

Final Report to North Carolina Department of Environment and Natural Resources

Project No.: G35-C17

Source Apportionment of PM_{2.5} in North Carolina

By

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November 5, 2004

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1. Introduction

Epidemiological studies revealed the adverse health effects of atmospheric fine particles (Dockery and Pope, 1994). Exposure to certain levels of fine particles may cause cough, respiratory symptoms of asthmatics, and reduced lung function (Michaels and Kleinman, 2000). With the increasing public health concern of fine particles, U.S. Environmental Protection Agency (U.S. EPA) established the new national ambient air quality standards (NAAQS) for fine particulate matter (PM_{2.5}) in July 1997. This new and more stringent air quality standard with the annual average as $15 \mu\text{g m}^{-3}$ and daily average as $65 \mu\text{g m}^{-3}$ may result in more areas in this country designated as “nonattainment areas”.

The implementation of emission control strategies in those nonattainment areas is helpful to reduce the level of PM_{2.5}. However, the effectiveness of emission control strategies for the reduction of PM_{2.5} relies on the extent of understanding of the emission source types as well as their contributions to fine particles.

Chemical mass balance (CMB) receptor modeling method has been used as an efficient tool to perform source apportionment of PM_{2.5}. The basic principle of CMB is to find the best-fit linear combination of the chemical tracers from specific emission sources in order to reconstruct the concentrations of organic tracers in aerosol samples. The organic tracer-based CMB receptor modeling developed by Schauer et al. (1996) has been successfully applied in several source apportionment programs in different regions of the United States such as the southeastern United States (Zheng et al., 2002), California (Schauer and Cass, 2000; Schauer et al., 2002a), and Houston, TX (Fraser et al., 2003).

Following the promulgation of the new NAAQS for PM_{2.5}, a network of PM_{2.5} monitors in 30 counties across the state of North Carolina has been established and operated by the North Carolina Department of Environment and Natural Resources since

January, 1999. The average of the annual arithmetic mean over three-year period (2001-2003) for each monitor is determined and compared to the PM_{2.5} annual standard. The annual PM_{2.5} concentrations in 2 out of 30 counties of North Carolina exceeded the 15 $\mu\text{g m}^{-3}$ annual standard. They are Davidson County (15.8 $\mu\text{g m}^{-3}$) and Catawba County (15.5 $\mu\text{g m}^{-3}$). A level slightly below the annual standard can be seen in the counties of Mecklenburg (14.9 $\mu\text{g m}^{-3}$), Forsyth (14.6 $\mu\text{g m}^{-3}$), and Cabarrus (14.5 $\mu\text{g m}^{-3}$). The rest of the 25 counties have the readings moderately to well below the annual standard ranging from 9.6 (New Hanover) to 14.2 $\mu\text{g m}^{-3}$ (McDowell).

For the five counties where PM_{2.5} annual average values close to or above the PM_{2.5} annual standard, it is important to know the major sources of PM_{2.5} as well as how much each source contributes to PM_{2.5} at those sites. Therefore, the present study aims to (1) characterize the solvent-extractable organic compounds and (2) identify and quantify the sources of organic carbon (OC) in PM_{2.5} or fine OC and PM_{2.5} collected from four counties including Davidson, Catawba, Mecklenburg, and Forsyth in North Carolina.

2. Experimental

2.1. Sample Preparation

A total of 283 exposed filters plus 33 field blank filters were collected from four sites in North Carolina from January 2003 to May 2004 (Tables 1, 2-1, and 2-2) including Garinger High School, Mecklenburg County (GHS), Hattie Avenue, Forsyth County (HA), Hickory, Catawba County (HI), and Lexington, Davidson County (LE). The Garinger High School site in Mecklenburg County is a National Air Monitoring Site for ozone and carbon monoxide. This site is in an area with relatively high population density. The nearest road, Sugar Creek Road, is about 452 m away from the site. The average daily

traffic (ADT) count is 18500 in 2001. The Hattie Avenue site in Forsyth County is located about 300 m south of East 14th Street, 400 m east of North Cleveland Avenue, and 600 m northwest from New Walkertown Road. The ADT counts in 2001 are 7300 on East 14th Street, 10,800 on North Cleveland Avenue, 13,000 on New Walkertown Road, and less than 4000 on Hattie Avenue and 12th Street. The Hickory site in Catawba County is located between two one-way streets with ADT count of 5500 going one way and 4500 going the other. A number of other activities including carving, furniture, and concrete are located in the vicinity of the Hickory site. The Lexington site in Davidson County is 27 m away (NW) from South Salisbury Street, which has the ADT count of 1000 in 1999. This site is located about 100 m southeast of Main Street, and it is close to the train track, with the nearest train track being 500 feet southeast. The ADT counts in 2002 on Main Street are 17,000 east of the railroad racks and 13,000 west of the railroad tracks. The site is also located about 200 meters NW of Talbert Blvd which has an ADT count of 9,300. Cotton Grove Road, which is between Talbert Blvd and Main Street, has an ADT count of 15,000. There are some food cooking and other activities such as car repair and furniture in the vicinity of this site (Steger, personal communication).

Each sample/filter was exposed for a period of 24 hours at a constant flow rate of $0.006 \text{ m}^3 \text{ min}^{-1}$. One punch or more were taken from each filter for the measurements of OC and elemental carbon (EC). The remaining filter was sent to Georgia Institute of Technology for the organic tracer and CMB analyses.

In order to obtain enough OC mass for the organic tracer analysis, filters from each site were combined into three seasonal composites: spring (from January to May in 2003 and 2004), summer (from June 2nd to October 18, 2003), and winter (from October 21 to December 29, 2003) (Table 1). Finally, a total of twelve samples (four composite samples from each of the GHS and HI sites, three from HA, and one from LE) were analyzed. Two

field blank composites with one collected from three sites (GHS, HA, and HI) in 2003 (Table 2-1), and the other from three sites (GHS, HI, and LE) in 2004 (Table 2-2) as well as two laboratory blanks (without any filter) were also analyzed along with the ambient samples.

2.2. Organic Speciation Analysis

2.2.1. Sample Extraction

The filters were stored in the freezer before analysis. All glassware was fired for 12 h at 550 °C prior to use. Each composite sample was placed in a pre-baked jar first, and then 40 mL of hexane (Fisher Scientific Optima grade) was added. Two deuterated internal standard mixtures, IS#1 and IS#2, were carefully spiked into the jar, which include 16 isotopically labeled compounds, benzaldehyde- d_6 , dodecane- d_{26} , decanoic acid- d_{19} , phthalic acid-3,4,5,6- d_4 , acenaphthene- d_{10} , levoglucosan- $^{13}C_6$ (carbon-13 uniform-labeled compound), hexadecane- d_{34} , eicosane- d_{42} , heptadecanoic acid- d_{33} , 4,4'-dimethoxybenzophenone- d_8 , chrysene- d_{12} , octacosane- d_{58} , 20R-5 α (H),14 α (H),17 α (H)-cholestane- d_4 , cholesterol-2,2,3,4,4,6- d_6 , dibenz(*ah*)anthracene- d_{14} , and hexatriacontane- d_{74} . Their concentrations are shown in Table 3. The OC mass in all composite samples ranges from 481 micrograms to 1545 micrograms. After spiked with deuterated standard mixtures, sample was extracted twice with hexane and then three successively extractions by 2:1 mixture of benzene and 2-propanol (benzene: EMD Chemicals, Inc. HPLC grade; 2-propanol: Fisher Scientific Optima grade). Benzene was distilled before use. About 40 mL solvent was used for each extraction. The extraction was conducted under mild sonication with ice bath under room temperature. The extracts of each sample, about 200 mL in total volume, were filtered through pre-baked glass wool and concentrated into 5-10 mL by a rotary evaporator. The volume of the extract was then

blown down to the volume of IS spiked before extraction by nitrogen gas. In the present study, each ambient sample or blank sample, except the GHS spring 2004 sample, was spiked with 250 μL of IS#1 and IS#2 each. The sample from GHS spring 2004 was spiked with 375 μL of each IS because it had the highest OC content (1545 μg). Therefore, the volume of the extract was reduced to approximately 250 μL for all samples except GHS spring 2004 (375 μL). It was then equally divided into two aliquots with one aliquot stored in the freezer and the other aliquot derivatized by freshly prepared diazomethane to convert organic acids to their methyl esters. The methylated samples were analyzed by gas chromatography/mass spectrum (GC/MS) for the first round to quantify all compounds except for levoglucosan and cholesterol, and then silylated by adding *N,O*-bis(trimethylsilyl) trifluoroacetamide (BSTFA) plus 1% trimethylchlorosilane (TMCS) (Pierce Biotechnology, Inc.) and analyzed by GC/MS for the second round for the quantification of levoglucosan and cholesterol.

2.2.2. Sample Methylation

Diethyl ether from Sigma-Aldrich, Inc. (3 mL) was added into the outer tube of the standard diazomethane generation apparatus, and then 1 mL of diethyl ether and 1 mL of carbitol (diethylene glycol monoethyl ether, 99%, Sigma-Aldrich, Inc.) was placed into the inner tube. The lower part of the outer tube, 1-2 inches below the joint of inner and outer tube, was immersed into the ice bath. About 0.4 grams of diazald (*N*-methyl-*N*-nitroso-*p*-toluenesulfonamide, 99%, Aldrich, Inc.) were weighted and transferred carefully into the inner tube, and then about 1.5 mL of 5N KOH was injected into the inner tube by using 5 mL syringe through the cap of inner tube. The gas-phase diazomethane was then generated gradually and dissolved in the diethyl ether in the outer tube. The whole reaction was complete after 40 minutes from KOH injection (Ngan and

Toofan, 1991). Freshly prepared diazomethane in diethyl ether (200 μL) was transferred into each extract, which contains 10 μL pre-added methanol (Fisher Scientific Optima grade). In about an hour, the methylated samples were then ready for the first round of GC/MS analysis.

2.2.3. Sample Silylation

Reagents from Pierce Biotechnology, Inc. (300 μL of BSTFA plus 1% TMCS) was added into each extract, which was then immediately placed in an oven at 70°C for one hour (Simoneit and Elias, 2000). The extract was then blown down to about 200 μL for the second round of GC/MS analysis.

2.2.4. GC/MS Analysis

The methylated and silylated extracts were analyzed, respectively, by a Hewlett-Packard gas chromatography (6890 GC) and mass selective detector (5973 MSD) equipped with a 30 m length \times 0.25 mm i.d. \times 0.25 μm film thickness HP-5 MS capillary column coated with 5% phenyl methyl siloxane. The GC/MS conditions were as follows: oven temperature isothermal hold at 65 °C for 10 minutes, rise to 300 °C at a rate of 10 °C min^{-1} , then isothermal hold at 300 °C for 22 minutes. Other settings include: GC/MS interface temperature as 300°C, ultrapure He as carrier gas with a flow rate of 1.0 mL min^{-1} , splitless injection mode, scan range of 50-550 amu, and electron ionization mode with 70 eV.

A series of authentic standards (PMSTD#1-#6) pre-mixed with IS#1 and IS#2, were analyzed by GC/MS along with the samples for assisting the identification and quantification of organic compounds in the ambient samples (Table 4). For those compounds that are not present in the PMSTD series, secondary standards including wax

extraction (*n*-alkanes and branched alkanes), wood smoke standard (polycyclic aromatic hydrocarbons (PAHs) and resin acids), and picene standard (AccuStandard, Inc.) were used. Relative response factor (RRF) of each target compound to the respective deuterated internal standard, which has similar retention time and chemical structure, was used in the quantification. For those compounds which RRFs are not available, RRFs from other compounds with similar polarity, retention time, and chemical structure were used instead. In the final report, we used chrysene-*d*₁₂ instead of dibenz(*ah*)anthracene-*d*₁₄ to quantify the PAHs with molecular weight (MW) greater than 228. Our findings in the most recent recovery study with the standard reference material of urban dust (SRM1649a) showed that a higher recovery could be achieved if the concentrations of PAHs with MW228 or greater were quantified by chrysene-*d*₁₂. The difference in PAH concentration introduced by using different internal standards for quantification is shown in Appendix A.

2.3. QA/QC

2.3.1. QA/QC for GC/MS Analysis

QA/QC procedures applied in the GC/MS analysis include:

- a. performing instrument autotune with PFTBA (perfluorotributylamine) to check the responses of detector and potential problems such as air leak and moisture before running any samples or standards;
- a. running a sample of solvent mixtures, which are used in the extraction, to ensure no contamination from solvents before running any samples or standards;
- b. running PMSTD#1 1:10 (ten-fold dilution) and PMSTD#4 1:10 (ten-fold dilution) to test the sensitivity of the instrument. The criteria of the sensitivity test include:
 - i) ratio of ion peak area (coronene 300 to pyrene 202 in PMSTD#1): minimum of 0.25;

- ii) coronene 300 ion peak area in PMSTD#1: minimum of 10000;
 - iii) cholesterol 386 ion peak area in PMSTD#4: minimum of 1,000,000;
- c. analyzing PMSTD standard mixtures (#1-#6) pre-mixed with deuterated internal standards (IS#1 and IS#2) before and after the analysis of ambient samples in the same sequence. Compared to the PMSTD concentrations shown in Table 4, PMSTD#1-#3 and #6 used in the GC/MS analysis are five-fold dilutions, and PMSTD#4 and #5 are ten-fold and two-fold dilutions, respectively. PMSTD#3 and PMSTD#6 were derivatized with diazomethane before GC/MS analysis. Secondary standards, including wood smoke standard and wax extraction standard, and the standard of picene were included at the end of the sequence;
- d. obtaining two RRFs of each target compound to its respective deuterated internal standard from the first run at the beginning and last run at the end of same sequence. The average of two RRFs was used in the calculation. These two RRFs should not shift from historical records more than 50 percent;
- e. reporting target compounds as “below detection limit” if its signal to noise ratio (measured by peak area) is below 3;
- f. removing the samples and standards vials from sample tray right after the injection. These vials were covered with solid caps, sealed with Teflon tapes, and stored in the freezer;
- g. replacing the septum every 50 injections (Bleed/Temp Optimized Inlet septum, part number 5183-4757, Agilent Technology) and the liner (part number 5062-3587, Agilent Technology) for every batch of sample;
- h. checking the ultrapure Helium tank pressure every day to ensure that the pressure of the cylinder is above 500 psi.

