Review Draft

Emissions Factor Uncertainty Assessment

February 2007

Prepared for:

U.S. Environmental Protection Agency
Office of Air Quality Planning and Standards
Research Triangle Park, NC 27711

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* RTI International is a trade name of Research Triangle Institute.

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List of Acronyms and Abbreviations

APCD	air pollution control device
AQM	Air Quality Management
BTU	British thermal units
CAA	Clean Air Act
CAAAC	Clean Air Act Advisory Committee
CAS	Chemical Abstracts Service
CDF	cumulative distribution function
CF	correction factor
CO	carbon monoxide
CV	coefficient of variance
DSI/FF	dry sorbent injection/fabric filter
EPA	U.S. Environmental Protection Agency
ESP	electrostatic precipitator
EU	emissions unit
FF	fabric filter
FIRE	Factor Information REtrieval
HAP	hazardous air pollutant
HCl	hydrogen chloride
IQR	inter-quartile-range
lb	pound
MC	mechanical collector
NARSTO	North American Research Strategy for Tropospheric Ozone
NOx	nitrogen oxides
NRC	National Research Council
PDF	probability density function
PF/MDI	phenol formaldehyde/methylene diphenyl diisocyanate
PM	particulate matter
q1	first quartile
q3	third quartile
RDF	refuse-derived fuel
SD/ESP	spray dryer/electrostatic precipitator
SD/FF	spray dryer/fabric filter
SO_2	sulfur dioxide
UNC	uncontrolled
UNC/PM	uncontrolled or PM control
VOCs	volatile organic compounds
W/OSB	Waferboard/Oriented Strandboard Manufacturing
WS	wet scrubber
WS/FF	wet scrubber or fabric filter

Disclaimer

This report summarizes the results of a study funded by and conducted for the U.S. Environmental Protection Agency (EPA) to evaluate uncertainty associated with emissions factors. This report has been reviewed by the Office of Air Quality Planning and Standards of the U.S. EPA, and approved for publication. Mention of trade names or commercial products is not intended to constitute endorsement or recommendation for use.

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Preface

This report was prepared for the U.S. Environmental Protection Agency (EPA) under RTI International (RTI) Contract No. 68-D-02-065, Work Assignments 3-08, “Develop Supporting Information and Policy Options for Using Emissions Factors in Noninventory Applications,” and 4-06, “Evaluating and Implementing Options for Revamping the Emissions Factor Program.” Revisions to the draft report were prepared by RTI under subcontract to E.H. Pechan & Associates, Inc., under Contract No. 68-D-00-264, Work Assignment 4-51, and RTI Contract No. 68-D-02-065, Work Assignment 4-06.

Individuals selected for their technical expertise peer-reviewed a preliminary draft of this report. The purpose of that independent review was to provide critical comments and recommendations for improvement. The peer reviewers were Dr. H. Christopher Frey, Professor, Department of Civil, Construction, and Environmental Engineering at North Carolina State University; and Dr. Mitchell J. Small, Professor, Departments of Civil & Environmental Engineering and Engineering & Public Policy at Carnegie-Mellon University. We want to thank Drs. Frey and Small for providing valuable comments and feedback for this report. Although they provided many constructive comments, they were not asked to endorse the results, nor have they seen the final report.

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Executive Summary

Objective

The objective of this study is to assess the uncertainty of the best rated emissions factors for categories of pollutants. Because uncertainty can be expressed as a probability distribution, the study used statistical procedures to determine the appropriate distribution and to calculate expected emissions factor values at various percentiles. Finally, the study presents uncertainty values expressed as ratios of expected emissions factor values at a given percentile and the average emissions factor values (as reported in AP-42).

What is an emissions factor?

An emissions factor is a numerical value that represents the quantity of a pollutant released to the atmosphere with an activity associated with the release of that pollutant. These factors are usually expressed as the weight of pollutant divided by a unit weight, volume, distance, or duration of the activity emitting the pollutant (e.g., kilograms of particulate emitted per megagram of coal burned). Such factors facilitate estimation of emissions from various sources of air pollution. In most cases, these factors are simply averages of all available data of acceptable quality and are generally assumed to be representative of long-term averages for all facilities in the source category (e.g., a population average).

The general equation for emissions estimation is

$$E = A \times EF \times \left(1 - \frac{ER}{100}\right)$$

where

E = Emissions
A = Activity rate
EF = Emissions factor
ER = Overall emissions reduction efficiency, %.

Emissions factors are typically expressed as an average (mean) value of a distribution of emissions data. Emissions factors were initially intended for estimating emissions for a large number of sources (e.g., a national inventory). In many cases, emissions factor use has expanded beyond the original purpose, including determination of permit (or rule) applicability (i.e., calculating emissions from a specific source to determine whether the source meets the emissions threshold for a permit or rule to apply); input to a site-specific risk assessment; and calculation of emissions for trading.

What is uncertainty?

According to the North American Research Strategy for Tropospheric Ozone (NARSTO), uncertainty is the lack of knowledge regarding the true value of a quantity. Uncertainties are often expressed as probability distributions; two common distributions are the probability density function (PDF) and the cumulative distribution function (CDF). In the context of this report, *uncertainty* is an all-encompassing term that includes the effects of bias or systematic error, random error, and variability or how a quantity differs over time, space, or members of a population (NARSTO 2005).

What is an easy way to express emissions factor uncertainty?

A convenient way to describe emissions factor uncertainty is to calculate the ratio of the expected emissions factor value at a specific percentile (as found using the appropriate statistical techniques) to the emissions factor value reported in AP-42. The emissions factor uncertainty ratio can be found using the following equation:

$$EF_{\text{uncertainty ratio}} = \frac{EF_{\text{target statistic}}}{EF}$$

where

$EF_{\text{target statistic}}$	=	Target population value of the emissions distribution (e.g., 95th percentile) in units of the AP-42 emissions factor
$EF_{\text{uncertainty ratio}}$	=	Estimate of the emissions factor uncertainty, unitless
EF	=	Emissions factor, as presented in AP-42, in units of the AP-42 emissions factor

What analyses were conducted during this study?

We analyzed the data for 43 A-rated and 1 B-rated AP-42 emissions factors for particulate matter (PM), sulfur dioxide (SO_2), nitrogen oxides (NOx), carbon monoxide (CO), and hazardous air pollutants (HAPs). A statistical analysis based on a Monte Carlo simulation technique was conducted on each of the emissions factor datasets to simulate the population of the emissions factor for the specific pollutant. The simulated population was repeatedly sampled, again using a Monte Carlo simulation technique, to obtain probability distributions of emissions factors based on various sample sizes *n* (e.g., $n = 3$, 5, 10, or 25 emissions tests), where an emissions test consists of generally three valid sample runs. As previously mentioned, one can view the full range of expected values of emissions factors and compare each one to the mean value, which is reported in AP-42. Emissions factor uncertainty ratios were calculated for each emissions factor dataset for various values of *n*. The emissions factor uncertainty ratios for each pollutant type and for similar values of *n* were combined to provide a series of composite emissions factor uncertainty ratios.

What are the results?

We have developed emissions factor uncertainty ratios based on target statistics of the population distribution of the emissions factor. We calculated emissions factor uncertainty ratios for numerous target statistics (e.g., 10^{th}, 25^{th}, 75^{th}, 90^{th}, 95^{th} percentiles) and values of *n*, where *n* equals the number of emissions tests used to determine the emissions factor. As expected, a consistent pattern is shown for all of the pollutants—as the number of emissions tests (*n*) increases, the value of the emissions factor uncertainty ratio decreases. The emissions factor uncertainty ratio increases as the variability of the emissions factor data increases.

The data for HAP emissions factors exhibit the highest degree of variability and result in the largest emissions factor uncertainty ratios. As an example, the composite emissions factor uncertainty ratios to calculate the 95^{th} percentile of the distribution are presented in the following table.

Example emissions factor uncertainty ratios at the 95^{th} percentile

Pollutant	Number of Emissions Tests Used to Determine AP-42 Emissions Factor	
	***n* < 3**	***n* ≥ 25**
HAP	13	3.9
PM-condensable	6.9	3.6
PM-filterable, controlled	3.9	2.7
PM-filterable, uncontrolled	2.7	2.2
Gaseous criteria pollutants	5.4	2.8

HAP = hazardous air pollutant
PM = particulate matter

1.0 Introduction

The U.S. Environmental Protection Agency (EPA) and its predecessors have used emissions factors since 1968 to quantify emissions from point and area sources. The emissions factors and descriptions of sources to which the emissions factors apply can be found in the compendium report, *Compilation of Air Pollutant Emissions Factors, AP-42, Fifth Edition, Volume I: Stationary Point and Area Sources*, which is often referenced as AP-42 (U.S. EPA, 1995). The AP-42 emissions factors are generally based on the average or the mean of the supporting emissions data. Over time, the number of source types presented in AP-42 has expanded, and as better and additional data have become available, EPA has revised and updated emissions factors. In 1990, EPA expanded the list of pollutants presented in the AP-42 sections to include the hazardous air pollutants (HAPs) identified in the 1990 Clean Air Act Amendments, as well as pollutants that may significantly influence global climate change.

In support of emissions factors development, EPA has and continues to collect test data, evaluate the quality of supporting data, and revise the various chapters and sections of AP-42. Because of program priorities and goals, EPA's emissions factor program primarily supported the development of the national trends emissions inventory and other inventories used for state and regional implementation plans.

During the past 10 years, the number of programs that use emissions factors has increased beyond the intended and supported national emissions inventory program use. In 2003, EPA began a complete re-evaluation of the emissions factor program. Part of this re-evaluation includes identifying ways to make the program more responsive to the broad and diverse range of emissions factors users, providing science-based recommendations on adapting emissions factors to achieve different program goals, characterizing the deficiencies of using emissions factors by quantifying the uncertainties associated with their use, and providing users with alternative methods of quantifying emissions to reduce the levels of uncertainty and increase user accountability.

The objective of this study is to assess the uncertainty of the best-rated emissions factors and to develop emissions factor uncertainty ratios for a range of probability levels. This study does not attempt to evaluate or provide guidance on the application of emissions factor uncertainty in making environmental decisions. How emissions factor uncertainty affects or can be incorporated into such decision making necessarily must reflect the needs of affected stakeholders consistent with various program objectives. We intend that the study results will inform that process.

1.1 Background and Terminology

1.1.1 Background

The National Research Council (NRC) of the National Academies, Committee on Air Quality Management in the United States prepared the report "Air Quality Management in the United States" (NRC, 2004). One of NRC's findings is that "*the nation's Air Quality Management (AQM) system has not developed a comprehensive program to track emissions and emissions trends accurately, and as a result, is unable to verify claimed reductions in pollutant emissions that have accrued as a result of implementation of the Clean Air Act (CAA).*" The NRC proposes that EPA should lead a coordinated effort with state, local, and Tribal air quality agencies to improve the current system of tracking emissions and their reductions in time. The NRC recommends basing emissions inventories on emissions measurements whenever possible, and incorporating more formal uncertainty analysis in the presentation and use of inventories. In response to the proposed actions presented in the NRC's report, the Clean Air Act Advisory Committee's (CAAAC's) Air Quality Management Work Group made recommendations related to emissions measurements, emissions factors, and estimation methods (U.S. EPA, 2004a). Among these recommendations are that EPA, in conjunction with state, local, Tribal agencies and affected stakeholders, improve emissions factors and emissions estimation methods where emissions measurement-based information is impractical to obtain for air quality assessments, and quantify and take actions to reduce uncertainty in emissions inventories, provide guidance, and improve communication of uncertainty to decision makers.

EPA's Office of the Inspector General states the following:

"*Quantifying air emissions is a vital aspect of air pollution programs. Regulatory authorities and others use emissions values in (1) developing emissions inventories, (2) identifying and evaluating control strategies, (3) determining applicability of permit and regulatory requirements, and (4) assessing risks. In the absence of direct measures, emissions factors are frequently used as a quick, low cost way to estimate emissions values.*" (U.S. EPA, 2006)

The uncertainty of emissions values used in these applications is important to decision makers. Uncertainty results from a lack of knowledge about the true value of a quantity. Uncertainties are often expressed as probability distributions; the probability density function (PDF) and cumulative distribution function (CDF) are two common distributions (defined in Section 1.1.2). In the context of this report, uncertainty is an all-encompassing term that includes the effects of bias or systematic error, random error, and variability or how a quantity differs over time, space, or members of a population (NARSTO 2005). An effective approach towards reducing uncertainty is to obtain more knowledge (e.g., additional information about the source or quality of the data, additional data, site-specific emissions data, and or continuous emissions monitoring data).

EPA uses a subjective rating system for the AP-42 emissions factors; they are assigned a quality rating of "A" through "E" based on the quality of the supporting emissions test data and on the amount and the representative characteristics of those data (e.g., how well the data represent the emissions source category). For example, A-rated emissions factors are calculated using highly rated source test data from many randomly chosen facilities in the industry. A-rated factors are considered excellent. On the other hand, E-rated emissions factors are calculated using source test data that have been rated "poor," and there may be reason to suspect that the facilities tested do not represent a random sample of industry. There may also be evidence of excessive or poorly represented variability within the source population. E-rated factors are considered poor.

This current rating system does not provide a quantitative assessment of uncertainty. EPA's Office of the Inspector General states the following:

"*The current rating system for emissions factors does not provide the user with a tool to adjust an emissions factor based on use. An emissions factor tool that quantifies uncertainty would provide users with valuable information for adjusting the emissions factor, as appropriate; taking into account the level of uncertainty during calculations can give a user a better understanding of the variations between actual emissions and emissions factors calculations. The uncertainty tool could allow the user to select an appropriate adjustment based on its use."* (U.S. EPA, 2006)

As an example, consider an emissions factor (based on the mean value of the emissions test data), which is 100 pound (lb)/ton of product, but when accounting for the uncertainty of the emissions factor, the probable range of emissions is estimated to be 50 to 220 lb/ton. With this uncertainty information, the user could select an emissions factor value that better supports the decision to be made. For instance, if the intended use is for a national emissions estimate comprised of a large number of sources, the user could choose the emissions factor or a value toward the middle of the range because of the likelihood that overestimates and underestimates would tend to cancel each other out. On the other hand, if the intended use is to determine whether a particular source's emissions are sufficiently large to establish applicability of a rule requirement, the user could select near the upper end of the range to reduce the chance that a specific source's applicability determination could be found to be incorrect, as might be evidenced from results of subsequent emissions testing showing measured emissions in excess of emissions estimated using the selected emissions factor.

During the past 10 years, a significant amount of work was conducted in relation to assessing the uncertainty of emissions estimates. A majority of this work focused on assessing and improving the uncertainty of emissions inventories. The North American Research Strategy for Tropospheric Ozone (NARSTO) recently published the document *Improving Emission Inventories for Effective Air Quality Management Across North America* (2005), which provides detailed information related to assessing the uncertainty in inventories. Chapter 8 of the NARSTO document, "Methods for Assessment of Uncertainty and Sensitivity in Inventories," discusses the motivations for uncertainty analysis, basic terminology and conceptual aspects, and methods for performing quantitative uncertainty analyses of emissions inventory information.

As the title indicates, the focus of NARSTO's report is on assessing the uncertainty of emissions inventories, whereas the focus of this study is not limited only to the uncertainty of emissions inventories due to using emissions factors. Nonetheless, the NARSTO report provides an excellent overview and discussion of terminology and methods, as well as a framework for emissions inventory analysis. Within the discussion of the sources of uncertainty (Chapter 8) in the NARSTO report, the following is stated:

> *"Variability of emissions sources can lead to uncertainty. The variability of emissions within a category and the limited sample size of measurements give rise to random sampling errors in estimation of the mean emission factor. The average emission factor, which is typically based upon the small data set available when an emission inventory is developed, is therefore subject to uncertainty. If the emission inventory includes a large sample of specific units within a source category, then the uncertainty analysis should typically focus on uncertainty in the mean emission rate. However, if an emission inventory includes only one unit from a given source category, and if no site-specific emission data are available, then an assumption might be made that the individual unit is a random sample from the population of all similar units. In this latter situation, the distribution of inter-unit variability would be the appropriate estimate of uncertainty."* (Emphasis added) (NARSTO, 2005)

The primary focus of this study is assessing the uncertainty of emissions factors. Of particular concern is the uncertainty associated with emissions factors used to represent emissions from a single or limited number of sources. In particular, the study focuses on assessing the distribution of inter-unit variability as an estimate of uncertainty.

1.1.2 Terminology

The following section defines some of the statistical terms used in this report.

Boundary statistic: Refers to lower or upper values of a probability distribution (e.g., the 95th percentile).

Cumulative distribution function (CDF): The CDF presents the relationship between cumulative probability and values of a random variable. The CDF gives the probability that the value of the variable is less than or equal to a specific number (e.g., the probability of observing a standard normal value greater or equal to 1.96 is 0.025). The CDF is useful for inferring specific numerical values in the data associated with determined levels of cumulative probability (e.g., the 50th and 95th percentiles). The CDF is often used to evaluate how well a model fits the data.

Data visualization: Using graphical displays to show data characteristics, such as the range and skewness. During this study, we used several data visualization techniques, such as histogram and plot of the empirical CDF.

Emissions factor: A numerical value that represents the quantity of a pollutant released into the atmosphere with an activity associated with the release of that pollutant; for example, lb of sulfur dioxide per million British thermal units (BTUs) of heat input. Where the AP-42 published emissions factor is derived from emissions test results, the emissions factor typically is the mean value of the available data.

Emissions test: As used in this report, except where noted otherwise, it is a direct measure of pollutant mass emitted from a facility, the result of which is reported as the average of the measurements for multiple (at least three) contiguous test runs. For the statistical analyses conducted during this study, the random variable, *n*, denotes the number of emissions tests (not the emissions test runs) used to calculate the corresponding emissions factor.

Emissions test run: The individual sample taken during an emissions test. An emissions test is typically comprised of three or more test runs.

Emissions unit: A specific process source of emissions (e.g., the emissions from boiler "A" at facility "B").

Estimators: Functions of the data and are used to estimate population parameters (e.g., the sample average is an estimator for the population mean).

Histogram: A graph of the frequency distribution in the form of a series of rectangles, each proportional in width to the range of values within a class and in height to the number of items falling in the class.

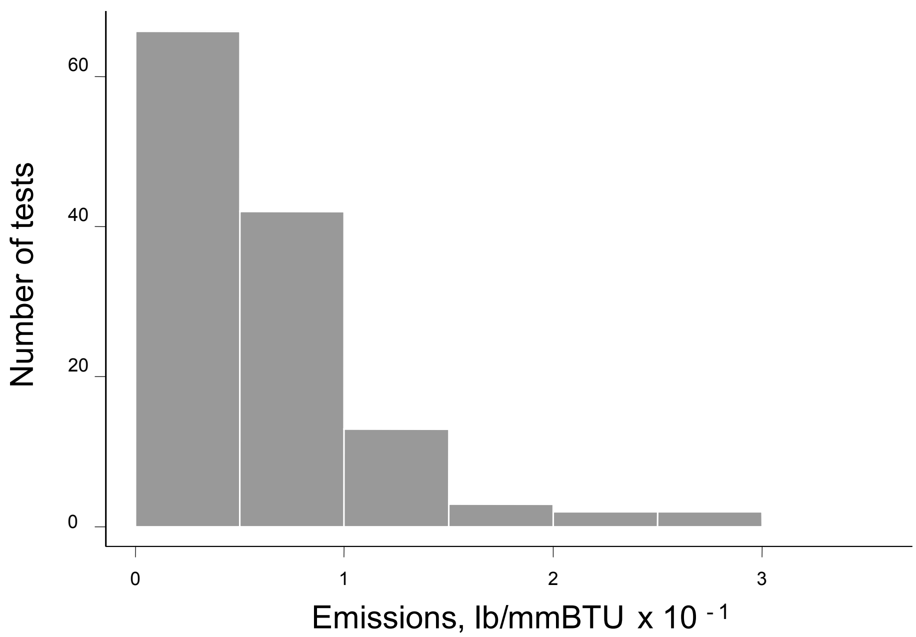

Figure 1-1. Example histogram.

Mean: The arithmetic average value. The mean of a probability distribution is the expected average of all possible outcomes of the random variable.

Median: A statistical term referring to the value (number) that divides numerically ordered data into two equal halves; half of the data values are smaller than the median and half of the values are greater than the median. Thus, the median has an associated cumulative probability of 0.50. The median is also referred to as the 50th percentile.

Monte Carlo simulation: Refers to a collection of stochastic techniques used to solve mathematical problems. The word “stochastic” means that it uses random numbers and probability statistics to provide solutions for specific problems. In Monte Carlo simulation, the random selection process is repeated many times to create multiple scenarios. Each time a value is randomly selected, it forms one possible scenario and simulation. Together, these scenarios give a range of possible solutions, some of which are more probable and some less probable. In this study, we typically used 10,000 simulations. For each emissions factor evaluated, we simulated a hypothetical population based on a statistical parametric distribution. Also, we generated sampling distributions of emissions factors based on different values of *n*, the number of emissions tests.

Normalized: A distribution is normalized by dividing each value in the distribution by the mean value of the distribution, resulting in a distribution with a mean value equal to 1.

Percentile: Represented by any of 100 points spaced at equal intervals within the range of the variable, with each point denoting that percentage of the data lying below it (e.g., the 95^{th} percentile denotes the numerical value of the data point below which 95 percent of the values lie and above which 5 percent of the values lie).

Population parameter, population value, or *population characteristic*: Refers to an unknown value of a characteristic or parameter of the population or the probability distribution (e.g., mean and variance are characteristics and parameters of the population), and also are referred to as parameters of the PDF.

Probability density function (PDF): The PDF presents the relationship between probability density and values of a random variable. The PDF denotes the probability that the variable takes a specific value. A PDF graph provides information on the central tendency, range, and shape of the distribution. The shape of the PDF provides insight regarding whether the distribution is symmetric or skewed.

Probability distribution: A probability distribution quantifies the range of possible values of the random variable (e.g., emissions). Uncertainty often is expressed in the form of a probability distribution. Probability distributions can be presented in various ways, including as a PDF or a CDF. Figure 1-2 displays example PDF and CDF functions and presents examples of symmetric (normal) and skewed distributions.

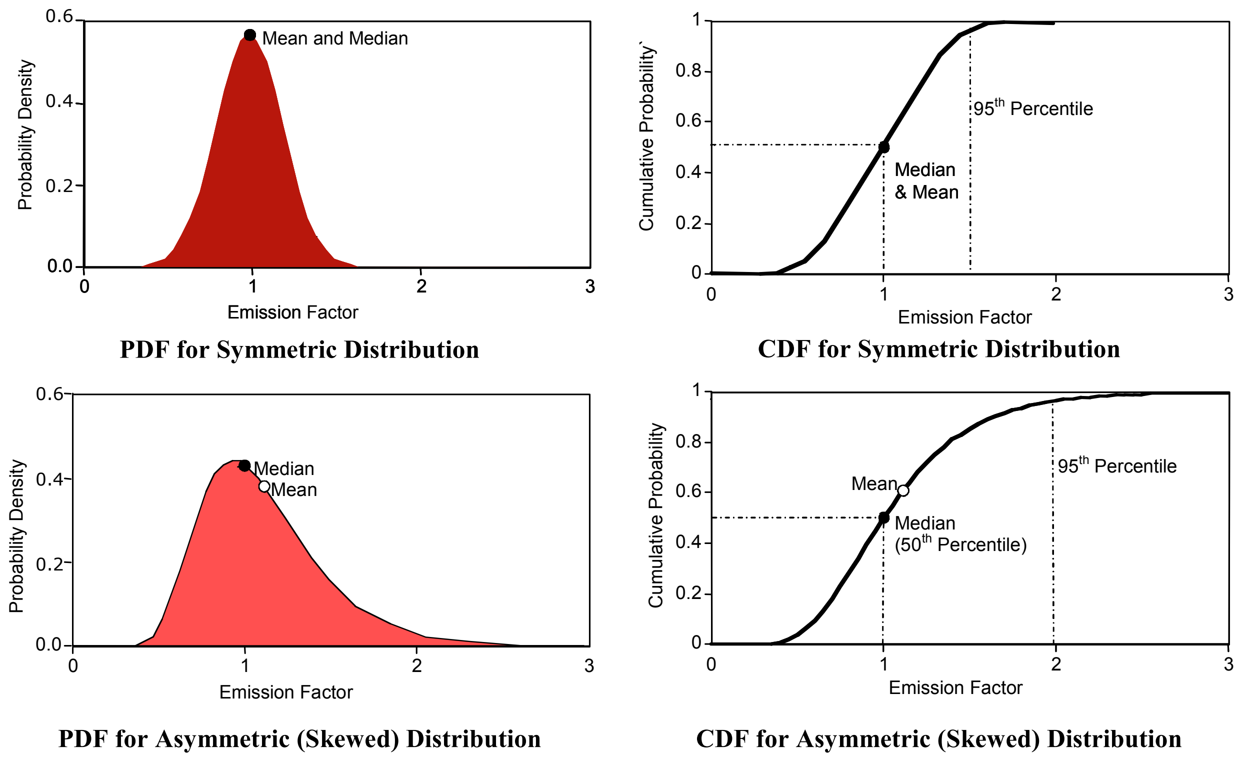

Figure 1-2. Schematic of probability density function (PDF) and cumulative distribution function (CDF) for symmetric and asymmetric distributions. (Adapted from NARSTO, 2005; Appendix C)

Sampling distribution: Refers to the distribution of a statistic (e.g., the mean) in all possible samples that can be chosen according to a sampling scheme. We used simulation techniques to create sampling distributions for means based on different sample sizes. The sampling distribution of the mean can be used as a basis for assessing uncertainty and comparing alternative procedures. We used the sampling distribution of means to create a sampling distribution of emissions factor uncertainty ratios.

Simulated (hypothetical population): This consists of all the values randomly generated from a PDF. We used Monte Carlo techniques to generate hypothetical populations.

Skewness: Refers to a departure from symmetry. The probability distributions of emissions factor data are typically skewed. In this study, we calculated the coefficient of variance (CV) as a measure of the skewness of each emissions factor dataset. The CV provides a relative measure of data dispersion compared to the mean. Probability densities frequently used to model skewed data include log-normal, Weibull, and Gamma distributions. During this study, we examined which parametric model best represented the emissions factor data.

Source: The process source of emissions (e.g., wood-fired boiler.) The term source also may refer to a specific source of emissions (i.e., a specific wood-fired boiler at a specific facility, although a specific source of emissions is often referred to as an emissions unit).

Symmetric distribution: Refers to a distribution that is symmetric with respect to the mean value. For this type of distribution, the mean and median coincide.

Target statistic: Refers to a population value or characteristic of interest.

Uncertainty: Refers to the lack of knowledge regarding the true value of a quantity. In practice, uncertainties are often expressed in the form of a probability distribution.

Variability: Refers to heterogeneity of a quantity over time or members of a population. Variability may result, for example, from differences in design or operating conditions from one source to another (inter-source variability) and in operating conditions from one time to another at a given source (intra-source variability).

1.2 Objective of Study

The objective of this study is to assess the uncertainty of the best-rated emissions factors and to develop emissions factor uncertainty ratios for a range of probability levels. This study does not attempt to evaluate or provide guidance on the application of emissions factor uncertainty in making environmental decisions. How emissions factor uncertainty affects or can be incorporated into such decision making necessarily must reflect the needs of affected stakeholders consistent with various program objectives. We intend that the study results inform that process. Finding the original emissions test data and other supporting information for an emissions factor is often a key difficulty in assessing uncertainty; furthermore, data availability may be limited (i.e., the emissions factor may be based on only a few emissions tests).

This study investigates the development of emissions factor uncertainty ratios based on statistical analysis of emissions factor supporting data for a variety of emissions source types and pollutants for which we have well-documented multiple sets of emissions test data. This report also presents the statistical approach used to determine emissions factor uncertainty ratios, the results, and composite emissions factor uncertainty ratios.

1.3 Report Organization

This report discusses the statistical analyses conducted to generate emissions factor uncertainty ratios and presents the results of these analyses. Section 1.0 introduces the issue of using emissions factors, provides background information on uncertainty analysis and statistical terminology, and presents the objective of this study. Section 2.0 presents a summary of the results and conclusions. Section 3.0 presents the emissions factor data used in the statistical analyses, along with the rationale for selecting the datasets and the statistical approach used. Section 4.0 presents the statistical results, the emissions factor uncertainty ratios by pollutant and industry (i.e., source category), and the composite emissions factor uncertainty ratios. The report's appendices provide additional information in greater detail on the emissions factor data used in the analyses, as well as more information on the statistical analyses and the results.

2.0 Summary of Results and Conclusions

The technical approach established for this project comprises the following steps:

1. Select and prepare initial emissions factor datasets for analysis.
2. Establish the statistical procedures.
3. Conduct statistical analyses of an emissions factor dataset for an industry and calculate preliminary emissions factor uncertainty ratios.
4. Review the initial results and refine the analytical approach.
5. Conduct statistical analyses of additional representative emissions factor datasets.
6. Calculate composite emissions factor uncertainty ratios for the combined datasets.
7. Consider alternative approaches and compare results to emissions factor uncertainty ratios.

This report presents the results of the analyses and composite emissions factor uncertainty ratios. We calculated emissions factor uncertainty ratios for multiple pollutants from A-rated and B-rated emissions factor datasets from four industries; Section 2.1 presents a summary of the emissions factor data that were used. Based on an approach using boundary (or target) population statistics, we calculated emissions factor uncertainty ratios for each emissions factor and categorized the data by pollutant. For each pollutant type, we calculated average values that we used to derive composite uncertainty ratios. The value of the composite uncertainty ratio depends on the number of emissions tests[1], *n*, used to support the reported emissions factor. Intuitively, the smaller the value of *n*, the larger the uncertainty ratio because there is more uncertainty that the emissions factor represents the emissions from the source category when there are fewer data available.

For this study, we also calculated normalized Monte Carlo sampling distributions of the mean. These distributions may be used to predict confidence intervals for the population mean based on a sample of a specified size. The confidence intervals define lower and upper values for the uncertainty ratio if the goal is to target the mean of the population (e.g., for application to many identical units in an area, such as an emissions inventory for a specific area). Section 2.2 presents a summary of composite emissions factor uncertainty ratios for a range of *n* values, including uncertainty ratios for population values of interest other than the mean (e.g., median, 25^{th} percentile, 75^{th} percentile), and selected percentiles of the normalized Monte Carlo sampling distributions for the population mean. The complete results are discussed in Section 4.0.

Figure 2-1 provides an overview of the statistical approach for developing the emissions factor uncertainty ratios. Section 3.0 and Appendix A present more information about the approach.

[1] An emissions test consists of multiple sample runs (typically at least three valid sample runs).

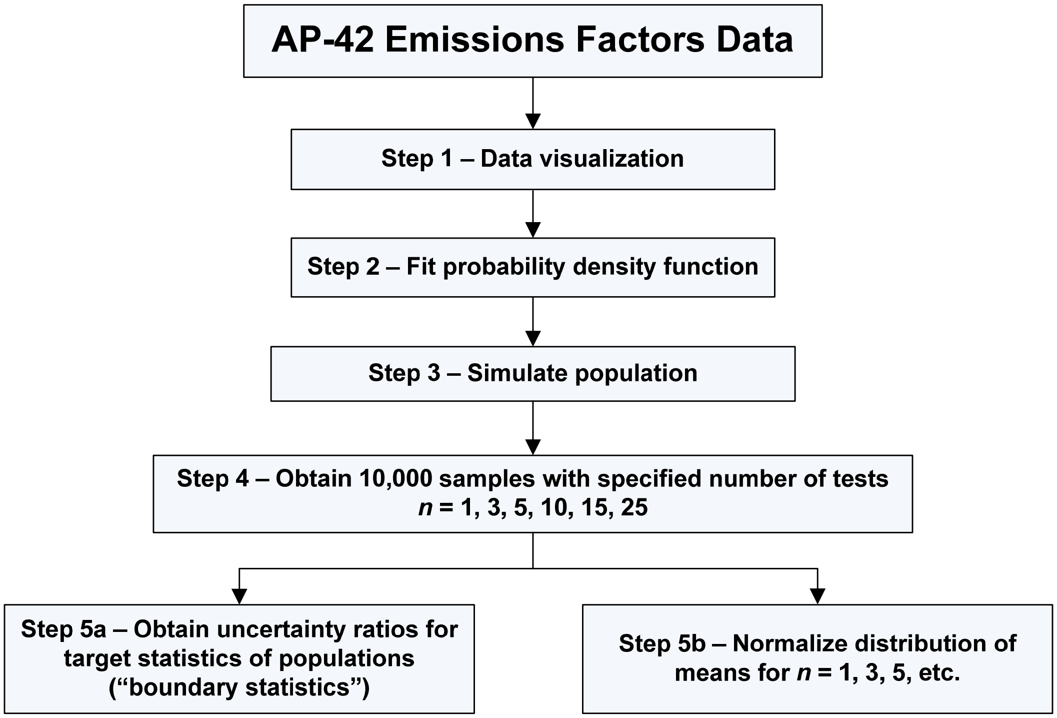

Figure 2-1. Overview of the statistical approach.

2.1 Emissions Factor Data

For the statistical analysis, we identified datasets from the AP-42 background documentation for four source categories or industries. We selected these categories because the respective sections of AP-42 included data for multiple pollutants, both criteria and HAPs, and for each a significant amount of supporting data, including well-documented test reports. The criteria used to select datasets are detailed in Section 3.1. These datasets included supporting emissions data for the following pollutants:

- Particulate matter (PM), including filterable, condensable, and total
- Sulfur dioxide (SO_2)
- Nitrogen oxides (NOx)
- Carbon monoxide
- HAPs, including acetaldehyde, arsenic, benzene, cadmium, chromium, formaldehyde, hydrogen chloride (HCl), lead, mercury, and nickel.

Table 2-1 presents an overview of the emissions factors data selected for analysis, organized by pollutant. Data analyses have been completed for 43 A-rated and 1 B-rated emissions factors. Section 3.1 and Appendix B provide additional detailed information on these emissions factor data. Examination of the data for each of the emissions factor datasets indicates that the data are skewed and are best represented by either log-normal or Weibull probability distribution functions.

Table 2-1. AP-42 Emissions Factors Datasets Listed by Pollutant

Pollutant	AP-42 Chapter	Process/Fuel Type	Control
Acetaldehyde	Chapter 1.6—Wood Residue Combustion in Boilers (External Combustion Sources)	All Fuels	Uncontrolled/PM Control
Arsenic	Chapter 1.6—Wood Residue Combustion in Boilers (External Combustion Sources)	All Fuels	Uncontrolled/PM Control
Arsenic	Chapter 2.1—Refuse Combustion (Solid Waste Disposal)	Mass Burn and Modular Excess Air	Spray Dryer, Fabric Filter
Benzene	Chapter 1.6—Wood Residue Combustion in Boilers (External Combustion Sources)	All Fuels	Uncontrolled/PM Control
Benzene	Chapter 11.1—Hot Mix Asphalt Plants (Mineral Products Industry)	Drum Mix, Natural Gas, No. 2 Fuel Oil, and Waste Oil	Fabric Filter
Cadmium	Chapter 1.6—Wood Residue Combustion in Boilers (External Combustion Sources)	All Fuels	Uncontrolled/PM Control
Cadmium	Chapter 2.1—Refuse Combustion (Solid Waste Disposal)	Mass Burn and Modular Excess Air	Spray Dryer/ESP
Carbon monoxide	Chapter 1.6—Wood Residue Combustion in Boilers (External Combustion Sources)	Bark, Wet Wood, and Dry Wood	Uncontrolled
Carbon monoxide	Chapter 2.1—Refuse Combustion (Solid Waste Disposal)	Mass Burn Waterwall	Uncontrolled
Chromium	Chapter 1.6—Wood Residue Combustion in Boilers (External Combustion Sources)	All Fuels	Uncontrolled/PM Control
PM-condensable	Chapter 1.6—Wood Residue Combustion in Boilers (External Combustion Sources)	All Fuels	Uncontrolled
PM-condensable (Inorganic)	Chapter 11.1—Hot Mix Asphalt Plants (Mineral Products Industry)	Drum Mix	Scrubber, Fabric Filter
PM-condensable (Inorganic)	Chapter 11.1—Hot Mix Asphalt Plants (Mineral Products Industry)	Batch Mix	Fabric Filter
PM-condensable (Organic)	Chapter 11.1—Hot Mix Asphalt Plants (Mineral Products Industry)	Drum Mix	Scrubber, Fabric filter
PM-condensable (Organic)	Chapter 11.1—Hot Mix Asphalt Plants (Mineral Products Industry)	Batch Mix	Fabric Filter
PM-filterable	Chapter 1.6—Wood Residue Combustion in Boilers (External Combustion Sources)	Wet Wood	Uncontrolled
PM-filterable	Chapter 1.6—Wood Residue Combustion in Boilers (External Combustion Sources)	Dry Wood	Uncontrolled
PM-filterable	Chapter 1.6—Wood Residue Combustion in Boilers (External Combustion Sources)	All Fuels	Wet Scrubber
PM-filterable	Chapter 1.6—Wood Residue Combustion in Boilers (External Combustion Sources)	Wet Wood	Mechanical Collector

(continued)

Table 2-1. (Continued)

Pollutant	AP-42 Chapter	Process/Fuel Type	Control
PM-Filterable	Chapter 1.6—Wood Residue Combustion in Boilers (External Combustion Sources)	Dry Wood	Mechanical Collector
PM-Filterable	Chapter 10.6.1—Waferboard/Oriented Strandboard (Wood Products Industry)	Hot Press, PF/MDI Resins	Uncontrolled
PM-Filterable	Chapter 11.1—Hot Mix Asphalt Plants (Mineral Products Industry)	Drum Mix	Fabric Filter
PM-Filterable	Chapter 11.1—Hot Mix Asphalt Plants (Mineral Products Industry)	Batch Mix	Fabric Filter
PM-Filterable	Chapter 2.1—Refuse Combustion (Solid Waste Disposal)	Mass Burn and Modular Excess Air	Duct Sorbent Injection/Fabric Filter
PM-Filterable	Chapter 2.1—Refuse Combustion (Solid Waste Disposal)	Mass Burn and Modular Excess Air	Spray Dryer/ESP
PM-Filterable	Chapter 2.1—Refuse Combustion (Solid Waste Disposal)	Mass Burn and Modular Excess Air	Spray Dryer/Fabric Filter
PM-Filterable	Chapter 2.1—Refuse Combustion (Solid Waste Disposal)	Mass Burn and Modular Excess Air	Uncontrolled
PM-Filterable	Chapter 2.1—Refuse Combustion (Solid Waste Disposal)	Mass Burn and Modular Excess Air	ESP
PM-Total (filterable)	Chapter 2.1—Refuse Combustion (Solid Waste Disposal)	Refuse-derived Fuel	ESP
PM-Total (filterable)	Chapter 2.1—Refuse Combustion (Solid Waste Disposal)	Refuse-derived Fuel	Uncontrolled
Formaldehyde	Chapter 1.6—Wood Residue Combustion in Boilers (External Combustion Sources)	All Fuels	Uncontrolled/PM Control
Formaldehyde	Chapter 11.1—Hot Mix Asphalt Plants (Mineral Products Industry)	Drum Mix, Natural Gas, No. 2 Fuel Oil, and Waste Oil	Fabric Filter
Hydrogen Chloride	Chapter 2.1—Refuse Combustion (Solid Waste Disposal)	Mass Burn and Modular Excess Air	Uncontrolled
Hydrogen Chloride	Chapter 2.1—Refuse Combustion (Solid Waste Disposal)	Mass Burn and Modular Excess Air	Spray Dryer/Fabric Filter
Lead	Chapter 2.1—Refuse Combustion (Solid Waste Disposal)	Mass Burn and Modular Excess Air	ESP
Lead	Chapter 2.1—Refuse Combustion (Solid Waste Disposal)	Mass Burn and Modular Excess Air	Spray Dryer/ESP
Mercury	Chapter 1.6—Wood Residue Combustion in Boilers (External Combustion Sources)	All Fuels	Uncontrolled/PM Control
Mercury	Chapter 2.1—Refuse Combustion (Solid Waste Disposal)	Mass Burn and Modular Excess Air	Spray Dryer/Fabric Filter

(continued)

Table 2-1. (Continued)

Pollutant	AP-42 Chapter	Process/Fuel Type	Control
Nickel	Chapter 1.6—Wood Residue Combustion in Boilers (External Combustion Sources)	All Fuels	Uncontrolled/PM Control
Nickel	Chapter 2.1—Refuse Combustion (Solid Waste Disposal)	Mass Burn and Modular Excess Air	Spray Dryer/Fabric Filter
Nitrogen oxides	Chapter 1.6—Wood Residue Combustion in Boilers (External Combustion Sources)	Bark and Wet Wood	Uncontrolled
Nitrogen oxides	Chapter 2.1—Refuse Combustion (Solid Waste Disposal)	Mass Burn Waterwall	Uncontrolled
Sulfur dioxide	Chapter 1.6—Wood Residue Combustion in Boilers (External Combustion Sources)	Bark and Wet Wood	Uncontrolled
Sulfur dioxide	Chapter 2.1—Refuse Combustion (Solid Waste Disposal)	Mass Burn and Modular Excess Air	Uncontrolled

ESP = electrostatic precipitator; PM = particulate matter; PF/MDI = phenol formaldehyde/methylene diphenyl diisocyanate.

