3.0 URBAN EXCESS METHODOLOGY

Urban PM2.5 originates from local and regional (upwind) emission sources. This chapter describes the concept of urban excess, a measure of the local contribution to urban PM2.5. These contributions can be characterized according to the major chemical components of PM2.5 (sulfates, nitrates, carbon and crustal matter) and differentiated according to their local and regional contributions. EPA used urban excess numbers to estimate the relative contributions of different pollutant emissions within a given nonattainment area. The application of the urban excess methodology to develop a "weighted emissions score" for each county assessed in the designations process is described in detail in Chapter 4 of this Technical Support Document. This chapter introduces the concept of urban excess, discusses uncertainties, and describes the associated site selection process.

3.1 Concept

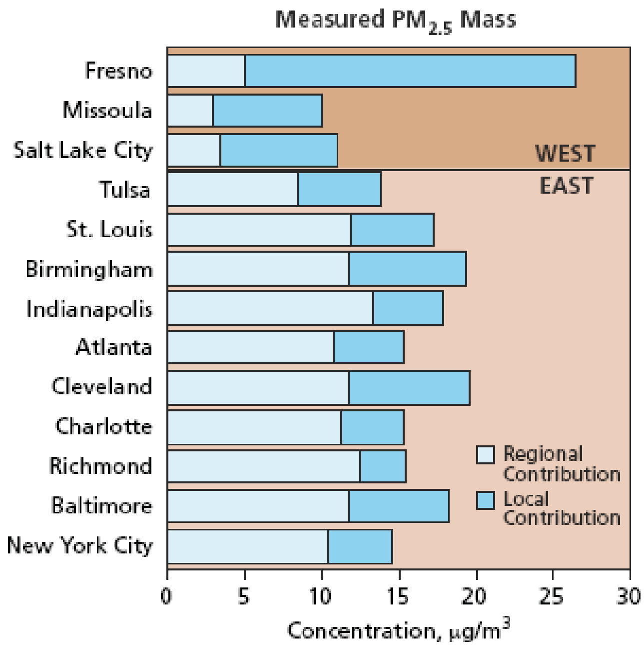
Both local and regional sources contribute to particle pollution. Figure 3.1 shows how much of the PM2.5 mass can be generally attributed to local versus regional sources for 13 selected urban areas arranged west to east. In each of these urban areas, a monitoring site was paired with a nearby rural site. The data were derived from the national speciation monitoring networks, the speciation trends network (STN) and the IMPROVE (Interagency Monitoring of Protected Visual Environments) network. Local and regional contributions to PM mass can be estimated by subtracting the rural concentration from the measured urban concentration.

Assuming that the rural concentrations represent the regional background concentration, this difference for each species was defined as urban excess:

Urban Excess = Urban Concentration (from urban EPA network) – Regional Background (from rural IMPROVE network) (Equation 1)

In the East, regional pollution generally contributes more than half of total PM2.5 concentrations. Rural background PM2.5 concentrations are high in the East and are somewhat uniform over large geographic areas. These regional concentrations come from emission sources such as power plants, urban pollution and natural sources, and can be transported hundreds of miles.

Figure 3.1. Urban excess PM2.5 for 13 Cities



Note: Urban and nearby rural $PM_{2.5}$ concentrations suggest substantial regional contributions to fine particles in the East. The measured $PM_{2.5}$ mass is not necessarily the maximum for each urban area.

As an example, and as used in EPA's recently released Particle Pollution Report[1], the regional and local contribution to PM2.5 mass for 13 cities are shown above using data for the year 2002. For the selected cities shown in Figure 3.1, local contributions range from 2 to 20 $\mu g/m^3$, with the West generally showing larger local contributions than the East. In the East, local contributions are greatest in cities with the highest annual average $PM_{2.5}$ concentrations. For these illustrations, the PM2.5 concentration is not necessarily the maximum concentration for each urban area.

Rural PM2.5 concentrations do not vary as significantly as urban concentrations. Accordingly, urban excess concentrations typically do not change significantly when an urban site is paired with multiple rural monitors. Rural concentrations of the major components of PM2.5 are spatially homogenous. The regional pattern of annual average concentrations of sulfates, nitrates and carbonaceous mass for 2002 are illustrated below.

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[1] U.S. EPA, The Particle Pollution Report, EPA 454-R-04-002, EPA Office of Air Quality Planning and Standards, Research Triangle Park, NC, December 2004.