2.3.2. Other QA/QC

Other QA/QC procedures include:

- a. baking all glassware, including jars, vials, pipettes, test tubes, beakers, measuring cylinders, adaptors and flasks, aluminum foils, and glass wool at 550°C for 12 hours prior to use;
- b. using solvents with the highest purity that can be obtained. Hexane, 2-propanol, and methanol used in the experiment are Optima grade. Diethyl ether and benzene are HPLC grade and benzene should be distilled prior to use;
- c. analyzing solvents used in the procedure before extracting samples with these solvents. Concentrate 200 mL of solvent mixture (2:2:1, v/v/v, mixture of hexane, benzene and 2-propanol) to about 250 μ L. The concentrated solvent mixture was then analyzed by GC/MS. If there are abnormal contamination peaks found in solvents, it will absolutely not be used for sample extraction.

2.4. CMB Modeling

In the CMB model, the source contributions are computed by determining the best-fit linear combinations of source effluents to reproduce the concentrations of organic tracers measured in the ambient samples. The concentration of chemical species i at receptor site k , c_{ik} , can be expressed as the following linear equation:

$$c_{ik} = \sum_{j=1}^m a_{ij} s_{jk} \quad (1)$$

where a_{ij} is the relative concentration of chemical species i in the fine particle emissions from source j and s_{jk} is the source contribution at receptor site k originating from source j . The equation (1) requires that the mass balance species must be from the m sources included in the model and that no selective loss or gain occurs during transport from the source to the receptor site. In the present study, the CMB analysis was conducted using

the CMB 8.0 software, which was originally developed by Watson et al. (1990). The target for the percent mass explained by the CMB model is $100 \pm 20\%$. Other diagnostics include R^2 (target 0.8 – 1.0), χ^2 (target 0 – 4.0), t-test (target >2.0), degree of freedom (DF, target >5), no cluster sources, and calculated-to-measured ratio for fitting species (C/M, target 0.5 – 2.0) (USEPA, 1987).

The selection criteria for the particle-phase organic tracers in the present study are based on the previous work by Schauer et al. (1996). The list of organic tracers recommended by Schauer et al. (1996) has been extended due to the recent development in the quantification of some molecular-markers such as levoglucosan (Simoneit et al., 1999) and cholesterol (McDonald et al., 2003) in the source testing studies. In the present study, individual organic tracers along with three chemical constituents (EC, silicon and aluminum) were applied in the CMB model to quantify the contribution of up to six primary emission source categories (Table 5). The organic tracers include nine *n*-alkanes (with the number of carbon atom between 25 – 33), seven hopanes and steranes (20S&R-5 α (H),14 β (H),17 β (H)-cholestanes, 20R-5 α (H),14 α (H),17 α (H)-cholestane, 20S&R-5 α (H),14 β (H),17 β (H)-ergostanes, 20S&R-5 α (H),14 β (H),17 β (H)-sitostanes, 22,29,30-trisnorneohopane, 17 α (H),21 β (H)-29-norhopane, and 17 α (H),21 β (H)-hopane), six PAHs (benzo(*b*)fluoranthene, benzo(*k*)fluoranthene, benzo(*e*)pyrene, indeno(1,2,3-*cd*)fluoranthene, indeno(1,2,3-*cd*)pyrene, and benzo(*ghi*)perylene), and three other organic tracers (nonanal, cholesterol, and levoglucosan).

Up to six source emission profiles including emissions from diesel-powered vehicles (Hildemann et al., 1991; Schauer et al., 1999a), combined catalyst and noncatalyst-equipped gasoline powered vehicles (Schauer et al., 2002b), wood combustion (Fine et al., 2002; Fine et al., 2004), paved road dust (Schauer, 1998), meat cooking (Schauer et al., 1999b; McDonald et al., 2003), and vegetative detritus (Rogge

et al., 1993) were used in the present study. The source profile of paved road dust have been reconstructed by Zheng et al. (2002) for the samples from the southeastern United States. The profile of wood combustion was made by combining four individual profiles including one softwood species of loblolly pine (Fine et al., 2002) and three hardwood species of white oak (Fine et al., 2004) , yellow poplar, and sweetgum (Fine et al., 2002), which are dominant wood species in North Carolina. The combination of these profiles was weighted based on the timber output of the above four species in North Carolina in 1999 (Johnson and Brown, 2002).

3. Results

3.1. Evaluation of Blank Samples

In order to evaluate the contamination introduced from the laboratory and the field blanks, the total mass (ng) of each identified organic compound from each sample, including twelve ambient samples, two field blanks, and two laboratory blanks, is shown in Table 6. One hundred and two organic compounds were identified, quantified and reported in this study (Table 7).

n-Alkanes were not found in the laboratory blanks while some *n*-alkanes were found in the field blanks. They are especially abundant in the field blank composite in 2004. Therefore, *n*-alkane concentrations in ambient samples in 2004 presented in Table 7 were based on the blank subtraction from the field blank composite in 2003. The comparison of *n*-alkane concentrations by subtracting different field blanks is shown in Appendix B.

Except for *n*-alkanes, the concentrations of organic compounds in all samples from 2003 in Table 7 were calculated by blank subtraction from the field blank in 2003, while the field blank in 2004 was used for the blank subtraction of ambient samples in 2004.

Some *n*-alkanoic acids with lower carbon number (C₁₄-C₁₈) were found in both

laboratory blanks and field blanks. High mass of *n*-alkenoic acids was found in two field blank composites.

Small amount of aromatic acids and levoglucosan (after silylation) were found in the field blank in 2003 and trace dehydroabiatic acid was detected in the field blank in 2004.

3.2. Chemical Species in PM_{2.5}

3.2.1. OC and EC

Figure 1 shows the distributions of EC and OC concentrations as well as the EC/OC ratios at the four sampling sites in North Carolina. It can be seen that higher concentrations for both EC and OC were found in the winter samples collected from all sites (no winter sample at LE). The concentrations of OC changed slightly in spring and summer across all sites investigated, with all values around 5 $\mu\text{g m}^{-3}$. The average concentration of EC was slightly higher at HI (0.78 $\mu\text{g m}^{-3}$) compared to the average values at GHS (0.66 $\mu\text{g m}^{-3}$) and HA (0.58 $\mu\text{g m}^{-3}$). Higher EC/OC ratios were found at HI in all seasons.

3.2.2. *n*-Alkanes

n-Alkanes exhibited seasonal variations with the highest concentrations in spring (GHS and HI) or winter (HA) and the lowest in summer. Spatial distribution pattern of *n*-alkanes was quite distinct, with the highest level at HI, followed by GHS, and then HA and LE (Figure 2).

3.2.3. Hopanes and Steranes (H+S)

H+S are mainly found in diesel fuel and lubricating oil used in both diesel-powered and gasoline-powered motor vehicles (Cass, 1998). The ratio of H+S to OC can

qualitatively indicate the relative importance of mobile source to OC. The results from previous source tests show that the H+S to EC ratio is 4.6×10^{-4} for diesel-powered vehicle exhaust, and 0.15 for gasoline-powered vehicle exhaust (Schauer et al., 1999a; Schauer et al., 2002b).

Among all samples, the highest H+S concentration was found in the winter samples and the lowest in the summer samples. The highest H+S was measured at HI in all seasons, while comparable levels were found at GHS and HA in the same season, suggesting the impact from mobile source is more significant at HI. The LE spring sample showed comparable H+S concentration to the spring 2004 sample collected at GHS.

The ratios of H+S to OC and H+S to EC are shown in Figure 3. Both ratios had similar distribution patterns. The highest average ratio was found at HI, followed by GHS, and HA. In samples collected in 2003, the highest ratios of H+S to OC and H+S to EC were both found in winter.

3.2.4. Levoglucosan

Levoglucosan, a major constituent of fine particle emissions, has been widely used as a distinct tracer for wood combustion (Simoneit et al., 1999).

Figure 4 shows the distribution of levoglucosan. The highest concentrations were recorded in the winter samples and the lowest in the summer samples. The highest level of levoglucosan was found at HI (148 ng m^{-3} on average), followed by HA (138 ng m^{-3}) and GHS (116 ng m^{-3}). This indicates that wood combustion was more important in winter, especially at HI.

3.2.5. Cholesterol

Cholesterol was detected in emissions from meat cooking and used as a typical tracer

of meat cooking (Rogge et al., 1991).

Seasonal and spatial distributions of cholesterol are shown in Figure 5. The seasonal distribution of cholesterol is different from the pattern of levoglucosan and H+S, which showed a distinct low level in summer and high level in winter at all sites. The highest average value was recorded at HI and HA (0.49 ng m^{-3} on average), followed by GHS (0.30 ng m^{-3}). The cholesterol concentration in the spring 2004 sample at LE was 0.23 ng m^{-3} .

3.2.6. Polycyclic Aromatic Hydrocarbons (PAHs)

PAHs are mainly emitted from incomplete combustion of carbonaceous materials, including fossil fuel and biomass. Spatial and seasonal distributions of PAHs are shown in Figure 6. The highest concentration for total PAHs was found in winter samples at all sites, followed by spring, and then summer samples. The highest average concentration was also found at HI (3.67 ng m^{-3}), followed by GHS (2.54 ng m^{-3}), and then HA (2.18 ng m^{-3}). The spring 2004 sample collected at LE had the highest concentration of total PAHs among all spring samples (3.70 ng m^{-3}).

3.3. Source Contributions to Fine OC in PM_{2.5}

Six sources including diesel exhaust, gasoline exhaust, vegetative detritus, meat cooking, paved road dust, and wood combustion were identified from samples collected at the four sampling sites in North Carolina. The contributions of these sources to fine OC concentrations are presented in Figure 7 and Table 8. For each sample, the sum of contributions from the six sources is defined as “primary OC”. The “other OC” was obtained by subtracting the primary OC concentration from the measured OC concentration.

Among the six emission sources in the 12 ambient samples, wood combustion (2.22 $\mu\text{g m}^{-3}$ on average) was the dominant source of OC, followed by diesel exhaust (0.45 $\mu\text{g m}^{-3}$), meat cooking (0.35 $\mu\text{g m}^{-3}$), gasoline exhaust (0.19 $\mu\text{g m}^{-3}$), paved road dust (0.07 $\mu\text{g m}^{-3}$), and vegetative detritus (0.03 $\mu\text{g m}^{-3}$). The spatial distributions of these six sources will be discussed below.

3.3.1. Garinger High School

The dominant source in Garinger High School samples collected from January 2003 to May 2004 was wood combustion, with an average of 1.91 $\mu\text{g m}^{-3}$ and accounting for 38% of the average OC mass concentration, followed by diesel exhaust (0.44 $\mu\text{g m}^{-3}$ and 9%), meat cooking (0.29 $\mu\text{g m}^{-3}$ and 6%), gasoline exhaust (0.10 $\mu\text{g m}^{-3}$ and 2%), paved road dust (0.08 $\mu\text{g m}^{-3}$ and 2%), and vegetative detritus (0.03 $\mu\text{g m}^{-3}$ and 1%). The “other OC” accounted for 44% of total OC.

The comparison between the spring 2003 and the spring 2004 samples showed a higher level of wood combustion in 2004 (1.66 $\mu\text{g m}^{-3}$ in 2003 vs. 2.46 $\mu\text{g m}^{-3}$ in 2004). The relative importance of other sources in these two samples was different. In the spring 2003 sample, it was diesel exhaust (0.47 $\mu\text{g m}^{-3}$ and 10%), meat cooking (0.21 $\mu\text{g m}^{-3}$ and 4%), paved road dust (0.08 $\mu\text{g m}^{-3}$ and 2%), gasoline exhaust (0.07 $\mu\text{g m}^{-3}$ and 1%), and vegetative detritus (0.03 $\mu\text{g m}^{-3}$ and 0.5%). For the spring 2004 sample, it was diesel exhaust (0.44 $\mu\text{g m}^{-3}$ and 9%), meat cooking (0.42 $\mu\text{g m}^{-3}$ and 8%), gasoline exhaust (0.15 $\mu\text{g m}^{-3}$ and 3%), paved road dust (0.080 $\mu\text{g m}^{-3}$ and 2%), and vegetative detritus (0.051 $\mu\text{g m}^{-3}$ and 1%). The “other OC” from the spring 2003 and 2004 samples accounted for 48% and 27% of OC, respectively.

3.3.2. Hattie Avenue

Wood combustion was the dominant source in samples from HA in 2003, with an average of $2.18 \mu\text{g m}^{-3}$, which explained 45% of OC measured at HA. The second important source was diesel exhaust ($0.51 \mu\text{g m}^{-3}$ and 11%), followed by meat cooking ($0.28 \mu\text{g m}^{-3}$ and 6%), gasoline exhaust ($0.09 \mu\text{g m}^{-3}$ and 2%), paved road dust ($0.07 \mu\text{g m}^{-3}$ and 1%), and vegetative detritus ($0.04 \mu\text{g m}^{-3}$ and 1%).

3.3.3. Hickory

For the samples from HI, the dominant source was also wood combustion, which was $2.57 \mu\text{g m}^{-3}$ on average and accounted for 49% of OC. Other sources, including meat cooking ($0.47 \mu\text{g m}^{-3}$ and 9%), diesel exhaust ($0.45 \mu\text{g m}^{-3}$ and 9%), gasoline exhaust ($0.35 \mu\text{g m}^{-3}$ and 7%), paved road dust ($0.07 \mu\text{g m}^{-3}$ and 1%), and vegetative detritus ($0.03 \mu\text{g m}^{-3}$ and 1%), contributed to 27% of OC measured at HI. Contribution from the “other OC” was about 30%.

When the source contributions to fine OC in PM_{2.5} between the spring 2003 and spring 2004 samples are compared, small variations can be seen for the following sources: diesel exhaust (0.39 vs. $0.35 \mu\text{g m}^{-3}$), and paved road dust (0.07 vs. $0.08 \mu\text{g m}^{-3}$), while the contributions increased in 2004 for gasoline exhaust (0.21 vs. $0.31 \mu\text{g m}^{-3}$) and vegetative detritus (0.02 vs. $0.04 \mu\text{g m}^{-3}$), and decreased for wood combustion (2.05 vs. $1.88 \mu\text{g m}^{-3}$) and meat cooking (0.33 vs. $0.17 \mu\text{g m}^{-3}$).

