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Air

Preparation of Fine Particulate Emission Inventories

Student Manual

APTI Course 419B

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Course Description

APTI 419B: *Preparation of Fine Particulate Emission Inventories* is a two-day, resident instructional course designed to present an advanced view of all major, practical aspects of developing an emission inventory for fine particulate matter. The course is intended primarily for employees that have a working knowledge of emission inventory terminology and techniques. The course focuses on the principal stationary nonpoint area and nonroad mobile source categories emitting PM fine particles. For select categories, the course provides a brief summary of how emissions are estimated for EPA's National Emissions Inventory (NEI), and how state/local/tribal agencies can improve upon those estimates. Case studies are used to provide real-world examples of how state or lo9cal agencies collected their own data to prepare inventories that are improvement to the NEI methods. The lessons include information on an overview of fine PM, an overview of the NEI, onroad mobile inventory development, onroad mobile inventory development, point source inventory development, area sources, fugitive dust area sources, combustion area sources, and other related topics.

The course is taught at an instructional level equivalent to that of an advanced, undergraduate university course. The Air Pollution Training Institute curriculum recommends APTI 419B: *Preparation of Fine Particulate Emission Inventories* as an advanced course for all areas of study. The student should have minimally completed a college-level education and APTI Course SI:419A – *Introduction to Emission Inventories* or have a minimum of six months of applicable work experience.

How to Use This Manual

This manual is to be used during classroom instruction and telecourse sessions. The workbook contains instructional objectives and materials for each of the nine subject areas.

Each chapter provides a lesson goal, instructional objectives, subject narrative, and reference materials that may guide your study. A separate Student Workbook also contains a reproduction of lecture slides intended to guide your notetaking. The slides are presented to generally follow the course outline; however, the instructor may on occasion vary the order of presentation or present material not included in the workbook. Each student, therefore, should take thorough notes of the lecture content throughout the course, but not rely solely upon graphic reproductions for the course content.

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LESSON GOAL

Demonstrate, through successful completion of the chapter review exercises, a general understanding of the composition of fine particulate matter in the atmosphere; how the components of fine particulate matter are formed; and the types of sources that contribute to the formation of fine particulate matter.

STUDENT OBJECTIVES

When you have mastered the material in this chapter, you should be able to:

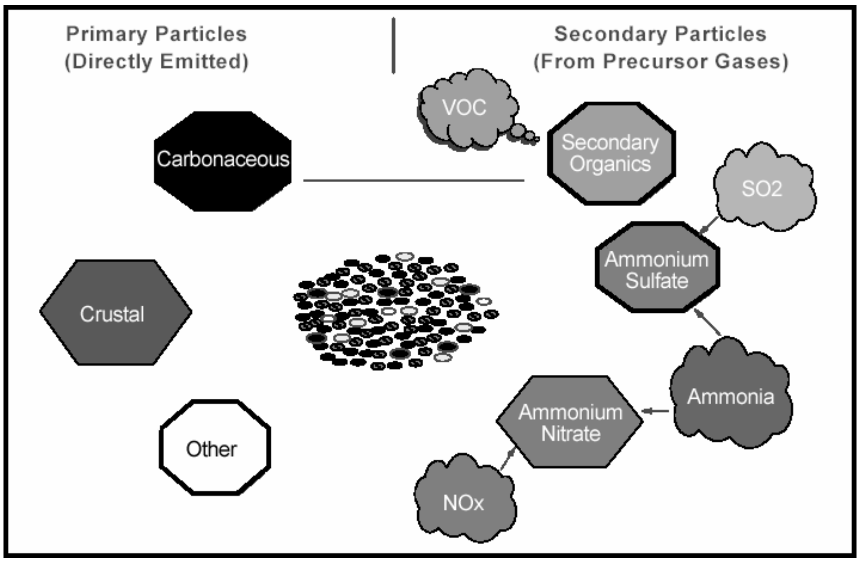
1. Explain the difference between primary and secondary particles.
2. Explain the geographical differences in $PM_{2.5}$ concentrations.
3. Define the term “urban excess.”
4. Describe the sources that emit precursors to the formation of secondary particles.
5. Explain the difference between crustal and carbon emissions.
6. Describe possible control strategies for reducing fine particulate matter concentrations.

Chapter 1: PM $_{2.5}$ Overview

1.1 PM COMPOSITION

In learning about particulate matter it is important to understand the difference between directly emitted or primary particles and secondary particles that are formed in the atmosphere from precursor gases. The distinction is graphically depicted in Figure 1-1. Primary particles consist mostly of elemental carbon (EC) and primary organic aerosol (POA) but will also contain crustal matter and a few other materials. Secondary particles consist of secondary organic aerosol (SOA) formed from volatile organic compounds, ammonium sulfate formed from SO_2 and ammonia gases, and ammonium nitrate, formed from NOx and ammonia gases. The term total carbonaceous matter is used to describe the combined mass of EC, POA and SOA.

Figure 1-1. $PM_{2.5}$ in Ambient Air



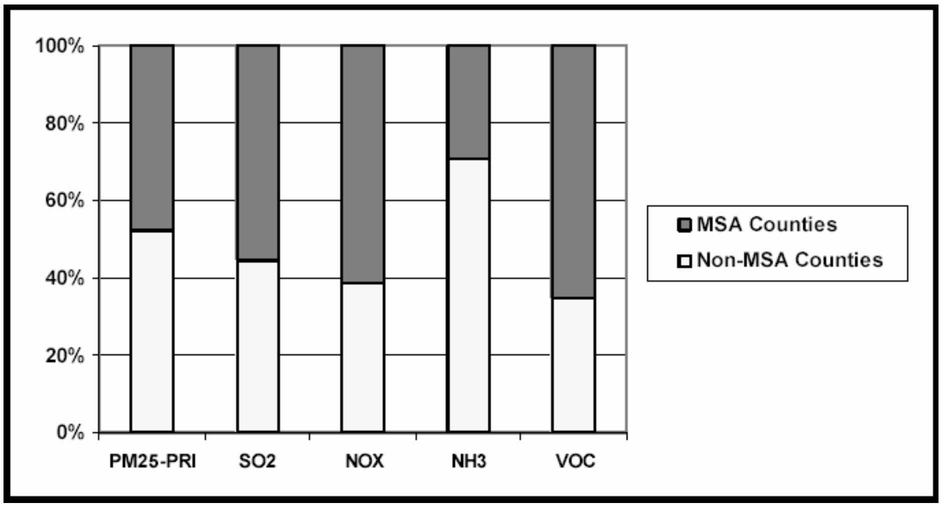
1.1.1 Urban Sites

A review of data from EPA's urban speciation trends network shows that particulate matter in the eastern half of the United States is very homogenous in terms of composition. Another feature of Eastern sites is that the PM is comprised of mainly carbonaceous aerosol and ammonium sulfate in roughly comparable amounts. It is also important to note that the data shows the crustal component of $PM_{2.5}$ is very small in both Western and Eastern urban monitoring sites, with the exception of a few places in the southwest and the central valley of California.

1.1.2 Urban and Rural Comparisons

Figure 1-2 represents the magnitude of the emissions of primary PM and the various precursors throughout the 37 state eastern and central United States. As this figure shows, about half of the PM primary is emitted in the Metropolitan Statistical Areas (MSAs) and about half in the rural areas. This figure also shows that ammonia is the only precursor with larger emissions in the rural areas than in the urban areas. This is due to the large contribution of agriculture to ammonia emissions. However, it should be noted that there is still some ammonia in the urban areas because of agriculture in the urban areas, and mobile sources.

Figure 1-2. MSA to Non-MSA Comparison of PM Emissions



An examination of ambient monitoring data from both urban and rural sites in the speciation trends network shows that there is more sulfate than carbon in the non-urban sites. Sulfate concentrations are only slightly higher in the urban areas than in the surrounding non-urban areas; however, carbon concentrations do increase substantially in the urban areas. The conclusion from this monitoring data is that sulfate is very much a regional problem. Carbon, on the other hand, does have a have a regional component, there is a significant excess of carbon in the urban areas, as evidenced by the marked increase in carbon from rural to urban areas. Urban air quality data is often compared to rural air quality data by noting the amount of “urban excess” for a particular component.

This concept is illustrated using data from the Atlanta area. As shown in Figure 1-3, almost all of the sulfate is associated with the regional contribution. In other words the sulfate that you find in Atlanta is only 10-15% higher in concentration than the sulfate that you find in the surrounding rural sites. The ammonium concentrations show the same pattern as the sulfate concentrations because most of the ammonium is associated with sulfate. The data also show that the nitrate and carbon concentrations are about twice as high in the urban areas as they are in the rural areas, a significant "excess". The top part of the bars in Figure 1-3 shows this "urban excess." It is also important to note that the concentration of total carbonaceous material is greater than the sulfate concentrations in Atlanta and that the concentration of crustal material is very small.

Figure 1-3. Example of "Urban Excess"

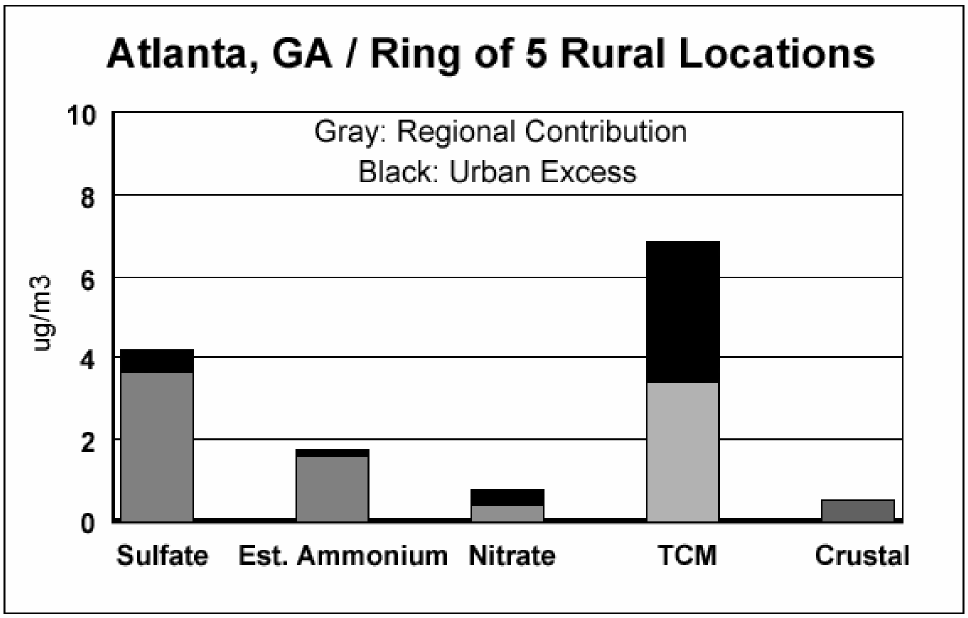
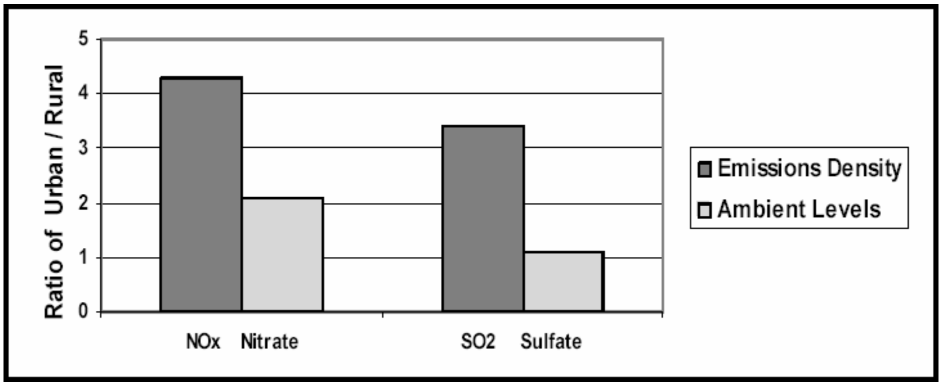


Figure 1-4 shows another comparison of urban and rural information by comparing emission densities with ambient concentrations. The density of NO_x emissions per square mile are about four times higher in urban areas than they are in the rural areas and the concentrations of nitrate are only about twice as high in the urban areas as in the rural areas. This suggests that the higher concentration of ammonium nitrate in urban areas is associated with the higher NOx emissions in the urban areas. Sulfate has a much higher density of emissions in the urban areas, but this ratio is not reflected in the ambient data. As seen in the Atlanta example, there is virtually no urban excess of sulfate there. This lack of urban excess sulfate is found throughout the East.

