrene concentrations with land use and location. Benzo(a)pyrene was used because it typically is the compound of greatest concern. To obtain the spatial distribution of benzo(a)pyrene concentrations, the natural-log transformed data was kriged using geospatial statistics in the GIS. Kriging is a geostatistical method used to statistically predict values at unsampled location based on the theory that points closer together are more similar than those farther apart. Kriging compares the values at pairs of sampling points (called bins) and considers the distance the points are from each other. The distribution of the bins were fit visually to a spherical spatial model using a semivariogram. A semivariogram graphs the variance in values with the distance that separates each pair of points.

Statistical Analysis of Censored Polynuclear Aromatic Hydrocarbon Data

Concentrations of naphthalene, acenaphthylene, acenaphthene, fluorene, and anthracene were below the detection limit in some of the samples (appendix 1) (table 3). Each of these compounds had multiple detection limits (the data are censored at multiple levels). Because concentrations for all of the samples are not known, assumptions about the presence of a normal or lognormal data distribution cannot be verified for the censored PAH compounds, which is a requirement for the use of parametric analytical techniques. As a consequence, the censored data were analyzed using nonparametric techniques described in Helsel and Hirsch (1995), Helsel and Cohn (1988), and Cohn (1988). Censored data were analyzed statistically as follows: test for two independent samples from the same population, graphical exploratory techniques, calculation of limited descriptive statistics, graphical analysis of lognormal distribution, test for outliers, and calculation of the 95th percentile and geometric mean. As was the case for the uncensored data, results of duplicate samples were averaged.

Graphical Analysis

Boxplots of raw and natural-log transformed censored data were made using Data Desk (Data Description, Inc., 1996). For construction of the boxplots, the censored values were used to create the portions of the box below the median. However, during visual analysis of the boxes, the highest censoring level of each PAH was considered and the parts of the box below that highest censored value were ignored. Boxplots were drawn with and without the data from sample PAH-CE-19.

Normal probability plots also were utilized during exploratory graphical analysis. Plotting positions for normal probability plots were calculated using a C program (Dave Lorenz, U.S. Geological Survey, written commun., 2002), which utilizes the methods outlined in Helsel and Cohn (1988). The program input is a specifically formatted ASCII file of the natural-log transformed data above and below the detection limit. The plotting positions output from the C program then were used in Data Desk (Data Description, Inc., 1996) to graph a scatterplot of the plotting positions with the natural-log transformed PAH concentrations. A regression line then was drawn for the scatterplot. Boxplots and normal probability plots were drawn with and without the data from sample PAH-CE-19.

Descriptive Statistics

Limited descriptive statistics for raw and natural-log transformed censored PAHs were calculated and estimated using robust methods described in Helsel and Hirsch (1995). Calculated statistics include: number of observations, number of censored values, range of censored values, maximum, median, 25th, 75th, and 95th percentile of the distribution, and geometric mean. The mean and standard deviations were estimated using robust log-probability regression based on plotting points for data censored at multiple levels using the methods outlined by Helsel and Cohn (1988) and Cohn (1988) and the C program (Dave Lorenz, U.S. Geological Survey, written commun, 2002). Another C program (Dave Lorenz, U.S. Geological Survey, written commun., 2002) that calculates an adjusted maximum-likelihood estimator following methods outlined by Helsel and Cohn (1988) and Cohn (1988) was used to estimate the median and quartiles. Descriptive statistics were performed with and without the data from sample PAH-CE-19.

Outlier Test

Outlier testing for the uncensored data set was performed using most of the same procedures as for the censored data. However, the 25th, 50th, and 75th percentiles for the censored data were estimated using a C program, which calculates an adjusted maximum-likelihood estimator following methods outlined by Helsel and Cohn (1988) and Cohn (1988). Estimates of the standard deviation were calculated by log-probability regression using a C program, which follows the methods outlined in Helsel and Cohn (1988), Cohn (1988), and Helsel and Hirsch (1995).

Relation between Polynuclear Aromatic Hydrocarbon Concentrations and Land Use

Because of the high number of non-detects for some of the censored PAH compounds, simple linear regression of PAH concentrations with land use could not be performed for these constituents. The natural-log transformed concentrations of individual censored PAH compounds were compared for samples grouped by land-use category using multiple-population parametric and nonparametric statistical tests in a manner similar to the analysis of the uncensored data. Censored analytes were not analyzed with regard to distance from the roadway. Censored data in the distribution testing and multiple-population tests were treated by replacing each censored datum with its estimated value calculated using robust log-probability regression, following Helsel (1990), Helsel and Cohn (1988), and Akritas and others (1994).

Correlation of Polynuclear Aromatic Hydrocarbon and Inorganic Concentrations

Pearson product-moment correlations (r values) were obtained from the natural-log transformed concentration of each of the PAH pairs as well as each of the PAHs and total organic carbon using Microsoft Excel. PAH samples below the detection limit were assigned a concentration value of 1.39 µg/Kg, the natural log of 4 µg/Kg, which is 1 µg/Kg lower than the lowest detection limit for any PAH. Correlations involving the PAHs were performed with and without the data from site PAH-CE-19. Pearson product-moment correlations also were obtained for every pair of inorganic constituents detected in more than 75 percent of the samples. Inorganic constituents below the detection limit were assigned a concentration value of two-thirds the detection limit. Results from site PAH-CE-19 were used for correlation of the inorganic constituents.

ANALYSIS OF POLYNUCLEAR AROMATIC HYDROCARBON DATA

The results of soil-quality sampling indicate that 11 or more of the 16 PAH compounds were detected in each of the 57 soil samples collected (samples and duplicates are counted as one sample) (appendix 1). Of the 57 samples collected, 35 contained detectable concentrations of every PAH compound analyzed (table 3). Of the 22 samples in which 1 or more PAH compounds were not detected, naphthalene was the most frequent non-detect, followed by acenaphthylene, fluorene and acenaphthene, and anthracene.

Fluoranthene was the PAH detected at the highest concentration of all the PAH compounds in every sample except samples PAH-SS-10 and PAH-SS-11. The concentration of benzo(g,h,i)perylene was highest in sample PAH-SS-10 and second highest in sample PAH-SS-11. The concentration of indeno(1,2,3-cd)pyrene was highest in sample PAH-SS-11 and second highest concentration in sample PAH-SS-10. Pyrene was present at the second highest concentration of any PAH compound in 37 of the samples. Samples PAH-SS-10 and PAH-SS-11 were the only samples where the ratio of fluoranthene to pyrene was less than one. Because the fluoranthene/pyrene ratio is an indicator of the temperature at which the PAHs were generated (McCarthy and others, 2000), the low value of this ratio in samples PAH-SS-10 and PAH-SS-11 may indicate that the PAHs at these locations were derived from a different source, or combination of sources, than most of the remainder of the city. However, there are no obvious anomalies in location, land use, or the soil descriptions at these sites to indicate differences in the source(s).

After fluoranthene and pyrene, PAH concentrations in a given sample, from highest to lowest, were roughly in the following order: benzo(b)fluoranthene, benzo(a)pyrene, phenanthrene, chrysene, benzo(a)anthracene, indeno(1,2,3-cd)pyrene, benzo(k)fluoranthene, benzo(g,h,i)perylene, anthracene, and dibenzo(a,h)anthracene. Naphthalene, acenaphthene, acenaphthylene, and fluorene consistently were present at the lowest concentrations in each sample (appendix 1).

Boxplots and histograms of the concentrations of the individual PAH compounds showed that the majority of the samples were in the lower end of the concentration range, with a smaller number of samples in the higher end of the range, including a number of potential outliers (figs. 5a and 5b). This left-skewed distribution indicated that the PAH concentrations in these samples did not exhibit a normal distribution. Boxplots and histograms of the natural-log transformed concentration data typically displayed a more symmetrical distribution, indicating that the PAH compounds may exhibit a lognormal distribution (figs. 6a and 6b). One remaining potential outlier (sample PAH-CE-19) was identified for each of the PAH compounds, except acenaphthylene, from the boxplots of the natural-log transformed data.

Analysis of the natural-log transformed concentration data for the uncensored PAH compounds indicated that the null hypothesis of a lognormal distribution could be accepted (p-value was greater than alpha level of 0.1) if the data from sample location PAH-CE-19 were excluded from the analysis (table 7). If the data from site PAH-CE-19 were included in the analysis, the hypothesis of a lognormal distribution was rejected (p-value was less than or equal to alpha level of 0.1) for pyrene, benzo(b)fluoranthene, benzo(k)fluoranthene, dibenzo(a,h)anthracene, benzo(g,h,i)perylene, and indeno(1,2,3-cd)pyrene. Normal probability plots of natural-log transformed censored PAH data without sample PAH-CE-19 were similar visually to those of the natural-log transformed uncensored PAH data without this sample (figs. 7a and 7b). Based on the visual comparison, the censored natural-log transformed PAH data also had a normal, or nearly normal distribution.

Maximum-likelihood estimation and log-probability regression on the natural-log transformed concentration data for the censored PAH compounds were used to calculate the mean, standard deviation, 25th percentile, median, and 75th percentile of the distribution for these compounds (table 8). Estimates of the values of these parameters varied with the method, but agreed within a factor of four in all cases, and typically agreed within a factor of two.

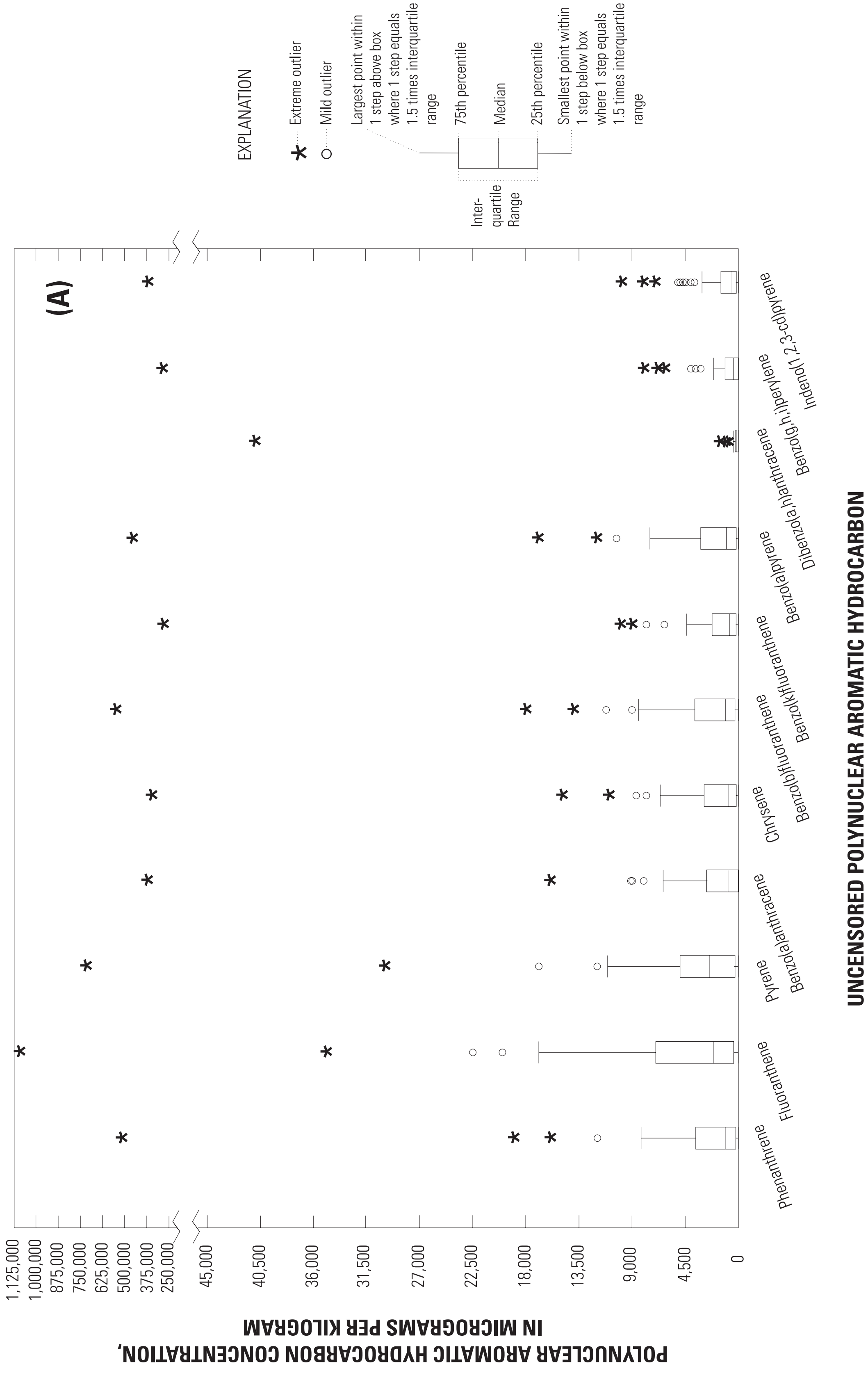


Figure 5. Boxplots of (A) uncensored and (B) censored polynuclear aromatic hydrocarbon concentrations in ambient surface soils, Chicago, Illinois.

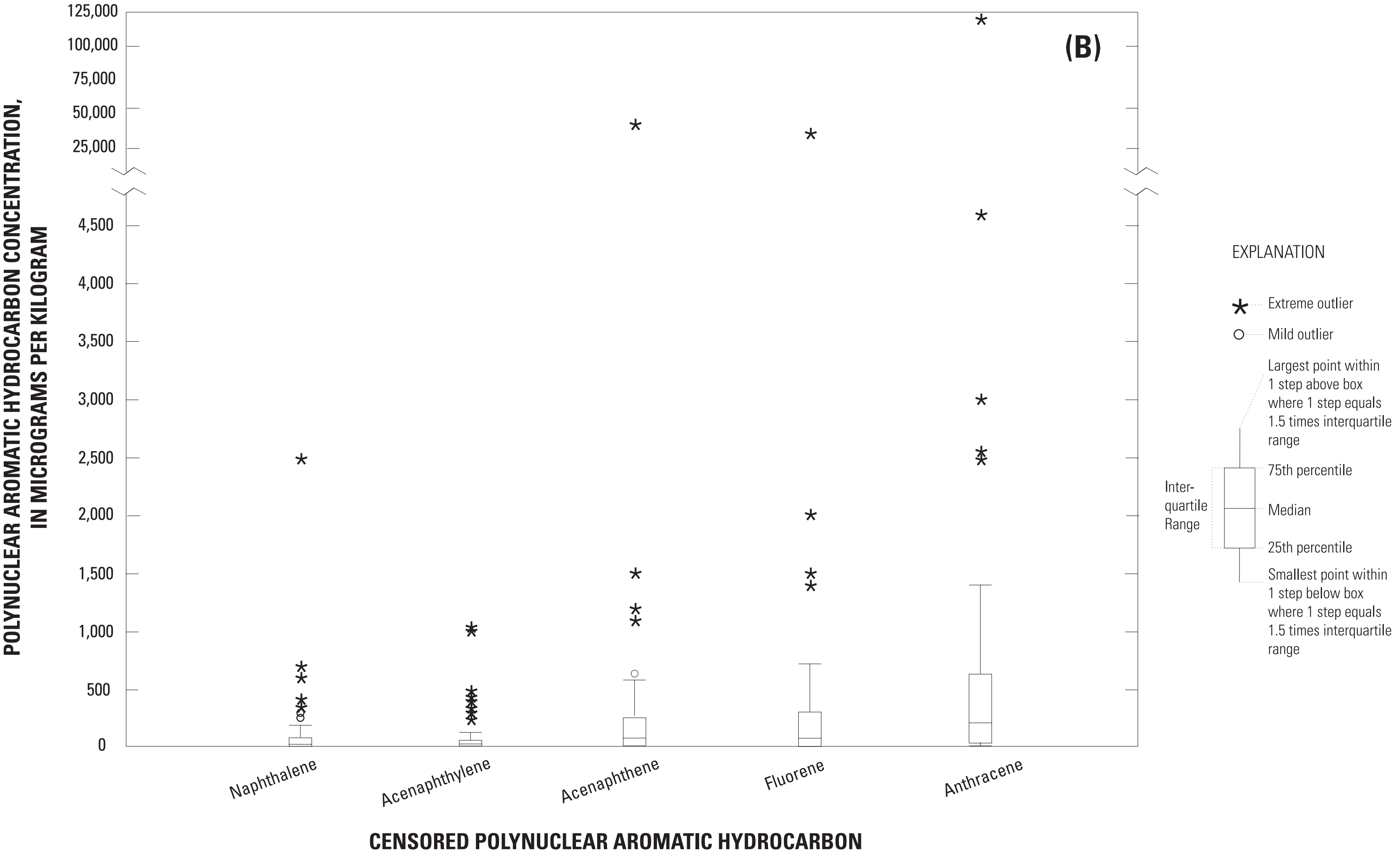


Figure 5. Boxplots of (A) uncensored and (B) censored polynuclear aromatic hydrocarbon concentrations in ambient surface soils, Chicago, Illinois—Continued.

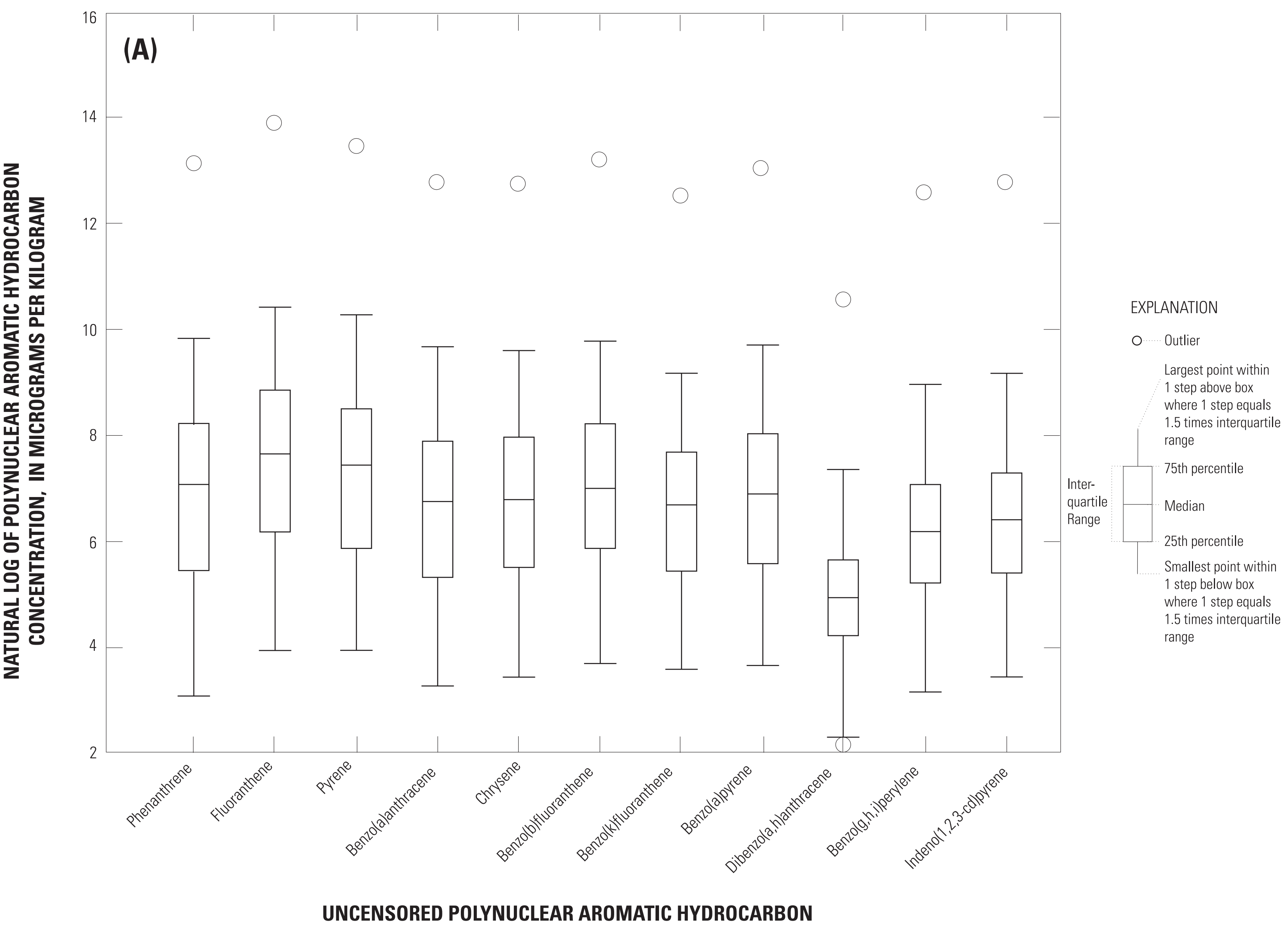


Figure 6. Boxplots of natural-log transformed (A) uncensored and (B) censored polynuclear aromatic hydrocarbon concentrations in ambient surface soils, Chicago, Illinois.