3.3.4. Lexington

In Lexington, only one sample collected in spring 2004 was analyzed. From the source apportionment result, wood combustion was the primary source ($2.24 \mu\text{g m}^{-3}$ and 45% of OC), followed by diesel exhaust ($0.33 \mu\text{g m}^{-3}$ and 7%), gasoline exhaust ($0.26 \mu\text{g m}^{-3}$ and 5%), meat cooking ($0.25 \mu\text{g m}^{-3}$ and 5%), paved road dust ($0.08 \mu\text{g m}^{-3}$ and 2%),

and vegetative detritus ($0.04 \mu\text{g m}^{-3}$ and 1%). The “other OC” contributed to 36% of OC.

3.4. Source Contributions to PM_{2.5}

With the ratios of OC to total fine particle mass obtained from source tests, the source contributions to PM_{2.5} can be calculated based on the source apportionment results of fine OC. The “Other OM” refers to other organic matter, which is obtained by multiplying the “other OC” by 1.4, a factor widely used to convert organic carbon to organic matter.

The contributions from the six primary sources as well as the secondary sources including secondary sulfate, nitrate, and ammonium to PM_{2.5} are shown in Figure 8 and Table 9. The “Others” represents the difference between the measured PM_{2.5} mass and the sum of the contributions from identified primary and secondary sources.

Higher “Others” and “Other OM” could be found in the summer samples at all sites (GHS, HA, and HI). The contributions from the primary sources identified plus secondary sources accounted for 91 – 108, 94 – 104, 93 – 104, and 83% of the measured PM_{2.5} mass concentration at GHS, HA, HI, and LE, respectively. The importance of the emission sources to PM_{2.5} mass concentration in the descending order is:

- (1) secondary sulfate ($4.00 \pm 1.39 \mu\text{g/m}^3$), wood combustion ($2.01 \pm 1.18 \mu\text{g m}^{-3}$), diesel exhaust ($1.44 \pm 0.52 \mu\text{g m}^{-3}$), secondary ammonium ($1.40 \pm 0.37 \mu\text{g m}^{-3}$), secondary nitrate ($1.01 \pm 0.48 \mu\text{g m}^{-3}$), paved road dust ($0.62 \pm 0.30 \mu\text{g m}^{-3}$), meat cooking ($0.52 \pm 0.20 \mu\text{g m}^{-3}$), gasoline exhaust ($0.12 \pm 0.11 \mu\text{g m}^{-3}$), and vegetative detritus ($0.09 \pm 0.05 \mu\text{g m}^{-3}$) at GHS;
- (2) secondary sulfate ($4.58 \pm 1.92 \mu\text{g m}^{-3}$), wood combustion ($2.29 \pm 1.65 \mu\text{g m}^{-3}$), diesel exhaust ($1.68 \pm 0.56 \mu\text{g m}^{-3}$), secondary ammonium ($1.59 \pm 0.36 \mu\text{g m}^{-3}$), secondary nitrate ($1.03 \pm 0.40 \mu\text{g m}^{-3}$), paved road dust ($0.50 \pm 0.32 \mu\text{g m}^{-3}$), meat cooking ($0.51 \pm 0.19 \mu\text{g m}^{-3}$), gasoline exhaust ($0.11 \pm 0.10 \mu\text{g m}^{-3}$), and vegetative detritus ($0.11 \pm 0.10 \mu\text{g m}^{-3}$) at HA;
- (3) secondary sulfate ($4.22 \pm 1.54 \mu\text{g m}^{-3}$), wood combustion ($2.70 \pm 2.04 \mu\text{g m}^{-3}$),

secondary ammonium ($1.52 \pm 0.31 \mu\text{g m}^{-3}$), diesel exhaust ($1.47 \pm 0.30 \mu\text{g m}^{-3}$), secondary nitrate ($1.17 \pm 0.43 \mu\text{g m}^{-3}$), meat cooking ($0.84 \pm 0.75 \mu\text{g m}^{-3}$), paved road dust ($0.55 \pm 0.39 \mu\text{g m}^{-3}$), gasoline exhaust ($0.43 \pm 0.18 \mu\text{g m}^{-3}$), and vegetative detritus ($0.11 \pm 0.04 \mu\text{g m}^{-3}$) at HI;

(4) secondary sulfate ($4.33 \mu\text{g m}^{-3}$), wood combustion ($2.35 \mu\text{g m}^{-3}$), secondary ammonium ($1.69 \mu\text{g m}^{-3}$), secondary nitrate ($1.40 \mu\text{g m}^{-3}$), diesel exhaust ($1.07 \mu\text{g m}^{-3}$), paved road dust ($0.58 \mu\text{g m}^{-3}$), meat cooking ($0.45 \mu\text{g m}^{-3}$), gasoline exhaust ($0.32 \mu\text{g m}^{-3}$), and vegetative detritus ($0.13 \mu\text{g m}^{-3}$) in the spring 2004 sample collected at LE.

4. Acknowledgements

We would like to thank Prof. James Schauer from the University of Wisconsin-Madison for providing the PM_{2.5} and IS standards, and Bo Wang, Meiyu Dong, and Lin Ke for the assistance in extracting samples and preparing reports. This project is supported by North Carolina Department of Environment and Natural Resources.

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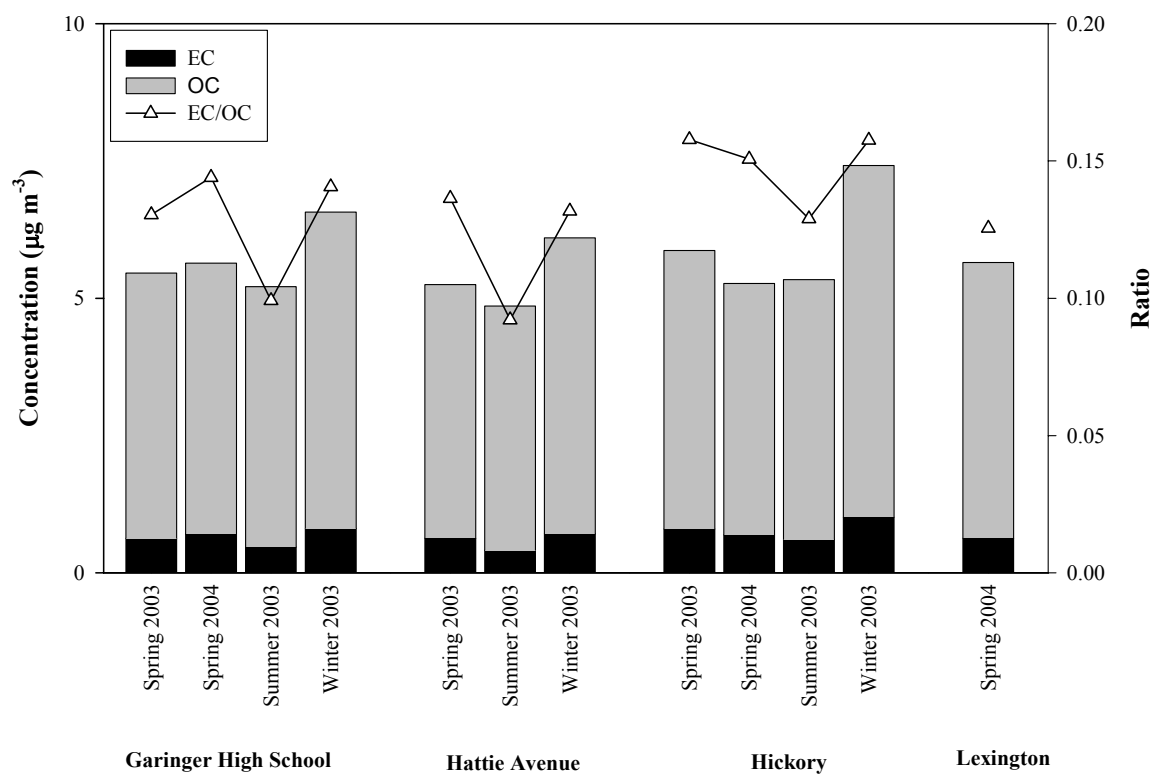


Figure 1. Spatial and seasonal distributions of OC and EC in PM_{2.5} collected at four sites in North Carolina.

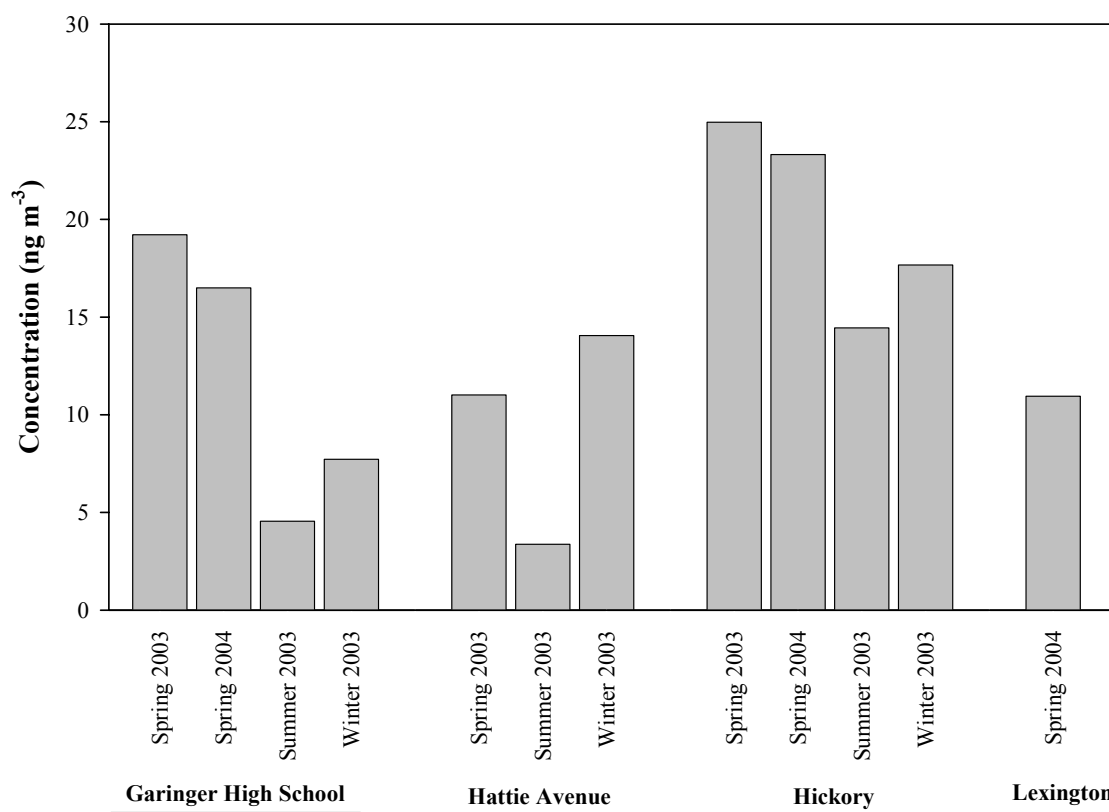


Figure 2. Spatial and seasonal distributions of *n*-alkanes in PM_{2.5} collected from four sites in North Carolina.

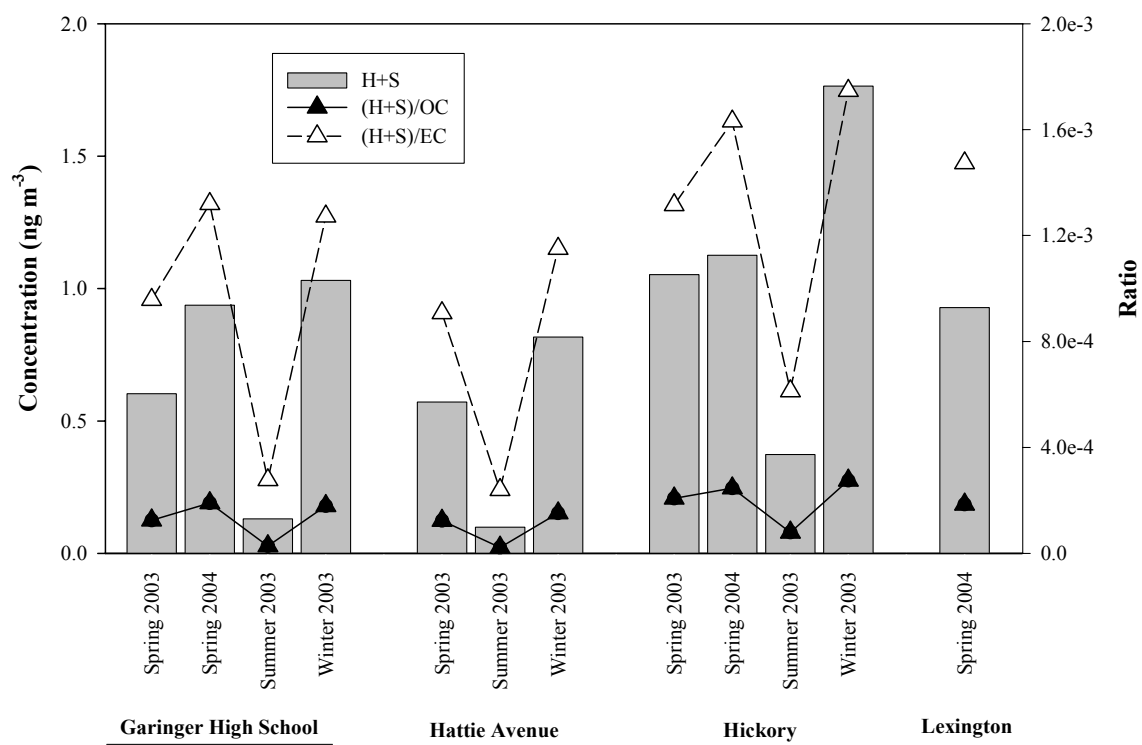


Figure 3. Spatial and seasonal distributions of hopanes and steranes (H+S) in PM_{2.5} collected at four sites in North Carolina.