Section 3.2 provides detailed information on the characterization of the individual emissions factor datasets, the statistical procedures used to simulate a distribution of the population (from the sample derived from the AP-42 emissions factor data), and the statistical procedures used to calculate uncertainty ratios and normalized Monte Carlo sampling distributions of the mean.

2.2 Composite Emissions Factor Uncertainty Ratios

We developed emissions factor uncertainty ratios by different statistical approaches for single emissions unit applications and for multiple emissions unit applications. To account for situations that occur between these types of emissions estimation applications (e.g., for multiple emissions units at a single source), we interpolated between the results of the two statistical approaches to better estimate the uncertainty.

Population percentiles (target statistic) approach. We calculated emissions factor uncertainty ratios to account for uncertainty when applying emissions factors for single emissions unit applications. The uncertainty ratio is a value by which the emissions factor is multiplied to estimate the desired statistic of the population, as shown in Equation 2-1.

$$EF_{\text{uncertainty ratio}} = \frac{EF_{\text{target statistic}}}{EF} \quad \text{(Eq. 2-1)}$$

where

$EF_{\text{uncertainty ratio}}$ = Estimate of the emissions factor uncertainty, unitless

$EF_{\text{target statistic}}$ = Target population value of the emissions distribution, hereafter referred to as the target statistic (e.g., 95^{th} percentile), in units of the AP-42 emissions factor

EF = Emissions factor, as presented in AP-42, in units of the AP-42 emissions factor.

Based on the statistical approach in Section 3.2, we calculated emissions factor uncertainty ratios for each emissions factor listed in Table 2-1. We calculated the uncertainty ratios for several population parameters of interest, including the 5^{th} percentile, 10^{th} percentile, 25^{th} percentile, median, mean, 75^{th} percentile, 90^{th} percentile, and the 95^{th} percentile of the data distribution. The uncertainty ratios are a function of the number of tests, *n*, on which the emissions factor is based.

We calculated the emissions factor uncertainty ratios for each dataset, and then we clustered them by type of pollutant and control (controlled vs. uncontrolled). Specifically, we clustered the uncertainty ratios as follows:

- HAPs
- PM-condensable
- PM-filterable, controlled
- PM-filterable, uncontrolled
- Gaseous criteria pollutants.

We calculated the mean value of the corresponding uncertainty ratios to determine composite emissions factor uncertainty ratios for each category of pollutant. Throughout the analyses conducted for this study, we calculated uncertainty ratios for the following values of *n*: 1, 3, 5, 10, 15, 20, and 25. We calculated the composite uncertainty ratios for each of these *n* values. Examining the composite values indicates that for each of the pollutant categories, the uncertainty ratio values begin to stabilize when *n* is 10 or greater; furthermore, the composite uncertainty ratios for $n = 5$ and $n = 10$ are similar. One can provide uncertainty ratio values for selected intervals of *n* for each pollutant category. The intervals we selected are $n < 3$, $3 \leq n < 10$, $10 \leq n < 25$, and $n \geq 25$. Table 2-2 presents the composite uncertainty ratios for HAP; PM-condensable; PM-filterable, controlled; PM-filterable, uncontrolled; and gaseous criteria pollutants.

<u>Normalized sampling distributions (confidence intervals for the mean)</u>. We also calculated normalized sampling distributions of emissions factors (means) obtained from Monte Carlo techniques applied to the hypothetical populations. Table 2-3 presents selected percentiles for the normalized distributions for selected sample sizes *n*, composited by pollutant category. Observe that each normalized sampling distribution can be considered as the sampling distribution of the emissions factor uncertainty ratio statistic if the goal is to target the population mean. With these sampling distributions, it is possible to obtain confidence intervals (e.g., 90, 95, 98, and 99 percent) for the uncertainty ratio value for the population mean. For example, a 90-percent confidence interval for the uncertainty ratio to the mean has endpoints equal to the 5^{th} and 95^{th} percentiles of the normalized sampling distribution. These endpoints will define the lower and upper values of the selected confidence interval for the uncertainty ratio if the goal is to target the mean of the hypothetical distribution. Because these uncertainty ratios provide measures of uncertainty around the mean, they are smaller than the composite uncertainty ratios that target boundary statistics other than the mean of the population (e.g., 90^{th} percentile).

Table 2-2. Composite Emissions Factor Uncertainty Ratios based on Population Percentiles (Based on Equation 2-1) by Target Statistic, Number of Emissions Tests, and Pollutant

Pollutant	Target Statistic	Number of Emissions Tests Used to Determine AP-42 Emissions Factor			
		$n < 3$	$3 \le n < 10$	$10 \le n < 25$	$n \ge 25$
HAP	10th percentile	0.2	0.1	0.1	0.1
	25th percentile	0.4	0.3	0.2	0.2
	Median	1.0	0.6	0.5	0.5
	75th percentile	2.9	1.5	1.2	1.1
	90th percentile	7.7	3.6	2.7	2.4
	95th percentile	13.4	6.0	4.3	3.9
PM-condensable	10th percentile	0.2	0.2	0.2	0.1
	25th percentile	0.5	0.3	0.3	0.3
	Median	1.0	0.7	0.6	0.6
	75th percentile	2.2	1.5	1.3	1.2
	90th percentile	4.4	3.0	2.5	2.4
	95th percentile	6.9	4.7	3.9	3.6
PM-filterable, controlled	10th percentile	0.4	0.3	0.3	0.3
	25th percentile	0.6	0.5	0.5	0.5
	Median	1.0	0.8	0.8	0.8
	75th percentile	1.7	1.4	1.3	1.2
	90th percentile	2.9	2.3	2.1	2.0
	95th percentile	3.9	3.1	2.8	2.7
PM-filterable, uncontrolled	10th percentile	0.5	0.5	0.4	0.4
	25th percentile	0.7	0.6	0.6	0.6
	Median	1.0	0.9	0.9	0.9
	75th percentile	1.5	1.3	1.3	1.2
	90th percentile	2.2	1.9	1.8	1.8
	95th percentile	2.7	2.3	2.2	2.2
Gaseous criteria pollutants	10th percentile	0.3	0.3	0.3	0.3
	25th percentile	0.6	0.5	0.5	0.5
	Median	1.0	0.8	0.8	0.8
	75th percentile	1.9	1.4	1.3	1.2
	90th percentile	3.5	2.5	2.1	2.0
	95th percentile	5.4	3.6	3.0	2.8

HAP = hazardous air pollutant; PM = particulate matter.

Table 2-3. Composite Emissions Factor Uncertainty Ratios Based on Normalized Sampling Distribution of Emissions Factor (Mean)

Pollutant	Distribution Statistic	Number of Emissions Tests Used to Determine AP-42 Emissions Factor			
		$n < 3$	$3 \leq n < 10$	$10 \leq n < 25$	$n \geq 25$
HAP	10th percentile	0.1	0.3	0.5	0.6
	25th percentile	0.2	0.4	0.6	0.2
	Median	0.5	0.7	0.8	0.9
	Mean	1.0	1.0	1.0	1.0
	75 th percentile	1.0	1.2	1.2	1.2
	90th percentile	2.2	2.0	1.7	1.5
	95th percentile	3.5	2.8	2.1	1.7
PM-condensable	10th percentile	0.1	0.3	0.5	0.6
	25th percentile	0.3	0.4	0.6	0.8
	Median	0.5	0.7	0.9	0.9
	Mean	1.0	1.0	1.0	1.0
	75th percentile	1.1	1.2	1.2	1.2
	90th percentile	2.2	1.9	1.6	1.4
	95th percentile	3.3	2.6	2.0	1.6
PM-filterable, controlled	10th percentile	0.3	0.5	0.7	0.8
	25th percentile	0.4	0.6	0.8	0.8
	Median	0.7	0.8	0.9	1.0
	Mean	1.0	1.0	1.0	1.0
	75th percentile	1.2	1.2	1.1	1.1
	90th percentile	2.0	1.7	1.4	1.3
	95th percentile	2.7	2.1	1.7	1.4
PM-filterable, uncontrolled	10th percentile	0.4	0.6	0.7	0.8
	25th percentile	0.6	0.7	0.8	0.9
	Median	0.8	0.9	1.0	1.0
	Mean	1.0	1.0	1.0	1.0
	75th percentile	1.2	1.2	1.1	1.1
	90th percentile	1.8	1.5	1.3	1.2
	95th percentile	2.3	1.8	1.5	1.3
Gaseous criteria pollutants	10th percentile	0.4	0.5	0.7	0.8
	25th percentile	0.5	0.7	0.8	0.9
	Median	0.8	0.9	0.9	1.0
	Mean	1.0	1.0	1.0	1.0
	75th percentile	1.2	1.2	1.1	1.1
	90th percentile	1.8	1.5	1.3	1.2
	95th percentile	2.3	1.9	1.5	1.3

Summary of the two statistical approaches taken. We applied two different statistical approaches to develop emissions factor uncertainty ratios. The first approach targets boundary statistics of the hypothetical population and is appropriate for consideration when applying emissions factors to a single emissions unit. The second approach estimates uncertainty about the mean of the population and is more appropriate for applying emission factors to many identical emissions units in an area (e.g., emissions inventory for a specific area). As expected, uncertainty ratios calculated using the first approach are greater because they target a boundary statistic (e.g., 90^{th} percentile) of the hypothetical population for a single measurement, whereas the second approach calculates an uncertainty ratio that provides uncertainty measures (confidence intervals) for the mean.

Some situations do not fall perfectly into one of these two categories, making it unclear which of the two uncertainty approaches may be most applicable. This is particularly true when estimating emissions from a small number of similar emissions units for purposes other than an area-wide inventory. One example might be estimating the total emissions from a facility with three similar boilers. Interpolation between the two uncertainty approaches may provide better uncertainty values for these "in between" applications. The uncertainty ratio values for situations involving a small number of emissions units should fall between the values calculated by the two approaches. One technique for addressing emissions factor uncertainty ratios for a multiple-source situation is to start with the uncertainty ratio applicable to a single source and apply a correction to reduce the uncertainty ratio applied because emissions from multiple emissions units are being estimated. We outlined in Section 4.0 a practical, nonstatistical, procedure based on a linear interpolation of the difference in the uncertainty ratios from the two statistical approaches to develop correction factors when applying the uncertainty ratios for multiple process applications up to 10 sources (i.e., emissions units). For 11 or more sources or emissions units, the emissions factor uncertainty ratio is equivalent to the uncertainty ratio determined by the normalized sample distribution about the mean (i.e., the second statistical approach). These correction factors are discussed in Section 4.4.

2.3 Consideration of Alternative Approaches

During the course of this study, we and our peer reviewers discussed, considered, and to a limited extent, explored two other statistical approaches. One approach explored, which was a Bayesian approach, uses a different procedure to determine the hypothetical population distribution parameters to account for the uncertainty associated with the unknown population distribution. Statisticians may follow a frequentist approach or a Bayesian approach when analyzing data. In the frequentist approach, the model parameters are considered fixed quantities (population values) and uncertainty arises from estimating these population parameters using a finite collection of data. In the Bayesian approach, parameters are considered random variables and, instead of one population parameter, there is a population of possible parameters. Uncertainty in this case comes from the data and the distribution of the parameters. For three emissions factor datasets, uncertainty ratios were recalculated following a Bayesian approach. In this Bayesian approach, we considered appropriate distributions for the model parameters. The results of these analyses show little difference in the uncertainty ratios for two of the three datasets. The two approaches resulted in a larger difference for the third dataset. Section 3.2.3 and Appendix F further discusses the results.

We also considered a second alternative approach that addressed the application of emissions factors involving a small number of similar emissions units (e.g., three boilers at a single facility). As indicated in Section 2.2, we used two statistical approaches to calculate emissions factor uncertainty ratios. The uncertainty ratios calculated by the first approach target a boundary statistic for application to a single source (emissions unit), while the uncertainty ratios calculated by the second approach target the uncertainty about the mean value of a large sample. During the review process for this report, a question arose about how to apply uncertainty ratio values for situations involving a small number of emissions units. As indicated in Section 2.2, we interpolated between the results of the two approaches to address uncertainty for situations involving a small number of emissions units. A commenter suggested and provided example calculations for another approach designed to address this situation. We reviewed the approach and example calculations provided, but we did not conduct any additional analysis because the approach is based on hypothetical populations and does not use the actual AP-42 emissions data. This approach considers the following three sources of variability: the skewness of the distribution of emissions data, the number of tests comprising the emissions factor, and the number of emissions units for which emissions are being estimated. The approach consisted of sampling independently from each of the hypothetical populations to develop independent populations; one dataset to replicate emissions factors ("calculated" emissions factor values) and the other to represent actual emissions from the emissions units. To compare the calculated emissions factors and the actual emissions of the emissions units, the calculated emissions factor value was subtracted from the actual emissions unit value. Nine independent sampling distributions were regenerated to represent actual emissions from nine different facilities having from one to nine similar emission units. Similarly, 20 sampling distributions were generated to represent calculated emissions factors developed from 1 to 20 emissions tests (i.e., $n = 1$ to 20). All combinations of differences between the nine sampling distributions, representing actual emissions from emission units, and the 20 sampling distributions, representing calculated emissions factor values were calculated. This approach simulates the distribution of the differences in emissions factors based on a different number of emissions units and emissions tests. The calculated differences were used to determine the emissions factor uncertainty ratio. Selected percentiles of the distribution of uncertainty ratios produced upper bounds for the emissions factor (mean).

A relevant aspect of this approach is the incorporation of the uncertainty due to the differences between the number of tests that the emissions factor was based on and the number of emissions units. Also, this approach is based on the assumption that it is possible to model all the pollutants using one probability distribution with few varying parameters, which in some sense follows the finding from this project (i.e., that the pollutants considered were either Weibull or log-normally distributed). As expected, when the number of emissions units increases, and the number of tests, n, used to calculate the emissions factor increases, the difference between the actual emissions factor and the calculated emissions factor will tend to zero. Section 3.2.3 and Appendix G provides more details on this statistical approach.

2.4 Conclusions

In summary, we developed emissions factor uncertainty ratios based on boundary (target) statistics of the population for numerous target statistics and values of n. To simplify presentation of the data and application of the results, we reported uncertainty ratios for selected target statistics. To simplify, we also reported composite uncertainty ratios for selected intervals of n. We could develop a more extensive presentation of additional target statistics for use in an electronic database or lookup table to provide a broader set of options, if needed. For applications where the target statistic of interest is the mean, such as for multiple emissions units in an area, the appropriate uncertainty ratio to use is a selected confidence interval (upper and/or lower confidence limits). We have calculated uncertainty ratios based on the normalized sampling distribution of the mean for $n = 1$ to 30. We could provide a more extensive presentation of additional confidence limits about the mean in an electronic database or lookup table implemented in a user-friendly Java applet to provide a broader set of options, if needed.

With respect to characterizing the uncertainty associated with the use of emissions factors, the following general conclusions result from the analyses:

- All of the emissions factor datasets examined are skewed and either Weibull or log-normally distributed. This is consistent with previous studies of emissions factor data.

- A consistent pattern is shown for all of the pollutants. As the number of tests, *n*, increases, the values of the emissions factor uncertainty ratios decrease. This pattern holds for all of the pollutants, regardless of the number of tests available from the supporting emissions dataset or the control status (controlled vs. uncontrolled).

- For each of the pollutant categories, the uncertainty ratio values nearly stabilize when *n* is 10 or greater.

- There are some differences from pollutant to pollutant about the range of the emissions factor uncertainty ratios as a function of *n*. For some pollutants, regardless of the *n* value, the uncertainty ratio does not significantly change (e.g., PM-filterable, uncontrolled). For other emissions factor datasets, the uncertainty ratio varies more widely depending on the *n* value.

- The HAP emissions factor data exhibit the highest degree of variability and result in the largest emissions factor uncertainty ratios.

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3.0 Technical Approach

First, the overall technical approach consists of selecting A-rated and B-rated emissions factor datasets for analysis and using exploratory data analysis techniques to visualize and characterize these datasets. Second, statistical techniques are applied to each of the selected emissions factor datasets to determine preliminary emissions factor uncertainty ratios. Third, emissions factor uncertainty ratios are calculated for combined datasets. During the course of the project, we explored or conducted several different statistical analyses. Section 3.1 describes the approach we used to identify and select emissions factor data for analysis and summarizes all the emissions factors analyzed. Section 3.2 describes the statistical analyses that we conducted on the emissions factor data and provides some example results for purposes of illustration. Section 4.0 summarizes the results for all of the emissions factor data.

3.1 Selection of Emissions Factor Data for Analysis

AP-42 provides air pollutant emissions factors for many different stationary point and area source types. Each emissions factor represents an industry and emissions unit average. All AP-42 emissions factors can be retrieved from the Factor Information REtrieval (FIRE) Data System (U.S. EPA, 2004b). The FIRE database allows users to obtain records based on source category, source classification code, pollutant name, Chemical Abstracts Service (CAS) number, control device, and emissions factor rating. The supporting emissions data used to develop the emissions factors are also publicly available in the background documentation for each AP-42 industry-specific section. These data are often summarized in table format and are sometimes available as an electronic data file. We used FIRE to sort and identify emissions factor datasets for analysis using the rationale and criteria identified in Section 3.1.1. After identifying potential datasets, we reviewed the AP-42 background files to determine whether the necessary data were readily available for analysis (i.e., electronic data files or concise table summaries of the test data used to calculate the emissions factor), and we selected the datasets to be analyzed.

3.1.1 Rationale

When selecting datasets for statistical analysis, we used rationale based on the following criteria:

- The quality rating of the emissions factor
- The quantity of emissions data used to develop the factors (i.e., number of emissions tests)
- The number of pollutants included
- The accessibility of the supporting emissions data.

In general, AP-42 emissions factors are assigned a quality rating of “A” through “E” based on the quality of the supporting emissions test data and on both the amount and the representative characteristics of those data (e.g., how well the data represent the emissions source category). AP-42 emissions factor ratings are assigned as follows (U.S. EPA, 1995, pp. 9–10):

- A-rated emissions factors are calculated using highly rated source test data from many randomly chosen facilities in the industry; the source category population is sufficiently specific (e.g., with regard to fuel type) to minimize variability. A-rated factors are considered excellent.
- B-rated emissions factors are calculated using highly rated source test data from a "reasonable" number of facilities; it is not clear whether the facilities tested represent a random sample of industry. As with A-rated factors, the source category is sufficiently specific to minimize variability. B-rated factors are considered above average.
- C-rated emissions factors are calculated using source test data from a "reasonable" number of facilities; it is not clear whether the facilities tested represent a random sample of industry. As with A- and B-rated factors, the source category is sufficiently specific to minimize variability. C-rated factors are considered average.
- D-rated emissions factors are calculated using source test data from a small number of facilities, and there may be reason to suspect that the facilities tested do not represent a random sample of industry. There may also be evidence of variability within the source population. D-rated factors are considered below average.
- E-rated emissions factors are calculated using source test data that have been rated "poor," and there may be reason to suspect that the facilities tested do not represent a random sample of industry. There also may be evidence of variability within the source population. E-rated factors are considered poor.

In selecting source categories/industries for analysis, we prioritized those with A- and B-rated emissions factors. Because A-rated factors are typically calculated based on many tests from a representative sample of the industry, we selected A-rated factors for analysis so that we had sufficient data for statistical analysis, followed by selection of some B-rated emissions factors. If datasets consist of many emissions tests (e.g., more than 20 tests), then we can simulate smaller datasets and conduct statistical analyses on these smaller datasets (e.g., datasets comprised of three tests, six tests, nine tests). Consequently, the FIRE database was first sorted to identify A- and B-rated factors.

The next criterion we used for selecting an industry was the availability of factors for multiple pollutants. We based this priority for selecting source categories/industries on the availability of emissions factors for the following pollutants (controlled and uncontrolled emissions):

- PM with and without a control device

- SO_2 with and without a control device
- NO_x without a control device
- Carbon monoxide with and without a control device
- Volatile organic compounds (VOCs) with and without a control device
- HAPs with and without a control device.

This criterion serves two purposes. First, evaluating emissions factors for different pollutants can reveal whether the data from these pollutants are distributed differently and thus require different uncertainty ratios. Second, selecting industries with emissions factors for multiple pollutants is more efficient in obtaining the data and establishing the database for statistical analysis.

The final criterion we used for selecting source category/industry was access to supporting background documentation and a detailed data summary for the specific source category/industry AP-42 section. Most sections in AP-42 provide background documentation that outlines how the emissions factors were determined. In most cases, background documentation includes a literature review, emissions factor methodologies, and reference materials; however, some sections of AP-42 did not provide an easily accessible and succinct summary of the data used to calculate the emissions factors. In those cases, we did not use the emissions factors for analysis.

The initial search of FIRE identified 2,331 A-quality rated emissions factors, of which 1,581 factors referenced a section of AP-42. This list was refined to identify 19 sections of AP-42 containing A-rated factors for multiple pollutants; a total of approximately 150 A-rated factors among the 19 sections. Six of these sections contained at least one A-rated factor for five of the pollutants of interest. We reviewed each of these six sections and selected three of the sections for analysis based on the number of factors available, the pollutants, and the availability of a data summary. An additional AP-42 section, Section 10.6.1—Waferboard/Oriented Strandboard Manufacturing, was also reviewed because the data were readily available and included emissions factors (B-rated) for PM-filterable, PM-condensable, and HAP. We compiled emissions factor datasets for statistical analysis from the following AP-42 sections:

- Wood Residue Combustion in Boilers (External Combustion Sources), Section 1.6
- Refuse Combustion (Solid Waste Disposal), Section 2.1
- Waferboard/Oriented Strandboard Manufacturing (Wood Products Industry), Section 10.6.1
- Hot Mix Asphalt Plants (Mineral Products Industry), Section 11.1.

Each of these AP-42 sections provided the supporting background documentation and detailed datasets used to develop the emissions factors.

3.1.2 Data Summary by Industry

The subsequent sections provide a summary of the emissions factor datasets from each of the four industries selected for statistical analysis. Each section presents a table that summarizes the emissions factor data selected, including the emissions source, pollutant, control device (if applicable), emissions factor, number of emissions tests, *n*, used to calculate the emissions factor, and number of test runs. Appendix B includes the detailed emissions factor datasets.

3.1.2.1 Wood Residue Combustion in Boilers (External Combustion Sources)

Table 3-1 summarizes the emissions factors datasets for Wood Residue Combustion in Boilers (Wood Residue Combustion). This industry includes A-rated emissions factor datasets for CO, NOx, PM-condensable, PM-filterable, SO_2, and specific HAPs (acetaldehyde, arsenic, benzene, cadmium, chromium, formaldehyde, lead, mercury, and nickel). Appendix B.1 (Tables B.1-1 through B.1-18) presents the detailed emissions data used in developing the emissions factors for Wood Residue Combustion. We used the average of test runs conducted during the emissions test to calculate emissions test data values from each individual facility. The overall emissions factors, as presented in AP-42, are the averages of all emissions tests and give equal weighting to each emissions test.

3.1.2.2 Refuse Combustion (Solid Waste Disposal)

Table 3-2 summarizes the emissions factors datasets for Refuse Combustion. These emissions factors include CO, NOx, PM-Total, PM-filterable, SO_2, and specific HAPs (arsenic, cadmium, hydrogen chloride, lead, mercury, and nickel). Appendix B.2 (Tables B.2-1 through B.2-17) presents detailed emissions data that we used to calculate the emissions factors.

Unlike the Wood Residue Combustion source category, the emissions factors for the Refuse Combustion source category are calculated from a weighted average. For Refuse Combustion, we calculated an emissions factor for each facility based on all emissions tests for that facility, and these are then averaged together to determine the overall emissions factor. This approach gives equal weight to each facility tested. For the purposes of our statistical analysis, we evaluated the emissions factor datasets in a slightly different manner. We converted the emissions factors datasets to a nonweighted average (i.e., all emissions tests were averaged together to determine the overall emissions factor). Although this approach yields a slightly different overall emissions factor for each pollutant tested, it is consistent with the approach used for the Wood Residue Combustion and the Hot Mix Asphalt Plants source categories.

3.1.2.3 Waferboard/Oriented Strandboard Manufacturing (Wood Products Industry)

Table 3-3 summarizes the emissions factors datasets for the Waferboard/Oriented Strandboard Manufacturing (hereafter referred to as W/OSB manufacturing) source category. We analyzed a single PM-filterable emissions factor from the W/OSB source category. Appendix B.3 (Table B.3-1) presents all emissions test data used in developing the emissions factor. As in the Refuse Combustion source category above, the emissions factor, as presented in AP-42, is calculated as a weighted average (i.e., an emissions factor is calculated for each facility, and then these are averaged together to determine the overall emissions factor). This approach gives equal weight to each facility tested. For the purposes of developing an emissions factor uncertainty ratio, we evaluated this dataset in a slightly different manner and used a nonweighted average to develop the overall emissions factors.

Table 3-1. Wood Residue Combustion in Boilers (External Combustion Sources) from AP-42 Section 1.6

Fuel	Pollutant	Control Method	Emissions Factor[a]	Unit	Measure	No. of Tests	No. of Test Runs
All Fuels	Acetaldehyde	Uncontrolled/PM Control	8.3E-04	lb	Million BTUs	21	24
All Fuels	Arsenic	Uncontrolled/PM Control	2.2E-05	lb	Million BTUs	23	24
All Fuels	Benzene	Uncontrolled/PM Control	4.2E-03	lb	Million BTUs	19	22
All Fuels	Cadmium	Uncontrolled/PM Control	4.1E-06	lb	Million BTUs	24	25
Bark, Wet Wood, and Dry Wood	Carbon Monoxide	Uncontrolled	6.0E-01	lb	Million BTUs	128	302
All Fuels	Chromium	Uncontrolled/PM Control	2.1E-05	lb	Million BTUs	27	30
All Fuels	Formaldehyde	Uncontrolled/PM Control	4.4E-03	lb	Million BTUs	48	59
All Fuels	Lead	Uncontrolled/PM Control	4.8E-05	lb	Million BTUs	26	28
All Fuels	Mercury	Uncontrolled/PM Control	3.5E-06	lb	Million BTUs	19	24
All Fuels	Nickel	Uncontrolled/PM Control	3.3E-05	lb	Million BTUs	22	23
Bark and Wet Wood	Nitrogen Oxides	Uncontrolled	2.2E-01	lb	Million BTUs	82	197
All Fuels	PM, condensable	Uncontrolled	1.7E-02	lb	Million BTUs	89	220
Wet Wood	PM, filterable	Uncontrolled	3.3E-01	lb	Million BTUs	17	43
Dry Wood	PM, filterable	Uncontrolled	4.0E-01	lb	Million BTUs	15	22
All Fuels	PM, filterable	Wet Scrubber	6.6E-02	lb	Million BTUs	32	95
Wet Wood	PM, filterable	Mechanical Collector	2.2E-01	lb	Million BTUs	42	120
Dry Wood	PM, filterable	Mechanical Collector	3.0E-01	lb	Million BTUs	30	38
Bark and Wet Wood	Sulfur dioxide	Uncontrolled	2.5E-02	lb	Million BTUs	28	40

[a] Emissions factors are A-rated factors.

Table 3-2. Refuse Combustion (Solid Waste Disposal) from AP-42 Section 2.1

Combustor Type	Pollutant	Control Method	AP-42 Emissions Factor[a]	Unit	Calculated Emissions Factor[b]	Unit	No. of Tests[c]	No. of Facilities
Mass Burn and Modular Excess Air	Arsenic	Spray Dryer/ Fabric Filter	4.23E-06	lb/ton	3.82E-06	lb/ton	35	4
Mass Burn and Modular Excess Air	Cadmium	Spray Dryer/ESP	7.51E-05	lb/ton	9.32E-05	lb/ton	18	6
Mass burn Waterwall	Carbon Monoxide	Uncontrolled	4.63E-01	lb/ton	4.07E-01	lb/ton	35	17
Mass Burn and Modular Excess Air	Hydrogen Chloride	Uncontrolled	6.40E+00	lb/ton	6.08E+00	lb/ton	40	10
Mass Burn and Modular Excess Air	Hydrogen Chloride	Spray Dryer/ Fabric Filter	2.11E-01	lb/ton	1.98E-01	lb/ton	14	6
Mass Burn and Modular Excess Air	Lead	Spray Dryer/ESP	9.15E-04	lb/ton	1.17E-03	lb/ton	18	6
Mass Burn and Modular Excess Air	Mercury	Spray Dryer/ Fabric Filter	2.20E-03	lb/ton	1.59E-03	lb/ton	60	13
Mass Burn and Modular Excess Air	Nickel	Spray Dryer/ Fabric Filter	5.0E-5	lb/ton	3.32E-05	lb/ton	37	6
Mass Burn Waterwall	Nitrogen Oxide	Uncontrolled	3.56E+00	lb/ton	3.62E+00	lb/ton	31	16
Mass Burn and Modular Excess Air	PM, filterable	Duct Sorbent Injection/Fabric Filter	1.79E-01	lb/ton	2.19E-01	lb/ton	15	5
Mass Burn and Modular Excess Air	PM, filterable	Spray Dryer/ESP	7.03E-02	lb/ton	7.25E-02	lb/ton	18	5

(continued)

Table 3-2. (Continued)

Combustor Type	Pollutant	Control Method	AP-42 Emissions Factor[a]	Unit	Calculated Emissions Factor[b]	Unit	No. of Tests[c]	No. of Facilities
Mass Burn Waterwall	Nitrogen Oxide	Uncontrolled	3.56E+00	lb/ton	3.62E+00	lb/ton	31	16
Mass Burn and Modular Excess Air	PM, filterable	Spray Dryer/ Fabric Filter	6.20E-02	lb/ton	6.28E-02	lb/ton	77	15
Mass Burn and Modular Excess Air	PM, filterable	Uncontrolled	2.51E+01	lb/ton	2.50E+01	lb/ton	24	10
Mass Burn and Modular Excess Air	PM, filterable	ESP	2.10E-01	lb/ton	1.97E-01	lb/ton	35	13
Refuse-derived Fuel	PM, total[d]	ESP	1.04E+00	lb/ton	0.812	lb/ton	10	5
Refuse-derived Fuel	PM, total[d]	Uncontrolled	6.96E+01	lb/ton	6.29E+01	lb/ton	13	7
Mass Burn and Modular Excess Air	Sulfur Dioxide	Uncontrolled	3.46E+00	lb/ton	3.44E+00	lb/ton	46	13

ESP = electrostatic precipitator; PM = particulate matter.

[a] Emissions factors presented in AP-42 are based on a weighted average and are A-rated factors. This approach provides equal weight to each facility tested.

[b] Calculated emissions factor not based on a weighted average.

[c] The number of sampling runs per test was not given. It is assumed that each test is comprised of at least three sampling runs.

[d] These PM-total emissions factors were included with the PM-filterable data.

Table 3-3. Waferboard/Oriented Strandboard (Wood Products Industry) from AP-42 Section 10.6.1

Process	Fuel Type	Pollutant	Control	AP-42 Emissions Factor[a]	Calculated Emissions Factor[b]	No. of Tests	No. of Runs
Hot Press, PF/MDI resins	Uncontrolled	PM, filterable	Uncontrolled	0.37 (lb/MSF)	0.22	26	78

MSF = thousand square feet of 3/8-inch thick panel; PF/MDI = phenol-formaldehyde/methylene diphenyl diisocyanate.

[a] Emissions factors presented in AP-42 are based on a weighted average and are B-rated factors. This approach provides equal weight to each facility tested.

[b] Calculated emissions factors not based on a weighted average.

3.1.2.4 Hot Mix Asphalt Plants (Mineral Products Industry)

Table 3-4 summarizes the emissions factor datasets for Hot Mix Asphalt Plants. The emissions factor dataset for Hot Mix Asphalt includes benzene, formaldehyde, PM-condensable (inorganic), PM-condensable (organic), and PM-filterable. Appendix B.4 (Tables B.4-1 through B.4-8) presents all emissions test data used in developing the emissions factors. The overall emissions factor gives equal weighting to each emissions test.

3.1.3 Data Summary by Pollutant

Table 3-5 presents an overview of the emissions factor datasets selected for analysis, organized by pollutant.

3.2 Statistical Analysis

We considered several statistical approaches to developing emissions factor uncertainty ratios. The primary approach selected for developing the emissions factor uncertainty ratios is designed to target selected boundary statistics of the population of emissions data. The true emissions from a single source of interest may fall anywhere within the range of emissions data. Section 3.2.1 provides more information about this statistical approach.

During the course of the project, several reviewers commented on the approach described above. They expressed concern that the approach could be considered inconsistent with the approach typically used for assessing uncertainty of an emissions factor for inventory use (i.e., determining the confidence interval about the mean [the emissions factor]). One reviewer also expressed concern that the approach applies to a single emissions unit; it does not account for any reduction in uncertainty one would expect for estimating total (or average) emissions from multiple emissions units (e.g., the emissions from a facility with multiple boilers). In response to these comments, we conducted additional statistical analyses to calculate emissions factor uncertainty ratios based on the normalized sampling distribution of emissions factors (means) from the population. Section 3.2.2 presents this statistical approach.

One reviewer suggested an approach based on the analysis of three hypothetical log-normal distribution populations, each with a population mean of 1.0 and standard deviations of 0.5, 1.0, and 2.0, respectively. Although we reviewed this approach, we did not conduct any additional analyses beyond what the reviewer provided because of time and budget constraints. Section 3.2.3 describes this approach. Finally, another reviewer recommended modifications to the analyses based on quantiles of the population. In response to these comments, we conducted limited analyses to determine the impact on results. Section 3.2.3 also describes these additional exploratory analyses.

Table 3-4. Hot Mix Asphalt Plants (Mineral Products Industry) from AP-42 Section 11.1

Process	Fuel Type	Pollutant	Control	Emissions Factor[a] (lb/ton)	No. of Tests	No. of Runs	No. of Facilities
Drum Mix Hot Mix Asphalt Plant	Natural Gas, No. 2 Fuel Oil, and Waste Oil	Benzene	Fabric Filter	0.0004	19	78	19
Drum Mix Hot Mix Asphalt Plant	Natural Gas, No. 2 Fuel Oil, and Waste Oil	Formaldehyde	Fabric Filter	0.0031	21	65	21
Drum Mix Hot Mix Asphalt Plant	All	PM, condensable (Inorganic)	Scrubber, Fabric Filter	0.0074	30	88	30
Batch Mix Asphalt Plant	All	PM, condensable (Inorganic)	Fabric Filter	0.013	35	98	35
Drum Mix Hot Mix Asphalt Plant	All	PM, condensable (Organic)	Scrubber, Fabric Filter	0.012	41	134	41
Batch Mix Asphalt Plant	All	PM, condensable (Organic)	Fabric Filter	0.0041	24	70	24
Drum Mix Hot Mix Asphalt Plant	All	PM, filterable	Fabric Filter	0.014	155	455	155
Batch Mix Asphalt Plant	All	PM, filterable	Fabric Filter	0.025	89	264	89

[a] Emissions factors are A-rated factors.

Table 3-5. AP-42 Emissions Factors Datasets Listed by Pollutant

Pollutant	AP-42 Section	Process/Fuel Type	Control
Acetaldehyde	Section 1.6—Wood Residue Combustion in Boilers (External Combustion Sources)	All Fuels	Uncontrolled/PM Control
Arsenic	Section 1.6—Wood Residue Combustion in Boilers (External Combustion Sources)	All Fuels	Uncontrolled/PM Control
Arsenic	Section 2.1—Refuse Combustion (Solid Waste Disposal)	Mass Burn and Modular Excess Air	Spray Dryer/Fabric Filter
Benzene	Section 1.6—Wood Residue Combustion in Boilers (External Combustion Sources)	All Fuels	Uncontrolled/PM Control
Benzene	Section 11.1—Hot Mix Asphalt Plants (Mineral Products Industry)	Drum Mix Hot Mix Asphalt Plant, Natural Gas, No. 2 Fuel Oil, and Waste Oil	Fabric Filter
Cadmium	Section 1.6—Wood Residue Combustion in Boilers (External Combustion Sources)	All Fuels	Uncontrolled/PM Control
Cadmium	Section 2.1—Refuse Combustion (Solid Waste Disposal)	Mass Burn and Modular Excess Air	Spray Dryer/ESP
Carbon monoxide	Section 1.6—Wood Residue Combustion in Boilers (External Combustion Sources)	Bark, Wet Wood, and Dry Wood	Uncontrolled
Carbon monoxide	Section 2.1—Refuse Combustion (Solid Waste Disposal)	Mass Burn Waterwall	Uncontrolled
Chromium	Section 1.6—Wood Residue Combustion in Boilers (External Combustion Sources)	All Fuels	Uncontrolled/PM Control
PM-Condensable	Section 1.6—Wood Residue Combustion in Boilers (External Combustion Sources)	All Fuels	Uncontrolled
PM-Condensable (Inorganic)	Section 11.1—Hot Mix Asphalt Plants (Mineral Products Industry)	Drum Mix Hot Mix Asphalt Plant	Scrubber, Fabric Filter

(continued)

Table 3-5. (Continued)

Pollutant	AP-42 Section	Process/Fuel Type	Control
PM-Condensable (Inorganic)	Section 11.1—Hot Mix Asphalt Plants (Mineral Products Industry)	Batch Mix Asphalt Plant	Fabric Filter
PM-Condensable (Organic)	Section 11.1—Hot Mix Asphalt Plants (Mineral Products Industry)	Drum Mix Hot Mix Asphalt Plant	Scrubber, Fabric Filter
PM-Condensable (Organic)	Section 11.1—Hot Mix Asphalt Plants (Mineral Products Industry)	Batch Mix Asphalt Plant	Fabric Filter
PM-Filterable	Section 1.6—Wood Residue Combustion in Boilers (External Combustion Sources)	Wet Wood	Uncontrolled
PM-Filterable	Section 1.6—Wood Residue Combustion in Boilers (External Combustion Sources)	Dry Wood	Uncontrolled
PM-Filterable	Section 1.6—Wood Residue Combustion in Boilers (External Combustion Sources)	All Fuels	Wet Scrubber
PM-Filterable	Section 1.6—Wood Residue Combustion in Boilers (External Combustion Sources)	Wet Wood	Mechanical Collector
PM-Filterable	Section 1.6—Wood Residue Combustion in Boilers (External Combustion Sources)	Dry Wood	Mechanical Collector
PM-Filterable	Section 10.6.1—Waferboard/Oriented Strandboard (Wood Products Industry)	Hot Press, PF/MDI Resins	Uncontrolled
PM-Filterable	Section 11.1—Hot Mix Asphalt Plants (Mineral Products Industry)	Drum Mix Hot Mix Asphalt Plant	Fabric Filter
PM-Filterable	Section 11.1—Hot Mix Asphalt Plants (Mineral Products Industry)	Batch Mix Asphalt Plant	Fabric Filter
PM-Filterable	Section 2.1—Refuse Combustion (Solid Waste Disposal)	Mass Burn and Modular Excess Air	Duct Sorbent Injection/Fabric Filter

(continued)

Table 3-5. (Continued)

Pollutant	AP-42 Section	Process/Fuel Type	Control
PM-Filterable	Section 2.1—Refuse Combustion (Solid Waste Disposal)	Mass Burn and Modular Excess Air	Spray Dryer/ESP
PM-Filterable	Section 2.1—Refuse Combustion (Solid Waste Disposal)	Mass Burn and Modular Excess Air	Spray Dryer/Fabric Filter
PM-Filterable	Section 2.1—Refuse Combustion (Solid Waste Disposal)	Mass Burn and Modular Excess Air	Uncontrolled
PM-Filterable	Section 2.1—Refuse Combustion (Solid Waste Disposal)	Mass Burn and Modular Excess Air	ESP
PM-Total	Section 2.1—Refuse Combustion (Solid Waste Disposal)	Refuse-Derived Fuel	ESP
PM-Total	Section 2.1—Refuse Combustion (Solid Waste Disposal)	Refuse-Derived Fuel	Uncontrolled
Formaldehyde	Section 1.6—Wood Residue Combustion in Boilers (External Combustion Sources)	All Fuels	Uncontrolled/PM Control
Formaldehyde	Section 11.1—Hot Mix Asphalt Plants (Mineral Products Industry)	Drum Mix Hot Mix Asphalt Plant, Natural Gas, No. 2 Fuel Oil, and Waste Oil	Fabric Filter
Hydrogen chloride	Section 2.1—Refuse Combustion (Solid Waste Disposal)	Mass Burn and Modular Excess Air	Uncontrolled
Hydrogen chloride	Section 2.1—Refuse Combustion (Solid Waste Disposal)	Mass Burn and Modular Excess Air	Spray Dryer/Fabric Filter
Lead	Section 1.6—Wood Residue Combustion in Boilers (External Combustion Sources)	All Fuels	Uncontrolled/PM Control
Lead	Section 2.1—Refuse Combustion (Solid Waste Disposal)	Mass Burn and Modular Excess Air	Spray Dryer/ESP

(continued)

Table 3-5. (Continued)

Pollutant	AP-42 Section	Process/Fuel Type	Control
Mercury	Section 1.6—Wood Residue Combustion in Boilers (External Combustion Sources)	All Fuels	Uncontrolled/PM Control
Mercury	Section 2.1—Refuse Combustion (Solid Waste Disposal)	Mass Burn and Modular Excess Air	Spray Dryer/Fabric Filter
Nickel	Section 1.6—Wood Residue Combustion in Boilers (External Combustion Sources)	All Fuels	Uncontrolled
Nickel	Section 2.1—Refuse Combustion (Solid Waste Disposal)	Mass Burn and Modular Excess Air	Spray Dryer/Fabric Filter
Nitrogen oxides	Section 1.6—Wood Residue Combustion in Boilers (External Combustion Sources)	Bark and Wet Wood	Uncontrolled
Nitrogen oxides	Section 2.1— Refuse Combustion (Solid Waste Disposal)	Mass Burn Waterwall	Uncontrolled
Sulfur dioxide	Section 1.6—Wood Residue Combustion in Boilers (External Combustion Sources)	Bark and Wet Wood	Uncontrolled
Sulfur dioxide	Section 2.1—Refuse Combustion (Solid Waste Disposal)	Mass Burn And Modular Excess Air	Uncontrolled

ESP = electrostatic precipitator; PF/MDI = phenol formaldehyde/methylene diphenyl diiosocyanate.