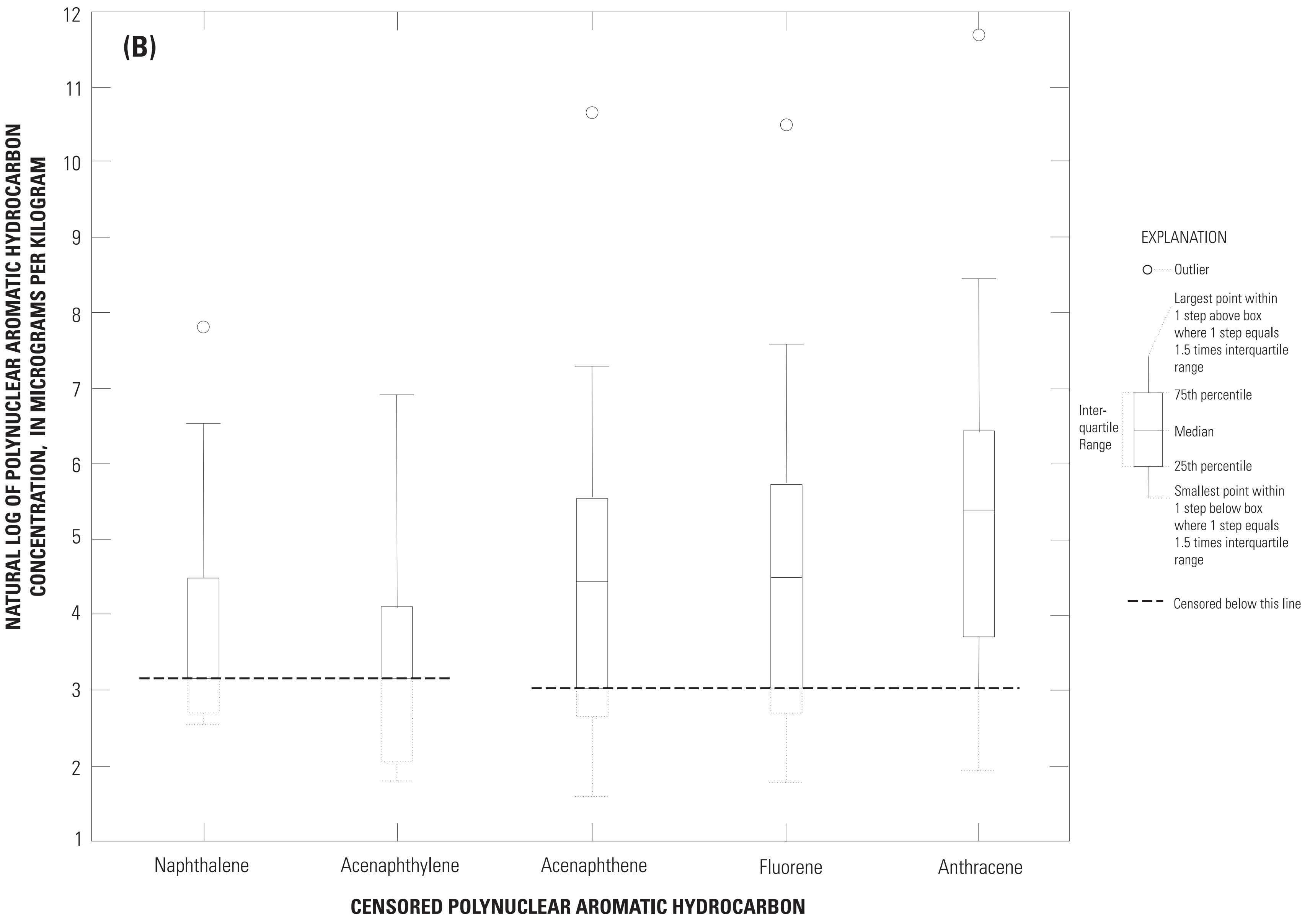


Figure 6. Boxplots of natural-log transformed (A) uncensored and (B) censored polynuclear aromatic hydrocarbon concentrations in ambient surface soils, Chicago, Illinois—Continued.

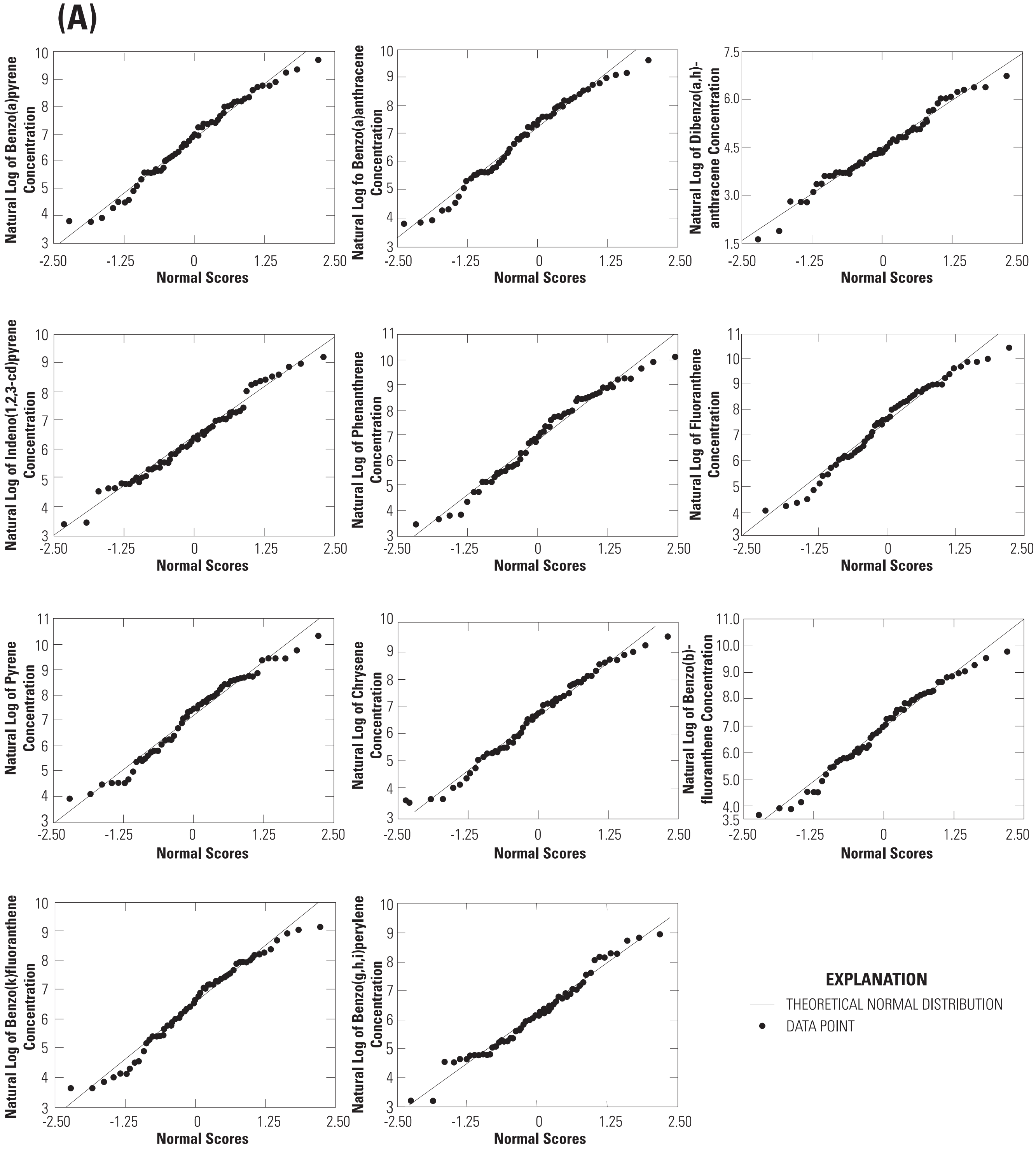


Figure 7. Normal probability plots of natural-log transformed (A) uncensored and (B) censored polynuclear aromatic hydrocarbon concentrations in ambient surface soils, Chicago, Illinois.

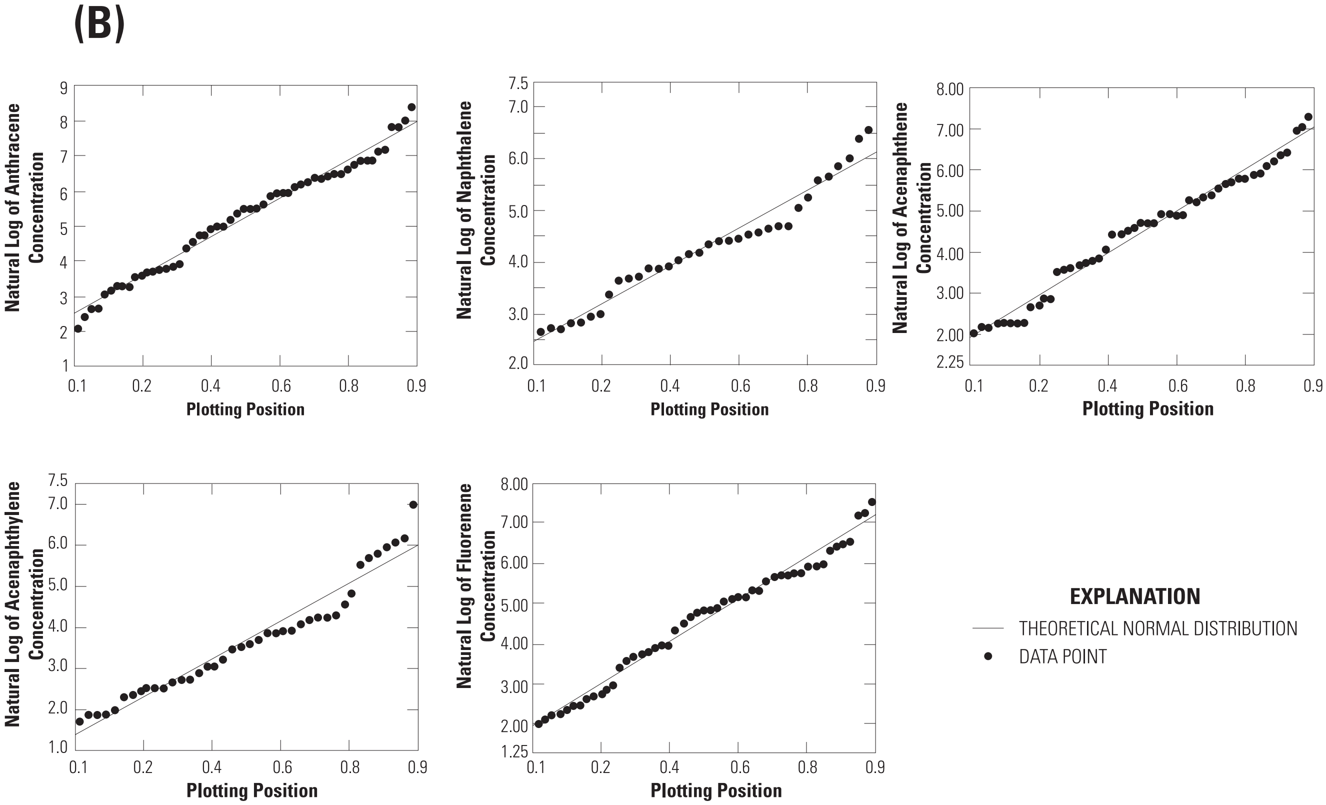


Figure 7. Normal probability plots of natural-log transformed (A) uncensored and (B) censored polynuclear aromatic hydrocarbon concentrations in ambient surface soils, Chicago, Illinois—Continued.

Estimates of mean and standard deviation were obtained by use of the log-probability regression, and estimates of percentiles were obtained by use of the maximum-likelihood regression (Helsel and Hirsch, 1995).

Outlier testing indicates that with the exception of acenaphthylene, concentrations of all of the PAHs in the sample from site PAH-CE-19 were five or more standard deviations greater than the next highest concentration, indicating that the PAH data from sample PAH-CE-19 are a statistical outlier (Helsel and Hirsch, 1995) (table 9). Therefore, the results from site PAH-CE-19 were omitted from all statistical analyses of the PAH compounds, including kriging of the benzo(a)pyrene distribution. As a consequence, the distribution of the uncensored PAH compounds in the surface soils could be considered lognormal, and reliably described by parametric statistical analyses (table 10).

The two-sided Wilcoxon-Rank-Sum test resulted in a p-value greater than the alpha value of 0.05, indicating that the null hypothesis, that the data from the city of Chicago and Commonwealth Edison properties represented a similar population, was acceptable (table 11). As a consequence, combination of all of the data (excluding the outlier sample from site PAH-CE-19) into one dataset for analysis was acceptable.

The Pearson product moment correlation coefficients for the natural-log transformed concentrations of the PAH compounds were 0.70 or greater (table 12), indicating a high degree of correlation. Naphthalene and acenaphthylene, the PAH compounds with the lowest molecular weights (table 13), were the only PAHs that did not show a correlation coefficient of 0.90 or higher with at least one other PAH. Naphthalene, the PAH compound with the lowest molecular weight (table 13), was the only PAH that did not show a correlation coefficient of 0.80 or higher with at least one other PAH.

The Pearson product moment correlation coefficients showed a low degree of positive correlation between the natural-log transformed concentrations of PAHs and the natural-log transformed concentration of total organic carbon, with the value of the correlation coefficient typically about 0.50 (table 12). This positive correlation may indicate that the PAH compounds attach to organic matter in the soil. However, the low value of the correlation coefficient indicated that the organic carbon content of the soil does not have a substantial limiting effect on PAH concentrations.

As would be expected of PAH compounds that tend to show a high degree of correlation, the concentrations of the various PAH compounds in soils tended to show similar patterns (appendix 1). Samples with high concentrations of one compound tended to have high concentrations of all compounds. Samples with low concentrations of one compound tended to have low concentrations of all compounds.

The distribution of PAH compounds at concentrations below the detection limit showed similar patterns. In all samples in which anthracene was not detected, acenaphthylene, fluorene, acenaphthene, and naphthalene also were not detected. In all samples in which fluorene and acenaphthene were not detected, acenaphthylene and naphthalene also were not detected. Sampling locations in which fluorene and acenaphthene were not detected are identical. In all samples in which acenaphthylene was not detected, naphthalene also was not detected.

Although this interpretation is complicated by differences in the detection limit among compounds, the frequency of detection tended to increase as the molecular weight of the compound increased (fig. 8). Naphthalene, the compound with the lowest frequency of detection, also has the lowest molecular weight of any PAH (128 grams per mole). Acenaphthylene (molecular weight 154 grams per mole) had the second lowest frequency of detection. Acenaphthene, fluorene, and anthracene, all with molecular weights below 180 grams per mole, also did not have a 100-percent detection frequency. Every PAH with a molecular weight of 202 grams per mole or higher, and phenanthrene with a molecular weight of 178 grams per mole, were detected in every sample analyzed.

Comparison of the PAH concentration and frequency of detection in ambient soils with PAH concentrations in the atmosphere over Chicago obtained from June through December 2000 show large differences. Naphthalene, the PAH detected least frequently and at among the lowest concentrations in soil samples, was the PAH detected at the highest concentrations in ambient air, by at least a factor of four (Illinois Environmental Protection Agency, 2002) (table 14). Fluoranthene and pyrene, the predominant PAH compounds in Chicago soils, were detected at the fourth and fifth highest concentrations, respectively, of the PAHs in the atmosphere. These results are consistent with air samples affected by various PAH sources within Chicago (Khalili and others, 1995), which typically show naphthalene present in the highest concentrations and substantially lower concentrations of fluoranthene and pyrene in air (table 14). These sampling efforts did not distinguish between concentrations of PAHs in the vapor and in the particulate phase.

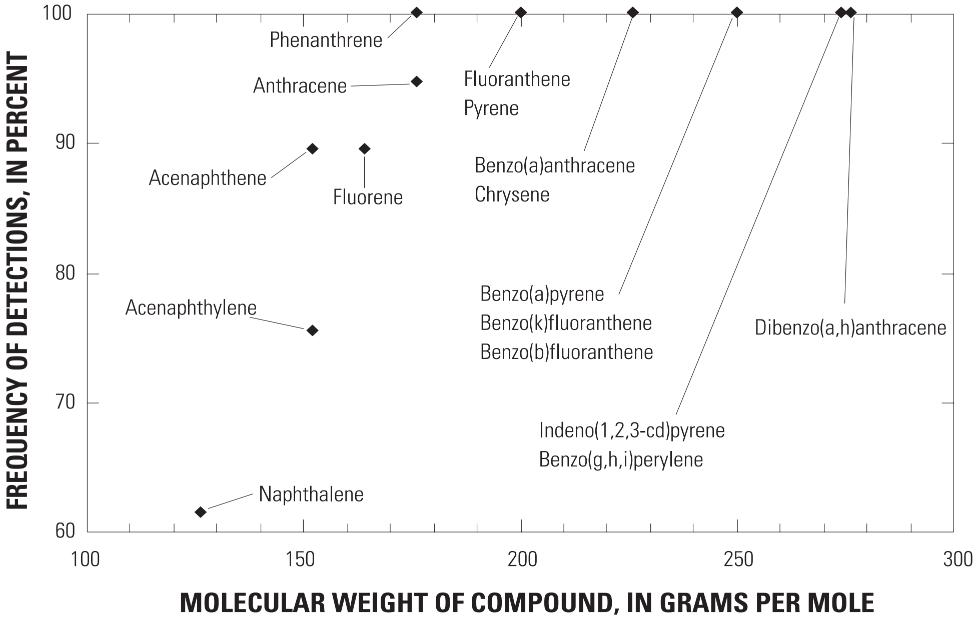


Figure 8. Frequency of detections of polynuclear aromatic hydrocarbons in ambient surface soils, Chicago, Illinois, plotted against molecular weight of compound.

The comparatively low correlation coefficient for the PAHs with low molecular weight, the frequency of detection of the PAH compounds in the soils, and the lack of correlation between the concentration of PAH compound in the atmosphere and in the ambient soils indicate that the concentration of PAH compounds in surface soils in the city of Chicago was affected by the physical properties of the compound. There are two aspects to this relation. First, the stability of a PAH compound in the soil environment increases with its molecular weight because of a decrease in its solubility in water and potential for volatilization and an increase in the potential to partition onto organic carbon and clay minerals (table 13). As a consequence, the tendency of a PAH to attach to particulate matter, and to stay attached to particulate matter, increases with increasing molecular weight. Second, the molecular weight of the PAH compound affects its phase in the atmosphere, through which the PAHs must travel from their sources to the ambient soil.

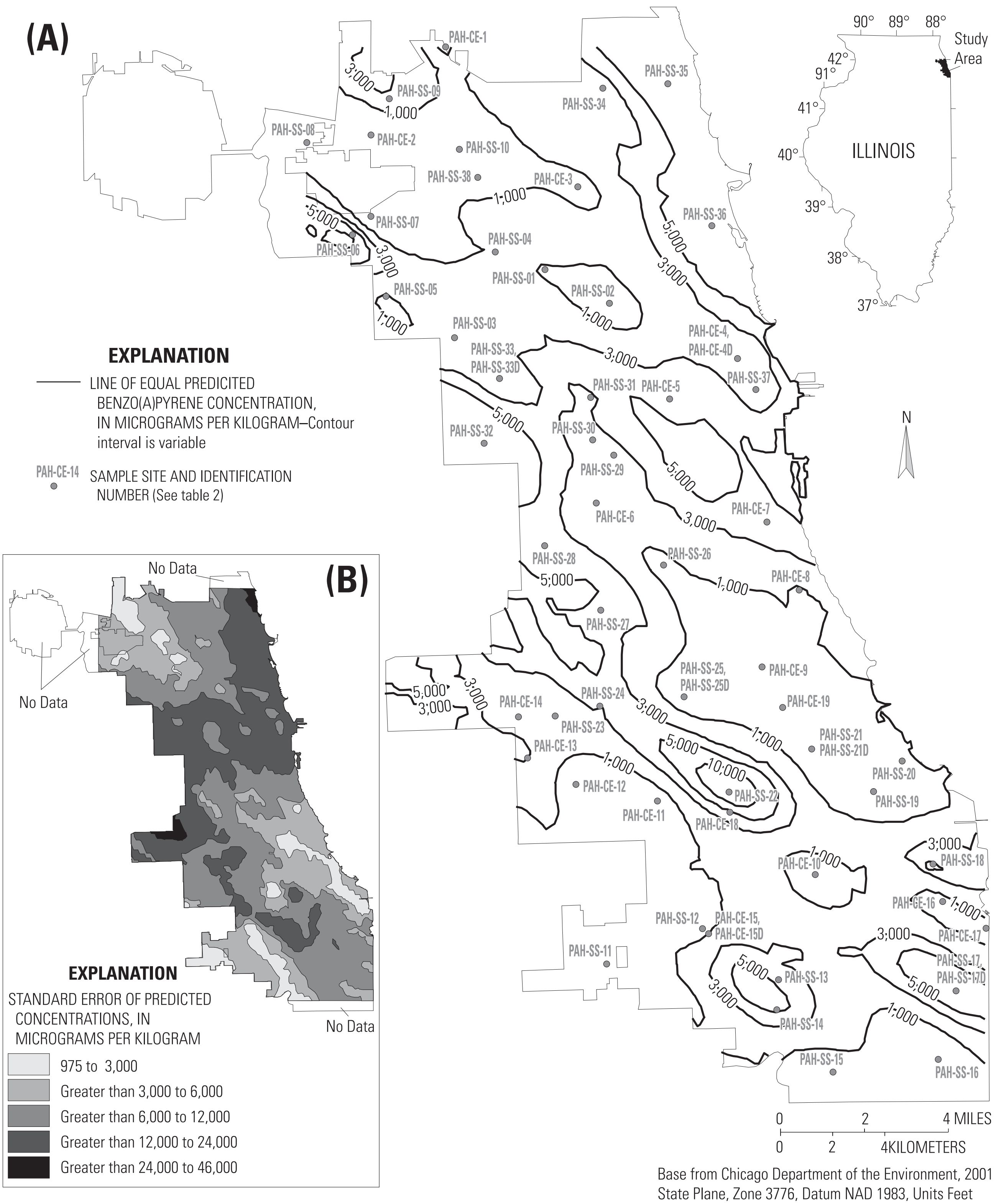
Although affected by temperature and particle size (Baek and others, 1991), PAHs with molecular weights equal to or less than that of phenanthrene (178 grams per mole) with a higher Henry's Law constant (table 13) partition primarily to the gas phase in the atmosphere. As the molecular weight of the PAH increases, partitioning to the gas phase decreases and partitioning to the particulate phase increases (Dickhut and Gustafson, 1995; Yaffe and others, 2001). PAHs with a molecular weight of more than about 247 grams per mole are primarily bound to particulate matter in the atmosphere. In comparison to the particulate-bound PAHs with higher molecular weights, the gas-phase PAHs with low molecular weights tend to remain in the atmosphere because they are less efficiently scavenged from the atmosphere by precipitation or particle settling. Higher molecular weight PAHs, therefore, are transported preferentially to the land surface where they can be incorporated into soils. The apparent effect of the phase of the PAH in the atmosphere on the presence of a PAH in ambient surface soils indicates that atmospheric settling of particulate matter is an important source of the PAH compounds in Chicago soils.

Concentrations of individual PAH compounds in ambient surface soils typically vary by at least three orders of magnitude across the city if the outlier sample is excluded (table 3). Data from sites PAH-SS-12 and PAH-CE-15 and 15D (fig. 4) indicate that individual PAH concentrations can vary by more than an order of magnitude across a distance of about 1,000 ft (appendix 1). Comparison of concentrations of the 16 PAH compounds at the 6 locations where duplicate samples were collected shows that PAH concentrations in the sample and its duplicate vary by less than a factor of 2 for 82 of the 96 analyses, vary by less than a factor of 3 for 90 of the 96 analyses, vary by less than a factor of 4 for 93 of the analysis, and vary by a factor of 7 or less in the remaining 3 analyses (appendix 1). Eleven of the analyses that varied by more than a factor of two were from sample PAH-CE-15 and its duplicate. The generally good agreement between the PAH concentrations in the sample and its duplicate indicates that PAH concentrations in ambient surface soils typically do not vary substantially over distances of less than about 10 ft.

The variability of PAH concentrations in the soils across the entire city, over distances of about 1,000 ft, and between samples and their duplicates indicates that PAH concentrations in ambient soils in Chicago are affected by site-specific factors. The apparent decrease in the variability of PAH concentrations with a decreasing scale of observation indicates that PAH concentrations in ambient soils also are affected by larger-scale processes.