Figure 1-4. Comparison of Urban –Rural Ratios



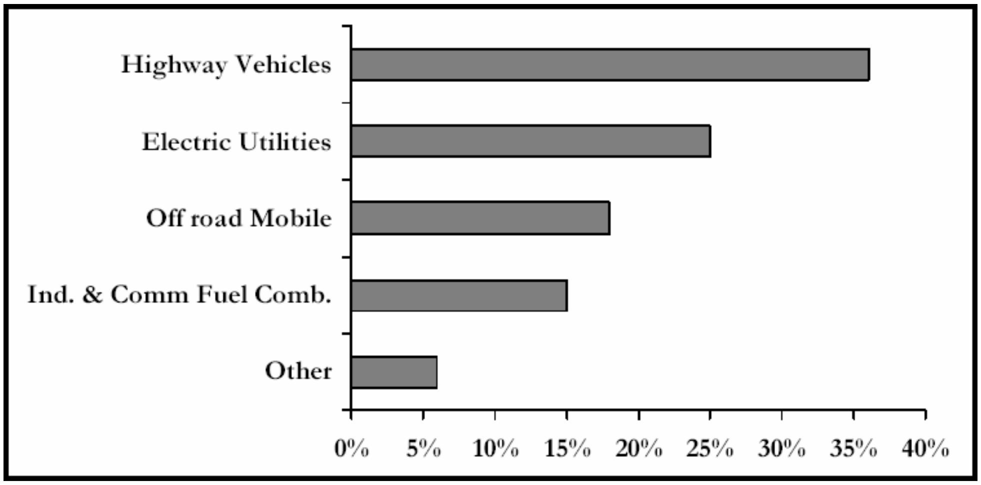
The reason for these differences between the urban excesses for nitrates and sulfates is due at least in part to the following. The NOx to nitrate reaction occurs fairly quickly and much of the transformation occurs before it gets transported very far. Also, nitrate is a little less stable and may revert to other compounds during transport. Sulfate, on the other hand, has a very long lifetime. Once it is converted from SO_2 to sulfate it stays around, sometimes for weeks, as a sulfate particle and can be transported long distances. So, even though the emission density of SO_2 is much higher in the urban areas than it is in the rural areas, the concentrations are fairly uniform over broad geographic areas. As a result, sulfate is considered a regional pollutant in terms of the impact on $PM_{2.5}$.

1.2 $PM_{2.5}$ SOURCE CATEGORIES

1.2.1 NO_x Emissions

National data indicates that NO_x emissions are about 23 million tons a year. Figure 1-5 shows that about 35% of those emissions are from highway vehicles, twenty five percent are from electric utilities, eighteen percent are from mobile sources, and fifteen percent are from industrial and commercial fuel combustion. All of these NO_x emission sources are associated with fuel combustion with the exception of the "Other" category, which is mostly emissions from industrial processes.

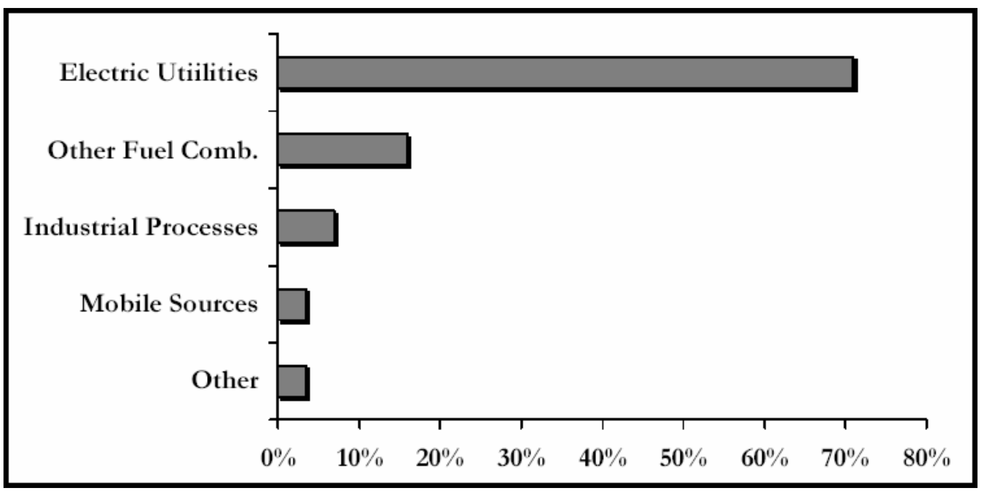
Figure 1-5. NO_x National Emissions



1.2.2 SO_2 Emissions

Figure 1-6 shows the source categories that contribute to the national SO_2 emissions. Electric utilities are responsible for about 70-75% of the emissions of SO_2. As stated previously, even though emissions from sources such as electric utilities tend to be concentrated more in the urban areas where the people live, the impacts of sulfate stretch across large geographic areas, due to the long lifetime of sulfate particles and their ability to transport long distances.

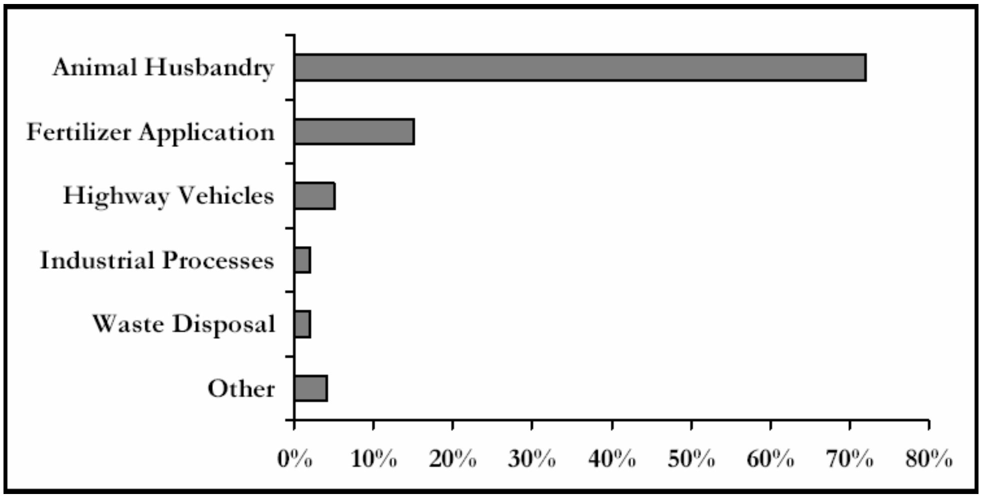
Figure 1-6. SO_2 National Emissions



1.2.3 NH_3 Emissions

Animal husbandry is by far the largest source of ammonia emissions, as indicated in Figure 1-7. The ammonia from animal husbandry operations comes from animal waste and depends on the manner in which the waste is processed. The largest single contributor to the animal husbandry category is cattle, followed by hogs and poultry. Fertilizer application is also a source of approximately 15-20% of the ammonia. There is a small percentage from highway vehicles, which can be important in an urban area.

Figure 1-7. NH_3 National Emissions



Ammonia emissions are spread out across large parts of the east and the Midwest. This is not surprising since this is the farm belt where a lot of the animals are raised. This is consistent with the pattern of measured ammonium ion deposition from the National Atmospheric Deposition Program (NADP). Specifically, there is a qualitatively good agreement between where the ammonia is deposited and where the ammonia emissions are estimated to occur.

1.2.4 Carbon and Crustal Emissions

1.2.4.1 Crustal Emissions

Crustal material mainly comes from fugitive dust. The main sources of fugitive dust are unpaved roads, agricultural tilling, construction, and wind-blown dust which is found to occur mostly in the arid areas of the west. A less significant source of crustal material is fly ash. Fly ash that comes out of a coal- or oil-fired boiler is chemically similar to crustal material.

There is a huge disparity between the crustal data in an emissions inventory and the crustal material found in ambient air quality samples. The ambient data say that there is less than a microgram per cubic meter of crustal material across most of the U.S., with the exception of the southwest. On the other hand, the emissions data indicates that $PM_{2.5}$ emissions are about 2.5 million tons a year, which is comparable to the carbon emissions.

This apparent anomaly can be explained by looking at what happens to the fugitive dust after it is emitted. Fugitive dust emissions are not always transported very far because they are emitted very close to the ground and get trapped in shrubbery, vegetation, buildings, etc. In short, fugitive dust emissions may not all be transported very far from where they are released. When fugitive emissions data are used in air quality dispersion models to simulate the impact of that dust several miles away, these models fail to take into account the fact that a lot of the fugitive dust is going to be deposited within a few hundred yards to a few miles of the source. It is estimated that, on average, about half of the fugitive dust emitted in eastern metropolitan areas are removed by surface features near the source. This inventory adjustment only applies when the inventory is being used in regional chemical transport modeling. Thus, as will be discussed later, this adjustment is made in the emissions processor, not in the emissions inventory.

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In summary, crustal materials are a relatively small part of $PM_{2.5}$ in the ambient air. Fugitive dust is released near the ground, and surface features often capture the dust near its source.

1.2.4.2 Carbon Emissions

Carbon is a huge component of $PM_{2.5}$ in the ambient air. You will recall from the previous section that carbon particles are those that are primary (or directly emitted) and secondary organic aerosol (SOA) particles, which are formed in the atmosphere primarily from VOCs. Primary carbon particles are comprised of elemental (or black) carbon (EC or BC), and those that have an organic structure, primary organic aerosol (POA). On average, approximately 20% of the primary carbon emissions are EC and the other 80% are POA.

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Figure 1-8 shows that primary carbon nationwide comes from wildfires, mobile sources, industrial and commercial combustion, residential heating and open burning, burning of construction debris, industrial and commercial processes; agricultural burning; and fugitive dust. Nationally, there are about 2.5 million tons per year of crustal materials emitted as compared to about 2 million tons per year of primary carbon emissions. However, the carbon emissions are found in a lot more abundance in the ambient air.

Figure 1-8. Primary Carbon in $PM_{2.5}$

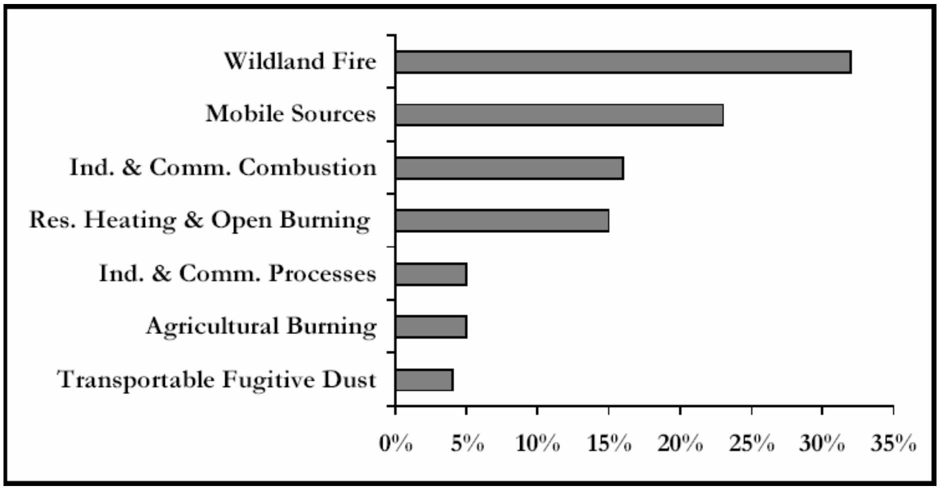


Figure 1-9 shows that the ratio of POA mass to EC mass for most sources is roughly 10 to 1. However, a major exception to this is diesel engines and diesel-powered vehicles, ships, trains and planes, where elemental carbon is a larger fraction than organic carbon. This higher elemental to organic ratio in diesels is due in part to the relatively higher combustion temperatures in diesel-fueled engines, which tends to more completely combust the organic carbon. Conversely, the lower temperature combustion processes will emit more organic matter, as a result of less complete combustion.