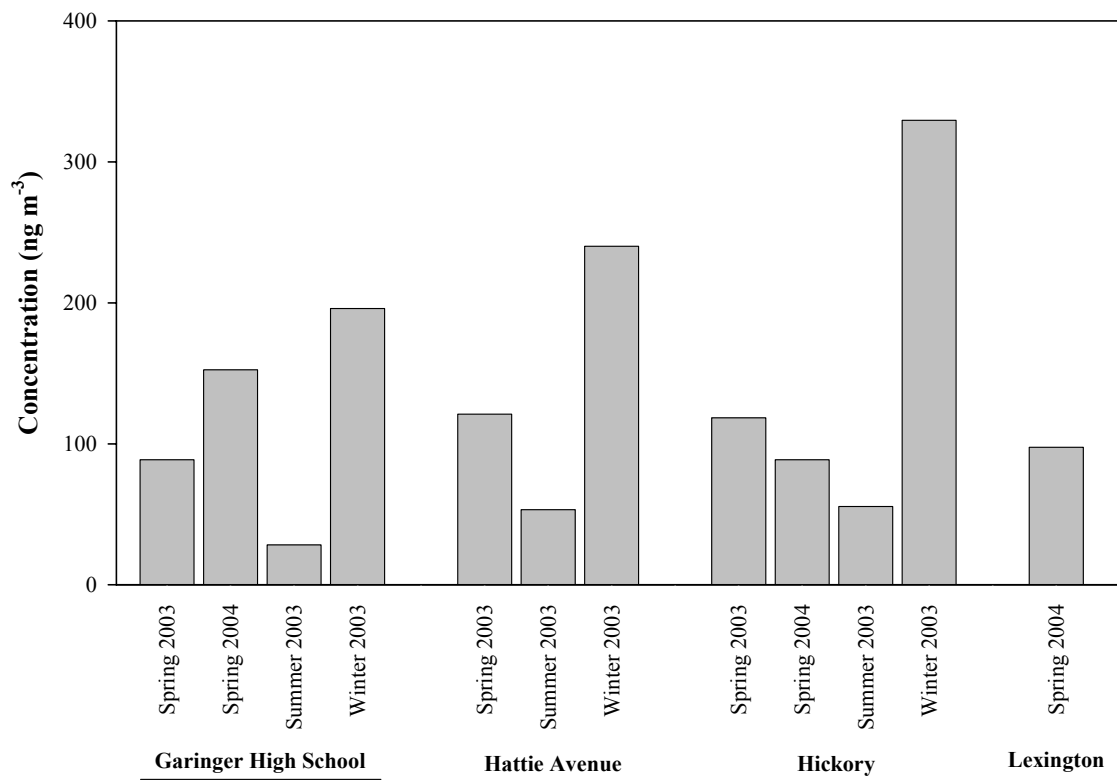


Figure 4. Spatial and seasonal distributions of levoglucosan in PM_{2.5} collected at four sites in North Carolina.

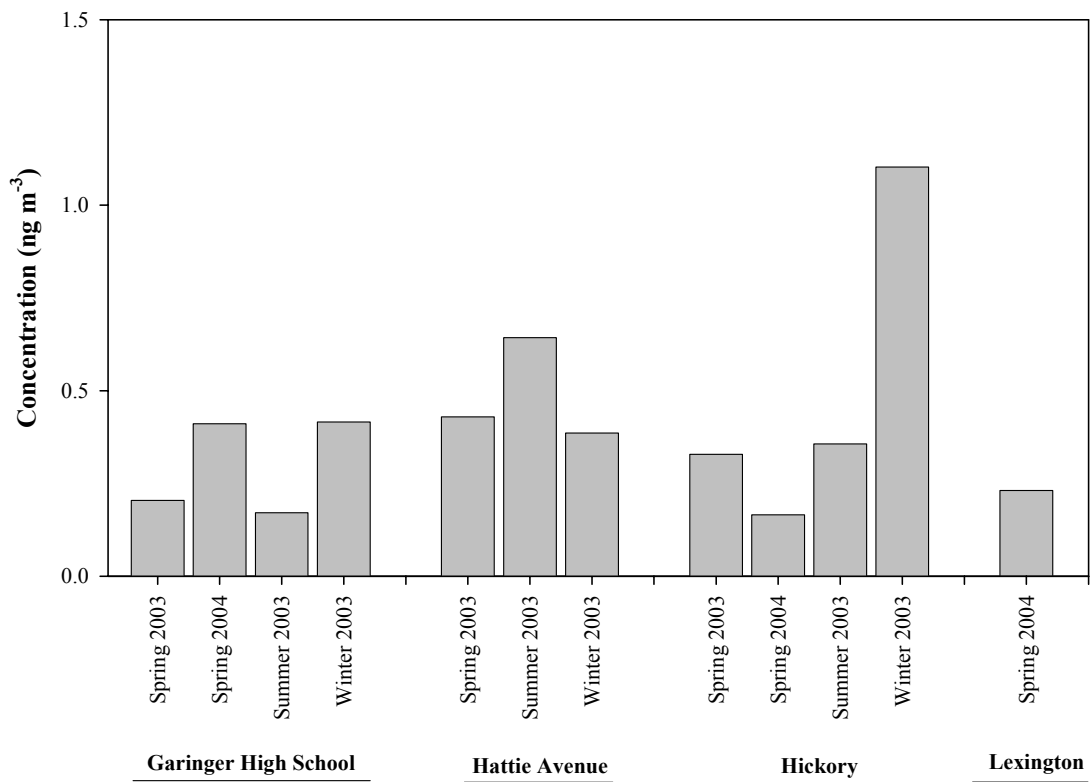


Figure 5. Spatial and seasonal distributions of cholesterol in PM_{2.5} collected at four sites in North Carolina.

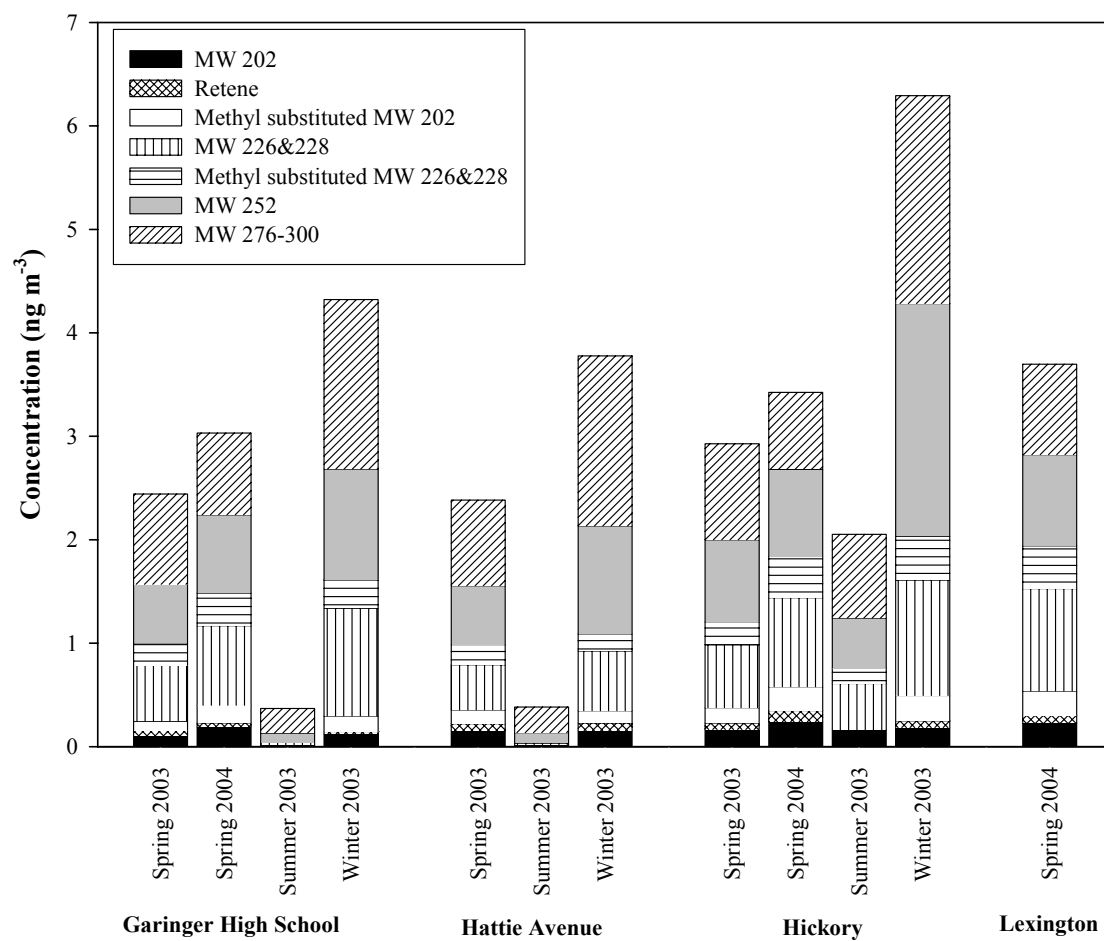


Figure 6. Spatial and seasonal distributions of PAHs in PM_{2.5} collected at four sites in North Carolina.

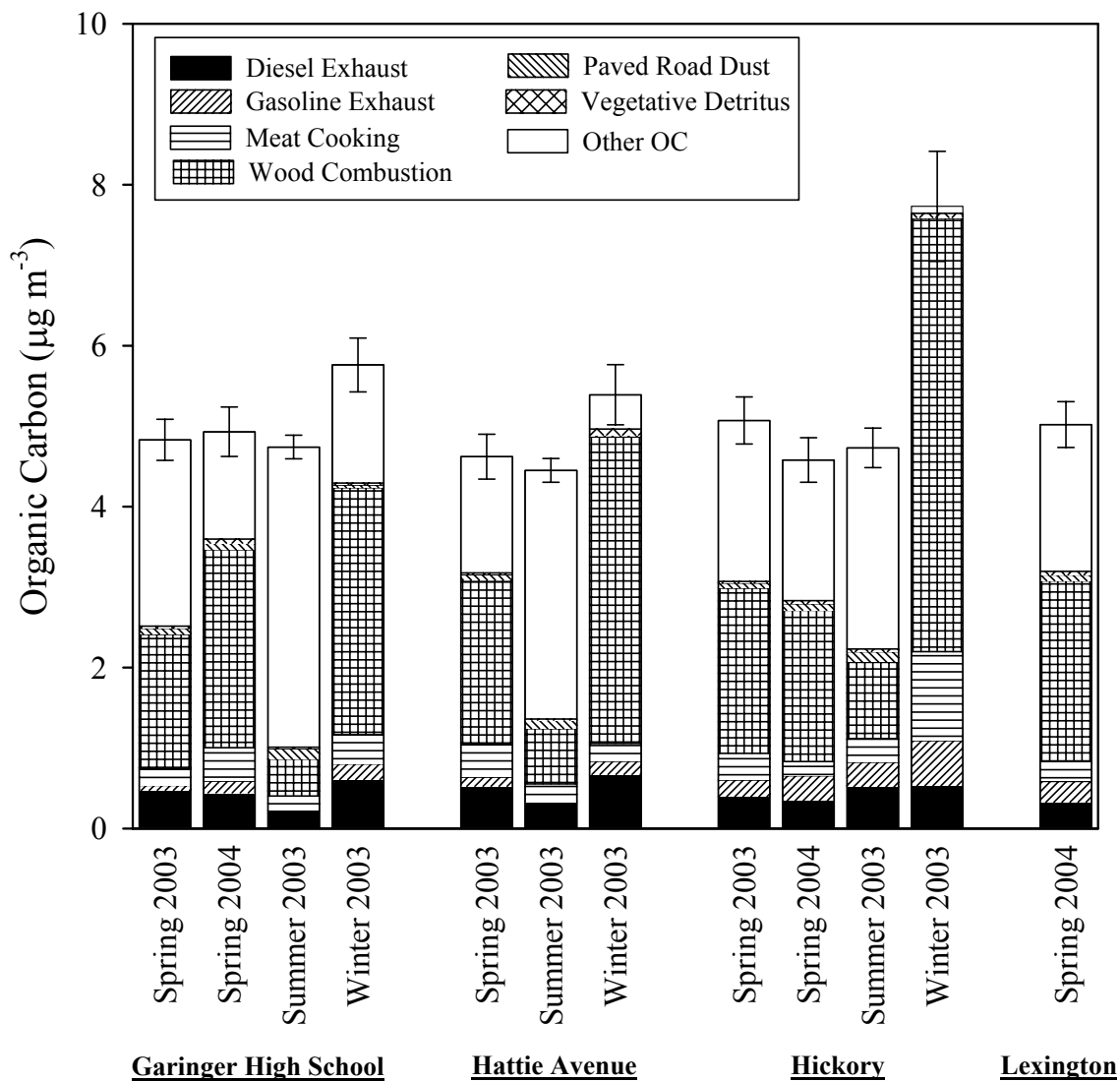


Figure 7. Source contributions to fine organic carbon in PM_{2.5} collected at four sites in North Carolina. The propagated errors of the identified primary sources are shown.