3.2.1 Emissions Factor Uncertainty Ratios Based on Population Percentiles

Figure 3-1 presents a flow diagram of the statistical procedure used to calculate the emissions factor uncertainty ratios based on boundary (target) population statistics of the population. The statistical analysis includes the following major steps:

1. Perform exploratory data analyses using summary statistics, histograms, and empirical CDFs.

2. Identify parametric theoretical PDFs to model the data and estimate the parameters of the density function based on the data. Perform a goodness-of-fit test using the Moran's statistic to assess how well the model fits the data. Using maximization approaches implemented in the statistic software Splus® 7.0 for Windows, obtain PDF parameter estimates.

3. For each dataset, use Monte Carlo techniques and the parameter estimates obtained in Step 2 to simulate the hypothetical population density of the emissions factor for the specific pollutant. For each simulated hypothetical population, calculate the following population statistics: minimum, 1st percentile, 5th percentile, 10th percentile, 15th percentile, 20th percentile, 25th percentile, median, mean, 75th percentile, 80th percentile, 85th percentile, 90th percentile, 95th percentile, 99th percentile, and maximum.

4. For each hypothetical population, select 10,000 random samples of a specified size. Calculate the sample mean for each of the 10,000 samples. Repeat for samples (*n* = number of tests) of size 1, 3, 5, 10, 15, 20, and 25.

5. For each distribution of 10,000 means based on *n* samples, calculate the ratio of the population statistics (obtained in Step 3) and the sample mean. Because the sample mean converges in probability to the population mean, the distribution of this ratio (sample mean to population mean) will approach 1 as the sample size increases. The distribution of ratios characterizes the distribution of the uncertainty ratio for the emissions factor.

For this analysis, we assumed that the data available were a representative sample of the population of interest. This is reasonable for A-rated emissions factors and the limited number of B-rated emissions factors included in the study. Furthermore, we decided to disregard any precision concerns regarding the difference in number of test runs comprising each emissions test value used to calculate the emissions factor.[2]

We performed data visualization (histograms and empirical CDF plots) to observe the range, skewness of the data, and other possible characteristics, such as the possible mixture of two or more distributions. We obtained summary statistics. For illustration purposes, a detailed description of the statistical analysis of the wood residue combustion in boilers is included in this

[2] Typically, each emissions test is comprised of multiple test runs (usually a minimum of three test runs comprises an emissions test).

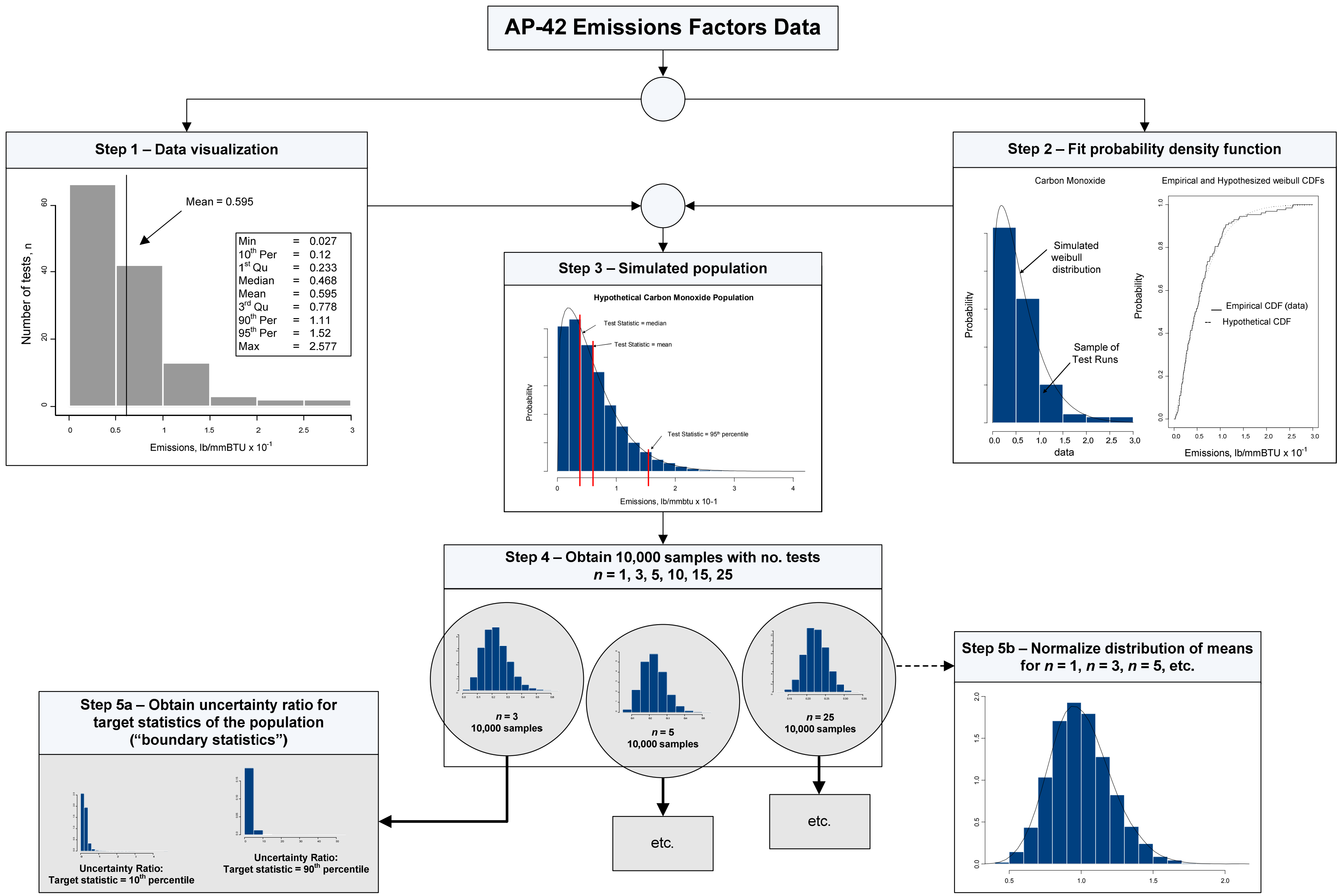

Figure 3-1. Schematic of statistical approach.

section, with emphasis on carbon monoxide. Figure 3-2 shows the histogram and the empirical CDF corresponding to the carbon monoxide data. The asymmetric shape of the histogram shows a positive skewness. Positive skewness is characterized by the asymmetric tail that extends toward more positive values. This asymmetric shape, which is typical of emissions factors, suggests that the normal distribution (which has a bell-shaped distribution) would not fit well with these data. The positive skewness also indicates that the sample mean, which is affected by extreme values, will be larger than the median. The empirical CDF shows that the maximum is around 2.5 and the median is around 0.5.

Empirical distributions can be used to estimate the characteristics of the population, but they should not be used to extrapolate beyond the observed values in the data. In the case of small datasets, this limitation is important because the variability in the true population may drastically differ from the observed variability in the dataset. To account for this limitation, we considered theoretical PDFs to model the data. The candidate probability density must be skewed and defined for positive values. Previous research from Frey and Bammi (2002), Zheng and Frey (2001), and Frey and Zheng (2002) discussed that Weibull, log-normal, beta, and gamma density functions were appropriate to model the emissions factors for nitrogen oxides, carbon monoxide, and hydrocarbons. Results from the data visualization stage suggested that the Weibull, log-normal, and gamma functions could be considered candidates for the modeling step (Step 2).

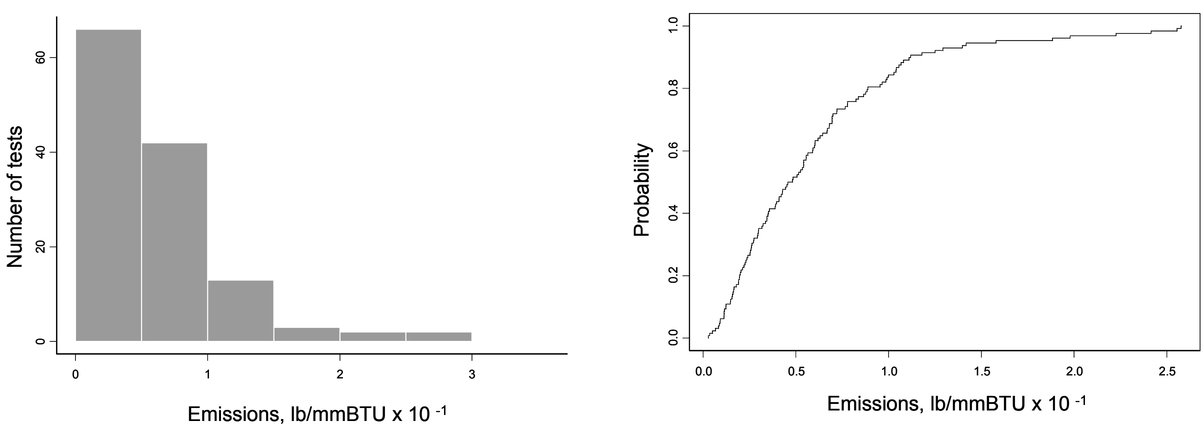

Figure 3-2. Histogram and empirical CDF of carbon monoxide.

Maximum likelihood estimation was used to estimate the parameters of the theoretical distribution. The method of moments estimation was used to obtain initial values for the maximization function. The method of moments estimator is an estimation technique that results by equating the population moments (which are population parameters) to sample estimates. Goodness of fit tests are used to assess how well a model fits the data. Lilliefors (1969, 1967) and Pierce (1982) showed that when the parameters of the distribution are estimated from the sample, the Kolmogorov Smirnov test provides non-correct p-values. Corrections for the Kolmogorov Smirnov tests are available for the normal and exponential distribution (Stephens, 1970, 1974, 1976; Dallal and Wilkinson, 1986; Iman, 1982; and Finkelstein and Schafer, 1971) but not for the Gamma distribution. Cheng and Stephens (1986) proposed a goodness-of-fit test based on the Moran's statistic. The proposed goodness-of-fit test has the same asymptotic distribution when the parameters are estimated from the sample as when the parameters are known. The test is based on the spacing of the data and provides reliable statistics for small sample sizes.

We fit the three parametric models (Weibull, log-normal, and gamma) to all of the datasets. The gamma density did not agree with any of the initial (Wood Residue Combustion) datasets considered (p-values <0.0001). The densities for log-normal and Weibull distributions showed more agreement with the datasets (see Table 3-6 for example p-values of Wood Residue Combustion emissions factors). When the p-values from two candidate densities were greater than 0.05, the best candidate was selected based on the larger p-value. In the case of carbon monoxide for Wood Residue Combustion, the Moran's test statistic showed large p-values (0.998 and 0.997) for both the Weibull and the log-normal. The Weibull distribution showed the larger p-value, but both of them are so close that one could decide to use either. Based on the larger p-value, the Weibull distribution was assumed for the carbon monoxide dataset. Table 3-7 shows the maximum likelihood estimates for the fit (the log-normal or Weibull distribution, as applicable) for selected Wood Residue Combustion datasets.

Table 3-6. Moran's Goodness-of-Fit Test p-Values by Pollutant and Probability Density for Wood Residue Combustion in Boilers

Pollutant	p-values		
	Weibull Density	**Gamma Density**	**Log-normal Density**
Acetaldehyde	0.049	0.000	0.156
Benzene	0.701	0.000	0.915
Carbon monoxide	**0.998**	0.000	0.997
Formaldehyde	0.447	0.000	0.696
Nitrogen oxides	0.004	0.000	0.214
Sulfur dioxide	1.00	0.000	1.00
PM-filterable, dry wood, mechanical collector	1.00	0.000	1.00
PM-filterable, wet wood, mechanical collector	0.707	0.000	0.305
PM-filterable, dry wood, uncontrolled	0.92	0.000	0.982
PM-filterable, wet wood, uncontrolled	0.571	0.000	0.604
PM-filterable, wet scrubber	0.145	0.000	0.245
PM-condensable	0.864	0.000	0.934

PM = particulate matter; CDF = cumulative distribution function.

Note: p-values greater than 0.05 suggest no statistical evidence against the agreement between the CDF of the pollutant data and the theoretical density function.

Table 3-7. Estimated Parameters for the Fit of the Hypothetical Distribution for Wood Residue Combustion in Boilers

Pollutant	Log-normal Distribution		Weibull Distribution	
	μ	σ	Scale	Shape
Acetaldehyde	-9.02	1.81		
Benzene	-7.95	2.12		
Formaldehyde	-7.06	1.86		
Nitrogen oxides	-1.66	0.53		
Sulfur dioxide	-4.83	1.63		
PM-filterable, dry wood, mechanical collector	-1.27	0.4		
PM-filterable, dry wood, uncontrolled	-1.00	0.4		
PM-filterable, wet wood, uncontrolled	-1.27	0.56		
PM-condensable	-4.66	1.13		
Carbon monoxide			**0.64**	**1.26**
PM-filterable, wet wood, mechanical collector			0.2	0.82
PM-filterable, wet scrubber	-2.76	0.09		

PM = particulate matter.

Ten thousand values were randomly drawn from the Weibull distribution with a 0.64 scale parameter and a 1.26 shape parameter. This collection of 10,000 values will be referred to hereafter as the hypothetical Weibull population or hypothetical distribution. The following population parameters were calculated from the hypothetical population: minimum, maximum, mean, median, and the 1^{st}, 5^{th}, 10^{th}, 15^{th}, 20^{th}, 25^{th}, 75^{th}, 80^{th}, 85^{th}, 90^{th}, 95^{th}, and 99^{th} percentiles. Figure 3-2 shows the histogram for the CO dataset with the density of the hypothetical Weibull distribution superimposed. Figure 3-3 presents the plot of the empirical CDF (continuous line), corresponding to the CO dataset, and the hypothetical Weibull CDF (dotted line). The similarity between the two lines observed in the CDF plot suggests a good fit was achieved for the dataset.

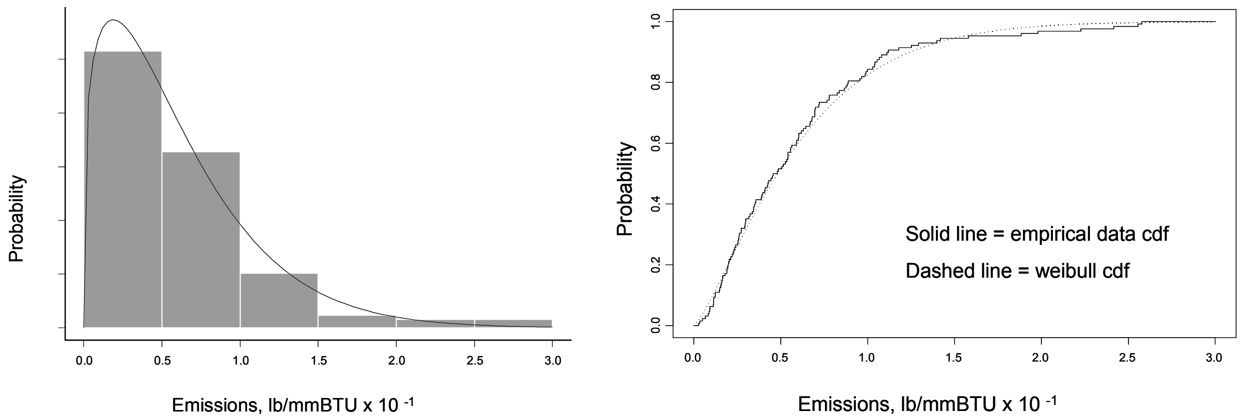

Figure 3-3. Graphical display of goodness-of-fit of the carbon monoxide data for wood residue combustion in boilers.

Monte Carlo simulations refer to the repeated sampling of the hypothetical distribution to make conclusions about the data obtained from the population. Ten thousand samples of sizes 1, 3 to 5, 10, 15, 20, and 25 were randomly drawn from the hypothetical populations using a Monte Carlo approach. For each sample size, the mean was calculated for each sample. Each data value in the sample represents an emissions test and the mean of these values represents the calculated emissions factor.

An emissions factor uncertainty ratio based on the Monte Carlo simulation is defined as the ratio between the target population statistic (minimum, maximum, mean, median, and the 1st, 5th, 10th, 15th, 20th, 25th, 75th, 80th, 85th, 90th, 95th, and 99th percentiles) and the emissions factor as shown below:

$$EF_{\text{uncertainty ratio}} = \frac{EF_{\text{target statistic}}}{EF} \qquad \text{(Eq. 3-1)}$$

where

$EF_{\text{uncertainty ratio}}$	=	Estimate of the emissions factor uncertainty
$EF_{\text{target statistic}}$	=	Target population value of the emissions distribution, hereafter referred to as the target statistic (e.g., 95th percentile), in units of the AP-42 emissions factor
EF	=	Emissions factor, as presented in AP-42, in units of the AP-42 emissions factor.

The sampling distribution of the uncertainty ratios was studied in order to select an uncertainty ratio value for the sample sizes considered. The sampling distribution of an uncertainty ratio to target a population value refers to the collection of 10,000 values of the ratio between each of the means obtained from the Monte Carlo simulation and a target statistic.

Figure 3-4 shows the Monte Carlo 95th percentile, median, and 5th percentile of the sampling distribution of uncertainty ratios for the following target population statistics: 5th and 10th percentiles, median, mean, and 90th and 95th percentiles of the hypothetical distribution of

CO for Wood Residue Combustion, respectively. The upper and lower lines correspond to the Monte Carlo 95th and 5th percentiles of the uncertainty ratios, respectively, and the dashed line corresponds to the median of the uncertainty ratios. The symmetry of the distribution of the uncertainty ratios increases with the sample size. This is observed in the narrowing and symmetric look of the 5th and 95th percentiles around the median.

Figure 3-4 also shows how the uncertainty ratio decreases with sample size. For sample sizes greater than 3, almost all of the uncertainty ratios obtained to target the 5th and 10th percentiles are below 1, suggesting a reduction effect on the emissions factor to estimate these percentiles. On the other hand, almost all of the uncertainty ratio values obtained to target the 90th and 95th percentiles are greater than 1, suggesting that the resulting uncertainty ratio will increase the emissions factor to estimate these upper population percentiles. About 50 percent of the uncertainty ratios obtained to target the median and mean are below 1, and about 50 percent are equal to 1.

For each pollutant, three statistics (the mean uncertainty ratio, the median uncertainty ratio, and the 95th percentile uncertainty ratio) were considered candidates for the final uncertainty ratio. The criterion for selecting these statistics was based on their importance in describing the population characteristics. By definition, 50 percent of the uncertainty ratios will be lower than the median and 50 percent will be higher than the median. Because the median is not affected by extreme values or long tails, it is considered a better summary statistic than the mean when the distributions are skewed. The 95th percentile provides a value that is larger than 95 percent of the uncertainty ratios and lower than 5 percent of the uncertainty ratios.

Table 3-8 shows the median, mean, and 95th percentile uncertainty ratios by number of tests and target statistic for CO for Wood Residue Combustion. For all three possible uncertainty ratio statistics considered (median, mean, 95th percentile), the uncertainty ratio to target all of the population statistics (5th percentile, 10th percentile, etc.) decreases with increasing sample size. The uncertainty ratio values increase as the target population statistic approaches the upper population percentiles for all sample sizes.

Referring to Table 3-8, the Monte Carlo median uncertainty ratio needed to estimate the 5th and 10th percentiles is approximately 0.2 and 0.3, respectively, for all number of tests. To target the population median, a factor of 0.9 was computed when the number of tests is greater than three. To target the 90th percentile, an uncertainty ratio of 2 seems appropriate for all sample sizes. To target the 95th percentile, an uncertainty ratio of 2.7 was computed for an emissions factor based on one test and an uncertainty ratio of 2.4 was computed for an emissions factor based on three or more tests.

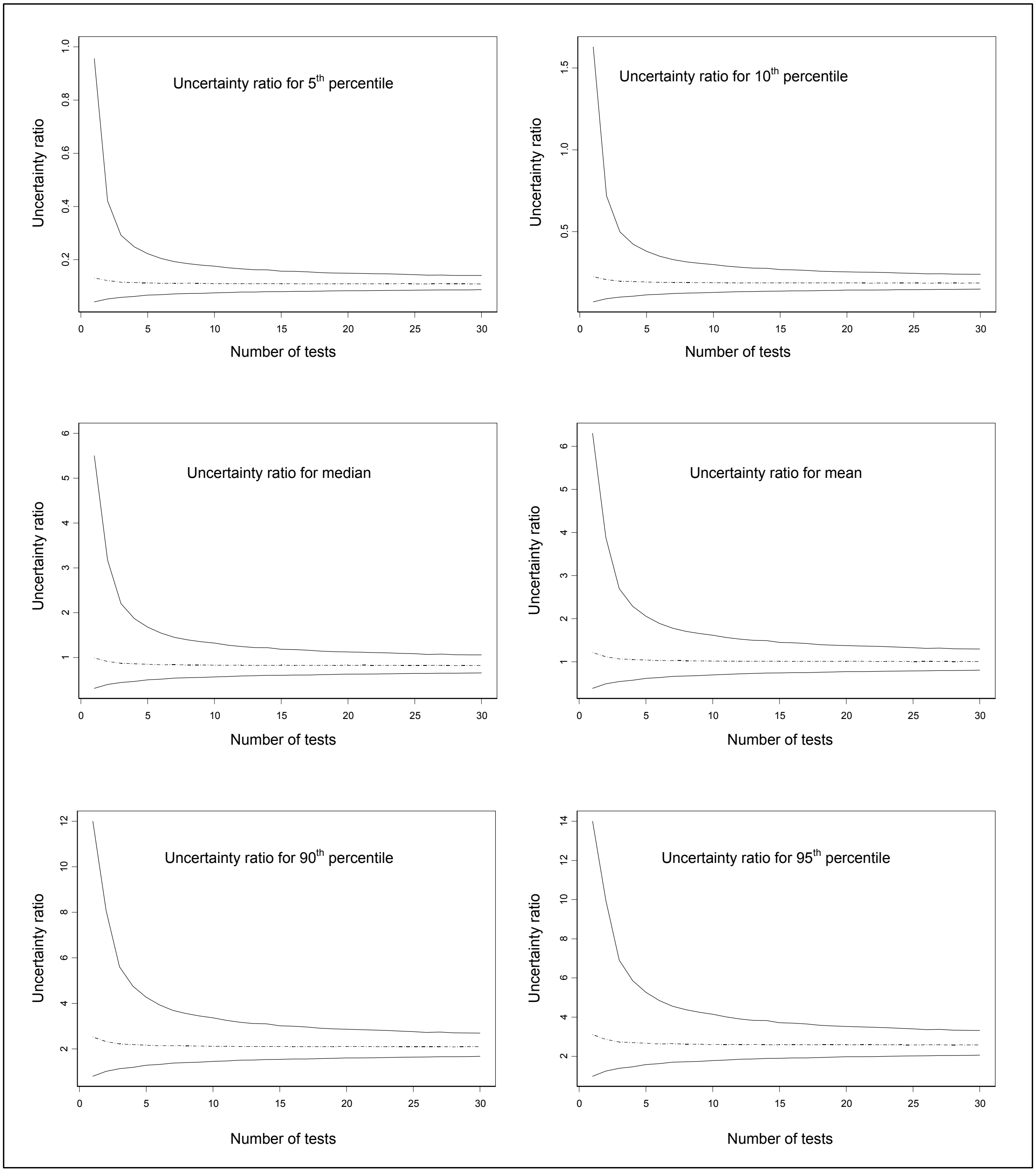

Figure 3-4. Monte Carlo 95th percentile, median, and 5th percentile for the distribution of uncertainty ratios for selected statistics (5th, 10th, median, mean, 90th, and 95th percentile) of the hypothetical population of carbon monoxide for wood residue combustion in boilers.

Table 3-8. Emissions Factor Uncertainty Ratios for Carbon Monoxide (Uncontrolled), Wood Refuse Combustion, by Number of Tests (*n*) and Target Statistic

Median (uncertainty ratio may tend to overestimate target statistic 50% of time and underestimate 50% of time)						
	Target Statistic					
n	**5th Percentile**	**10th Percentile**	**Median**	**Mean**	**90th Percentile**	**95th Percentile**
1	0.19	0.30	1.0	1.2	2.2	2.7
3	0.17	0.27	0.91	1.0	2.0	2.4
5	0.16	0.26	0.89	1.0	1.9	2.3
10	0.16	0.26	0.88	1.0	1.9	2.3
15	0.16	0.26	0.88	1.0	1.9	2.3
20	0.16	0.26	0.88	1.0	1.9	2.3
25	0.16	0.26	0.88	1.0	1.9	2.3
Mean (arithmetic average value of the uncertainty ratio for the target statistic)						
n	**5th Percentile**	**10th Percentile**	**Median**	**Mean**	**90th Percentile**	**95th Percentile**
1	0.37	0.60	2.0	2.3	4.5	5.4
3	0.19	0.30	1.0	1.2	2.3	2.7
5	0.18	0.28	0.96	1.1	2.1	2.5
10	0.17	0.27	0.91	1.0	2.0	2.4
15	0.16	0.26	0.90	1.0	2.0	2.4
20	0.16	0.26	0.90	1.0	2.0	2.4
25	0.16	0.26	0.89	1.0	1.9	2.3
95th Percentile (uncertainty ratio may underestimate target statistic 5% of time and overestimate 95% of time)						
n	**5th Percentile**	**10th Percentile**	**Median**	**Mean**	**90th Percentile**	**95th Percentile**
1	1.0	1.6	5.5	6.3	12	14
3	0.36	0.58	2.0	2.3	4.3	5.2
5	0.29	0.47	1.6	1.8	3.5	4.2
10	0.24	0.38	1.3	1.5	2.8	3.4
15	0.22	0.35	1.2	1.4	2.6	3.1
20	0.21	0.34	1.1	1.3	2.5	3.0
25	0.20	0.32	1.1	1.3	2.4	2.9

If the mean of the uncertainty ratios is used to estimate the 5th percentile, the uncertainty ratio is approximately 0.4 for an emissions factor based on one test, and 0.2 for three or more tests. Estimating the 10th percentile requires an uncertainty ratio of 0.6 or 0.3 for an emissions factor based on one test or three or more tests, respectively. To estimate the population median, an uncertainty ratio of 2 is needed for an emissions factor based on one test and an uncertainty ratio of 0.9 for an emissions factor based on 10 or more tests. When estimating the population mean, an uncertainty ratio of 2.3 is needed only when the number of tests used is one. To target the 90th percentile, an uncertainty ratio of 4.5 is needed for an emissions factor based on one test, 2.3 and 2.0 are needed when the number of tests used is three and more than five, respectively. In the case of the 95th percentile, an uncertainty ratio of 5.4 is needed for an emissions factor based on one test; an uncertainty ratio of 2.7 and 2.5 would be needed to target the 95th percentile when the number of tests is three and five or more, respectively.

If the 95th percentile uncertainty ratio is selected, the uncertainty ratio value is 0.36 to estimate the population 5th percentile using an emissions factor based on three tests. If the target is the median, the uncertainty ratio value is 5.5 for an emissions factor based on one test, 2 for those based on two to three tests, and 1.1 for 20 or more tests. When estimating the mean, the uncertainty ratio is 6.3 for an emissions factor based on one test, 2.3 for three tests, and up to 1.3 for 20 or more tests. The estimation of the 90th percentile requires an uncertainty ratio of 12 for an emissions factor based on one test, 4.3 for three tests, 3.5 for five tests, 2.8 for 10 tests, and 2.4 for 25 or more tests. The 95th percentile estimation requires an uncertainty ratio of 14 to adjust the emissions factor based on one test, 5.2 for three tests, and an uncertainty ratio of 3 for 15 or more tests.

3.2.2 Emissions Factor Uncertainty Ratios Based on a Normalized Sampling Distribution of Emissions Factors (Means)

Similar to the description of statistical analyses in Section 3.2.1, we conducted the statistical analyses described in this section on the AP-42 emissions factor data described in Section 3.1. The first four steps of the analyses are the same as those described in Section 3.2.1; however, the fifth step differed. Figure 3-5 presents the approach. The distribution of means obtained in Step 4 for each value of n (for $n = 1$ to 30) is known in the statistical literature as the "sampling distribution" of the mean. The range of the sampling distribution of the mean decreases as the sample size increases, but the mean of the distribution, which approaches the mean of the hypothetical distribution, is not affected by the sample size; therefore, all sampling distributions are centered in the population mean. In Step 5b, all sampling distributions obtained in Step 4 were "normalized." In other words, each value in the sampling distribution was divided by the mean of the corresponding sampling distribution.

As a result, all 30 normalized sampling distributions have a mean equal to 1. As an example, Figure 3-6 presents the normalized sampling distribution for CO, where $n = 15$. Observe that each normalized sampling distribution can be considered as the sampling distribution of the uncertainty ratio statistic if the goal is to target the population mean. The sampling distribution shows the probability of observing the different values of this uncertainty ratio statistic. With this "sampling distribution," it is possible to predict the 68 percent, 95 percent, and 99 percent confidence intervals for the population mean (emissions factor) based on a sample size (number of emissions tests) of a specified size *n*. The 95 percent confidence interval around the mean of this sampling distribution has endpoints equal to the 2.5^{th} and 97.5^{th} percentiles of the normalized sampling distribution. The 95 percent confidence intervals are centered on 1. These endpoints will define the lower and upper values for the uncertainty ratio if the goal is to target the mean of the hypothetical distribution. As a result, a 95 percent confidence interval for this uncertainty ratio produces an approximated 95 percent confidence interval for the mean (the emissions factor). As an example, Table 3-9 presents selected sampling distribution percentiles for selected *n* values for CO.

3.2.3 Alternative Approaches Explored

As a result of comments received during the course of this study, two other statistical approaches were discussed, considered, and to a limited extent, explored. One explored approach uses a different procedure to determine the hypothetical population distribution parameters to account for the uncertainty associated with the unknown population distribution. Statisticians may follow a frequentist approach or a Bayesian approach when analyzing data. We used the frequentist approach, which is where model parameters are considered fixed quantities (population values) and uncertainty arises due to estimating these population parameters using a finite collection of data. In the Bayesian approach, parameters are considered random variables and instead of one population parameter we have a population of possible parameters. Uncertainty in this case comes from the data and the distribution of the parameters. In the Bayesian approach, we assumed a uniform distribution for the model parameters; therefore, we defined an interval of possible values (a plausible range) for each of the parameters of the probability distribution. Then, we randomly selected and used parameters from the respective intervals to fit a probability distribution model to the data. If the resulting probability distribution is a good adjustment to the data, then one random value is generated from this distribution. This process is repeated 10,000 times, resulting in a distribution of values that constitutes the hypothetical population. During the study, we re-evaluated three emissions factor datasets using this revised technique that incorporates the Bayesian approach to account for the uncertainty in the model parameters. We examined the emissions factor datasets for formaldehyde, CO, and NOx for Wood Residue Combustion. The results of these limited analyses show little difference in the uncertainty ratios for two of the three datasets (formaldehyde and CO). For example, for formaldehyde the uncertainty ratios for the 90^{th} percentile for $n = 25$ are 2.63 and 2.53 for the original (frequentist) approach and alternative (Bayesian) approach, respectively. The results between the two approaches resulted in a greater difference for the third dataset, NOx; for example, the uncertainty ratios for the 90^{th} percentile for $n = 25$ are 2.45 and 1.70 for the original (frequentist) approach and alternative (Bayesian) approach, respectively. Appendix F presents the complete results for the analysis of these three datasets.

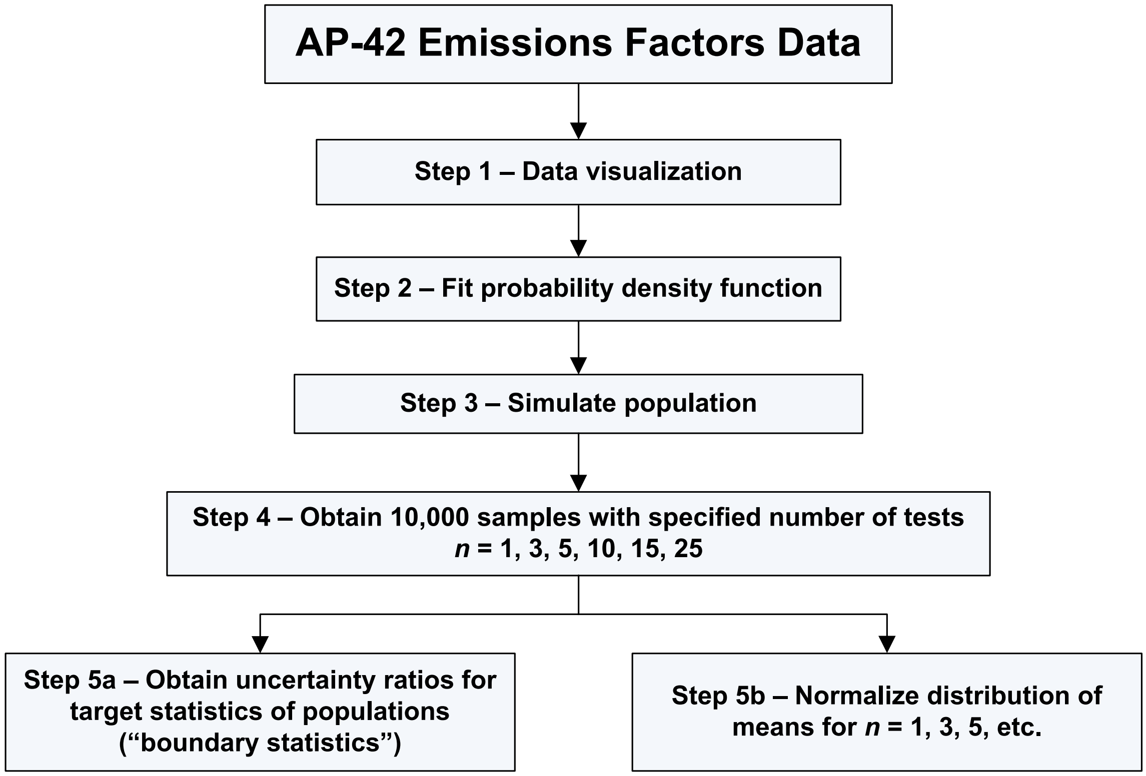

Figure 3-5. Overview of statistical approach.

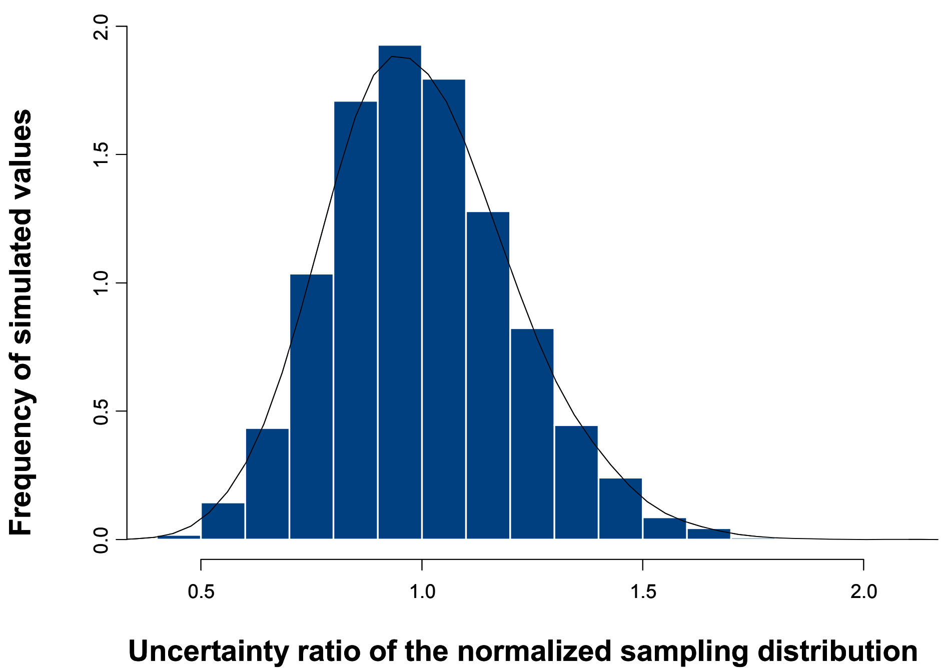

Figure 3-6. Normalized Monte Carlo sampling distribution of the mean (*n* = 15) of carbon monoxide for wood residue combustion in boilers.