Figure 3.2 Rural sulfate concentrations.

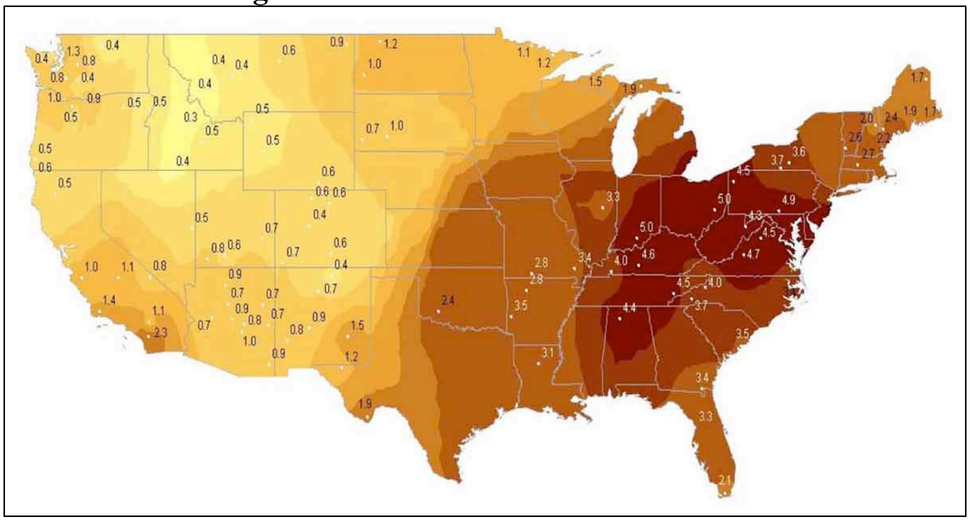


Figure 3.3. Rural nitrate concentrations.

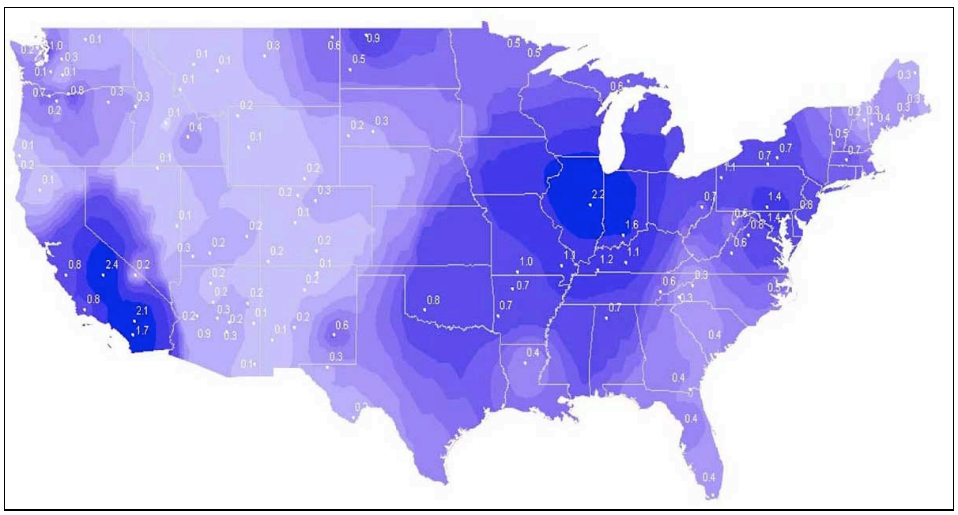
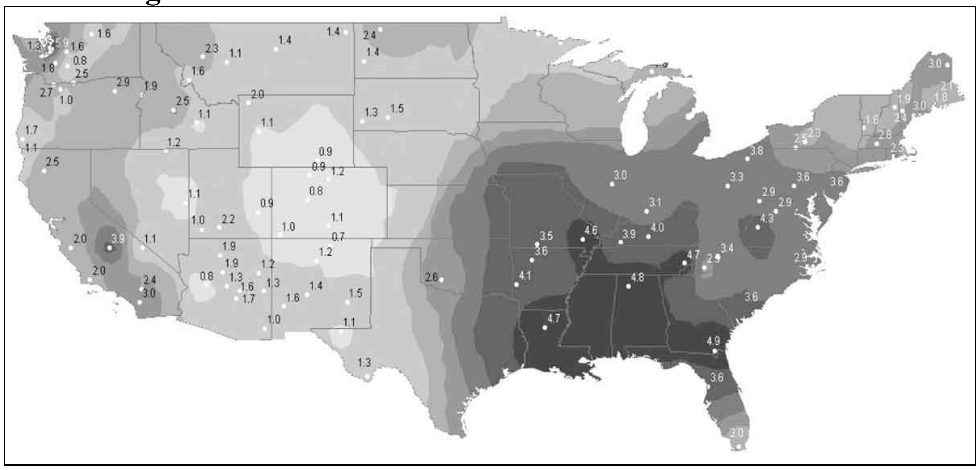
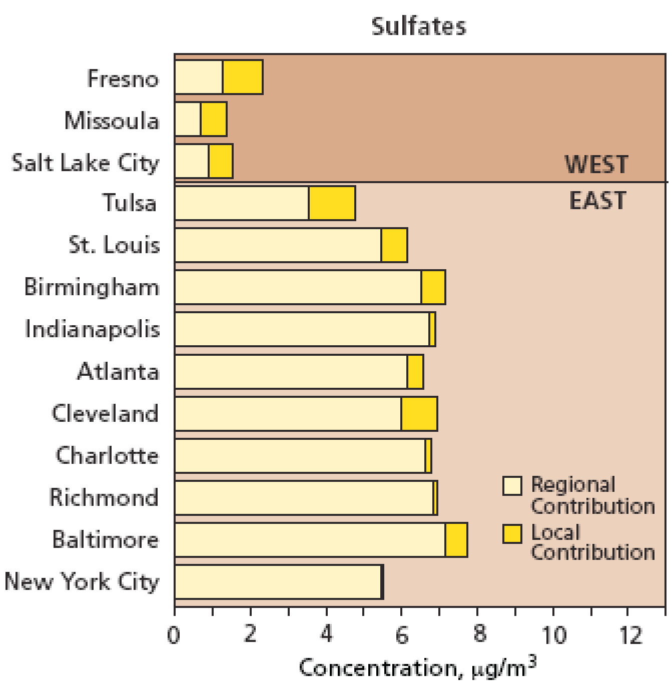