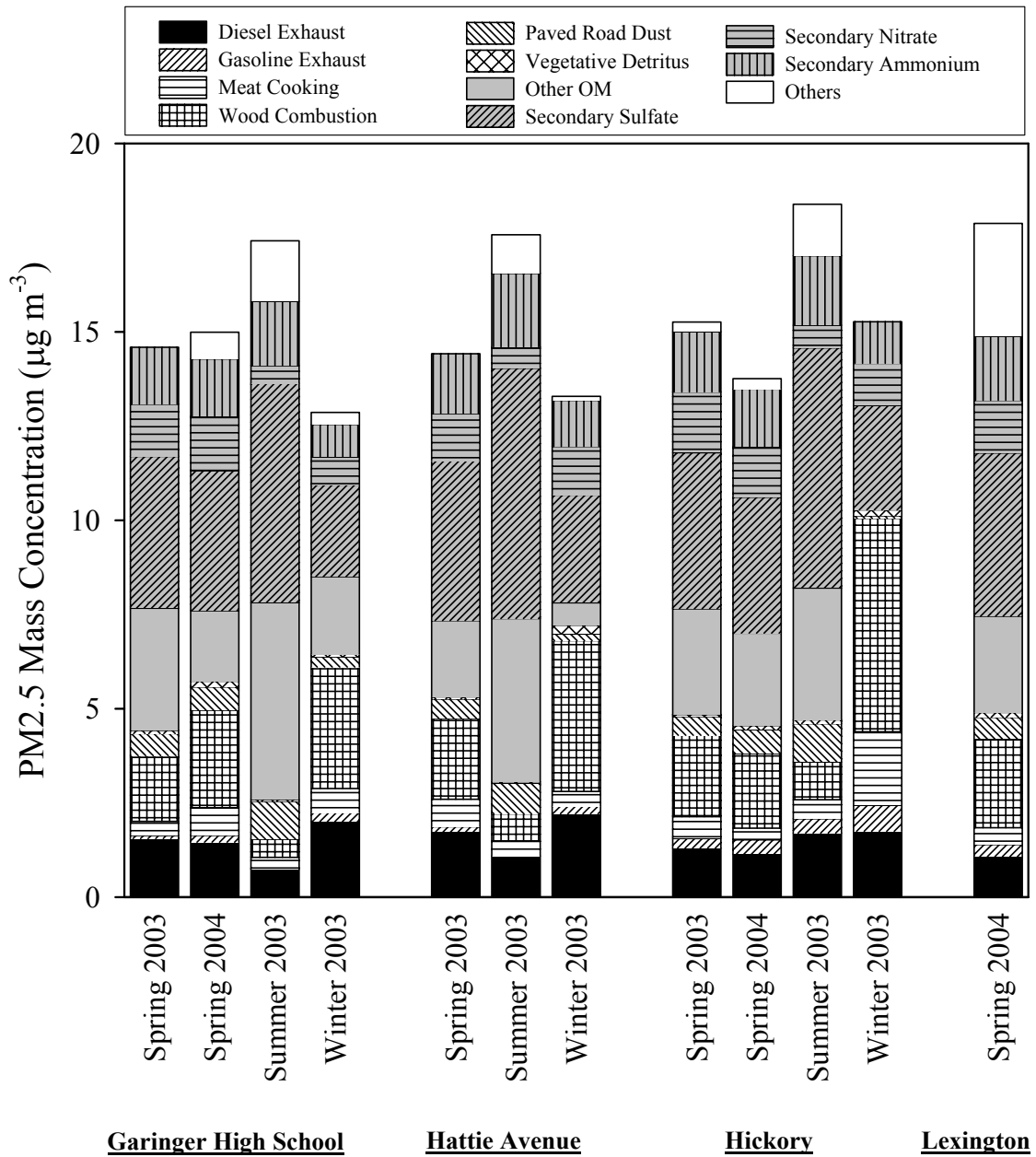


Figure 8. Source contributions to PM2.5 collected at four sites in North Carolina. OM stands for organic matter.

Table 1. Information of ambient samples collected from North Carolina.

Site	Sampling Period	Designated Season	Number of Filters	Total Organic Carbon (μg)
Garinger High School	January 3 to May 30, 2003	Spring	34	1231
Garinger High School	January 1 to May 30, 2004	Spring	42	1545
Garinger High School	June 5 to October 18, 2003	Summer	36	1264
Garinger High School	October 21 to December 26, 2003	Winter	18	753
Hattie Avenue	January 3 to May 27, 2003	Spring	21	724
Hattie Avenue	June 2 to October 18, 2003	Summer	20	649
Hattie Avenue	October 24 to December 29, 2003	Winter	12	481
Hickory	January 3 to May 27, 2003	Spring	23	866
Hickory	January 4 to May 27, 2004	Spring	22	733
Hickory	June 2 to October 18, 2003	Summer	23	809
Hickory	October 24 to December 29, 2003	Winter	10	481
Lexington	January 16 to May 27, 2004	Spring	22	805

Table 2-1. Information of the field blank in 2003 (composite with the following filters).

Sample collection Date	Site	Filter ID (field blank)	Organic Carbon (μg per filter)
20030109	Garinger High School	A224290O	6.7
20030130	Garinger High School	A216720S	14.0
20030226	Garinger High School	A189752S	5.1
20030427	Garinger High School	A2347599	4.7
20030524	Garinger High School	A2527193	5.0
20030626	Garinger High School	A239914M	17.8
20030723	Garinger High School	A251242J	33.1
20030819	Garinger High School	A267033S	12.9
20030921	Garinger High School	A2733457	15.0
20031012	Garinger High School	A263784L	7.6
20030226	Hattie Avenue	A228518S	9.6
20030427	Hattie Avenue	A231640J	13.7
20030626	Hattie Avenue	A229546D	15.3
20030819	Hattie Avenue	A264715C	11.7
20031012	Hattie Avenue	A2730583	9.1
20030109	Hickory	A2203296	14.5
20030226	Hickory	A230918Q	9.2
20030427	Hickory	A231682T	14.6
20030626	Hickory	A234267U	12.8
20030819	Hickory	A255845K	11.8
20031012	Hickory	A277542Q	9.9

Table 2-2. Information of the field blank in 2004 (composite with the following filters).

Sample collection Date	Site	Filter ID (field blank)	Organic Carbon (μg per filter)
20040107	Garinger High School	A2898104	6.78
20040125	Garinger High School	A297799N*	
20040209	Garinger High School	A298301P	7.75
20040307	Garinger High School	A300729E	8.43
20040403	Garinger High School	A282310X	5.71
20040427	Garinger High School	A315620R	12.7
20040506	Garinger High School	A325421R	44.1
20040209	Hickory	A303548N	10.2
20040403	Hickory	A298921B	8.53
20040427	Hickory	A316854B	10.6
20040209	Lexington	A3006097	11.5
20040403	Lexington	A3021807	11.5
20040427	Lexington	A316182U	24.6

Note:

* Trip blank. The measured mass is $8.78 \pm 2.80 \mu\text{g}$.

Table 3. Concentration of the deuterated internal standards (IS#1 and IS#2).

IS	Concentration (ng μL^{-1})
benzaldehyde- <i>d</i> ₆	10.2
dodecane- <i>d</i> ₂₆	10.9
decanoic acid- <i>d</i> ₁₉ methyl ester	4.5
phthalic acid 3,4,5,6- <i>d</i> ₄ methyl ester	4.6
acenaphthene- <i>d</i> ₁₀	2.4
levoglucosan-U- ¹³ C ₆	31.3
hexadecane- <i>d</i> ₃₄	2.4
eicosane- <i>d</i> ₄₂	1.9
heptadecanoic acid- <i>d</i> ₃₃ methyl ester	4.4
4,4'-dimethoxybenzophenone- <i>d</i> ₈	9.6
chrysene- <i>d</i> ₁₂	1.8
octacosane- <i>d</i> ₅₈	4.9
20 <i>R</i> -5 α (<i>H</i>),14 α (<i>H</i>),17 α (<i>H</i>)-cholestane - <i>d</i> ₄	0.4
cholesterol-2,2,3,4,4,6- <i>d</i> ₆	9.9
dibenz(<i>ah</i>)anthracene- <i>d</i> ₁₄	4.8
hexatriacontane- <i>d</i> ₇₄	10.2

Table 4. Concentration of PMSTD#1-#6.

Compound	Concentration (ng μL^{-1})	Compound	Concentration (ng μL^{-1})
PMSTD#1		PMSTD#2	
naphthalene	20.0	decane	20.5
acenaphthylene	40.0	undecane	20.5
acenaphthene	20.0	dodecane	20.5
fluorene	4.0	tridecane	20.5
phenanthrene	2.0	tetradecane	20.5
anthracene	2.0	pentadecane	20.5
fluoranthene	4.0	hexadecane	20.5
pyrene	2.0	heptadecane	20.5
benzo(<i>a</i>)anthracene	2.0	octadecane	20.5
chrysene	2.0	eicosane	20.5
benzo(<i>b</i>)fluoranthene	4.0	tetracosane	20.5
benzo(<i>k</i>)fluoranthene	2.0	octacosane	20.5
benzo(<i>a</i>)pyrene	2.0	dotriacontane	20.5
benzo(<i>ghi</i>)perylene	4.0	hexatriacontane	20.5
indeno(<i>cd</i>)pyrene	2.0	tetracontane	20.5
dibenzo(<i>a,h</i>)anthracene	4.0	tetratetracontane	20.5
bis(2-ethylhexyl)phthalate	20.0	3-methylnonadecane	4.9
butyl benzyl phthalate	20.0	2-methylnonadecane	4.9
diethyl phthalate	20.0	cyclopenta(<i>cd</i>)pyrene	4.9
dimethyl phthalate	20.0	dibenzo(<i>a,e</i>)pyrene	1.0
di- <i>n</i> -butyl phthalate	20.0	pyrene	1.0
di- <i>n</i> -octyl phthalate	20.0	benzo(<i>a</i>)pyrene	9.8
20 <i>R</i> -5 α (<i>H</i>),14 β (<i>H</i>),17 β (<i>H</i>)-cholestane	1.0	methylfluoranthene	1.0
20 <i>R</i> -5 β (<i>H</i>), 14 α (<i>H</i>),17 α (<i>H</i>)-cholestane	1.0	methylchrysene	1.0
20 <i>S</i> -5 α (<i>H</i>), 14 α (<i>H</i>), 17 α (<i>H</i>)-cholestane	1.0	retene	4.9
20 <i>R</i> -5 α (<i>H</i>), 14 α (<i>H</i>), 17 α (<i>H</i>)-cholestane	1.0	anthroquinone	11.8
20 <i>R</i> -5 α (<i>H</i>), 14 β (<i>H</i>), 17 β (<i>H</i>)-ergostane	1.0	9-fluorenone	21.7
20 <i>R</i> -5 α (<i>H</i>), 14 β (<i>H</i>), 17 β (<i>H</i>)-sitostane	1.0	benz(<i>a</i>)anthracene-7,12-dione	20.7
17 α (<i>H</i>)-22,29,30-trisnorhopane	1.0	1,8-naphthalic anhydride	20.4
17 β (<i>H</i>)-21 α (<i>H</i>)-30-norhopane	1.0	squalene	41.4
17 β (<i>H</i>)-21 β (<i>H</i>)-hopane	1.0	triacontane	43.0
17 β (<i>H</i>)-21 α (<i>H</i>)-hopane	1.0	1-octadecene	38.3
17 α (<i>H</i>)-21 β (<i>H</i>)-hopane	1.0		
methylfluorene	10.0	PMSTD#3	
octylcyclohexane	10.0	oxalic acid (C2)	11.8
decylcyclohexane	10.0	malonic acid (C3)	12.7
tridecylcyclohexane	10.0	maleic acid (C4=)	11.6
nonadecylcyclohexane	10.0	fumaric acid (C4=)	12.2
norpristane	10.0	succinic acid (C4)	12.5
pristane	10.0	glutaric acid (C5)	14.8
phytane	10.0	adipic acid (C6)	12.8
coronene	2.5	pimeric acid (C7)	12.9
1-methylnaphthalene	22.4	subiric acid (C8)	12.9
2-methylnaphthalene	24.2	azelaic acid (C9)	11.5
2,6-dimethylnaphthalene	19.2	sebacic acid (C10)	11.7
9-methylanthracene	19.6	phthalic acid (1,2)	12.6
squalane	20.9	iso-phthalic acid (1,3)	13.1

Table 4. (Cont'd)

Compound	Concentration (ng μL^{-1})	Compound	Concentration (ng μL^{-1})
terephthalic acid (1,4)	12.4	octadecamide	8.4
1,2,4-benzenetricarboxylic acid	12.3	1-phenyl-naphthalene	8.9
1,2,4,5-benzenetetracarboxylic acid	12.1		
methylphthalic acid	12.8	PMSTD#6	
hexanoic acid	38.1	dehydroabietic acid	54.6
octanoic acid	37.8	isopimaric acid	57.3
decanoic acid	29.9	pimaric acid	(unknown)
dodecanoic acid	35.0	cholesta-3,5-diene	45.4
tetradecanoic acid	30.7		
hexadecanoic acid	30.0		
octadecanoic acid	23.8		
eicosanoic acid	24.6		
docasanoic acid	24.9		
tetracosanoic acid	28.0		
abietic acid	36.0		
octacosanoic acid	30.3		
triacontanoic acid	29.8		
pinonic acid	45.1		
palmitoleic acid (C16:1)	32.1		
oleic acid (C18:1)	33.7		
linoleic acid (C18:2)	28.7		
linolenic acid	35.9		
PMSTD#4			
levoglucosan	1540		
cholesterol	2000		
stigmasterol	1664		
monopalmitin (C16:1)	310		
monoolein (C18:1)	310		
monostearin (C18:0)	310		
glycerine	1500		
PMSTD#5			
guaiacol	32.8		
2-methoxymethylphenol	46.0		
ethylguaiacol	42.1		
propylguaiacol	39.9		
eugenol	42.2		
acetovanillone	53.9		
3,5-dimethoxy-4-hydroxycinnamaldehyde	19.2		
iso-eugenol	22.7		
vanillin	37.6		
syringaldehyde	35.3		
4-hydroxy-3-methoxycinnamaldehyde	24.1		
3,5-dimethoxyphenol	39.3		
3,5-dimethoxy-4-hydroxyacetophenone	34.3		
dimethoxycoumarin	9.2		
4-methylphenylacetone	10.6		

Table 5. Molecular markers for major sources.

Molecular Markers	Major Urban Sources
pentacosane ^b	gasoline vehicles, diesel vehicles
hexacosane ^b	gasoline vehicles, diesel vehicles
heptacosane ^b	gasoline vehicles, diesel vehicles
octacosane ^a	gasoline vehicles, diesel vehicles
nonacosane ^b	vegetative detritus
triacontane ^b	variety
hentriacontane ^b	vegetative detritus
dotriacontane ^a	variety
triotriacontane ^c	vegetative detritus
20 <i>S,R</i> -5 α (<i>H</i>), 14 β (<i>H</i>), 17 β (<i>H</i>)-cholestanes ^a	gasoline vehicles, diesel vehicles
20R-5 α (<i>H</i>), 14 α (<i>H</i>), 17 α (<i>H</i>)-cholestane ^a	gasoline vehicles, diesel vehicles
20 <i>S,R</i> -5 α (<i>H</i>), 14 β (<i>H</i>), 17 β (<i>H</i>)-ergostanes ^a	gasoline vehicles, diesel vehicles
20 <i>S,R</i> -5 α (<i>H</i>), 14 β (<i>H</i>), 17 β (<i>H</i>)-sitostanes ^a	gasoline vehicles, diesel vehicles
22,29,30-trisnorneohopane ^b	gasoline vehicles, diesel vehicles
17 α (<i>H</i>), 21 β (<i>H</i>)-29-norhopane ^b	gasoline vehicles, diesel vehicles
17 α (<i>H</i>), 21 β (<i>H</i>)-hopane ^a	gasoline vehicles, diesel vehicles
nonanal ^b	meat cooking
cholesterol ^a	meat cooking
levoglucosan ^a	wood combustion
benzo(<i>b</i>)fluoranthene ^a	wood combustion, gasoline vehicles
benzo(<i>k</i>)fluoranthene ^a	wood combustion, gasoline vehicles
benzo(<i>e</i>)pyrene ^c	wood combustion, gasoline vehicles
indeno(<i>cd</i>)fluoranthene ^c	wood combustion, gasoline vehicles
indeno(<i>cd</i>)pyrene ^c	wood combustion, gasoline vehicles
benzo(<i>ghi</i>)perylene ^c	wood combustion, gasoline vehicles
elemental carbon	diesel exhaust
aluminum	crustal material
silicon	crustal material

Note:

^a Identified and quantified by using authentic standard (PMSTD, IS#1, and IS#2);

^b Identified by using mass spectra and quantified using authentic standard with similar structure and retention time;

^c Identified by using secondary standards (picene standard, wood smoke standard, and wax extraction) and quantified using authentic standard with similar structure and retention time.