The variability of PAH concentrations within the city is approximated by the distribution of benzo(a)pyrene, which showed a complex distribution (fig. 9). Higher concentrations were detected in the area near Lake Michigan in the northern part of the city, in much of the western part of the city, and in various pockets in the southern part of the city. Lower concentrations were detected in much of the northwestern, south-central, southwestern, and far southern parts of the city. Areas of lower benzo(a)pyrene concentration corresponded to areas where one or more PAH compound was not detected.

Previous investigators have identified an inverse correlation between concentrations of PAH compounds in surface soils and distance from a roadway (Bradley and others, 1994). Therefore, it was anticipated that proximity to a roadway may have been one of the site-specific factors affecting PAH concentrations in the city. However, linear regression of the concentrations of the uncensored PAHs and distance from the nearest roadway indicated no trend,



Base from Chicago Department of the Environment, 2001
State Plane, Zone 3776, Datum NAD 1983, Units Feet

Figure 9. (A) Kriged concentrations of benzo(a)pyrene in ambient surface soils, Chicago, Illinois and (B) standard errors of predicted concentrations.

with all coefficients of determination (R^2) less than 0.02. An analysis of variance did not indicate that mean concentrations of the uncensored PAHs differ in a statistically significant manner with distance from the roadway (table 15). These analyses indicate either that distance from roadways does not have a substantial affect on PAH concentrations in ambient soils in the city of Chicago or that other factors, such as the amount of traffic and the prevailing wind direction, need to be considered.

Analysis was performed to determine if PAH concentrations are related to land use. Results of the multiple-population tests for comparing the natural-log transformed concentrations of individual PAH compounds indicate that there are no statistically significant differences in the mean PAH concentration among land-use categories (tables 16 and 17). It should be cautioned that the unequal sample sizes or "lack of balance" in the statistical tests can result in low power, or diminished capability of the tests to correctly reject the null hypothesis that the means of the land-use categories are not statistically different when the null hypothesis is false.

Linear regression of natural-log transformed PAH concentrations with the percent industrial land use within a 1-mi radius of the sampling location yields a t-statistic for the slope coefficient greater than two for each PAH. Linear regression of natural-log transformed PAH concentrations with percent industrial land use within a 0.5-mi radius of the sampling location yields a t-statistic for the slope coefficient greater than 2 for each PAH except dibenzo(a,h)anthracene. Regressions using percentages of transportation, commercial, vacant, and residential land use showed no relation. A t-statistic for the slope coefficient greater than 2 indicates a statistically significant direct linear relation between the amount of industrial land use in the area and the PAH concentration in the sample (Helsel and Hirsch, 1995) (table 18). The t-statistic for the slope coefficient was near two for each compound and the linear correlation coefficient between percent industrial land use and the PAH concentration is less than 0.10, indicating that this correlation (if present) is weak. Linear regression of natural-log transformed PAH concentrations with percent industrial land use within a 0.25-mi radius of the sampling location yielded a t-statistic for the slope coefficient less than 2 for each PAH. This result indicates no statistically significant direct linear relation between the amount of industrial land use within 0.25 mi of the sample and the PAH concentration in the sample. Simple linear regressions of mean distance to industrial land use and concentrations of uncensored PAH compounds did not show a relation. These data are insufficient to determine if the apparent relation between PAH concentrations and percent industrial land use is because of industrial emissions, increased traffic density in industrial areas, or some other source.

ANALYSIS OF INORGANIC DATA

Surface soils in the city of Chicago are composed of a mixture of compounds, and 34 of the 45 inorganic constituents were detected in more than 75 percent of the samples collected. This frequency of detection allowed the arithmetic mean, standard deviation, and ranges for these analytes to be calculated (table 19). An additional 11 constituents were not quantifiable because all or many samples contained less than the lower limit of detection (LOD). Those elements, with their LOD, are silver (2 mg/Kg), gold (8 mg/Kg), beryllium (1 mg/Kg), bismuth (50 mg/Kg), cadmium (2 mg/Kg), europium (2 mg/Kg), holmium (4 mg/Kg), tin (50 mg/Kg), thallium (40 mg/Kg), uranium (100 mg/Kg), and ytterbium (1 mg/Kg).

The arithmetic mean of the concentration of the 34 inorganic analytes detected in more than 75 percent of the samples of Chicago soils was compared with the arithmetic mean concentration of these analytes in 106 samples of A-horizon soils collected primarily from agricultural areas within 500 kilometers of Chicago (Boerngen and Shacklette, 1981). The mean concentration of arsenic, mercury, calcium, magnesium, phosphorus, copper, molybdenum, zinc, and selenium was from two to six times higher in Chicago soils, and concentrations of lead were about 20 times higher than in soils from the surrounding area (table 20).

Inter-element correlation coefficients for the inorganic analytes were calculated to provide additional insight into the sources of the inorganic constituents (table 21). The sets of elements showing strong mutual correlations can indicate causative factors for the observed concentrations and distribution of these elements.

Concentrations of all of the major element compositions, except for sodium, and many of the trace elements showed trends consistent with naturally developed soils. Bedrock beneath and near Chicago is composed of dolomite (a calcium, magnesium carbonate) and shale, a rock composed largely of clays, which are alumino-silicate minerals often rich in aluminum and potassium. The high (r^2 greater than 0.98) Pearson product moment correlation coefficients among calcium, magnesium, and carbonate carbon reflect the widespread distribution of dolomite in the soils. The lack of other highly correlated elements further suggests that the dolomite does not contain appreciable amounts of other trace elements. Likewise, high correlations (r^2 greater than 0.70) between aluminum and other clay-borne elements such as potassium and trace constituents expected in clays including barium, cerium, gallium, lanthanum, lithium, neodymium, scandium, titanium, vanadium, and yttrium demonstrate the extent the clays affect the soil composition.

Although the bulk of the compositional trends in Chicago soils are explainable by varying proportions of dolomite and shale, which likely are soil parent material, the elevated (in comparison to surrounding agricultural soils) concentrations of arsenic, copper, lead, mercury, molybdenum, nickel, phosphorus, selenium, and zinc indicate a potential anthropogenic source of these elements. Lead (concentration factor of 20.4), zinc (7.4), and mercury (4.5) especially are enriched relative to background soils and all seem likely to indicate substantial and widespread anthropogenic modifications to the trace-element character of the soils.

The high correlation between lead and zinc ($r^2 = 0.91$) suggests that the two elements have been added to soils largely from the same material or process rather than as independently distributed constituents. Mercury shows low correlation with all other constituents, including organic carbon ($r^2 = 0.135$). In many natural settings mercury and organic carbon are highly correlated so the lack of correlation in Chicago soils suggests an anthropogenic addition largely independent of natural processes.

Other correlations of possible significance are among chromium, manganese, iron, and molybdenum. All four of these elements are major or trace constituents in various ferroalloys, which indicates that man-made steel products, or breakdown products from them, might be widely dispersed. The strong correlation among sulfur, organic carbon, and molybdenum also is noteworthy. In Chicago soils, sulfur primarily occurs in organic compounds in contrast to more typical occurrences as naturally occurring iron-sulfide minerals. Conversely, the lack of strong correlation among sulfur and elements that typically concentrate in sulfide minerals, such as copper, lead, zinc, nickel, and cobalt, further indicates that sulfide minerals do not substantially affect the composition of Chicago soils.

SUMMARY AND CONCLUSIONS

The U.S. Geological Survey, in cooperation with the Chicago Department of Environment, assessed the concentration of polynuclear aromatic hydrocarbons (PAHs) and inorganic constituents in ambient surface soils within the city of Chicago. At least 11 of the 16 polynuclear aromatic hydrocarbon constituents were detected in each of the 57 soil samples collected. The distribution of the uncensored PAH compounds in the surface soils can be considered log normal once the data from the outlier location were excluded from the analysis.

PAH concentrations, from highest to lowest, were typically in the following order: fluoranthene, pyrene, benzo(b)fluoranthene, phenanthrene, benzo(a)pyrene, chrysene, benzo(a)anthracene, benzo(k)fluoranthene, indeno(1,2,3-cd)pyrene, benzo(g,h,i)perylene, dibenzo(a,h)anthracene, and anthracene. Naphthalene, acenaphthene, acenaphthylene, and fluorene consistently were at the lowest concentrations in each sample. Concentrations of the PAH compounds were highly correlated, but did show some variation with the molecular weight of the compound. PAH compounds appear to be derived from similar combinations of sources, and most of the PAHs tend to behave similarly once released into the air, water, and soil.

Concentrations of individual PAH compounds in soils typically varied by at least 3 orders of magnitude for each compound across the city and varied by more than an order of magnitude over a distance of about 1,000 ft. Data from duplicate samples indicate that PAH concentrations typically varied by less than a factor of two over a distance of a few feet. Variations in the concentrations of a given PAH in ambient surface soils may be affected by proximity to industrial areas. Variations in the concentrations of a given PAH in ambient surface soils did not appear to be affected by proximity to roadways or non-industrial land uses and did not appear to be strongly affected by the organic carbon content of the soil.

The concentration of the different PAH compounds in ambient surface soils appears to have been affected by the physical properties of the compound, which are affected by its molecular weight. Lower molecular-weight PAH compounds, which were in lower concentrations in the soils, were primarily in the vapor phase in the atmosphere. Higher molecular-weight PAH compounds, which often were in higher concentrations in the soils, were primarily in the particulate phase in the atmosphere. The apparent effect of the phase of the PAH in the atmosphere on the concentration of a PAH in ambient surface soils indicated that atmospheric settling of particulate matter is an important source of the PAH compounds in ambient Chicago soils.

The distribution of benzo(a)pyrene, which approximated the distribution of the remaining PAH compounds within the city, was complex. Elevated concentrations (greater than 4,084 micrograms per kilogram) were detected near Lake Michigan in the northern part of the city, in much of the western part of the city, and in isolated areas in the southern part of the city. Comparatively low concentrations (less than 419 micrograms per kilogram) were detected in much of the northwestern, south-central, southwestern, and far southern parts of the city.

Concentrations of various inorganic constituents in surface soils in the city of Chicago appeared to be affected by the natural development of the soils. The arithmetic mean concentration of arsenic, mercury, calcium, magnesium, phosphorus, copper, molybdenum, zinc, selenium were from 2 to 8 times higher, and concentrations of lead were about 20 times higher, than in typical soils from the surrounding area and may indicate an anthropogenic source for these analytes. Elevated concentrations of calcium and magnesium appeared to be related to the effects of dolomite bedrock on the chemical composition of the soil.

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Tables

Table 1. Illinois Environmental Protection Agency Tier 1 remediation objectives for polynuclear aromatic hydrocarbons in soils
[na, not applicable]

Constituent	Remedial objective for residential soil				Remedial objective for industrial or commercial soil					
	Exposure route-specific values for soils		Soil component of the ground-water ingestion exposure route values		Exposure route-specific values for soils				Soil component of the ground-water ingestion exposure route values	
					Industrial commercial		Construction worker			
	Ingestion (milligrams per kilogram)	Inhalation (milligrams per kilogram)	Class I (milligrams per kilo-gram)	Class II (milligrams per kilo-gram)	Ingestion (milligrams per kilogram)	Inhalation (milligrams per kilogram)	Ingestion (milligrams per kilogram)	Inhalation (milligrams per kilogram)	Class I (milligrams per kilo-gram)	Class II (milligrams per kilo-gram)
Acenaphthene	4,700.	na	570	2,900.	120,000.	na	120,000	na	570	2,900
Acenaphthylene	na	na	na	na	na	na	na	na	na	na
Anthracene	23,000.	na	12,000	59,000.	610,000.	na	610,000	na	12,000	59,000
Benzo(a)anthracene	.9	na	2	8.	8.	na	170	na	2	8
Benzo(b)fluoranthene	.9	na	5	25.	8.	na	170	na	2	8
Benzo(k)fluoranthene	9.	na	49	250.	78.	na	1,700	na	49	250
Benzo(g,h,i)perylene	na	na	na	na	na	na	na	na	na	na
Benzo(a)pyrene	.09	na	8	82.	.8	na	17	na	8	82
Chrysene	88.	na	160	800.	780.	na	17,000	na	160	800
Dibenzo(a,h)anthracene	.09	na	2	7.6	.8	na	17	na	2	8
Fluoranthene	3,100.	na	4,300	21,000.	82,000.	na	82,000	na	4,300	21,000
Fluorene	3,100.	na	560	2,800.	82,000.	na	82,000	na	560	2,800
Indeno(1,2,3-cd)pyrene	.9	na	14	69.	8.	na	170	na	14	69
Naphthalene	3,100.	na	84	420.	82,000.	na	82,000	na	84	420
Phenanthrene	na	na	na	na	na	na	na	na	na	na
Pyrene	2,300.	na	4,200	21,000.0	61,000.	na	61,000	na	4,200	21,000

Table 2. Soil-sampling site data collected during the investigation, Chicago, Illinois

[D, duplicate sample; USGS, U.S. Geological Survey]

Sample number (location shown in figure 4)	Latitude	Longitude	USGS site identification number	Land use at site	Distance from nearest roadway (feet)	Date of sample collection
PAH-CE-1	42°00’35”	87°46’20”	420003508746201	Commercial	25	1/24/2002
PAH-CE-2	41°58’46”	87°48’25”	415846087482501	Transportation	40	1/24/2002
PAH-CE-3	41°57’40”	87°42’41”	415740087424101	Commercial	61	1/24/2002
PAH-CE-4	41°54’04”	87°38’18”	415404087381801	Commercial	190	1/24/2002
PAH-CE-4D	41°54’04”	87°38’18”	415404087381802	Commercial	190	1/24/2002
PAH-CE-5	41°53’16”	87°40’11”	415316087401101	Industrial	118	1/24/2002
PAH-CE-6	41°51’07”	87°42’14”	415107087421401	Commercial	7	1/24/2002
PAH-CE-7	41°50’42”	87°37’31”	415042087373101	Industrial	74	1/24/2002
PAH-CE-8	41°49’17”	87°36’38”	414917087363801	Residential	78	1/24/2002
PAH-CE-9	41°47’43”	87°37’41”	414743087374101	Vacant or wetland	125	1/24/2002
PAH-CE-10	41°43’24”	87°36’16”	414324087361601	Transportation	16	1/24/2002
PAH-CE-11	41°44’57”	87°40’37”	414457087403701	Industrial	221	1/24/2002
PAH-CE-12	41°45’18”	87°42’51”	414518087425101	Residential	37	1/24/2002
PAH-CE-13	41°45’51”	87°44’12”	414551087441201	Industrial	626	1/24/2002
PAH-CE-14	41°46’42”	87°44’26”	414642087442601	Commercial	41	1/24/2002
PAH-CE-15	41°42’11”	87°39’13”	414211087391301	Industrial	140	1/25/2002
PAH-CE-15D	41°42’11”	87°39’13”	414211087391302	Industrial	140	1/25/2002
PAH-CE-16	41°42’49”	87°32’45”	414249087324501	Vacant or wetland	85	1/25/2002
PAH-CE-17	41°42’15”	87°31’33”	414215087313301	Transportation	69	1/25/2002
PAH-CE-18	41°44’42”	87°38’37”	414442087383701	Commercial	69	1/25/2002
PAH-CE-19	41°46’52”	87°37’08”	414652087370801	Vacant or wetland	120	1/25/2002
PAH-SS-01	41°55’57”	87°43’37”	415557087435701	Industrial	30	6/5/2001
PAH-SS-02	41°55’15”	87°41’50”	415515087415001	Commercial	10	6/5/2001
PAH-SS-03	41°54’33”	87°46’08”	415433087460801	Commercial	10	6/5/2001
PAH-SS-04	41°56’20”	87°45’00”	415620087450001	Commercial	45	6/5/2001
PAH-SS-05	41°55’25”	87°48’02”	415525087480201	Commercial	35	6/5/2001
PAH-SS-06	41°56’42”	87°48’57”	415642087485701	Residential	1	6/5/2001
PAH-SS-07	41°57’05”	87°48’26”	415705087482601	Commercial	45	6/5/2001
PAH-SS-08	41°58’37”	87°50’12”	415837087501201	Residential	16	6/5/2001
PAH-SS-09	41°59’31”	87°47’54”	415931087475401	Open space	22	6/5/2001
PAH-SS-10	41°58’27”	87°45’59”	415827087455901	Commercial	32	6/5/2001
PAH-SS-11	41°41’35”	87°42’03”	414135087420301	Commercial	30	6/5/2001
PAH-SS-12	41°42’18”	87°39’24”	414218087392401	Transportation	25	6/5/2001
PAH-SS-13	41°41’14”	87°37’18”	414114087371801	Commercial	20	6/5/2001
PAH-SS-14	41°40’36”	87°31’21”	414036087312101	Residential	10	6/5/2001

Table 2. Soil-sampling site data collected during the investigation, Chicago, Illinois—Continued

[D, duplicate sample; USGS, U.S. Geological Survey]

Sample number (location shown in figure 4)	Latitude	Longitude	USGS site identification number	Land use at site	Distance from nearest roadway (feet)	Date of sample collection
PAH-SS-15	41°39’19”	87°35’50”	413919087355001	Commercial	50	6/5/2001
PAH-SS-16	41°39’34”	87°32’55”	413934087325501	Vacant or wetland	10	6/5/2001
PAH-SS-17	41°40’58”	87°32’24”	414058087322401	Vacant or wetland	23	6/5/2001
PAH-SS-17D	41°40’58”	87°32’24”	414058087322402	Vacant or wetland	23	6/5/2001
PAH-SS-18	41°43’35”	87°33’00”	414335087330001	Vacant or wetland	10	6/5/2001
PAH-SS-19	41°45’06”	87°34’38”	414506087343801	Commercial	20	6/5/2001
PAH-SS-20	41°45’44”	87°33’50”	414544087335001	Residential	20	6/5/2001
PAH-SS-21	41°46’00”	87°36’20”	414600087362001	Commercial	10	6/5/2001
PAH-SS-21D	41°46’00”	87°36’20”	414600087362002	Commercial	10	6/5/2001
PAH-SS-22	41°45’07”	87°38’38”	414507087383801	Commercial	5	6/5/2001
PAH-SS-23	41°46’43”	87°43’25”	414643087432501	Commercial	5	6/6/2001
PAH-SS-24	41°46’55”	87°42’11”	414655087421101	Commercial	5	6/6/2001
PAH-SS-25	41°47’06”	87°39’51”	414706087395101	Commercial	10	6/6/2001
PAH-SS-25D	41°47’06”	87°39’51”	414706087395102	Commercial	10	6/6/2001
PAH-SS-26	41°49’49”	87°40’24”	414949087402401	Commercial	5	6/6/2001
PAH-SS-27	41°48’54”	87°42’09”	414854087420901	Commercial	20	6/6/2001
PAH-SS-28	41°50’14”	87°43’41”	415014087434101	Residential	20	6/6/2001
PAH-SS-29	41°52’06”	87°41’45”	415206087414501	Residential	20	6/6/2001
PAH-SS-30	41°52’25”	87°42’50”	415225087425001	Institutional	10	6/6/2001
PAH-SS-31	41°53’18”	87°42’23”	415318087422301	Institutional	10	6/6/2001
PAH-SS-32	41°52’22”	87°45’20”	415222087452001	Transportation	10	6/6/2001
PAH-SS-33	41°53’42”	87°44’54”	415342087445401	Commercial	10	6/6/2001
PAH-SS-33D	41°53’42”	87°44’54”	415342087445402	Commercial	10	6/6/2001
PAH-SS-34	41°59’42”	87°41’58”	415942087415801	Commercial	10	6/6/2001
PAH-SS-35	41°59’47”	87°40’10”	415947087401001	Residential	50	6/6/2001
PAH-SS-36	41°56’50”	87°38’58”	415650087385801	Institutional	10	6/6/2001
PAH-SS-37	41°53’27”	87°37’48”	415327087374801	Transportation	20	1/25/2002
PAH-SS-38	41°57’52”	87°45’28”	415752087452801	Commercial	10	1/25/2002

Table 3. Summary of polynuclear aromatic hydrocarbon data in ambient surface soils, Chicago, Illinois

[<, less than; na, not applicable]

Constituent	Number of samples collected	Number of detections	Percentage of samples with analyte detected	Range of detected concentrations including sample PAH-CE-19 (micrograms per kilogram)	Range of detected concentrations without sample PAH-CE-19 (micrograms per kilogram)	Number of samples exceeding Tier 1 remedial objectives for residential soil because of ingestion[1]	Number of samples exceeding Tier 1 remedial objectives for industrial or commercial soil because of ingestion[1]	Number of samples exceeding Tier 1 remedial objectives for construction workers because of ingestion[1]
Acenaphthene	57	51	89	<5-43,000	<5-1,500	0	0	0
Acenaphthylene	57	43	75	<6-1,035	<6-1,035	na	na	na
Anthracene	57	54	95	<7-120,000	<7-4,600	0	0	0
Benzo(a)anthracene	57	57	100	26-370,000	26-16,000	27	5	1
Benzo(b)fluoranthene	57	57	100	40-550,000	40-18,000	32	6	1
Benzo(k)fluoranthene	57	57	100	36-280,000	36-10,000	3	1	0
Benzo(g,h,i)perylene	57	57	100	24-290,000	24-8,100	na	na	na
Benzo(a)pyrene	57	57	100	39-460,000	39-17,000	51	31	2
Chrysene	57	57	100	31-350,000	31-15,000	1	0	0
Dibenzo(a,h)anthracene	57	57	100	8-41,000	8-1,600	38	7	1
Fluoranthene	57	57	100	52-1,100,000	52-35,000	0	0	0
Fluorene	57	51	89	<6-36,000	<6-2,000	0	0	0
Indeno(1,2,3-cd)pyrene	57	57	100	31-370,000	31-9,900	22	3	1
Naphthalene	57	35	61	<13-2,500	<13-700	0	0	0
Phenanthrene	57	57	100	22-520,000	22-19,000	na	na	na
Pyrene	57	57	100	51-720,000	51-30,000	0	0	0

[1] Illinois Pollution Control Board, 2002

Table 4. Mean distance from sample locations to nearby major land-use categories, Chicago, Illinois

[--, no data]