Figure 3.4. Rural total carbonaceous mass concentrations.



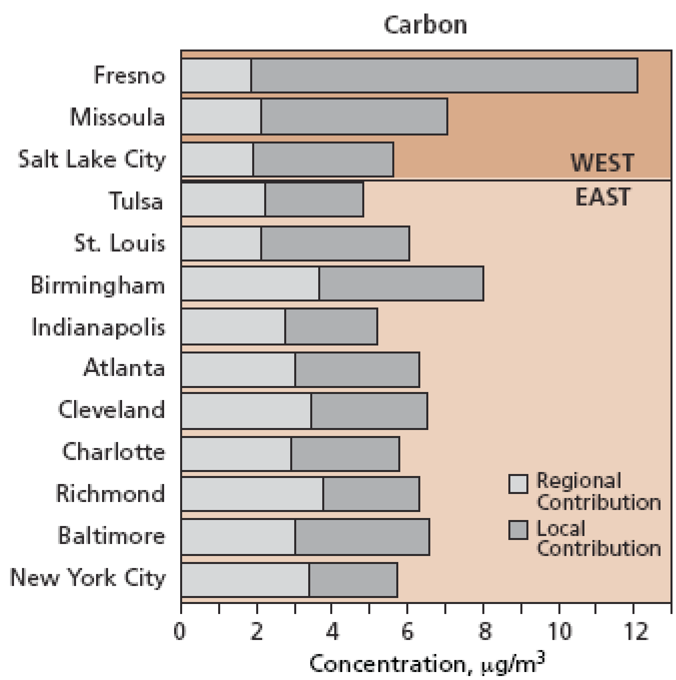
The spatial patterns of rural concentrations of the specific PM2.5 components result from the geographic distribution of contributing sources, atmospheric formation of secondary aerosols, and transport. Sulfate aerosols are formed in the atmosphere after the oxidation of sulfur dioxide. The chemistry is sufficiently slow so that days are required for complete oxidation to occur. During this time period, sufficient atmospheric mixing occurs such that the pollutant generally appears well distributed regionally. As shown in Figure 3.5 (reference EPA Particle Pollution Report, 2004) , rural and urban ambient monitors measure similar concentrations of sulfate aerosols.