Table 3-9. Percentiles of the Normalized Monte Carlo Sampling Distribution of Emissions Factors (Means) from the Population: Wood Residue Combustion, Carbon Monoxide, Uncontrolled, by Number of Emissions Tests (Sample size, *n*)

EF Sample Size	Percentile															
	Minimum	1st	5th	10th	15th	20th	25th	50th (Median)	75th	80th	85th	90th	95th	99th	Maximum	Mean
n = 1	0.001	0.03	0.10	0.19	0.27	0.34	0.41	0.81	1.38	1.55	1.76	2.04	2.55	3.69	7.50	1.00
n = 2	0.01	0.13	0.27	0.37	0.45	0.52	0.59	0.90	1.31	1.42	1.56	1.75	2.07	2.72	4.26	1.00
n = 3	0.05	0.23	0.37	0.47	0.54	0.61	0.66	0.94	1.26	1.35	1.46	1.60	1.86	2.35	3.62	1.00
n = 4	0.07	0.29	0.45	0.54	0.60	0.66	0.72	0.95	1.23	1.31	1.40	1.54	1.73	2.13	3.82	1.00
n = 5	0.14	0.35	0.49	0.58	0.65	0.70	0.75	0.96	1.21	1.28	1.36	1.47	1.64	1.98	2.88	1.00
n = 6	0.23	0.40	0.53	0.61	0.67	0.72	0.77	0.97	1.20	1.26	1.33	1.42	1.57	1.88	2.61	1.00
n = 7	0.17	0.43	0.56	0.64	0.70	0.74	0.78	0.97	1.19	1.24	1.31	1.40	1.54	1.79	2.96	1.00
n = 8	0.25	0.46	0.58	0.66	0.72	0.76	0.80	0.97	1.17	1.22	1.29	1.37	1.50	1.74	2.43	1.00
n = 9	0.25	0.47	0.60	0.68	0.73	0.78	0.82	0.98	1.16	1.21	1.27	1.34	1.46	1.70	2.21	1.00
n = 10	0.28	0.51	0.62	0.69	0.74	0.79	0.82	0.98	1.16	1.20	1.25	1.33	1.44	1.67	2.37	1.00
n = 11	0.36	0.52	0.65	0.71	0.76	0.79	0.83	0.98	1.15	1.19	1.25	1.31	1.41	1.63	2.18	1.00
n = 12	0.30	0.55	0.65	0.72	0.76	0.80	0.84	0.99	1.14	1.19	1.24	1.30	1.40	1.61	2.10	1.00
n = 13	0.38	0.55	0.66	0.73	0.78	0.82	0.85	0.99	1.14	1.18	1.22	1.28	1.38	1.57	2.02	1.00
n = 14	0.33	0.57	0.68	0.74	0.78	0.82	0.85	0.99	1.14	1.18	1.22	1.28	1.36	1.56	2.01	1.00
n = 15	0.33	0.58	0.69	0.75	0.79	0.82	0.86	0.99	1.13	1.17	1.21	1.26	1.35	1.52	2.07	1.00
n = 16	0.36	0.60	0.70	0.76	0.80	0.83	0.86	0.99	1.12	1.16	1.20	1.26	1.34	1.51	1.87	1.00
n = 17	0.40	0.60	0.71	0.77	0.81	0.84	0.87	0.99	1.12	1.15	1.19	1.25	1.33	1.50	1.92	1.00
n = 18	0.43	0.61	0.71	0.77	0.81	0.84	0.87	0.99	1.12	1.15	1.19	1.24	1.32	1.48	1.80	1.00
n = 19	0.47	0.63	0.71	0.77	0.81	0.84	0.87	0.99	1.12	1.15	1.19	1.24	1.31	1.48	1.72	1.00
n = 20	0.47	0.63	0.72	0.78	0.82	0.85	0.88	0.99	1.12	1.15	1.18	1.23	1.31	1.46	1.83	1.00
n = 21	0.49	0.64	0.73	0.78	0.82	0.85	0.88	0.99	1.11	1.14	1.18	1.23	1.30	1.43	1.79	1.00
n = 22	0.46	0.64	0.74	0.79	0.83	0.86	0.88	0.99	1.11	1.14	1.17	1.22	1.29	1.43	1.83	1.00
n = 23	0.45	0.66	0.75	0.80	0.83	0.86	0.88	0.99	1.11	1.14	1.17	1.21	1.28	1.42	1.89	1.00
n = 24	0.45	0.66	0.75	0.80	0.83	0.86	0.89	0.99	1.10	1.13	1.17	1.21	1.28	1.40	1.78	1.00
n = 25	0.45	0.67	0.76	0.81	0.84	0.87	0.89	0.99	1.10	1.13	1.16	1.21	1.27	1.40	1.89	1.00
n = 26	0.51	0.66	0.75	0.80	0.84	0.87	0.89	1.00	1.10	1.12	1.16	1.20	1.27	1.39	1.65	1.00
n = 27	0.48	0.68	0.77	0.81	0.84	0.87	0.90	0.99	1.10	1.12	1.15	1.19	1.26	1.38	1.82	1.00
n = 28	0.53	0.68	0.76	0.81	0.84	0.87	0.90	0.99	1.10	1.12	1.15	1.19	1.26	1.38	1.62	1.00
n = 29	0.54	0.69	0.77	0.81	0.84	0.87	0.90	0.99	1.10	1.12	1.15	1.19	1.25	1.38	1.64	1.00
n = 30	0.54	0.69	0.77	0.82	0.85	0.88	0.90	0.99	1.09	1.12	1.15	1.19	1.25	1.36	1.68	1.00

A commenter suggested a second approach that was designed to account for the uncertainty induced by three sources of variability. The commenter provided example calculations. This approach was suggested as a technique to address applications of emissions factors involving a small number of similar emissions units (e.g., three boilers at a single facility). The three sources of variability considered in this approach are the skewness of the distribution of emissions data, the number of tests comprising the emissions factor, and the number of process (emissions) units for which emissions are being estimated. This analysis is based on hypothetical populations and does not use the AP-42 emissions data. In this approach, three hypothetical log-normally distributed populations were generated, each comprised of 10,000 data points. The three populations have a population mean of 1.0 and standard deviations of 0.5, 1.0, and 2.0, respectively. Two populations were generated by randomly drawing independent samples from each of the hypothetical populations; one population to replicate emissions factors ("calculated" emissions factor values) and the other to represent "actual" emissions from the emissions units. To compare the calculated emissions factors and the actual emissions of the emissions units, the calculated emissions factor value was subtracted from the actual emissions unit value.

As previously mentioned, each hypothetical population consisted of 10,000 values drawn with replacement from a log-normal distribution with a mean equal to 1 and standard deviation equal to 0.5, 1.0, or 2.0. This sample represents 10,000 repetitions of "actual emissions" because they are drawn from the hypothetical population of emissions. Nine independent sampling distributions of size of 10,000 were generated by repeated independent sampling from a population of "actual emissions" to represent emissions from nine different facilities having from one to nine similar emissions units. The distribution corresponding to the first emissions unit represents a facility with only one emissions unit, and the 10,000 values are actual emissions based on a sample size of one. The first two emissions units (population distributions) represent a facility with two emissions units; therefore, actual emissions are based on samples of size two, one value from each emissions unit. Following the same reasoning, all the nine emissions units (population distributions) represent a facility with nine emissions units that will generate actual emissions based on sample sizes of nine. The result consists of nine sampling distributions, where sampling distribution i ($i = 1,..., 9$) represents the sampling distribution of the emissions factor based on i emissions units. Similarly, 20 sampling distributions were generated to represent calculated emissions factors developed using from 1 to 20 emissions tests, n ($n = 1,...., 20$).

Next, all combinations of differences between the nine sampling distributions representing actual emissions from emissions units and the 20 sampling distributions representing calculated emissions factor values were calculated. This approach simulates the distribution of the differences in emissions factors based on different sample sizes. An uncertainty ratio for the emissions factor was defined as (1 plus differences). Selected percentiles of the distribution of uncertainty ratios produced upper bounds for the emissions factor (mean). A relevant aspect of this approach is the incorporation of the uncertainty due to the differences between the number of tests the emissions factor was based on and the number of emissions units. Also, this approach is based on the assumption that it is possible to model all the pollutants using one probability distribution with few varying parameters, which in some sense follows the finding from this project, that the pollutants considered were either Weibull or log-normally distributed. As expected, when the number of emissions units increases and the number of tests, *n*, used to calculate the emissions factor increases, the difference between the actual emission factor and the calculated emission factor will tend to zero. We did not conduct any additional analyses using this statistical technique beyond the calculations provided by the commenter. Appendix G presents an example of the results provided to us by the commenter.

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4.0 Results

This section summarizes the results of the analyses for the 44 emissions factor datasets during this study. The appendices present detailed results for each emissions factor analysis. Section 4.1 shows the summary statistics for the theoretical PDFs. Section 4.2 summarizes the emissions factor uncertainty ratios by pollutant based on population values other than the mean. Section 4.3 presents the results of the normalized sampling distribution of emissions factors (means) from the population. Section 4.4 discusses the results from different analyses.

4.1 Summary Statistics of Probability Density Functions

We have identified and obtained the following four datasets for statistical analysis: Wood Residue Combustion, Refuse Combustion, Hot Mix Asphalt Plants, and W/OSB. We included a total of 44 emissions factors in the analyses for the four datasets. As discussed in Section 3.2, we considered theoretical PDFs to model the emissions factor data. Candidate models were the Weibull, log-normal, and gamma PDFs. We used maximum likelihood estimation to estimate the parameters of the theoretical distributions. Table 4-1 presents Moran's goodness-of-fit test p-values by probability density for each emissions factor dataset. Table 4-2 presents the estimated parameters for the fit of the probability distribution for each emissions factor dataset. Appendix C provides a histogram of each emissions factor data with the fitted Weibull or log-normal probability density function superimposed, as well as the CDF.

4.2 Emissions Factor Uncertainty Ratios for Population Percentiles (for Use Based on Population Values Other than the Mean)

Based on the statistical approach presented in Section 3.2.1, we calculated emissions factor uncertainty ratios for each emissions factor in the datasets. For some sources and pollutants, multiple emissions factors were available for different combinations of air pollution control device (APCD) type and the type of fuel (e.g., separate uncontrolled PM-filterable emissions factors for Wood Residue Combustion of Dry Wood and Wet Wood, as well as PM-Filterable emissions factors for Wood Residue Combustion of Dry and Wet Wood with a mechanical collector control device).

Section 3.2.1 presents the statistical approach used to calculate emissions factor uncertainty ratios and example results for CO emissions from Wood Residue Combustion. Table 4-3 presents the example emissions factor uncertainty ratios for CO from Wood Residue Combustion. Emissions factor uncertainty ratios are provided for several pertinent population statistics of interest, including the 5^{th} percentile, 10^{th} percentile, median, mean, 90^{th} percentile, and the 95^{th} percentile of the data distribution. The uncertainty ratios are a function of the number of emissions tests, n, on which the emissions factor is based, and include uncertainty ratios for $n = 1$ to $n = 25$. As explained in Section 3.2.1, Table 4-3 includes emissions factor uncertainty ratios based on three different statistics obtained from the Monte Carlo sampling distribution of uncertainty ratios; these are the median, the mean, and the 95th percentile. Given the skewness of the sampling distribution of uncertainty ratios, it is anticipated that the statistic selected from the Monte Carlo sampling distribution of uncertainty ratios has a significant impact on the uncertainty ratio values.

As previously stated in Section 3.2.1, use of the 95th percentile from the Monte Carlo sampling distribution of uncertainty ratios is a very conservative approach; it means that 95 percent of the uncertainty ratios calculated from the Monte Carlo simulation (10,000 samples) are less than the uncertainty ratio value selected. We propose to use the uncertainty ratio value represented by the median of the Monte Carlo distribution of uncertainty ratios; this is the uncertainty ratio value for which 50 percent of the uncertainty ratio values calculated from the Monte Carlo simulation (10,000 samples) are less than and 50 percent are greater than the uncertainty ratio value selected (the median value). Given the observed skewness (asymmetry) of the uncertainty ratio values distribution, the median (which is not affected by extreme values) will provide a better center measure than the mean. Throughout the remainder of this section, the results presented and the discussion will be based on the median of the Monte Carlo sampling distribution of uncertainty ratios. Appendix D presents summary tables of the uncertainty ratio values for various target statistics, *n* values, and the median, mean, and 95th percentile Monte Carlo distributions for each emissions factor.

4.2.1 Summary of the Uncertainty Ratios by Pollutant

Table 4-4 shows the emissions factor uncertainty ratios, listed by pollutant and by APCD, calculated for all 44 emissions factors from the four datasets. Each of the pollutants is discussed in the following sections.

HAPs. Each set of the supporting emissions data for the 18 emissions factors for the HAP pollutants shown in Table 4-4 contained a significant number of tests (by emissions factor development standards), for example

- 21 emissions tests for acetaldehyde, all fuels, uncontrolled or with PM control (Wood Residue Combustion)
- 22 tests for nickel, uncontrolled or with PM control (Wood Residue Combustion)
- 37 tests for nickel, spray dryer/fabric filter (SD/FF) (Refuse Combustion, Mass Burn and Modular Excess Air Units)
- 19 tests for benzene, all fuels, uncontrolled or with PM control (Wood Residue Combustion)
- 19 tests for benzene, fabric filter (Asphalt, Drum Mix)
- 48 tests for formaldehyde, all fuels, uncontrolled or with PM control (Wood Residue Combustion)
- 21 tests for formaldehyde, fabric filter (Asphalt, Drum Mix).

As expected, for the 18 emissions factors for the HAP pollutants, the uncertainty ratio decreases as *n* increases. For the 18 factors there is significant variability in the emissions factor uncertainty ratios, especially for values of $n \leq 5$. For example, for acetaldehyde emissions from Wood Residue Combustion, the uncertainty ratios for the 90th percentile range from 4.9 to 2.5, for $n = 1$ to $n = 25$, respectively. For nickel emissions from Wood Residue Combustion, the 90th percentile uncertainty ratios range from 14 to 2.8, for $n = 1$ to $n = 25$, respectively. The 90th percentile uncertainty ratios for controlled nickel emissions (SD/FF) from Refuse Combustion (Mass Burn) range from 3.5 to 2.2 for $n = 1$ to $n = 25$.

The uncertainty ratios for the mean value approach 1 for most of the HAP emissions factors when $n = 25$; however, when $n = 1$, the uncertainty ratios for the mean value range from 1.1 (HCl, uncontrolled, Refuse Combustion) to 11 (Arsenic, uncontrolled or with PM control, Wood Combustion).

As with the other pollutants that show variability (discussed below), when $n > 5$, the values of the uncertainty ratios begin to stabilize. With the HAP pollutants, the uncertainty ratios continue to decrease, but at a much slower rate.

PM-condensable. Five emissions factors for PM-condensable, including both organic and inorganic, were analyzed and the uncertainty ratios are shown in Table 4-4. There is less variability in the uncertainty ratio values for PM-condensable than for the HAPs. As expected, the uncertainty ratio decreases as *n* increases. For example, for PM-condensable, all fuels, uncontrolled emissions from Wood Combustion, the 90th percentile uncertainty ratios range from 4.4 to 2.4 when $n = 1$ to $n = 25$, respectively. For PM-condensable organic emissions from Hot Mix Asphalt (Drum Mixer) with WS/FF controls, the 90th percentile uncertainty ratios range from 6.0 to 2.5 when $n = 1$ to $n = 25$, respectively. While the uncertainty ratio values vary as a function of *n* in all of the source categories, the uncertainty ratio values begin to stabilize when $n > 5$.

The uncertainty ratios for the mean value approach 1 for the PM-condensable emissions factors when $n = 25$. When $n = 1$, the uncertainty ratios for the mean value range from 1.4 (Inorganic, Asphalt-Drum Mix, WS/FF) to 2.6 (Organic, Asphalt-Drum Mix, WS/FF).

PM-filterable. Table 4-4 shows the emissions factor uncertainty ratios that we calculated for the 15 PM-filterable emissions factors. For these emissions factors, there was less variability in the uncertainty ratios with respect to *n* than for other pollutants. For example, for PM-filterable, uncontrolled (Refuse Combustion, Refuse-Derived Fuel [RDF]), the uncertainty ratios for the 90th percentile range from 1.6 to 1.5, when $n = 1$ to $n = 25$, respectively. The largest variability with respect to *n* seen for PM-filterable emissions factors is for Refuse Combustion (RDF) with ESP control; the uncertainty ratio for the 90th percentile ranges from 5.2 to 2.5, when $n = 1$ to $n = 25$, respectively. For several of the PM-filterable emissions factors, there is little to no variability in the uncertainty ratio as *n* changes, for each statistic of interest.

The uncertainty ratios for the mean value approach 1 for the PM-filterable emissions factors when $n > 20$ for all of the factors except Refuse Combustion (RDF) with ESP control, which is 1.1 for $n = 20$. When $n = 1$, the uncertainty ratios for the mean value range from 1.1 (Wood Combustion, WS) to 2.3 (Refuse Combustion [RDF] with ESP).

Gaseous criteria pollutants. For purposes of discussion, we grouped the NOx, SO_2, and CO emissions factors as gaseous criteria pollutants. We analyzed a total of six emissions factors (two for each pollutant). Table 4-4 presents the uncertainty ratios for these six emissions factors.

The CO analysis was conducted from supporting emissions data for 128 emissions tests for Wood Residue Combustion and for 35 emissions tests for Refuse Combustion. For CO, there is little variability in the emissions factor uncertainty ratios as a function of *n*. This stability is true for both source categories shown. Data for CO emissions collected from well-operating combustion sources (i.e., no products of incomplete combustion) would be expected to have little variability. For Wood Residue Combustion, the uncertainty ratio for the 90^{th} percentile ranges from 2.2 to 1.9 when $n = 1$ to $n = 25$, respectively; for the Refuse Combustion (Mass Burn Waterwall) the uncertainty ratio ranges from 2.7 to 2.0 when $n = 1$ to $n = 25$, respectively. For CO, the uncertainty ratio for the mean value is 1 when $n > 10$ and ranges from 1.2 (Wood Combustion) to 1.4 (Refuse Combustion) when $n = 1$.

We conducted the NOx analysis from supporting emissions data that included 82 emissions tests (Wood Residue Combustion) and 31 emissions tests (Refuse Combustion, Mass Burn Waterwall). There is a large difference in the results for the two factors. For Wood Residue Combustion, the uncertainty ratio for the 90^{th} percentile ranges from 4.9 to 2.5 when $n = 1$ to $n = 25$, respectively. For Refuse Combustion, there is no variation in the uncertainty ratio for the 90^{th} percentile as *n* changes; it remains unchanged at 1.3. For Wood Residue Combustion, the uncertainty ratios for the mean value range from 2.2 to 1.1 when $n = 1$ to $n = 25$, respectively. For Refuse Combustion, there is no variation in the uncertainty ratio for the mean value; it remains unchanged at 1.

The SO_2 analysis was conducted on a dataset of 28 tests for Wood Residue Combustion and 46 tests for Refuse Combustion (Mass Burn and Modular Excess Air). Like the NOx uncertainty ratios, there is a large difference in the results for the two factors because the wood residue combustion data distribution is more skewed than the Refuse Combustion data. For Wood Residue Combustion, the uncertainty ratio for the 90^{th} percentile ranges from 8.2 to 2.6 when $n = 1$ to $n = 25$, respectively. For Refuse Combustion, there is little variation in the uncertainty ratio for the 90^{th} percentile as *n* changes; it ranges only from 1.8 to 1.7 when $n = 1$ to $n = 25$. For Wood Residue Combustion, the uncertainty ratios for the mean value range from 3.8 to 1.2 when $n = 1$ to $n = 25$, respectively. For Refuse Combustion, there is no variation in the uncertainty ratio for the mean value; it remains unchanged at 1.

For all three gaseous criteria pollutants, CO, NOx, and SO_2, once $n > 5$, the changes in the uncertainty ratio values stabilize.

4.2.2 Composite Emissions Factor Uncertainty Ratios

In this section, we discuss the calculation of composite emissions factor uncertainty ratios from the uncertainty ratio values determined for the individual emissions factor categories. The objective is to develop emissions factor uncertainty ratios that can be used as a tool for taking uncertainty into account. Presented in this report are the approaches considered, the procedures used, and the results of the analyses. We considered two approaches to developing composite uncertainty ratios. The first approach looked at clustering (categorizing) the individual uncertainty ratios based on the similarity of the distribution of the emissions factor data as measured by some statistical parameters (e.g., uncertainty ratios for emissions factors where the data exhibit a similar degree of skewness would be clustered). The second approach looked at clustering the individual uncertainty ratios based on an engineering/scientific property related to the emissions factor (e.g., similar pollutants [gaseous vs. PM], controlled vs. uncontrolled emissions, type of process, etc.). The following sections discuss each of these two approaches in more detail.

4.2.2.1 Composite Uncertainty Ratios – Categorized by Statistical Parameter

One approach to developing composite uncertainty ratios is to combine the uncertainty ratio values based on similarity of the emissions factor dataset. Table 4-5 shows the summary statistics of the emissions data from all the emissions factor categories analyzed in this study. The statistics shown in the table include *n* (sample size = number of emissions tests), mean, range of the data (minimum value minus maximum value), standard deviation, skewness, and the CV. The statistics suggest a considerable variability in mean values, the range of the data, and the standard deviations. In cases where a comparison criteria is needed for data with varying descriptive statistics, it is recommended to use statistics that measure the asymmetry and variation of the dataset. We included the CV and the skewness statistics for comparison of the data.

The skewness statistic provides a measure of the asymmetry of the data, while the CV statistic provides a relative measure of the dispersion of the data. Equation 4-1 defines the skewness statistic.

$$skewness = \frac{\sum_{i=1}^{n} (y_i - \overline{y})^3}{(n-1)s^3} \qquad \text{(Eq. 4-1)}$$

where:

skewness	=	measure of the asymmetry of the data
s	=	the standard deviation of the data
y_i	=	the measurement in the dataset
$\overline{y}$	=	mean of the data
n	=	number of values in the dataset.

Negative values for the skewness statistic indicate the data are skewed left while positive values indicate the data are skewed right. A skewness value of zero denotes a symmetric distribution around the mean (i.e., the normal distribution). A skewed left distribution is a distribution that has a left tail heavier than the right tail. Similarly, a skewed right distribution is a distribution with a right tail heavier than the left tail. Some measurements (such as these pollutant measurements) have a lower bound (zero) and are expected to be skewed right.

The CV statistic provides a relative measure of data dispersion compared to the mean; because the CV is scale free, it is particularly useful in making comparisons between different data. Equation 4-2 defines the CV statistic.

$$CV = \frac{s}{\bar{y}} \qquad \text{(Eq. 4-2)}$$

where:

CV	=	coefficient of variation
s	=	the standard deviation of the data
$\bar{y}$	=	the mean of the data.

When the CV value is small, we expect the data scatter compared to the mean to be small. On the other hand, if the CV value is large, then we expect the amount of variation with respect to the mean to be large. The squared CV (CV^2), is an increasing function of CV; therefore, it has the same properties of CV and is used in this document to characterize the uncertainty ratios.

$$CV^2 = \frac{s^2}{\bar{y}^2}$$

Exploratory analysis of the emissions factor data and values of the uncertainty ratios showed that datasets with similar skewness and CV values resulted in similar emissions factor uncertainty ratios. This conclusion is not surprising given the statistics used to estimate the parameters of the two distributions (Weibull and log-normal) that best fit the pollutants and to generate the uncertainty ratios are functions of the CV. The CV^2 was selected as the statistic to use to categorize the uncertainty ratio values. Table 4-6 presents the uncertainty ratio values listed by ascending (increasing) CV^2. The uncertainty ratios were grouped by CV^2 range (e.g., $CV^2 \leq 0.5$, $0.5 < CV^2 \leq 1.0$). We calculated the average uncertainty ratio values for each CV^2 range selected and they are presented (in bold type) in Table 4-6. These average uncertainty ratio values represent potential composite uncertainty ratio values. For each of the CV^2 categories, the uncertainty ratio value stabilizes when $n \geq 10$.

While analyzing the data for the CV^2 analysis and categorization, some data in the emissions factor datasets appeared to be potential outliers (either very large or very small observations). Given that the mean and the CV^2 statistics are affected by the presence of outliers or extreme observations, we performed an outlier check in the emissions factor datasets. We examined the existence of potential outliers using a rule of thumb to specify outliers based on the inter-quartile-range (IQR), which is a measure of the spread of the data. The IQR is defined as the third quartile (q3) minus the first quartile (q1). It was used to flag observations that lie outside of q1-(3*IQR) and q3+(3*IQR) as problematic outliers. We identified a number of datasets with outliers, most notably the HAPs. Fifteen of the 18 HAP emissions factors had at least one potential outlier in the dataset. Because these emissions factors account for a significant portion of the HAP dataset, we could not exclude these uncertainty ratios from the analysis. One possible approach is to go back to the original emissions factor dataset, recalculate the emissions factors without the outliers, and then repeat the statistical analyses on the revised emissions factor data to calculate the uncertainty ratios. However, the outlier data points were included in the original emissions factor development analysis because they were believed to be representative of the source category, and they are included in the emissions factor to be adjusted. Consequently, as a practical matter, it may not be appropriate to exclude them from the uncertainty ratio analysis. The effect of potential outliers would be seen in both the estimation of the parameters for the PDF assumed and the construction of the emissions factor uncertainty ratios.

4.2.2.2 Composite Uncertainty Ratios—Categorized by a Selected Engineering Property Related to the Emissions Factor

A second approach to developing composite emissions factor uncertainty ratios is to combine the uncertainty ratios based on an engineering or scientific property related to the factors (e.g., controlled vs. uncontrolled factors, particulate vs. gaseous pollutants, emissions resulting from similar process operations, such as combustion, material handling, coating operations). One of the objectives of this study is to develop uncertainty ratios that can easily be applied on a broad basis; developing factors based on the type of process operations would result in an increased number of uncertainty ratios and would further complicate matters.

We categorized the uncertainty ratios by pollutant type. Furthermore, where both controlled and uncontrolled data are available, we calculated separate composite uncertainty ratios for controlled and uncontrolled factors. Table 4-7 presents the emissions factor uncertainty ratios sorted based on pollutant as follows: HAP; PM-condensable; PM-filterable, controlled; PM-filterable, uncontrolled; and gaseous criteria pollutants. We determined composite emissions factor uncertainty ratios for each category of pollutant by calculating the mean value. Table 4-8 summarizes the composite emissions factor uncertainty ratios by pollutant. As previously discussed and as indicated in Table 4-8, throughout the analyses conducted for this study, we calculated uncertainty ratios for different values of n including $n = 1$, $n = 3$, $n = 5$, $n = 10$, $n = 20$, and $n = 25$. For each of the individual pollutant categories, the uncertainty ratio values nearly stabilize when n is 10 or greater. Furthermore, the composite uncertainty ratios for $n = 5$ and $n = 10$ are similar. Consequently, to further simplify the application of emissions factor uncertainty ratios, we recommend providing fewer uncertainty ratios that apply to a broader n range. Our recommendation is to provide composite uncertainty ratios, as follows:

Composite factor for application when	Based on factor for
$n < 3$	$n = 1$
$3 \le n < 10$	$n = 3$
$10 \le n < 25$	$n = 10$
$n \ge 25$	$n = 25$

Tables 4-9 through 4-13 summarize the recommended composite emissions factor uncertainty ratios for HAP; PM-condensable; PM-filterable, controlled; PM- filterable, uncontrolled; and gaseous criteria pollutants, respectively.

4.3 Normalized Monte Carlo Sampling Distribution of Emissions Factors (Means) from the Population

4.3.1 Summary of the Uncertainty Ratios by Pollutant

This section presents and discusses the normalized sampling distribution of emissions factors (means) obtained from the Monte Carlo techniques applied to the hypothetical population. This statistical analysis was conducted on all 44 AP-42 emissions factors, as described in Section 3.2.2. Table 4-14 presents the (selected) percentiles for the normalized distributions for selected sample sizes *n*, listed by pollutant and by air pollution control device, calculated for all 44 emissions factors from the four datasets. Observe that each normalized sampling distribution can be considered as the sampling distribution of the emissions factor uncertainty ratio statistic if the goal is to target the population mean. With these "sampling distributions," it is possible to obtain confidence intervals (e.g., 90, 95, 98, and 99 percent), for the population parameter (the uncertainty ratio value for the population mean). A 95 percent confidence interval for the uncertainty ratio to the mean has endpoints equal to the 2.5 and 97.5 percentiles of the normalized sampling distribution. Similarly, a 90 percent confidence interval has endpoints equal to the 5^{th} and 95^{th} percentiles of the normalized sampling distribution, and the 98 percent confidence interval has endpoints equal to the 1^{st} and 99^{th} percentiles of the normalized sampling distributions. Observe that the confidence intervals are centered on 1. These endpoints will define the lower and upper values for the uncertainty ratio if the goal is to target the mean of the hypothetical distribution. When these endpoints (uncertainty ratios) are multiplied by the emissions factor, the results are confidence intervals for the true emissions factor. The percentiles and *n* values selected for presentation in Table 4-14 were selected for comparison to the percentiles presented for the boundary statistic analyses (approach presented in Section 4.2). Appendix E presents the data for additional percentiles of the distributions for $n = 1$ to $n = 30$. One reviewer suggested reporting the 2.5 and 97.5 percentiles because these percentiles define the 95^{th} confidence interval, which is a commonly used confidence interval. These percentiles were not calculated for the emissions factors uncertainty ratios, and they have not been reported for the normalized sampling distributions at this time.

Because these uncertainty ratios are based on estimating the uncertainty around the mean, the uncertainty ratios are smaller than the factors calculated (and presented in Section 4.2) for targeting selected boundary statistics of the population. As expected, the uncertainty ratios decrease with increasing sample size, *n*. The HAP and the PM-condensable emissions factors exhibit the greatest variation considering *n* value, and the largest uncertainty ratios, in general. Overall, however, these uncertainty ratios (intervals about the mean) do not exhibit nearly as much variation as the uncertainty ratios calculated to target the boundary statistics. Again, this is not unexpected given that the uncertainty ratios times the AP-42 emissions factor represent the confidence limits around the population mean (true emissions factor). Table 4-15 present the data organized by increasing CV^2 value.

4.3.2 Composite Uncertainty Ratios

For comparison purposes, composite uncertainty ratios were calculated for the five categories of pollutants: HAPs, condensable PM, controlled filterable PM, uncontrolled filterable PM, and gaseous criteria pollutants. Table 4-16 presents the composite uncertainty ratios by pollutant category. These values were further composited by *n* value (i.e., $n < 3$, $3 \leq n < 10$, $10 \leq n < 25$, and $n \geq 25$); these results are presented in Tables 4-17 through 4-21.

4.4 Comparison of Results from Different Analyses

We conducted two different statistical analyses to develop emissions factor uncertainty ratios. The results of the two different analyses appear in previous sections. This section briefly addresses similarities and differences among the results, as well as how the approaches complement each other. Also, we present a technique for using the two approaches to complement each other for noninventory and inventory uses.

The first statistical approach targets boundary statistics of the hypothetical population and is appropriate when applying emissions factors to a single emissions unit. The second statistical approach estimates uncertainty about the mean of the population and is more appropriate for uses of emission factors for many identical emissions units in an area. As expected, uncertainty ratios calculated using the first approach are greater because they target a boundary statistic of the hypothetical population for a single measurement, whereas the second approach calculates an uncertainty ratio that provides uncertainty measures (confidence intervals) for the mean. The difference in uncertainty ratio values by the two approaches is greater for a smaller n. That is, the sample size, n, has a greater impact on the uncertainty ratio by using the first approach. Although in both cases, the uncertainty ratio decreases as n increases. For example, for HAPs, the composite emissions factor uncertainty ratios to target the 90^{th} percentile are 7.7 and 2.4 for $n < 3$ and $n \geq 25$. By comparison, for the second approach, the uncertainty ratios based on the 90^{th} percentile of the normalized distribution of the emissions factor mean are 2.2 for $n < 3$ and 1.5 for $n \geq 25$, respectively. This pattern holds for all of the uncertainty ratios.

The uncertainty ratios calculated by the first approach target a boundary statistic for application to a single emissions unit while the uncertainty ratios calculated by the second approach target the uncertainty about the mean value of a large sample. Some situations do not perfectly fall into one of these two categories, making it unclear which uncertainty ratio is more appropriate. This is particularly true when estimating emissions from a small number of similar sources (emissions units), for example, when estimating the total emissions from a facility with three similar boilers. Another example is the situation where a regulatory agency is estimating emissions from multiple facilities; for example, five facilities in a local region or 25 facilities in the state. The uncertainty ratio values for situations involving a small number of emissions units should fall between the values calculated by the two approaches.

One approach to addressing the type of situations described above is to start with the emissions factor uncertainty ratio and apply a correction to reduce the uncertainty ratio for situations where emissions from multiple emissions units are being estimated. A review of the data from the first statistical approach (boundary statistic) indicates the uncertainty ratio for the mean as the target statistic approaches 1 for all pollutants, with the exception of uncontrolled HAPs when $n > 10$; the uncertainty ratio is 1.1 or less for $n > 10$. Therefore, a practical approach is to state that for more than 10 sources (emissions units), the uncertainty ratio value based on the distribution about the mean (i.e., the second statistical approach) can be used. We calculated the difference between the uncertainty ratios determined by the two statistical approaches for each percentile and it is called the correction factor (CF) for multiple emissions units (EU). Table 4-22 presents the CFs. A linear reduction in the emissions factor uncertainty ratio is assumed for one to 10 emissions units such that the uncertainty ratio based on the boundary statistic is reduced by 1/10 of the CF for each emissions unit greater than one up to a maximum of 10 emissions units. For 11 or more emissions units, the entire CF is subtracted from the emissions factor uncertainty ratio; thus for 11 or more emissions units, the emissions factor uncertainty ratio is equivalent to the uncertainty ratio determined by the normalized sample distribution about the mean. The equation for correcting the emissions factor uncertainty ratio for multiple emissions units follows.

If there are at least two, but less than 11, similar EUs, the following equation is used to calculate the emissions factor uncertainty ratio:

$$EF_{\text{uncertainty ratio}} = \left[\frac{\text{EF}_{\text{target statistic}}}{\text{EF}} - \left(\frac{1}{10} \times \text{CF} \times (\text{EU} - 1) \right) \right] \qquad \text{(Eq. 4-3)}$$

where

$EF_{\text{target statistic}}$	=	Target population value of the emissions distribution, hereafter referred to as the target statistic (e.g., 95th percentile), in units of the AP-42 emissions factor
EF	=	Emissions factor, as presented in AP-42, in units of the AP-42 emissions factor
CF	=	Correction factor for multiple EUs (see values in Table 4-22)
EU	=	Number of emissions units.

If there are 11 or more similar EUs, the following equation is used to calculate the emissions factor uncertainty ratio:

$$EF_{\text{uncertainty ratio}} = \left[\frac{\text{EF}_{\text{target statistic}}}{\text{EF}} - \text{CF} \right] \qquad \text{(Eq. 4-4)}$$

where

$EF_{\text{target statistic}}$	=	Target population value of the emissions distribution, hereafter referred to as the target statistic (e.g., 95th percentile), in units of the AP-42 emissions factor
EF	=	Emissions factor, as presented in AP-42, in units of the AP-42 emissions factor
CF	=	Correction factor for multiple EUs (see values in Table 4-22).

4.5 Relative Accuracy Assessment

To assess the performance of the composite emissions factor uncertainty ratios, we compared the calculated emissions factor target statistics to the hypothetical population values of the target statistic for each emissions factor evaluated during the study. The following equation was used to calculate relative accuracy:

$$RA = (EF_{\text{target statistic}} - HP_{\text{target statistic}})/HP_{\text{target statistic}} \times 100 \qquad \text{(Eq. 4-5)}$$

where

RA	=	Relative accuracy
$EF_{\text{target statistic}}$	=	Target population value of the emissions distribution, hereafter referred to as the target statistic (e.g., 95th percentile), in units of the AP-42 emissions factor
$HP_{\text{target statistic}}$	=	Actual value of the hypothetical population for the target statistic of interest for the emissions factor (e.g., 95th percentile of the hypothetical population distribution).

And

$$EF_{\text{target statistic}} = EF * EF_{\text{uncertainty ratio}} \qquad \text{(Eq. 4-6)}$$

where

$EF_{\text{uncertainty ratio}}$	=	Composite uncertainty ratio for the pollutant and target statistic of interest

An example calculation for the HAP, HCl–Refuse Combustion, Mass Burn, follows.

Given

a) Published AP-42 emissions factor = 0.198 lb/ton
b) Number of tests that the published emissions factor is based upon, $n = 14$
c) 95th percentile of the hypothetical population, $HP_{95th} = 0.67$ lb/ton
d) Composite emissions factor uncertainty ratio for HAPs, where the target statistic is the 95th percentile and $10 \leq n < 25 = 4.3$ (per Table 4-9).

Then

$EF_{\text{target statistic}}$	=	$(EF) * (EF_{\text{uncertainty ratio}})$
$EF_{\text{95th percentile}}$	=	0.198 lb/ton * 4.3
	=	0.85 lb/ton

and

RA	=	$(EF_{\text{target statistic}} - HP_{\text{target statistic}})/HP_{\text{target statistic}} * 100$
	=	(0.85 - 0.67)/0.67 * 100
	=	27%

Similarly for the target statistic of the 90th percentile for the same pollutant:

Given

a) Published AP-42 emissions factor = 0.198 lb/ton
b) Number of tests that the published emissions factor is based upon, $n = 14$
c) 90th percentile of the hypothetical population, $HP_{90th} = 0.49$ lb/ton
d) Composite emissions factor uncertainty ratio for HAPs, where the target statistic is the 90th percentile and $10 \leq n < 25$, = 2.7 (per Table 4-9).

Then

$$EF_{target\ statistic} = (EF) * (EF_{uncertainty\ ratio})$$

$$EF_{90th\ percentile} = 0.198\ lb/ton * 2.7$$

$$= 0.53\ lb/ton$$

and

$$RA = (EF_{target\ statistic} - HP_{target\ statistic})/HP_{target\ statistic} * 100$$

$$= (0.53 - 0.49)/0.49 * 100$$

$$= 10\%$$

In these two examples, the emissions factor target statistic calculated using the composite emissions factor uncertainty ratio overestimates the 90th and 95th percentiles by 10 and 27 percent, respectively.

Table 4-23 summarizes the relative accuracy results for each emissions factor evaluated during this study for the 10th, 25th, median, 75th, 90th, and 95th target statistics. The average, median, minimum, and maximum relative accuracy values are presented for each pollutant type for which composite emissions factors were developed (e.g., HAPs, PM-condensable, PM-filterable, controlled; PM-filterable, uncontrolled; and gaseous criteria pollutants).

With the exception of PM-condensable, the composite emissions factor uncertainty ratios overestimate the target statistics, on average. In particular, the percentiles below the median (e.g., the 10th and 25th percentiles) are overestimated by the composite emissions factor uncertainty ratios. Appendix H presents the complete relative accuracy calculation results.