Sample number (location shown in figure 4)	Mean distance to unclassified land use (feet)	Mean distance to residential land use (feet)	Mean distance to commercial land use (feet)	Mean distance to institutional land use (feet)	Mean distance to industrial, warehousing, and wholesale land use (feet)	Mean distance to transportation, communication, and utilities land use (feet)	Mean distance to agricultural land use (feet)	Mean distance to open space land use (feet)	Mean distance to vacant or wetland land use (feet)	Mean distance to water (feet)
PAH-CE-1	--	4,356	4,265	5,216	2,395	8,144	--	4,936	6,384	--
PAH-CE-2	5,253	3,403	2,645	3,441	--	1,970	--	2,294	1,361	--
PAH-CE-3	--	4,911	4,974	6,659	6,082	6,244	--	5,373	6,979	5,111
PAH-CE-4	--	4,967	5,055	4,288	4,737	4,944	--	5,459	3,786	5,235
PAH-CE-5	--	5,073	4,787	6,209	3,516	4,838	--	4,939	3,947	--
PAH-CE-6	--	3,767	3,531	3,957	4,944	4,428	--	2,922	4,585	6,241
PAH-CE-7	--	5,086	5,436	3,846	5,595	5,536	--	5,017	5,503	6,224
PAH-CE-8	--	4,727	4,621	4,601	6,503	5,926	--	5,385	3,801	--
PAH-CE-9	--	4,479	4,415	4,592	6,564	3,681	--	4,572	3,907	--
PAH-CE-10	--	4,973	5,277	4,041	5,024	5,901	--	7,191	6,299	--
PAH-CE-11	9,308	4,924	4,597	4,531	3,720	3,549	--	5,767	5,197	--
PAH-CE-12	10,330	5,321	5,448	7,313	2,457	3,294	--	4,829	3,933	4,874
PAH-CE-13	4,376	4,523	4,736	2,909	2,531	2,102	--	2,320	2,054	--
PAH-CE-14	11,084	9,809	9,386	10,373	10,686	5,856	--	8,757	5,353	--
PAH-CE-15	10,271	5,054	4,971	5,196	6,916	5,514	--	5,525	7,751	--
PAH-CE-16	--	4,386	3,752	5,079	3,195	5,434	--	5,964	6,269	2,825
PAH-CE-17	--	2,963	1,882	3,162	1,260	1,939	--	4,104	2,331	--
PAH-CE-18	--	4,829	4,670	4,213	3,401	4,642	--	4,908	4,800	--
PAH-CE-19	--	5,081	4,985	5,618	2,469	3,748	--	6,244	4,103	4,854
PAH-SS-01	--	4,130	3,963	3,865	4,061	5,186	--	3,497	5,280	--
PAH-SS-02	--	4,772	5,106	5,193	6,193	5,571	--	4,559	5,644	6,288
PAH-SS-03	4,951	3,904	4,059	4,690	3,946	3,012	--	4,016	3,757	--
PAH-SS-04	--	4,269	4,200	4,708	3,253	5,039	--	4,270	3,086	--
PAH-SS-05	5,112	4,083	4,035	3,988	3,297	5,758	--	4,542	3,632	--
PAH-SS-06	3,942	3,482	4,513	5,343	9,768	--	--	7,798	5,695	9,734
PAH-SS-07	4,008	4,556	3,244	3,868	4,659	--	--	4,504	5,144	--
PAH-SS-08	6,461	8,073	7,135	14,488	19,612	19,974	25,114	6,211	19,443	13,079
PAH-SS-09	12,046	6,017	5,384	4,158	3,059	4,909	--	4,396	6,918	--
PAH-SS-10	6,691	4,678	3,765	4,720	4,678	4,054	--	5,734	7,861	--

Table 4. Mean distance from sample locations to nearby major land-use categories, Chicago, Illinois—Continued

[--, no data]

Sample number (location shown in figure 4)	Mean distance to unclassified land use (feet)	Mean distance to residential land use (feet)	Mean distance to commercial land use (feet)	Mean distance to institutional land use (feet)	Mean distance to industrial, warehousing, and wholesale land use (feet)	Mean distance to transportation, communication, and utilities land use (feet)	Mean distance to agricultural land use (feet)	Mean distance to open space land use (feet)	Mean distance to vacant or wetland land use (feet)	Mean distance to water (feet)
PAH-SS-11	7,930	5,957	6,824	5,864	9,956	7,545	5,100	4,773	9,022	8,472
PAH-SS-12	9,651	5,263	6,921	4,228	4,723	3,305	--	5,157	4,614	--
PAH-SS-13	--	4,071	3,364	3,495	5,610	5,632	--	7,401	7,434	9,507
PAH-SS-14	9,539	5,118	4,268	6,900	5,639	4,961	--	4,125	6,320	7,822
PAH-SS-15	6,413	3,198	2,922	2,360	6,322	4,260	--	3,128	5,162	6,367
PAH-SS-16	--	3,092	3,149	1,965	4,905	4,658	--	4,534	4,836	5,619
PAH-SS-17	--	3,126	1,875	2,911	5,158	4,474	--	3,609	5,864	6,788
PAH-SS-18	--	4,660	3,464	3,910	5,408	4,188	--	4,147	4,286	4,422
PAH-SS-19	--	3,958	3,961	3,745	3,807	3,729	--	4,842	4,620	--
PAH-SS-20	--	3,460	3,179	3,261	7,256	6,708	--	5,963	3,163	7,755
PAH-SS-21	--	4,331	4,516	3,113	3,236	3,680	--	7,257	4,838	7,231
PAH-SS-22	--	4,080	3,679	4,115	3,914	4,162	--	3,911	3,804	--
PAH-SS-23	--	3,492	3,705	3,033	6,983	7,376	--	3,410	1,243	--
PAH-SS-24	--	3,738	3,586	5,390	6,296	5,196	--	4,974	2,384	4,936
PAH-SS-25	--	4,606	4,585	4,682	5,326	5,788	--	4,556	4,311	--
PAH-SS-26	--	4,776	5,471	5,451	5,491	4,644	--	3,512	5,365	5,106
PAH-SS-27	--	4,472	4,286	5,376	5,175	4,607	--	6,033	6,008	6,165
PAH-SS-28	4,916	4,148	4,412	4,414	5,242	5,287	--	4,592	5,995	5,768
PAH-SS-29	--	4,666	4,839	4,706	3,737	5,070	--	3,823	4,047	2,323
PAH-SS-30	--	3,954	3,596	3,410	3,009	3,201	--	3,723	3,457	--
PAH-SS-31	--	4,316	4,518	3,347	3,486	3,529	--	3,914	3,455	3,401
PAH-SS-32	4,696	4,580	4,329	3,628	4,288	3,680	--	4,197	5,107	3,300
PAH-SS-33	--	4,077	4,636	3,977	4,068	4,148	--	4,630	4,471	--
PAH-SS-34	--	5,083	4,959	5,919	7,734	4,692	--	5,801	5,036	3,950
PAH-SS-35	--	5,303	5,328	4,591	5,361	7,664	--	6,556	4,915	4,792
PAH-SS-36	--	5,728	5,115	5,708	7,533	5,392	--	6,121	6,529	7,589
PAH-SS-37	--	4,946	3,944	4,716	5,538	5,058	--	5,559	4,974	3,570
PAH-SS-38	--	4,175	3,898	6,574	4,395	3,785	--	5,187	--	--

Table 5. Percentages of major land-use categories around soil-sampling sites, Chicago, Illinois

Sample number (location shown in figure 4)	Residential	Commercial and services	Institutional	Industrial, warehousing, and wholesale	Transportation, communication, and utilities	Open space	Vacant or wetland	Agricul-ture	Water	Unclassified (outside of city boundary)
	Percent land use within a 0.25-mile radius (0.5-mile diameter) around the sampling site									
PAH-CE-1	46.9	28.9	0	15.3	0	0	0	0	0	8.9
PAH-CE-2	66.3	13.6	0	0	19.3	0	.8	0	0	0
PAH-CE-3	71.2	26.3	2.5	0	0	0	0	0	0	0
PAH-CE-4	37.1	8.9	10	11.5	3.3	13.1	16.2	0	0	0
PAH-CE-5	7.9	3.7	1.4	68.8	10.9	.2	7.0	0	0	0
PAH-CE-6	59.4	30.7	5.6	1.0	0	0.9	2.4	0	0	0
PAH-CE-7	19.6	11.4	14.9	22.0	6.8	3.8	21.5	0	0	0
PAH-CE-8	60.5	10.3	7.2	3.1	.0	1.3	17.6	0	0	0
PAH-CE-9	33.2	24.9	1.9	6.6	12.5	6.9	14.1	0	0	0
PAH-CE-10	31.5	7.0	16.8	21.2	16.2	.7	6.6	0	0	0
PAH-CE-11	45.2	15.5	0	16.0	14.5	8.8	0	0	0	0
PAH-CE-12	59.9	0	0	21.6	16.9	0	1.6	0	0	0
PAH-CE-13	0	0	0	48.0	33.6	0	18.4	0	0	0
PAH-CE-14	48.4	26.2	.2	0	15.3	3.5	6.4	0	0	0
PAH-CE-15	39.5	2.8	11.1	21.4	19.2	0	6.0	0	0	0
PAH-CE-16	0	0.7	0	31.0	32.3	4.3	20.0	0	11.7	0
PAH-CE-17	27.8	16.0	0	9.3	14.1	0	1.3	0	0	31.5
PAH-CE-18	58.6	12.5	.6	25.5	0	1.0	1.8	0	0	0
PAH-CE-19	44.0	8.7	4.8	10.5	25.3	0	6.7	0	0	0
PAH-SS-01	47.4	15.2	.7	28.3	0	7.7	.7	0	0	0
PAH-SS-02	61.4	28.6	6.3	2.1	0	1.5	0.1	0	0	0
PAH-SS-03	77.1	14.7	3.6	1.6	0	3.0	0	0	0	0
PAH-SS-04	63.9	21.6	10.6	2.6	.8	0	.5	0	0	0
PAH-SS-05	62.7	25.5	4.9	4.5	0	1.9	.5	0	0	0
PAH-SS-06	94.4	2.5	3.1	0	0	0	0	0	0	0
PAH-SS-07	59.7	15.1	11.6	0	0	0	0.5	0	0	13.1
PAH-SS-08	80.7	9.7	5.9	0	0	0	0	0	0	3.7
PAH-SS-09	68.9	15.5	10.8	2.5	0	2.3	0	0	0	0
PAH-SS-10	54.7	14.5	3.3	6.5	21.0	0	0	0	0	0
PAH-SS-11	76.1	20.7	3.2	0	0	0	0	0	0	0

Table 5. Percentages of major land-use categories around soil-sampling sites, Chicago, Illinois—Continued

Sample number (location shown in figure 4)	Residential	Commercial and services	Institutional	Industrial, warehousing, and wholesale	Transportation, communication, and utilities	Open space	Vacant or wetland	Agricul-ture	Water	Unclassified (outside of city boundary)
PAH-SS-12	31.7	10.2	14.5	16.6	17.8	0.4	8.8	0	0	0
PAH-SS-13	52.5	41.2	5.1	0	0	.2	1.0	0	0	0
PAH-SS-14	84.6	14.2	0	0	0	0	1.2	0	0	0
PAH-SS-15	55.6	14.1	10.4	0	1.3	16.5	2.1	0	0	0
PAH-SS-16	58.4	2.9	2.8	0	10.0	13.6	12.3	0	0	0
PAH-SS-17	5.8	28.9	0	23.8	0	9.6	31.8	0	0	0
PAH-SS-18	15.9	31.7	0.8	11.1	20.0	0	20.5	0	0	0
PAH-SS-19	78.9	14.8	5.9	0	0	0	.4	0	0	0
PAH-SS-20	82.5	11.5	2.4	1.0	0	0	2.6	0	0	0
PAH-SS-21	28.2	11.4	28.8	8.3	17.1	0	2.8	0	3.4	0
PAH-SS-22	60.4	26.8	8.0	0	1.3	0	3.5	0	0	0
PAH-SS-23	66.6	31.1	1.8	0	0	0	.5	0	0	0
PAH-SS-24	78.2	17.7	3.5	0	0	0	.6	0	0	0
PAH-SS-25	60.7	24.0	4.5	1.4	0	2.4	7.0	0	0	0
PAH-SS-26	60.8	26.1	1.8	3.3	0	.7	7.3	0	0	0
PAH-SS-27	54.8	28.6	4.3	12.3	0	0	0	0	0	0
PAH-SS-28	78.4	5.3	2.5	.9	0	12.2	.7	0	0	0
PAH-SS-29	36.6	7.1	5.7	15.5	4.7	9.7	20.7	0	0	0
PAH-SS-30	42.5	14.6	10.8	12.2	11.0	5.1	3.8	0	0	0
PAH-SS-31	43.1	4.2	16.8	15.1	1.7	8.1	11.0	0	0	0
PAH-SS-32	43.2	12.8	7.9	11.9	21.9	0	2.3	0	0	0
PAH-SS-33	66.3	23.7	2.8	6.3	0	0	.9	0	0	0
PAH-SS-34	68.5	25.0	6.5	0	0	0	0	0	0	0
PAH-SS-35	66.6	25.0	6.0	0	0	1.1	1.3	0	0	0
PAH-SS-36	63.7	23.2	10.4	0	2.4	0	.3	0	0	0
PAH-SS-37	1.8	56.2	8.6	3.8	22.1	0.3	3.7	0	3.5	0
PAH-SS-38	66.4	18.9	4.1	0	3.6	7.0	0	0	0	0

Table 5. Percentages of major land-use categories around soil-sampling sites, Chicago, Illinois—Continued

Sample number (location shown in figure 4)	Residential	Commercial and services	Institutional	Industrial, warehousing, and wholesale	Transportation, communication, and utilities	Open space	Vacant or wetland	Agricul-ture	Water	Unclassified (outside of city boundary)
	Percent landuse within a 1/2-mile radius (1-mile diameter) around the sampling site									
PAH-CE-1	48.4	9.3	1.9	19.5	0	1.2	0	0	0	19.8
PAH-CE-2	71.5	10.0	4.5	0	9.6	3.9	.6	0	0	0
PAH-CE-3	79.5	15.9	4.3	0	.3	0	.1	0	0	0
PAH-CE-4	29.7	15.7	9.1	21.4	7.1	5.1	9.7	0	2.1	0
PAH-CE-5	25.6	10.7	5.3	39.2	5.0	3.6	10.7	0	0	0
PAH-CE-6	55.9	19.2	8.0	0.3	1.8	11.8	3.1	0	0	0
PAH-CE-7	23.7	10.5	14.5	16.7	16.2	8.3	10.1	0	0	0
PAH-CE-8	58.1	9.9	4.3	1.1	.9	8.4	17.5	0	0	0
PAH-CE-9	47.2	12.5	4.6	1.9	14.4	4.2	15.2	0	0	0
PAH-CE-10	45.2	6.3	20.9	12.8	7.9	2.3	4.6	0	0	0
PAH-CE-11	53.5	12.4	6.4	8.9	10.1	8.1	0.7	0	0	0
PAH-CE-12	57.9	3.8	4.1	18.7	13.2	1.0	1.2	0	0	0
PAH-CE-13	8.4	2.1	2.4	44.2	27.8	1.7	13.4	0	0	0
PAH-CE-14	48.9	14.0	1.6	9.0	20.1	2.1	4.4	0	0	0
PAH-CE-15	63.3	5.1	5.8	7.7	9.7	4.0	4.4	0	0	0
PAH-CE-16	20.7	2.8	0.7	26.5	17.7	2.7	17.3	0	11.6	0
PAH-CE-17	33.5	8.3	.7	2.9	9.2	1.1	1.6	0	0	42.7
PAH-CE-18	56.4	10.5	6.8	15.1	4.0	1.5	5.7	0	0	0
PAH-CE-19	44.0	8.5	2.6	13.9	19.2	2.6	9.2	0	0	0
PAH-SS-01	56.9	12.4	3.5	23.4	.9	2.7	.3	0	0	0
PAH-SS-02	65.2	20.7	5.2	2.8	0.2	4.8	1.1	0	0	0
PAH-SS-03	75.4	8.2	2.1	5.8	5.5	1.2	1.8	0	0	0
PAH-SS-04	72.9	13.6	3.5	9.5	.2	0	.4	0	0	0
PAH-SS-05	61.3	15.2	4.4	6.3	0	3.3	0.5	0	0	9.1
PAH-SS-06	83.7	4.5	10.7	0	0	1.1	0	0	0	0
PAH-SS-07	53.6	8.2	12.2	0	0	0	0.1	0	0	25.9
PAH-SS-08	77.7	12.3	4.8	0	4.3	0	0	0	0	1.0
PAH-SS-09	79.5	6.6	7.0	1.9	0	5.1	0	0	0	0
PAH-SS-10	71.0	12.2	2.2	2.5	9.0	3.1	0	0	0	0
PAH-SS-11	69.0	7.1	23.2	0	0	.7	0	0	0	0

Table 5. Percentages of major land-use categories around soil-sampling sites, Chicago, Illinois—Continued

Sample number (location shown in figure 4)	Residential	Commercial and services	Institutional	Industrial, warehousing, and wholesale	Transportation, communication, and utilities	Open space	Vacant or wetland	Agricul-ture	Water	Unclassified (outside of city boundary)
PAH-SS-12	65.9	4.7	5.6	7.7	10.0	1.3	4.9	0	0	0
PAH-SS-13	61.2	24.6	6.2	0	0	7.2	.9	0	0	0
PAH-SS-14	81.8	9.6	2.4	.4	1.7	1.1	2.6	0	.5	0
PAH-SS-15	30.6	3.5	10.1	0	17.2	26.8	6.3	0	5.6	0
PAH-SS-16	51.3	4.6	2.8	.5	23.2	6.2	11.4	0	0	0
PAH-SS-17	15.9	9.7	4.1	32.6	6.0	5.4	26.2	0	0	0
PAH-SS-18	34.9	14.3	3.4	14.5	14.3	1.3	12.3	0	5.0	0
PAH-SS-19	71.1	8.6	5.5	2.9	7.0	3.1	1.8	0	0	0
PAH-SS-20	65.1	11.1	2.0	.3	0	8.3	2.9	0	0	10.4
PAH-SS-21	45.3	8.2	28.1	4.9	9.1	.7	1.7	0	1.9	0
PAH-SS-22	66.0	13.1	3.5	4.2	4.2	1.5	7.6	0	0	0
PAH-SS-23	77.1	15.2	3.1	0	0	4.4	.2	0	0	0
PAH-SS-24	80.9	16.1	2.3	0	0	0	.7	0	0	0
PAH-SS-25	69.4	17.2	4.4	.8	.8	1.0	6.4	0	0	0
PAH-SS-26	55.4	12.8	2.2	15.5	2.4	7.3	4.4	0	0	0
PAH-SS-27	60.7	15.8	4.6	18.7	0	0.2	0	0	0	0
PAH-SS-28	60.4	5.7	2.1	19.5	5.8	4.8	1.8	0	0	0
PAH-SS-29	35.8	6.2	7.4	16.6	7.5	12.0	13.0	0	1.6	0
PAH-SS-30	45.6	11.2	7.7	11.3	7.6	2.5	14.1	0	0	0
PAH-SS-31	44.0	4.9	5.9	20.9	4.8	7.4	12.3	0	0	0
PAH-SS-32	44.2	5.8	6.2	24.4	16.6	1.5	1.4	0	0	0
PAH-SS-33	60.2	11.0	4.0	19.9	4.0	0	.8	0	0	0
PAH-SS-34	73.5	18.0	3.7	.3	0	4.3	.3	0	0	0
PAH-SS-35	68.6	15.5	8.5	3.3	.1	2.4	1.6	0	0	0
PAH-SS-36	58.7	22.7	4.4	.7	4.6	7.7	.7	0	0	.6
PAH-SS-37	1.9	56.3	6.9	5.9	17.9	2.9	2.4	0	5.9	0
PAH-SS-38	68.1	15.9	1.7	3.7	6.8	3.8	0	0	0	0
Percent landuse within a 1-mile radius (2-mile diameter) around the sampling site										
PAH-CE-1	32.0	3.8	1.8	8.5	0	17.1	0.1	0	0	36.9
PAH-CE-2	74.2	3.9	9.7	.5	4.2	2.5	.2	0	0	4.8

Table 5. Percentages of major land-use categories around soil-sampling sites, Chicago, Illinois—Continued

Sample number (location shown in figure 4)	Residential	Commercial and services	Institutional	Industrial, warehousing, and wholesale	Transportation, communication, and utilities	Open space	Vacant or wetland	Agricul-ture	Water	Unclassified (outside of city boundary)
PAH-CE-3	71.4	15.5	4.0	0.8	0.3	6.5	0.2	0	1.4	0
PAH-CE-4	25.1	19.1	6.5	19.6	10.1	5.3	7.7	0	3.0	3.6
PAH-CE-5	32.8	15.7	7.1	25.0	7.8	2.7	9.0	0	0	0
PAH-CE-6	49.4	12.7	8.6	8.8	3.8	10.3	5.8	0	.6	0
PAH-CE-7	23.6	13.5	10.1	11.3	20.2	7.5	9.5	0	.9	3.4
PAH-CE-8	42.9	11.1	5.8	1.5	4.9	10.5	12.5	0	0	10.9
PAH-CE-9	39.6	9.5	4.9	4.2	15.6	13.8	12.0	0	.5	0
PAH-CE-10	52.2	3.7	10.8	14.5	9.2	3.9	5.8	0	0	0
PAH-CE-11	53.9	8.5	4.1	8.3	9.6	12.8	2.8	0	0	0
PAH-CE-12	55.5	7.0	7.4	11.1	9.6	5.4	3.5	0	.6	0
PAH-CE-13	28.8	10.4	6.0	24.8	11.5	1.9	5.7	0	0	11.0
PAH-CE-14	39.1	7.3	1.0	6.4	30.5	3.3	6.1	0	0	6.3
PAH-CE-15	75.7	6.8	4.9	2.2	5.5	2.5	2.5	0	0	0
PAH-CE-16	33.7	6.0	1.3	17.9	13.4	6.3	15.0	0	5.8	.6
PAH-CE-17	30.3	3.5	1.4	4.3	4.5	5.9	1.5	0	.7	47.9
PAH-CE-18	58.4	10.0	3.8	12.4	6.2	3.2	6.0	0	0	0
PAH-CE-19	45.1	9.3	7.7	6.2	12.1	10.3	8.5	0	.9	0
PAH-SS-01	68.2	12.0	3.3	12.2	1.3	2.4	.6	0	0	0
PAH-SS-02	59.9	17.1	3.5	6.2	3.4	6.6	3.0	0	.4	0
PAH-SS-03	65.7	9.0	3.3	9.1	3.1	4.5	1.8	0	0	3.4
PAH-SS-04	72.7	13.0	3.7	7.4	0.5	2.6	0.3	0	0	0
PAH-SS-05	49.8	12.7	2.2	8.7	0	2.8	1.1	0	0	22.7
PAH-SS-06	67.0	5.0	13.7	0	0	1.8	.0	0	0	12.5
PAH-SS-07	46.5	5.1	20.3	.3	0	1.0	2.8	0	0	24.0
PAH-SS-08	56.4	10.3	2.8	0	4.7	17.4	.6	0	.1	7.8
PAH-SS-09	62.8	6.3	16.8	1.5	3.5	8.2	0.2	0	0	0.8
PAH-SS-10	69.4	10.2	2.8	5.5	5.0	6.9	.2	0	0	0
PAH-SS-11	65.0	5.0	14.1	.1	0	7.6	1.2	2.6	.1	4.4
PAH-SS-12	77.5	5.8	4.3	2.2	5.4	2.5	2.4	0	0	0
PAH-SS-13	64.7	11.3	5.3	10.3	2.6	2.5	3.2	0	.2	0