Figure 3.5 Local and regional contribution to the sulfate component of PM2.5



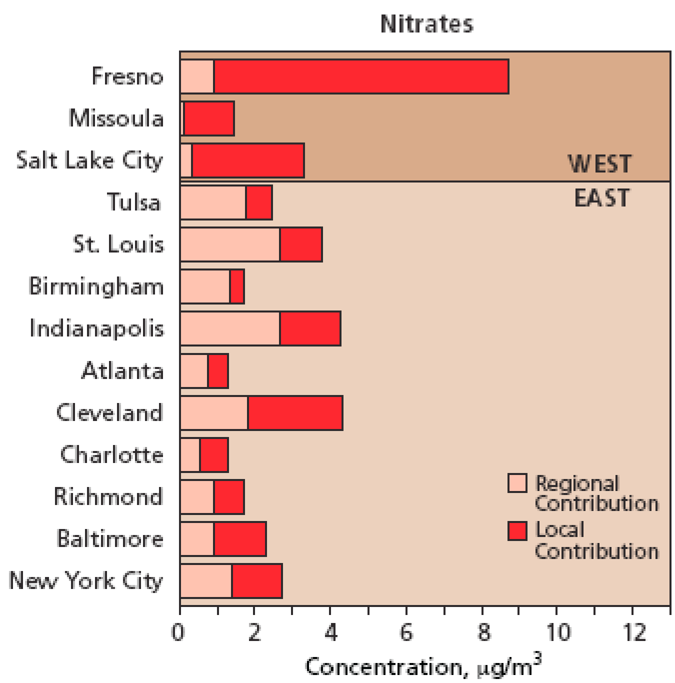
Carbon has the largest local contribution of the three major chemical components. Carbonaceous mass is estimated from speciation measurements of organic and elemental carbon in combination with a multiplier to account for the mass associated with oxygen, hydrogen, and other elements found in carbon components found in fine particles. A multiplier value of 1.4 is used for the computation of urban excess. Carbon particles associated with the urban excess originate from a combination of mobile and stationary combustion sources (including power plants and other industrial facilities). The regional contribution, which varies from 30% to 60% of the total carbon at urban locations, is from rural emission sources such as vegetation and wildfires, as well as region-wide sources such as cars and trucks.

Figure 3.6 Local and regional contribution to the carbonaceous component of PM2.5



Nitrates represent only about 10% to 30% of annual average $PM_{2.5}$, and urban concentrations are higher than the nearby regional levels. This is likely due to local NOx sources such as cars, trucks, and small stationary combustion sources. The nitrates and sulfate constituent of PM2.5 are represented as ammonium nitrates and ammonium sulfates. [The ammonium portion of particulate matter is not separately considered. It originates from ammonia (from sources such as fertilizer and animal feeding operations) which contribute to the formation of sulfates and nitrates]

Figure 3.7 Local and regional contribution to the carbonaceous component of PM2.5



3.2 Derivation of Urban Excess

For this exercise, the data sets used to calculate urban excess spanned the one year April 2002-March 2003. The following steps were used to compute urban excess for this time period:

1. EPA's speciation network (STN) was used to represent PM2.5 speciation data at urban locations. The IMPROVE network was used to represent PM2.5 speciation data at rural locations.
2. For the year in question, every location with monitoring data was checked for completeness. Completeness consisted of checking whether there were a minimum of 11 valid observations of each of the major chemical species for each of the four quarters that comprise the one year in question. Major species in the STN network include organic carbon, elemental carbon, ammonium, crustal, sulfates, and nitrates Major species in the rural IMPROVE network include organic carbon, elemental carbon, sulfate, crustal, and nitrate. These criteria resulted in a total of 137 urban locations having complete data for the year in question.
3. For each of the 137 urban sites that were complete, the nearest complete rural IMPROVE site was identified using a geographic information system. These site pairs were then

used to compute the urban increment, component by component using Equation 1 above. Note that this procedure often results in the same rural site being matched to various different urban sites in close proximity to each other.

The annual average urban excess was calculated in this fashion for the major PM2.5 species: sulfate, ammonium, nitrate, total carbon, and crustal matter. Equations used to convert measured urban and rural speciation concentrations into estimated PM2.5 constituents and inter-network differences and uncertainties are described elsewhere. [See the *National Air Quality and Emissions Trends Report, 2003 Special Studies Edition*]. Computed urban excess concentrations less than zero were set to zero. The complete list of matched sites and all urban excess estimates are shown in table 1 below.