Table 6. Total mass of organic compounds extracted from the samples, the field blanks, and the laboratory blanks (ng).

					Garinger High School				Hattie Avenue			Hickory				Lexington
	Lab blank1 ^a	Lab blank2 ^b	Filed blank1 ^c	Field blank2 ^d	Spring -2003	Spring -2004	Summer -2003	Winter -2003	Spring -2003	Summer -2003	Winter -2003	Spring -2003	Spring -2004	Summer -2003	Winter -2003	Spring -2004
<i>n</i>-Alkanes																
heptadecane	0	0	17	19	46	70	19	20	42	17	25	40	42	48	15	48
octadecane	0	0	0	0	0	0	0	0	0	0	13	21	54	0	0	0
nonadecane	0	0	11	13	52	336	0	14	32	30	26	58	168	39	19	186
eicosane	0	0	18	0	1195	322	251	30	299	41	29	706	91	144	30	63
heneicosane	0	0	21	0	1170	342	195	53	307	29	31	726	131	159	45	86
docosane	0	0	18	28	947	299	191	65	253	29	40	639	142	143	54	90
tricosane	0	0	24	41	345	328	75	83	163	44	78	278	228	163	84	156
tetracosane	0	0	34	41	125	485	56	81	86	19	98	142	280	125	104	217
pentacosane	0	0	15	48	163	307	65	92	89	46	111	165	255	278	136	122
hexacosane	0	0	0	64	120	227	43	69	82	32	90	105	238	210	131	64
heptacosane	0	0	0	96	190	343	102	110	121	64	152	192	321	338	197	121
octacosane	0	0	0	115	151	349	99	81	81	55	84	183	250	256	142	85
nonacosane	0	0	0	91	257	407	160	165	133	90	227	913	1167	351	200	167
triacontane	0	0	0	76	96	237	38	55	50	28	79	73	110	106	66	72
hentriacontane	0	0	0	54	160	411	100	136	86	59	167	98	189	171	106	166
dotriacontane	0	0	0	47	53	171	26	50	30	22	44	38	0	73	35	48
tritriacontane	0	0	0	0	62	193	41	21	32	22	50	37	68	59	39	63
tetracontane	0	0	0	0	36	132	0	25	0	0	0	23	0	0	0	0
pentatriacontane	0	0	0	0	0	209	0	0	0	0	0	0	0	0	0	0
Branched alkanes																
isononacosane	0	0	0	0	0	0	47	0	0	0	0	0	0	0	0	0
anteisotriacontane	0	0	0	0	42	45	32	38	0	0	0	0	0	0	0	0
isohentriacontane	0	0	0	0	31	53	27	37	22	16	33	0	0	0	0	0
Hopanes and Steranes																
17 α (H)-21 β (H)-29-norhopane	0	0	0	0	18	39	7	22	19	7	11	23	23	11	20	27
17 α (H)-21 β (H)-hopane	0	0	0	0	22	37	9	31	19	7	15	23	27	14	22	26
22,29,30-trisnorhopane	0	0	0	0	5	14	0	0	0	0	5	9	0	0	0	12
22,29,30-trisnorhopane	0	0	0	0	0	14	0	0	0	0	0	5	0	0	0	0
22S,17 α (H),21 β (H)-homohopane	0	0	0	0	13	34	6	12	12	0	11	15	15	8	12	15

					Garinger High School				Hattie Avenue			Hickory				Lexington
	Lab blank1	Lab blank2	Filed blank1	Field blank2	Spring -2003	Spring -2004	Summer -2003	Winter -2003	Spring -2003	Summer -2003	Winter -2003	Spring -2003	Spring -2004	Summer -2003	Winter -2003	Spring -2004
Hopanes and Steranes																
22R,17 α (H),21 β (H)-homohopane	0	0	0	0	13	20	7	9	10	0	8	11	15	6	10	12
22S,17 α (H),21 β (H)-bishomohopane	0	0	0	0	7	13	5	8	7	0	6	8	13	0	11	0
22R,17 α (H),21 β (H)-bishomohopane	0	0	0	0	6	15	0	7	0	0	9	7	8	0	8	0
22S,17 α (H),21 β (H)-trishomohopane	0	0	0	0	8	11	0	0	0	0	0	8	9	0	0	0
22R,17 α (H),21 β (H)-trishomohopane	0	0	0	0	5	9	0	0	0	0	0	0	12	0	0	0
20S,R-5 α (H),14 β (H),17 β (H)-cholestanes	0	0	0	0	14	30	0	11	9	0	0	22	17	12	20	19
20R-5 α (H),14 α (H),17 α (H)-cholestane	0	0	0	0	9	14	0	10	11	0	0	19	23	11	13	20
20S,R-5 α (H),14 β (H),17 β (H)-ergostanes	0	0	0	0	10	12	0	9	0	0	0	7	0	0	0	0
20S,R-5 α (H),14 β (H),17 β (H)-sitostanes	0	0	0	0	17	30	0	15	0	0	7	18	18	0	13	19
n-Alkanoic acids																
tetradecanoic acid	15	27	425	171	483	662	594	197	355	540	213	279	270	987	190	372
pentadecanoic acid	9	15	225	118	235	336	246	100	147	255	119	153	125	494	107	178
hexadecanoic acid	56	95	2269	910	3867	3883	2808	1468	1909	1789	1764	2103	1698	5376	1298	2367
heptadecanoic acid	0	4	78	36	133	136	91	56	70	63	62	80	56	179	44	76
octadecanoic acid	25	31	916	405	1688	1575	1255	668	716	635	681	889	620	2131	450	747
nonadecanoic acid	0	0	0	0	31	37	18	16	15	11	19	17	17	40	13	19
eicosanoic acid	0	0	0	0	105	123	62	58	55	39	82	64	62	139	49	64
heneicosanoic acid	0	0	0	0	47	60	17	33	23	12	40	25	25	41	22	30
docosanoic acid	0	0	0	0	209	274	74	141	107	53	179	127	129	200	102	138
tricosanoic acid	0	0	0	0	104	153	34	77	49	23	90	59	61	82	53	73
tetracosanoic acid	0	0	0	0	504	747	141	414	230	92	380	261	286	312	210	364
pentacosanoic acid	0	0	0	0	52	75	22	36	25	14	40	29	28	50	24	35
hexacosanoic acid	0	0	0	0	248	360	69	212	108	43	200	126	129	150	112	156
heptacosanoic acid	0	0	0	0	25	34	14	14	11	8	24	16	13	34	13	15
octacosanoic acid	0	0	0	0	95	133	62	62	49	34	130	66	51	132	76	61
nonacosanoic acid	0	0	0	0	16	26	10	9	6	5	16	12	11	21	10	9
triacontanoic acid	0	0	0	0	93	123	68	56	41	33	132	69	45	133	82	49

					Garinger High School				Hattie Avenue			Hickory				Lexington
	Lab blank1	Lab blank2	Filed blank1	Field blank2	Spring -2003	Spring -2004	Summer -2003	Winter -2003	Spring -2003	Summer -2003	Winter -2003	Spring -2003	Spring -2004	Summer -2003	Winter -2003	Spring -2004
<i>n</i>-Alkenoic acids																
9-hexadecenoic acid	0	0	272	177	74	151	52	74	126	100	98	54	54	272	132	99
9,12-octadecanedienoic acid	0	0	164	9	0	169	0	0	0	0	0	0	39	0	0	77
9-octadecenoic acid	0	21	253	115	0	318	196	158	243	98	75	0	84	261	131	112
Alkanedioic acids																
butanedioic acid	0	0	0	0	460	300	0	0	406	0	56	387	138	1496	27	435
methyl butanedioic acid	0	0	0	0	119	112	27	0	88	0	19	86	49	274	13	102
pentanedioic acid	0	0	0	0	237	220	65	17	163	0	31	171	113	646	22	227
hexanedioic acid	0	0	0	0	159	158	45	0	67	15	0	63	42	165	9	91
heptanedioic acid	0	0	0	0	41	51	0	0	35	11	0	40	91	85	10	176
octanedioic acid	0	0	0	0	104	112	68	0	56	36	86	68	88	211	30	100
nonanedioic acid	0	0	0	0	260	340	114	17	141	66	111	174	182	399	104	279
Aromatic acids																
1,2-benzenedicarboxylic acid	0	0	8	0	123	259	15	4	97	5	11	105	18	340	8	63
1,4-benzenedicarboxylic acid	0	0	4	0	79	114	21	4	77	14	84	86	90	228	46	93
1,3-benzenedicarboxylic acid	0	0	0	0	20	28	4	2	16	3	7	21	17	45	6	24
Resin acids																
pimaric acid	0	0	0	0	11	17	0	5	6	0	8	9	6	0	5	11
sandaracopimaric acid	0	0	0	0	32	42	0	27	20	4	20	22	26	13	14	24
isopimaric acid	0	0	0	0	69	42	0	26	25	0	0	28	34	0	0	55
dehydroabietic acid	0	0	0	22	646	978	137	418	581	119	739	710	871	463	518	618
abietic acid	0	0	0	0	21	18	0	11	11	0	0	18	14	0	0	13
abieta-6,8,11,13,15-pentae-18-oic acid	0	0	0	0	12	12	0	0	0	0	0	10	7	0	0	10
abieta-8,11,13,15-tetraen-18-oic acid	0	0	0	0	11	17	1	8	6	2	7	8	9	5	6	8
7-oxodehydroabietic acid	0	0	0	10	229	409	114	102	145	92	235	181	253	422	134	218

					Garinger High School				Hattie Avenue			Hickory				Lexington
	Lab blank1	Lab blank2	Filed blank1	Field blank2	Spring -2003	Spring -2004	Summer -2003	Winter -2003	Spring -2003	Summer -2003	Winter -2003	Spring -2003	Spring -2004	Summer -2003	Winter -2003	Spring -2004
PAHs																
fluoranthene	0	0	0	0	14	26	2	7	11	2	6	12	16	10	7	16
acephenanthrylene	0	0	0	0	0	6	0	2	2	0	0	2	4	10	0	3
pyrene	0	0	0	0	13	27	2	7	11	1	8	14	19	8	7	17
retene	0	0	0	0	13	13	0	3	11	0	7	11	17	0	5	12
methyl-substituted MW 202 PAH	0	0	0	0	23	53	0	20	21	0	10	25	37	0	18	38
benzo(<i>ghi</i>)fluoranthene	0	0	0	0	17	22	2	12	10	0	6	15	14	8	8	15
cyclopenta(<i>cd</i>)pyrene	0	0	0	0	83	152	0	95	37	0	26	56	82	46	43	96
benz(<i>a</i>)anthracene	0	0	0	0	17	24	2	14	8	0	8	13	14	9	11	16
chrysene/triphenylene	0	0	0	0	21	43	3	17	13	2	11	20	29	13	21	31
methyl-substituted MW 228 PAH	0	0	0	0	32	52	0	21	16	0	7	18	31	13	14	27
methyl-substituted MW 226 PAH	0	0	0	0	24	47	0	15	15	0	8	20	32	13	18	39
benzo(<i>b</i>)fluoranthene	0	0	0	0	35	60	6	38	24	4	24	36	43	27	58	36
benzo(<i>k</i>)fluoranthene	0	0	0	0	29	52	4	24	20	3	21	24	26	12	29	33
benzo(<i>j</i>)fluoranthene	0	0	0	0	4	8	0	5	2	0	2	3	3	0	2	6
benzo(<i>e</i>)pyrene	0	0	0	0	44	66	10	41	26	6	30	51	40	35	57	38
benzo(<i>a</i>)pyrene	0	0	0	0	27	42	4	27	13	2	12	18	19	8	17	23
perylene	0	0	0	0	7	10	0	6	3	0	4	4	4	0	5	7
indeno(<i>cd</i>)fluoranthene	0	0	0	0	15	24	4	14	11	0	11	11	8	8	9	15
indeno(<i>cd</i>)pyrene	0	0	0	0	44	59	10	42	28	8	33	32	32	23	39	36
benzo(<i>ghi</i>)perylene	0	0	0	0	72	8	20	72	42	10	45	52	3	46	53	4
picene	0	0	0	0	3	92	0	5	2	0	0	3	43	0	4	46
coronene	0	0	0	0	89	65	30	82	53	18	57	60	33	62	45	39
Other compounds																
levoglucosan	0	0	74	0	22786	47766	7691	25887	19024	7838	21463	20303	27769	9558	24759	30576
acetonysyringol	0	0	0	0	1231	789	0	308	324	0	245	361	211	0	110	341
propionysyringol	0	0	0	0	0	138	0	38	0	0	0	0	0	0	0	0
benz(<i>de</i>)anthracen-7-one	0	0	0	0	278	485	0	259	183	0	180	220	257	87	136	277
cholesterol	0	0	0	0	50	129	46	55	67	94	34	56	52	61	83	72
nonanal	0	0	0	0	402	623	296	214	290	114	79	274	139	218	60	199

Note:

^a Lab blank1: analyzed in the first batch (samples collected in 2003); ^b Lab blank2: analyzed in the second batch (samples in collected in 2004); ^c Field blank1: the field blank composite in 2003; ^d Field blank2: the field blank composite in 2004.