Table 5. Percentages of major land-use categories around soil-sampling sites, Chicago, Illinois—Continued

Sample number (location shown in figure 4)	Residential	Commercial and services	Institutional	Industrial, warehousing, and wholesale	Transportation, communication, and utilities	Open space	Vacant or wetland	Agriculture	Water	Unclassified (outside of city boundary)
PAH-SS-14	59.3	8.8	2.4	9.9	11.6	2.6	4.6	0	0.9	0
PAH-SS-15	14.7	1.5	3.5	13.5	39.5	13.2	6.6	0	7.5	0
PAH-SS-16	24.0	2.2	.8	18.8	19.5	5.3	17.6	0	11.9	0
PAH-SS-17	14.4	3.4	2.8	26.2	10.8	15.7	13.7	0	7.7	5.3
PAH-SS-18	40.3	7.1	2.7	14.9	13.9	3.2	13.8	0	4.0	0
PAH-SS-19	71.1	11.9	5.0	3.3	4.6	2.4	1.6	0	0	0
PAH-SS-20	53.4	7.2	2.4	.5	.6	9.1	1.5	0	25.3	0
PAH-SS-21	58.0	11.1	12.4	4.4	7.2	1.5	5.0	0	.5	0
PAH-SS-22	61.1	10.6	4.1	12.6	3.0	3.5	5.1	0	0	0
PAH-SS-23	77.1	9.7	2.4	1.1	2.5	4.7	2.4	0	0	0
PAH-SS-24	77.5	9.4	3.4	0	1.2	7.0	0.4	0	1.1	0
PAH-SS-25	61.6	10.6	4.6	4.6	1.4	8.3	8.9	0	0	0
PAH-SS-26	22.3	8.2	1.2	40.3	10.7	5.1	8.3	0	4.0	0
PAH-SS-27	40.1	9.4	1.7	34.1	12.4	1.0	1.4	0	0	0
PAH-SS-28	34.0	7.1	1.3	31.9	13.0	1.2	4.0	0	2.1	5.3
PAH-SS-29	35.6	11.8	6.9	14.2	10.1	9.2	11.5	0	0.6	0
PAH-SS-30	43.3	8.9	5.7	9.0	5.8	12.9	13.0	0	1.3	0
PAH-SS-31	43.2	8.0	4.6	15.1	7.4	11.7	9.3	0	.7	0
PAH-SS-32	35.8	10.6	3.0	22.6	7.4	7.2	3.0	0	.3	10.2
PAH-SS-33	55.0	8.8	3.6	20.0	6.2	1.8	4.5	0	0	0
PAH-SS-34	56.7	13.9	10.3	1.6	0.6	8.8	1.8	0	1.1	5.3
PAH-SS-35	56.3	10.2	16.4	2.9	.2	4.8	1.3	0	.2	7.7
PAH-SS-36	47.2	14.5	8.7	.7	2.8	8.8	.8	0	0	16.6
PAH-SS-37	11.0	36.0	5.6	7.5	15.8	8.5	7.5	0	4.0	4.1
PAH-SS-38	67.3	13.1	2.8	5.7	7.5	3.5	.1	0	0	0

Table 6. Number of soil-sampling sites near each major land-use category, Chicago, Illinois.

	Land-use category						
	Residential	Commercial and services	Institutional	Industrial, warehousing and wholesale	Transportation, communication, and utilities	Open space	Vacant or wetland
Code	1100	1200	1300	1400	1500	3000	4000
Number of samples in the category	9	26	3	5	5	2	6

Table 7. Shapiro-Wilk test statistic for normal distribution of natural-log-transformed polynuclear aromatic hydrocarbon data in ambient surface soils, Chicago, Illinois

[Alpha = 0.1. Null hypothesis (H_o) is that the distribution is lognormal.]

	Shapiro-Wilk test statistic					
	Excluding sample PAH-CE-19			Including sample PAH-CE-19		
Constituent (natural-log transformed)	Value	p-value	Conclusion	Value	p-value	Conclusion
Phenanthrene	0.968	0.14	Fail to reject H_o	0.971	0.19	Fail to reject H_o
Fluoranthene	.969	.16	Fail to reject H_o	.967	.13	Fail to reject H_o
Pyrene	.969	.16	Fail to reject H_o	.962	.07	Reject H_o
Benzo(a)anthracene	.973	.24	Fail to reject H_o	.971	.18	Fail to reject H_o
Chrysene	.977	.35	Fail to reject H_o	.971	.19	Fail to reject H_o
Benzo(b)fluoranthene	.976	.31	Fail to reject H_o	.965	.10	Reject H_o
Benzo(k)fluoranthene	.970	.17	Fail to reject H_o	.961	.08	Reject H_o
Benzo(a)pyrene	.977	.35	Fail to reject H_o	.966	.11	Fail to reject H_o
Dibenzo(a,h)anthracene	.981	.50	Fail to reject H_o	.937	.01	Reject H_o
Benzo(g,h,i)perylene	.974	.26	Fail to reject H_o	.931	.00	Reject H_o
Indeno(1,2,3-cd)pyrene	.978	.40	Fail to reject H_o	.939	.01	Reject H_o

Table 8. Statistical summary of log-transformed polynuclear aromatic hydrocarbon data for censored compounds in ambient surface soils, Chicago, Illinois

[Bold denotes retained estimates]

Constituent (natural-log transformed)	Number of samples	Number less than detection limit	Number of detection limits	Maximum detection limit (micro-grams per kilogram)	Mean (micro-grams per kilogram)	Standard deviation (micro-grams per kilogram)	Value of 25th percentile (micro-grams per kilogram)	Median (micro-grams per kilogram)	Value of 75th percentile (micro-grams per kilogram)
Estimates using log-probability regression of samples with concentrations greater than the detection limit									
All Samples									
Acenaphthene	57	7	5	3.05	4.24	1.86	2.41	4.44	5.63
Acenaphthylene	57	16	6	3.18	3.22	1.55	1.91	2.83	4.18
Anthracene	57	3	3	3.05	5.22	1.89	3.68	5.39	6.48
Fluorene	57	7	5	3.05	4.36	1.88	2.53	4.51	5.75
Naphthalene	57	22	7	3.18	3.56	1.44	2.42	3.00	4.54
Excluding Sample PAH-CE-19									
Acenaphthene	56	7	5	3.05	**4.14**	**1.65**	2.45	4.44	5.52
Acenaphthylene	56	16	6	3.18	**3.16**	**1.47**	1.90	2.80	4.10
Anthracene	56	3	3	3.05	**5.10**	**1.69**	3.66	5.32	6.44
Fluorene	56	7	5	3.05	**4.25**	**1.69**	2.53	4.43	5.72
Naphthalene	56	22	7	3.18	**3.51**	**1.30**	2.46	2.97	4.49
Estimates using adjusted lognormal maximum likelihood regression of samples with concentrations above the detection limit									
All Samples									
Acenaphthene	57	7	5	3.05	4.26	2.32	2.66	4.44	5.63
Acenaphthylene	57	16	6	3.18	3.22	1.76	2.00	2.83	4.18
Anthracene	57	3	3	3.05	5.24	2.15	3.68	5.39	6.48
Fluorene	57	7	5	3.05	4.38	2.27	2.79	4.51	5.75
Naphthalene	57	22	7	3.18	3.51	1.65	2.35	3.18	4.54
Excluding Sample PAH-CE-19									
Acenaphthene	56	7	5	3.05	4.15	2.17	**2.64**	**4.44**	**5.52**
Acenaphthylene	56	16	6	3.18	3.16	1.68	**1.99**	**2.79**	**4.10**
Anthracene	56	3	3	3.05	5.13	2.02	**3.66**	**5.32**	**6.44**
Fluorene	56	7	5	3.05	4.27	2.13	**2.78**	**4.43**	**5.72**
Naphthalene	56	22	7	3.18	3.44	1.54	**2.36**	**3.14**	**4.49**

Table 9. Test for outliers in polynuclear aromatic hydrocarbon concentrations in sample PAH-CE-19, Chicago, Illinois

[%, percent; unk, unknown]

Constituent	Lowest value (0%)	First quartile (Q1) (25%)	Median (50%)	Third quartile (Q3) (75%)	Interquartile range (IQR) (Q3-Q1)	Value in sample PAH-CE-19	Next highest value below PAH-CE-19	Standard deviation	1 Step (1.5 * IQR)	Number of steps between Q3 and the value in PAH-CE-19	Number of standard deviations between maximum value and the next highest value
Phenanthrene	22	230	1,200	3,700	3,470	520,000	19,000	68,633	5,205	99	7
Fluoranthene	52	495	2,100	7,100	6,605	1,100,000	35,000	145,200	9,907	110	7
Pyrene	51	350	1,700	5,000	4,650	720,000	30,000	95,044	6,975	103	7
Benzo(a)anthracene	26	210	880	2,700	2,490	370,000	16,000	48,825	3,735	98	7
Chrysene	31	245	910	2,900	2,655	350,000	15,000	46,176	3,982	87	7
Benzo(b)fluoranthene	40	350	1,100	3,700	3,350	550,000	18,000	72,593	5,025	109	7
Benzo(k)fluoranthene	36	230	820	2,200	1,970	280,000	10,000	36,932	2,955	94	7
Benzo(a)pyrene	39	270	1,000	3,200	2,930	460,000	17,000	60,710	4,395	104	7
Dibenzo(a,h)anthracene	8	70	140	290	220	41,000	1,600	5,404	330	123	7
Benzo(g,h,i)perylene	24	190	490	1,200	1,010	290,000	8,100	38,298	1,515	191	7
Indeno(1,2,3-cd)pyrene	31	220	610	1,500	1,280	370,000	9,900	48,861	1,920	192	7
Naphthalene	unk	8	26	94	86	2,500	700	350	128	19	5
Acenaphthene	unk	16	85	279	263	43,000	1,500	5,678	393	109	7
Anthracene	unk	40	220	655	616	120,000	4,600	15,848	923	129	7
Fluorene	unk	18	91	315	297	36,000	2,000	4,753	445	80	7

Table 10. Statistical summary of natural-log transformed polynuclear aromatic hydrocarbon concentrations in ambient surface soils, Chicago, Illinois

[na, not applicable.]

Constituent (natural-log transformed)	Number of samples collected[1]	Censored data	Mean concentration (micrograms per kilogram)	Standard deviation (micrograms per kilogram)	Median (micrograms per kilogram)	95th percentile of the distribution (micrograms per kilogram)	Upper 95-percent confidence limit on the mean (micrograms per kilogram)	Lower 95-percent confidence limit on the mean (micrograms per kilogram)
Acenaphthene	56	yes	4.14	1.65	4.44	7.00	na	na
Acenaphthylene	56	yes	3.16	1.47	2.79	6.09	na	na
Anthracene	56	yes	5.10	1.69	5.32	7.84	na	na
Benzo(a)anthracene	56	no	6.58	1.65	6.75	9.12	7.03	6.14
Benzo(b)fluoranthene	56	no	6.90	1.56	6.96	9.32	7.32	6.49
Benzo(k)fluoranthene	56	no	6.52	1.51	6.64	8.97	6.92	6.11
Benzo(g,h,i)perylene	56	no	6.19	1.34	6.13	8.75	6.55	5.83
Benzo(a)pyrene	56	no	6.78	1.56	6.88	9.24	7.19	6.36
Chrysene	56	no	6.65	1.59	6.78	9.08	7.08	6.23
Dibenzo(a,h)anthracene	56	no	5.03	1.16	4.94	7.00	5.34	4.72
Fluoranthene	56	no	7.49	1.67	7.63	9.90	7.93	7.04
Fluorene	56	yes	4.25	1.69	4.43	7.24	na	na
Indeno(1,2,3-cd)pyrene	56	no	6.41	1.37	6.39	8.87	6.77	6.04
Naphthalene	56	yes	3.51	1.30	3.14	6.02	na	na
Phenanthrene	56	no	6.75	1.76	7.00	9.39	7.22	6.28
Pyrene	56	no	7.14	1.61	7.41	9.39	7.57	6.71

[1] Excludes data from sample PAH-CE-19

Table 11. Results of Wilcoxon-Rank-Sum test comparing polynuclear aromatic hydrocarbon concentrations in surface soils collected at city properties and Commonwealth Edison properties, Chicago, Illinois

[Value of detection limit used to compute rank for censored data. Data from site PAH-CE-19 excluded from analysis. Alpha = 0.05. Null hypothesis (H_o) is that city and Commonwealth Edison properties have the same mean value.]

Constituent	Rank sum normal statistic with correction	p-value	Conclusion
Uncensored Data			
Phenanthrene	1.26	0.207	Fail to reject H_o
Fluoranthene	1.09	.277	Fail to reject H_o
Pyrene	1.00	.317	Fail to reject H_o
Benzo(a)anthracene	.98	.326	Fail to reject H_o
Chrysene	1.16	.247	Fail to reject H_o
Benzo(b)fluoranthene	.75	.456	Fail to reject H_o
Benzo(k)fluoranthene	.54	.593	Fail to reject H_o
Benzo(a)pyrene	.90	.366	Fail to reject H_o
Dibenzo(a,h)anthracene	1.85	.064	Fail to reject H_o
Benzo(g,h,i)perylene	1.40	.160	Fail to reject H_o
Indeno(1,2,3-cd)pyrene	1.16	.247	Fail to reject H_o
Censored Data			
Naphthalene	1.82	0.069	Fail to reject H_o
Acenaphthylene	-.46	.648	Fail to reject H_o
Acenaphthene	-.48	.629	Fail to reject H_o
Fluorene	-.64	.522	Fail to reject H_o
Anthracene	-.97	.335	Fail to reject H_o

Table 12. Pearson product-moment correlation coefficients for natural-log transformed concentrations of polynuclear aromatic hydrocarbons and total organic carbon in ambient surface soils, Chicago, Illinois

[Italic denotes constituents with censored data. --, not applicable]

Constituent	***Acenaphthene***	***Acenaphthylene***	***Anthracene***	**Benzo(a)anthracene**	**Benzo(b)fluoranthene**	**Benzo(k)fluoranthene**	**Benzo(g,h,i)perylene**	**Benzo(a)pyrene**	**Chrysene**	**Dibenzo(a,h)anthracene**	**Fluoranthene**	***Fluorene***	**Indeno(1,2,3-cd)pyrene**	***Naphthalene***	**Phenanthrene**	**Pyrene**	**Total organic carbon**
Acenaphthene	--	0.79	0.97	0.93	0.92	0.92	0.86	0.92	0.92	0.81	0.94	0.98	0.88	0.73	0.95	0.94	0.48
Acenaphthylene	--	--	.83	.87	.87	.87	.84	.87	.86	.75	.85	.83	.86	.78	.83	.87	.49
Anthracene	--	--	--	.98	.97	.96	.92	.97	.98	.87	.98	.98	.94	.76	.99	.97	.52
Benzo(a)anthracene	--	--	--	--	.99	.99	.95	1.00	1.00	.89	1.00	.95	.97	.74	.99	.99	.55
Benzo(b)fluoranthene	--	--	--	--	--	.99	.95	1.00	.99	.89	.99	.94	.97	.74	.98	.98	.56
Benzo(k)fluoranthene	--	--	--	--	--	--	.94	.99	.98	.88	.98	.94	.96	.75	.97	.97	.57
Benzo(g,h,i)perylene	--	--	--	--	--	--	--	.96	.96	.95	.95	.88	.99	.72	.94	.95	.57
Benzo(a)pyrene	--	--	--	--	--	--	--	--	1.00	.90	.99	.94	.98	.74	.98	.99	.57
Chrysene	--	--	--	--	--	--	--	--	--	.90	.99	.94	.98	.73	.98	.99	.56
Dibenzo(a,h)anthracene	--	--	--	--	--	--	--	--	--	--	.88	.82	.95	.70	.89	.88	.57
Fluoranthene	--	--	--	--	--	--	--	--	--	--	--	.95	.96	.72	.99	.99	.55
Fluorene	--	--	--	--	--	--	--	--	--	--	--	--	.90	.77	.96	.95	.48
Indeno(1,2,3-cd)pyrene	--	--	--	--	--	--	--	--	--	--	--	--	--	.73	.96	.96	.57
Naphthalene	--	--	--	--	--	--	--	--	--	--	--	--	--	--	.75	.75	.40
Phenanthrene	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	.99	.53
Pyrene	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	.54

Table 13. Physical properties of select polynuclear aromatic hydrocarbons

[°C, degrees Celsius]

Constituent	Molecular weight (grams per mole)	Solubility in water at 25°C (micrograms per liter)	Octonal-water partition coefficient (dimensionless)	Organic carbon partition coefficient (milliliters water per gram carbon)	Henry's Law Constant (cubic meters atmosphere per mole)
Acenaphthene	154	3,930.	9,600	4,600	1.40E-04
Acenaphthylene	154	3,420.	5,300	2,500	1.45E-03
Anthracene	178	59.	14,000	28,000	5.87E-05
Benzo(a)anthracene	228	11.	410,000	200,000	3.01E-06
Benzo(b)fluoranthene	252	2.4	1,100,000	550,000	1.22E-05
Benzo(k)fluoranthene	252	2.4	1,150,000	550,000	7.48E-07
Benzo(g,h,i)perylene	276	.3	3,200,000	1,600,000	1.44E-07
Benzo(a)pyrene	252	3.8	1,550,000	5,500,000	1.28E-09
Chrysene	228	1.9	410,000	200,000	8.45E-05
Dibenzo(a,h)anthracene	278	.4	6,900,000	3,300,000	1.33E-08
Fluoranthene	202	260.	79,000	38,000	1.45E-05
Fluorene	166	800.	15,000	7,300	5.74E-05
Indeno(1,2,3-cd)pyrene	276	.5	3,200,000	1,600,000	6.95E-08
Naphthalene	128	12,500.	2,344	1,290	1.08E-03
Phenanthrene	178	435.	28,000	14,000	1.45E-04
Pyrene	202	133.	80,000	38,000	9.92E-06

Table 14. Summary of average polynuclear aromatic hydrocarbon concentrations in air samples, Chicago, Illinois
[bdl, below detection limit]

Constituent	Chicago-Washington School [1] (micrograms per cubic meter)	Coke ovens [2] (micrograms per cubic meter)	Warm diesel engines[2] (microgram per cubic meter)	Highway tunnel[2] (micrograms per cubic meter)	Gasoline engines[2] (micrograms per cubic meter)	Wood combustion[2] (micrograms per cubic meter)
Acenaphthene	12.8	0.023	0.566	0.168	0.0377	0.0515
Acenaphthylene	3.6	.747	.464	.445	.0708	1.83
Anthracene	1.5	.158	.251	.177	.0446	.0959
Benzo(a)anthracene	1.	.0076	.249	.09	.0059	.0187
Benzo(b)fluoranthene	.6	.0048	.137	.044	.033	.0234
Benzo(k)fluoranthene	bdl	.008	.098	.041	.0255	.0446
Benzo(g,h,i)perylene	bdl	.0007	.108	.017	.0092	bdl
Benzo(a)pyrene	.1	.0053	.302	.063	.027	.203
Chrysene	1.2	.0147	.143	.078	.0283	.0328
Dibenzo(a,h)anthracene	bdl	bdl	.170	.015	bdl	bdl
Fluoranthene	8.6	.0883	.081	.117	.0446	.0959
Fluorene	14.7	.502	.651	.406	.123	.128
Indeno(1,2,3-cd)pyrene	bdl	.0011	.250	.02	bdl	bdl
Naphthalene	202.9	22.4	.386	8.03	2.46	.402
Phenanthrene	46.8	.5	.472	.3	.0398	.219
Pyrene	4.9	.0563	.049	.193	.0719	.100

[1] From Illinois Environmental Protection Agency, 2002

[2] From Khalili and others, 1995

Table 15. Results of one-way analysis of variance of polynuclear aromatic hydrocarbon concentrations and distance from nearest roadway, Chicago, Illinois
[Alpha = 0.05. Null hypothesis (H_o) is that all means are equal.]

Constituent (natural-log transformed)	F value	Probability of (F)[1]	Conclusion
Benzo(a)anthracene	0.31	0.93	Fail to reject H_o
Benzo(a)pyrene	.29	.94	Fail to reject H_o
Benzo(b)fluoranthene	.36	.90	Fail to reject H_o
Benzo(g,h,i)perylene	.34	.91	Fail to reject H_o
Benzo(k)fluoranthene	.32	.93	Fail to reject H_o
Chrysene	.42	.86	Fail to reject H_o
Dibenzo(a,h)anthracene	.39	.88	Fail to reject H_o
Fluoranthene	.31	.93	Fail to reject H_o
Indeno(1,2,3-cd)pyrene	.56	.76	Fail to reject H_o
Phenanthrene	.26	.95	Fail to reject H_o
Pyrene	.43	.86	Fail to reject H_o

[1] Probability of observing an F value this large by chance alone. Probabilities less than 0.05 are considered statistically significant.