It is important to be aware that the organic carbon reported from analysis of a source or ambient sample does not include the oxygens, hydrogens and other elements that comprise the organic carbonaceous matter (OCM). The organic carbon matter is often called primary organic aerosol (POA). The OC to POA multiplier for "fresh" POA in the emissions is usually estimated as

$$POA = OC \times 1.2$$

to approximate the amount of oxygen and hydrogen that is found in POA emissions. In the atmosphere, these particles "age" through oxidation. As such, a different "multiplier" is often applied to the POA by (within) the chemical transport models to account for the "aging" or further oxidation of the POA emissions:

$$POA = OC \times 1.4 \text{ to } 2.4$$

Atmospheric transport and transformation models contain this additional multiplier, but only apply it to the POA, not the EC or SOA. It is important to note that the multiplier is **not** related to the model's estimate of secondary organic aerosol formed in the atmosphere from precursor gases. It is purely to account for further oxidation of primary particle emissions as the aerosol "ages". Transport models contain a separate module to simulate the amount of secondary organic carbon formed in the atmosphere from precursor gases and the OCM of those particles is estimated directly by that module.

The derivation of a multiplier for ambient OC is much more complicated because the sample usually contains both POA *and* SOA, but the relative proportions of each are not known. Thus, a single multiplier is applied to ambient OC, to adjust both primary *and* secondary OC that may be in the sample. The use of a single multiplier introduces error since it is likely that the multipliers would not be the same for both fractions. A multiplier of 1.4 to 2.4 is often used for ambient data.

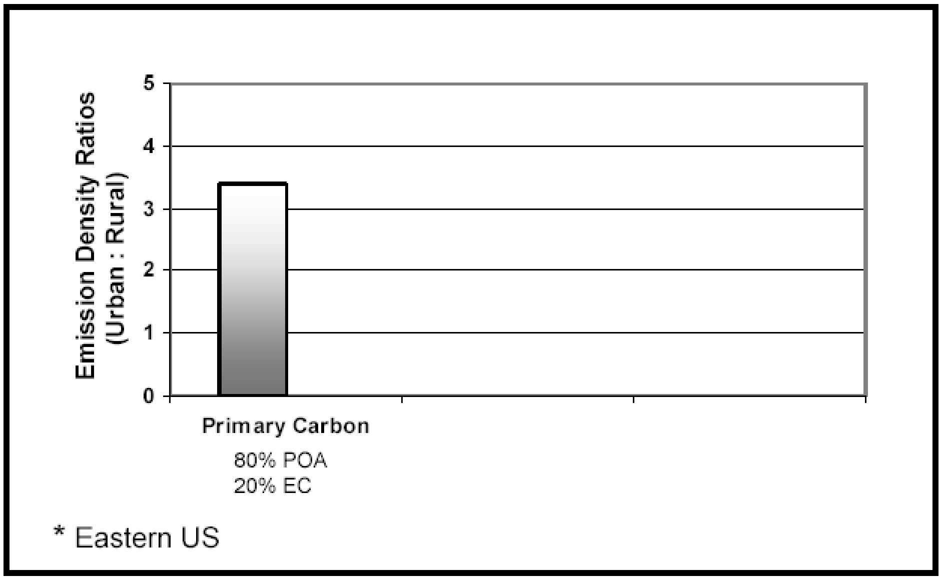
As of this writing, there is no agreed upon standard adjustment that is consistently applied in either monitoring and modeling studies.

Figure 1-9. Characteristics of Primary Carbon

Category	Ratio of Organic Carbon Mass to Elemental Carbon Mass (Average)	Potential Range of Ratios
Forest Fires	9.9	6 – 28
Managed Burning	12	6 – 28
Agricultural Burning	12	2.5 – 12
Open Burning – Debris	9.9	
Non-road Diesel Engines & Vehicles	**0.4**	**0.4 – 3**
On-road Diesel Vehicles	**0.4**	**0.4 – 3**
Trains, Ships, Planes	**0.4**	**0.4 – 25**
Non-road Gas Engines & Vehicles	14	0.25 – 14
On-road Gas Vehicles	4.2	0.25 – 14
Fugitive Dust – Roads	22	3 - 65
Woodstoves	7.4	3 - 50
Fireplaces	7.4	3 - 50
Residential Heating – Other	26	
Commercial Cooking	111	13 - 111

Figure 1-10 shows a comparison of the emission density ratios for urban carbon emissions and rural carbon emissions. There is about three times as much primary carbon emitted in urban areas as there is in the rural areas; about 80% of this is primary organic aerosol and about 20% is elemental carbon.

Figure 1-10. Primary Carbon Emission Density Ratios*



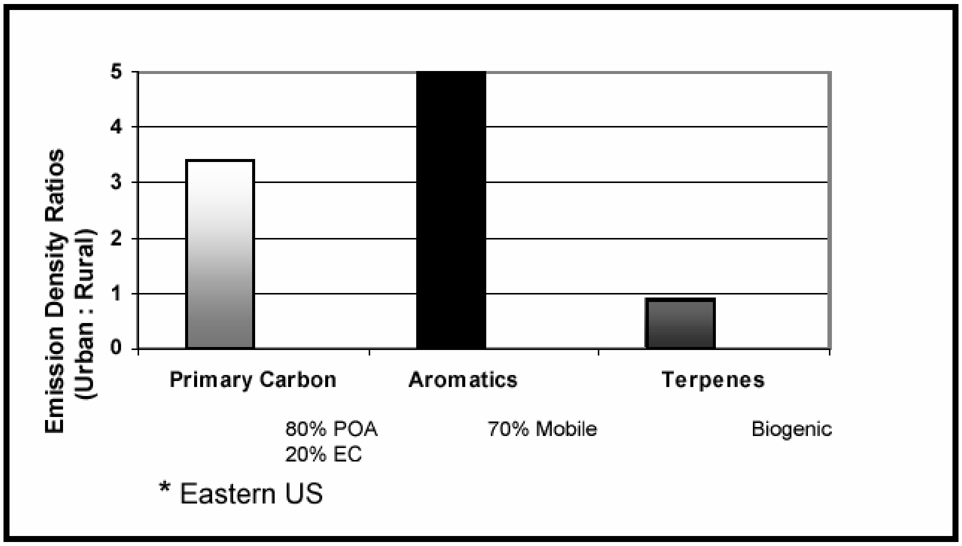
The primary particles are comprised of approximately 80 percent primary organic aerosols and 20 percent elemental carbon. Some of EPA's emission factors identify a condensable part. This represents the organics that are in the vapor phase when they are measured at stack temperatures and condense to form particles when the plume cools. Condensibles are included in the POA emissions estimate.

1.2.5 Volatile Organic Compound Emissions

Aromatics and terpenes are the VOC precursors that react to produce secondary organic aerosols. About 70 percent of aromatics come from mobile sources and include benzene, toluene, and xylene. Toluene and xylene are the two aromatics that are generally associated with secondary aerosol formation. Since the majority of these VOC precursors are emitted from cars, it is not surprising that the emission density of aromatics is about five times higher in urban areas than in the rural areas. The formation of SOA from these aromatic precursors is another potential cause of the urban excess that was discussed in Section 1.1.

Terpenes are another big source of secondary organic aerosols. Almost all terpenes are biogenic in origin in that they are emitted by a variety of vegetation. However, their emissions are not limited to rural areas. In fact, there is almost as much terpene emissions in a square mile of urban area as there is in a square mile of rural area (See Figure 1-11). This is due to the fact, despite land clearing, there are many trees in urban areas.

Figure 1-11. Comparison of Emission Density Ratios*



1.3 SUMMARY

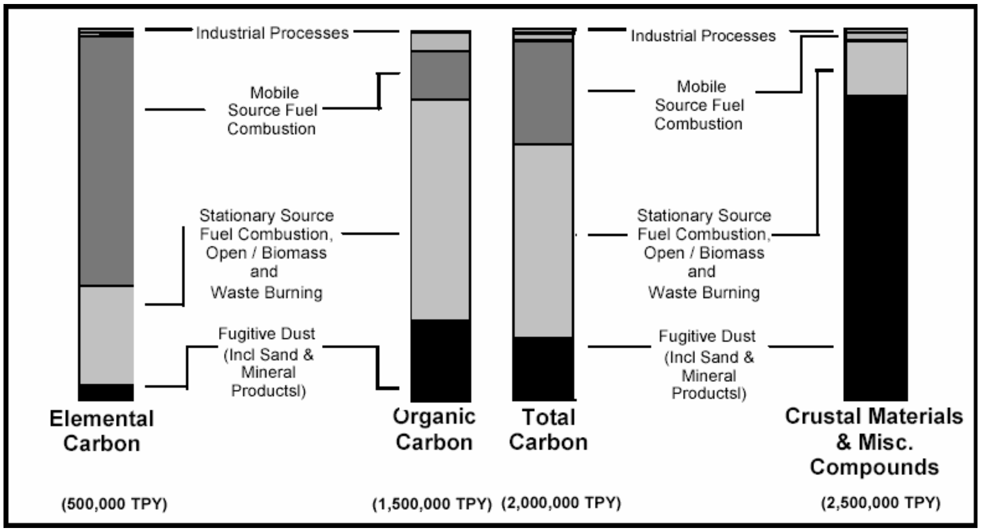
Figure 1-12 presents a summary of the larger source categories of $PM_{2.5}$ direct and precursor emissions. These are presented in no particular order; however, the larger categories are in boldfaced type.

Figure 1-12. Summary of Important $PM_{2.5}$ Source Categories		
Direct Emissions	**Precursor Emissions**	
Combustion a,b	**SO2** c	**NH3**
• **Open Burning (all types)** • **Non-Road & On-Road Mobile** • **Residential Wood Burning** • **Wildfires** • Power Gen • Boilers (Oil, Gas, Coal) • Boilers (Wood)	• **Power Gen (Coal)** • **Boilers (Coal)** • Boilers (Oil) • Industrial Processes	• **On-Road Mobile** • **Animal Husbandry** • **Fertilizer Application** • Wastewater Treatment • Boilers
Crustal / Metals b	**NOx**	**VOC d**
• **Fugitive Dust** • Mineral Prod Ind • Ferrous Metals	• **On-Road Mobile (Gas, Diesel)** • **Power Gen (Coal)** • **Non-Road Mobile (Diesel)** • **Boilers (Gas, Coal)** • Residential (Gas, Oil) • Industrial Processes	• **Biogenics** • **Solvent Use** • **On-Road (Gas)** • Storage and Transport • Residential Wood • Petrochemical Industry • Waste Disposal
a Includes primary organic particles, elemental carbon and condensable organic particles; also some flyash b Impact of carbonaceous emissions on ambient PM 5 to 10 times more than crustal emissions impact c Includes SO and SO and HSO condensable inorganics d Contributes to formation of secondary organic aerosols		**NOTE**: Categories in **BOLD** are most important nationally. Their relative importance varies among and between urban and rural areas.

Figure 1-13 illustrates several important features of PM2.5 emissions. First, it shows that the majority of both elemental and organic carbon comes from combustion sources. It also shows that almost all of the crustal materials are associated with fugitive dust and very little of the total carbon is associated with fugitive dust.

Emissions of primary carbonaceous $PM_{2.5}$ are about two million tons per year, and about a fourth of that is elemental carbon. However, the emissions of crustal materials is about 2.5M tons per year, roughly similar in magnitude. However, due the further adjustments made to the EI for carbon and crustal materials previously discussed, (carbon emissions increase and the crustal emissions are reduced), carbon is usually found in much greater quantity on ambient $PM_{2.5}$ samples than are crustal materials.

Figure 1-13. Summary of $PM_{2.5}$ Primary Emission Sources



The formation of secondary organics from terpenes associated with VOC emissions from vegetation occurs relatively fast. The formation of secondary organics from aromatics associated with VOC emissions from mobile sources occurs slower than the terpene reaction. From a control strategy standpoint it is important to recognize that reducing aromatics would reduce secondary organic aerosol.

Ammonium sulfate is formed from SO_2 that is emitted from the combustion of sulfur containing fuels. Compared to ozone, the sulfate forms and deposits more slowly and therefore may be transported much longer distances than either ozone or nitrate. If there were insufficient ammonia the formation product would be partially neutralized particles of ammonium bisulfate, or possibly even sulfuric acid. From a control strategy standpoint, reducing emissions of SO_2 will lower ammonium sulfate concentrations.

Ammonium nitrate is formed from NO_x that is emitted from fuel combustion. Nitrates are formed relatively quickly. If there is insufficient ammonia, the ammonia will react to form ammonium sulfate before it forms ammonium nitrate. Higher temperatures and a lower relative humidity will shift equilibrium so that less nitrate and more nitric acid will be formed. Reducing NO_x emissions may reduce nitrates, sulfates and secondary organic aerosols, but the outcomes are complicated, involve ozone chemistry and can't be generalized.