Table 7. Concentrations of organic compounds in PM_{2.5} collected at four sites in North Carolina (ng m⁻³)^a

	Garinger High School				Hattie Avenue			Hickory				Lexington
	Spring -2003	Spring ^b -2004	Summer -2003	Winter -2003	Spring -2003	Summer -2003	Winter -2003	Spring -2003	Spring ^b -2004	Summer -2003	Winter -2003	Spring ^b -2004
<i>n</i>-Alkanes												
heptadecane	0.07	0.11		0.04	0.16	0.01	0.17	0.12	0.15	0.15	0.08	0.19
octadecane							0.15	0.12	0.34			
nonadecane	0.13	1.00			0.13	0.14	0.22	0.27	0.98	0.14	0.18	1.09
eicosane	4.56	0.91	0.82	0.11	1.79	0.16	0.21	4.02	0.45	0.71	0.29	0.28
heneicosane	4.44	0.96	0.59	0.27	1.82	0.07	0.22	4.12	0.69	0.78	0.47	0.41
docosane	3.59	0.84	0.60	0.38	1.50	0.08	0.33	3.62	0.77	0.70	0.60	0.45
tricosane	1.20	0.89	0.13	0.48	0.89	0.15	0.72	1.47	1.27	0.78	0.96	0.82
tetracosane	0.28	1.33		0.40	0.34		0.89	0.64	1.54	0.52	1.17	1.15
pentacosane	0.54	0.88	0.15	0.60	0.47	0.22	1.15	0.87	1.50	1.51	1.71	0.67
hexacosane	0.47	0.72	0.16	0.52	0.52	0.22	1.01	0.62	1.49	1.23	1.74	0.40
heptacosane	0.75	1.09	0.38	0.83	0.77	0.44	1.70	1.12	2.01	1.98	2.63	0.76
octacosane	0.59	1.11	0.37	0.61	0.52	0.38	0.95	1.07	1.56	1.50	1.89	0.53
nonacosane	1.01	1.30	0.60	1.25	0.85	0.62	2.54	5.34	7.29	2.06	2.67	1.04
triacontane	0.37	0.76	0.14	0.42	0.32	0.19	0.89	0.43	0.69	0.62	0.89	0.45
hentriacontane	0.63	1.31	0.37	1.03	0.55	0.40	1.87	0.57	1.18	1.00	1.42	1.04
dotriacontane	0.21	0.55	0.10	0.38	0.19	0.15	0.49	0.22	0.35	0.43	0.47	0.30
tritriacontane	0.24	0.62	0.15	0.16	0.20	0.15	0.56	0.22	0.42	0.35	0.52	0.39
tetratriacontane	0.14	0.42		0.19				0.14				
pentatriacontane		0.67										
Sum of <i>n</i>-Alkanes	19.21	15.48	4.56	7.67	11.02	3.37	14.05	24.98	22.67	14.45	17.67	9.96
Branched alkanes												
isononacosane			0.18									
anteisotriacontane	0.17	0.14	0.12	0.29								
isohentriacontane	0.12	0.17	0.10	0.28	0.14	0.11	0.37					
Sum of Branched Alkanes	0.29	0.31	0.40	0.57	0.14	0.11	0.37	0.00	0.00	0.00	0.00	0.00
Hopanes and Steranes												
17 α (H)-21 β (H)-29-norhopane	0.07	0.12	0.03	0.17	0.12	0.05	0.13	0.13	0.14	0.06	0.27	0.17
17 α (H)-21 β (H)-hopane	0.09	0.12	0.03	0.23	0.12	0.05	0.17	0.14	0.17	0.08	0.29	0.16
22,29,30-trisnorhopane	0.02	0.05					0.05	0.06				0.08
22,29,30-trisnorhopane		0.05						0.03				
22S,17 α (H),21 β (H)-homohopane	0.05	0.11	0.02	0.09	0.08		0.12	0.09	0.09	0.04	0.17	0.09

Table 7. (Cont'd)	Garinger High School				Hattie Avenue			Hickory				Lexington
	Spring -2003	Spring -2004	Summer -2003	Winter -2003	Spring -2003	Summer -2003	Winter -2003	Spring -2003	Spring -2004	Summer -2003	Winter -2003	Spring -2004
Hopanes and Steranes												
22 <i>R</i> ,17 <i>α</i> (<i>H</i>),21 <i>β</i> (<i>H</i>)-homohopane	0.05	0.06	0.03	0.07	0.07		0.09	0.06	0.10	0.04	0.13	0.08
22 <i>S</i> ,17 <i>α</i> (<i>H</i>),21 <i>β</i> (<i>H</i>)-bishomohopane	0.03	0.04	0.02	0.06	0.05		0.07	0.05	0.08		0.15	
22 <i>R</i> ,17 <i>α</i> (<i>H</i>),21 <i>β</i> (<i>H</i>)-bishomohopane	0.02	0.05		0.05			0.10	0.04	0.05		0.10	
22 <i>S</i> ,17 <i>α</i> (<i>H</i>),21 <i>β</i> (<i>H</i>)-trishomohopane	0.03	0.04						0.05	0.06			
22 <i>R</i> ,17 <i>α</i> (<i>H</i>),21 <i>β</i> (<i>H</i>)-trishomohopane	0.02	0.03							0.07			
20 <i>S</i> , <i>R</i> -5 <i>α</i> (<i>H</i>),14 <i>β</i> (<i>H</i>),17 <i>β</i> (<i>H</i>)-cholestanes	0.06	0.10		0.09	0.06			0.14	0.11	0.08	0.29	0.12
20 <i>R</i> -5 <i>α</i> (<i>H</i>),14 <i>α</i> (<i>H</i>),17 <i>α</i> (<i>H</i>)-cholestane	0.04	0.04		0.08	0.08			0.12	0.14	0.07	0.19	0.12
20 <i>S</i> , <i>R</i> -5 <i>α</i> (<i>H</i>),14 <i>β</i> (<i>H</i>),17 <i>β</i> (<i>H</i>)-ergostanes	0.04	0.04		0.07				0.05				
20 <i>S</i> , <i>R</i> -5 <i>α</i> (<i>H</i>),14 <i>β</i> (<i>H</i>),17 <i>β</i> (<i>H</i>)-sitostanes	0.07	0.10		0.12			0.09	0.11	0.11		0.18	0.12
Sum of Hopanes and Steranes	0.60	0.94	0.13	1.03	0.57	0.10	0.82	1.05	1.13	0.37	1.76	0.93
<i>n</i>-Alkanoic acids												
tetradecanoic acid		0.32				1.04 ^c				3.07 ^c		0.49
pentadecanoic acid						0.34 ^c				1.46 ^c		
hexadecanoic acid	0.85 ^c	2.85 ^c					5.40 ^c		0.86	17.03 ^c	2.84 ^c	5.04
heptadecanoic acid	0.03 ^c	0.05 ^c					0.20 ^c			0.55 ^c	0.09 ^c	0.09
octadecanoic acid	0.84	0.78					1.83 ^c			6.64 ^c	0.15 ^c	0.33
nonadecanoic acid	0.12	0.12	0.07	0.12	0.10	0.08	0.21	0.10	0.11	0.23	0.17	0.12
eicosanoic acid	0.41	0.39	0.23	0.44	0.35	0.27	0.92	0.37	0.39	0.82	0.66	0.40
heneicosanoic acid	0.18	0.19	0.06	0.25	0.15	0.08	0.44	0.15	0.16	0.24	0.29	0.19
docosanoic acid	0.82	0.88	0.28	1.07	0.68	0.37	2.00	0.74	0.81	1.17	1.36	0.86
tricosanoic acid	0.41	0.49	0.13	0.58	0.31	0.16	1.01	0.35	0.38	0.48	0.70	0.46
tetracosanoic acid	1.97	2.38	0.53	3.14	1.47	0.63	4.26	1.53	1.79	1.83	2.80	2.27
pentacosanoic acid	0.21	0.24	0.08	0.27	0.16	0.10	0.45	0.17	0.17	0.30	0.32	0.22
hexacosanoic acid	0.97	1.15	0.26	1.61	0.69	0.30	2.25	0.74	0.81	0.88	1.49	0.98
heptacosanoic acid	0.10	0.11	0.05	0.11	0.07	0.06	0.27	0.09	0.08	0.20	0.18	0.09
octacosanoic acid	0.37	0.42	0.23	0.47	0.31	0.24	1.46	0.39	0.32	0.77	1.01	0.38
nonacosanoic acid	0.06	0.08	0.04	0.07	0.04	0.03	0.18	0.07	0.07	0.12	0.13	0.06
triacontanoic acid	0.37	0.39	0.25	0.42	0.26	0.23	1.48	0.41	0.28	0.78	1.10	0.30
Sum of <i>n</i>-Alkanoic Acids	7.70	10.84	2.21	8.55	4.59	3.90	22.36	5.10	6.23	36.58	13.29	12.26

Table 7. (Cont'd)	Garinger High School				Hattie Avenue			Hickory				Lexington
	Spring -2003	Spring -2004	Summer -2003	Winter -2003	Spring -2003	Summer -2003	Winter -2003	Spring -2003	Spring -2004	Summer -2003	Winter -2003	Spring -2004
<i>n</i>-Alkenoic acids												
9-hexadecenoic acid											0.03	
9,12-octadecanedienoic acid		0.44						0.14				0.38
9-octadecenoic acid											0.13	
Sum of <i>n</i>-Alkenoic Acids	0.00	0.44	0.00	0.00	0.00	0.00	0.00	0.00	0.14	0.00	0.16	0.38
Alkanedioic acids												
butanedioic acid	1.80	0.96			2.59		0.63	2.27	0.86	8.75	0.37	2.72
methyl butanedioic acid	0.46	0.36	0.10		0.56		0.21	0.51	0.31	1.60	0.17	0.64
pentanedioic acid	0.93	0.70	0.24	0.13	1.04		0.35	1.00	0.71	3.78	0.29	1.42
hexanedioic acid	0.62	0.50	0.17		0.43	0.11		0.37	0.26	0.96	0.12	0.57
heptanedioic acid	0.16	0.16			0.22	0.08		0.23	0.57	0.50	0.14	1.10
octanedioic acid	0.40	0.36	0.25		0.36	0.25	0.97	0.40	0.55	1.24	0.40	0.62
nonanedioic acid	1.02	1.08	0.43	0.13	0.90	0.45	1.25	1.02	1.14	2.34	1.39	1.74
Sum of Alkanedioic Acids	5.40	4.12	1.19	0.26	6.11	0.89	3.40	5.79	4.40	19.18	2.88	8.81
Aromatic acids												
1,2-benzenedicarboxylic acid	0.43	0.83			0.56		0.07	0.56	0.11	1.93	0.05	0.39
1,4-benzenedicarboxylic acid	0.28	0.36	0.06	0.01	0.47	0.07	0.92	0.48	0.56	1.31	0.59	0.58
1,3-benzenedicarboxylic acid	0.08	0.09	0.02	0.01	0.10	0.02	0.08	0.12	0.11	0.26	0.08	0.15
Sum of Aromatic Acids	0.79	1.28	0.08	0.02	1.13	0.09	1.07	1.16	0.78	3.50	0.72	1.12
Resin acids												
pimaric acid	0.04	0.06		0.04	0.04		0.09	0.05	0.04		0.06	0.07
sandaracopimaric acid	0.12	0.13		0.21	0.13	0.03	0.22	0.13	0.16	0.08	0.18	0.15
isopimaric acid	0.27	0.14		0.20	0.16			0.16	0.21			0.34
dehydroabietic acid	2.53	3.12	0.51	3.17	3.71	0.82	8.28	4.16	5.44	2.71	6.91	3.86
abietic acid	0.08	0.06		0.08	0.07			0.10	0.09			0.08
abieta-6,8,11,13,15-pentae-18-oic acid	0.05	0.04		0	0			0.06	0.04			0.06
abieta-8,11,13,15-tetraen-18-oic acid	0.04	0.05		0.06	0.04	0.01	0.08	0.05	0.06	0.03	0.07	0.05
7-oxodehydroabietic acid	0.90	1.31	0.43	0.77	0.93	0.63	2.64	1.06	1.58	2.47	1.78	1.36
Sum of Resin Acids	4.03	4.90	0.94	4.54	5.10	1.49	11.31	5.77	7.61	5.28	9.01	5.97