Table 4-1. Moran's Goodness-of-Fit Test p-Values by Emissions Factor and Probability Density

Pollutant	Control	Industry/Source	p-Values		
			Weibull Density	Gamma Density	Log-normal Density
Acetaldehyde	UNC/PM	Wood Combustion	0.049	0.000	0.156
Arsenic	SD/FF	Refuse Combustion, Mass Burn	1.00	0.000	1.00
Arsenic	UNC/PM	Wood Combustion	0.863	0.000	0.651
Benzene	FF	Asphalt, Drum Mix	1.00	0.000	1.00
Benzene	UNC/PM	Wood Combustion	0.701	0.000	0.915
Cadmium	SD/ESP	Refuse Combustion, Mass Burn	1.00	0.000	1.00
Cadmium	UNC/PM	Wood Combustion	0.059	0.000	0.000
Carbon monoxide	UNC	Refuse Combustion, Mass Burn	1.00	0.000	1.00
Carbon monoxide	UNC	Wood Combustion	0.998	0.000	0.997
Chromium	UNC/PM	Wood Combustion	0.33	0.000	0.027
Formaldehyde	FF	Asphalt, Drum Mix	0.994	0.000	1.00
Formaldehyde	UNC/PM	Wood Combustion	0.447	0.000	0.696
Hydrogen chloride	UNC	Refuse Combustion	1.00	0.000	1.00
Hydrogen chloride	SD/FF	Refuse Combustion, Mass Burn	0.308	0.005	0.179
Lead	SD/ESP	Refuse Combustion, Mass Burn	1.00	0.000	1.00
Lead	UNC/PM	Wood Combustion	0.885	0.000	0.288
Mercury	SD/FF	Refuse Combustion, Mass Burn	0.052	0.000	0.107
Mercury	UNC/PM	Wood Combustion	0.349	0.000	0.059
Nickel	SD/FF	Refuse Combustion, Mass Burn	0.071	0.000	0.19
Nickel	UNC/PM	Wood Combustion	0.151	0.000	0.012
Nitrogen oxides	UNC	Refuse Combustion, Mass Burn Waterwall	0.265	0.000	0.095
Nitrogen oxides	UNC	Wood Combustion	0.004	0.000	0.214
PM-condensable	UNC	Wood Combustion	0.864	0.000	0.934
PM-condensable (Inorganic)	FF	Asphalt, Batch Mixer	1.00	0.000	1.00
PM-condensable (Organic)	FF	Asphalt, Batch Mixer	1.00	0.000	1.00
PM-condensable (Inorganic)	WS/FF	Asphalt, Drum Mixer	1.00	0.000	1.00
PM-condensable (Organic)	WS/FF	Asphalt, Drum Mixer	1.00	0.000	1.00
PM-filterable	FF	Asphalt, Batch Mixer	1.00	0.000	1.00
PM-filterable	FF	Asphalt, Drum Mixer	1.00	0.000	1.00
PM-filterable	UNC	W/OSB, Hot Press	0.074	0.000	0.484
PM-filterable	DSI/FF	Refuse Combustion, Mass Burn	1.00	0.000	1.00

(continued)

Table 4-1. (continued)

Pollutant	Control	Industry/Source	p-Values		
			Weibull Density	Gamma Density	Log-normal Density
PM-filterable	ESP	Refuse Combustion, Mass Burn	1.00	0.000	1.00
PM-filterable	SD/ESP	Refuse Combustion, Mass Burn	1.00	0.000	1.00
PM-filterable	SD/FF	Refuse Combustion, Mass Burn	1.00	0.000	1.00
PM-filterable	UNC	Refuse Combustion, Mass Burn	0.598	0.000	0.536
PM-filterable	ESP	Refuse Combustion, RDF	0.738	0.454	0.781
PM-filterable	UNC	Refuse Combustion, RDF	0.902	0.000	0.927
PM-filterable	WS	Wood Combustion	0.145	0.000	0.245
PM-filterable	MC	Wood Combustion, Dry Wood	1.00	0.000	1.00
PM-filterable	UNC	Wood Combustion, Dry Wood	0.92	0.000	0.982
PM-filterable	MC	Wood Combustion, Wet Wood	0.707	0.000	0.305
PM-filterable	UNC	Wood Combustion, Wet Wood	0.571	0.000	0.604
Sulfur dioxide	UNC	Refuse Combustion	1.00	0.000	1.00
Sulfur dioxide	UNC	Wood Combustion	1.00	0.000	1.00

CDF = cumulative distribution function; DSI/FF = dry sorbent injection/fabric filter; ESP = electrostatic precipitator; FF = fabric filter; MC = mechanical collector (e.g., cyclone); PM = particulate matter; RDF = refuse-derived fuel; SD/ESP = spray dryer/electrostatic precipitator; SD/FF = spray dryer/fabric filter; UNC = uncontrolled; W/OSB = Waferboard/Oriented Strandboard Manufacturing; WS = wet scrubber; WS/FF = wet scrubber or fabric filter; UNC/PM = uncontrolled or PM control.

Note: p-values larger than 0.05 suggest no statistical evidence against the agreement between the CDF of the pollutant data and the theoretical density function.

Table 4-2. Estimated Parameters for the Fit of the Hypothetical Distribution

			Log-normal Distribution		Weibull Distribution	
Pollutant	**Control**	**Industry/Source**	**μ**	**σ**	**Scale**	**Shape**
Acetaldehyde	UNC/PM	Wood Combustion	−9.02	1.81		
Arsenic	SD/FF	Refuse Combustion, Mass Burn	−12.72	0.50		
Arsenic	UNC/PM	Wood Combustion			5.24E-06	0.37
Benzene	FF	Asphalt, Drum Mix	−8.13	0.59		
Benzene	UNC/PM	Wood Combustion	−7.95	2.12		
Cadmium	SD/ESP	Refuse Combustion, Mass Burn	−9.66	0.83		
Cadmium	UNC/PM	Wood Combustion			3.10E-06	0.61
Carbon monoxide	UNC	Refuse Combustion, Mass Burn	−1.18	0.57		
Carbon monoxide	UNC	Wood Combustion			0.64	1.26
Chromium	UNC/PM	Wood Combustion			1.23E-05	0.52
Formaldehyde	FF	Asphalt, Drum Mix	−6.28	1.01		
Formaldehyde	UNC/PM	Wood Combustion	−7.06	1.86		
Hydrogen chloride	UNC	Refuse Combustion			6.78	1.77
Hydrogen chloride	SD/FF	Refuse Combustion, Mass Burn			0.18	0.82
Lead	SD/ESP	Refuse Combustion, Mass Burn	−7.12	0.82		
Lead	UNC/PM	Wood Combustion			2.59E-05	0.49
Mercury	SD/FF	Refuse Combustion, Mass Burn	−6.95	1.09		
Mercury	UNC/PM	Wood Combustion			1.61E-06	0.49
Nickel	SD/FF	Refuse Combustion, Mass Burn	−10.83	0.98		
Nickel	UNC/PM	Wood Combustion			1.62E-05	0.46
Nitrogen oxides	UNC	Refuse Combustion, Mass Burn Waterwall			3.96	4.19
Nitrogen oxides	UNC	Wood Combustion	−1.66	0.53		
PM-condensable	UNC	Wood Combustion	−4.66	1.13		
PM-condensable (Inorganic)	FF	Asphalt, Batch Mixer	−5.26	1.62		
PM-condensable (Inorganic)	WS/FF	Asphalt, Drum Mixer	−5.24	0.66		
PM-condensable (Organic)	FF	Asphalt, Batch Mixer			3.96E-03	0.91
PM-condensable (Organic)	WS/FF	Asphalt, Drum Mixer	−5.26	1.89		
PM-filterable	FF	Asphalt, Batch Mixer	−4.27	1.13		

(continued)

Table 4-2. (continued)

			Log-normal Distribution		Weibull Distribution	
Pollutant	**Control**	**Industry/Source**	**μ**	**σ**	**Scale**	**Shape**
PM-filterable	FF	Asphalt, Drum Mixer	−4.72	0.81		
PM-filterable	UNC	W/OSB, Hot Press	−2.35	0.93		
PM-filterable	DSI/FF	Refuse Combustion, Mass Burn			0.23	1.13
PM-filterable	ESP	Refuse Combustion, Mass Burn	-2.05	0.94		
PM-filterable	SD/ESP	Refuse Combustion, Mass Burn	−2.74	0.27		
PM-filterable	SD/FF	Refuse Combustion, Mass Burn	−3.15	0.87		
PM-filterable	UNC	Refuse Combustion, Mass Burn	3.11	0.24		
PM-filterable	ESP	Refuse Combustion, RDF	−1.00	1.81		
PM-filterable	UNC	Refuse Combustion, RDF	4.08	0.13		
PM-filterable	WS	Wood Combustion	-2.76	0.09		
PM-filterable	MC	Wood Combustion, Dry Wood	−1.27	0.40		
PM-filterable	UNC	Wood Combustion, Dry Wood	−1.00	0.40		
PM-filterable	MC	Wood Combustion, Wet Wood			0.20	0.82
PM-filterable	UNC	Wood Combustion, Wet Wood	−1.27	0.56		
Sulfur dioxide	UNC	Refuse Combustion			3.88	2.1
Sulfur dioxide	UNC	Wood Combustion	−4.83	1.63		

DSI/FF = dry sorbent injection/fabric filter; ESP = electrostatic precipitator; FF = fabric filter; MC = mechanical collector (e.g., cyclone); PM = particulate matter; RDF = refuse-derived fuel; SD/ESP = spray dryer/electrostatic precipitator; SD/FF = spray dryer/fabric filter; UNC = uncontrolled; W/OSB = Waferboard/Oriented Strandboard Manufacturing; WS = wet scrubber; WS/FF = wet scrubber or fabric filter; UNC/PM = uncontrolled or PM control.

Table 4-3. Emissions Factor Uncertainty Ratios for Carbon Monoxide (from Wood Residue Combustion), by Number of Tests (*n*) and Target Statistic

Median						
	Target Statistic					
n	**5th Percentile**	**10th Percentile**	**Median**	**Mean**	**90th Percentile**	**95th Percentile**
1	0.19	0.30	1.0	1.2	2.2	2.7
3	0.17	0.27	0.91	1.0	2.0	2.4
5	0.16	0.26	0.89	1.0	1.9	2.3
10	0.16	0.26	0.88	1.0	1.9	2.3
15	0.16	0.26	0.88	1.0	1.9	2.3
20	0.16	0.26	0.88	1.0	1.9	2.3
25	0.16	0.26	0.88	1.0	1.9	2.3
Mean						
n	**5th Percentile**	**10th Percentile**	**Median**	**Mean**	**90th Percentile**	**95th Percentile**
1	0.37	0.60	2.0	2.3	4.5	5.4
3	0.19	0.30	1.0	1.2	2.3	2.7
5	0.18	0.28	0.96	1.1	2.1	2.5
10	0.17	0.27	0.91	1.0	2.0	2.4
15	0.16	0.26	0.90	1.0	2.0	2.4
20	0.16	0.26	0.90	1.0	2.0	2.4
25	0.16	0.26	0.89	1.0	1.9	2.3
95th Percentile						
n	**5th Percentile**	**10th Percentile**	**Median**	**Mean**	**90th Percentile**	**95th Percentile**
1	1.0	1.6	5.5	6.3	12	14
3	0.36	0.58	2.0	2.3	4.3	5.2
5	0.29	0.47	1.6	1.8	3.5	4.2
10	0.24	0.38	1.3	1.5	2.8	3.4
15	0.22	0.35	1.2	1.4	2.6	3.1
20	0.21	0.34	1.1	1.3	2.5	3.0
25	0.20	0.32	1.1	1.3	2.4	2.9

n = number of emissions tests.

Table 4-4. Uncertainty Ratios Based on Boundary Statistics Listed by Pollutant, Control Device, and Industry/Source

			Uncertainty Ratio (MC Median)																																									
		Target Statistic→	10th Percentile						25th Percentile						Median						Mean						75th Percentile						90th Percentile						95th Percentile					
Pollutant	Control	Industry/Source	n=1	n=3	n=5	n=10	n=20	n=25	n=1	n=3	n=5	n=10	n=20	n=25	n=1	n=3	n=5	n=10	n=20	n=25	n=1	n=3	n=5	n=10	n=20	n=25	n=1	n=3	n=5	n=10	n=20	n=25	n=1	n=3	n=5	n=10	n=20	n=25	n=1	n=3	n=5	n=10	n=20	n=25
Acetaldehyde	UNC/PM	Wood Combustion	0.20	0.13	0.12	0.11	0.10	0.10	0.43	0.29	0.26	0.23	0.22	0.22	0.99	0.67	0.59	0.54	0.51	0.50	2.13	1.44	1.28	1.16	1.10	1.08	2.34	1.58	1.40	1.27	1.20	1.18	4.90	3.30	2.93	2.66	2.52	2.47	7.63	5.14	4.56	4.14	3.93	3.86
Arsenic	SD/FF	Refuse Combustion, Mass Burn	0.41	0.35	0.33	0.32	0.32	0.32	0.62	0.53	0.51	0.49	0.49	0.48	1.00	0.85	0.82	0.80	0.79	0.78	1.30	1.10	1.06	1.03	1.02	1.01	1.65	1.40	1.35	1.31	1.30	1.29	2.53	2.15	2.07	2.01	2.00	1.98	3.15	2.68	2.58	2.51	2.49	2.46
Arsenic	UNC/PM	Wood Combustion	0.01	0.00	0.00	0.00	0.00	0.00	0.09	0.02	0.02	0.01	0.01	0.01	1.01	0.26	0.18	0.14	0.12	0.11	10.59	2.72	1.89	1.45	1.23	1.18	6.34	1.63	1.13	0.87	0.74	0.71	25.02	6.43	4.46	3.44	2.91	2.79	51.17	13.15	9.13	7.03	5.96	5.71
Benzene	FF	Asphalt, Drum Mix	0.37	0.32	0.30	0.29	0.28	0.28	0.59	0.51	0.48	0.47	0.45	0.46	1.00	0.85	0.82	0.79	0.77	0.77	1.33	1.13	1.08	1.04	1.02	1.02	1.67	1.42	1.36	1.31	1.28	1.28	2.62	2.23	2.13	2.06	2.00	2.01	3.45	2.94	2.81	2.71	2.64	2.65
Benzene	UNC/PM	Wood Combustion	0.06	0.03	0.02	0.01	0.01	0.01	0.23	0.10	0.07	0.05	0.04	0.04	1.00	0.42	0.31	0.23	0.19	0.18	7.78	3.23	2.40	1.80	1.47	1.38	3.86	1.60	1.19	0.89	0.73	0.69	13.45	5.59	4.16	3.11	2.54	2.39	28.76	11.94	8.89	6.66	5.44	5.10
Cadmium	SD/ESP	Refuse Combustion, Mass Burn	0.31	0.25	0.23	0.22	0.21	0.21	0.54	0.42	0.40	0.38	0.37	0.37	1.00	0.79	0.74	0.70	0.68	0.68	1.52	1.19	1.12	1.07	1.04	1.03	1.88	1.48	1.39	1.33	1.28	1.28	3.24	2.54	2.38	2.28	2.20	2.20	4.35	3.41	3.20	3.06	2.96	2.96
Cadmium	UNC/PM	Wood Combustion	0.04	0.02	0.02	0.02	0.02	0.02	0.23	0.12	0.11	0.10	0.09	0.09	0.98	0.53	0.46	0.42	0.39	0.39	2.69	1.46	1.27	1.15	1.06	1.06	3.05	1.65	1.44	1.31	1.20	1.21	7.08	3.84	3.33	3.04	2.80	2.80	10.87	5.89	5.12	4.66	4.29	4.30
Chromium	UNC/PM	Wood Combustion	0.03	0.01	0.01	0.01	0.01	0.03	0.20	0.08	0.07	0.06	0.06	0.06	1.04	0.42	0.36	0.31	0.29	0.29	3.95	1.60	1.37	1.17	1.11	1.08	3.96	1.60	1.37	1.18	1.11	1.09	10.49	4.24	3.63	3.12	2.95	2.88	17.28	6.99	5.99	5.14	4.86	4.75
Formaldehyde	FF	Asphalt, Drum Mix	0.28	0.21	0.20	0.18	0.18	0.18	0.50	0.38	0.35	0.33	0.32	0.32	1.00	0.76	0.71	0.66	0.64	0.63	1.65	1.25	1.16	1.09	1.06	1.04	1.94	1.47	1.37	1.28	1.24	1.23	3.64	2.75	2.56	2.40	2.33	2.30	5.20	3.93	3.66	3.43	3.33	3.29
Formaldehyde	UNC/PM	Wood Combustion	0.09	0.04	0.03	0.03	0.02	0.02	0.29	0.13	0.10	0.08	0.07	0.07	0.97	0.45	0.35	0.27	0.24	0.23	5.79	2.71	2.12	1.63	1.41	1.36	3.48	1.63	1.27	0.98	0.85	0.82	11.18	5.23	4.08	3.15	2.73	2.63	21.50	10.06	7.85	6.05	5.25	5.06
Hydrogen chloride	SD/FF	Refuse Combustion, Mass Burn	0.10	0.07	0.06	0.06	0.06	0.06	0.35	0.24	0.23	0.21	0.21	0.21	1.00	0.69	0.65	0.61	0.59	0.59	1.73	1.19	1.12	1.05	1.02	1.02	2.30	1.58	1.49	1.40	1.36	1.35	4.30	2.95	2.79	2.62	2.54	2.53	5.99	4.12	3.89	3.65	3.54	3.53
Hydrogen chloride	UNC	Refuse Combustion	0.34	0.31	0.31	0.31	0.31	0.31	0.61	0.57	0.56	0.56	0.56	0.56	1.01	0.95	0.93	0.93	0.93	0.93	1.09	1.02	1.01	1.01	1.00	1.00	1.47	1.37	1.36	1.36	1.35	1.35	1.97	1.84	1.82	1.82	1.81	1.81	2.27	2.12	2.10	2.10	2.08	2.09
Lead	SD/ESP	Refuse Combustion, Mass Burn	0.32	0.25	0.23	0.22	0.21	0.21	0.55	0.42	0.40	0.38	0.37	0.36	1.01	0.78	0.74	0.70	0.68	0.67	1.48	1.15	1.09	1.03	1.00	0.99	1.83	1.43	1.35	1.27	1.23	1.22	3.15	2.45	2.32	2.18	2.12	2.10	4.28	3.33	3.16	2.97	2.89	2.86
Lead	UNC/PM	Wood Combustion	0.02	0.01	0.01	0.01	0.00	0.00	0.16	0.06	0.05	0.04	0.04	0.04	1.01	0.41	0.33	0.28	0.26	0.25	4.41	1.79	1.43	1.22	1.12	1.09	4.08	1.66	1.32	1.13	1.04	1.01	11.72	4.76	3.81	3.24	2.98	2.89	20.28	8.23	6.58	5.60	5.15	5.00
Mercury	SD/FF	Refuse Combustion, Mass Burn	0.26	0.20	0.18	0.17	0.16	0.16	0.49	0.37	0.34	0.32	0.30	0.30	1.00	0.76	0.70	0.64	0.62	0.61	1.71	1.30	1.20	1.10	1.06	1.05	1.99	1.50	1.39	1.27	1.23	1.22	3.75	2.84	2.62	2.40	2.32	2.30	5.45	4.13	3.81	3.50	3.37	3.35
Mercury	UNC/PM	Wood Combustion	0.02	0.01	0.01	0.01	0.01	0.01	0.19	0.07	0.06	0.05	0.05	0.05	1.06	0.40	0.34	0.29	0.26	0.26	4.44	1.70	1.44	1.20	1.09	1.08	4.27	1.64	1.39	1.16	1.05	1.04	11.83	4.54	3.85	3.21	2.91	2.89	19.85	7.61	6.45	5.39	4.89	4.84
Nickel	SD/FF	Refuse Combustion, Mass Burn	0.28	0.21	0.20	0.19	0.18	0.18	0.51	0.39	0.37	0.35	0.33	0.33	1.00	0.77	0.72	0.67	0.65	0.65	1.61	1.24	1.16	1.09	1.05	1.04	1.93	1.48	1.39	1.30	1.25	1.25	3.46	2.66	2.49	2.33	2.25	2.24	4.92	3.78	3.54	3.32	3.20	3.18
Nickel	UNC/PM	Wood Combustion	0.02	0.01	0.01	0.00	0.00	0.00	0.14	0.05	0.04	0.03	0.03	0.03	1.01	0.36	0.30	0.24	0.21	0.21	5.40	1.90	1.62	1.27	1.13	1.11	4.57	1.61	1.37	1.07	0.96	0.94	13.80	4.87	4.14	3.24	2.89	2.84	25.14	8.87	7.54	5.89	5.27	5.17
PM-cond	UNC	Wood Combustion	0.24	0.17	0.15	0.14	0.13	0.13	0.46	0.33	0.29	0.27	0.25	0.25	1.01	0.71	0.63	0.58	0.55	0.54	1.96	1.38	1.23	1.13	1.07	1.06	2.19	1.54	1.38	1.26	1.20	1.18	4.42	3.10	2.78	2.54	2.42	2.39	6.77	4.76	4.26	3.90	3.71	3.66
PM-cond (Inorganic)	FF	Asphalt, Batch Mixer	0.19	0.13	0.11	0.10	0.09	0.09	0.42	0.27	0.25	0.22	0.21	0.20	0.98	0.64	0.57	0.51	0.48	0.47	2.28	1.48	1.33	1.18	1.11	1.09	2.38	1.55	1.39	1.22	1.16	1.14	5.18	3.36	3.02	2.67	2.52	2.48	8.36	5.43	4.88	4.31	4.07	4.00
PM-cond (Inorganic)	WS/FF	Asphalt, Drum Mixer	0.35	0.29	0.27	0.26	0.26	0.25	0.58	0.47	0.45	0.43	0.42	0.42	1.02	0.83	0.79	0.75	0.74	0.74	1.42	1.16	1.10	1.05	1.03	1.02	1.75	1.43	1.36	1.30	1.28	1.26	2.90	2.37	2.25	2.14	2.11	2.09	3.96	3.23	3.07	2.92	2.88	2.85
PM-cond (Organic)	FF	Asphalt, Batch Mixer	0.27	0.20	0.19	0.18	0.17	0.17	0.51	0.38	0.35	0.33	0.32	0.32	1.01	0.76	0.70	0.66	0.64	0.63	1.66	1.24	1.15	1.09	1.05	1.04	1.99	1.49	1.38	1.30	1.26	1.24	3.60	2.69	2.49	2.35	2.27	2.24	5.23	3.91	3.62	3.42	3.30	3.26
PM-cond (Organic)	WS/FF	Asphalt, Drum Mixer	0.18	0.11	0.09	0.08	0.08	0.08	0.41	0.25	0.21	0.19	0.18	0.17	1.02	0.63	0.54	0.48	0.44	0.43	2.60	1.59	1.36	1.23	1.13	1.10	2.56	1.57	1.34	1.21	1.11	1.08	5.99	3.66	3.14	2.82	2.60	2.53	9.98	6.11	5.23	4.71	4.33	4.22
PM-filt	DSI/FF	Refuse Combustion, Mass Burn	0.19	0.15	0.15	0.14	0.14	0.14	0.45	0.37	0.36	0.35	0.35	0.35	1.00	0.82	0.79	0.77	0.76	0.76	1.32	1.09	1.05	1.02	1.01	1.01	1.85	1.52	1.46	1.42	1.42	1.41	2.91	2.39	2.30	2.24	2.23	2.22	3.66	3.01	2.89	2.82	2.81	2.80
PM-filt	ESP	Refuse Combustion, Mass Burn	0.29	0.22	0.21	0.19	0.19	0.19	0.52	0.40	0.37	0.35	0.34	0.34	1.02	0.78	0.72	0.68	0.65	0.65	1.62	1.24	1.15	1.08	1.04	1.04	1.94	1.49	1.38	1.29	1.25	1.25	3.48	2.67	2.47	2.32	2.24	2.23	5.03	3.86	3.56	3.35	3.24	3.22
PM-filt	ESP	Refuse Combustion, RDF	0.17	0.11	0.10	0.09	0.08	0.08	0.39	0.26	0.23	0.20	0.19	0.19	0.96	0.65	0.57	0.51	0.48	0.47	2.26	1.53	1.34	1.20	1.12	1.10	2.27	1.53	1.35	1.20	1.12	1.10	5.17	3.48	3.07	2.74	2.56	2.51	8.32	5.61	4.94	4.42	4.13	4.05
PM-filt	FF	Asphalt, Drum Mixer	0.32	0.26	0.24	0.23	0.22	0.22	0.53	0.43	0.41	0.39	0.37	0.37	0.99	0.81	0.76	0.72	0.70	0.69	1.47	1.20	1.13	1.07	1.04	1.03	1.82	1.48	1.39	1.32	1.28	1.27	3.09	2.51	2.37	2.24	2.18	2.16	4.38	3.56	3.36	3.18	3.09	3.06

(continued)

Table 4-4. (continued)

			Uncertainty Ratio (MC Median)																																									
		Target Statistic→	10th Percentile						25th Percentile						Median						Mean						75th Percentile						90th Percentile						95th Percentile					
Pollutant	Control	Industry/Source	*n*=1	*n*=3	*n*=5	*n*=10	*n*=20	*n*=25	*n*=1	*n*=3	*n*=5	*n*=10	*n*=20	*n*=25	*n*=1	*n*=3	*n*=5	*n*=10	*n*=20	*n*=25	*n*=1	*n*=3	*n*=5	*n*=10	*n*=20	*n*=25	*n*=1	*n*=3	*n*=5	*n*=10	*n*=20	*n*=25	*n*=1	*n*=3	*n*=5	*n*=10	*n*=20	*n*=25	*n*=1	*n*=3	*n*=5	*n*=10	*n*=20	*n*=25
PM-filt	FF	Asphalt, Batch Mixer	0.26	0.19	0.18	0.17	0.16	0.16	0.49	0.37	0.34	0.32	0.30	0.30	0.99	0.74	0.68	0.64	0.62	0.61	1.70	1.28	1.18	1.10	1.06	1.05	1.96	1.48	1.36	1.27	1.22	1.21	3.76	2.83	2.60	2.44	2.35	2.32	5.46	4.10	3.77	3.54	3.40	3.37
PM-filt	MC	Wood Combustion, Dry Wood	0.59	0.56	0.56	0.55	0.55	0.55	0.76	0.72	0.71	0.70	0.70	0.70	1.00	0.95	0.94	0.93	0.93	0.93	1.08	1.03	1.02	1.01	1.00	1.00	1.31	1.25	1.24	1.22	1.22	1.22	1.68	1.60	1.58	1.56	1.56	1.56	1.93	1.84	1.82	1.80	1.79	1.79
PM-filt	MC	Wood Combustion, Wet Wood	0.60	0.56	0.56	0.56	0.55	0.55	0.77	0.72	0.72	0.71	0.71	0.71	1.01	0.94	0.94	0.93	0.93	0.92	1.10	1.03	1.02	1.01	1.00	1.00	1.32	1.24	1.23	1.22	1.21	1.21	1.70	1.59	1.58	1.56	1.55	1.55	1.96	1.83	1.82	1.81	1.80	1.79
PM-filt	SD/ESP	Refuse Combustion, Mass Burn	0.51	0.48	0.47	0.46	0.46	0.46	0.70	0.65	0.64	0.63	0.62	0.62	0.99	0.92	0.90	0.89	0.88	0.88	1.14	1.06	1.03	1.02	1.01	1.01	1.40	1.30	1.27	1.25	1.24	1.24	1.94	1.80	1.76	1.73	1.72	1.71	2.34	2.17	2.12	2.09	2.07	2.07
PM-filt	SD/FF	Refuse Combustion, Mass Burn	0.30	0.24	0.22	0.21	0.20	0.20	0.52	0.41	0.39	0.36	0.36	0.36	0.98	0.78	0.73	0.69	0.67	0.67	1.52	1.20	1.13	1.06	1.04	1.03	1.86	1.46	1.38	1.29	1.27	1.26	3.30	2.60	2.45	2.30	2.26	2.24	4.53	3.57	3.36	3.16	3.10	3.09
PM-filt	WS	Wood Combustion	0.68	0.66	0.65	0.65	0.65	0.65	0.81	0.78	0.78	0.78	0.78	0.77	1.00	0.96	0.96	0.96	0.95	0.95	1.05	1.01	1.01	1.01	1.00	1.00	1.24	1.19	1.19	1.18	1.18	1.18	1.49	1.44	1.43	1.42	1.42	1.42	1.68	1.62	1.61	1.60	1.60	1.60
PM-filt	UNC	Refuse Combustion, RDF	0.62	0.59	0.59	0.59	0.59	0.58	0.77	0.74	0.74	0.73	0.73	0.73	1.00	0.95	0.95	0.94	0.94	0.94	1.07	1.02	1.02	1.01	1.00	1.00	1.28	1.22	1.22	1.21	1.20	1.20	1.60	1.53	1.53	1.51	1.51	1.51	1.83	1.75	1.75	1.73	1.72	1.72
PM-filt	UNC	Wood Combustion, Dry Wood	0.59	0.57	0.56	0.56	0.55	0.55	0.76	0.73	0.72	0.71	0.71	0.71	1.00	0.96	0.94	0.93	0.93	0.93	1.08	1.04	1.02	1.01	1.01	1.00	1.30	1.25	1.23	1.22	1.22	1.21	1.65	1.59	1.56	1.55	1.54	1.54	1.93	1.86	1.82	1.81	1.80	1.80
PMfilt	UNC	Refuse Combustion, Mass Burn	0.54	0.49	0.48	0.48	0.48	0.48	0.72	0.66	0.65	0.65	0.64	0.64	1.00	0.92	0.90	0.89	0.89	0.88	1.14	1.04	1.03	1.01	1.01	1.01	1.41	1.29	1.27	1.26	1.25	1.24	1.90	1.74	1.71	1.69	1.68	1.67	2.25	2.06	2.02	2.00	1.99	1.98
PM-filt	UNC	Wood Combustion, Wet Wood	0.48	0.44	0.43	0.43	0.42	0.42	0.68	0.62	0.61	0.60	0.60	0.59	0.99	0.90	0.89	0.87	0.86	0.86	1.15	1.05	1.04	1.02	1.01	1.01	1.43	1.31	1.29	1.27	1.26	1.25	2.04	1.86	1.84	1.81	1.79	1.78	2.48	2.27	2.23	2.20	2.17	2.17
PM-filt	UNC	W/OSB, Hot Press	0.30	0.22	0.21	0.20	0.19	0.19	0.53	0.39	0.37	0.35	0.34	0.33	1.02	0.76	0.71	0.68	0.65	0.64	1.63	1.22	1.14	1.09	1.04	1.03	1.97	1.47	1.37	1.31	1.25	1.25	3.56	2.66	2.48	2.38	2.27	2.26	5.05	3.78	3.51	3.37	3.21	3.20
Sulfur dioxide	UNC	Refuse Combustion	0.40	0.39	0.39	0.39	0.39	0.39	0.64	0.62	0.61	0.61	0.61	0.61	0.99	0.96	0.95	0.95	0.95	0.95	1.05	1.01	1.01	1.00	1.00	1.00	1.39	1.34	1.34	1.33	1.33	1.33	1.77	1.71	1.70	1.70	1.69	1.69	1.99	1.92	1.91	1.91	1.90	1.90
Sulfur dioxide	UNC	Wood Combustion	0.12	0.07	0.05	0.04	0.04	0.04	0.33	0.18	0.15	0.12	0.11	0.11	0.99	0.53	0.44	0.36	0.32	0.31	3.82	2.05	1.71	1.40	1.23	1.22	2.99	1.61	1.34	1.10	0.96	0.95	8.21	4.41	3.68	3.01	2.65	2.62	14.96	8.04	6.71	5.49	4.83	4.78
Nitrogen oxides	UNC	Refuse Combustion, Mass Burn Waterwall	0.64	0.65	0.65	0.65	0.65	0.65	0.81	0.82	0.82	0.82	0.82	0.82	1.00	1.01	1.01	1.01	1.01	1.01	0.99	1.00	1.00	1.00	1.00	1.00	1.18	1.19	1.19	1.19	1.19	1.19	1.33	1.34	1.34	1.34	1.34	1.34	1.42	1.43	1.43	1.43	1.43	1.43
Nitrogen oxides	UNC	Wood Combustion	0.20	0.14	0.12	0.11	0.10	0.10	0.43	0.29	0.26	0.23	0.22	0.22	1.00	0.67	0.60	0.53	0.50	0.50	2.16	1.44	1.29	1.15	1.09	1.08	2.33	1.55	1.39	1.24	1.17	1.16	4.92	3.27	2.93	2.61	2.48	2.45	7.68	5.10	4.57	4.06	3.86	3.82
Carbon monoxide	UNC	Wood Combustion	0.30	0.27	0.26	0.26	0.26	0.26	0.58	0.51	0.50	0.50	0.50	0.50	1.02	0.91	0.89	0.88	0.88	0.88	1.16	1.04	1.02	1.01	1.01	1.00	1.61	1.44	1.41	1.40	1.40	1.39	2.22	1.97	1.94	1.92	1.92	1.91	2.66	2.37	2.33	2.31	2.31	2.30
Carbon monoxide	UNC	Refuse Combustion, Mass Burn	0.39	0.32	0.31	0.30	0.29	0.29	0.61	0.50	0.48	0.47	0.46	0.46	1.03	0.85	0.81	0.79	0.77	0.77	1.36	1.13	1.08	1.04	1.02	1.02	1.69	1.40	1.34	1.30	1.27	1.27	2.68	2.21	2.12	2.05	2.01	2.00	3.52	2.91	2.79	2.70	2.65	2.64

DSI/FF = dry sorbent injection/fabric filter; ESP = electrostatic precipitator; FF = fabric filter; MC = mechanical collector (e.g., cyclone); PM = particulate matter; RDF = refuse-derived fuel; SD/ESP = spray dryer/electrostatic precipitator; SD/FF = spray dryer/fabric filter; UNC = uncontrolled; W/OSB = Waferboard/Oriented Strandboard Manufacturing; WS = wet scrubber; WS/FF = wet scrubber or fabric filter; UNC/PM = uncontrolled or PM control.

Table 4-5. AP-42 Emissions Data by Pollutant

Pollutant	Target Statistic	Control Method	Emissions Factor	Unit	*n* (Tests)	Min	Max	Range	Standard Deviation	Skewness	CV	CV^2
Acetaldehyde	Wood Combustion	Uncontrolled/PM Control	8.3E-04	lb/mmBTU	21	7.80E-06	1.20E-02	1.20E-02	2.60E-03	4.38E+00	3.13E+00	9.79E+00
Arsenic	Wood Combustion	Uncontrolled/PM Control	2.2E-05	lb/mmBTU	23	2.49E-11	2.88E-04	2.88E-04	6.12E-05	4.11E+00	2.78E+00	7.71E+00
Arsenic	Refuse Combustion, Mass Burn	Spray Dryer/Fabric Filter	3.82E-06	lb/ton	35	4.03E-07	1.37E-05	1.33E-05	3.03E-06	1.94E+00	7.92E-01	6.27E-01
Benzene	Wood Combustion	Uncontrolled/PM Control	4.2E-03	lb/mmBTU	19	1.54E-05	6.48E-02	6.47E-02	1.47E-02	4.32E+00	3.50E+00	1.23E+01
Benzene	Asphalt Drum Mix	Fabric Filter	3.90E-04	lb/ton	19	6.30E-05	1.20E-03	1.14E-03	3.13E-04	1.61E+00	8.02E-01	6.43E-01
Cadmium	Wood Combustion	Uncontrolled/PM Control	4.1E-06	lb/mmBTU	24	3.01E-13	1.63E-05	1.63E-05	4.83E-06	1.50E+00	1.18E+00	1.39E+00
Cadmium	Refuse Combustion, Mass Burn	Spray Dryer/ESP	9.32E-05	lb/ton	18	8.27E-06	3.06E-04	2.98E-04	8.36E-05	1.46E+00	8.97E-01	8.04E-01
Carbon monoxide	Wood Combustion	Uncontrolled	6.0E-01	lb/mmBTU	128	2.76E-02	2.58E+00	2.55E+00	5.10E-01	1.86E+00	8.50E-01	7.22E-01
Carbon monoxide	Refuse Combustion, Mass Burn	Uncontrolled	4.07E-01	lb/ton	35	3.76E-02	2.02E+00	1.98E+00	3.66E-01	2.87E+00	8.99E-01	8.08E-01
Chromium	Wood Combustion	Uncontrolled/PM Control	2.1E-05	lb/mmBTU	27	3.99E-12	1.61E-04	1.61E-04	3.40E-05	3.07E+00	1.62E+00	2.62E+00
Formaldehyde	Wood Combustion	Uncontrolled/PM Control	4.4E-03	lb/mmBTU	48	1.11E-05	4.90E-02	4.90E-02	1.02E-02	3.40E+00	2.32E+00	5.38E+00
Formaldehyde	Asphalt Drum Mix	Fabric Filter	3.10E-03	lb/ton	21	3.00E-04	1.40E-02	1.37E-02	3.58E-03	2.01E+00	1.16E+00	1.34E+00
Hydrogen chloride	Refuse Combustion	Uncontrolled	6.08E+00	lb/ton	40	4.92E-01	1.25E+01	1.20E+01	3.40E+00	-2.28E-01	5.59E-01	3.13E-01
Hydrogen chloride	Refuse Combustion, Mass Burn	Spray Dryer/Fabric Filter	1.98E-01	lb/ton	14	2.46E-03	6.03E-01	6.00E-01	1.99E-01	1.12E+00	1.01E+00	1.01E+00
Lead	Wood Combustion	Uncontrolled/PM Control	4.8E-05	lb/mmBTU	26	1.60E-11	2.84E-04	2.84E-04	7.61E-05	1.24E-03	1.59E+00	2.51E+00
Lead	Refuse Combustion, Mass Burn	Spray Dryer/ESP	1.17E-03	lb/ton	18	1.23E-04	3.95E-03	3.83E-03	1.02E-03	1.46E+00	8.72E-01	7.61E-01
Mercury	Wood Combustion	Uncontrolled/PM Control	3.5E-06	lb/mmBTU	19	8.85E-13	4.20E-05	4.20E-05	9.52E-06	4.07E+00	2.72E+00	7.40E+00
Mercury	Refuse Combustion, Mass Burn	Spray Dryer/Fabric Filter	1.59E-03	lb/ton	60	7.48E-05	1.03E-02	1.02E-02	1.73E-03	2.53E+00	1.09E+00	1.18E+00
Nickel	Wood Combustion	Uncontrolled/PM Control	3.3E-05	lb/mmBTU	22	2.97E-12	2.62E-04	2.62E-04	6.17E-05	2.86E+00	1.87E+00	3.50E+00
Nickel	Refuse Combustion, Mass Burn	Spray Dryer/Fabric Filter	3.32E-05	lb/ton	37	1.61E-06	2.08E-04	2.06E-04	4.33E-05	2.84E+00	1.30E+00	1.70E+00
Nitrogen oxides	Refuse Combustion, Mass Burn, Waterwall	Uncontrolled	3.62E+00	lb/ton	31	1.05E+00	5.73E+00	4.68E+00	9.43E-01	5.84E-02	2.61E-01	6.80E-02
Nitrogen oxides	Wood Combustion	Uncontrolled	2.2E-01	lb/mmBTU	82	2.30E-02	1.28E+00	1.26E+00	1.78E-01	4.27E+00	8.10E-01	6.55E-01
PM-condensable	Wood Combustion	Uncontrolled	1.7E-02	lb/mmBTU	89	5.18E-05	2.24E-01	2.24E-01	2.83E-02	5.27E+00	1.66E+00	2.76E+00
PM-condensable (Inorganic)	Asphalt, Drum Mixer	Wet Scrubber/Fabric Filter	7.40E-03	lb/ton	30	1.20E-03	2.70E-02	2.58E-02	6.34E-03	1.50E+00	8.57E-01	7.34E-01
PM-condensable (Inorganic)	Asphalt, Batch Mixer	Fabric Filter	1.30E-02	lb/ton	35	7.30E-04	1.20E-01	1.19E-01	2.43E-02	3.29E+00	1.87E+00	3.48E+00

(continued)

Table 4-5. (continued)