In general a reduction in VOC emissions would reduce ozone levels and that would result in less secondary organic aerosols, sulfate and nitrate formation. However, this is very complicated issue and must collectively consider ozone formation, ozone precursors, sulfates, nitrates, and the secondary organics because the reactions are interrelated.

Review Exercises

1. Which of the following is **not** a component of secondary particles that are formed in the atmosphere?
   a. ammonium sulfate
   b. ammonium nitrate
   c. crustal particles
   d. secondary organics

2. Which of the following characteristics are common to particulate mater in the eastern half of the United States?
   a. It is composition is chemically similar across a number of urban areas
   b. It is comprised of mostly carbon
   c. The ammonium and sulfate components are comparable to the carbon component
   d. All of the above

3. The density of NOx emissions per square mile are about ______ times higher in urban areas than they are in the rural areas, but the concentrations of nitrate are only about _____ times higher in the urban areas as in the rural areas.
   a. four, two
   b. two, four
   c. ten, five
   d. three, two

4. Twenty-five percent of total NOx emissions are associated with _______, the second largest contributor.
   a. Highway vehicles
   b. Farm animals
   c. Fugitive dust
   d. Electric utilities

5. Which of the following is the least significant source of crustal material?
   a. Unpaved roads
   b. Agricultural tilling
   c. Construction
   d. Coal and oil-fired boilers

6. Approximately _______ percent of primary carbon is elemental.
   a. 10
   b. 25
   c. 50
   d. 75

7. Which of the following sources of primary carbon has a low ratio of organic carbon mass to elemental carbon mass?
   a. Wildfires
   b. Fugitive dust
   c. Diesel engines
   d. All of the above

8. Which of the following is **not** an aromatic VOC precursor to secondary organic formation?
   a. Benzene
   b. Toluene
   c. Terpenes
   d. Xylene

9. Secondary organic aerosol formation _______ when the ambient temperature increases.
   a. increases
   b. decreases
   c. remains constant
   d. ceases

10. _______ is (are) the only precursor with much larger emission density in rural areas than in urban areas.
   a. Terpenes
   b. Benzene
   c. Ammonia
   d. Sulfates

Review Answers

1. c. carbonaceous particles

2. d. All of the above

3. a. four, two

4. d. Electric utilities

5. d. Coal and oil-fired boilers

6. b. 25

7. c. Diesel engines

8. c. Terpenes

9. a. increases

10. c. ammonia

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Chapter 2: The National Emissions Inventory and Emission Inventory Tools

LESSON GOAL

Demonstrate, through successful completion of the chapter review exercises, a general understanding of the National Emissions Inventory and the process by which it was developed. Also, the student should be able to describe the emission inventory preparation tools that are available as well as those that are under development.

STUDENT OBJECTIVES

When you have mastered the material in this chapter, you should be able to:

1. Describe the purpose of the National Emission Inventory (NEI).
2. Describe some of the data contained in the NEI.
3. Identify inventory preparation tools that currently exist.
4. Explain the purpose of process based emission models.
5. Identify source categories where better data for estimating emissions is needed.

Chapter 2: The National Emissions Inventory and Emission Inventory Tools

2.1 THE NATIONAL EMISSIONS INVENTORY

The information contained in the NEI includes data on 52,000-point sources by latitude/longitude with over 4,500 types of processes represented. There are about 400 categories of highway and nonroad mobile sources and 300 categories of area sources in the NEI. Emissions for area and mobile sources are allocated by county. The NEI includes annual emissions, the dates that sources started or stopped operations, and stack parameters. There are also HAPs emissions for over 6,000 types of processes.

Figure 2-1. Evolution of the NEI

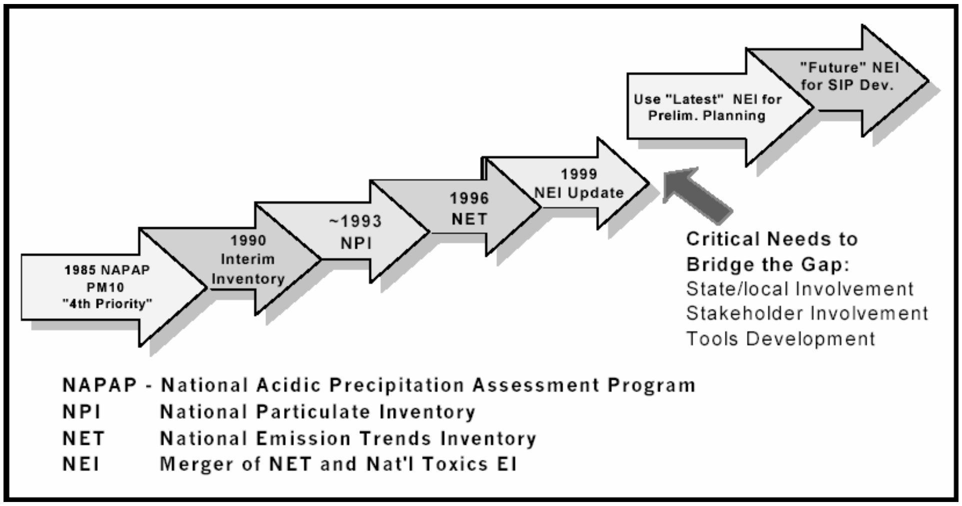

Figure 2-1 presents a timeline showing the evolution of the National Emissions Inventory (NEI). The first PM inventory in the NEI was in the 1985 National Acidic Precipitation Assessment Program (NAPAP). This inventory was for PM_{10} and it was developed without any input from the states. It has only been recently that the states have become involved in the development of the NEI for PM.

During the early 1990s there was minimal activity on developing PM inventories, although a National Particle Inventory was prepared in 1993. In 1996 it was called the

National Emissions Trends Inventory (NET). The NET was updated in 1999 and was renamed the NEI. Integration of the National Air Toxics Assessment Inventory was begun with the 1999 NEI and was completed with the 2002 NEI. Improving and updating the NEI is a continuing process.

In the 2002 NEI, some areas of the US began to include large fires as point sources. Data on when they started, when they ended, and where they were located are essential to accurately model their impact on air quality. Smaller fires may continue to be treated as area sources. These are allocated to counties using data on forested land area and emissions are assigned to months of the year using temporal allocation factors. Treating fires as point sources is important, for example, where a fire may have a major impact on a Class 1 area it could relate to the 20% worst days at that area. When fires are treated as area sources, it is impossible to know where the fire occurred or when. As a result, it is impossible to determine if the particulate matter emissions in the Class 1 area are attributable to the fire.

The process of developing the NEI begins with data on emission factors and models, various databases for source activity levels, default values for emissions related variables, existing point source data, and growth factors for source categories. This data is combined to form what is called the preliminary NEI. The preliminary NEI is provided to State and local air agencies for their refinements and improvements. Working with stakeholders and using factor and model improvements, and local activity levels and variables provided by State and local agencies, the preliminary NEI is transformed into the improved NEI. This process is repeated yearly, but emphasized every three years.

2.2 INVENTORY PREPARATION TOOLS

2.2.1 Introduction

One of the tools used to prepare the NEI is the Factor Information and Retrieval database (FIRE), which is available at www.epa.gov/ttn/chief. There are about 20,000 emission factors in this database that are used in developing the NEI. However, since industrial processes vary over time and from facility to facility, there are representativeness issues with many of these factors.

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Another inventory preparation tool is process-based emission models. TANKS is an example of a model that is used for estimating storage tank emissions of VOCs. The NONROAD model is used to estimate emissions from non-road vehicles and BEIS is used to estimate biogenic emissions.

Other tools include special characterization and locator aids such as GIS (Geographic Information Systems) and global positioning systems (GPS). Satellites are beginning to be used to locate fires, especially in Mexico and Canada. It should be noted that there are some severe limitations in using satellites to locate certain fires, such as those that are below a certain size or through cloud cover, for instance.

2.2.2 Emissions Processors

The purpose of an emissions processor is to provide an efficient tool for converting emissions inventory data into the formatted emission files required by an air quality dispersion model.

After the NEI emissions data is developed it goes into an emissions processor such as SMOKE (Sparse Matrix Operator Kernel Emissions) modeling system. Speciation factors are applied to the emissions data by the SMOKE emissions processor. These steps happen to the inventory after the NEI, and it is something that is generally performed when the inventory is to be used by air quality dispersion modelers. It is important to recognize that emissions modeling depends on speciation factors, temporalization factors, and species allocation factors. The data flow is from the NEI to the emissions processor and then into the air quality model. The output of the emissions processor is a gridded, hourly emissions file speciated into elemental carbon, organics, primary sulfates, and primary nitrates. It should be noted that the speciated inventory data is especially useful in modeling for regional haze. For example, carbon particles absorb and scatter light with a different efficiency than other particles, such as sulfate particles. As a result, it is necessary to consider different types of particles separately when doing regional haze work.

Area source data is input to the emissions processor as an annual county level inventory and point source data is input as annual data, located by latitude and longitude. CEM data feeds into the emission processor separately through a CEM database. The emissions processor contains default factors and profiles, including county to grid allocation factors, temporal allocation profiles, and speciation profiles. Using this data, the emissions processor turns the annual, (sometimes) county level inventory into a gridded, hourly emission file speciated into EC, POA, Primary SO4, Primary Nitrate and Other, which contains crustal materials/fugitive dust and unidentified species. It is then ready to be used as input to a dispersion model.

The emissions processor assigns all of the $PM_{2.5}$ sources to one of several dozen speciation profiles. Note that elemental carbon and the primary organic aerosols are derived within the emission processor from $PM_{2.5}$ data using speciation profiles. As such, they are not part of the NEI inventory.

There are some issues with compiling a carbon inventory. The split between elemental carbon and primary organic aerosols is subject to some analytical uncertainties and there are a lot of questions about how to do that type of analysis. It is an operational definition of what to call elemental carbon and what to call organic carbon when doing those analyses. Also these analyses provide data for organic carbon, not the organic carbonaceous matter that accounts for all the oxygens and hydrogens. As mentioned in Section 1, it is necessary to use a multiplier or a compound adjustment to go from organic carbon to primary organic aerosols.

2.2.3 Processed-based Emission Models

There is another set of tools becoming available called process-based emission models. Process-based models consider spatially and temporally available activity parameters as a part of the emissions estimation in an effort to reflect real world conditions like wind, temperature, relative humidity, vegetation type, soil type, moisture, etc. For example, these models will eventually include algorithms to develop a wind-blown dust inventory by examining the wind fields for the whole modeling domain and deciding when the wind is going to blow fast enough to create dust emissions. Other examples are a model under development to estimate fire emissions by taking into account such factors as relative humidity, moisture, and wind speed and a fugitive dust, model.

These models would have to links to various databases such as MM5, the meteorological data processor. They would also be linked to GIS coverages of soil and vegetation types, and would contain emission algorithms responsive to these variables. Currently there are several models containing some aspects of process-based emission models. These include the MOBILE 6 model and the BEIS 3 model because they take temperature into account. Consideration of temperature is critical for estimating biogenic emissions.

There are a number of other needs for process-based emission models. Some examples include estimating emissions of ammonia and residential wood burning. In the future, some of these process-based models will be integrated with the emissions processor and some will be stand-alone. Currently, the biogenics model (BEIS) is always integrated with the emissions processor. The onroad model MOBILE 6 can optionally be integrated with the emissions processor. The development of process-based emissions models for ammonia, fugitive dust and wildland fires are currently underway.

2.2.3.1 Wildland Fires Model

The inputs for the wildland fire model include fire locations, duration, and size. This model will access meteorological data for wind speed and moisture and uses fuel-loading defaults from a one-kilometer resolved national map of fuel loadings. Although a fuel map currently exists (e.g., NFDRS) there is a project currently being funded to develop a map that will provide better fuel-loading data. Fuel moistures are calculated using the MM5 data. Fuel consumption will be done using CONSUME or the First Order Fire Effects Model (FOFEM) for fuel consumption. The emissions projection model, together with the Briggs’ Plume Rise equation modified for fires calculates emissions, heat release, and plume rise. When it is completed, this emissions module will provide gridded, hourly emissions and plume characteristics that will take into account the real world meteorological conditions that would effect fire behavior and emissions.