PM2.5 DESIGNATIONS - DATA USED IN CALCULATING URBAN EXCESS PERCENTAGES BY PM2.5 COMPONENT

PM2.5 Speciation Data from the period 4/02 - 3/03

URBAN PM2.5 SPECIATION MONITORING SITE INFORMATION

Metropolitan Area(s) with Violating Monitor	State	County	MSA	EPA Air Quality System (AQS) Site Code	Carbon Mass	Crustal Mass	Amm. Sulfate Mass	Amm. Nitrate Mass	Carbon % of Mass	Crustal % of Mass	Sulfates % of Mass	Nitrates % of Mass	Sum of 4 Urban Components
Athens, GA	GEORGIA	CLARKE	Athens,GA	130590001	5.9	0.8	7.7	1.5	37%	5%	48%	10%	15.9
Atlanta, GA; Macon, GA	GEORGIA	DE KALB	Atlanta,GA	130890002	6.3	0.5	6.5	1.3	43%	3%	45%	9%	14.6
Baltimore, MD	MARYLAND	BALTIMORE	Baltimore,MD	240053001	6.5	0.6	7.7	2.3	38%	4%	45%	13%	17.2
Birmingham, AL	ALABAMA	JEFFERSON	Birmingham,AL	010732003	6.5	1.5	7.3	1.7	38%	9%	43%	10%	17.0
Canton, OH; Youngstown, OH; Steubenville, OH-WV	OHIO	MAHONING	Youngstown-Warren,OH	390990014	5.5	1.0	6.5	3.1	34%	6%	40%	19%	16.1
Charleston, WV; Parkersburg, WV-OH; Huntington, WV-KY-OH	KENTUCKY	BOYD	Huntington-Ashland,WV-K	210190017	5.7	0.5	8.1	1.7	36%	3%	51%	11%	15.9
Chattanooga, TN-GA	TENNESSEE	HAMILTON	Chattanooga,TN-GA	470654002	6.3	1.0	7.0	1.5	40%	7%	44%	10%	15.9
Chicago,IL-IN-WI; Elkhart, IN	ILLINOIS	COOK	Chicago,IL	170310076	4.9	0.8	6.2	4.0	31%	5%	39%	25%	15.9
Cincinnati, OH-KY-IN	KENTUCKY	KENTON	Cincinnati,OH-KY-IN	211170007	4.4	0.5	6.9	3.0	30%	3%	47%	20%	14.8
Cleveland, OH	OHIO	CUYAHOGA	Cleveland-Lorain-Elyria,OH	390350060	6.5	1.3	6.9	4.3	34%	7%	36%	23%	19.0
Columbus, GA-AL	ALABAMA	MONTGOMERY	Montgomery,AL	011011002	5.5	0.7	6.1	1.0	42%	5%	46%	7%	13.3
Columbus, OH; Dayton, OH	OHIO	BUTLER	Hamilton-Middletown,OH	390171004	4.3	0.6	6.2	3.2	30%	4%	43%	22%	14.3
Detroit, MI	MICHIGAN	WAYNE	Detroit,MI	261630001	5.3	0.7	6.0	4.2	33%	5%	37%	26%	16.1
Evansville, IN-KY	KENTUCKY	DAVIESS	Owensboro,KY	210590014	3.8	0.8	7.3	3.0	26%	5%	49%	20%	14.9
Greensboro, NC	NORTH CAROLINA	GUILFORD	Greensboro-Winston Sale	370810013	6.9	2.3	7.3	1.6	38%	13%	40%	9%	18.1