Table 7. (Cont'd)	Garinger High School				Hattie Avenue			Hickory				Lexington
	Spring -2003	Spring -2004	Summer -2003	Winter -2003	Spring -2003	Summer -2003	Winter -2003	Spring -2003	Spring -2004	Summer -2003	Winter -2003	Spring -2004
PAHs												
fluoranthene	0.05	0.08	0.01	0.05	0.07	0.01	0.07	0.07	0.10	0.06	0.09	0.10
acephenanthrylene		0.02		0.02	0.01			0.01	0.02	0.06		0.02
pyrene	0.05	0.09	0.01	0.05	0.07	0.01	0.09	0.08	0.12	0.05	0.09	0.11
retene	0.05	0.04		0.03	0.07		0.07	0.06	0.11		0.06	0.08
methyl-substituted MW 202 PAH	0.09	0.17		0.15	0.13		0.12	0.15	0.23		0.24	0.23
benzo(<i>ghi</i>)fluoranthene	0.07	0.07	0.01	0.09	0.06		0.07	0.09	0.09	0.05	0.11	0.10
cyclopenta(<i>cd</i>)pyrene	0.32	0.48		0.72	0.24		0.29	0.33	0.51	0.27	0.58	0.60
benz(<i>a</i>)anthracene	0.07	0.08	0.01	0.11	0.05		0.09	0.08	0.09	0.05	0.15	0.10
chrysene/triphenylene	0.08	0.14	0.01	0.13	0.08	0.01	0.13	0.12	0.18	0.08	0.28	0.19
methyl-substituted MW 228 PAH	0.12	0.17		0.16	0.10		0.08	0.10	0.20	0.07	0.18	0.17
methyl-substituted MW 226 PAH	0.09	0.15		0.12	0.09		0.09	0.12	0.20	0.07	0.24	0.25
benzo(<i>b</i>)fluoranthene	0.14	0.19	0.02	0.29	0.16	0.02	0.27	0.21	0.27	0.16	0.77	0.22
benzo(<i>k</i>)fluoranthene	0.11	0.17	0.02	0.18	0.13	0.02	0.24	0.14	0.16	0.07	0.39	0.20
benzo(<i>j</i>)fluoranthene	0.02	0.02		0.04	0.01		0.03	0.02	0.02		0.03	0.03
benzo(<i>e</i>)pyrene	0.17	0.21	0.04	0.31	0.17	0.04	0.34	0.30	0.25	0.21	0.76	0.23
benzo(<i>a</i>)pyrene	0.10	0.13	0.01	0.20	0.08	0.02	0.13	0.10	0.12	0.05	0.23	0.14
perylene	0.03	0.03		0.05	0.02		0.04	0.02	0.03		0.07	0.04
indeno(<i>cd</i>)fluoranthene	0.06	0.08	0.01	0.11	0.07		0.12	0.07	0.05	0.05	0.12	0.09
indeno(<i>cd</i>)pyrene	0.17	0.19	0.04	0.32	0.18	0.05	0.37	0.19	0.20	0.13	0.51	0.23
benzo(<i>ghi</i>)perylene	0.28	0.29	0.07	0.55	0.27	0.07	0.51	0.30	0.27	0.27	0.71	0.29
picene		0.02		0.04				0.02	0.02		0.06	0.02
coronene	0.35	0.21	0.11	0.62	0.30	0.12	0.64	0.35	0.21	0.37	0.60	0.24
Sum of PAHs	2.43	3.03	0.37	4.32	2.37	0.38	3.78	2.93	3.42	2.05	6.29	3.70
Other compounds												
levoglucosan ^d	89	152	28	196	121	53	240	118	89	55	329	98
acetonylsyringol	4.82	2.52		2.34	2.07		2.75	2.11	1.32		1.47	2.13
propionylsyringol		0.44		0.29								
benz(<i>de</i>)anthracen-7-one	1.09	1.55		1.96	1.17		2.02	1.29	1.60	0.51	1.81	1.73
cholesterol ^d	0.20	0.41	0.17	0.42	0.43	0.64	0.39	0.33	0.17	0.36	1.10	0.23
nonanal	1.57	1.99	1.10	1.63	1.85	0.78	0.89	1.60	0.87	1.27	0.79	1.24
Sum of Other Compounds	96.7	159	29.3	203	127	54.4	246	123	93.0	57.1	334	103

Note:

^a The concentrations were obtained after the field blank subtraction; ^b For samples collected in spring 2004 from Garinger High School, Hickory, and Lexington, the quantification of *n*-alkanes was obtained by subtracting the mass of the field blank in 2003; ^c The values are different from those in the Progress Report submitted on September 1, 2004 due to incorrect blank subtraction; ^d The quantification is based on the results from silylated extracts.

Table 8. Source contributions from primary emissions to organic carbon mass concentrations in PM_{2.5} collected at four sites in North Carolina ($\mu\text{g m}^{-3}$)

Site Name	County	Sampling Time	Measured OC	Diesel Exhaust	Gasoline Exhaust	Vegetative Detritus	Meat Cooking	Paved Road Dust	Wood Combustion	Other OC	Primary OC	R ²	χ^2	% Mass Explained	DF
Garinger High School	Mecklenburg	Spring 2003	4.83±0.52	0.47±0.13	0.06±0.04	0.027±0.004	0.21±0.10	0.076±0.011	1.66±0.22	2.32	2.51	0.85	2.75	52	19
Garinger High School	Mecklenburg	Spring 2004	4.93±0.53	0.44±0.18	0.15±0.06	0.051±0.008	0.42±0.10	0.080±0.014	2.46±0.30	1.33	3.60	0.89	1.95	73	19
Garinger High School	Mecklenburg	Summer 2003	4.74±0.51	0.22±0.03		0.016±0.002	0.18±0.08	0.131±0.015	0.46±0.08	3.73	1.01	0.87	2.51	21	14
Garinger High School	Mecklenburg	Winter 2003	5.76±0.62	0.61±0.18	0.20±0.07	0.023±0.004	0.36±0.09	0.035±0.008	3.07±0.40	1.47	4.29	0.89	2.09	75	18
Hattie Avenue	Forsyth	Spring 2003	4.62±0.52	0.53±0.15	0.11±0.05	0.019±0.003	0.41±0.10	0.068±0.012	2.04±0.25	1.45	3.17	0.89	2.15	69	17
Hattie Avenue	Forsyth	Summer 2003	4.45±0.50	0.33±0.04		0.014±0.002	0.22±0.05	0.106±0.014	0.69±0.10	3.09	1.36	0.87	2.62	31	14
Hattie Avenue	Forsyth	Winter 2003	5.39±0.61	0.67±0.23	0.16±0.09	0.075±0.012	0.22±0.05	0.023±0.011	3.81±0.47	0.43	4.96	0.79	3.75	92	18
Hickory	Catawba	Spring 2003	5.07±0.53	0.39±0.17	0.21±0.06	0.018±0.004	0.33±0.08	0.065±0.010	2.05±0.28	2.00	3.07	0.86	2.72	61	17
Hickory	Catawba	Spring 2004	4.58±0.48	0.35±0.16	0.31±0.06	0.035±0.007	0.17±0.04	0.083±0.012	1.88±0.27	1.75	2.83	0.84	3.46	62	15
Hickory	Catawba	Summer 2003	4.73±0.50	0.52±0.16	0.31±0.06	0.033±0.006	0.28±0.07	0.133±0.018	0.95±0.16	2.50	2.23	0.87	3.32	47	12
Hickory	Catawba	Winter 2003	6.41±0.67	0.53±0.25	0.56±0.11	0.051±0.009	1.10±0.52	0.009±0.008	5.39±0.74	0.00	7.64	0.83	3.42	119	14
Lexington	Davidson	Spring 2004	5.02±0.55	0.33±0.15	0.26±0.06	0.041±0.006	0.25±0.06	0.076±0.012	2.24±0.30	1.83	3.19	0.89	2.14	64	19

Table 9. Source contributions from primary emissions to PM2.5 collected at four sites in North Carolina ($\mu\text{g m}^{-3}$)

Site Name	County	Sampling Time	Diesel Exhaust	Gasoline Exhaust	Vegetative Detritus	Meat Cooking	Paved Road Dust	Wood Combustion	Other OM	Secondary Sulfate	Secondary Nitrate	Secondary Ammonium	Identified PM2.5 Mass	Measured PM2.5 Mass	Others	% Mass
Garinger High School	Mecklenburg	Spring 2003	1.55	0.08	0.08	0.37	0.58	1.75	3.24	4.03	1.39	1.51	14.6	13.5	0.0	108
Garinger High School	Mecklenburg	Spring 2004	1.46	0.18	0.16	0.74	0.62	2.59	1.87	3.72	1.45	1.52	14.3	15.0	0.7	95
Garinger High School	Mecklenburg	Summer 2003	0.74		0.05	0.32	1.00	0.48	5.22	5.82	0.47	1.70	15.8	17.4	1.6	91
Garinger High School	Mecklenburg	Winter 2003	2.00	0.24	0.07	0.64	0.27	3.23	2.06	2.44	0.74	0.87	12.5	12.9	0.3	97
Hattie Avenue	Forsyth	Spring 2003	1.73	0.14	0.06	0.73	0.52	2.14	2.02	4.24	1.25	1.59	14.4	13.9	0.0	104
Hattie Avenue	Forsyth	Summer 2003	1.09		0.04	0.40	0.81	0.72	4.33	6.64	0.57	1.95	16.5	17.6	1.0	94
Hattie Avenue	Forsyth	Winter 2003	2.21	0.20	0.23	0.39	0.18	4.00	0.60	2.86	1.29	1.22	13.2	13.3	0.1	99
Hickory	Catawba	Spring 2003	1.30	0.26	0.05	0.58	0.50	2.16	2.80	4.14	1.61	1.60	15.0	15.3	0.3	98
Hickory	Catawba	Spring 2004	1.14	0.38	0.11	0.31	0.64	1.98	2.45	3.61	1.34	1.53	13.5	13.8	0.3	98
Hickory	Catawba	Summer 2003	1.70	0.38	0.10	0.50	1.02	1.00	3.50	6.37	0.60	1.84	17.0	18.4	1.4	93
Hickory	Catawba	Winter 2003	1.75	0.69	0.16	1.95	0.07	5.66	0.00	2.77	1.12	1.10	15.3	14.7	0.0	104
Lexington	Davidson	Spring 2004	1.07	0.32	0.13	0.45	0.58	2.35	2.56	4.33	1.40	1.69	14.9	17.9	3.0	83

Appendix A

Comparison of PAH concentrations (ng m^{-3}) quantified by different internal standards. Samples were collected from Garinger High School, Hattie Avenue, and Hickory in 2003.

	Garinger High School			Hattie Avenue			Hickory		
	Spring 2003	Summer 2003	Winter 2003	Spring 2003	Summer 2003	Winter 2003	Spring 2003	Summer 2003	Winter 2003
benzo(<i>b</i>)fluoranthene	0.14 ^a (0.23 ^b)	0.02 (0.04)	0.29 (0.46)	0.16 (0.25)	0.02 (0.04)	0.27 (0.44)	0.21 (0.34)	0.16 (0.27)	0.77 (1.23)
benzo(<i>k</i>)fluoranthene	0.11 (0.12)	0.02 (0.02)	0.18 (0.19)	0.13 (0.13)	0.02 (0.02)	0.24 (0.25)	0.14 (0.15)	0.07 (0.08)	0.39 (0.39)
benzo(<i>j</i>)fluoranthene	0.02 (0.02)		0.04 (0.04)	0.01 (0.01)		0.03 (0.03)	0.02 (0.02)		0.03 (0.03)
benzo(<i>e</i>)pyrene	0.17 (0.20)	0.04 (0.04)	0.31 (0.35)	0.17 (0.19)	0.04 (0.05)	0.34 (0.40)	0.30 (0.34)	0.21 (0.25)	0.76 (0.86)
benzo(<i>a</i>)pyrene	0.10 (0.12)	0.01 (0.02)	0.20 (0.23)	0.08 (0.10)	0.02 (0.02)	0.13 (0.16)	0.10 (0.12)	0.05 (0.06)	0.23 (0.26)
perylene	0.03 (0.03)		0.05 (0.05)	0.02 (0.02)		0.04 (0.05)	0.02 (0.03)		0.07 (0.07)
indeno(<i>cd</i>)fluoranthene	0.06 (0.07)	0.01 (0.02)	0.11 (0.12)	0.07 (0.08)		0.12 (0.14)	0.07 (0.08)	0.05 (0.05)	0.12 (0.14)
indeno(<i>cd</i>)pyrene	0.17 (0.20)	0.04 (0.05)	0.32 (0.36)	0.18 (0.20)	0.05 (0.06)	0.37 (0.44)	0.19 (0.22)	0.13 (0.16)	0.51 (0.58)
benzo(<i>ghi</i>)perylene	0.28 (0.38)	0.07 (0.10)	0.55 (0.71)	0.27 (0.35)	0.07 (0.09)	0.51 (0.69)	0.30 (0.40)	0.27 (0.37)	0.71 (0.92)
picene			0.04 (0.05)				0.02 (0.02)		0.06 (0.06)
coronene	0.35 (0.35)	0.11 (0.11)	0.62 (0.60)	0.30 (0.30)	0.12 (0.12)	0.64 (0.65)	0.35 (0.35)	0.37 (0.38)	0.60 (0.58)

Note:

^a Quantified by the internal standard of dibenz(*ah*)anthracene-*d*₁₄;

^b Quantified by the internal standard of chrysene-*d*₁₂ (in the Progress Report submitted on September 1, 2004).

Appendix B

Comparison of *n*-alkane concentrations (ng m⁻³) in the spring 2004 samples by subtracting different field blanks.

Compounds	Garinger High School		Hickory		Lexington	
	Subtraction field blank in 2003	Subtraction field blank in 2004	Subtraction field blank in 2003	Subtraction field blank in 2004	Subtraction field blank in 2003	Subtraction field blank in 2004
<i>n</i>-Alkanes						
heptadecane	0.11	0.02	0.15	0.07	0.19	0.10
octadecane		0.00	0.34	0.34		
nonadecane	1.00	0.93	0.98	0.91	1.09	1.03
eicosane	0.91	1.03	0.45	0.57	0.28	0.39
heneicosane	0.96	1.09	0.69	0.82	0.41	0.54
docosane	0.84	0.66	0.77	0.60	0.45	0.28
tricosane	0.89	0.62	1.27	1.00	0.82	0.55
tetracosane	1.33	1.12	1.54	1.32	1.15	0.93
pentacosane	0.88	0.48	1.50	1.10	0.67	0.27
hexacosane	0.72	0.06	1.49	0.83	0.40	NA ^a
heptacosane	1.09	0.08	2.01	1.02	0.76	NA
octacosane	1.11	NA	1.56	0.38	0.53	NA
nonacosane	1.30	0.34	7.29	6.35	1.04	0.11
triacontane	0.76	NA	0.69	NA	0.45	NA
hentriacontane	1.31	0.75	1.18	0.63	1.04	0.49
dotriacontane	0.55	0.06	0.35	NA	0.30	NA
tritriacontane	0.62	0.62	0.42	0.42	0.39	0.39
tetratriacontane	0.42	0.42				
pentatriacontane	0.67	0.67				

Note:

^a Negative value after field blank subtraction.

Appendix C

Corrigenda for the concentrations (ng m^{-3}) of *n*-tetracosane, cholesterol, and levoglucosan listed in Table 7 in the Progress Report submitted on September 1, 2004.

Sample Name	<i>n</i> -tetracosane		cholesterol		levoglucosan	
	Original ^a	Corrected	Original	Corrected	Original	Corrected
GHS-spring-2003	NA ^b	0.28	0.21	0.20	96	89
GHS-summer-2003			0.19	0.17	31	28
GHS-winter-2003	0.09	0.40	0.45	0.42	213	196
Hattie Avenue-spring-2003	0.02	0.34	0.47	0.43	131	121
Hattie Avenue- summer-2003			0.70	0.64	58	53
Hattie Avenue-winter-2003	0.57	0.89	0.42	0.39	261	240
Hickory-spring-2003	0.30	0.64	0.36	0.33	128	118
Hickory-summer-2003	0.12	0.52	0.39	0.36	60	55
Hickory-winter-2003	0.85	1.17	1.20	1.10	357	329

Note:

^a Data in the Progress Report submitted on September 1, 2004;

^b Negative value after field blank subtraction.