2.2.3.2 Fugitive Dust Model

Another model that is currently under development is a fugitive dust model. The approach for developing a fugitive dust model is to establish a consistent database of resource information such as soil, land use, vegetation, moisture, precipitation, and wind speed that can be used to estimate emissions for use with grid models. Currently, a proof of concept of this emission model is being demonstrated for wind-erosion, unpaved roads, construction, and other dust sources.

2.2.4 Receptor Models

Receptor modeling is an important toolset that can be used in the development of an emissions inventory. An estimate of the amount of fossil versus contemporary carbon can be obtained by using radiocarbon analysis. Some receptor models can use specific tracers for gas versus diesel particles by looking at the specific organic compounds that make up those particles and identifying whether those carbon particles are emitted from gas or diesel engines and also whether they are emitted from cold starts or smokers. Other tracers (or groups of tracers, called source profiles) are available for a variety of source types. One model commonly used is the Chemical Mass Balance, a dedicated weighted least squares model to infer source contribution estimates from ambient speciated data and source profiles. Multivariate models are the Positive Matrix Factorization (PMF) model and UNMIX, which is somewhat similar to PMF.

2.3 OTHER NEEDS

There are a number of specific $PM_{2.5}$ categories that generally need better emissions models and emissions data. Some of these categories include wildland, forest and rangeland burning, particularly private and state and tribal burners. For these categories, data on acreage burned, fuel loadings for the largest fires, and the timing of those fires is needed.

Other source categories that need better emissions data include:

- Residential open burning, household waste, and yard waste. For these categories, data on the volumes, burning practices, regulations and their effectiveness, and local surveys of burn activities are needed.
- Construction debris and logging slash. Data on the regulations and their effectiveness, including local surveys of burn activities, is needed.
- Agricultural field burning is another source category and data on acreages, fuel loadings, and timing of the burn events is needed.
- Residential wood combustion, fireplaces and wood stoves. Data from local surveys of fuel burn is needed. This includes data on whether the wood is being burned in a fireplace or a wood stoves.
- Area-specific industrial process sources are another category for which better data are needed. However, since these source constitute a small percentage of the industrial process sources, it is important to pick those sources that have the biggest errors associated with them.

Finally, data on local conditions contributing to fugitive dust are needed in some cases.

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Review Exercises

1. Which of the following was the first particulate matter inventory in the NEI?
   a. National Acidic Precipitation Assessment Program
   b. National Particle Inventory
   c. National Emissions Trends Inventory
   d. None of the above

2. Which of the following best describes how large fires are **currently** handled in the NEI?
   a. Large fires are treated as point sources.
   b. Large fires are treated as area sources.
   c. Large fires are not currently included in the NEI.
   d. Large fire emissions are allocated seasonally across the entire state.

3. Which of the following is **not** an example of an existing emissions inventory preparation tool?
   a. FIRE
   b. TANKS
   c. BIES3
   d. NET

4. _______ models apply space and time sensitivities to emissions.
   a. Receptor
   b. Grid
   c. Process-based emission
   d. Photochemical dispersion

5. Which of the following best describes the emissions data that is the output of an emissions processor?
   a. Unspeciated annual averages
   b. Speciated hourly averages
   c. Speciated annual averages
   d. Unspeciated hourly averages

6. Process-based emission models are needed for estimating emissions from _______.
   a. ammonia sources
   b. fugitive dust
   c. wildland fires
   d. All of the above

7. Which of the following is **not** an input that would be needed for a process-based emissions model for wildland fires?
   a. Fire location
   b. Fire temperature
   c. Size of the fire
   d. Fuel loading

8. _______ models can identify the source of an emission.
   a. Receptor
   b. Grid
   c. Process-based emission
   d. Photochemical

9. Efforts to develop data for _______ sources should be limited to those sources that have the biggest errors associated with them.
   a. mobile
   b. open burning
   c. specific industrial processes
   d. fugitive dust

Review Answers

1. a. National Acidic Precipitation Assessment Program

2. b. Large fires are treated as area sources.

3. d. NET (National Emissions Trends Inventory)

4. c. Process-based emission

5. b. Speciated hourly averages

6. d. All of the above

7. b. Fire temperature

8. a. Receptor

9. c. specific industrial processes

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Chapter 3: Onroad Mobile Inventory Development

LESSON GOAL

Demonstrate, through successful completion of the chapter review exercises, a general understanding of EPA's MOBILE 6 model and the National Mobile Inventory Model (NMIM). Also, the student should be able to describe the concept of vehicle miles traveled and how it is used to calculate emissions from onroad vehicles.

STUDENT OBJECTIVES

When you have mastered the material in this chapter, you should be able to:

1. Describe the inputs required to run the MOBILE 6 model.
2. Explain the purpose of the NMIM.
3. Identify sources for obtaining VMT data.
4. Explain the approach for calculating onroad vehicular emissions from VMT data.
5. Identify additional sources of information for calculating onroad emissions.

Chapter 3: Onroad Mobile Inventory Development

3.1 MOBILE 6

3.1.1 Overview

EPA's Office of Transportation and Air Quality (OTAQ) has developed MOBILE 6 to estimate emissions from mobile sources. The MOBILE 6 model includes emission factors for $PM_{2.5}$, SO_2, NH_3, PM_{10}, VOC and CO. The MOBILE6 model and the User Guide can be downloaded from www.epa.gov/otaq/m6.htm. The $PM_{2.5}$ and the PM_{10} emission factors represent primary emissions. Data on vehicle miles traveled (VMT) is matched to the corresponding MOBILE 6 emission factors to form the basis of emission calculations.

PART 5 was EPA's prior model for modeling PM emissions and the data and algorithms that were previously in PART 5, with some updates, have been integrated into the MOBILE 6 model. However, the fugitive dust emission factors that were included in PART 5 have been excluded from MOBILE 6. Consequently, the calculation of emissions from re-entrained road dust is done separately outside the model. In addition, MOBILE 6 also includes emission estimates for gaseous SO_2 as well as ammonia.

3.1.2 Modeling Inputs

In most cases MOBILE 6 uses the same type of inputs that were required for prior versions. This includes registration, distribution, ambient conditions such as temperature and humidity, speeds and speed distributions, and fuel parameters such as the Reid Vapor Pressure of gasoline and oxygenated fuel. It also includes control programs such as Stage II or Inspection and Maintenance programs, and data on VMT by vehicle type.

One additional data input required for MOBILE 6 modeling that was not required in the past is the diesel sulfur content expressed in parts per million. Also, there are additional commands needed for generating $PM_{2.5}$ inventories in MOBILE 6. These are described in the MOBILE user's guides that OTAQ has developed. One thing to note is when developing a PM inventory you cannot do a $PM_{2.5}$ and a PM_{10} inventory at the same time. As a result, it is necessary to specify just one particle size per each run.

3.2 NATIONAL MOBILE INVENTORY MODEL

The National Mobile Inventory Model (NMIM) is a tool developed by EPA's Office of Transportation and Air Quality (OTAG) to create national or sub-national emission inventories for any calendar year using county-specific input parameters. It is a consolidated emissions modeling system for EPA's MOBILE and NONROAD models. It combines a graphical user interface, MOBILE, NONROAD, and a database that contains modeling information for each county in the United States. Currently this database contains the most recent information (e.g., fuel parameters, registration data, temperatures, etc.) used by EPA to generate the default National Emission Inventory (NEI) estimates for each county.

NMIM is capable of calculating both criteria (including ammonia) and HAPs for the source categories included in the MOBILE6 and NONROAD models. The true beauty of NMIM is that it consolidates all the model inputs into a single data base such that all the estimates are based on the same input parameters in each county (e.g., fuel programs, inspection/maintenance, humidity, temperatures).

EPA used a draft version of NMIM to generate the preliminary EPA default 2002 NEI inventories for nonroad engines. For states, NMIM is an optional tool that should simplify estimating mobile source inventories by organizing and automating emission inventory development for highway vehicles and NONROAD categories. It is not a substantively different approach than directly using MOBILE6.2 and NONROAD2002.

EPA expects to complete NMIM and release it for general use in 2004 but states will not be required to use it to generate inventory estimates. This tool was developed to make creating inventories easier and does not change the answers that are obtained from running MOBILE or NONROAD individually. In the future, states may wish to tailor all or part of their own inventory generation process to the NMIM model approach to take advantage of its efficiency and transparency and to align the NEI inventory results more closely with their own inventory estimates. State and local agencies will be able to use the database to view the county-level default values and to replace them with data that better represents their geographic areas.

3.3 VMT DATA

3.3.1 Sources

State departments of transportation typically provide VMT data. In addition, metropolitan planning organizations (MPOs) track these data for certain areas. However, VMT data should be used from whatever source it is available. As a case in point, the 1999 NEI included VMT data that was provided by eight states and this data was used in conjunction with MOBILE6 emission factors. VMT data for the remaining states were obtained from the Federal Highway Administration's (FHWA) data summaries. The FHWA data contains vehicle miles traveled by roadway type, by state, as well as VMT by roadway type for specific urban areas. The 1999 NEI relied upon a national distribution for the VMT mix by vehicle type.   As a result, the same mix of vehicles was assumed for all areas unless the state provided their own data. Documentation for the 1999 NEI can be found at this web address: www.epa.gov/ttn/chief/net/1999inventory.html.

3.3.2 Approach

In the case of the NEI, the VMT data was developed for use in conjunction with MOBILE 6 by using the distributions of VMT by roadway type and vehicle type. In some cases this activity data may be available by hour of the day. Regardless of the format, these fractions can be applied directly to the total VMT, or they can be included within the MOBILE 6 input files in order to generate a weighted emission factor in MOBILE 6.

It should be noted that it is important to have speeds matched to the roadway types, either as an average speed or as speed distributions by speed ranges. This latter approach is the approach needed for link-based VMT development and some transportation demand models.

3.3.3 Level of Detail

Ideally, the level of VMT data that should be used is by county and by the various roadway types or link level if modeling at that level is planned. Using data by vehicle type is important since emission rates can vary greatly among the different vehicle types. Using vehicle type data will allow the adjustments to be made to the national defaults that are typically used. Finally, it is important to match the VMT data (daily or hourly) to the appropriate time period for modeling.

3.4 CALCULATING EMISSIONS

VMT data needs to be matched to a corresponding MOBILE 6 emission factor and mapped according to speed, roadway type, vehicle type, and time period. Emissions are calculated by multiplying the VMT data by an emissions factor as shown in the following equation.

$$\text{Emissions} = \text{VMT} * \text{EF} * \text{K}$$

where: Emissions = emissions in tons by roadway type and vehicle type
VMT = vehicle miles traveled by roadway type and vehicle type
EF = emission factor in grams/mile by roadway type and vehicle type
K = conversion factor

3.5 ADDITIONAL RESOURCES

Since this has been cursory treatment of onroad sources, Table 3-1 provides a number of online resources that should be consulted when developing an emissions inventory for onroad sources. This includes EPA's online user's guide for using MOBILE 6.1 and 6.2 as well as technical documentation describing how all the defaults were developed. There are also links to training materials that have been developed as MOBILE 6 has been updated.

Table 3-1 ONROAD SOURCES
Additional Resources

Reference	Web Site
User's Guide to MOBILE 6.1 and MOBILE 6.2: Mobile Source Emission Factor Model, EPA420-R-02-028, October 2002.	www.epa.gov/otaq/m6.htm
MOBILE 6.1 Particulate Emission Factor Model Technical Description,Draft,EPA420-R-02-012, March 2002	www.epa.gov/OMS/models/mobile6/r02012.pdf
Links to MOBILE 6 Training Materials	www.epa.gov/otaq/m6.htm#m6train
Documentation for the Onroad NEI for Base Years 1970 - 2002	ftp://ftp.epa.gov/EmisInventory/finalnei99ver3/haps/documentation /onroad/nei_onroad_jan04.pdf

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Review Exercises

1. Which of the following pollutants does **not** have an emission factor included in MOBILE 6?
   a. $PM_{2.5}$
   b. Ammonia
   c. Carbon dioxide
   d. Volatile Organic Compounds

2. Which of the following MOBILE inputs are required for MOBILE 6, but were not required for MOBILE 6.0?
   a. Reid Vapor Pressure
   b. VMT data by vehicle type
   c. Ambient humidity
   d. Sulfur content of diesel fuel

3. The National Mobile Inventory Model is a graphical interface that uses _______.
   a. MOBILE 6.2
   b. NONROAD 2002
   c. a county level database
   d. All of the above

4. The development of VMT data in the NEI for use in conjunction with MOBILE 6 is done by using the distributions of VMT by ________.
   a. vehicle type and speed ranges
   b. roadway type and vehicle type
   c. roadway type and speed ranges
   d. roadway type and link level

5. VMT data needs to be matched to a corresponding MOBILE 6 emission factor and mapped according to ________.
   a. speed
   b. roadway type
   c. vehicle type
   d. All of the above

6. Which of the following is needed to calculate emissions from onroad vehicles?
   a. VMT data
   b. Emission factor by roadway type
   c. Emission factor by vehicle type
   d. All of the above

Review Answers

1. c. Carbon dioxide

2. d. Sulfur content of diesel fuel

3. d. All of the above

4. b. roadway type and vehicle type

5. d. All of the above

6. d. All of the above

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Chapter 4: Nonroad Mobile Inventory Development

LESSON GOAL

Demonstrate, through successful completion of the chapter review exercises, a general understanding of EPA's NONROAD model. Also, the student should be able to describe the approaches for estimating PM emissions from aircraft, commercial marine vessels, and locomotives.