Greenville, SC	SOUTH CAROLINA	GREENVILLE	Greenville-Spartanburg-An	450450009	5.9	0.5	7.1	1.2	40%	3%	48%	8%	14.7
Hickory, NC	NORTH CAROLINA	MECKLENBURG	Charlotte-Gastonia-Rock H	371190041	5.8	0.5	6.8	1.3	40%	3%	47%	9%	14.3
Indianapolis, IN	INDIANA	MARION	Indianapolis,IN	180970078	5.2	0.7	6.9	4.2	31%	4%	40%	25%	17.1
Knoxville, KY	NORTH CAROLINA	BUNCOMBE	Asheville,NC	370210034	4.8	0.5	6.4	1.1	37%	4%	50%	9%	12.7
Lexington, KY	KENTUCKY	FAYETTE	Lexington,KY	210670012	4.1	0.5	7.2	3.1	27%	3%	49%	21%	14.9
Lincoln County, MT	MONTANA	LINCOLN	Not in a MSA	300530018	14.5	0.6	1.0	0.8	85%	4%	6%	5%	17.0
Los Angeles, CA	CALIFORNIA	RIVERSIDE	Riverside-San Bernardino,	060658001	9.4	1.4	4.6	15.9	30%	4%	15%	51%	31.2
Louisville, KY-IN	KENTUCKY	JEFFERSON	Louisville,KY-IN	211110043	5.5	0.7	6.8	2.9	35%	4%	43%	18%	15.8
New York, NY-NJ-CT-PA	NEW JERSEY	UNION	Newark,NJ	340390004	7.9	0.7	5.9	3.1	45%	4%	34%	17%	17.5
Philadelphia, PA-NJ-DE-MD	PENNSYLVANIA	DELAWARE	Philadelphia,PA-NJ	420450002	6.1	0.6	6.9	3.1	36%	4%	41%	19%	16.7
Reading, PA; Lancaster, PA	PENNSYLVANIA	LANCASTER	Lancaster,PA	420710007	5.6	0.6	7.9	5.5	29%	3%	40%	28%	19.6
San Diego, CA	CALIFORNIA	SAN DIEGO	San Diego,CA	060730003	6.6	0.7	4.1	5.1	40%	4%	25%	31%	16.5
San Joaquin, CA	CALIFORNIA	KERN	Bakersfield,CA	060290014	8.9	1.4	2.7	8.1	42%	7%	13%	38%	21.1
St. Louis, MO-IL	MISSOURI	ST LOUIS (CITY)	St. Louis,MO-IL	295100085	6.1	1.3	6.2	3.8	35%	8%	36%	22%	17.4
Toledo, OH	OHIO	LUCAS	Toledo,OH	390950026	4.7	0.5	5.4	4.6	31%	3%	35%	30%	15.3
Washington, DC-MD-VA-WV	DISTRICT OF COLUMBIA	WASHINGTON	Washington,DC-MD-VA-W	110010043	5.5	0.6	7.5	2.4	34%	4%	47%	15%	15.9
Wheeling, WV-OH; Pittsburgh, PA; Marion County, WV; Johnstown, PA	PENNSYLVANIA	WESTMORELAND	Pittsburgh,PA	421290008	5.7	0.7	8.7	2.3	33%	4%	50%	13%	17.4
York, PA; Harrisburg, PA	PENNSYLVANIA	DAUPHIN	Harrisburg-Lebanon-Carlis	420430401	6.1	0.5	7.0	3.6	35%	3%	41%	21%	17.2