Table 16. Statistical description of polynuclear aromatic hydrocarbons in ambient soils for different land-use categories, Chicago, Illinois

[Bold denotes rejection of the assumption of normal distribution for the constituent. %, percent]

Constituent (natural-log transformed)	Mean	Standard deviation	Lowest value (0%)	First quartile (25%)	Median (50%)	Third quartile (75%)	Highest value (100%)	Shapiro-Wilk test (p-value)
Vacant or Wetland (6 cases)								
Phenanthrene	6.34	2.37	3.40	4.03	6.46	8.65	9.02	0.47
Fluoranthene	7.22	2.43	4.16	5.08	7.38	9.31	10.02	.45
Pyrene	6.74	2.20	4.09	4.61	6.87	8.67	9.31	.41
Benzo(a)anthracene	6.34	2.39	3.33	4.08	6.49	8.50	9.13	.53
Chrysene	6.45	2.28	3.58	4.37	6.53	8.61	9.08	.51
Benzo(b)fluoranthene	6.83	2.30	3.91	4.57	7.17	8.82	9.32	.35
Benzo(k)fluoranthene	6.49	2.23	3.78	4.06	6.96	8.19	8.97	.28
Benzo(a)pyrene	6.72	2.30	3.81	4.39	7.11	8.63	9.24	.36
Dibenzo(a,h)anthracene	4.95	1.58	2.30	4.23	5.08	6.25	6.72	.74
Benzo(g,h,i)perylene	6.23	2.11	3.18	4.79	6.22	8.22	8.75	.88
Indeno(1,2,3-cd)pyrene	6.38	2.09	3.43	4.87	6.40	8.32	8.87	.83
Transportation, Communication, and Utilities (5 cases)								
Phenanthrene	5.69	2.33	3.09	4.87	5.08	6.02	9.39	0.54
Fluoranthene	6.42	2.04	4.30	5.44	6.02	6.59	9.74	.46
Pyrene	6.09	2.05	3.93	5.01	5.86	6.25	9.39	.52
Benzo(a)anthracene	5.62	1.99	3.40	4.70	5.35	5.89	8.76	.66
Chrysene	5.66	1.95	3.56	4.79	5.30	5.89	8.79	.56
Benzo(b)fluoranthene	5.94	1.79	3.91	5.01	5.77	6.29	8.70	.78
Benzo(k)fluoranthene	5.71	1.98	3.58	4.55	5.30	6.36	8.75	.77
Benzo(a)pyrene	5.84	1.91	3.71	4.87	5.52	6.31	8.79	.78
Dibenzo(a,h)anthracene	4.30	1.80	2.08	3.30	4.22	5.08	6.85	.99
Benzo(g,h,i)perylene	5.38	1.88	3.18	4.60	4.87	6.06	8.19	.84
Indeno(1,2,3-cd)pyrene	5.58	1.85	3.50	4.87	4.94	6.15	8.43	.66
Commercial (26 cases)								
Phenanthrene	6.54	1.60	3.30	5.44	6.76	7.65	9.85	0.67
Fluoranthene	7.29	1.56	3.95	6.36	7.55	8.27	10.46	.76
Pyrene	6.99	1.49	4.48	6.06	7.27	7.86	10.31	.40
Benzo(a)anthracene	6.39	1.55	3.26	5.39	6.59	7.31	9.68	.89
Chrysene	6.47	1.46	3.43	5.52	6.71	7.31	9.62	.91
Benzo(b)fluoranthene	6.70	1.47	3.69	5.83	6.85	7.65	9.80	.95
Benzo(k)fluoranthene	6.29	1.40	3.58	5.39	6.53	7.17	9.21	.80
Benzo(a)pyrene	6.57	1.44	3.66	5.58	6.80	7.38	9.74	.90
Dibenzo(a,h)anthracene	4.94	.98	3.64	4.22	4.74	5.39	7.38	**.01**
Benzo(g,h,i)perylene	6.07	1.10	4.61	5.30	6.02	6.36	9.00	.09
Indeno(1,2,3-cd)pyrene	6.26	1.16	4.59	5.42	6.29	6.77	9.20	.36

Table 16. Statistical description of polynuclear aromatic hydrocarbons in ambient soils for different land-use categories, Chicago, Illinois—Continued

[Bold denotes rejection of the assumption of normal distribution for the constituent. %, percent]

Constituent (natural-log transformed)	Mean	Standard deviation	Lowest value (0%)	First quartile (25%)	Median (50%)	Third quartile (75%)	Highest value (100%)	Shapiro-Wilk test (p-value)
Industrial, Warehousing, and Wholesale (5 cases)								
Phenanthrene	7.15	1.28	5.19	6.55	7.65	8.10	8.27	0.34
Fluoranthene	7.91	1.14	6.13	7.44	8.40	8.70	8.87	.28
Pyrene	7.55	1.14	6.06	6.72	7.74	8.56	8.68	.48
Benzo(a)anthracene	7.00	1.17	5.35	6.40	7.09	8.07	8.10	.49
Chrysene	7.04	1.10	5.39	6.58	7.17	7.97	8.07	.52
Benzo(b)fluoranthene	7.37	1.01	5.86	6.91	7.63	8.13	8.34	.57
Benzo(k)fluoranthene	6.95	1.13	5.44	6.11	7.33	7.90	7.97	.31
Benzo(a)pyrene	7.18	1.08	5.60	6.63	7.41	8.07	8.19	.51
Dibenzo(a,h)anthracene	5.07	1.01	3.30	5.25	5.39	5.56	5.83	**.03**
Benzo(g,h,i)perylene	6.35	1.02	4.70	6.02	6.84	7.09	7.09	.12
Indeno(1,2,3-cd)pyrene	6.59	0.98	5.08	6.15	7.04	7.31	7.38	.21
Residential (9 cases)								
Phenanthrene	7.33	1.77	4.87	5.48	7.60	8.67	9.68	0.40
Fluoranthene	8.03	1.61	5.70	6.48	8.37	9.39	9.90	.33
Pyrene	7.65	1.63	5.52	5.86	8.24	8.73	9.74	.22
Benzo(a)anthracene	7.10	1.64	4.94	5.35	7.44	8.54	9.12	.24
Chrysene	7.14	1.64	5.08	5.39	7.44	8.67	9.31	.27
Benzo(b)fluoranthene	7.38	1.61	5.25	5.91	7.55	8.88	9.55	.47
Benzo(k)fluoranthene	6.91	1.52	4.61	5.67	7.17	8.29	9.11	.82
Benzo(a)pyrene	7.24	1.60	5.08	5.67	7.50	8.73	9.39	.45
Dibenzo(a,h)anthracene	5.28	1.21	3.33	4.44	5.30	6.23	7.00	.82
Benzo(g,h,i)perylene	6.52	1.51	4.79	5.14	6.59	7.60	8.84	.41
Indeno(1,2,3-cd)pyrene	6.81	1.54	4.87	5.39	6.82	8.37	9.00	.37

Table 17. Results of analysis of variance of uncensored polynuclear aromatic hydrocarbon concentrations in ambient soil by land use, Chicago, Illinois

[Alpha = 0.05. Null hypothesis (H_o) is that mean concentrations are not significantly different among land-use categories.]

Constituent (natural-log transformed)	F value	Probability[1]	Conclusion
Benzo(a)anthracene	0.92	0.49	Fail to reject H_o
Benzo(a)pyrene	.94	.48	Fail to reject H_o
Benzo(b)fluoranthene	.93	.48	Fail to reject H_o
Benzo(g,h,i)perylene	.66	.68	Fail to reject H_o
Benzo(k)fluoranthene	.81	.57	Fail to reject H_o
Chrysene	.92	.49	Fail to reject H_o
Dibenzo(a,h)anthracene	.85	.54	Fail to reject H_o
Fluoranthene	1.01	.43	Fail to reject H_o
Indeno(1,2,3-cd)pyrene	.69	.66	Fail to reject H_o
Phenanthrene	1.01	.43	Fail to reject H_o
Pyrene	1.12	.37	Fail to reject H_o

[1] Probability of observing an F value this large by chance alone. Probabilities less than 0.05 are considered statistically significant.

Table 18. Regression of polynuclear aromatic hydrocarbon concentrations in surface soils and percent industrial land use within a 1-mile radius of the sample, Chicago, Illinois.

Constituent (natural-log transformed)	T-ratio of slope coefficient	p-value	Correlation coefficient
Phenanthrene	2.01	0.049	0.070
Fluoranthene	2.27	.027	.087
Pyrene	2.33	.023	.092
Benzo(a)anthracene	2.41	.019	.097
Chrysene	2.32	.024	.091
Benzo(b)fluoranthene	2.34	.023	.092
Benzo(k)fluoranthene	2.38	.021	.095
Benzo(a)pyrene	2.43	.019	.098
Dibenzo(a,h)anthracene	2.11	.040	.076
Benzo(g,h,i)perylene	2.22	.030	.084
Indeno(1,2,3-cd)pyrene	2.24	.030	.085

Table 19. Summary of data on inorganic constituents in ambient surface soils, Chicago, Illinois

[<, less than; nc, not calculated]

Constituent	Number of samples collected	Number of detections	Percentage of samples with analyte detected	Arithmetic mean	Standard deviation	Range of detected concentrations
Aluminum (weight percent)	57	57	100	4.8	1.7	0.775-7.45
Arsenic (milligrams per kilogram)	57	47	82	19.5	31.8	<10-220
Barium (milligrams per kilogram)	57	57	100	427.2	126.	100-697
Beryllium (milligrams per kilogram)	57	49	86	nc	nc	<1-14
Bismuth (milligrams per kilogram)	57	1	2	nc	nc	<50-57
Cadmium (milligrams per kilogram)	57	18	32	nc	nc	<2-7
Calcium (weight percent)	57	57	100	4.1	3.4	0.61-16.4
Cerium (milligrams per kilogram)	57	55	96	47.4	21.8	6-104
Chromium (milligrams per kilogram)	57	57	100	71.2	49.6	8-363
Cobalt (milligrams per kilogram)	57	57	100	11.1	3.7	4-26
Copper (milligrams per kilogram)	57	57	100	150.5	373.7	9-2,780
Europium (milligrams per kilogram)	57	1	2	nc	nc	<2-3
Gallium (milligrams per kilogram)	57	54	95	13.9	4.3	5-23
Gold (milligrams per kilogram)	57	0	0	nc	nc	<8
Holmium (milligrams per kilogram)	57	0	0	nc	nc	<4
Iron (weight percent)	57	57	100	3.3	2.1	0.56-14.5
Lanthanum (milligrams per kilogram)	57	57	100	25.7	9.3	6.5-52
Lead (milligrams per kilogram)	57	57	100	395.	494.2	13-1,910
Lithium (milligrams per kilogram)	57	57	100	31.3	14.3	5-67
Magnesium (weight percent)	57	57	100	2.5	2.2	0.504-11.3
Manganese (milligrams per kilogram)	57	57	100	583.4	511.	158-3,670
Mercury (milligrams per kilogram)	57	56	98	.6	1.9	<0.02-13.1
Molybdenum (milligrams per kilogram)	57	52	91	5.7	3.7	<2-17
Neodymium (milligrams per kilogram)	57	51	89	24.8	7.7	<9-49
Nickel (milligrams per kilogram)	57	57	100	36.4	23.5	5-154
Niobium (milligrams per kilogram)	57	56	98	9.7	3.3	<4-23
Phosphorus (weight percent)	57	57	100	.1	.1	0.01-.28
Potassium (weight percent)	57	57	100	1.8	.6	0.33-2.86
Scandium (milligrams per kilogram)	57	55	96	8.6	3.3	3-18
Selenium (milligrams per kilogram)	57	55	96	1.	.6	<0.2-3.1
Silver (milligrams per kilogram)	57	0	0	nc	nc	<2
Sodium (weight percent)	57	57	100	0.5	0.2	0.0825-8.05
Strontium (milligrams per kilogram)	57	57	100	113.6	31.5	66-299
Sulfur (weight percent)	57	57	100	.1	.1	0.05-0.63
Tantalum (milligrams per kilogram)	57	0	0	nc	nc	<40
Thorium (milligrams per kilogram)	57	44	77	9.	1.7	6-13
Tin (milligrams per kilogram)	57	4	7	nc	nc	<50-248
Titanium (weight percent)	57	57	100	.2	.1	0.045-3.83
Uranium (milligrams per kilogram)	57	0	0	nc	nc	<100
Vanadium (milligrams per kilogram)	57	57	100	76.5	26.9	24-145
Ytterbium (milligrams per kilogram)	57	48	84	nc	nc	<1-3
Yttrium (milligrams per kilogram)	57	57	100	15.8	5.2	6-38
Zinc (milligrams per kilogram)	57	57	100	396.6	410.8	79-1,690
Carbonate carbon (weight percent)	57	57	100	1.9	2.3	0.04-11.15
Organic carbon (weight percent)	57	57	100	5.7	3.9	0.22-22.31

Table 20. Comparison of arithmetic mean concentrations of select inorganic constituents in ambient surface soils, Chicago, Illinois with mean concentrations from surrounding agricultural soils

[Bold denotes analytes concentrated by a factor of two or more; mg/Kg, milligrams per kilogram]

Constituent	Arithmetic mean concentration in 57 Chicago soil samples	Arithmetic mean concentration in 106 soil samples collected within 500 kilometers of Chicago	Concentration factor in Chicago soils relative to soils within 500 kilometers of Chicago
Aluminum (weight percent)	4.8	4.86	0.99
Arsenic (mg/Kg)	**19.5**	**6.56**	**2.97**
Barium (mg/Kg)	427.3	499.3	.86
Beryllium (mg/Kg)	2.2	1.2	1.83
Calcium (weight percent)	**4.06**	**.82**	**4.95**
Total Carbon (weight percent)	**7.61**	**2.55**	**2.98**
Chromium (mg/Kg)	71.2	44.1	1.61
Cobalt (mg/Kg)	11.	8.51	1.29
Copper (mg/Kg)	**150.5**	**18.4**	**8.18**
Gallium (mg/Kg)	13.9	12.8	1.09
Iron (weight percent)	3.3	1.85	1.78
Lanthanum (mg/Kg)	25.7	36.2	.71
Lead (mg/Kg)	**395.3**	**19.4**	**20.38**
Lithium (mg/Kg)	31.3	19.74	1.59
Magnesium (weight percent)	**2.47**	**.4**	**6.18**
Manganese (mg/Kg)	583.4	460.4	1.27
Mercury (mg/Kg)	**.64**	**.14**	**4.57**
Molybdenum (mg/Kg)	**5.74**	**2.46**	**2.33**
Nickel (mg/Kg)	**36.44**	**15.95**	**2.28**
Phosphorus (weight percent)	**.086**	**.043**	**2.00**
Potassium (weight percent)	1.75	1.56	1.12
Scandium (mg/Kg)	8.6	8.2	1.05
Selenium (mg/Kg)	**1.**	**.46**	**2.17**
Sodium (weight percent)	.52	.73	.71
Strontium (mg/Kg)	113.6	122.1	.93
Thorium (mg/Kg)	9.	8.2	1.10
Titanium (weight percent)	.22	.27	.81
Vanadium (mg/Kg)	76.5	61.1	1.25
Yttrium (mg/Kg)	15.8	20.8	.76
Zinc (mg/Kg)	**396.68**	**53.57**	**7.40**

Table 21. Pearson product-moment correlation coefficients for selected inorganic constituents in ambient surface soils, Chicago, Illinois

[Positive coefficients greater than 0.70 in bold]

	ALUMINUM	ARSENIC	BARIUM	CALCIUM	CARBONATE CARBON	ORGANIC CARBON	CERIUM	CHROMIUM	COBALT	COPPER	GALLIUM	IRON	LANTHANUM	LEAD	LITHIUM	MAGNESIUM
ALUMINUM	1.00															
ARSENIC	-.13	1.00														
BARIUM	**.71**	.13	1.00													
CALCIUM	-.73	.07	-.71	1.00												
CARBONATE CARBON	-.75	.07	-.73	**.99**	1.00											
ORGANIC CARBON	.02	.19	.13	-.17	-.26	1.00										
CERIUM	**.94**	-.17	.69	-.62	-.62	-.14	1.00									
CHROMIUM	.25	.16	.33	-.15	-.24	.29	.27	1.00								
COBALT	**.75**	.14	.66	-.44	-.50	.39	**.72**	.34	1.00							
COPPER	-.07	.17	.12	.08	.05	.21	-.05	.13	.11	1.00						
GALLIUM	**.92**	-.07	**.72**	-.62	-.65	.08	**.89**	.30	**.79**	.02	1.00					
IRON	.29	.22	.39	-.28	-.35	.68	.20	.57	.62	.21	.37	1.00				
LANTHANUM	**.96**	-.14	**.71**	-.64	-.65	-.05	**.98**	.30	**.76**	-.08	**.90**	.25	1.00			
LEAD	-.22	.46	.33	.12	.07	.42	-.19	.29	.25	.51	-.01	.48	-.18	1.00		
LITHIUM	**.93**	-.13	.62	-.52	-.55	.03	**.91**	.30	**.80**	-.03	**.91**	.30	**.92**	-.13	1.00	
MAGNESIUM	-.70	.05	-.71	**.98**	**1.00**	-.28	-.57	-.23	-.47	.07	-.59	-.35	-.60	.06	-.49	1.00
MANGANESE	.17	-.04	.18	-.11	-.19	.21	.21	**.93**	.20	.05	.17	.53	.23	.11	.18	-.19
MERCURY	.00	.13	.14	.14	.14	.03	.02	.10	.20	.10	.06	.06	.05	.29	.10	.14
MOLYBDENUM	.21	.31	.34	-.11	-.22	.66	.10	**.75**	.57	.34	.26	**.79**	.19	.51	.27	-.22
NICKEL	.27	.18	.44	-.12	-.19	.39	.28	.47	.53	**.78**	.39	.55	.29	.61	.37	-.16
PHOSPHOROUS	.41	.08	.55	-.30	-.35	.30	.51	.47	.61	.26	.57	.53	.50	.44	.49	-.32
POTASSIUM	**.88**	-.22	.55	-.68	-.67	-.27	**.83**	.11	.47	-.13	**.80**	.01	**.80**	-.39	**.81**	-.61
SCANDIUM	**.96**	-.08	.67	-.61	-.64	.15	**.91**	.29	**.86**	-.01	**.91**	.39	**.94**	-.10	**.95**	-.59
SELENIUM	.29	.24	.48	-.26	-.31	.57	.32	.41	.66	.24	.48	.65	.32	.60	.36	-.30
SODIUM	.49	-.02	.58	-.74	-.74	-.04	.45	.04	.21	-.06	.44	.14	.44	-.09	.25	-.73
SULFUR	-.06	.22	.11	-.04	-.13	**.90**	-.25	.26	.36	.17	-.03	.68	-.15	.46	-.06	-.16
STRONTIUM	.29	.17	.46	-.21	-.29	.39	.32	.33	.58	.11	.36	.42	.36	.40	.35	-.31
THORIUM	.22	.12	.28	-.39	-.35	-.12	.17	-.17	.13	-.23	.06	-.15	.22	-.17	.14	-.38
TITANIUM	**.95**	-.10	**.71**	-.68	-.70	.14	**.89**	.30	**.78**	.00	**.87**	.40	**.94**	-.12	**.87**	-.66
VANADIUM	**.89**	-.02	.66	-.56	-.61	.27	**.83**	.55	**.86**	.01	**.85**	.60	**.88**	.01	**.88**	-.57
YTTRIUM	**.83**	.01	.66	-.48	-.54	.30	**.81**	.35	**.91**	.05	**.81**	.53	**.87**	.07	**.84**	-.50
ZINC	-.19	.46	.32	.16	.09	.52	-.18	.30	.32	.54	.00	.49	-.14	**.91**	-.08	.08

Table 21. Pearson product-moment correlation coefficients for selected inorganic constituents in ambient surface soils, Chicago, Illinois–Continued

[Positive coefficients greater than 0.70 in bold]

	MANGANESE	MERCURY	MOLYBDENUM	NICKEL	PHOSPHOROUS	POTASSIUM	SCANDIUM	SELENIUM	SODIUM	SULFUR	STRONTIUM	THORIUM	TITANIUM	VANADIUM	YTTRIUM	ZINC
ALUMINUM																
ARSENIC																
BARIUM																
CALCIUM																
CARBONATE CARBON																
ORGANIC CARBON																
CERIUM																
CHROMIUM																
COBALT																
COPPER																
GALLIUM																
IRON																
LANTHANUM																
LEAD																
LITHIUM																
MAGNESIUM																
MANGANESE	1.00															
MERCURY	-.03	1.00														
MOLYBDENUM	.62	.12	1.00													
NICKEL	.31	.16	.65	1.00												
PHOSPHOROUS	.37	.28	.42	.60	1.00											
POTASSIUM	.07	-.06	-.06	.07	.20	1.00										
SCANDIUM	.17	.08	.34	.39	.49	**.78**	1.00									
SELENIUM	.28	.20	.57	.56	.70	.02	.40	1.00								
SODIUM	.08	-.15	-.09	-.03	.22	.49	.32	.12	1.00							
SULFUR	.17	.04	**.74**	.33	.13	-.34	.08	.46	-.14	1.00						
STRONTIUM	.22	.23	.48	.43	.59	-.02	.41	.56	.22	.35	1.00					
THORIUM	-.20	.05	-.10	-.14	-.10	.19	.16	-.09	.24	-.12	.19	1.00				
TITANIUM	.20	.01	.30	.36	.43	**.74**	**.94**	.33	.42	.06	.33	.15	1.00			
VANADIUM	.45	.08	.55	.47	.56	.64	**.93**	.49	.26	.22	.43	.10	**.90**	1.00		
YTTRIUM	.24	.16	.47	.47	.60	.51	**.92**	.52	.27	.24	.61	.14	**.89**	**.92**	1.00	
ZINC	.11	.37	.59	.68	.43	-.41	-.04	.57	-.15	.56	.50	-.11	-.06	.07	.16	1.00

Appendix 1. Polynuclear aromatic hydrocarbons in ambient surface soils, Chicago, Illinois.