STUDENT OBJECTIVES

When you have mastered the material in this chapter, you should be able to:

1. Describe the source categories and pollutants that are included in the NONROAD model.
2. Explain the methodology used by the NONROAD model to estimate emissions.
3. Define the source categories that comprise the aircraft category.
4. Explain the methodology used to estimate aircraft emissions in the NEI and how a state or local agency can improve on those results.
5. Identify the source categories that comprise the commercial marine vessel category.
6. Explain the methodology used to estimate commercial marine vessel emissions in the NEI and how a state or local agency can improve on those results.
7. Identify the source categories that comprise the locomotive category.
8. Explain the methodology used to estimate locomotive emissions in the NEI and how a state or local agency can improve on those results.

Chapter 4: Nonroad Mobile Inventory Development

The discussion of EPA's National Mobile Inventory Model (NMIM) that was presented in Chapter 3 is also applicable to the nonroad category, but will not be repeated here. It should be noted that aircraft, railroad, and commercial marine vessel inventories are not included in the NONROAD model and are estimated independently.

4.1 NONROAD Model

The latest version of EPA's NONROAD model can be accessed at this web address:

www.epa.gov/otaq/nonrdmdl.htm.

This web site contains documentation, a user's guide, as well as technical reports to describe the sources and development of all the default input values (e.g., equipment populations, geographic allocations, growth factors, and emission rates).

4.1.1 Sources

Table 4-1 lists the source categories that are included in the NONROAD model. The four-digit source classification code (SCC) generally denotes the engine type, or fuel that is used in the nonroad equipment. There are two exceptions where the four-digit SCC denotes the equipment type instead of the engine type: the recreational marine and railroad maintenance categories.

Table 4-1. Engine Types Included in the NONROAD Model

SCCs	Type
2260xxxxxx	2-Stroke Gasoline
2265xxxxxx	4-Stroke Gasoline
2267xxxxxx	Liquefied Petroleum Gasoline (LPG)
2268xxxxxx	Compressed Natural Gas (CNG)
2270xxxxxx	Diesel
2282xxxxxx	Recreational Marine
2285xxxxxx	Railroad Maintenance

Table 4-2 lists the 12 different equipment categories denoted by the seven-digit SCC that are included in the NONROAD model. Within each of these categories there are multiple applications that are specified at the 10-digit SCC level.

Table 4-2. Equipment Categories Included in the NONROAD Model

Equipment Category (7-digit SCC denotes equipment)	
Airport Ground Support	Logging
Agricultural	Recreational Marine Vehicles
Construction	Recreational Equipment
Industrial	Oil Field
Commercial	Underground Mining
Residential/Commercial Lawn and Garden	Railway Maintenance

4.1.2 Pollutants

The pollutants included in the NONROAD model are PM_{10} and $PM_{2.5}$ (representing primary PM), CO, NO_x, VOC, SO_2 and CO_2. Ammonia is not a direct output of the NONROAD model, but it can be estimated based on fuel consumption estimates that are obtained from the model and EPA emission factors derived from light-duty onroad vehicle emission measurements. In addition to exhaust pollutants, the NONROAD model estimates evaporative VOC components from crankcase emissions, spillage, and vapor displacement.

4.1.3 Emission Calculations

The NONROAD model calculates exhaust emissions by assuming that they are dependent on equipment activity. The model takes into account a number of measures of equipment activity, including how many hours per year the equipment is used, the load factor at which the engine is operating, the average rate of horse power of the engine, and the equipment population (i.e., how many pieces of equipment are in use). These equipment activity measures are multiplied by emissions factors in tons per horsepower-hour to obtain emission estimates as shown in Equation 4-1.

Equation 4-1. NONROAD Model Emission Equation

$$I_{exh} = E_{exh} * A * L * P * N$$

where: I_{exh} = Exhaust emissions (tons/year)
E_{exh} = Exhaust emission factor (ton/hp-hr)
A = Equipment activity (hours/year)
L = Load factor (proportion of rated power used on average basis)
P = Average rated power for modeled engines (hp)
N = Equipment population

Values for the equipment activity measures are generally obtained from a market engine research firm that conducted telephone surveys of equipment owners and operators to generate default values for the different equipment categories. However, there are some exceptions that are described in the documentation for the NONROAD model.

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The emission factors are dependent on the engine type as well as the engine size, or horsepower. Future year emission controls or standards are reflected in revised emission rates, so that as older engines are scrapped and new engines replace them, revised emission rates are applied to the new engines to reflect the standards that they need to meet.

SO_2, CO_2 and evaporative VOC emissions are based on fuel consumption. In the NONROAD model, PM_{10} is assumed to be equivalent to total PM and for gasoline and diesel engines, $PM_{2.5}$ is assumed to be 0.92 times PM_{10}. For liquefied petroleum gas (LPG) and compressed natural gas engines, all PM is assumed to be less than $PM_{2.5}$.

4.1.4 Geographic and Temporal Allocation

Because there are no estimates of county level populations, the NONROAD model estimates those populations using surrogate indicators. The model starts with national or state level equipment populations (either by equipment type or horsepower range) and allocates them to the county level by using surrogate indicators that correlate with nonroad activity for a specific equipment type.

The NONROAD model also accounts for temporal variations in activity. The temporal profiles vary by month and depend on the equipment category and the geographic region of the country. The model contains typical weekday and weekend day activity profiles by equipment category, however, those do not vary by region.

4.1.5 Improving the NONROAD Results

One way to improve EPA's latest 2002 model results is to specify local fuel characteristics and the ambient temperatures specific to the area being modeled. Also, if possible, the NONROAD default activity inputs should be replaced with state or local data. However, it can be resource intensive to obtain reasonable estimates to replace the default values. In order to obtain this data it would be necessary to perform a local survey of equipment owners and users.

Another way to improve the model results is to obtain local information to improve the geographic allocation (i.e., going from state to county). Obtaining local data used for the temporal profiles can also improve the model results.

Finally, another approach to improve the model results is to focus on priority categories and obtain better data for those categories. For example, for fine PM, priority categories would be diesel construction, diesel farm, diesel industrial, gasoline lawn and garden, and gasoline recreational marine.

4.2 AIRCRAFT

The SCCs representing the aircraft categories that have been historically reported in the NEI are listed with their definitions in Table 4-3. The activity data used for aircraft are known as a landing and takeoff operations, or LTO. Emissions are estimated by applying emission factors to the LTO data that are either specific to an aircraft or engine type. If the make-up of the aircraft fleet is unknown, fleet averages are available to be applied to the emission factors.

Table 4-3. Aircraft SCC

SCC	Aircraft Type	Definition
2275020000	Commercial Aircraft	Aircraft used for scheduled service to transport passengers, freight, or both
2275050000	General Aviation	Aircraft used on an unscheduled basis for recreational flying, personal transportation, and other activities, including business travel
2275060000	Air Taxis	Smaller aircraft operating on a more limited basis to transport passengers and freight
2275001000	Military Aircraft	Aircraft used to support military operations

The LTO cycle consists of different modes including: the approach, taxi idle in, taxi idle out, take off, and climb out. The operation time in each of these modes is dependent on the aircraft category, meteorological conditions, as well as how the airport is operating (e.g., the length of time waiting to take off). In addition, there can be substantial variations in these modes from airport to airport. Because different emission rates result when the aircraft are operating in each of these modes, it is important to consider all of these factors in estimating emissions from aircraft.

4.2.1 NEI Method

The NEI estimated emissions for commercial aircraft by using national-level FAA LTO data by aircraft type and emission rates from the Emissions and Dispersion Modeling System (EDMS) version 4.0. The NEI estimated emissions from the general aviation, air taxi, and military aircraft categories by also using national LTO data, however, data was not available for specific aircraft types within each of the aircraft categories. Consequently, emissions for these three categories were estimated by multiplying total LTO by an emission factor as shown in Equation 4-2.

Equation 4-2. NEI Method – General Aviation, Air Taxi, and Military Aircraft

$$\text{National Emissions}_{c,p} = \text{National LTO}_c * EF_{c,p}$$

where: LTO = Landing and take-off operations
EF = Emission factor
c = Aircraft category
p = criteria pollutant

Using PM as an example, the emission factors are LTO-based and represent a fleet average emission factor for the general aviation, air taxi, and military aircraft categories. Table 4-4 presents these PM emission factors. The $PM_{2.5}$ primary emissions are estimated, as they are for many combustion sources, by applying a particle-sized multiplier of 0.92 to the PM_{10}.

Table 4-4. LTO-Based PM Emission Factors

Category	PM Emission Factor (lbs/LTO)
General Aviation	0.2367
Air Taxi	0.60333
Military Aircraft	0.60333

Once national emissions are calculated for the four aircraft categories, the NEI allocates them to the county level based on airport level LTO data. This is shown in Equation 4-3. Using La Guardia airport as an example, the NEI assumes that a fraction of the total LTO is assigned to La Guardia, and the emissions calculated from this allocation are assigned to the corresponding county.

Equation 4-3. Emissions Allocation for Aircraft Categories

$$\text{Airport Emissions}_{c,p,x} = \text{National Emissions}_{c,p} * \text{AF}_{c,p,x}$$

where: AF = allocation factor
x = airport (e.g., La Guardia)
c = Aircraft category
p = criteria pollutant

More information on the NEI methodology for estimating emissions from aircraft categories can be found at the following web address: ftp://ftp.epa.gov/EmisInventory/finalnei99ver3/criteria/documentation/nonroad/99nonroad_voli_oct2003.pdf.

4.2.2 General Approach

Although it may be acceptable to rely upon the NEI data for smaller airports in an area, a bottom up inventory should be developed for the larger airports. There are seven steps for developing an aircraft inventory for a specific airport.

- Step 1 - Determine the mixing height to be used to define the LTO cycle. The mixing height is important because above the mixing height, emissions are not expected to contribute much to ground level pollutant concentrations.

- Step 2 - Define the fleet make-up for the airport.

- Step 3 - Determine airport activity in terms of the number of LTO by aircraft and their associated engine-type.

- Step 4 - Select emission factors for each engine model that is associated with the aircraft fleet at the airport being inventoried (Instead of using defaults that EDMS may apply for a specific aircraft type).

- Step 5 – Estimate the time-in-mode for the aircraft fleet at the airport.

- Step 6 - Calculate the emissions (based on the aircraft LTO data, the emission rates for each aircraft engine model, and the time-in- mode data).

- Step 7 – Aggregate the emissions across aircraft to obtain a total for the airport.

4.2.3 NEI Improvements

Developing an emissions inventory for a local airport involves determining the engine types associated with the local aircraft types. This data is an improvement over the assumptions used in the NEI for the commercial aircraft category. In addition, developing information on climb-out, take-off, approach time, and taxi idle times will be an improvement over the defaults used in the NEI.

Because the current version of EDMS does not include PM emission rates, EPA recommends that the few PM emission factors that are available in the 1992 version of the Mobile Sources Procedures document be matched to the aircraft engines in the local fleet as best as possible. EPA is aware of this limitation and work is underway to try to get better data on PM emission factors for commercial aircraft. Some regional inventories have looked at using emission factor ratios to develop the PM emission rates for commercial aircraft. Specifically, the ratio based on the PM_{10} and NO_X emission factor ratios for air toxics was applied to the commercial aircraft NO_X emissions.