Pollutant	Target Statistic	Control Method	Emissions Factor	Unit	*n* (Tests)	Min	Max	Range	Standard Deviation	Skewness	CV	CV^2
PM-condensable (Organic)	Asphalt, Drum Mixer	Wet Scrubber/Fabric Filter	1.20E-02	lb/ton	41	3.50E-04	7.40E-02	7.37E-02	1.61E-02	2.35E+00	1.34E+00	1.81E+00
PM-condensable (Organic)	Asphalt, Batch Mixer	Fabric Filter	4.10E-03	lb/ton	24	1.20E-05	1.80E-02	1.80E-02	4.17E-03	1.74E+00	1.02E+00	1.04E+00
PM-filterable	Wood Combustion, Wet Wood	Uncontrolled	3.3E-01	lb/mmBTU	17	1.18E-01	6.24E-01	5.06E-01	1.79E-01	4.30E-01	5.43E-01	2.95E-01
PM-filterable	Wood Combustion, Dry Wood	Uncontrolled	4.0E-01	lb/mmBTU	15	1.81E-01	8.44E-01	6.63E-01	1.83E-01	1.34E+00	4.58E-01	2.09E-01
PM-filterable	Wood Combustion	Wet Scrubber	6.6E-02	lb/mmBTU	32	3.11E-02	1.31E-01	1.00E-01	2.09E-02	9.04E-01	3.16E-01	1.00E-01
PM-filterable	Wood Combustion, Wet Wood	Mechanical Collector	2.2E-01	lb/mmBTU	42	1.43E-04	1.89E+00	1.89E+00	3.32E-01	3.65E+00	1.51E+00	2.28E+00
PM-filterable	Wood Combustion, Dry Wood	Mechanical Collector	3.0E-01	lb/mmBTU	30	1.25E-01	6.25E-01	5.00E-01	1.28E-01	9.75E-01	4.28E-01	1.83E-01
PM-filterable	W/OSB, Hot Press	Uncontrolled	2.15E-01	lb/MSF	26	1.71E-02	2.94E+00	2.92E+00	5.62E-01	4.91E+00	2.61E+00	6.81E+00
PM-filterable	Asphalt, Drum Mixer	Fabric Filter	1.40E-02	lb/ton	155	8.90E-04	1.40E-01	1.39E-01	1.73E-02	4.72E+00	1.24E+00	1.53E+00
PM-filterable	Asphalt, Batch Mixer	Fabric Filter	2.50E-02	lb/ton	89	2.30E-03	1.80E-01	1.78E-01	3.34E-02	2.66E+00	1.34E+00	1.79E+00
PM-filterable	Refuse Combustion, Mass Burn	Duct Sorbent Injection/Fabric Filter	2.19E-01	lb/ton	15	5.53E-03	6.46E-01	6.40E-01	1.91E-01	1.54E+00	8.73E-01	7.62E-01
PM-filterable	Refuse Combustion, Mass Burn	Spray Dryer/ESP	7.25E-02	lb/ton	18	1.57E-02	1.53E-01	1.37E-01	3.48E-02	1.02E+00	4.80E-01	2.31E-01
PM-filterable	Refuse Combustion, Mass Burn	Spray Dryer/Fabric Filter	6.28E-02	lb/ton	77	3.69E-03	2.93E-01	2.90E-01	5.66E-02	1.82E+00	9.01E-01	8.12E-01
PM-filterable	Refuse Combustion, Mass Burn	Uncontrolled	2.50E+01	lb/ton	24	7.97E+00	4.52E+01	3.73E+01	1.16E+01	3.00E-01	4.63E-01	2.14E-01
PM-filterable	Refuse Combustion, Mass Burn	ESP	1.97E-01	lb/ton	35	1.84E-02	6.82E-01	6.64E-01	1.75E-01	1.10E+00	8.92E-01	7.96E-01
PM, total	Refuse Combustion, RDF	ESP	8.12E-01	lb/ton	10	4.73E-02	3.13E+00	3.08E+00	1.03E+00	1.70E+00	1.27E+00	1.61E+00
PM, total	Refuse Combustion, RDF	Uncontrolled	6.29E+01	lb/ton	13	3.31E+01	1.04E+02	7.13E+01	2.34E+01	4.46E-01	3.73E-01	1.39E-01
Sulfur dioxide	Wood Combustion	Uncontrolled	2.5E-02	lb/mmBTU	28	4.00E-04	1.26E-01	1.25E-01	3.74E-02	2.04E+00	1.50E+00	2.24E+00
Sulfur dioxide	Refuse Combustion, Mass Burn	Uncontrolled	3.44E+00	lb/ton	46	1.94E-01	7.16E+00	6.97E+00	1.73E+00	6.89E-01	5.03E-01	2.53E-01

ESP = electrostatic precipitator; PM = particulate matter; W/OSB = Waferboard/Oriented Strandboard Manufacturing

Table 4-6. Uncertainty Ratios Based on Boundary Statistics Listed by Increasing CV^2 Value

				Uncertainty Ratio (MC Median)																																									
			Target Statistic→	10th Percentile						25th Percentile						Median						Mean						75th Percentile						90th Percentile						95th Percentile					
CV[1]	Pollutant	Control	Industry/Source	*n*=1	*n*=3	*n*=5	*n*=10	*n*=20	*n*=25	*n*=1	*n*=3	*n*=5	*n*=10	*n*=20	*n*=25	*n*=1	*n*=3	*n*=5	*n*=10	*n*=20	*n*=25	*n*=1	*n*=3	*n*=5	*n*=10	*n*=20	*n*=25	*n*=1	*n*=3	*n*=5	*n*=10	*n*=20	*n*=25	*n*=1	*n*=3	*n*=5	*n*=10	*n*=20	*n*=25	*n*=1	*n*=3	*n*=5	*n*=10	*n*=20	*n*=25
0.07	Nitrogen oxides	UNC	Refuse Combustion, Mass Burn Waterwall	0.64	0.65	0.65	0.65	0.65	0.65	0.81	0.82	0.82	0.82	0.82	0.82	1.00	1.01	1.01	1.01	1.01	1.01	0.99	1.00	1.00	1.00	1.00	1.00	1.18	1.19	1.19	1.19	1.19	1.19	1.33	1.34	1.34	1.34	1.34	1.34	1.42	1.43	1.43	1.43	1.43	1.43
0.10	PM-filt	WS	Wood Combustion	0.68	0.66	0.65	0.65	0.65	0.65	0.81	0.78	0.78	0.78	0.78	0.77	1.00	0.96	0.96	0.96	0.95	0.95	1.05	1.01	1.01	1.01	1.00	1.00	1.24	1.19	1.19	1.18	1.18	1.18	1.49	1.44	1.43	1.42	1.42	1.42	1.68	1.62	1.61	1.60	1.60	1.60
0.14	PM-filt	UNC	Refuse Combustion, RDF	0.62	0.59	0.59	0.59	0.59	0.58	0.77	0.74	0.74	0.73	0.73	0.73	1.00	0.95	0.95	0.94	0.94	0.94	1.07	1.02	1.02	1.01	1.00	1.00	1.28	1.22	1.22	1.21	1.20	1.20	1.60	1.53	1.53	1.51	1.51	1.51	1.83	1.75	1.75	1.73	1.72	1.72
0.18	PM-filt	MC	Wood Combustion, Dry Wood	0.59	0.56	0.56	0.55	0.55	0.55	0.76	0.72	0.71	0.70	0.70	0.70	1.00	0.95	0.94	0.93	0.93	0.93	1.08	1.03	1.02	1.01	1.00	1.00	1.31	1.25	1.24	1.22	1.22	1.22	1.68	1.60	1.58	1.56	1.56	1.56	1.93	1.84	1.82	1.80	1.79	1.79
0.21	PM-filt	UNC	Wood Combustion, Dry Wood	0.59	0.57	0.56	0.56	0.55	0.55	0.76	0.73	0.72	0.71	0.71	0.71	1.00	0.96	0.94	0.93	0.93	0.93	1.08	1.04	1.02	1.01	1.01	1.00	1.30	1.25	1.23	1.22	1.22	1.21	1.65	1.59	1.56	1.55	1.54	1.54	1.93	1.86	1.82	1.81	1.80	1.80
0.21	PM-filt	UNC	Refuse Combustion, Mass Burn	0.54	0.49	0.48	0.48	0.48	0.48	0.72	0.66	0.65	0.65	0.64	0.64	1.00	0.92	0.90	0.89	0.89	0.88	1.14	1.04	1.03	1.01	1.01	1.01	1.41	1.29	1.27	1.26	1.25	1.24	1.90	1.74	1.71	1.69	1.68	1.67	2.25	2.06	2.02	2.00	1.99	1.98
0.23	PM-filt	SD/ESP	Refuse Combustion, Mass Burn	0.51	0.48	0.47	0.46	0.46	0.46	0.70	0.65	0.64	0.63	0.62	0.62	0.99	0.92	0.90	0.89	0.88	0.88	1.14	1.06	1.03	1.02	1.01	1.01	1.40	1.30	1.27	1.25	1.24	1.24	1.94	1.80	1.76	1.73	1.72	1.71	2.34	2.17	2.12	2.09	2.07	2.07
0.25	Sulfur dioxide	UNC	Refuse Combustion	0.40	0.39	0.39	0.39	0.39	0.39	0.64	0.62	0.61	0.61	0.61	0.61	0.99	0.96	0.95	0.95	0.95	0.95	1.05	1.01	1.01	1.00	1.00	1.00	1.39	1.34	1.34	1.33	1.33	1.33	1.77	1.71	1.70	1.70	1.69	1.69	1.99	1.92	1.91	1.91	1.90	1.90
0.29	PM-filt	UNC	Wood Combustion, Wet Wood	0.48	0.44	0.43	0.43	0.42	0.42	0.68	0.62	0.61	0.60	0.60	0.59	0.99	0.90	0.89	0.87	0.86	0.86	1.15	1.05	1.04	1.02	1.01	1.01	1.43	1.31	1.29	1.27	1.26	1.25	2.04	1.86	1.84	1.81	1.79	1.78	2.48	2.27	2.23	2.20	2.17	2.17
0.31	Hydrogen chloride	UNC	Refuse Combustion	0.34	0.31	0.31	0.31	0.31	0.31	0.61	0.57	0.56	0.56	0.56	0.56	1.01	0.95	0.93	0.93	0.93	0.93	1.09	1.02	1.01	1.01	1.00	1.00	1.47	1.37	1.36	1.36	1.35	1.35	1.97	1.84	1.82	1.82	1.81	1.81	2.27	2.12	2.10	2.10	2.08	2.09
$CV^2 \leq 0.5$				**0.54**	**0.51**	**0.51**	**0.51**	**0.50**	**0.50**	**0.73**	**0.69**	**0.68**	**0.68**	**0.68**	**0.68**	**1.00**	**0.95**	**0.94**	**0.93**	**0.93**	**0.93**	**1.08**	**1.03**	**1.02**	**1.01**	**1.00**	**1.00**	**1.34**	**1.27**	**1.26**	**1.25**	**1.24**	**1.24**	**1.74**	**1.65**	**1.63**	**1.61**	**1.61**	**1.60**	**2.01**	**1.90**	**1.88**	**1.87**	**1.86**	**1.85**
0.63	Arsenic	SD/FF	Refuse Combustion, Mass Burn	0.41	0.35	0.33	0.32	0.32	0.32	0.62	0.53	0.51	0.49	0.49	0.48	1.00	0.85	0.82	0.80	0.79	0.78	1.30	1.10	1.06	1.03	1.02	1.01	1.65	1.40	1.35	1.31	1.30	1.29	2.53	2.15	2.07	2.01	2.00	1.98	3.15	2.68	2.58	2.51	2.49	2.46
0.64	Benzene	FF	Asphalt, Drum Mix	0.37	0.32	0.30	0.29	0.28	0.28	0.59	0.51	0.48	0.47	0.45	0.46	1.00	0.85	0.82	0.79	0.77	0.77	1.33	1.13	1.08	1.04	1.02	1.02	1.67	1.42	1.36	1.31	1.28	1.28	2.62	2.23	2.13	2.06	2.00	2.01	3.45	2.94	2.81	2.71	2.64	2.65
0.65	Nitrogen oxides	UNC	Wood Combustion	0.20	0.14	0.12	0.11	0.10	0.10	0.43	0.29	0.26	0.23	0.22	0.22	1.00	0.67	0.60	0.53	0.50	0.50	2.16	1.44	1.29	1.15	1.09	1.08	2.33	1.55	1.39	1.24	1.17	1.16	4.92	3.27	2.93	2.61	2.48	2.45	7.68	5.10	4.57	4.06	3.86	3.82
0.72	Carbon monoxide	UNC	Wood Combustion	0.30	0.27	0.26	0.26	0.26	0.26	0.58	0.51	0.50	0.50	0.50	0.50	1.02	0.91	0.89	0.88	0.88	0.88	1.16	1.04	1.02	1.01	1.01	1.00	1.61	1.44	1.41	1.40	1.40	1.39	2.22	1.97	1.94	1.92	1.92	1.91	2.66	2.37	2.33	2.31	2.31	2.30
0.73	PM-cond (Inorganic)	WS/FF	Asphalt, Drum Mixer	0.35	0.29	0.27	0.26	0.26	0.25	0.58	0.47	0.45	0.43	0.42	0.42	1.02	0.83	0.79	0.75	0.74	0.74	1.42	1.16	1.10	1.05	1.03	1.02	1.75	1.43	1.36	1.30	1.28	1.26	2.90	2.37	2.25	2.14	2.11	2.09	3.96	3.23	3.07	2.92	2.88	2.85
0.76	Lead	SD/ESP	Refuse Combustion, Mass Burn	0.32	0.25	0.23	0.22	0.21	0.21	0.55	0.42	0.40	0.38	0.37	0.36	1.01	0.78	0.74	0.70	0.68	0.67	1.48	1.15	1.09	1.03	1.00	0.99	1.83	1.43	1.35	1.27	1.23	1.22	3.15	2.45	2.32	2.18	2.12	2.10	4.28	3.33	3.16	2.97	2.89	2.86
0.76	PM-filt	DSI/FF	Refuse Combustion, Mass Burn	0.19	0.15	0.15	0.14	0.14	0.14	0.45	0.37	0.36	0.35	0.35	0.35	1.00	0.82	0.79	0.77	0.76	0.76	1.32	1.09	1.05	1.02	1.01	1.01	1.85	1.52	1.46	1.42	1.42	1.41	2.91	2.39	2.30	2.24	2.23	2.22	3.66	3.01	2.89	2.82	2.81	2.80
0.79	PM-filt	ESP	Refuse Combustion, Mass Burn	0.29	0.22	0.21	0.19	0.19	0.19	0.52	0.40	0.37	0.35	0.34	0.34	1.02	0.78	0.72	0.68	0.65	0.65	1.62	1.24	1.15	1.08	1.04	1.04	1.94	1.49	1.38	1.29	1.25	1.25	3.48	2.67	2.47	2.32	2.24	2.23	5.03	3.86	3.56	3.35	3.24	3.22
0.80	Cadmium	SD/ESP	Refuse Combustion, Mass Burn	0.31	0.25	0.23	0.22	0.21	0.21	0.54	0.42	0.40	0.38	0.37	0.37	1.00	0.79	0.74	0.70	0.68	0.68	1.52	1.19	1.12	1.07	1.04	1.03	1.88	1.48	1.39	1.33	1.28	1.28	3.24	2.54	2.38	2.28	2.20	2.20	4.35	3.41	3.20	3.06	2.96	2.96
0.81	Carbon monoxide	UNC	Refuse Combustion, Mass Burn	0.39	0.32	0.31	0.30	0.29	0.29	0.61	0.50	0.48	0.47	0.46	0.46	1.03	0.85	0.81	0.79	0.77	0.77	1.36	1.13	1.08	1.04	1.02	1.02	1.69	1.40	1.34	1.30	1.27	1.27	2.68	2.21	2.12	2.05	2.01	2.00	3.52	2.91	2.79	2.70	2.65	2.64
0.81	PM-filt	SD/FF	Refuse Combustion, Mass Burn	0.30	0.24	0.22	0.21	0.20	0.20	0.52	0.41	0.39	0.36	0.36	0.36	0.98	0.78	0.73	0.69	0.67	0.67	1.52	1.20	1.13	1.06	1.04	1.03	1.86	1.46	1.38	1.29	1.27	1.26	3.30	2.60	2.45	2.30	2.26	2.24	4.53	3.57	3.36	3.16	3.10	3.09
$0.5 < CV^2 \leq 1.0$				**0.31**	**0.25**	**0.24**	**0.23**	**0.22**	**0.22**	**0.55**	**0.44**	**0.42**	**0.40**	**0.39**	**0.39**	**1.01**	**0.81**	**0.77**	**0.73**	**0.72**	**0.72**	**1.47**	**1.17**	**1.11**	**1.05**	**1.03**	**1.02**	**1.83**	**1.46**	**1.38**	**1.31**	**1.29**	**1.28**	**3.08**	**2.44**	**2.31**	**2.19**	**2.14**	**2.13**	**4.21**	**3.31**	**3.12**	**2.96**	**2.89**	**2.88**
1.01	Hydrogen chloride	SD/FF	Refuse Combustion, Mass Burn	0.10	0.07	0.06	0.06	0.06	0.06	0.35	0.24	0.23	0.21	0.21	0.21	1.00	0.69	0.65	0.61	0.59	0.59	1.73	1.19	1.12	1.05	1.02	1.02	2.30	1.58	1.49	1.40	1.36	1.35	4.30	2.95	2.79	2.62	2.54	2.53	5.99	4.12	3.89	3.65	3.54	3.53
1.18	Mercury	SD/FF	Refuse Combustion, Mass Burn	0.26	0.20	0.18	0.17	0.16	0.16	0.49	0.37	0.34	0.32	0.30	0.30	1.00	0.76	0.70	0.64	0.62	0.61	1.71	1.30	1.20	1.10	1.06	1.05	1.99	1.50	1.39	1.27	1.23	1.22	3.75	2.84	2.62	2.40	2.32	2.30	5.45	4.13	3.81	3.50	3.37	3.35
1.33	Formaldehyde	FF	Asphalt, Drum Mix	0.28	0.21	0.20	0.18	0.18	0.18	0.50	0.38	0.35	0.33	0.32	0.32	1.00	0.76	0.71	0.66	0.64	0.63	1.65	1.25	1.16	1.09	1.06	1.04	1.94	1.47	1.37	1.28	1.24	1.23	3.64	2.75	2.56	2.40	2.33	2.30	5.20	3.93	3.66	3.43	3.33	3.29
1.39	Cadmium	UNC/PM	Wood Combustion	0.04	0.02	0.02	0.02	0.02	0.02	0.23	0.12	0.11	0.10	0.09	0.09	0.98	0.53	0.46	0.42	0.39	0.39	2.69	1.46	1.27	1.15	1.06	1.06	3.05	1.65	1.44	1.31	1.20	1.21	7.08	3.84	3.33	3.04	2.80	2.80	10.87	5.89	5.12	4.66	4.29	4.30
1.53	PM-filt	FF	Asphalt, Drum Mixer	0.32	0.26	0.24	0.23	0.22	0.22	0.53	0.43	0.41	0.39	0.37	0.37	0.99	0.81	0.76	0.72	0.70	0.69	1.47	1.20	1.13	1.07	1.04	1.03	1.82	1.48	1.39	1.32	1.28	1.27	3.09	2.51	2.37	2.24	2.18	2.16	4.38	3.56	3.36	3.18	3.09	3.06
$1.0 < CV^2 \leq 1.5$				**0.20**	**0.15**	**0.14**	**0.13**	**0.13**	**0.13**	**0.42**	**0.31**	**0.29**	**0.27**	**0.26**	**0.26**	**1.00**	**0.71**	**0.66**	**0.61**	**0.59**	**0.58**	**1.85**	**1.28**	**1.18**	**1.09**	**1.05**	**1.04**	**2.22**	**1.54**	**1.42**	**1.32**	**1.26**	**1.26**	**4.37**	**2.98**	**2.74**	**2.54**	**2.43**	**2.42**	**6.38**	**4.33**	**3.97**	**3.68**	**3.53**	**3.51**

(continued)

Table 4-6. (continued)

				Uncertainty Ratio (MC Median)																																									
			Target Statistic→	10th Percentile						25th Percentile						Median						Mean						75th Percentile						90th Percentile						95th Percentile					
CV[1]	Pollutant	Control	Industry/Source	*n*=1	*n*=3	*n*=5	*n*=10	*n*=20	*n*=25	*n*=1	*n*=3	*n*=5	*n*=10	*n*=20	*n*=25	*n*=1	*n*=3	*n*=5	*n*=10	*n*=20	*n*=25	*n*=1	*n*=3	*n*=5	*n*=10	*n*=20	*n*=25	*n*=1	*n*=3	*n*=5	*n*=10	*n*=20	*n*=25	*n*=1	*n*=3	*n*=5	*n*=10	*n*=20	*n*=25	*n*=1	*n*=3	*n*=5	*n*=10	*n*=20	*n*=25
1.61	PM-filt	ESP	Refuse Combustion, RDF	0.17	0.11	0.10	0.09	0.08	0.08	0.39	0.26	0.23	0.20	0.19	0.19	0.96	0.65	0.57	0.51	0.48	0.47	2.26	1.53	1.34	1.20	1.12	1.10	2.27	1.53	1.35	1.20	1.12	1.10	5.17	3.48	3.07	2.74	2.56	2.51	8.32	5.61	4.94	4.42	4.13	4.05
1.70	Nickel	SD FF	Refuse Combustion, Mass Burn	0.28	0.21	0.20	0.19	0.18	0.18	0.51	0.39	0.37	0.35	0.33	0.33	1.00	0.77	0.72	0.67	0.65	0.65	1.61	1.24	1.16	1.09	1.05	1.04	1.93	1.48	1.39	1.30	1.25	1.25	3.46	2.66	2.49	2.33	2.25	2.24	4.92	3.78	3.54	3.32	3.20	3.18
1.78	PM-filt	FF	Asphalt, Batch Mixer	0.26	0.19	0.18	0.17	0.16	0.16	0.49	0.37	0.34	0.32	0.30	0.30	0.99	0.74	0.68	0.64	0.62	0.61	1.70	1.28	1.18	1.10	1.06	1.05	1.96	1.48	1.36	1.27	1.22	1.21	3.76	2.83	2.60	2.44	2.35	2.32	5.46	4.10	3.77	3.54	3.40	3.37
1.80	PM-cond (Organic)	WS/FF	Asphalt, Drum Mixer	0.18	0.11	0.09	0.08	0.08	0.08	0.41	0.25	0.21	0.19	0.18	0.17	1.02	0.63	0.54	0.48	0.44	0.43	2.60	1.59	1.36	1.23	1.13	1.10	2.56	1.57	1.34	1.21	1.11	1.08	5.99	3.66	3.14	2.82	2.60	2.53	9.98	6.11	5.23	4.71	4.33	4.22
1.5 < CV[2] ≤ 2.0				**0.22**	**0.16**	**0.14**	**0.13**	**0.13**	**0.12**	**0.45**	**0.32**	**0.29**	**0.26**	**0.25**	**0.25**	**0.99**	**0.70**	**0.63**	**0.58**	**0.55**	**0.54**	**2.04**	**1.41**	**1.26**	**1.15**	**1.09**	**1.07**	**2.18**	**1.51**	**1.36**	**1.25**	**1.18**	**1.16**	**4.59**	**3.16**	**2.82**	**2.58**	**2.44**	**2.40**	**7.17**	**4.90**	**4.37**	**3.99**	**3.77**	**3.70**
2.24	Sulfur dioxide	UNC	Wood Combustion	0.12	0.07	0.05	0.04	0.04	0.04	0.33	0.18	0.15	0.12	0.11	0.11	0.99	0.53	0.44	0.36	0.32	0.31	3.82	2.05	1.71	1.40	1.23	1.22	2.99	1.61	1.34	1.10	0.96	0.95	8.21	4.41	3.68	3.01	2.65	2.62	14.96	8.04	6.71	5.49	4.83	4.78
2.28	PM-filt	MC	Wood Combustion, Wet Wood	0.60	0.56	0.56	0.56	0.55	0.55	0.77	0.72	0.72	0.71	0.71	0.71	1.01	0.94	0.94	0.93	0.93	0.92	1.10	1.03	1.02	1.01	1.00	1.00	1.32	1.24	1.23	1.22	1.21	1.21	1.70	1.59	1.58	1.56	1.55	1.55	1.96	1.83	1.82	1.81	1.80	1.79
2.51	Lead	UNC/PM	Wood Combustion	0.02	0.01	0.01	0.01	0.00	0.00	0.16	0.06	0.05	0.04	0.04	0.04	1.01	0.41	0.33	0.28	0.26	0.25	4.41	1.79	1.43	1.22	1.12	1.09	4.08	1.66	1.32	1.13	1.04	1.01	11.72	4.76	3.81	3.24	2.98	2.89	20.28	8.23	6.58	5.60	5.15	5.00
2 < CV[2] ≤ 2.5				**0.25**	**0.21**	**0.21**	**0.20**	**0.20**	**0.20**	**0.42**	**0.32**	**0.31**	**0.29**	**0.28**	**0.28**	**1.00**	**0.63**	**0.57**	**0.52**	**0.50**	**0.50**	**3.11**	**1.62**	**1.39**	**1.21**	**1.12**	**1.10**	**2.80**	**1.50**	**1.30**	**1.15**	**1.07**	**1.06**	**7.21**	**3.59**	**3.02**	**2.60**	**2.39**	**2.36**	**12.40**	**6.03**	**5.04**	**4.30**	**3.92**	**3.86**
2.62	Chromium	UNC/PM	Wood Combustion	0.03	0.01	0.01	0.01	0.01	0.03	0.20	0.08	0.07	0.06	0.06	0.06	1.04	0.42	0.36	0.31	0.29	0.29	3.95	1.60	1.37	1.17	1.11	1.08	3.96	1.60	1.37	1.18	1.11	1.09	10.49	4.24	3.63	3.12	2.95	2.88	17.28	6.99	5.99	5.14	4.86	4.75
2.77	PM-cond	UNC	Wood Combustion	0.24	0.17	0.15	0.14	0.13	0.13	0.46	0.33	0.29	0.27	0.25	0.25	1.01	0.71	0.63	0.58	0.55	0.54	1.96	1.38	1.23	1.13	1.07	1.06	2.19	1.54	1.38	1.26	1.20	1.18	4.42	3.10	2.78	2.54	2.42	2.39	6.77	4.76	4.26	3.90	3.71	3.66
3.49	PM-cond (Inorganic)	FF	Asphalt, Batch Mixer	0.19	0.13	0.11	0.10	0.09	0.09	0.42	0.27	0.25	0.22	0.21	0.20	0.98	0.64	0.57	0.51	0.48	0.47	2.28	1.48	1.33	1.18	1.11	1.09	2.38	1.55	1.39	1.22	1.16	1.14	5.18	3.36	3.02	2.67	2.52	2.48	8.36	5.43	4.88	4.31	4.07	4.00
3.50	Nickel	UNC/PM	Wood Combustion	0.02	0.01	0.01	0.00	0.00	0.00	0.14	0.05	0.04	0.03	0.03	0.03	1.01	0.36	0.30	0.24	0.21	0.21	5.40	1.90	1.62	1.27	1.13	1.11	4.57	1.61	1.37	1.07	0.96	0.94	13.80	4.87	4.14	3.24	2.89	2.84	25.14	8.87	7.54	5.89	5.27	5.17
5.37	Formaldehyde	UNC/PM	Wood Combustion	0.09	0.04	0.03	0.03	0.02	0.02	0.29	0.13	0.10	0.08	0.07	0.07	0.97	0.45	0.35	0.27	0.24	0.23	5.79	2.71	2.12	1.63	1.41	1.36	3.48	1.63	1.27	0.98	0.85	0.82	11.18	5.23	4.08	3.15	2.73	2.63	21.50	10.06	7.85	6.05	5.25	5.06
6.83	PM-filt	UNC	W/OSB, Hot Press	0.30	0.22	0.21	0.20	0.19	0.19	0.53	0.39	0.37	0.35	0.34	0.33	1.02	0.76	0.71	0.68	0.65	0.64	1.63	1.22	1.14	1.09	1.04	1.03	1.97	1.47	1.37	1.31	1.25	1.25	3.56	2.66	2.48	2.38	2.27	2.26	5.05	3.78	3.51	3.37	3.21	3.20
7.40	Mercury	UNC/PM	Wood Combustion	0.02	0.01	0.01	0.01	0.01	0.01	0.19	0.07	0.06	0.05	0.05	0.05	1.06	0.40	0.34	0.29	0.26	0.26	4.44	1.70	1.44	1.20	1.09	1.08	4.27	1.64	1.39	1.16	1.05	1.04	11.83	4.54	3.85	3.21	2.91	2.89	19.85	7.61	6.45	5.39	4.89	4.84
7.74	Arsenic	UNC/PM	Wood Combustion	0.01	0.00	0.00	0.00	0.00	0.00	0.09	0.02	0.02	0.01	0.01	0.01	1.01	0.26	0.18	0.14	0.12	0.11	10.59	2.72	1.89	1.45	1.23	1.18	6.34	1.63	1.13	0.87	0.74	0.71	25.02	6.43	4.46	3.44	2.91	2.79	51.17	13.15	9.13	7.03	5.96	5.71
9.81	Acetaldehyde	UNC/PM	Wood Combustion	0.20	0.13	0.12	0.11	0.10	0.10	0.43	0.29	0.26	0.23	0.22	0.22	0.99	0.67	0.59	0.54	0.51	0.50	2.13	1.44	1.28	1.16	1.10	1.08	2.34	1.58	1.40	1.27	1.20	1.18	4.90	3.30	2.93	2.66	2.52	2.47	7.63	5.14	4.56	4.14	3.93	3.86
12.25	Benzene	UNC/PM	Wood Combustion	0.06	0.03	0.02	0.01	0.01	0.01	0.23	0.10	0.07	0.05	0.04	0.04	1.00	0.42	0.31	0.23	0.19	0.18	7.78	3.23	2.40	1.80	1.47	1.38	3.86	1.60	1.19	0.89	0.73	0.69	13.45	5.59	4.16	3.11	2.54	2.39	28.76	11.94	8.89	6.66	5.44	5.10
103.44	PM-cond (Organic)	FF	Asphalt, Batch Mixer	0.27	0.20	0.19	0.18	0.17	0.17	0.51	0.38	0.35	0.33	0.32	0.32	1.01	0.76	0.70	0.66	0.64	0.63	1.66	1.24	1.15	1.09	1.05	1.04	1.99	1.49	1.38	1.30	1.26	1.24	3.60	2.69	2.49	2.35	2.27	2.24	5.23	3.91	3.62	3.42	3.30	3.26
CV[2] > 2.5				**0.13**	**0.09**	**0.08**	**0.07**	**0.07**	**0.07**	**0.32**	**0.19**	**0.17**	**0.15**	**0.14**	**0.14**	**1.01**	**0.53**	**0.46**	**0.40**	**0.38**	**0.37**	**4.33**	**1.87**	**1.54**	**1.29**	**1.17**	**1.14**	**3.40**	**1.58**	**1.33**	**1.14**	**1.05**	**1.02**	**9.77**	**4.18**	**3.46**	**2.90**	**2.63**	**2.57**	**17.89**	**7.42**	**6.06**	**5.03**	**4.54**	**4.42**

Table 4-7. Uncertainty Ratios Based on Boundary Statistics Listed by Pollutant and Control

			Target Statistic→	Uncertainty Ratio (MC Median) 10th Percentile						25th Percentile						Median						Mean						75th Percentile						90th Percentile						95th Percentile					
Pollutant		Control	Industry/Source	*n*=1	*n*=3	*n*=5	*n*=10	*n*=20	*n*=25	*n*=1	*n*=3	*n*=5	*n*=10	*n*=20	*n*=25	*n*=1	*n*=3	*n*=5	*n*=10	*n*=20	*n*=25	*n*=1	*n*=3	*n*=5	*n*=10	*n*=20	*n*=25	*n*=1	*n*=3	*n*=5	*n*=10	*n*=20	*n*=25	*n*=1	*n*=3	*n*=5	*n*=10	*n*=20	*n*=25	*n*=1	*n*=3	*n*=5	*n*=10	*n*=20	*n*=25
HAP	Cadmium	SD/ESP	Refuse Combustion, Mass Burn	0.31	0.25	0.23	0.22	0.21	0.21	0.54	0.42	0.40	0.38	0.37	0.37	1.00	0.79	0.74	0.70	0.68	0.68	1.52	1.19	1.12	1.07	1.04	1.03	1.88	1.48	1.39	1.33	1.28	1.28	3.24	2.54	2.38	2.28	2.20	2.20	4.35	3.41	3.20	3.06	2.96	2.96
HAP	Lead	SD/ESP	Refuse Combustion, Mass Burn	0.32	0.25	0.23	0.22	0.21	0.21	0.55	0.42	0.40	0.38	0.37	0.36	1.01	0.78	0.74	0.70	0.68	0.67	1.48	1.15	1.09	1.03	1.00	0.99	1.83	1.43	1.35	1.27	1.23	1.22	3.15	2.45	2.32	2.18	2.12	2.10	4.28	3.33	3.16	2.97	2.89	2.86
HAP	Arsenic	SD/FF	Refuse Combustion, Mass Burn	0.41	0.35	0.33	0.32	0.32	0.32	0.62	0.53	0.51	0.49	0.49	0.48	1.00	0.85	0.82	0.80	0.79	0.78	1.30	1.10	1.06	1.03	1.02	1.01	1.65	1.40	1.35	1.31	1.30	1.29	2.53	2.15	2.07	2.01	2.00	1.98	3.15	2.68	2.58	2.51	2.49	2.46
HAP	Hydrogen chloride	SD/FF	Refuse Combustion, Mass Burn	0.10	0.07	0.06	0.06	0.06	0.06	0.35	0.24	0.23	0.21	0.21	0.21	1.00	0.69	0.65	0.61	0.59	0.59	1.73	1.19	1.12	1.05	1.02	1.02	2.30	1.58	1.49	1.40	1.36	1.35	4.30	2.95	2.79	2.62	2.54	2.53	5.99	4.12	3.89	3.65	3.54	3.53
HAP	Mercury	SD/FF	Refuse Combustion, Mass Burn	0.26	0.20	0.18	0.17	0.16	0.16	0.49	0.37	0.34	0.32	0.30	0.30	1.00	0.76	0.70	0.64	0.62	0.61	1.71	1.30	1.20	1.10	1.06	1.05	1.99	1.50	1.39	1.27	1.23	1.22	3.75	2.84	2.62	2.40	2.32	2.30	5.45	4.13	3.81	3.50	3.37	3.35
HAP	Nickel	SD/FF	Refuse Combustion, Mass Burn	0.28	0.21	0.20	0.19	0.18	0.18	0.51	0.39	0.37	0.35	0.33	0.33	1.00	0.77	0.72	0.67	0.65	0.65	1.61	1.24	1.16	1.09	1.05	1.04	1.93	1.48	1.39	1.30	1.25	1.25	3.46	2.66	2.49	2.33	2.25	2.24	4.92	3.78	3.54	3.32	3.20	3.18
HAP	Acetaldehyde	UNC/PM	Wood Combustion	0.20	0.13	0.12	0.11	0.10	0.10	0.43	0.29	0.26	0.23	0.22	0.22	0.99	0.67	0.59	0.54	0.51	0.50	2.13	1.44	1.28	1.16	1.10	1.08	2.34	1.58	1.40	1.27	1.20	1.18	4.90	3.30	2.93	2.66	2.52	2.47	7.63	5.14	4.56	4.14	3.93	3.86
HAP	Arsenic	UNC/PM	Wood Combustion	0.01	0.00	0.00	0.00	0.00	0.00	0.09	0.02	0.02	0.01	0.01	0.01	1.01	0.26	0.18	0.14	0.12	0.11	10.6	2.72	1.89	1.45	1.23	1.18	6.34	1.63	1.13	0.87	0.74	0.71	25.02	6.43	4.46	3.44	2.91	2.79	51.17	13.15	9.13	7.03	5.96	5.71
HAP	Benzene	UNC/PM	Wood Combustion	0.06	0.03	0.02	0.01	0.01	0.01	0.23	0.10	0.07	0.05	0.04	0.04	1.00	0.42	0.31	0.23	0.19	0.18	7.78	3.23	2.40	1.80	1.47	1.38	3.86	1.60	1.19	0.89	0.73	0.69	13.45	5.59	4.16	3.11	2.54	2.39	28.76	11.94	8.89	6.66	5.44	5.10
HAP	Cadmium	UNC/PM	Wood Combustion	0.04	0.02	0.02	0.02	0.02	0.02	0.23	0.12	0.11	0.10	0.09	0.09	0.98	0.53	0.46	0.42	0.39	0.39	2.69	1.46	1.27	1.15	1.06	1.06	3.05	1.65	1.44	1.31	1.20	1.21	7.08	3.84	3.33	3.04	2.80	2.80	10.87	5.89	5.12	4.66	4.29	4.30
HAP	Chromium	UNC/PM	Wood Combustion	0.03	0.01	0.01	0.01	0.01	0.03	0.20	0.08	0.07	0.06	0.06	0.06	1.04	0.42	0.36	0.31	0.29	0.29	3.95	1.60	1.37	1.17	1.11	1.08	3.96	1.60	1.37	1.18	1.11	1.09	10.49	4.24	3.63	3.12	2.95	2.88	17.28	6.99	5.99	5.14	4.86	4.75
HAP	Formaldehyde	UNC/PM	Wood Combustion	0.09	0.04	0.03	0.03	0.02	0.02	0.29	0.13	0.10	0.08	0.07	0.07	0.97	0.45	0.35	0.27	0.24	0.23	5.79	2.71	2.12	1.63	1.41	1.36	3.48	1.63	1.27	0.98	0.85	0.82	11.18	5.23	4.08	3.15	2.73	2.63	21.50	10.06	7.85	6.05	5.25	5.06
HAPs				**0.18**	**0.13**	**0.13**	**0.12**	**0.12**	**0.12**	**0.37**	**0.26**	**0.25**	**0.23**	**0.22**	**0.22**	**1.01**	**0.62**	**0.56**	**0.51**	**0.49**	**0.48**	**3.37**	**1.62**	**1.38**	**1.20**	**1.11**	**1.09**	**2.92**	**1.54**	**1.35**	**1.20**	**1.13**	**1.12**	**7.67**	**3.62**	**3.09**	**2.68**	**2.49**	**2.45**	**13.42**	**6.02**	**5.05**	**4.32**	**3.97**	**3.90**
PM-cond		UNC	Wood Combustion	0.24	0.17	0.15	0.14	0.13	0.13	0.46	0.33	0.29	0.27	0.25	0.25	1.01	0.71	0.63	0.58	0.55	0.54	1.96	1.38	1.23	1.13	1.07	1.06	2.19	1.54	1.38	1.26	1.20	1.18	4.42	3.10	2.78	2.54	2.42	2.39	6.77	4.76	4.26	3.90	3.71	3.66
PM-condensable, uncontrolled				**0.24**	**0.17**	**0.15**	**0.14**	**0.13**	**0.13**	**0.46**	**0.33**	**0.29**	**0.27**	**0.25**	**0.25**	**1.01**	**0.71**	**0.63**	**0.58**	**0.55**	**0.54**	**1.96**	**1.38**	**1.23**	**1.13**	**1.07**	**1.06**	**2.19**	**1.54**	**1.38**	**1.26**	**1.20**	**1.18**	**4.42**	**3.10**	**2.78**	**2.54**	**2.42**	**2.39**	**6.77**	**4.76**	**4.26**	**3.90**	**3.71**	**3.66**
PM-cond (Inorganic)		FF	Asphalt, Batch Mixer	0.19	0.13	0.11	0.10	0.09	0.09	0.42	0.27	0.25	0.22	0.21	0.20	0.98	0.64	0.57	0.51	0.48	0.47	2.28	1.48	1.33	1.18	1.11	1.09	2.38	1.55	1.39	1.22	1.16	1.14	5.18	3.36	3.02	2.67	2.52	2.48	8.36	5.43	4.88	4.31	4.07	4.00
PM-cond (Inorganic)		WS/FF	Asphalt, Drum Mixer	0.35	0.29	0.27	0.26	0.26	0.25	0.58	0.47	0.45	0.43	0.42	0.42	1.02	0.83	0.79	0.75	0.74	0.74	1.42	1.16	1.10	1.05	1.03	1.02	1.75	1.43	1.36	1.30	1.28	1.26	2.90	2.37	2.25	2.14	2.11	2.09	3.96	3.23	3.07	2.92	2.88	2.85
PM-cond (Organic)		FF	Asphalt, Batch Mixer	0.27	0.20	0.19	0.18	0.17	0.17	0.51	0.38	0.35	0.33	0.32	0.32	1.01	0.76	0.70	0.66	0.64	0.63	1.66	1.24	1.15	1.09	1.05	1.04	1.99	1.49	1.38	1.30	1.26	1.24	3.60	2.69	2.49	2.35	2.27	2.24	5.23	3.91	3.62	3.42	3.30	3.26
PM-cond (Organic)		WS/FF	Asphalt, Drum Mixer	0.18	0.11	0.09	0.08	0.08	0.08	0.41	0.25	0.21	0.19	0.18	0.17	1.02	0.63	0.54	0.48	0.44	0.43	2.60	1.59	1.36	1.23	1.13	1.10	2.56	1.57	1.34	1.21	1.11	1.08	5.99	3.66	3.14	2.82	2.60	2.53	9.98	6.11	5.23	4.71	4.33	4.22
PM-condensable, controlled				**0.25**	**0.18**	**0.17**	**0.16**	**0.15**	**0.15**	**0.48**	**0.34**	**0.32**	**0.29**	**0.28**	**0.28**	**1.01**	**0.71**	**0.65**	**0.60**	**0.58**	**0.57**	**1.99**	**1.37**	**1.24**	**1.13**	**1.08**	**1.06**	**2.17**	**1.51**	**1.37**	**1.26**	**1.20**	**1.18**	**4.42**	**3.02**	**2.72**	**2.50**	**2.38**	**2.34**	**6.88**	**4.67**	**4.20**	**3.84**	**3.65**	**3.58**
PM-condensable, all				**0.25**	**0.18**	**0.16**	**0.15**	**0.15**	**0.14**	**0.48**	**0.34**	**0.31**	**0.29**	**0.28**	**0.27**	**1.01**	**0.71**	**0.65**	**0.60**	**0.57**	**0.56**	**1.98**	**1.37**	**1.24**	**1.13**	**1.08**	**1.06**	**2.17**	**1.51**	**1.37**	**1.26**	**1.20**	**1.18**	**4.42**	**3.04**	**2.74**	**2.51**	**2.39**	**2.35**	**6.86**	**4.69**	**4.21**	**3.85**	**3.66**	**3.60**
PM-filt		DSI/FF	Refuse Combustion, Mass Burn	0.19	0.15	0.15	0.14	0.14	0.14	0.45	0.37	0.36	0.35	0.35	0.35	1.00	0.82	0.79	0.77	0.76	0.76	1.32	1.09	1.05	1.02	1.01	1.01	1.85	1.52	1.46	1.42	1.42	1.41	2.91	2.39	2.30	2.24	2.23	2.22	3.66	3.01	2.89	2.82	2.81	2.80
PM-filt		ESP	Refuse Combustion, Mass Burn	0.29	0.22	0.21	0.19	0.19	0.19	0.52	0.40	0.37	0.35	0.34	0.34	1.02	0.78	0.72	0.68	0.65	0.65	1.62	1.24	1.15	1.08	1.04	1.04	1.94	1.49	1.38	1.29	1.25	1.25	3.48	2.67	2.47	2.32	2.24	2.23	5.03	3.86	3.56	3.35	3.24	3.22
PM-filt		ESP	Refuse Combustion, RDF	0.17	0.11	0.10	0.09	0.08	0.08	0.39	0.26	0.23	0.20	0.19	0.19	0.96	0.65	0.57	0.51	0.48	0.47	2.26	1.53	1.34	1.20	1.12	1.10	2.27	1.53	1.35	1.20	1.12	1.10	5.17	3.48	3.07	2.74	2.56	2.51	8.32	5.61	4.94	4.42	4.13	4.05
PM-filt		FF	Asphalt, Drum Mixer	0.32	0.26	0.24	0.23	0.22	0.22	0.53	0.43	0.41	0.39	0.37	0.37	0.99	0.81	0.76	0.72	0.70	0.69	1.47	1.20	1.13	1.07	1.04	1.03	1.82	1.48	1.39	1.32	1.28	1.27	3.09	2.51	2.37	2.24	2.18	2.16	4.38	3.56	3.36	3.18	3.09	3.06
PM-filt		FF	Asphalt, Batch Mixer	0.26	0.19	0.18	0.17	0.16	0.16	0.49	0.37	0.34	0.32	0.30	0.30	0.99	0.74	0.68	0.64	0.62	0.61	1.70	1.28	1.18	1.10	1.06	1.05	1.96	1.48	1.36	1.27	1.22	1.21	3.76	2.83	2.60	2.44	2.35	2.32	5.46	4.10	3.77	3.54	3.40	3.37
PM-filt		MC	Wood Combustion, Dry Wood	0.59	0.56	0.56	0.55	0.55	0.55	0.76	0.72	0.71	0.70	0.70	0.70	1.00	0.95	0.94	0.93	0.93	0.93	1.08	1.03	1.02	1.01	1.00	1.00	1.31	1.25	1.24	1.22	1.22	1.22	1.68	1.60	1.58	1.56	1.56	1.56	1.93	1.84	1.82	1.80	1.79	1.79
PM-filt		MC	Wood Combustion, Wet Wood	0.60	0.56	0.56	0.56	0.55	0.55	0.77	0.72	0.72	0.71	0.71	0.71	1.01	0.94	0.94	0.93	0.93	0.92	1.10	1.03	1.02	1.01	1.00	1.00	1.32	1.24	1.23	1.22	1.21	1.21	1.70	1.59	1.58	1.56	1.55	1.55	1.96	1.83	1.82	1.81	1.80	1.79