REGIONAL PM2.5 SPECIATION MONITORING SITE INFORMATION

Metropolitan Area(s) with Violating Monitor	Site Code	Site Name	State	Carbon Mass	Crustal Mass	Amm. Sulfate Mass	Amm. Nitrate Mass	Carbon % of Mass	Crustal % of Mass	Sulfates % of Mass	Nitrates % of Mass	Sum of 4 Regional Components
Athens, GA	COHU1	Cohutta	Georgia	3.0	0.5	6.2	1.2	28%	5%	57%	11%	10.9
Atlanta, GA; Macon, GA	COHU1	Cohutta	Georgia	3.0	0.5	6.2	1.2	28%	5%	57%	11%	10.9
Baltimore, MD	AREN1	Arendtsville	Pennsylvania	3.3	0.6	7.2	2.5	24%	4%	53%	19%	13.6
Birmingham, AL	SIPS1	Sipsey Wilderness	Alabama	3.7	0.7	6.6	1.4	30%	5%	53%	11%	12.3
Canton, OH; Youngstown, OH; Steubenville, OH-WV	MKGO1	M.K. Goddard	Pennsylvania	3.5	0.6	6.0	1.9	29%	5%	50%	16%	11.9
Charleston, WV; Parkersburg, WV-OH; Huntington, WV-KY-OH	QUCI1	Quaker City	Ohio	3.0	0.8	7.8	1.5	23%	6%	59%	12%	13.1
Chattanooga, TN-GA	COHU1	Cohutta	Georgia	3.0	0.5	6.2	1.2	28%	5%	57%	11%	10.9
Chicago,IL-IN-WI; Elkhart, IN	BOND1	Bondville	Illinois	2.6	0.8	5.3	3.7	21%	6%	43%	30%	12.3
Cincinnati, OH-KY-IN	LIVO1	Livonia	Indiana	2.8	0.7	6.8	2.7	21%	6%	52%	21%	13.0
Cleveland, OH	MKGO1	M.K. Goddard	Pennsylvania	3.5	0.6	6.0	1.9	29%	5%	50%	16%	11.9
Columbus, GA-AL	SIPS1	Sipsey Wilderness	Alabama	3.7	0.7	6.6	1.4	30%	5%	53%	11%	12.3
Columbus, OH; Dayton, OH	LIVO1	Livonia	Indiana	2.8	0.7	6.8	2.7	21%	6%	52%	21%	13.0
Detroit, MI	MKGO1	M.K. Goddard	Pennsylvania	3.5	0.6	6.0	1.9	29%	5%	50%	16%	11.9
Evansville, IN-KY	MACA1	Mammoth Cave Natio	Kentucky	3.3	0.7	6.8	1.8	26%	5%	54%	14%	12.7
Greensboro, NC	JARI1	James River Face	Virginia	3.8	0.6	6.9	0.9	31%	5%	56%	8%	12.2
Greenville, SC	SHRO1	Shining Rock Wildern	North Carolina	2.9	0.7	7.6	0.5	25%	6%	66%	4%	11.6
Hickory, NC	LIGO1	Linville Gorge	North Carolina	3.0	0.5	6.7	0.6	28%	5%	62%	5%	10.7
Indianapolis, IN	LIVO1	Livonia	Indiana	2.8	0.7	6.8	2.7	21%	6%	52%	21%	13.0
Knoxville, KY	SHRO1	Shining Rock Wildern	North Carolina	2.9	0.7	7.6	0.5	25%	6%	66%	4%	11.6
Lexington, KY	LIVO1	Livonia	Indiana	2.8	0.7	6.8	2.7	21%	6%	52%	21%	13.0
Lincoln County, MT	CABI1	Cabinet Mountains	Montana	2.4	0.8	0.8	0.3	56%	20%	18%	6%	4.2
Los Angeles, CA	SAGO1	San Gorgonio Wildern	California	2.9	1.2	1.8	4.6	28%	11%	17%	44%	10.5
Louisville, KY-IN	LIVO1	Livonia	Indiana	2.8	0.7	6.8	2.7	21%	6%	52%	21%	13.0
New York, NY-NJ-CT-PA	BRIG1	Brigantine National W	New Jersey	3.4	0.5	5.5	1.4	32%	5%	51%	13%	10.9
Philadelphia, PA-NJ-DE-MD	BRIG1	Brigantine National W	New Jersey	3.4	0.5	5.5	1.4	32%	5%	51%	13%	10.9
Reading, PA; Lancaster, PA	AREN1	Arendtsville	Pennsylvania	3.3	0.6	7.2	2.5	24%	4%	53%	19%	13.6
San Diego, CA	AGTI1	Agua Tibia	California	2.7	1.2	2.8	2.6	29%	13%	30%	28%	9.3
San Joaquin, CA	DOME1	Dome Lands Wilderne	California	3.5	1.2	1.6	2.0	42%	15%	20%	23%	8.4
St. Louis, MO-IL	MING1	Mingo	Missouri	2.5	1.0	5.6	2.0	22%	9%	51%	18%	11.1
Toledo, OH	QUCI1	Quaker City	Ohio	3.0	0.8	7.8	1.5	23%	6%	59%	12%	13.1
Washington, DC-MD-VA-WV	AREN1	Arendtsville	Pennsylvania	3.3	0.6	7.2	2.5	24%	4%	53%	19%	13.6
Wheeling, WV-OH; Pittsburgh, PA; Marion County, WV; Johnstown, PA	DOSO1	Dolly Sods /Otter Cre	West Virginia	3.1	0.5	7.2	0.9	26%	5%	62%	8%	11.7
York, PA; Harrisburg, PA	AREN1	Arendtsville	Pennsylvania	3.3	0.6	7.2	2.5	24%	4%	53%	19%	13.6