For the other categories (general aviation, air taxis, and military aircraft) the NEI can be improved by obtaining local LTO estimates (i.e., the LTO not covered by the FAA data). Obtaining this data from smaller airports that may not be reporting to the FAA would be an improvement. The same is true for military bases, although the heightened security over the last couple years has made it harder to obtain data from military operations.

Another improvement is to obtain information on the aircraft/engine types that comprise the fleet for these other categories. If data on the mix of aircraft types in a fleet are available, engine specific emission factors or EDMS could be used to estimate emissions. Finally, the NEI can be improved by maintaining the latitude/longitude of the airport so the emissions are not “smeared” across the entire county.

4.3 COMMERCIAL MARINE VESSELS

The SCCs representing the commercial marine vessel categories that are currently used in the NEI are listed in Table 4-5. This includes diesel activity for ships in port and underway, as well as residual or steamships for those two categories.

Table 4-5. Commercial Marine Vessel SCC

SCC	Type
2280002100	Diesel, In Port
2280002200	Diesel, Underway
2280003100	Residual, In Port
2280003200	Residual, Underway

4.3.1 NEI Method

The NEI methodology for commercial marine vessels is a top down method that splits national diesel and residual emissions into port and underway components. The methodology makes assumptions about what portion of the activity for both diesel and residual ships takes place in ports and what portion takes place underway (i.e., away from ports or on their way between ports). These are allocated separately since port activity surrounds a port area, while underway covers a larger area such as along a river system. Both port and underway emissions are assigned to counties, however, port emissions are assigned to a single county in a port area.

More information on the NEI methodology for estimating emissions from the commercial marine vessel categories can be found at the following web address: ftp://ftp.epa.gov/EmisInventory/finalnei99ver3/criteria/documentation/nonroad/99nonroad_voli_oct2003.pdf.

4.3.2 NEI Improvements

One approach to improving the NEI emission estimates for the commercial marine vessel category is to review the spatial allocation of commercial marine emissions that is included in the NEI. The NEI method looks at port traffic for the 150 largest ports in the United States and only allocates those emissions. However, there are additional ports that are not accounted for in the allocation method. Identifying smaller ports that are not accounted for in the NEI would be an improvement.

Another approach to improving the NEI method is to allocate port emissions to the appropriate counties. Port emissions in the NEI are being assigned to a single county in the port area. While that may hold for some ports (e.g., deep sea ports or coastal ports) where the port activity is centered on one county, there are other ports along the Mississippi and the Ohio Rivers that span multiple counties and even state boundaries. Assigning these port emissions to the appropriate counties and states is another way to improve the NEI results.

Another approach to improving the NEI results is to conduct a bottom-up inventory by obtaining activity estimates at the state or local level from the DOT or Port Authority. This can include data on fuel consumption, as well as data to define the actual categories and characteristics of the vessels in terms of the number, size and horsepower in each category. Similar to aircraft, there are different emission rates depending on the operating mode of the vessels (i.e., cruising or reduced speed zone, maneuvering or hotelling), so data on the fraction of the time engines are spent in those modes would also be an improvement.

Finally, underway emissions can be improved by using available GIS data to monitor vessel movement.

Equation 4-4 shows the methodology for calculating emissions from commercial marine vessels. It requires data on vessel populations, horsepower, load factor, and the time-in-mode operation. Applying this emission equation with this data will produce a better inventory.

Equation 4-4. Emission Methodology for Commercial Marine Vessels

$$\text{Emissions} = \text{Pop} * \text{HP} * \text{LF} * \text{ACT} * \text{EF}$$

where:
Pop = Vessel Population or Ship Calls
HP = Average Power (hp)
LF = Load Factor (fraction of available power)
ACT = Activity (hours)
EF = Emission Factor (g/hp-hr)

4.3.3 Activity Profiles

In 1999 EPA completed two studies that provide commercial marine activity profiles for select ports, and present a method for an inventory preparer to allocate detailed time-in-mode activity data from a typical port to another similar port. These studies are *Commercial Marine Activity for Deep Sea Ports in the United States* and *Commercial Marine Activity for Great Lake and Inland River Ports in the United States*. The specific variables that are collected for the typical ports in these studies include: 1) the number of vessels in each category, 2) the vessel characterization, including propulsion size (horsepower), capacity tonnage, and engine age, and 3) the number of hours at each time-in-mode associated with cruising, reduced speed zone, maneuvering, and hotelling.

These studies also contain data on the number of trips and the tons of cargo handled by vessel type for the top 95 deep-sea ports and the top 60 Great Lake and inland river ports. Based on the data calculated for a typical port, more detailed activity can be estimated for these ports. These reports also describe how the typical port inventories were developed and how they can be scaled that to a port activity in a specific area.

4.3.4 Emission Factors

Horsepower-based emission factors are available for use with activity data on the number and size of engines. There are also fuel-based emission factors available for use with activity data on fuel consumption. EPA has been performing studies to develop updated emission factors as part of their rulemaking activities, such as the Category 3 engine final rulemaking that was published in 2003.

Table 4-6 presents EPA recommended PM_{10} emission factors that EPA has developed for specific categories of commercial marine engines, on a gram per kilowatt-hour basis for Category 1 and Category 2 engines (i.e., small commercial marine vessel engines).

Table 4-6. Small Commercial Marine Vessel PM_{10} Emission Factors

Engine Category	PM10 [g/kW-hr]
Category 1: 37-75 kW	0.90
Category 1: 75-225 kW	0.40
Category 1: 225+ kW	0.30
Category 2: (5-30 l/cylinder)	0.32

EPA recommended PM_{10} emission factors for the larger engines are listed in Table 4-7. These factors are listed by the different modes of operation.

Table 4-7. Large Commercial Marine Vessel PM_{10} Emission Factors

Mode: Engine	PM10 [g/kW-hr]
Cruise and Reduced Speed Zone: 2-stroke	1.73
Cruise and Reduced Speed Zone: 4-stroke	1.76
Maneuvering: 2-stroke	2.91
Maneuvering: 4-stroke	2.98
Hotelling: 2-stroke	0.32
Hotelling: 4-stroke	0.32
All Modes: Steam Generators	2.49

Emission factors in grams per gallon of fuel consumed are also available from *Procedures for Emissions Inventory Preparation, Volume IV: Mobile Sources*, EPA-450/4-81-026d (Revised), U.S. EPA, OAQPS, July 1989. As with aircraft category, $PM_{2.5}$ emissions from commercial marine vessels are estimated to be 92% of the PM_{10} emissions.

4.4 LOCOMOTIVES

The SCCs representing the locomotive categories that are currently used in the NEI are listed in Table 4-8. This includes larger Class I line haul locomotives that travel through many states, as well as the smaller Class II and III line haul locomotives that tend to operate in a smaller area. The NEI also has information on passenger Amtrak trains, commuter trains, and switchyard operations.

Table 4-8. Locomotive SCC

SCC	Type
2285002006	Diesel Class I Line Haul
2285002007	Diesel Class II/III Line Haul
2285002008	Diesel Passenger (Amtrak)
2285002009	Diesel Commuter
2285002010	Diesel Switchyard Locomotives

4.4.1 NEI Method

The PM emission factors in that are used in the NEI for the line haul and yard operations are listed in Table 4-9.

Table 4-9. NEI Locomotive PM Emission Factors

Type	PM10	PM2.5
Line-Haul	6.7 g/gallon	6.03 g/gallon
Yard	9.2 g/gallon	8.28 g/gallon

The activity data are based on a national estimate of the gallons of distillate fuel oil consumed. This national fuel consumption is allocated among four of the five categories of railroads to develop a national activity value for these four categories (i.e., Class I, Class II/III, Passenger, and Commuter). Switchyard operation activity is estimated by multiplying the national Class I fuel consumption by the estimated line-haul percentage of the total fuel consumption. In other words, the fuel consumption estimates for Class I line-haul locomotives are assumed to include switchyard fuel consumption. This assumption is based on the fact that the larger line-haul railroads are the ones that tend to operate in a switchyard.

The allocation of the activity data to the county level is based on a ratio of county to national rail activity. This rail activity is measured as a product of density (gross tons per mile) for each rail line and mileage for the associated rail line in the county. Mileage for each rail line in the county is measured using a GIS database that is available from the Bureau of Transportation Statistics.

Detailed documentation on the procedures used to develop criteria and HAP pollutant locomotive emission estimates for the 1999 NEI can be found at the following web address:

ftp://ftp.epa.gov/EmisInventory/finalnei99ver3/criteria/documentation/nonroad/99nonroad_voli_oct2003.pdf.

4.4.2 NEI Improvements

The first step in improving the NEI locomotive emission estimates is to examine the NEI data for reasonableness. If the NEI data does not represent emissions in a specific area, more representative fuel consumption at the local or state level should be obtained. Also, because the NEI makes an assumption to estimate switchyard emissions, an improvement could be made by obtaining information on the actual switchyard activity in the study area.

4.4.3 Case Study

This case study describes the development of a county level locomotive inventory for Sedgwick County, Kansas. This case study reviews the activity data that was collected to calculate fuel consumption, and demonstrates how emissions were separately estimated for line-haul and switchyard operations. In developing this inventory only two SCCs (Line-Haul and Switchyard Operations) were included. The activity data was obtained through a survey of railroad companies operating in the inventory area. Emission factors in pounds per gallon were applied to these activity data to estimate emissions for PM_{10} and $PM_{2.5}$.

4.4.3.1 Data Collected

The types of data that were obtained from the survey included locomotive fuel consumption rates and traffic density for the large line-haul locomotives; fuel consumption rates and percentage of the total track in the inventory area for smaller line-haul locomotives; and the number of yard locomotives for switchyard locomotives. Because the railroad operated outside the county, the total annual fuel consumption represented locomotives that were operated outside of the inventory area. To adjust for this, the fuel consumption in the inventory area was estimated by applying the percentage of the total track length in the inventory area to the total fuel consumption estimate.

The PM emissions factors that were applied to the activity data were the same factors that were used in the NEI (listed in Table 4-9). In addition, it was assumed that 92% of PM_{10} is $PM_{2.5}$.

The specific data provided by the railroad companies included the gross tonnage by a specific line segment of the rail as well as an estimate of the distance and miles for each of these segments. They also provided a fuel consumption index of 0.00139, which relates gallons consumed to gross ton mile. This estimate was assumed to apply for all line segments. This data is presented in Table 4-10.

Table 4-10. Locomotive Data Provided by Railroads

Line Segment	Gross Tonnage, Million GT	Distance in Miles
1	15.0	17.0
2	8.0	15.0
3	0.0	10.5

4.4.3.2 Line Haul Emission Calculations

Line haul emissions were estimated by calculating traffic density for each line segment. This is obtained by multiplying gross tonnage by the total miles of track. Using the data provided in Table 4-10, a traffic density value of 255 million gross ton miles is calculated for line segment 1. The next step in the emissions calculation process is to estimate the fuel consumption. This is obtained by multiplying the estimated traffic density by the fuel consumption index. Using the case study data, this value is estimated to be 354,450 gallons. The third step is to multiply the fuel consumption (gallons per year) by the PM_{10} emission factor (pounds per gallon) to obtain an emission estimate of 2.62 tons of PM10-PRI per year. The final step is to calculate the $PM_{2.5}$ emission by applying the particle size multiplier of 0.92 to the PM_{10} emission estimate. These steps are done for each of the three line segments, however, the third line segment has zero gross tons operating on that segment, so that segment has zero emissions.

Table 4-11 presents the collected data and the data that was calculated for each of the line segments and the sum of total emissions for the entire inventory area.

Table 4-11. Summary of Line Haul Emission Calculations

Line Segment	Gross Tonnage Million GT	Distance in Miles	Density Million GTM	Fuel Use in Gallons	PM10-PRI Emissions, TPY
1	15.0	17.0	255.0	354,450	2.62
2	8.0	15.0	120.0	166,800	1.23
3	0.0	10.5	0.0	0	0
Total	23	42.5	375	521,250	3.86

4.4.3.3 Switchyard Emission Calculations

The first step in estimating switch yard emissions is to multiply the number of switch yard locomotives that was provided by the railroad company by EPA's default value of 82,500 gallons of fuel consumed for each switchyard locomotive to obtain a fuel consumption estimate. This particular railroad operates two switchyards and provided an estimate of how often throughout the year each yard was operating. Because EPA assumes that each locomotive in a switchyard operates 24 hours a day, 365 days a year, this data was very useful in developing a more accurate inventory.