Appendix 1. Polynuclear aromatic hydrocarbons in ambient surface soils, Chicago, Illinois

[µg/Kg, micrograms per kilogram; 15 U, constituent not detected and detection limit; J, estimated; D, duplicate sample]

Sample Number	Naphthalene (µg/Kg)	Acenaphthylene (µg/Kg)	Acenaphthene (µg/Kg)	Fluorene (µg/Kg)	Phenanthrene (µg/Kg)	Anthracene (µg/Kg)	Fluoranthene (µg/Kg)	Pyrene (µg/Kg)
	Constituent							
PAH-SS-01	15 UJ	9 UJ	44	49	700	150	1,700	830 J
PAH-SS-02	14 U	6 UJ	9	11	200	38	580	240 J
PAH-SS-03	15 U	7 J	93	77	1,000	220	2,100	1,300 J
PAH-SS-04	14 U	14 J	57	53	900	140	2,000	1,700 J
PAH-SS-05	13 U	6 J	37	36	690	97	1,600	1,200 J
PAH-SS-06	160	340	370	400	8,100	1,000	20,000	12,000
PAH-SS-07	14 U	7 U	7 UJ	8 UJ	83	14 J	130	100 J
PAH-SS-08	15 U	7 U	14 J	10 J	190	37	480	290 J
PAH-SS-09	15 J	23	450	680	5,900	1,300	7,800	4,400 J
PAH-SS-10	14 U	7 U	6 U	7 U	27	7 U	52	88 J
PAH-SS-11	14 U	6 U	5 U	7 U	33	8 J	81	98 J
PAH-SS-12	14 U	6 U	8 J	11 J	130	28	230	150 J
PAH-SS-13	30	62	320	260	4,600	890	8,400	4,100
PAH-SS-14	41	440	110	330	5,800	680	12,000	6,200 J
PAH-SS-15	16 U	7 U	8 J	8 J	130	25	340	220 J
PAH-SS-16	14 U	6 U	5 U	7 U	56	11 J	160	100
PAH-SS-17	290	970	520	990	11,000	3,200	26,000	13,000
PAH-SS-17D	240	1,100	74	460	5,600	1,900	19,000	9,200
PAH-SS-18	15 U	77	640	420	5,700	980	11,000	5,800
PAH-SS-19	13 U	6 U	5 U	6 U	84	14 J	220	110
PAH-SS-20	13 UJ	7 J	7 J	7 J	130	22	300	250
PAH-SS-21	19 J	21	8 J	12 J	210	39	460	430
PAH-SS-21D	19 J	26	10 J	16 J	250	53	530	430
PAH-SS-22	350 J	480	1,500	2,000	19,000	4,600	35,000	30,000
PAH-SS-23	15 J	28	39	46	820	150	2,000	1,600
PAH-SS-24	58 J	390	98	310	3,700	540	7,200	5,500
PAH-SS-25	14 UJ	10 J	12 J	12 J	220	39	570	490
PAH-SS-25D	14 UJ	11 J	17 J	18 J	280	48	650	560
PAH-SS-26	17 J	16 J	41	43	670	120	1,300	1,000
PAH-SS-27	90 J	130	220	210	3,500	620	8,400	7,000
PAH-SS-28	40 J	51	140	130	2,000	380	4,300	3,800
PAH-SS-29	78 J	35	380	390	4,000	620	5,300	4,500
PAH-SS-30	65 J	37	190	170	1,800	400	3,600	2,900
PAH-SS-31	290 J	74	330	340	4,500	1,000	6,000	5,000
PAH-SS-32	610 J	100	1,100	1,400	12,000	2,500	17,000	12,000
PAH-SS-33	36 J	39	150	170	1,900	390	3,200	2,700

Appendix 1. Polynuclear aromatic hydrocarbons in ambient surface soils, Chicago, Illinois—Continued

[µg/Kg, micrograms per kilogram; 15 U, constituent not detected and detection limit; J, estimated; D, duplicate sample]

	Constituent							
Sample Number	Benzo(a)-anthracene (µg/Kg)	Chrysene (µg/Kg)	Benzo(b)-fluoranthene (µg/Kg)	Benzo(k)-fluoranthene (µg/Kg)	Benzo(a)-pyrene (µg/Kg)	Dibenzo-(a,h)anthra-cene (µg/Kg)	Benzo-(g,h,i)-perylene (µg/Kg)	Indeno-(1,2,3-cd)-pyrene (µg/Kg)
PAH-SS-01	600	720	1,000	450	760	190	410	470
PAH-SS-02	200	250	340	220	260	93	200	210
PAH-SS-03	720	800	920	650	850	140	430	500
PAH-SS-04	740	910	1,100	900	1,000	150	490	610
PAH-SS-05	510	650	760	530	680	110	360	430
PAH-SS-06	9,100	11,000	14,000	9,000	12,000	770	6,900	8,100
PAH-SS-07	47	54	100	53	81	68	120	110
PAH-SS-08	180	220	260	220	250	96	170	200
PAH-SS-09	2,700	2,900	3,000	2,200	3,000	290	1,000	1,300
PAH-SS-10	26	31	40	36	39	62	110	98
PAH-SS-11	43	61	63	59	66	62	100	110
PAH-SS-12	110	120	150	95	130	68	130	140
PAH-SS-13	3,400	3,500	4,000	1,900	3,700	640	1,300	1,500
PAH-SS-14	5,100	5,800	7,200	4,400	6,200	510	2,000	4,300
PAH-SS-15	160	180	240	140	200	82	160	170
PAH-SS-16	59	79	97	58	81	69	120	130
PAH-SS-17	10,000	9,300	13,000	7,100	11,000	870	7,100	8,100
PAH-SS-17D	8,400	8,200	9,400	8,600	9,700	780	5,500	6,100
PAH-SS-18	4,900	5,500	6,800	3,600	5,600	520	3,700	4,100
PAH-SS-19	77	99	99	70	95	70	130	140
PAH-SS-20	140	160	190	100	160	28	120	130
PAH-SS-21	210	230	300	170	250	44	180	210
PAH-SS-21D	230	260	330	190	280	52	200	240
PAH-SS-22	16,000	15,000	18,000	10,000	17,000	1,600	8,100	9,900
PAH-SS-23	880	980	970	1,000	1,000	110	490	620
PAH-SS-24	2,500	2,600	3,700	2,000	3,000	290	1,500	1,800
PAH-SS-25	240	280	340	210	280	59	210	250
PAH-SS-25D	280	330	380	270	340	70	230	280
PAH-SS-26	550	540	530	340	570	71	280	370
PAH-SS-27	3,800	4,200	5,700	2,900	4,200	760	3,200	3,800
PAH-SS-28	2,000	1,900	2,600	1,300	2,100	280	920	1,100
PAH-SS-29	1,700	1,700	1,900	1,300	1,800	200	730	920
PAH-SS-30	1,700	1,600	1,600	1,500	1,600	280	640	830
PAH-SS-31	2,400	2,500	3,000	1,700	2,400	370	930	1,200
PAH-SS-32	6,400	6,600	6,000	6,300	6,600	940	3,600	4,600
PAH-SS-33	1,300	1,300	1,300	1,400	1,400	220	570	700

Appendix 1. Polynuclear aromatic hydrocarbons in ambient surface soils, Chicago, Illinois—Continued

[µg/Kg, micrograms per kilogram; 15 U, constituent not detected and detection limit; J, estimated; D, duplicate sample]

	Constituent							
Sample Number	**Naphthalene (µg/Kg)**	**Acenaph-thylene (µg/Kg)**	**Acenaph-thene (µg/Kg)**	**Fluorene (µg/Kg)**	**Phenanthrene (µg/Kg)**	**Anthracene (µg/Kg)**	**Fluoranthene (µg/Kg)**	**Pyrene (µg/Kg)**
PAH-SS-33D	50 J	48	130	150	1,700	340	3,000	2,500
PAH-SS-34	50 J	17 J	190	180	2,100	380	3,900	3,100
PAH-SS-35	700 J	300	1,200	1,500	16,000	3,000	20,000	17,000
PAH-SS-36	190 J	250	510	630	8,200	1,400	16,000	12,000
PAH-SS-37	68	54	210	210	2,200	470	4,700	2,000
PAH-SS-38	24 UJ	24 UJ	33	40	430	84	990	500
PAH-CE-1	21 UJ	21 UJ	17 J	18 J	330	48	880	610
PAH-CE-2	18 U	18 U	18 U	18 U	22	18 UJ	74	51
PAH-CE-3	110	8 J	46	52	620	120	1,100	840
PAH-CE-4	20	13 J	170	170	2,100	300	3,500	2,600
PAH-CE-4D	14 J	9 J	100	110	1,400	200	3,100	1,800
PAH-CE-5	97	72	140	180	2,100	510	6,000	5,200
PAH-CE-6	50	17 J	84	91	1,200	190	1,800	1,800
PAH-CE-7	410	50	260	320	3,900	680	7,100	5,900
PAH-CE-8	20	7 J	110	120	1,200	290	2,300	1,500
PAH-CE-9	21 U	21 U	21 U	21 U	30	21 U	64	60
PAH-CE-10	21 UJ	7 J	9 J	9 J	160	29	410	350
PAH-CE-11	18 UJ	18 U	9 J	9 J	180	28	460	430
PAH-CE-12	14 J	13 J	36	31	240	49	650	350
PAH-CE-13	51	69	85	110	1,500	260	5,700	2,800
PAH-CE-14	110	55	110	130	1,700	260	3,400,	2,100
PAH-CE-15	180 J	17 J	920 J	950 J	5,100	980 J	6,200	3,400
PAH-CE-15D	38	11 J	250	220	1,500	280	2,700	1,200
PAH-CE-16	84	14 J	9 J	13 J	270	41	450	330
PAH-CE-17	98	20	17 J	17 J	410	53	730	520
PAH-CE-18	86	40	310	290	3,600	770	8,600	6,000
PAH-CE-19	2,500	1,000	43,000	36,000	520,000	120,000	1,100,000	720,000 J

Appendix 1. Polynuclear aromatic hydrocarbons in ambient surface soils, Chicago, Illinois—Continued

[µg/Kg, micrograms per kilogram; 15 U, constituent not detected and detection limit; J, estimated; D, duplicate sample]

	Constituent							
Sample Number	**Benzo(a)-anthracene (µg/Kg)**	**Chrysene (µg/Kg)**	**Benzo(b)-fluoranthene (µg/Kg)**	**Benzo(k)-fluoranthene (µg/Kg)**	**Benzo(a)-pyrene (µg/Kg)**	**Dibenzo-(a,h)anthra-cene (µg/Kg)**	**Benzo-(g,h,i)-perylene (µg/Kg)**	**Indeno-(1,2,3-cd)-pyrene (µg/Kg)**
PAH-SS-33D	1,300	1,300	1,700	950	1,400	220	540	700
PAH-SS-34	1,500	1,600	2,100	720	1,600	220	920	1,200
PAH-SS-35	8,100	7,800	9,000	4,000	7,500	1,100	4,100	5,000
PAH-SS-36	6,100	6,400	8,500	3,900	6,600	1,100	4,000	5,200
PAH-SS-37	1,800 J	1,500	2,600	1,300	1,700	130	570	870 J
PAH-SS-38	300 J	310	440 J	490	490	140	220	360 J
PAH-CE-1	320	380	480	330	410	38	200	270
PAH-CE-2	30	35	50	36	41	8 J	24	33
PAH-CE-3	430	430	550	410	480	48	200	260
PAH-CE-4	1,400	1,400	1,800	1,400	1,600	120	560	790
PAH-CE-4D	1,000	1,000	1,300	950 J	1,200	130 J	560	770
PAH-CE-5	3,200	2,900	3,400	2,900	3,600	260 J	1,200	1,500
PAH-CE-6	880	850	1,200	820	950	120	580	700
PAH-CE-7	3,300	3,200	4,200	2,700	3,200	340 J	1,200	1,600
PAH-CE-8	830	730	830	620	780	78	290	410
PAH-CE-9	28	36	50	44	45	10 J	24	31
PAH-CE-10	210	200	320	200	250	27	99	130
PAH-CE-11	210	220	350	230	270	27	110	160
PAH-CE-12	210 J	200	370 J	290	290	85	130	220 J
PAH-CE-13	1,800 J	1,800	3,900	2,900	3,500	200	820 J	1,200
PAH-CE-14	1,300 J	1,300	2,100	1,800	1,600	200	390	580 J
PAH-CE-15	1,600 J	1,800 J	2,600	2,100	2,100	220 J	1,300 J	1,500 J
PAH-CE-15D	810 J	790	1,500 J	960	1,200	220	560	780 J
PAH-CE-16	240 J	260	430 J	380	430	130	310	300 J
PAH-CE-17	360 J	360	540 J	580	550	160	430	470
PAH-CE-18	4,100	3,700	4,000	3,200	4,100	980	2,100	3,100
PAH-CE-19	370,000	350,000 J	550,000	280,000	460,000	41,000	290,000	370,000

Appendix 2. Inorganic constituents in ambient surface soils, Chicago, Illinois.

Appendix 2. Inorganic constituents in ambient surface soils, Chicago, Illinois

[percent, percent-weight; D, duplicate sample; <50, constituent not detected and detection limit]

	Constituent							
Sample Number	Carbon Dioxide (percent)	Carbonate Carbon (percent)	Total Carbon (percent)	Total Organic Carbon (percent)	Aluminum (percent)	Calcium (percent)	Iron (percent)	Magnesium (percent)
PAH-SS-01	0.91	0.25	6.01	5.76	5.66	1.27	2.78	0.92
PAH-SS-02	2.02	.55	4.50	3.95	5.83	1.77	2.29	1.16
PAH-SS-03	2.38	.65	5.64	4.99	6.90	1.94	3.50	1.47
PAH-SS-04	3.77	1.03	6.79	5.76	5.68	2.65	2.63	1.77
PAH-SS-05	16.30	4.45	7.77	3.32	4.33	7.95	2.57	5.25
PAH-SS-06	16.40	4.48	11.50	7.02	4.58	8.95	3.19	5.65
PAH-SS-07	1.97	.54	2.49	1.95	7.13	1.68	3.23	1.43
PAH-SS-08	1.54	.42	4.85	4.43	6.26	1.48	2.90	1.18
PAH-SS-09	1.88	.51	5.99	5.48	5.89	1.70	2.97	1.23
PAH-SS-10	.14	.04	2.21	2.17	6.04	.62	2.99	.59
PAH-SS-11	2.76	0.75	4.88	4.13	5.54	2.34	2.83	1.39
PAH-SS-12	.35	.10	2.39	2.29	6.12	.86	2.88	.74
PAH-SS-13	3.15	.86	5.13	4.27	6.74	2.64	3.63	1.71
PAH-SS-14	3.38	.92	6.95	6.03	6.52	2.77	3.94	1.68
PAH-SS-15	3.49	.95	3.50	2.55	6.39	2.66	3.30	1.67
PAH-SS-16	1.46	0.40	3.32	2.92	6.48	1.67	3.21	1.04
PAH-SS-17	4.40	1.20	8.26	7.06	5.42	4.15	5.27	1.82
PAH-SS-17D	4.54	1.24	7.94	6.70	5.32	4.58	5.61	1.82
PAH-SS-18	3.85	1.05	16.00	14.95	3.78	3.43	14.50	1.52
PAH-SS-19	1.33	.36	2.62	2.26	6.49	1.32	3.05	1.16
PAH-SS-20	4.23	1.15	9.30	8.15	4.58	3.30	3.83	1.76
PAH-SS-21	.76	.21	3.21	3.00	6.71	1.15	3.00	.94
PAH-SS-21D	.80	.22	3.16	2.94	6.78	1.18	3.02	.98
PAH-SS-22	15.10	4.12	7.93	3.81	4.82	8.55	2.76	4.58
PAH-SS-23	1.83	.50	5.91	5.41	5.86	1.80	3.07	1.09
PAH-SS-24	0.61	0.17	5.69	5.52	6.26	1.15	3.19	0.94
PAH-SS-25	.90	.25	3.55	3.30	5.78	1.15	2.63	.86
PAH-SS-25D	.94	.26	3.56	3.30	5.83	1.23	2.70	.95
PAH-SS-26	6.97	1.90	7.98	6.08	4.92	4.42	2.75	2.53
PAH-SS-27	9.55	2.61	10.50	7.89	4.73	5.45	4.18	3.46
PAH-SS-28	2.18	0.59	6.07	5.48	7.00	1.89	3.98	1.67
PAH-SS-29	26.90	7.34	9.77	2.43	3.09	12.90	2.24	8.06
PAH-SS-30	1.97	.54	4.73	4.19	6.44	1.79	4.28	1.22
PAH-SS-31	3.07	.84	10.90	10.06	4.56	2.41	5.75	1.39
PAH-SS-32	5.49	1.50	8.99	7.49	5.89	3.96	3.67	2.09

Appendix 2. Inorganic constituents in ambient surface soils, Chicago, Illinois—Continued

[percent, percent-weight; D, duplicate sample; <50, constituent not detected and detection limit]

	Constituent							
Sample Number	Carbon Dioxide (percent)	Carbonate Carbon (percent)	Total Carbon (percent)	Total Organic Carbon (percent)	Aluminum (percent)	Calcium (percent)	Iron (percent)	Magnesium (percent)
PAH-SS-33	4.25	1.16	8.38	7.22	5.97	3.10	3.36	1.95
PAH-SS-33D	4.30	1.17	8.34	7.17	5.86	3.18	3.31	1.94
PAH-SS-34	6.89	1.88	5.53	3.65	5.44	3.85	2.79	2.82
PAH-SS-35	5.68	1.55	11.50	9.95	7.46	4.55	5.51	1.94
PAH-SS-36	6.97	1.90	11.80	9.90	4.30	4.53	4.32	2.59
PAH-SS-37	7.35	2.01	6.94	4.93	2.60	3.89	2.15	2.16
PAH-SS-38	.65	.18	7.35	7.17	5.26	1.23	2.44	.81
PAH-CE-01	16.00	4.37	13.40	9.03	2.33	7.38	1.23	4.60
PAH-CE-02	29.20	7.97	8.19	.22	1.21	12.30	.56	7.84
PAH-CE-03	18.40	5.02	9.11	4.09	3.44	8.10	2.38	5.44
PAH-CE-04	40.00	10.92	12.10	1.18	0.83	15.90	0.80	10.80
PAH-CE-04D	41.70	11.38	12.20	.82	.73	16.90	.73	11.80
PAH-CE-05	7.13	1.95	11.60	9.65	3.81	4.09	5.59	2.20
PAH-CE-06	9.89	2.70	6.60	3.90	1.92	5.29	2.52	3.03
PAH-CE-07	5.22	1.42	16.20	14.78	3.45	3.38	6.36	1.76
PAH-CE-08	8.46	2.31	3.46	1.15	2.91	4.68	0.91	2.44
PAH-CE-09	.28	.08	2.71	2.63	5.94	.75	2.75	.77
PAH-CE-10	1.79	.49	3.78	3.29	3.07	1.37	1.24	.68
PAH-CE-11	33.20	9.06	10.20	1.14	1.47	14.20	.78	9.42
PAH-CE-12	5.35	1.46	6.37	4.91	5.34	3.00	2.96	2.02
PAH-CE-13	1.44	0.39	22.70	22.31	5.74	3.48	9.31	0.50
PAH-CE-14	9.11	2.49	8.44	5.95	3.45	5.23	2.90	2.76
PAH-CE-15	1.50	.41	8.48	8.07	4.48	1.74	2.10	.89
PAH-CE-15D	1.38	.38	8.33	7.95	4.47	1.69	2.09	.87
PAH-CE-16	9.29	2.54	5.50	2.96	2.64	4.85	1.47	2.88
PAH-CE-17	5.25	1.43	5.99	4.56	3.04	3.85	2.69	1.68
PAH-CE-18	4.02	1.10	5.59	4.49	3.70	2.74	2.52	1.40
PAH-CE-19	11.20	3.06	18.70	15.64	1.75	6.04	1.45	3.31

Appendix 2. Inorganic constituents in ambient surface soils, Chicago, Illinois—Continued

[percent, percent-weight; D, duplicate sample; <50, constituent not detected and detection limit]

	Constituent							
Sample Number	**Phosphorus (percent)**	**Potassium (percent)**	**Sodium (percent)**	**Sulfur (percent)**	**Titanium (percent)**	**Arsenic (milligrams per kilogram)**	**Barium (milligrams per kilogram)**	**Beryllium (milligrams per kilogram)**
PAH-SS-01	0.080	2.04	0.56	0.08	0.273	15	445	2
PAH-SS-02	.090	1.84	.74	.05	.273	<10	449	1
PAH-SS-03	.070	2.45	.47	.09	.278	16	453	2
PAH-SS-04	.175	2.19	.49	.10	.247	10	403	2
PAH-SS-05	.070	1.71	.56	.06	.210	12	278	1
PAH-SS-06	0.090	1.62	0.67	0.12	0.221	12	403	2
PAH-SS-07	.055	2.63	.59	.05	.305	11	475	2
PAH-SS-08	.085	2.31	.76	.06	.284	<10	481	2
PAH-SS-09	.110	2.24	.70	.08	.252	11	463	2
PAH-SS-10	.065	1.98	.81	<0.05	.305	13	540	1
PAH-SS-11	0.095	1.84	0.61	0.05	0.268	11	499	1
PAH-SS-12	.065	1.88	.69	<0.05	.310	10	543	1
PAH-SS-13	.210	2.60	.51	.09	.257	20	572	2
PAH-SS-14	.100	2.28	.54	.13	.268	12	666	3
PAH-SS-15	.055	2.34	.52	.05	.289	17	442	2
PAH-SS-16	.070	2.43	0.53	0.05	0.326	15	485	2
PAH-SS-17	.120	1.91	.45	.16	.252	<10	426	2
PAH-SS-17D	.130	1.87	.44	.14	.247	<10	436	2
PAH-SS-18	.240	.94	.64	.30	.200	25	477	3
PAH-SS-19	.060	2.45	.58	<0.05	.305	13	505	2
PAH-SS-20	0.140	1.55	0.70	0.14	0.210	19	397	2
PAH-SS-21	.065	2.51	.60	<0.05	.305	<10	473	2
PAH-SS-21D	.065	2.53	.60	.05	.294	14	483	2
PAH-SS-22	.055	1.93	.42	.11	.221	11	450	2
PAH-SS-23	.125	1.94	.58	.09	.289	17	588	2
PAH-SS-24	0.090	2.25	0.66	0.08	0.294	15	498	2
PAH-SS-25	.080	2.16	.62	.05	.305	10	494	1
PAH-SS-25D	.085	2.20	.63	.05	.294	15	536	2
PAH-SS-26	.075	1.91	.53	.17	.226	13	394	1
PAH-SS-27	.150	1.72	.46	.13	.242	13	451	2
PAH-SS-28	.095	2.86	0.46	0.10	0.268	21	460	3
PAH-SS-29	.050	1.24	.29	.11	.158	11	284	1
PAH-SS-30	.100	2.34	.63	.07	.284	16	494	2
PAH-SS-31	.120	1.53	.54	.25	.221	27	414	2
PAH-SS-32	.125	2.16	.41	.14	.257	18	519	3

Appendix 2. Inorganic constituents in ambient surface soils, Chicago, Illinois—Continued

[percent, percent-weight; D, duplicate sample; <50, constituent not detected and detection limit]