Table 1. Data Used in Calculating Urban Excess Percentages

PM2.5 DESIGNATIONS - DATA USED IN CALCULATING URBAN EXCESS PERCENTAGES BY PM2.5 COMPONENT

PM2.5 Speciation Data from the period 4/02 - 3/03

	URBAN EXCESS INFORMATION								
Metropolitan Area(s) with Violating Monitor	**Carbon Mass**	**Crustal Mass**	**Sulfates Mass**	**Nitrates Mass**	**Sum of 4 Components**	**Carbon %**	**Crustal %**	**Sulfates %**	**Nitrates %**
Athens, GA	2.91	0.27	1.52	0.37	5.06	57%	5%	30%	7%
Atlanta, GA; Macon, GA	3.29	0.00	0.37	0.10	3.76	88%	0%	10%	3%
Baltimore, MD	3.26	0.06	0.51	0.00	3.83	85%	2%	13%	0%
Birmingham, AL	2.82	0.84	0.73	0.28	4.68	60%	18%	16%	6%
Canton, OH; Youngstown, OH; Steubenville, OH-WV	2.05	0.41	0.47	1.24	4.18	49%	10%	11%	30%
Charleston, WV; Parkersburg, WV-OH; Huntington, WV-KY-OH	2.65	0.00	0.32	0.20	3.17	84%	0%	10%	6%
Chattanooga, TN-GA	3.32	0.52	0.85	0.36	5.05	66%	10%	17%	7%
Chicago,IL-IN-WI; Elkhart, IN	2.32	0.05	0.91	0.30	3.58	65%	2%	25%	8%
Cincinnati, OH-KY-IN	1.61	0.00	0.14	0.31	2.05	78%	0%	7%	15%
Cleveland, OH	3.01	0.76	0.92	2.43	7.11	42%	11%	13%	34%
Columbus, GA-AL	1.83	0.00	0.00	0.00	1.83	100%	0%	0%	0%
Columbus, OH; Dayton, OH	1.50	0.00	0.00	0.55	2.05	73%	0%	0%	27%
Detroit, MI	1.80	0.17	0.00	2.29	4.27	42%	4%	0%	54%
Evansville, IN-KY	0.50	0.13	0.44	1.14	2.21	23%	6%	20%	51%
Greensboro, NC	3.12	1.73	0.46	0.64	5.95	52%	29%	8%	11%
Greenville, SC	3.08	0.00	0.00	0.72	3.80	81%	0%	0%	19%
Hickory, NC	2.79	0.00	0.12	0.74	3.64	77%	0%	3%	20%
Indianapolis, IN	2.42	0.00	0.11	1.58	4.11	59%	0%	3%	38%
Knoxville, KY	1.90	0.00	0.00	0.63	2.52	75%	0%	0%	25%
Lexington, KY	1.29	0.00	0.46	0.40	2.15	60%	0%	22%	19%
Lincoln County, MT	12.11	0.00	0.25	0.60	12.96	93%	0%	2%	5%
Los Angeles, CA	6.46	0.16	2.81	11.31	20.74	31%	1%	14%	55%
Louisville, KY-IN	2.72	0.00	0.00	0.20	2.92	93%	0%	0%	7%
New York, NY-NJ-CT-PA	4.43	0.18	0.39	1.64	6.65	67%	3%	6%	25%
Philadelphia, PA-NJ-DE-MD	2.65	0.10	1.39	1.69	5.83	45%	2%	24%	29%
Reading, PA; Lancaster, PA	2.32	0.01	0.67	3.01	6.01	39%	0%	11%	50%
San Diego, CA	3.92	0.00	1.27	2.51	7.71	51%	0%	16%	33%
San Joaquin, CA	5.38	0.22	1.02	6.13	12.75	42%	2%	8%	48%
St. Louis, MO-IL	3.60	0.29	0.51	1.81	6.21	58%	5%	8%	29%
Toledo, OH	1.73	0.00	0.00	3.08	4.81	36%	0%	0%	64%
Washington, DC-MD-VA-WV	2.21	0.03	0.26	0.00	2.51	88%	1%	11%	0%
Wheeling, WV-OH; Pittsburgh, PA; Marion County, WV; Johnstown, PA	2.63	0.17	1.52	1.37	5.69	46%	3%	27%	24%
York, PA; Harrisburg, PA	2.78	0.00	0.00	1.07	3.86	72%	0%	0%	28%