(continued)

Table 4-7. (continued)

			Uncertainty Ratio (MC Median)																																									
		Target Statistic→	10th Percentile						25th Percentile						Median						Mean						75th Percentile						90th Percentile						95th Percentile					
Pollutant	**Control**	**Industry/Source**	***n*=1**	***n*=3**	***n*=5**	***n*=10**	***n*=20**	***n*=25**	***n*=1**	***n*=3**	***n*=5**	***n*=10**	***n*=20**	***n*=25**	***n*=1**	***n*=3**	***n*=5**	***n*=10**	***n*=20**	***n*=25**	***n*=1**	***n*=3**	***n*=5**	***n*=10**	***n*=20**	***n*=25**	***n*=1**	***n*=3**	***n*=5**	***n*=10**	***n*=20**	***n*=25**	***n*=1**	***n*=3**	***n*=5**	***n*=10**	***n*=20**	***n*=25**	***n*=1**	***n*=3**	***n*=5**	***n*=10**	***n*=20**	***n*=25**
PM-filt	SD/ESP	Refuse Combustion, Mass Burn	0.51	0.48	0.47	0.46	0.46	0.46	0.70	0.65	0.64	0.63	0.62	0.62	0.99	0.92	0.90	0.89	0.88	0.88	1.14	1.06	1.03	1.02	1.01	1.01	1.40	1.30	1.27	1.25	1.24	1.24	1.94	1.80	1.76	1.73	1.72	1.71	2.34	2.17	2.12	2.09	2.07	2.07
PM-filt	SD/FF	Refuse Combustion, Mass Burn	0.30	0.24	0.22	0.21	0.20	0.20	0.52	0.41	0.39	0.36	0.36	0.36	0.98	0.78	0.73	0.69	0.67	0.67	1.52	1.20	1.13	1.06	1.04	1.03	1.86	1.46	1.38	1.29	1.27	1.26	3.30	2.60	2.45	2.30	2.26	2.24	4.53	3.57	3.36	3.16	3.10	3.09
PM-filt	WS	Wood Combustion	0.68	0.66	0.65	0.65	0.65	0.65	0.81	0.78	0.78	0.78	0.78	0.77	1.00	0.96	0.96	0.96	0.95	0.95	1.05	1.01	1.01	1.01	1.00	1.00	1.24	1.19	1.19	1.18	1.18	1.18	1.49	1.44	1.43	1.42	1.42	1.42	1.68	1.62	1.61	1.60	1.60	1.60
PM-filterable, controlled			**0.39**	**0.34**	**0.33**	**0.32**	**0.32**	**0.32**	**0.59**	**0.51**	**0.49**	**0.48**	**0.47**	**0.47**	**0.99**	**0.84**	**0.80**	**0.77**	**0.76**	**0.75**	**1.43**	**1.16**	**1.10**	**1.06**	**1.03**	**1.03**	**1.70**	**1.39**	**1.32**	**1.27**	**1.24**	**1.23**	**2.85**	**2.29**	**2.16**	**2.06**	**2.01**	**1.99**	**3.93**	**3.12**	**2.93**	**2.78**	**2.70**	**2.68**
PM-filt	UNC	Refuse Combustion, RDF	0.62	0.59	0.59	0.59	0.59	0.58	0.77	0.74	0.74	0.73	0.73	0.73	1.00	0.95	0.95	0.94	0.94	0.94	1.07	1.02	1.02	1.01	1.00	1.00	1.28	1.22	1.22	1.21	1.20	1.20	1.60	1.53	1.53	1.51	1.51	1.51	1.83	1.75	1.75	1.73	1.72	1.72
PM-filt	UNC	Wood Combustion, Dry Wood	0.59	0.57	0.56	0.56	0.55	0.55	0.76	0.73	0.72	0.71	0.71	0.71	1.00	0.96	0.94	0.93	0.93	0.93	1.08	1.04	1.02	1.01	1.01	1.00	1.30	1.25	1.23	1.22	1.22	1.21	1.65	1.59	1.56	1.55	1.54	1.54	1.93	1.86	1.82	1.81	1.80	1.80
PM-filt	UNC	Refuse Combustion, Mass Burn	0.54	0.49	0.48	0.48	0.48	0.48	0.72	0.66	0.65	0.65	0.64	0.64	1.00	0.92	0.90	0.89	0.89	0.88	1.14	1.04	1.03	1.01	1.01	1.01	1.41	1.29	1.27	1.26	1.25	1.24	1.90	1.74	1.71	1.69	1.68	1.67	2.25	2.06	2.02	2.00	1.99	1.98
PM-filt	UNC	Wood Combustion, Wet Wood	0.48	0.44	0.43	0.43	0.42	0.42	0.68	0.62	0.61	0.60	0.60	0.59	0.99	0.90	0.89	0.87	0.86	0.86	1.15	1.05	1.04	1.02	1.01	1.01	1.43	1.31	1.29	1.27	1.26	1.25	2.04	1.86	1.84	1.81	1.79	1.78	2.48	2.27	2.23	2.20	2.17	2.17
PM-filt	UNC	W/OSB, Hot Press	0.30	0.22	0.21	0.20	0.19	0.19	0.53	0.39	0.37	0.35	0.34	0.33	1.02	0.76	0.71	0.68	0.65	0.64	1.63	1.22	1.14	1.09	1.04	1.03	1.97	1.47	1.37	1.31	1.25	1.25	3.56	2.66	2.48	2.38	2.27	2.26	5.05	3.78	3.51	3.37	3.21	3.20
PM-filterable, uncontrolled			**0.51**	**0.46**	**0.46**	**0.45**	**0.45**	**0.44**	**0.69**	**0.63**	**0.62**	**0.61**	**0.60**	**0.60**	**1.00**	**0.90**	**0.88**	**0.86**	**0.85**	**0.85**	**1.21**	**1.07**	**1.05**	**1.03**	**1.01**	**1.01**	**1.48**	**1.31**	**1.28**	**1.25**	**1.23**	**1.23**	**2.15**	**1.88**	**1.82**	**1.79**	**1.76**	**1.75**	**2.71**	**2.34**	**2.27**	**2.22**	**2.18**	**2.17**
Sulfur dioxide	UNC	Refuse Combustion	0.40	0.39	0.39	0.39	0.39	0.39	0.64	0.62	0.61	0.61	0.61	0.61	0.99	0.96	0.95	0.95	0.95	0.95	1.05	1.01	1.01	1.00	1.00	1.00	1.39	1.34	1.34	1.33	1.33	1.33	1.77	1.71	1.70	1.70	1.69	1.69	1.99	1.92	1.91	1.91	1.90	1.90
Sulfur dioxide	UNC	Wood Combustion	0.12	0.07	0.05	0.04	0.04	0.04	0.33	0.18	0.15	0.12	0.11	0.11	0.99	0.53	0.44	0.36	0.32	0.31	3.82	2.05	1.71	1.40	1.23	1.22	2.99	1.61	1.34	1.10	0.96	0.95	8.21	4.41	3.68	3.01	2.65	2.62	14.96	8.04	6.71	5.49	4.83	4.78
Nitrogen oxides	UNC	Refuse Combustion, Mass Burn Waterwall	0.64	0.65	0.65	0.65	0.65	0.65	0.81	0.82	0.82	0.82	0.82	0.82	1.00	1.01	1.01	1.01	1.01	1.01	0.99	1.00	1.00	1.00	1.00	1.00	1.18	1.19	1.19	1.19	1.19	1.19	1.33	1.34	1.34	1.34	1.34	1.34	1.42	1.43	1.43	1.43	1.43	1.43
Nitrogen oxides	UNC	Wood Combustion	0.20	0.14	0.12	0.11	0.10	0.10	0.43	0.29	0.26	0.23	0.22	0.22	1.00	0.67	0.60	0.53	0.50	0.50	2.16	1.44	1.29	1.15	1.09	1.08	2.33	1.55	1.39	1.24	1.17	1.16	4.92	3.27	2.93	2.61	2.48	2.45	7.68	5.10	4.57	4.06	3.86	3.82
Carbon monoxide	UNC	Wood Combustion	0.30	0.27	0.26	0.26	0.26	0.26	0.58	0.51	0.50	0.50	0.50	0.50	1.02	0.91	0.89	0.88	0.88	0.88	1.16	1.04	1.02	1.01	1.01	1.00	1.61	1.44	1.41	1.40	1.40	1.39	2.22	1.97	1.94	1.92	1.92	1.91	2.66	2.37	2.33	2.31	2.31	2.30
Carbon monoxide	UNC	Refuse Combustion, Mass Burn	0.39	0.32	0.31	0.30	0.29	0.29	0.61	0.50	0.48	0.47	0.46	0.46	1.03	0.85	0.81	0.79	0.77	0.77	1.36	1.13	1.08	1.04	1.02	1.02	1.69	1.40	1.34	1.30	1.27	1.27	2.68	2.21	2.12	2.05	2.01	2.00	3.52	2.91	2.79	2.70	2.65	2.64
Gaseous criteria pollutants			**0.34**	**0.30**	**0.30**	**0.29**	**0.29**	**0.29**	**0.57**	**0.49**	**0.47**	**0.46**	**0.45**	**0.45**	**1.00**	**0.82**	**0.78**	**0.75**	**0.74**	**0.74**	**1.76**	**1.28**	**1.18**	**1.10**	**1.06**	**1.05**	**1.87**	**1.42**	**1.33**	**1.26**	**1.22**	**1.22**	**3.52**	**2.49**	**2.28**	**2.10**	**2.01**	**2.00**	**5.37**	**3.63**	**3.29**	**2.98**	**2.83**	**2.81**

DSI/FF = dry sorbent injection/fabric filter; ESP = electrostatic precipitator; FF = fabric filter; MC = mechanical collector (e.g., cyclone); PM = particulate matter; RDF = refuse-derived fuel; SD/ESP = spray dryer/electrostatic precipitator; SD/FF = spray dryer/fabric filter; UNC = uncontrolled; W/OSB = Waferboard/Oriented Strandboard Manufacturing; WS = wet scrubber; WS/FF = wet scrubber or fabric filter; UNC/PM = uncontrolled or PM control.

Table 4-8. Composite Uncertainty Ratios Based on Boundary Statistics by Pollutant and Control

Pollutant	Number of Ratios Averaged	Target Statistic ➔	Uncertainty Ratio (MC Median)																																									
			10th Percentile						25th Percentile						Median						Mean						75th Percentile						90th Percentile						95th Percentile					
			n=1	*n*=3	*n*=5	*n*=10	*n*=20	*n*=25	*n*=1	*n*=3	*n*=5	*n*=10	*n*=20	*n*=25	*n*=1	*n*=3	*n*=5	*n*=10	*n*=20	*n*=25	*n*=1	*n*=3	*n*=5	*n*=10	*n*=20	*n*=25	*n*=1	*n*=3	*n*=5	*n*=10	*n*=20	*n*=25	*n*=1	*n*=3	*n*=5	*n*=10	*n*=20	*n*=25	*n*=1	*n*=3	*n*=5	*n*=10	*n*=20	*n*=25
All HAPs	18		0.18	0.13	0.13	0.12	0.12	0.12	0.37	0.26	0.25	0.23	0.22	0.22	1.01	0.62	0.56	0.51	0.49	0.48	3.37	1.62	1.38	1.20	1.11	1.09	2.92	1.54	1.35	1.20	1.13	1.12	7.67	3.62	3.09	2.68	2.49	2.45	13.42	6.02	5.05	4.32	3.97	3.90
PM-condensable	5		0.25	0.18	0.16	0.15	0.15	0.14	0.48	0.34	0.31	0.29	0.28	0.27	1.01	0.71	0.65	0.60	0.57	0.56	1.98	1.37	1.24	1.13	1.08	1.06	2.17	1.51	1.37	1.26	1.20	1.18	4.42	3.04	2.74	2.51	2.39	2.35	6.86	4.69	4.21	3.85	3.66	3.60
PM-filterable, controlled	10		0.39	0.34	0.33	0.32	0.32	0.32	0.59	0.51	0.49	0.48	0.47	0.47	0.99	0.84	0.80	0.77	0.76	0.75	1.43	1.16	1.10	1.06	1.03	1.03	1.70	1.39	1.32	1.27	1.24	1.23	2.85	2.29	2.16	2.06	2.01	1.99	3.93	3.12	2.93	2.78	2.70	2.68
PM-filterable, uncontrolled	5		0.51	0.46	0.46	0.45	0.45	0.44	0.69	0.63	0.62	0.61	0.60	0.60	1.00	0.90	0.88	0.86	0.85	0.85	1.21	1.07	1.05	1.03	1.01	1.01	1.48	1.31	1.28	1.25	1.23	1.23	2.15	1.88	1.82	1.79	1.76	1.75	2.71	2.34	2.27	2.22	2.18	2.17
Gaseous criteria pollutants	6		0.34	0.30	0.30	0.29	0.29	0.29	0.57	0.49	0.47	0.46	0.45	0.45	1.00	0.82	0.78	0.75	0.74	0.74	1.76	1.28	1.18	1.10	1.06	1.05	1.87	1.42	1.33	1.26	1.22	1.22	3.52	2.49	2.28	2.10	2.01	2.00	5.37	3.63	3.29	2.98	2.83	2.81

HAP = hazardous air pollutant; PM = particulate matter.

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Table 4-9. Composite Emissions Factor Uncertainty Ratios Based on Boundary Statistics for HAP

Target Statistic	Number of Emissions Tests Used to Determine AP-42 Emissions Factor			
	n **< 3**	**3 ≤ *n* < 10**	**10≤ *n* <25**	***n*** **≥ 25**
10th Percentile	0.2	0.1	0.1	0.1
25th Percentile	0.4	0.3	0.2	0.2
Median	1.0	0..6	0.5	0.5
Mean	3.4	1.6	1.2	1.1
75th Percentile	2.9	1.5	1.2	1.1
90th Percentile	7.7	3.6	2.7	2.4
95th Percentile	13.4	6.0	4.3	3.9

HAP = hazardous air pollutant.

Table 4-10. Composite Emissions Factor Uncertainty Ratios Based on Boundary Statistics for PM-Condensable

Target Statistic	Number of Emissions Tests Used to Determine AP-42 Emissions Factor			
	n **< 3**	**3 ≤ *n* < 10**	**10 ≤ *n* < 25**	***n*** **≥ 25**
10th Percentile	0.2	0.2	0.2	0.1
25th Percentile	0.5	0.3	0.3	0.3
Median	1	0.7	0.6	0.6
Mean	2.0	1.4	1.1	1.1
75th Percentile	2.2	1.5	1.3	1.2
90th Percentile	4.4	3.0	2.5	2.4
95th Percentile	6.9	4.7	3.9	3.6

PM = particulate matter.

Table 4-11. Composite Emissions Factor Uncertainty Ratios Based on Boundary Statistics for PM-Filterable, Controlled

Target Statistic	Number of Emissions Tests Used to Determine AP-42 Emissions Factor			
	n **< 3**	**3 ≤ *n* < 10**	**10 ≤ *n* < 25**	***n*** **≥ 25**
10th Percentile	0.4	0.3	0.3	0.3
25th Percentile	0.6	0.5	0.5	0.5
Median	1	0.8	0.8	0.8
Mean	1.4	1.2	1.1	1.0
75th Percentile	1.7	1.4	1.3	1.2
90th Percentile	2.9	2.3	2.1	2.0
95th Percentile	3.9	3.1	2.8	2.7

PM = particulate matter.

Table 4-12. Composite Emissions Factor Uncertainty Ratios Based on Boundary Statistics for PM-Filterable, Uncontrolled

Target Statistic	Number of Emissions Tests Used to Determine AP-42 Emissions Factor			
	$n < 3$	$3 \leq n < 10$	$10 \leq n < 25$	$n \geq 25$
10th Percentile	0.5	0.5	0.4	0.4
25th Percentile	0.7	0.6	0.6	0.6
Median	1	0.9	0.9	0.9
Mean	1.2	1.1	1	1.0
75th Percentile	1.5	1.3	1.3	1.2
90th Percentile	2.2	1.9	1.8	1.8
95th Percentile	2.7	2.3	2.2	2.2

PM = particulate matter.

Table 4-13. Composite Emissions Factor Uncertainty Ratios Based on Boundary Statistics for Gaseous Criteria Pollutants

Target Statistic	Number of Emissions Tests Used to Determine AP-42 Emissions Factor			
	$n < 3$	$3 \leq n < 10$	$10 \leq n < 25$	$n \geq 25$
10th Percentile	0.3	0.3	0.3	0.3
25th Percentile	0.6	0.5	0.5	0.5
Median	1	0.8	0.8	0.8
Mean	1.8	1.3	1.1	1.0
75th Percentile	1.9	1.4	1.3	1.2
90th Percentile	3.5	2.5	2.1	2.0
95th Percentile	5.4	3.6	3.0	2.8

Table 4-14. Emissions Factor Uncertainty Ratios Based on Normalized Sampling Distribution of Emissions Factor (Mean), Listed by Pollutant, Control Device, and Industry/Source

Pollutant	Control	Distribution Statistic→	Uncertainty Ratio																																													
			10th Percentile						25th Percentile						Median						Mean						75th Percentile						90th Percentile						95th Percentile						99th Percentile					
		Industry/Source	n=1	n=3	n=5	n=10	n=20	n=25	n=1	n=3	n=5	n=10	n=20	n=25	n=1	n=3	n=5	n=10	n=20	n=25	n=1	n=3	n=5	n=10	n=20	n=25	n=1	n=3	n=5	n=10	n=20	n=25	n=1	n=3	n=5	n=10	n=20	n=25	n=1	n=3	n=5	n=10	n=20	n=25	n=1	n=3	n=5	n=10	n=20	n=25
Acetaldehyde	UNC/PM	Wood Combustion	0.02	0.09	0.15	0.26	0.38	0.42	0.06	0.18	0.27	0.40	0.53	0.57	0.20	0.42	0.53	0.68	0.79	0.83	1.00	1.00	1.00	1.00	1.00	1.00	0.69	0.98	1.10	1.19	1.22	1.21	2.29	2.23	2.23	2.04	1.81	1.74	4.33	3.82	3.43	2.81	2.34	2.18	14.24	9.12	7.32	5.32	3.95	3.55
Arsenic	SD/FF	Refuse Combustion, Mass Burn	0.46	0.65	0.72	0.80	0.86	0.87	0.64	0.78	0.84	0.88	0.92	0.93	0.88	0.96	0.98	0.99	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.24	1.17	1.14	1.10	1.08	1.07	1.68	1.40	1.31	1.22	1.15	1.14	1.99	1.56	1.42	1.30	1.20	1.18	2.82	1.89	1.67	1.44	1.30	1.27
Arsenic	UNC/PM	Wood Combustion	0.00	0.03	0.08	0.18	0.33	0.37	0.01	0.11	0.20	0.34	0.51	0.54	0.08	0.36	0.51	0.67	0.82	0.84	1.00	1.00	1.00	1.00	1.00	1.00	0.56	1.06	1.19	1.29	1.28	1.28	2.29	2.64	2.44	2.16	1.89	1.82	4.52	4.29	3.54	2.92	2.35	2.24	14.56	8.80	6.95	5.14	3.52	3.29
Benzene	FF	Asphalt, Drum Mix	0.40	0.60	0.67	0.76	0.83	0.84	0.56	0.74	0.79	0.86	0.90	0.91	0.84	0.94	0.96	0.98	0.99	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.23	1.19	1.16	1.12	1.09	1.08	1.82	1.48	1.39	1.26	1.18	1.16	2.21	1.69	1.54	1.35	1.25	1.22	3.31	2.17	1.87	1.55	1.37	1.33
Benzene	UNC/PM	Wood Combustion	0.01	0.05	0.09	0.16	0.27	0.29	0.03	0.11	0.18	0.28	0.40	0.42	0.12	0.28	0.39	0.52	0.65	0.67	1.00	1.00	1.00	1.00	1.00	1.00	0.48	0.78	0.91	1.02	1.13	1.12	1.63	2.00	2.20	2.02	1.98	1.91	3.65	3.66	3.55	3.14	2.87	2.66	14.37	12.01	9.54	7.33	5.30	5.94
Cadmium	SD/ESP	Refuse Combustion, Mass Burn	0.24	0.45	0.54	0.65	0.74	0.77	0.40	0.62	0.69	0.78	0.84	0.86	0.71	0.86	0.91	0.95	0.98	0.98	1.00	1.00	1.00	1.00	1.00	1.00	1.25	1.23	1.21	1.17	1.13	1.11	2.06	1.70	1.56	1.41	1.29	1.25	2.79	2.06	1.82	1.57	1.40	1.35	4.77	2.97	2.46	1.93	1.65	1.55
Cadmium	UNC/PM	Wood Combustion	0.02	0.17	0.27	0.43	0.57	0.61	0.09	0.34	0.46	0.61	0.73	0.75	0.37	0.69	0.80	0.89	0.94	0.95	1.00	1.00	1.00	1.00	1.00	1.00	1.14	1.32	1.32	1.27	1.21	1.19	2.65	2.21	1.97	1.71	1.50	1.45	4.11	2.90	2.44	2.01	1.69	1.64	8.08	4.68	3.69	2.82	2.19	2.07
Chromium	UNC/PM	Wood Combustion	0.01	0.10	0.19	0.34	0.48	0.53	0.05	0.24	0.37	0.53	0.66	0.69	0.26	0.59	0.71	0.85	0.90	0.92	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.31	1.29	1.29	1.24	1.22	2.82	2.38	2.12	1.86	1.63	1.57	4.55	3.22	2.91	2.28	1.92	1.79	9.49	5.75	4.83	3.27	2.57	2.36
Formaldehyde	FF	Asphalt, Drum Mix	0.17	0.36	0.46	0.58	0.68	0.71	0.31	0.52	0.62	0.72	0.80	0.82	0.61	0.79	0.86	0.92	0.95	0.96	1.00	1.00	1.00	1.00	1.00	1.00	1.20	1.24	1.22	1.19	1.15	1.14	2.20	1.86	1.70	1.50	1.38	1.34	3.17	2.37	2.05	1.76	1.53	1.48	6.30	3.80	3.05	2.35	1.87	1.78
Formaldehyde	UNC/PM	Wood Combustion	0.02	0.08	0.14	0.25	0.37	0.39	0.05	0.17	0.26	0.38	0.51	0.53	0.19	0.38	0.51	0.63	0.76	0.76	1.00	1.00	1.00	1.00	1.00	1.00	0.66	0.87	1.01	1.09	1.16	1.12	1.93	1.91	2.02	1.86	1.73	1.65	3.69	3.13	3.10	2.54	2.26	2.09	13.25	7.93	6.75	5.01	4.15	4.09
Hydrogen chloride	SD/FF	Refuse Combustion, Mass Burn	0.06	0.29	0.41	0.55	0.67	0.70	0.19	0.49	0.60	0.72	0.81	0.82	0.57	0.83	0.89	0.95	0.97	0.98	1.00	1.00	1.00	1.00	1.00	1.00	1.36	1.33	1.28	1.23	1.17	1.15	2.47	1.91	1.73	1.52	1.36	1.32	3.39	2.34	2.05	1.71	1.48	1.44	5.74	3.56	2.75	2.10	1.77	1.65
Hydrogen chloride	UNC	Refuse Combustion	0.31	0.59	0.68	0.77	0.84	0.85	0.56	0.76	0.81	0.87	0.91	0.92	0.93	0.98	0.98	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.36	1.21	1.17	1.12	1.09	1.08	1.77	1.44	1.34	1.24	1.17	1.15	2.05	1.58	1.46	1.32	1.22	1.19	2.61	1.87	1.66	1.47	1.32	1.28
Lead	SD/ESP	Refuse Combustion, Mass Burn	0.24	0.47	0.55	0.66	0.75	0.77	0.42	0.63	0.69	0.78	0.85	0.86	0.72	0.88	0.92	0.95	0.97	0.98	1.00	1.00	1.00	1.00	1.00	1.00	1.23	1.23	1.20	1.16	1.12	1.11	2.07	1.65	1.55	1.39	1.28	1.25	2.75	2.03	1.81	1.57	1.40	1.36	4.89	2.98	2.43	2.01	1.64	1.58
Lead	UNC/PM	Wood Combustion	0.00	0.09	0.17	0.31	0.46	0.50	0.04	0.22	0.33	0.49	0.62	0.66	0.22	0.56	0.68	0.79	0.89	0.89	1.00	1.00	1.00	1.00	1.00	1.00	0.93	1.21	1.27	1.25	1.24	1.22	2.61	2.34	2.17	1.93	1.68	1.61	4.32	3.50	2.95	2.43	1.98	1.89	11.73	6.70	5.21	3.73	2.77	2.58
Mercury	SD/FF	Refuse Combustion, Mass Burn	0.13	0.31	0.42	0.54	0.65	0.68	0.27	0.48	0.58	0.68	0.77	0.79	0.56	0.75	0.83	0.90	0.94	0.95	1.00	1.00	1.00	1.00	1.00	1.00	1.15	1.22	1.23	1.20	1.16	1.16	2.24	1.93	1.76	1.57	1.42	1.38	3.36	2.60	2.19	1.88	1.61	1.56	7.26	4.43	3.44	2.80	2.11	1.91
Mercury	UNC/PM	Wood Combustion	0.00	0.03	0.08	0.18	0.31	0.36	0.01	0.10	0.19	0.34	0.49	0.53	0.08	0.33	0.49	0.66	0.79	0.81	1.00	1.00	1.00	1.00	1.00	1.00	0.56	1.00	1.16	1.26	1.25	1.26	2.28	2.52	2.39	2.13	1.92	1.89	4.71	4.03	3.58	3.04	2.56	2.42	14.34	10.11	8.13	5.41	4.13	3.51
Nickel	SD/FF	Refuse Combustion, Mass Burn	0.17	0.38	0.47	0.59	0.69	0.72	0.32	0.54	0.63	0.73	0.80	0.82	0.63	0.82	0.87	0.93	0.96	0.96	1.00	1.00	1.00	1.00	1.00	1.00	1.20	1.24	1.22	1.19	1.14	1.13	2.16	1.80	1.67	1.48	1.36	1.31	3.05	2.24	2.00	1.71	1.50	1.46	5.94	3.56	3.05	2.31	1.93	1.78
Nickel	UNC/PM	Wood Combustion	0.00	0.07	0.15	0.28	0.44	0.48	0.03	0.20	0.32	0.47	0.61	0.64	0.20	0.52	0.65	0.79	0.88	0.90	1.00	1.00	1.00	1.00	1.00	1.00	0.89	1.22	1.27	1.30	1.26	1.25	2.50	2.42	2.24	1.99	1.72	1.66	4.33	3.57	3.17	2.50	2.05	1.94	12.04	6.82	5.18	3.79	2.78	2.61
PM-cond	UNC	Wood Combustion	0.12	0.31	0.40	0.53	0.64	0.67	0.24	0.47	0.56	0.68	0.76	0.79	0.52	0.76	0.83	0.90	0.94	0.95	1.00	1.00	1.00	1.00	1.00	1.00	1.13	1.23	1.22	1.20	1.18	1.16	2.28	1.96	1.80	1.59	1.44	1.39	3.35	2.60	2.29	1.89	1.62	1.56	7.56	4.19	3.52	2.59	2.06	1.90
PM-cond (Inorganic)	FF	Asphalt, Batch Mixer	0.03	0.13	0.21	0.32	0.44	0.47	0.08	0.25	0.34	0.47	0.58	0.62	0.26	0.52	0.61	0.74	0.82	0.85	1.00	1.00	1.00	1.00	1.00	1.00	0.79	1.08	1.16	1.20	1.19	1.19	2.12	2.22	2.03	1.91	1.74	1.66	4.01	3.44	2.99	2.55	2.24	2.09	11.84	7.58	6.80	4.69	3.71	3.40
PM-cond (Inorganic)	WS/FF	Asphalt, Drum Mixer	0.33	0.55	0.63	0.72	0.80	0.82	0.51	0.70	0.76	0.83	0.88	0.89	0.81	0.92	0.94	0.97	0.98	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.26	1.20	1.18	1.14	1.10	1.09	1.86	1.55	1.44	1.32	1.22	1.20	2.37	1.80	1.63	1.45	1.30	1.27	3.90	2.52	2.07	1.73	1.49	1.42
PM-cond (Organic)	FF	Asphalt, Batch Mixer	0.08	0.33	0.46	0.59	0.70	0.73	0.24	0.54	0.65	0.76	0.83	0.85	0.63	0.87	0.93	0.96	0.98	0.98	1.00	1.00	1.00	1.00	1.00	1.00	1.35	1.31	1.26	1.20	1.15	1.14	2.41	1.84	1.64	1.45	1.32	1.29	3.23	2.22	1.92	1.63	1.43	1.38	5.40	3.13	2.45	1.97	1.66	1.57
PM-cond (Organic)	WS/FF	Asphalt, Drum Mixer	0.01	0.07	0.13	0.22	0.32	0.35	0.05	0.15	0.23	0.35	0.44	0.48	0.16	0.35	0.46	0.58	0.66	0.71	1.00	1.00	1.00	1.00	1.00	1.00	0.58	0.85	0.96	1.04	1.11	1.15	1.90	1.93	1.88	2.07	1.97	1.89	3.66	3.64	3.32	3.15	2.81	2.64	15.09	11.24	10.34	7.88	6.55	5.58
PM-filt	DSI/FF	Refuse Combustion, Mass Burn	0.14	0.42	0.54	0.66	0.76	0.79	0.35	0.62	0.72	0.80	0.86	0.88	0.76	0.92	0.95	0.98	0.99	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.40	1.29	1.24	1.17	1.13	1.11	2.18	1.68	1.51	1.37	1.26	1.23	2.74	1.95	1.71	1.50	1.34	1.30	3.97	2.53	2.12	1.73	1.51	1.46
PM-filt	ESP	Refuse Combustion, Mass Burn	0.20	0.40	0.49	0.61	0.71	0.74	0.34	0.57	0.65	0.75	0.82	0.84	0.66	0.84	0.88	0.93	0.96	0.97	1.00	1.00	1.00	1.00	1.00	1.00	1.22	1.24	1.22	1.17	1.14	1.13	2.19	1.77	1.63	1.47	1.33	1.30	3.00	2.24	1.98	1.69	1.47	1.41	5.76	3.48	2.84	2.19	1.75	1.64
PM-filt	ESP	Refuse Combustion, RDF	0.02	0.10	0.16	0.27	0.38	0.42	0.06	0.20	0.29	0.41	0.52	0.57	0.22	0.44	0.56	0.67	0.77	0.81	1.00	1.00	1.00	1.00	1.00	1.00	0.72	0.99	1.09	1.13	1.20	1.19	2.13	2.09	2.15	2.02	1.81	1.74	3.97	3.55	3.34	2.92	2.39	2.25	12.84	9.03	7.01	5.51	4.24	3.76
PM-filt	FF	Asphalt, Drum Mixer	0.25	0.47	0.55	0.66	0.75	0.77	0.41	0.63	0.70	0.78	0.84	0.86	0.72	0.87	0.91	0.95	0.97	0.98	1.00	1.00	1.00	1.00	1.00	1.00	1.25	1.23	1.20	1.16	1.13	1.11	2.04	1.67	1.55	1.40	1.28	1.25	2.71	2.01	1.81	1.58	1.40	1.35	4.69	2.91	2.46	1.98	1.64	1.54
PM-filt	FF	Asphalt, Batch Mixer	0.13	0.30	0.39	0.52	0.63	0.66	0.25	0.46	0.56	0.67	0.76	0.78	0.53	0.74	0.83	0.89	0.94	0.94	1.00	1.00	1.00	1.00	1.00	1.00	1.10	1.23	1.23	1.20	1.17	1.15	2.28	1.93	1.79	1.59	1.44	1.41	3.42	2.64	2.22	1.95	1.65	1.61	7.08	4.60	3.72	2.82	2.11	2.03
PM-filt	MC	Wood Combustion, Dry Wood	0.55	0.71	0.77	0.84	0.88	0.89	0.70	0.83	0.87	0.91	0.93	0.94	0.93	0.97	0.98	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.22	1.14	1.12	1.08	1.06	1.05	1.54	1.32	1.25	1.17	1.12	1.11	1.79	1.44	1.33	1.23	1.16	1.14	2.35	1.72	1.51	1.34	1.25	1.22
PM-filt	MC	Wood Combustion, Wet Wood	0.06	0.28	0.40	0.55	0.67	0.70	0.20	0.49	0.60	0.72	0.81	0.82	0.57	0.83	0.89	0.95	0.97	0.98	1.00	1.00	1.00	1.00	1.00	1.00	1.32	1.33	1.29	1.22	1.17	1.15	2.42	1.93	1.75	1.52	1.37	1.33	3.50	2.37	2.06	1.72	1.50	1.45	5.81	3.40	2.76	2.13	1.77	1.70
PM-filt	SD/ESP	Refuse Combustion, Mass Burn	0.68	0.81	0.85	0.89	0.92	0.93	0.80	0.89	0.91	0.94	0.96	0.96	0.96	0.99	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.15	1.10	1.08	1.06	1.04	1.04	1.37	1.21	1.16	1.11	1.08	1.07	1.52	1.28	1.21	1.15	1.11	1.09	1.82	1.43	1.32	1.22	1.16	1.13
PM-filt	SD/FF	Refuse Combustion, Mass Burn	0.23	0.44	0.52	0.64	0.74	0.76	0.38	0.60	0.68	0.77	0.84	0.85	0.68	0.86	0.90	0.95	0.97	0.97	1.00	1.00	1.00	1.00	1.00	1.00	1.23	1.24	1.21	1.17	1.13	1.12	2.08	1.72	1.59	1.42	1.30	1.27	2.88	2.10	1.86	1.61	1.42	1.37	5.10	3.08	2.56	1.98	1.69	1.65
PM-filt	WS	Wood Combustion	0..64	0.78	0.82	0.88	0.91	0.92	0.77	0.87	0.90	0.93	0.95	0.96	0.96	0.98	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.17	1.11	1.09	1.07	1.05	1.04	1.42	1.24	1.18	1.13	1.09	1.08	1.59	1.32	1.25	1.17	1.12	1.11	1.92	1.51	1.36	1.25	1.17	1.16
PM-filt	UNC	Refuse Combustion, RDF	0.84	0.90	0.92	0.95	0.96	0.97	0.91	0.95	0.96	0.97	0.98	0.98	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.08	1.05	1.04	1.03	1.02	1.02	1.18	1.10	1.08	1.05	1.04	1.03	1.23	1.13	1.10	1.07	1.05	1.04	1.35	1.19	1.15	1.10	1.07	1.06
PM-filt	UNC	Wood Combustion, Dry Wood	0.55	0.71	0.77	0.84	0.88	0.90	0.69	0.82	0.87	0.91	0.93	0.94	0.92	0.97	0.98	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.21	1.14	1.11	1.08	1.06	1.05	1.56	1.32	1.25	1.18	1.12	1.11	1.80	1.45	1.34	1.23	1.16	1.14	2.38	1.72	1.54	1.34	1.24	1.22

(continued)

Table 4-14. (continued)

Pollutant	Control	Distribution Statistic→	Uncertainty Ratio: 10th Percentile						25th Percentile						Median						Mean						75th Percentile						90th Percentile						95th Percentile						99th Percentile					
		Industry/Source	*n*=1	*n*=3	*n*=5	*n*=10	*n*=20	*n*=25	*n*=1	*n*=3	*n*=5	*n*=10	*n*=20	*n*=25	*n*=1	*n*=3	*n*=5	*n*=10	*n*=20	*n*=25	*n*=1	*n*=3	*n*=5	*n*=10	*n*=20	*n*=25	*n*=1	*n*=3	*n*=5	*n*=10	*n*=20	*n*=25	*n*=1	*n*=3	*n*=5	*n*=10	*n*=20	*n*=25	*n*=1	*n*=3	*n*=5	*n*=10	*n*=20	*n*=25	*n*=1	*n*=3	*n*=5	*n*=10	*n*=20	*n*=25
PM-filt	UNC	Refuse Combustion, Mass Burn	0.71	0.83	0.86	0.90	0.93	0.94	0.82	0.90	0.92	0.95	0.96	0.97	0.97	0.99	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.15	1.09	1.07	1.05	1.04	1.03	1.32	1.19	1.14	1.10	1.07	1.06	1.45	1.25	1.19	1.13	1.09	1.08	1.74	1.39	1.29	1.20	1.14	1.12
PM-filt	UNC	Wood Combustion, Wet Wood	0.42	0.62	0.70	0.78	0.84	0.85	0.60	0.76	0.81	0.87	0.91	0.92	0.86	0.94	0.96	0.98	0.99	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.25	1.18	1.15	1.11	1.08	1.07	1.72	1.44	1.35	1.25	1.17	1.16	2.10	1.63	1.48	1.33	1.23	1.21	2.99	2.07	1.79	1.52	1.36	1.32
PM-filt	UNC	W/OSB, Hot Press	0.20	0.39	0.49	0.60	0.70	0.73	0.34	0.56	0.65	0.74	0.82	0.83	0.64	0.83	0.88	0.93	0.96	0.97	1.00	1.00	1.00	1.00	1.00	1.00	1.22	1.23	1.21	1.17	1.13	1.12	2.12	1.76	1.61	1.46	1.33	1.30	2.97	2.19	1.95	1.67	1.49	1.44	5.58	3.58	3.07	2.31	1.90	1.77
Sulfur dioxide	UNC	Refuse Combustion	0.39	0.64	0.72	0.80	0.86	0.87	0.62	0.80	0.84	0.89	0.92	0.93	0.95	0.99	0.99	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.32	1.19	1.15	1.10	1.07	1.07	1.68	1.38	1.30	1.21	1.14	1.13	1.90	1.50	1.38	1.26	1.19	1.17	2.38	1.73	1.55	1.38	1.27	1.24
Sulfur dioxide	UNC	Wood Combustion	0.03	0.13	0.20	0.31	0.44	0.48	0.08	0.25	0.34	0.46	0.58	0.62	0.26	0.51	0.61	0.73	0.82	0.85	1.00	1.00	1.00	1.00	1.00	1.00	0.82	1.07	1.17	1.17	1.17	1.18	2.11	2.17	2.08	1.92	1.66	1.60	3.82	3.37	3.01	2.51	2.10	2.03	13.32	6.80	6.56	4.97	3.95	3.69
Nitrogen oxides	UNC	Refuse Combustion, Mass Burn Waterwall	0.64	0.80	0.84	0.89	0.92	0.93	0.82	0.89	0.92	0.94	0.96	0.96	1.01	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.19	1.11	1.08	1.06	1.04	1.04	1.35	1.20	1.16	1.11	1.08	1.07	1.44	1.26	1.20	1.14	1.10	1.09	1.58	1.35	1.28	1.19	1.14	1.12
Nitrogen oxides	UNC	Wood Combustion	0.44	0.63	0.70	0.78	0.84	0.86	0.61	0.77	0.82	0.87	0.91	0.92	0.87	0.94	0.97	0.98	0.99	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.24	1.18	1.14	1.11	1.08	1.07	1.71	1.44	1.34	1.24	1.17	1.15	2.05	1.62	1.47	1.32	1.22	1.20	2.99	2.02	1.75	1.50	1.33	1.30
Carbon monoxide	UNC	Wood Combustion	0.19	0.47	0.58	0.69	0.78	0.81	0.41	0.66	0.75	0.82	0.88	0.89	0.81	0.94	0.96	0.98	0.99	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.38	1.26	1.21	1.16	1.12	1.10	2.04	1.60	1.47	1.33	1.23	1.21	2.55	1.86	1.64	1.44	1.31	1.27	3.69	2.35	1.98	1.67	1.46	1.40
Carbon monoxide	UNC	Refuse Combustion, Mass Burn	0.42	0.61	0.69	0.77	0.84	0.85	0.58	0.75	0.81	0.86	0.90	0.91	0.86	0.94	0.96	0.98	0.99	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.25	1.18	1.15	1.11	1.08	1.08	1.76	1.45	1.35	1.25	1.18	1.16	2.17	1.65	1.50	1.34	1.24	1.21	3.10	2.11	1.86	1.55	1.36	1.32

DSI/FF = dry sorbent injection/fabric filter; ESP = electrostatic precipitator; FF = fabric filter; MC = mechanical collector (e.g., cyclone); PM = particulate matter; RDF = refuse-derived fuel; SD/ESP = spray dryer/electrostatic precipitator; SD/FF = spray dryer/fabric filter; UNC = uncontrolled; W/OSB = Waferboard/Oriented Strandboard Manufacturing; WS = wet scrubber; WS/FF = wet scrubber or fabric filter; UNC/PM = uncontrolled or PM control.