	Constituent							
Sample Number	**Phosphorus (percent)**	**Potassium (percent)**	**Sodium (percent)**	**Sulfur (percent)**	**Titanium (percent)**	**Arsenic (milligrams per kilogram)**	**Barium (milligrams per kilogram)**	**Beryllium (milligrams per kilogram)**
PAH-SS-33	0.095	2.09	0.50	0.14	0.268	13	431	2
PAH-SS-33D	.090	2.06	.51	.13	.273	12	428	2
PAH-SS-34	.075	2.25	.53	.07	.226	<10	394	2
PAH-SS-35	.280	1.32	.49	.20	.383	32	697	9
PAH-SS-36	.140	1.30	.49	.17	.236	28	541	2
PAH-SS-37	0.095	1.10	0.48	0.11	0.145	<10	390	<1
PAH-SS-38	.100	1.84	.49	.07	.245	14	437	1
PAH-CE-01	.080	1.12	.38	.12	.090	31	227	<1
PAH-CE-02	.010	.82	.20	<0.05	.045	<10	106	<1
PAH-CE-03	.090	1.51	.35	.10	.155	51	412	1
PAH-CE-04	0.020	0.35	0.10	<0.05	0.050	35	110	<1
PAH-CE-04D	.015	.31	.07	.05	.040	31	91	<1
PAH-CE-05	.080	1.18	.60	.24	.180	220	521	4
PAH-CE-06	.075	.85	.35	.09	.125	35	506	1
PAH-CE-07	.050	.98	.56	.52	.180	20	693	3
PAH-CE-08	0.025	1.62	0.78	<0.05	0.075	11	349	<1
PAH-CE-09	.045	2.34	.50	<0.05	.275	13	468	1
PAH-CE-10	.070	1.45	.65	.05	.105	13	378	<1
PAH-CE-11	.020	.88	.13	<0.05	.075	<10	113	<1
PAH-CE-12	.070	2.35	.46	.09	.230	14	366	2
PAH-CE-13	0.020	1.08	0.25	0.63	0.345	<10	257	14
PAH-CE-14	.045	1.45	.44	.19	.140	16	362	2
PAH-CE-15	.065	1.62	.52	.16	.175	11	413	1
PAH-CE-15D	.060	1.63	.53	.14	.180	13	408	1
PAH-CE-16	.020	1.32	.67	.10	.085	11	295	1
PAH-CE-17	0.040	1.22	0.71	0.11	0.120	<10	371	2
PAH-CE-18	.075	1.51	.57	.08	.150	15	407	2
PAH-CE-19	.030	.75	.42	.20	.090	<10	169	<1

Appendix 2. Inorganic constituents in ambient surface soils, Chicago, Illinois—Continued

[percent, percent-weight; D, duplicate sample; <50, constituent not detected and detection limit]

Sample Number	Bismuth (milligrams per kilogram)	Cadmium (milligrams per kilogram)	Cesium (milligrams per kilogram)	Chromium (milligrams per kilogram)	Cobalt (milligrams per kilogram)	Copper (milligrams per kilogram)	Europium (milligrams per kilogram)	Gallium (milligrams per kilogram)
PAH-SS-01	<50	<2	63	65	11	43	<2	14
PAH-SS-02	<50	<2	61	53	10	37	<2	15
PAH-SS-03	<50	<2	63	75	13	57	<2	18
PAH-SS-04	<50	3	54	66	11	69	<2	17
PAH-SS-05	<50	<2	41	44	9	51	<2	16
PAH-SS-06	<50	6	44	78	12	343	<2	17
PAH-SS-07	<50	<2	72	70	14	39	<2	19
PAH-SS-08	<50	<2	62	64	12	35	<2	16
PAH-SS-09	<50	<2	61	64	11	43	<2	16
PAH-SS-10	<50	<2	64	54	11	28	<2	13
PAH-SS-11	<50	<2	61	56	9	36	<2	16
PAH-SS-12	<50	<2	71	68	11	38	<2	15
PAH-SS-13	<50	<2	69	78	14	66	<2	20
PAH-SS-14	<50	<2	67	102	13	73	<2	17
PAH-SS-15	<50	<2	68	63	14	42	<2	16
PAH-SS-16	<50	<2	75	66	15	36	<2	15
PAH-SS-17	<50	<2	55	340	11	75	<2	16
PAH-SS-17D	<50	<2	60	387	11	76	<2	13
PAH-SS-18	<50	7	38	192	16	395	<2	14
PAH-SS-19	<50	<2	69	61	12	42	<2	16
PAH-SS-20	<50	<2	43	66	11	67	<2	13
PAH-SS-21	<50	<2	70	76	11	44	<2	18
PAH-SS-21D	<50	<2	73	72	12	47	<2	17
PAH-SS-22	<50	<2	46	57	13	89	<2	15
PAH-SS-23	<50	<2	63	69	12	74	<2	16
PAH-SS-24	<50	<2	64	73	13	57	<2	17
PAH-SS-25	<50	<2	58	59	10	35	<2	16
PAH-SS-25D	<50	<2	63	61	10	37	<2	14
PAH-SS-26	<50	<2	51	64	11	48	<2	10
PAH-SS-27	<50	5	48	94	12	2,780	<2	14
PAH-SS-28	<50	2	70	78	16	117	<2	23
PAH-SS-29	<50	3	33	50	9	208	<2	8
PAH-SS-30	<50	<2	66	76	14	99	<2	18
PAH-SS-31	<50	<2	44	82	13	214	<2	17
PAH-SS-32	<50	<2	60	79	14	134	<2	18

Appendix 2. Inorganic constituents in ambient surface soils, Chicago, Illinois—Continued

[percent, percent-weight; D, duplicate sample; <50, constituent not detected and detection limit]

Sample Number	Constituent							
	Bismuth (milligrams per kilogram)	Cadmium (milligrams per kilogram)	Cesium (milligrams per kilogram)	Chromium (milligrams per kilogram)	Cobalt (milligrams per kilogram)	Copper (milligrams per kilogram)	Europium (milligrams per kilogram)	Gallium (milligrams per kilogram)
PAH-SS-33	<50	<2	60	77	12	84	<2	17
PAH-SS-33D	<50	<2	59	81	14	83	<2	18
PAH-SS-34	<50	<2	54	61	11	46	<2	16
PAH-SS-35	<50	3	104	129	26	234	3	23
PAH-SS-36	<50	7	45	118	12	355	<2	17
PAH-SS-37	<50	3	15	67	7	73	<2	7
PAH-SS-38	57	<2	52	45	12	35	<2	13
PAH-CE-01	<50	3	19	29	8	47	<2	6
PAH-CE-02	<50	<2	<5	8	5	9	<2	<4
PAH-CE-03	<50	4	23	90	10	66	<2	10
PAH-CE-04	<50	3	<5	20	5	98	<2	<4
PAH-CE-04D	<50	2	<5	17	4	77	<2	<4
PAH-CE-05	<50	7	23	131	14	475	<2	11
PAH-CE-06	<50	6	8	87	5	419	<2	6
PAH-CE-07	<50	7	16	88	14	484	<2	11
PAH-CE-08	<50	<2	11	19	5	12	<2	7
PAH-CE-09	<50	<2	60	55	13	25	<2	17
PAH-CE-10	<50	<2	18	31	4	24	<2	8
PAH-CE-11	<50	<2	13	23	5	24	<2	<4
PAH-CE-12	<50	<2	47	54	13	78	<2	15
PAH-CE-13	<50	5	13	82	16	45	<2	11
PAH-CE-14	<50	<2	29	45	10	63	<2	9
PAH-CE-15	<50	<2	41	43	11	46	<2	12
PAH-CE-15D	<50	<2	38	42	9	42	<2	11
PAH-CE-16	<50	<2	16	26	6	13	<2	6
PAH-CE-17	<50	<2	25	56	6	59	<2	8
PAH-CE-18	<50	3	30	45	9	200	<2	11
PAH-CE-19	<50	3	6	26	5	59	<2	5

Appendix 2. Inorganic constituents in ambient surface soils, Chicago, Illinois—Continued

[percent, percent-weight; D, duplicate sample; <50, constituent not detected and detection limit]

	Constituent							
Sample Number	Gold (milligrams per kilogram)	Holmium (milligrams per kilogram)	Lanthanum (milligrams per kilogram)	Lead (milligrams per kilogram)	Lithium (milligrams per kilogram)	Manganese (milligrams per kilogram)	Mercury (milligrams per kilogram)	Molybdenum (milligrams per kilogram)
PAH-SS-01	<8	<4	32	93	36	561	0.11	4
PAH-SS-02	<8	<4	33	40	32	327	.09	2
PAH-SS-03	<8	<4	34	198	52	461	.86	5
PAH-SS-04	<8	<4	30	283	43	365	.31	4
PAH-SS-05	<8	<4	23	150	29	433	.17	4
PAH-SS-06	<8	<4	25	654	37	628	0.32	6
PAH-SS-07	<8	<4	35	42	52	390	.07	5
PAH-SS-08	<8	<4	33	87	40	507	.09	3
PAH-SS-09	<8	<4	31	224	38	582	.38	3
PAH-SS-10	<8	<4	34	27	28	751	.08	3
PAH-SS-11	<8	<4	33	35	30	699	0.08	3
PAH-SS-12	<8	<4	36	39	29	651	.19	2
PAH-SS-13	<8	<4	34	323	51	524	1.89	6
PAH-SS-14	<8	<4	33	504	55	821	.33	6
PAH-SS-15	<8	<4	34	47	42	694	.07	5
PAH-SS-16	<8	<4	36	65	44	795	0.08	5
PAH-SS-17	<8	<4	30	240	39	3,250	.18	15
PAH-SS-17D	<8	<4	33	246	38	4,090	.16	17
PAH-SS-18	<8	<4	21	1,690	28	2,330	.93	14
PAH-SS-19	<8	<4	35	44	43	634	.07	3
PAH-SS-20	<8	<4	24	239	25	802	0.25	4
PAH-SS-21	<8	<4	34	72	51	427	.27	3
PAH-SS-21D	<8	<4	35	70	51	420	.59	3
PAH-SS-22	<8	<4	25	303	36	541	1.91	6
PAH-SS-23	<8	<4	33	198	39	442	.28	5
PAH-SS-24	<8	<4	34	109	38	683	0.17	5
PAH-SS-25	<8	<4	31	82	33	471	.06	2
PAH-SS-25D	<8	<4	33	90	35	549	.06	3
PAH-SS-26	<8	<4	27	105	31	459	.14	6
PAH-SS-27	<8	<4	24	1,310	33	697	1.65	11
PAH-SS-28	<8	<4	35	275	49	415	0.39	7
PAH-SS-29	<8	<4	18	473	25	512	.70	5
PAH-SS-30	<8	<4	34	355	42	544	.25	6
PAH-SS-31	<8	<4	24	469	26	631	.31	7
PAH-SS-32	<8	<4	29	528	42	495	.21	7

Appendix 2. Inorganic constituents in ambient surface soils, Chicago, Illinois—Continued

[percent, percent-weight; D, duplicate sample; <50, constituent not detected and detection limit]

	Constituent							
Sample Number	**Gold (milligrams per kilogram)**	**Holmium (milligrams per kilogram)**	**Lanthanum (milligrams per kilogram)**	**Lead (milligrams per kilogram)**	**Lithium (milligrams per kilogram)**	**Manganese (milligrams per kilogram)**	**Mercury (milligrams per kilogram)**	**Molybdenum (milligrams per kilogram)**
PAH-SS-33	<8	<4	31	281	46	411	0.44	6
PAH-SS-33D	<8	<4	31	283	45	405	.43	6
PAH-SS-34	<8	<4	28	175	36	533	.12	4
PAH-SS-35	<8	<4	52	1,270	67	710	5.13	12
PAH-SS-36	<8	<4	24	1,910	28	642	.75	6
PAH-SS-37	<8	<4	13	1,000	12	390	0.25	4
PAH-SS-38	<8	<4	28	85	32	484	.08	3
PAH-CE-01	<8	<4	13	260	13	240	.12	2
PAH-CE-02	<8	<4	10	13	7	196	<0.02	<2
PAH-CE-03	<8	<4	18	886	24	335	13.10	5
PAH-CE-04	<8	<4	7	270	5	166	0.08	<2
PAH-CE-04D	<8	<4	6	200	5	150	.12	<2
PAH-CE-05	<8	<4	19	1,450	20	415	.38	13
PAH-CE-06	<8	<4	11	1,500	8	327	.21	6
PAH-CE-07	<8	<4	17	1,680	17	517	.41	15
PAH-CE-08	<8	<4	12	70	7	276	0.03	<2
PAH-CE-09	<8	<4	32	30	42	479	.03	3
PAH-CE-10	<8	<4	12	98	8	241	.28	<2
PAH-CE-11	<8	<4	13	66	15	236	.02	2
PAH-CE-12	<8	<4	28	167	40	368	.06	6
PAH-CE-13	<8	<4	21	49	32	579	0.03	17
PAH-CE-14	<8	<4	18	977	22	405	.11	6
PAH-CE-15	<8	<4	23	135	32	346	.10	6
PAH-CE-15D	<8	<4	22	114	32	333	.07	6
PAH-CE-16	<8	<4	11	30	8	311	.03	2
PAH-CE-17	<8	<4	17	332	14	954	0.48	4
PAH-CE-18	<8	<4	20	428	22	414	.44	3
PAH-CE-19	<8	<4	10	90	7	320	.09	<2

Appendix 2. Inorganic constituents in ambient surface soils, Chicago, Illinois—Continued

[percent, percent-weight; D, duplicate sample; <50, constituent not detected and detection limit]

	Constituent							
Sample Number	**Niobium (milligrams per kilogram)**	**Neodymium (milligrams per kilogram)**	**Nickel (milligrams per kilogram)**	**Scandium (milligrams per kilogram)**	**Selenium (milligrams per kilogram)**	**Silver (milligrams per kilogram)**	**Strontium (milligrams per kilogram)**	**Tantalum (milligrams per kilogram)**
PAH-SS-01	9	27	29	10	0.7	<2	98	<40
PAH-SS-02	7	31	27	9	.7	<2	102	<40
PAH-SS-03	7	30	41	12	1.0	<2	100	<40
PAH-SS-04	8	27	37	10	.8	<2	125	<40
PAH-SS-05	10	24	26	7	.6	<2	100	<40
PAH-SS-06	11	24	52	8	0.9	<2	123	<40
PAH-SS-07	6	29	38	13	.5	<2	98	<40
PAH-SS-08	8	30	30	11	.7	<2	99	<40
PAH-SS-09	6	32	29	10	.8	<2	107	<40
PAH-SS-10	10	32	25	9	.7	<2	98	<40
PAH-SS-11	7	28	24	9	0.7	<2	122	<40
PAH-SS-12	10	31	27	10	.6	<2	99	<40
PAH-SS-13	12	33	41	13	1.2	<2	106	<40
PAH-SS-14	13	31	45	12	1.3	<2	106	<40
PAH-SS-15	9	30	32	11	.8	<2	104	<40
PAH-SS-16	10	32	31	12	0.9	<2	94	<40
PAH-SS-17	10	25	54	10	1.2	<2	132	<40
PAH-SS-17D	13	32	57	9	1.2	<2	127	<40
PAH-SS-18	16	21	77	7	2.7	<2	143	<40
PAH-SS-19	7	29	30	11	.6	<2	91	<40
PAH-SS-20	9	23	28	8	1.5	<2	122	<40
PAH-SS-21	10	30	34	12	.8	<2	141	<40
PAH-SS-21D	7	32	33	12	.7	<2	141	<40
PAH-SS-22	11	23	34	9	.7	<2	133	<40
PAH-SS-23	7	30	34	10	.7	<2	131	<40
PAH-SS-24	11	28	34	11	1.0	<2	101	<40
PAH-SS-25	11	29	25	9	.7	<2	98	<40
PAH-SS-25D	10	30	25	10	.7	<2	99	<40
PAH-SS-26	10	24	32	9	1.0	<2	112	<40
PAH-SS-27	14	22	154	9	1.3	<2	115	<40
PAH-SS-28	11	34	51	14	1.9	<2	94	<40
PAH-SS-29	11	19	35	6	.7	<2	97	<40
PAH-SS-30	9	28	43	11	1.3	<2	114	<40
PAH-SS-31	10	26	43	8	2.7	<2	102	<40
PAH-SS-32	11	27	53	11	1.2	<2	146	<40

Appendix 2. Inorganic constituents in ambient surface soils, Chicago, Illinois—Continued

[percent, percent-weight; D, duplicate sample; <50, constituent not detected and detection limit]

	Constituent							
Sample Number	Niobium (milligrams per kilogram)	Neodymium (milligrams per kilogram)	Nickel (milligrams per kilogram)	Scandium (milligrams per kilogram)	Selenium (milligrams per kilogram)	Silver (milligrams per kilogram)	Strontium (milligrams per kilogram)	Tantalum (milligrams per kilogram)
PAH-SS-33	10	31	41	11	1.2	<2	116	<40
PAH-SS-33D	10	27	40	11	1.2	<2	114	<40
PAH-SS-34	8	29	31	10	.9	<2	94	<40
PAH-SS-35	18	49	93	18	3.1	<2	299	<40
PAH-SS-36	10	23	55	8	3.1	<2	144	<40
PAH-SS-37	7	<9	22	3	0.5	<2	104	<40
PAH-SS-38	10	25	24	9	1.0	<2	108	<40
PAH-CE-01	6	<9	26	3	.8	<2	103	<40
PAH-CE-02	6	<9	5	<2	<0.2	<2	78	<40
PAH-CE-03	13	13	25	6	.9	<2	93	<40
PAH-CE-04	12	9	15	<2	0.3	<2	65	<40
PAH-CE-04D	6	<9	12	<2	.3	<2	67	<40
PAH-CE-05	10	18	48	7	1.5	<2	153	<40
PAH-CE-06	8	12	88	3	.7	<2	94	<40
PAH-CE-07	16	10	48	6	1.6	<2	125	<40
PAH-CE-08	5	<9	8	3	0.2	<2	128	<40
PAH-CE-09	13	23	28	10	.8	<2	87	<40
PAH-CE-10	9	<9	10	3	.5	<2	117	<40
PAH-CE-11	8	13	11	3	<0.2	<2	83	<40
PAH-CE-12	12	20	39	9	.8	<2	91	<40
PAH-CE-13	23	11	50	13	0.9	<2	142	<40
PAH-CE-14	8	16	24	6	.8	<2	114	<40
PAH-CE-15	13	14	27	7	1.4	<2	114	<40
PAH-CE-15D	7	17	26	7	1.7	<2	113	<40
PAH-CE-16	<4	11	11	3	.3	<2	115	<40
PAH-CE-17	4	10	19	4	0.6	<2	153	<40
PAH-CE-18	6	18	23	6	.8	<2	121	<40
PAH-CE-19	6	<9	12	3	.7	<2	83	<40

Appendix 2. Inorganic constituents in ambient surface soils, Chicago, Illinois

[percent, percent-weight; D, duplicate sample; <50, constituent not detected and detection limit]

	Constituent						
Sample Number	Thorium (milligrams per kilogram)	Tin (milligrams per kilogram)	Uranium (milligrams per kilogram)	Vanadium (milligrams per kilogram)	Ytterbium (milligrams per kilogram)	Yttrium (milligrams per kilogram)	Zinc (milligrams per kilogram)
PAH-SS-01	9	<50	<100	84	2	17	137
PAH-SS-02	8	<50	<100	82	2	19	83
PAH-SS-03	10	<50	<100	104	2	19	213
PAH-SS-04	<6	<50	<100	83	2	17	380
PAH-SS-05	<6	<50	<100	63	2	14	109
PAH-SS-06	<6	<50	<100	70	2	16	804
PAH-SS-07	8	<50	<100	106	3	19	97
PAH-SS-08	9	<50	<100	91	2	17	112
PAH-SS-09	9	<50	<100	85	2	17	170
PAH-SS-10	9	<50	<100	89	2	18	79
PAH-SS-11	9	<50	<100	83	2	18	90
PAH-SS-12	9	<50	<100	93	2	20	105
PAH-SS-13	10	<50	<100	105	2	19	235
PAH-SS-14	8	<50	<100	106	2	20	388
PAH-SS-15	9	<50	<100	99	3	19	112
PAH-SS-16	9	<50	<100	95	3	18	108
PAH-SS-17	<6	<50	<100	116	2	18	325
PAH-SS-17D	7	<50	<100	122	2	17	320
PAH-SS-18	<6	105	<100	105	1	19	1,180
PAH-SS-19	8	<50	<100	94	3	18	99
PAH-SS-20	<6	<50	<100	70	2	18	239
PAH-SS-21	9	<50	<100	95	2	18	173
PAH-SS-21D	8	<50	<100	95	3	18	165
PAH-SS-22	<6	<50	<100	72	2	16	359
PAH-SS-23	9	<50	<100	90	2	20	243
PAH-SS-24	9	<50	<100	92	3	18	172
PAH-SS-25	9	<50	<100	81	2	16	115
PAH-SS-25D	9	<50	<100	86	2	17	124
PAH-SS-26	<6	<50	<100	73	2	16	172
PAH-SS-27	<6	248	<100	78	1	17	1,240
PAH-SS-28	7	<50	<100	115	2	20	260
PAH-SS-29	<6	<50	<100	47	1	12	623
PAH-SS-30	8	<50	<100	93	2	19	243
PAH-SS-31	<6	<50	<100	79	1	14	507
PAH-SS-32	7	<50	<100	96	2	18	760

Appendix 2. Inorganic constituents in ambient surface soils, Chicago, Illinois

[percent, percent-weight; D, duplicate sample; <50, constituent not detected and detection limit]

	Constituent						
Sample Number	Thorium (milligrams per kilogram)	Tin (milligrams per kilogram)	Uranium (milligrams per kilogram)	Vanadium (milligrams per kilogram)	Ytterbium (milligrams per kilogram)	Yttrium (milligrams per kilogram)	Zinc (milligrams per kilogram)
PAH-SS-33	8	<50	<100	91	2	18	348
PAH-SS-33D	8	<50	<100	88	2	18	339
PAH-SS-34	<6	<50	<100	81	2	17	191
PAH-SS-35	13	<50	<100	145	3	38	1,500
PAH-SS-36	<6	<50	<100	79	1	16	1,140
PAH-SS-37	6	<50	<100	42	1	9	431
PAH-SS-38	11	<50	<100	71	2	16	133
PAH-CE-01	7	<50	<100	35	<1	9	606
PAH-CE-02	10	<50	<100	24	<1	6	100
PAH-CE-03	8	101	<100	62	1	13	930
PAH-CE-04	8	<50	<100	34	<1	7	242
PAH-CE-04D	<6	<50	<100	32	<1	8	187
PAH-CE-05	11	<50	<100	73	2	16	1,260
PAH-CE-06	10	<50	<100	38	<1	8	1,400
PAH-CE-07	8	51	<100	70	1	14	1,690
PAH-CE-08	11	<50	<100	27	<1	7	83
PAH-CE-09	10	<50	<100	88	3	17	80
PAH-CE-10	8	<50	<100	30	<1	7	106
PAH-CE-11	<6	<50	<100	34	<1	9	142
PAH-CE-12	13	<50	<100	82	2	15	174
PAH-CE-13	8	<50	<100	124	3	26	490
PAH-CE-14	7	<50	<100	58	2	13	251
PAH-CE-15	11	<50	<100	65	2	14	163
PAH-CE-15D	12	<50	<100	63	2	14	158
PAH-CE-16	10	<50	<100	34	<1	8	89
PAH-CE-17	12	<50	<100	50	2	11	528
PAH-CE-18	7	<50	<100	53	2	13	371
PAH-CE-19	6	<50	<100	34	<1	7	264

Kay and others—Concentrations of Polynuclear Aromatic Hydrocarbons and Inorganic Constituents in Ambient
Surface Soils, Chicago, Illinois: 2001-02—U.S. Geological Survey Water-Resources Investigations Report 03-4105