Table 4-15. Emissions Factor Uncertainty Ratios Based on Normalized Sampling Distribution of Emissions Factor (Mean), Listed by Increasing CV^2 Value

			Distribution Statistic→	Uncertainty Ratio																																											
				10th Percentile						25th Percentile						Median						Mean						75th Percentile						90th Percentile						95th Percentile						99th Percentile					
CV^2	Pollutant	Control	Industry/Source	*n*=1	*n*=3	*n*=5	*n*=10	*n*=20	*n*=25	*n*=1	*n*=3	*n*=5	*n*=10	*n*=20	*n*=25	*n*=1	*n*=3	*n*=5	*n*=10	*n*=20	*n*=25	*n*=1	*n*=3	*n*=5	*n*=10	*n*=20	*n*=25	*n*=1	*n*=3	*n*=5	*n*=10	*n*=20	*n*=25	*n*=1	*n*=3	*n*=5	*n*=10	*n*=20	*n*=25	*n*=1	*n*=3	*n*=5	*n*=10	*n*=20	*n*=25	*n*=1	*n*=3	*n*=5	*n*=10	*n*=20	*n*=25
0.07	Nitrogen oxides	UNC	Refuse Combustion, Mass Burn Waterwall	0.64	0.80	0.84	0.89	0.92	0.93	0.82	0.89	0.92	0.94	0.96	0.96	1.01	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.19	1.11	1.08	1.06	1.04	1.04	1.35	1.20	1.16	1.11	1.08	1.07	1.44	1.26	1.20	1.14	1.10	1.09	1.58	1.35	1.28	1.19	1.14	1.12
0.10	PM-filt	WS	Wood Combustion	0.64	0.78	0.82	0.88	0.91	0.92	0.77	0.87	0.90	0.93	0.95	0.96	0.96	0.98	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.17	1.11	1.09	1.07	1.05	1.04	1.42	1.24	1.18	1.13	1.09	1.08	1.59	1.32	1.25	1.17	1.12	1.11	1.92	1.51	1.36	1.25	1.17	1.16
0.14	PM-filt	UNC	Refuse Combustion, RDF	0.84	0.90	0.92	0.95	0.96	0.97	0.91	0.95	0.96	0.97	0.98	0.98	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.08	1.05	1.04	1.03	1.02	1.02	1.18	1.10	1.08	1.05	1.04	1.03	1.23	1.13	1.10	1.07	1.05	1.04	1.35	1.19	1.15	1.10	1.07	1.06
0.18	PM-filt	MC	Wood Combustion, Dry Wood	0.55	0.71	0.77	0.84	0.88	0.89	0.70	0.83	0.87	0.91	0.93	0.94	0.93	0.97	0.98	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.22	1.14	1.12	1.08	1.06	1.05	1.54	1.32	1.25	1.17	1.12	1.11	1.79	1.44	1.33	1.23	1.16	1.14	2.35	1.72	1.51	1.34	1.25	1.22
0.21	PM-filt	UNC	Wood Combustion, Dry Wood	0.55	0.71	0.77	0.84	0.88	0.90	0.69	0.82	0.87	0.91	0.93	0.94	0.92	0.97	0.98	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.21	1.14	1.11	1.08	1.06	1.05	1.56	1.32	1.25	1.18	1.12	1.11	1.80	1.45	1.34	1.23	1.16	1.14	2.38	1.72	1.54	1.34	1.24	1.22
0.21	PM-filt	UNC	Refuse Combustion, Mass Burn	0.71	0.83	0.86	0.90	0.93	0.94	0.82	0.90	0.92	0.95	0.96	0.97	0.97	0.99	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.15	1.09	1.07	1.05	1.04	1.03	1.32	1.19	1.14	1.10	1.07	1.06	1.45	1.25	1.19	1.13	1.09	1.08	1.74	1.39	1.29	1.20	1.14	1.12
0.23	PM-filt	SD/ESP	Refuse Combustion, Mass Burn	0.68	0.81	0.85	0.89	0.92	0.93	0.80	0.89	0.91	0.94	0.96	0.96	0.96	0.99	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.15	1.10	1.08	1.06	1.04	1.04	1.37	1.21	1.16	1.11	1.08	1.07	1.52	1.28	1.21	1.15	1.11	1.09	1.82	1.43	1.32	1.22	1.16	1.13
0.25	Sulfur dioxide	UNC	Refuse Combustion	0.39	0.64	0.72	0.80	0.86	0.87	0.62	0.80	0.84	0.89	0.92	0.93	0.95	0.99	0.99	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.32	1.19	1.15	1.10	1.07	1.07	1.68	1.38	1.30	1.21	1.14	1.13	1.90	1.50	1.38	1.26	1.19	1.17	2.38	1.73	1.55	1.38	1.27	1.24
0.29	PM-filt	UNC	Wood Combustion, Wet Wood	0.42	0.62	0.70	0.78	0.84	0.85	0.60	0.76	0.81	0.87	0.91	0.92	0.86	0.94	0.96	0.98	0.99	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.25	1.18	1.15	1.11	1.08	1.07	1.72	1.44	1.35	1.25	1.17	1.16	2.10	1.63	1.48	1.33	1.23	1.21	2.99	2.07	1.79	1.52	1.36	1.32
0.31	Hydrogen chloride	UNC	Refuse Combustion	0.31	0.59	0.68	0.77	0.84	0.85	0.56	0.76	0.81	0.87	0.91	0.92	0.93	0.98	0.98	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.36	1.21	1.17	1.12	1.09	1.08	1.77	1.44	1.34	1.24	1.17	1.15	2.05	1.58	1.46	1.32	1.22	1.19	2.61	1.87	1.66	1.47	1.32	1.28
CV^2 $\leq$ 0.5																																																			
0.63	Arsenic	SD FF	Refuse Combustion, Mass Burn	0.46	0.65	0.72	0.80	0.86	0.87	0.64	0.78	0.84	0.88	0.92	0.93	0.88	0.96	0.98	0.99	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.24	1.17	1.14	1.10	1.08	1.07	1.68	1.40	1.31	1.22	1.15	1.14	1.99	1.56	1.42	1.30	1.20	1.18	2.82	1.89	1.67	1.44	1.30	1.27
0.64	Benzene	FF	Asphalt, Drum Mix	0.40	0.60	0.67	0.76	0.83	0.84	0.56	0.74	0.79	0.86	0.90	0.91	0.84	0.94	0.96	0.98	0.99	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.23	1.19	1.16	1.12	1.09	1.08	1.82	1.48	1.39	1.26	1.18	1.16	2.21	1.69	1.54	1.35	1.25	1.22	3.31	2.17	1.87	1.55	1.37	1.33
0.65	Nitrogen oxides	UNC	Wood Combustion	0.44	0.63	0.70	0.78	0.84	0.86	0.61	0.77	0.82	0.87	0.91	0.92	0.87	0.94	0.97	0.98	0.99	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.24	1.18	1.14	1.11	1.08	1.07	1.71	1.44	1.34	1.24	1.17	1.15	2.05	1.62	1.47	1.32	1.22	1.20	2.99	2.02	1.75	1.50	1.33	1.30
0.72	Carbon monoxide	UNC	Wood Combustion	0.19	0.47	0.58	0.69	0.78	0.81	0.41	0.66	0.75	0.82	0.88	0.89	0.81	0.94	0.96	0.98	0.99	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.38	1.26	1.21	1.16	1.12	1.10	2.04	1.60	1.47	1.33	1.23	1.21	2.55	1.86	1.64	1.44	1.31	1.27	3.69	2.35	1.98	1.67	1.46	1.40
0.73	PM-cond (Inorganic)	WS/FF	Asphalt, Drum Mixer	0.33	0.55	0.63	0.72	0.80	0.82	0.51	0.70	0.76	0.83	0.88	0.89	0.81	0.92	0.94	0.97	0.98	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.26	1.20	1.18	1.14	1.10	1.09	1.86	1.55	1.44	1.32	1.22	1.20	2.37	1.80	1.63	1.45	1.30	1.27	3.90	2.52	2.07	1.73	1.49	1.42
0.76	Lead	SD/ESP	Refuse Combustion, Mass Burn	0.24	0.47	0.55	0.66	0.75	0.77	0.42	0.63	0.69	0.78	0.85	0.86	0.72	0.88	0.92	0.95	0.97	0.98	1.00	1.00	1.00	1.00	1.00	1.00	1.23	1.23	1.20	1.16	1.12	1.11	2.07	1.65	1.55	1.39	1.28	1.25	2.75	2.03	1.81	1.57	1.40	1.36	4.89	2.98	2.43	2.01	1.64	1.58
0.76	PM-filt	DSI/FF	Refuse Combustion, Mass Burn	0.14	0.42	0.54	0.66	0.76	0.79	0.35	0.62	0.72	0.80	0.86	0.88	0.76	0.92	0.95	0.98	0.99	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.40	1.29	1.24	1.17	1.13	1.11	2.18	1.68	1.51	1.37	1.26	1.23	2.74	1.95	1.71	1.50	1.34	1.30	3.97	2.53	2.12	1.73	1.51	1.46
0.79	PM-filt	ESP	Refuse Combustion, Mass Burn	0.20	0.40	0.49	0.61	0.71	0.74	0.34	0.57	0.65	0.75	0.82	0.84	0.66	0.84	0.88	0.93	0.96	0.97	1.00	1.00	1.00	1.00	1.00	1.00	1.22	1.24	1.22	1.17	1.14	1.13	2.19	1.77	1.63	1.47	1.33	1.30	3.00	2.24	1.98	1.69	1.47	1.41	5.76	3.48	2.84	2.19	1.75	1.64
0.80	Cadmium	SD/ESP	Refuse Combustion, Mass Burn	0.24	0.45	0.54	0.65	0.74	0.77	0.40	0.62	0.69	0.78	0.84	0.86	0.71	0.86	0.91	0.95	0.98	0.98	1.00	1.00	1.00	1.00	1.00	1.00	1.25	1.23	1.21	1.17	1.13	1.11	2.06	1.70	1.56	1.41	1.29	1.25	2.79	2.06	1.82	1.57	1.40	1.35	4.77	2.97	2.46	1.93	1.65	1.55

(continued)

Table 4-15. (continued)

			Distribution Statistic→	Uncertainty Ratio																																															
				10th Percentile						25th Percentile						Median						Mean						75th Percentile						90th Percentile						95th Percentile						99th Percentile					
CV^2	Pollutant	Control	Industry/Source	n=1	n=3	n=5	n=10	n=20	n=25	n=1	n=3	n=5	n=10	n=20	n=25	n=1	n=3	n=5	n=10	n=20	n=25	n=1	n=3	n=5	n=10	n=20	n=25	n=1	n=3	n=5	n=10	n=20	n=25	n=1	n=3	n=5	n=10	n=20	n=25	n=1	n=3	n=5	n=10	n=20	n=25	n=1	n=3	n=5	n=10	n=20	n=25
0.81	Carbon monoxide	UNC	Refuse Combustion, Mass Burn	0.42	0.61	0.69	0.77	0.84	0.85	0.58	0.75	0.81	0.86	0.90	0.91	0.86	0.94	0.96	0.98	0.99	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.25	1.18	1.15	1.11	1.08	1.08	1.76	1.45	1.35	1.25	1.18	1.16	2.17	1.65	1.50	1.34	1.24	1.21	3.10	2.11	1.86	1.55	1.36	1.32
0.81	PM-filt	SD/FF	Refuse Combustion, Mass Burn	0.23	0.44	0.52	0.64	0.74	0.76	0.38	0.60	0.68	0.77	0.84	0.85	0.68	0.86	0.90	0.95	0.97	0.97	1.00	1.00	1.00	1.00	1.00	1.00	1.23	1.24	1.21	1.17	1.13	1.12	2.08	1.72	1.59	1.42	1.30	1.27	2.88	2.10	1.86	1.61	1.42	1.37	5.10	3.08	2.56	1.98	1.69	1.65
0.5 < CV^2 ≤ 1.0																																																			
1.01	HCl	SD/FF	Refuse Combustion, Mass Burn	0.06	0.29	0.41	0.55	0.67	0.70	0.19	0.49	0.60	0.72	0.81	0.82	0.57	0.83	0.89	0.95	0.97	0.98	1.00	1.00	1.00	1.00	1.00	1.00	1.36	1.33	1.28	1.23	1.17	1.15	2.47	1.91	1.73	1.52	1.36	1.32	3.39	2.34	2.05	1.71	1.48	1.44	5.74	3.56	2.75	2.10	1.77	1.65
1.18	Mercury	SD/FF	Refuse Combustion, Mass Burn	0.13	0.31	0.42	0.54	0.65	0.68	0.27	0.48	0.58	0.68	0.77	0.79	0.56	0.75	0.83	0.90	0.94	0.95	1.00	1.00	1.00	1.00	1.00	1.00	1.15	1.22	1.23	1.20	1.16	1.16	2.24	1.93	1.76	1.57	1.42	1.38	3.36	2.60	2.19	1.88	1.61	1.56	7.26	4.43	3.44	2.80	2.11	1.91
1.33	Formaldehyde	FF	Asphalt, Drum Mix	0.17	0.36	0.46	0.58	0.68	0.71	0.31	0.52	0.62	0.72	0.80	0.82	0.61	0.79	0.86	0.92	0.95	0.96	1.00	1.00	1.00	1.00	1.00	1.00	1.20	1.24	1.22	1.19	1.15	1.14	2.20	1.86	1.70	1.50	1.38	1.34	3.17	2.37	2.05	1.76	1.53	1.48	6.30	3.80	3.05	2.35	1.87	1.78
1.39	Cadmium	UNC/PM	Wood Combustion	0.02	0.17	0.27	0.43	0.57	0.61	0.09	0.34	0.46	0.61	0.73	0.75	0.37	0.69	0.80	0.89	0.94	0.95	1.00	1.00	1.00	1.00	1.00	1.00	1.14	1.32	1.32	1.27	1.21	1.19	2.65	2.21	1.97	1.71	1.50	1.45	4.11	2.90	2.44	2.01	1.69	1.64	8.08	4.68	3.69	2.82	2.19	2.07
1.0 < CV^2 ≤ 1.5																																																			
1.53	PM-filt	FF	Asphalt, Drum Mixer	0.25	0.47	0.55	0.66	0.75	0.77	0.41	0.63	0.70	0.78	0.84	0.86	0.72	0.87	0.91	0.95	0.97	0.98	1.00	1.00	1.00	1.00	1.00	1.00	1.25	1.23	1.20	1.16	1.13	1.11	2.04	1.67	1.55	1.40	1.28	1.25	2.71	2.01	1.81	1.58	1.40	1.35	4.69	2.91	2.46	1.98	1.64	1.54
1.61	PM-filt	ESP	Refuse Combustion, RDF	0.02	0.10	0.16	0.27	0.38	0.42	0.06	0.20	0.29	0.41	0.52	0.57	0.22	0.44	0.56	0.67	0.77	0.81	1.00	1.00	1.00	1.00	1.00	1.00	0.72	0.99	1.09	1.13	1.20	1.19	2.13	2.09	2.15	2.02	1.81	1.74	3.97	3.55	3.34	2.92	2.39	2.25	12.84	9.03	7.01	5.51	4.24	3.76
1.70	Nickel	SD/FF	Refuse Combustion, Mass Burn	0.17	0.38	0.47	0.59	0.69	0.72	0.32	0.54	0.63	0.73	0.80	0.82	0.63	0.82	0.87	0.93	0.96	0.96	1.00	1.00	1.00	1.00	1.00	1.00	1.20	1.24	1.22	1.19	1.14	1.13	2.16	1.80	1.67	1.48	1.36	1.31	3.05	2.24	2.00	1.71	1.50	1.46	5.94	3.56	3.05	2.31	1.93	1.78
1.78	PM-filt	FF	Asphalt, Batch Mixer	0.13	0.30	0.39	0.52	0.63	0.66	0.25	0.46	0.56	0.67	0.76	0.78	0.53	0.74	0.83	0.89	0.94	0.94	1.00	1.00	1.00	1.00	1.00	1.00	1.10	1.23	1.23	1.20	1.17	1.15	2.28	1.93	1.79	1.59	1.44	1.41	3.42	2.64	2.22	1.95	1.65	1.61	7.08	4.60	3.72	2.82	2.11	2.03
1.80	PM-cond (Organic)	WS/FF	Asphalt, Drum Mixer	0.01	0.07	0.13	0.22	0.32	0.35	0.05	0.15	0.23	0.35	0.44	0.48	0.16	0.35	0.46	0.58	0.66	0.71	1.00	1.00	1.00	1.00	1.00	1.00	0.58	0.85	0.96	1.04	1.11	1.15	1.90	1.93	1.88	2.07	1.97	1.89	3.66	3.64	3.32	3.15	2.81	2.64	15.09	11.24	10.34	7.88	6.55	5.58
1.5<CV^2 ≤ 2.0																																																			
2.24	Sulfur dioxide	UNC	Wood Combustion	0.03	0.13	0.20	0.31	0.44	0.48	0.08	0.25	0.34	0.46	0.58	0.62	0.26	0.51	0.61	0.73	0.82	0.85	1.00	1.00	1.00	1.00	1.00	1.00	0.82	1.07	1.17	1.17	1.17	1.18	2.11	2.17	2.08	1.92	1.66	1.60	3.82	3.37	3.01	2.51	2.10	2.03	13.32	6.80	6.56	4.97	3.95	3.69
2.28	PM-filt	MC	Wood Combustion, Wet Wood	0.06	0.28	0.40	0.55	0.67	0.70	0.20	0.49	0.60	0.72	0.81	0.82	0.57	0.83	0.89	0.95	0.97	0.98	1.00	1.00	1.00	1.00	1.00	1.00	1.32	1.33	1.29	1.22	1.17	1.15	2.42	1.93	1.75	1.52	1.37	1.33	3.50	2.37	2.06	1.72	1.50	1.45	5.81	3.40	2.76	2.13	1.77	1.70
2.51	Lead	UNC/PM	Wood Combustion	0.00	0.09	0.17	0.31	0.46	0.50	0.04	0.22	0.33	0.49	0.62	0.66	0.22	0.56	0.68	0.79	0.89	0.89	1.00	1.00	1.00	1.00	1.00	1.00	0.93	1.21	1.27	1.25	1.24	1.22	2.61	2.34	2.17	1.93	1.68	1.61	4.32	3.50	2.95	2.43	1.98	1.89	11.73	6.70	5.21	3.73	2.77	2.58
2 < CV^2 ≤ 2.5																																																			
2.62	Chromium	UNC/PM	Wood Combustion	0.01	0.10	0.19	0.34	0.48	0.53	0.05	0.24	0.37	0.53	0.66	0.69	0.26	0.59	0.71	0.85	0.90	0.92	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.31	1.29	1.29	1.24	1.22	2.82	2.38	2.12	1.86	1.63	1.57	4.55	3.22	2.91	2.28	1.92	1.79	9.49	5.75	4.83	3.27	2.57	2.36
2.77	PM-cond	UNC	Wood Combustion	0.12	0.31	0.40	0.53	0.64	0.67	0.24	0.47	0.56	0.68	0.76	0.79	0.52	0.76	0.83	0.90	0.94	0.95	1.00	1.00	1.00	1.00	1.00	1.00	1.13	1.23	1.22	1.20	1.18	1.16	2.28	1.96	1.80	1.59	1.44	1.39	3.35	2.60	2.29	1.89	1.62	1.56	7.56	4.19	3.52	2.59	2.06	1.90
3.49	PM-cond (Inorganic)	FF	Asphalt, Batch Mixer	0.03	0.13	0.21	0.32	0.44	0.47	0.08	0.25	0.34	0.47	0.58	0.62	0.26	0.52	0.61	0.74	0.82	0.85	1.00	1.00	1.00	1.00	1.00	1.00	0.79	1.08	1.16	1.20	1.19	1.19	2.12	2.22	2.03	1.91	1.74	1.66	4.01	3.44	2.99	2.55	2.24	2.09	11.84	7.58	6.80	4.69	3.71	3.40
3.50	Nickel	UNC/PM	Wood Combustion	0.00	0.07	0.15	0.28	0.44	0.48	0.03	0.20	0.32	0.47	0.61	0.64	0.20	0.52	0.65	0.79	0.88	0.90	1.00	1.00	1.00	1.00	1.00	1.00	0.89	1.22	1.27	1.30	1.26	1.25	2.50	2.42	2.24	1.99	1.72	1.66	4.33	3.57	3.17	2.50	2.05	1.94	12.04	6.82	5.18	3.79	2.78	2.61
5.37	Formaldehyde	UNC/PM	Wood Combustion	0.02	0.08	0.14	0.25	0.37	0.39	0.05	0.17	0.26	0.38	0.51	0.53	0.19	0.38	0.51	0.63	0.76	0.76	1.00	1.00	1.00	1.00	1.00	1.00	0.66	0.87	1.01	1.09	1.16	1.12	1.93	1.91	2.02	1.86	1.73	1.65	3.69	3.13	3.10	2.54	2.26	2.09	13.25	7.93	6.75	5.01	4.15	4.09
6.83	PM-filt	UNC	W/OSB, Hot Press	0.20	0.39	0.49	0.60	0.70	0.73	0.34	0.56	0.65	0.74	0.82	0.83	0.64	0.83	0.88	0.93	0.96	0.97	1.00	1.00	1.00	1.00	1.00	1.00	1.22	1.23	1.21	1.17	1.13	1.12	2.12	1.76	1.61	1.46	1.33	1.30	2.97	2.19	1.95	1.67	1.49	1.44	5.58	3.58	3.07	2.31	1.90	1.77
7.40	Mercury	UNC/PM	Wood Combustion	0.00	0.03	0.08	0.18	0.31	0.36	0.01	0.10	0.19	0.34	0.49	0.53	0.08	0.33	0.49	0.66	0.79	0.81	1.00	1.00	1.00	1.00	1.00	1.00	0.56	1.00	1.16	1.26	1.25	1.26	2.28	2.52	2.39	2.13	1.92	1.89	4.71	4.03	3.58	3.04	2.56	2.42	14.34	10.11	8.13	5.41	4.13	3.51
7.74	Arsenic	UNC/PM	Wood Combustion	0.00	0.03	0.08	0.18	0.33	0.37	0.01	0.11	0.20	0.34	0.51	0.54	0.08	0.36	0.51	0.67	0.82	0.84	1.00	1.00	1.00	1.00	1.00	1.00	0.56	1.06	1.19	1.29	1.28	1.28	2.29	2.64	2.44	2.16	1.89	1.82	4.52	4.29	3.54	2.92	2.35	2.24	14.56	8.80	6.95	5.14	3.52	3.29
9.81	Acetaldehyde	UNC/PM	Wood Combustion	0.02	0.09	0.15	0.26	0.38	0.42	0.06	0.18	0.27	0.40	0.53	0.57	0.20	0.42	0.53	0.68	0.79	0.83	1.00	1.00	1.00	1.00	1.00	1.00	0.69	0.98	1.10	1.19	1.22	1.21	2.29	2.23	2.23	2.04	1.81	1.74	4.33	3.82	3.43	2.81	2.34	2.18	14.24	9.12	7.32	5.32	3.95	3.55
12.25	Benzene	UNC/PM	Wood Combustion	0.01	0.05	0.09	0.16	0.27	0.29	0.03	0.11	0.18	0.28	0.40	0.42	0.12	0.28	0.39	0.52	0.65	0.67	1.00	1.00	1.00	1.00	1.00	1.00	0.48	0.78	0.91	1.02	1.13	1.12	1.63	2.00	2.20	2.02	1.98	1.91	3.65	3.66	3.55	3.14	2.87	2.66	14.37	12.01	9.54	7.33	5.30	5.94
103.44	PM-cond (Organic)	FF	Asphalt, Batch Mixer	0.08	0.33	0.46	0.59	0.70	0.73	0.24	0.54	0.65	0.76	0.83	0.85	0.63	0.87	0.93	0.96	0.98	0.98	1.00	1.00	1.00	1.00	1.00	1.00	1.35	1.31	1.26	1.20	1.15	1.14	2.41	1.84	1.64	1.45	1.32	1.29	3.23	2.22	1.92	1.63	1.43	1.38	5.40	3.13	2.45	1.97	1.66	1.57
CV^2 > 2.5																																																			

DSI/FF = dry sorbent injection/fabric filter; ESP = electrostatic precipitator; FF = fabric filter; MC = mechanical collector (e.g., cyclone); PM = particulate matter; RDF = refuse-derived fuel; SD/ESP = spray dryer/electrostatic precipitator; SD/FF = spray dryer/fabric filter; UNC = uncontrolled; W/OSB = Waferboard/Oriented Strandboard Manufacturing; WS = wet scrubber; WS/FF = wet scrubber or fabric filter; UNC/PM = uncontrolled or PM control.

Table 4-16. Composite Uncertainty Ratios

Pollutant	Number of Ratios Averaged	Uncertainty Ratio																							
		10th Percentile						25th Percentile						Median						Mean					
		n=1	*n*=3	*n*=5	*n*=10	*n*=20	*n*=25	*n*=1	*n*=3	*n*=5	*n*=10	*n*=20	*n*=25	*n*=1	*n*=3	*n*=5	*n*=10	*n*=20	*n*=25	*n*=1	*n*=3	*n*=5	*n*=10	*n*=20	*n*=25
HAPs	12	0.13	0.27	0.35	0.46	0.57	0.60	0.22	0.40	0.49	0.60	0.70	0.73	0.45	0.66	0.75	0.84	0.90	0.91	1.00	1.00	1.00	1.00	1.00	1.00
PM-condensable	18	0.15	0.31	0.39	0.50	0.61	0.64	0.26	0.45	0.54	0.64	0.73	0.76	0.51	0.71	0.79	0.86	0.92	0.93	1.00	1.00	1.00	1.00	1.00	1.00
PM-filterable, controlled	10	0.29	0.47	0.55	0.65	0.73	0.76	0.43	0.62	0.69	0.77	0.83	0.85	0.70	0.84	0.89	0.93	0.96	0.96	1.00	1.00	1.00	1.00	1.00	1.00
PM-filterable, uncontrolled	5	0.42	0.59	0.65	0.74	0.80	0.82	0.55	0.71	0.77	0.83	0.88	0.89	0.79	0.90	0.93	0.96	0.98	0.98	1.00	1.00	1.00	1.00	1.00	1.00
Gaseous criteria pollutants	6	0.35	0.55	0.62	0.71	0.78	0.80	0.52	0.69	0.75	0.81	0.86	0.87	0.79	0.89	0.91	0.94	0.96	0.97	1.00	1.00	1.00	1.00	1.00	1.00

Pollutant	Uncertainty Ratio																							
	75th Percentile						90th Percentile						95th Percentile						99th Percentile					
	n=1	*n*=3	*n*=5	*n*=10	*n*=20	*n*=25	*n*=1	*n*=3	*n*=5	*n*=10	*n*=20	*n*=25	*n*=1	*n*=3	*n*=5	*n*=10	*n*=20	*n*=25	*n*=1	*n*=3	*n*=5	*n*=10	*n*=20	*n*=25
HAPs	1.01	1.16	1.19	1.19	1.17	1.16	2.19	1.99	1.88	1.68	1.52	1.48	3.50	2.81	2.50	2.10	1.81	1.73	8.65	5.51	4.44	3.32	2.57	2.45
PM-condensable	1.07	1.18	1.19	1.19	1.16	1.15	2.17	1.93	1.81	1.62	1.47	1.43	3.35	2.64	2.34	1.98	1.72	1.64	7.80	4.94	3.99	3.01	2.36	2.25
PM-filterable, controlled	1.18	1.19	1.18	1.14	1.12	1.11	1.96	1.66	1.56	1.42	1.31	1.28	2.71	2.09	1.88	1.65	1.46	1.41	5.13	3.37	2.76	2.22	1.83	1.73
PM-filterable, uncontrolled	1.18	1.17	1.15	1.12	1.09	1.08	1.77	1.51	1.42	1.31	1.22	1.20	2.30	1.80	1.62	1.45	1.32	1.29	3.87	2.60	2.22	1.81	1.54	1.47
Gaseous criteria pollutants	1.20	1.16	1.15	1.12	1.09	1.09	1.77	1.54	1.45	1.34	1.24	1.22	2.32	1.87	1.70	1.50	1.36	1.33	4.51	2.73	2.49	2.04	1.75	1.68

HAP = hazardous air pollutant; PM = particulate matter.

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Table 4-17. Composite Emissions Factor Uncertainty Ratios Based on Normalized Sampling Distribution of Emissions Factor (Mean) for HAP

Distribution Statistic	Number of Emissions Tests Used to Determine AP-42 Emissions Factor			
	***n* < 3**	**3 ≤ *n* < 10**	**10 ≤ *n* < 25**	***n* ≥ 25**
10th Percentile	0.1	0.3	0.5	0.6
25th Percentile	0.2	0.4	0.6	0.7
Median	0.5	0.7	0.8	0.9
Mean	1.0	1.0	1.0	1.0
75th Percentile	1.0	1.2	1.2	1.2
90th Percentile	2.2	2.0	1.7	1.5
95th Percentile	3.5	2.8	2.1	1.7

HAP = hazardous air pollutant.

Table 4-18. Composite Emissions Factor Uncertainty Ratios Based on Normalized Sampling Distribution of Emissions Factor (Mean) for PM-Condensable

Distribution Statistic	Number of Emissions Tests Used to Determine AP-42 Emissions Factor			
	***n* < 3**	**3 ≤ *n* < 10**	**10 ≤ *n* < 25**	***n* ≥ 25**
10th Percentile	0.1	0.3	0.5	0.6
25th Percentile	0.3	0.4	0.6	0.8
Median	0.5	0.7	0.9	0.9
Mean	1.0	1.0	1.0	1.0
75th Percentile	1.1	1.2	1.2	1.2
90th Percentile	2.2	1.9	1.6	1.4
95th Percentile	3.3	2.6	2.0	1.6

PM = particulate matter.

Table 4-19. Composite Emissions Factor Uncertainty Ratios Based on Normalized Sampling Distribution of Emissions Factor (Mean) for PM-Filterable, Controlled

Distribution Statistic	Number of Emissions Tests Used to Determine AP-42 Emissions Factor			
	***n* < 3**	**3 ≤ *n* < 10**	**10 ≤ *n* < 25**	***n* ≥ 25**
10th Percentile	0.3	0.5	0.7	0.8
25th Percentile	0.4	0.6	0.8	0.8
Median	0.7	0.8	0.9	1.0
Mean	1.0	1.0	1.0	1.0
75th Percentile	1.2	1.2	1.1	1.1
90th Percentile	2.0	1.7	1.4	1.3
95th Percentile	2.7	2.1	1.7	1.4

PM = particulate matter.

Table 4-20. Composite Emissions Factor Uncertainty Ratios Based on Normalized Sampling Distribution of Emissions Factor (Mean) for PM-Filterable, Uncontrolled

Distribution Statistic	Number of Emissions Tests Used to Determine AP-42 Emissions Factor			
	$n < 3$	$3 \leq n < 10$	$10 \leq n < 25$	$n \geq 25$
10th Percentile	0.4	0.6	0.7	0.8
25th Percentile	0.6	0.7	0.8	0.9
Median	0.8	0.9	1.0	1.0
Mean	1.0	1.0	1.0	1.0
75th Percentile	1.2	1.2	1.1	1.1
90th Percentile	1.8	1.5	1.3	1.2
95th Percentile	2.3	1.8	1.5	1.3

PM = particulate matter.

Table 4-21. Composite Emissions Factor Uncertainty Ratios Based on Normalized Sampling Distribution of Emissions Factor (Mean) for Gaseous Criteria Pollutants

Distribution Statistic	Number of Emissions Tests Used to Determine AP-42 Emissions Factor			
	$n < 3$	$3 \leq n < 10$	$10 \leq n < 25$	$n \geq 25$
10th Percentile	0.4	0.5	0.7	0.8
25th Percentile	0.5	0.7	0.8	0.9
Median	0.8	0.9	0.9	1.0
Mean	1.0	1.0	1.0	1.0
75th Percentile	1.2	1.2	1.1	1.1
90th Percentile	1.8	1.5	1.3	1.2
95th Percentile	2.3	1.9	1.5	1.3

Table 4-22. Correction Factors to Account for Multiple Emissions Units

Pollutant	Target Statistic	Correction Factor			
		Number of Emissions Tests Used to Determine AP-42 Emissions Factor			
		$n < 3$	$3 \leq n < 10$	$10 \leq n < 25$	$n \geq 25$
HAP	10th Percentile	0.05	-0.13	-0.34	-0.49
	25th Percentile	0.15	-0.14	-0.37	-0.51
	Median	0.55	-0.05	-0.32	-0.42
	Mean	2.37	0.62	0.20	0.09
	75th Percentile	1.91	0.38	-0.01	-0.04
	90th Percentile	5.48	1.63	1.00	0.97
	95th Percentile	9.92	3.21	2.22	2.17
PM-condensable	10th Percentile	0.10	-0.13	-0.35	-0.50
	25th Percentile	0.22	-0.11	-0.35	-0.48
	Median	0.50	0.00	-0.27	-0.36
	Mean	0.98	0.37	0.13	0.06
	75th Percentile	1.11	0.34	0.07	0.03
	90th Percentile	2.24	1.11	0.89	0.92
	95th Percentile	3.51	2.04	1.87	1.96
PM-filterable, controlled	10th Percentile	0.10	-0.13	-0.33	-0.44
	25th Percentile	0.17	-0.10	-0.29	-0.38
	Median	0.30	-0.01	-0.16	-0.21
	Mean	0.43	0.16	0.06	0.03
	75th Percentile	0.52	0.20	0.12	0.12
	90th Percentile	0.89	0.63	0.64	0.71
	95th Percentile	1.22	1.03	1.13	1.27
PM-filterable, uncontrolled	10th Percentile	0.08	-0.12	-0.29	-0.38
	25th Percentile	0.14	-0.08	-0.22	-0.29
	Median	0.21	-0.00	-0.09	-0.13
	Mean	0.21	0.07	0.03	0.01
	75th Percentile	0.30	0.14	0.13	0.15
	90th Percentile	0.38	0.37	0.48	0.55
	95th Percentile	0.41	0.54	0.77	0.89
Gaseous criteria pollutants	10th Percentile	-0.01	-0.24	-0.42	-0.51
	25th Percentile	0.05	-0.20	-0.35	-0.42
	Median	0.21	-0.07	-0.19	-0.23
	Mean	0.76	0.28	0.10	0.05
	75th Percentile	0.67	0.26	0.14	0.13
	90th Percentile	1.75	0.94	0.76	0.78
	95th Percentile	3.05	1.75	1.48	1.48

HAP = hazardous air pollutant; PM = particulate matter.

Table 4-23. Relative Accuracy of Calculated Emissions Factors Target Statistic Compared to Hypothetical Population for Selected Target Statistics

Pollutant		10th Percentile	25th Percentile	Median	75th Percentile	90th Percentile	95th Percentile
HAP	Average	2886%	447%	101%	35%	26%	35%
	Median	323%	72%	6%	3%	20%	27%
	Min	-71%	-61%	-47%	-16%	-16%	-24%
	Max	23060%	2773%	514%	261%	129%	128%
PM-condensable	Average	64%	58%	14%	-4%	-6%	-3%
	Median	107%	22%	8%	-2%	-5%	-4%
	Min	-67%	-35%	-16%	-23%	-51%	-62%
	Max	168%	158%	49%	8%	46%	70%
PM-filterable, controlled	Average	123%	59%	20%	0%	5%	12%
	Median	45%	42%	21%	-2%	-5%	-2%
	Min	-52%	-33%	-16%	-15%	-54%	-67%
	Max	594%	276%	77%	21%	66%	100%
PM-filterable uncontrolled	Average	16%	19%	21%	22%	31%	38%
	Median	-27%	-14%	0%	23%	24%	24%
	Min	-49%	-30%	-4%	5%	4%	3%
	Max	200%	158%	105%	46%	62%	88%
Gaseous criteria Pollutants	Average	103%	53%	19%	2%	16%	33%
	Median	-20%	-9%	-3%	-1%	18%	43%
	Min	-54%	-39%	-20%	-14%	-20%	-41%
	Max	672%	370%	151%	26%	50%	97%

HAP = hazardous air pollutant; PM = particulate matter.

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