This explains why the data in Table 4-12 shows fractions of switchyard locomotives in use in each switchyard.

Table 4-12. Summary of Switchyard Emission Calculations

Switch Yard	EPA Estimated Yearly Fuel Consumption	Number of SwitchYard Locomotives	Fuel Use in Gallons	PM10-PRI Emissions, TPY
1	82,500	1.3	107,250	1.09
2	82,500	0.5	41,250	0.42
Total		1.8	148,500	1.51

The estimated fuel consumption for the two switchyards is added together to obtain the fuel consumption for both switchyards in the inventory area. The next step is to multiply the fuel consumption (gallons per year) by the PM_{10} emission factor (pounds per gallon) to obtain an emission estimate of 1.51 tons of PM10-PRI per year. The final step is to calculate the $PM_{2.5}$ emission by applying the particle size multiplier of 0.92 to the PM_{10} emission estimate.

Finally, another smaller railroad company was operating in the inventory area. However, this railroad company did not have records on the gross tonnage to allow the traffic density to be estimated. In this case, the fuel consumption for that railroad was estimated by multiplying the railroad's total fuel consumption by the percent of the railroad's track mileage in the inventory area. This estimated fuel consumption is then multiplied by the emission factor and the particle size multiplier to obtain emissions estimates for PM10 and $PM_{2.5}$.

Review Exercises

1. Which of the following types of equipment are denoted by a four-digit SCC instead of the usual seven-digit designation?
   a. Logging
   b. Railroad Maintenance
   c. Underground Mining
   d. Recreational Equipment

2. Which of the following pollutants does **not** have an emission factor included in the NONROAD model?
   a. CO
   b. CO2
   c. Ammonia
   d. VOC

3. Which of the following is a measure of equipment activity that is used by the NONROAD model to estimate exhaust emissions?
   a. Load factor
   b. Horsepower
   c. Equipment population
   d. All of the above

4. For gasoline and diesel engines, the NONROAD model assumes that $PM_{2.5}$ is _______ PM_{10}.
   a. equal to
   b. one half of
   c. 0.08 times
   d. 0.92 times

5. National aircraft emissions in the NEI are allocated to the county level based on _______.
   a. population
   b. airport LTO data
   c. the number of airports
   d. All of the above

6. The first step in estimating aircraft emissions for a specific airport in the NEI involves _______.
   a. estimating the time-in-mode for the aircraft fleet
   b. defining the fleet make-up for the airport
   c. determining the mixing height
   d. determining the number of LTO at the airport

7. The NEI methodology for commercial marine vessels allocates _______ emissions to a single county.
   a. port
   b. underway
   c. both port and underway
   d. neither port nor underway

8. Which of the following is **not** an example of activity data that characterizes a commercial marine vessel?
   a. Propulsion size
   b. Time-in-mode
   c. Capacity tonnage
   d. Engine age

9. The NEI allocates national fuel consumption to develop a national activity for all the locomotive categories **except _______**.
   a. Class I
   b. Passenger
   c. Commuter
   d. Switchyard

10. Which of the following types of data is least likely to be obtained in a survey of a railroad company, especially for smaller companies?
    a. fuel consumption
    b. total miles of track
    c. gross tonnage
    d. number of locomotives

Review Answers

1. b. Railroad Maintenance

2. c. Ammonia

3. d. All of the above

4. d. 0.92 times

5. b. airport LTO data

6. c. determining the mixing height

7. a. port

8. b. Time-in-mode

9. d. Switchyard

10. c. gross tonnage

Chapter 5: Point Source Inventory Development

LESSON GOAL

Demonstrate, through successful completion of the chapter review exercises, a general understanding of the issues associated with identifying point sources for inclusion in an emissions inventory, including the form of the particulate matter and the particle size. You should be able to describe the methods for estimating emissions and be able to articulate the overlap issues associated with point and nonpoint source emission inventories.

STUDENT OBJECTIVES

When you have mastered the material in this chapter, you should be able to:

1. Explain the difference between filterable and condensable particles.
2. Explain the difference between primary and secondary particulate matter.
3. Identify the form of particulate matter that States must report to EPA.
4. Describe the approach for calculating the particle size of particulate matter from specific source categories.
5. Identify the available tools for estimating particulate matter emissions.
6. Identify and explain the overlap issues that exist between point and nonpoint source emission inventories.

Chapter 5: Point Source Inventory Development

5.1 IDENTIFYING POINT SOURCES

Point sources are stationary sources that are included in a point source inventory. Total plant or facility emissions for a given pollutant is usually the criterion for deciding if a specific source should be included in a point source inventory or an nonpoint source inventory. These criteria are defined by either state, local or tribal regulations or policy, or the reporting thresholds contained in the Consolidated Emissions Reporting Rule (CERR).

5.1.1 Filterable versus Condensable PM

Filterable PM is particles that are directly emitted as a solid or liquid at stack or release conditions and captured on the filter of a stack test train. Filterable PM may be PM_{10} or $PM_{2.5}$. Condensable PM is material that is in the vapor phase at stack conditions but condenses and/or reacts upon cooling and dilution in the ambient air to form a solid or a liquid particulate immediately after discharge from the stack. Condensable PM is almost always $PM_{2.5}$ or less.

Combustion sources typically emit both filterable and condensable emissions. Examples include boilers, furnaces and kilns, and both reciprocating internal combustion engines and turbines. Fugitive dust sources emit filterable emissions only. Examples of fugitive dust sources include storage piles and unpaved roads at industrial sites.

5.1.2 Primary versus Secondary PM

Primary PM is the sum of the filterable and the condensable PM. All primary particles are emitted directly from a stack. Secondary PM is particles that form through chemical reactions in the ambient air after dilution and condensation has occurred. Secondary PM is formed downwind of the source. Precursors of secondary PM include SO_2, NO_x, ammonia and VOC. The secondary PM should **not** be reported in the emission inventory, just the precursor emissions.

5.1.3 Ammonia Sources

Sources of ammonia emissions fall into three broad categories: industrial processes, use of ammonia as a reagent in NO_x control (e.g., selective catalytic reduction or selective non-catalytic reduction), and refrigeration losses. Examples of industrial processes that emit ammonia include combustion sources, ammonium nitrate and phosphate production, petroleum refining, pulp and paper production, and beet sugar production. These industrial processes represent the more significant contributors of ammonia emissions from industrial processes as reported in the 2000 Toxics Release Inventory (TRI).

5.1.4 Resources

Resources for identifying point sources of fine PM and ammonia include Volume II of the Emissions Inventory Improvement Program (EIIP) guidance document for point sources, AP-42 emission factors document, and existing inventories such as the NEI and the TRI (for ammonia).

5.2 REPORTING PM

When States report their $PM_{2.5}$ primary (PM2.5-PRI) emissions to the EPA, either $PM_{2.5}$ primary or the $PM_{2.5}$ filterable and PM condensable components individually can be reported. All PM condensable is assumed to be in the $PM_{2.5}$ size. When States report their PM_{10} primary emissions to the EPA, either PM_{10} primary or the PM_{10} filterable and PM condensable components individually can be reported.

In addition, if a state can't determine whether the emissions represent the $PM_{2.5}$ or PM_{10} size fraction, the total primary PM measured can be reported. Alternatively, the filterable total primary PM measured and the condensable PM can be reported individually. These two PM components are the components measured by a stack sampling train such as EPA Method 5 and have no upper particle size limit.

Reporting should be done by using the NIF 3.0 PM pollutant code extensions that identify the forms of the PM. This includes PRI for primary filterable, FIL for filterable, and CON for condensable. The database management system will need to be updated to record these pollutant code extensions.

The form of the PM should be verified to ensure that PM emissions that are recorded as PM_{10} or $PM_{2.5}$ are correctly identified as filterable, condensable, or primary emissions. This verification may require an examination of the emission factors on which the emissions are based. If the emissions were reported by facilities, the verification will require that States contact the facilities to ask them what emission factors were used to calculate the emissions. Alternatively, if the emissions estimates provided by the sources are based on stack test data, the States will need to ask them what method was used to measure the emissions in order to determine the form of PM.

Examining the test method used to collect the data can identify the form of the PM. EPA's Reference Method 5 series is used to measure total PM filterable emissions. Most of the AP-42 emission factors are based on Method 5 and, therefore, represent PM-filterable. Method 17 is similar to the Method 5, however it is infrequently used.

Method 201/201A is designed for PM_{10} filterable. In order to calculate or measure the PM_{10} filterable or the $PM_{2.5}$ filterable, a particle size analysis of the total PM must be conducted to develop the size fractions or cut points for PM_{10} or $PM_{2.5}$. This information is used to develop particle size specific emission factors in AP-42. However, most of the emission factors in AP-42 are for filterable emissions, although there are some condensable emission factors for combustion sources. The filterable and condensable emission factors need to be summed to obtain a PM primary emission factor. There are some exemptions so it is important to always understand the form of the PM that the emission factor represents.

For condensable, Preliminary Method 4 is being developed by the EPA to measure both $PM_{2.5}$ filterable and condensable. Method 202 is a method for condensable PM, but it is not used frequently, mainly because regulations do not require sources to measure condensable emissions.

5.3 PARTICLE SIZE

AP-42 provides particle size distribution data and particle size specific emission factors. Some of the source categories (e.g., combustion) in AP-42 have particle size specific emission factors for PM and, for those categories, that data should be used first. Appendix B1 should be used for source categories that do not have particle size specific emission factors. Appendix B1 contains particle size distribution data and particle size emission factors for selected sources. It is based on documented emissions data available for specific processes. In the event that Appendix B1 does not have particle size data for the source category of interest, Appendix B2 should be used. Appendix B2 contains generalized particle size distributions that are based on data for similar processes. These distributions are approximations and should only be used in the absence of source specific particle size distribution data.

Prior to consulting AP-42, any source specific data at the local or state level should be examined. Any information reported by a source is going to be the best data. If source provided information does not exist, the hierarchy of resources from AP-42 discussed above should be used. AP-42 chapters are not always clear on what source test methods were used to develop the particle size data, so the background information documents that were used to develop the chapters for AP-42 may need to be consulted. AP-42 is available in EPA's Clearinghouse for Inventories and Emission Factors (CHIEF) website at www.epa.gov/ttn/chief/.

5.4 EMISSION ESTIMATION TOOLS

5.4.1 Factor Information Retrieval System (FIRE)

The Factor Information Retrieval System (FIRE) is a compilation of emission factors from AP-42 and other documents. It is an electronic database that is available on the CHIEF web site. EPA is in the process of developing a complete set of PM_{10} and

$PM_{2.5}$ filterable and PM condensable emission factors that will be incorporated into FIRE.

5.4.2 The PM Calculator

The PM Calculator is a tool developed by EPA to calculate uncontrolled and controlled filterable $PM_{2.5}$ and PM_{10} emissions using AP-42 particle size data. For example, it can be used to calculate the $PM_{2.5}$ filterable emissions based on the PM_{10} filterable emissions contained in an inventory. It can also be used to calculate PM_{10} and $PM_{2.5}$ from the total PM filterable emissions. The calculator only deals with the filterable emissions (i.e., it does not address the condensable portion) and is for point sources only. Although it contains over 2300 SCCs, it is limited in that it is based on AP-42 particle size data that is not available for many sources. As a result, many times it uses the generic particle size data that is contained in Appendix B2 of AP-42 or other sources. It is also available on the CHIEF web site.

5.5 POINT AND NONPOINT SOURCE OVERLAP ISSUES

For categories included in the point and nonpoint source emission inventories, the total point activity must be subtracted from the total state activity to obtain a total nonpoint source activity. Using the fuel combustion category as an example, the point source activity is the fuel throughput from the point source inventory. Total activity is the statewide fuel throughput obtained from the state or local government agency or from the state energy data reports published by the Interior Energy Administration in the U.S. Department of Energy.

Ideally, the point source subtraction is based on activity data. For example, the point source fuel throughput for a given year (e.g., 2002) is subtracted from the total statewide fuel consumption for the same year. However, in a lot of cases, the activity data for performing that calculation may not be available. In this case, an emissions based calculation is acceptable. Under the emissions based approach, the total source category activity and the point activity need to be on the same control level. This control level should be an uncontrolled emissions basis because the total statewide activity represents uncontrolled sources. In this case, it is important to ensure that the point source emissions represent uncontrolled levels. It is also important to check the uncontrolled emissions to make sure that they seem reasonable.

5.5.1 Geographic Adjustment

The geographic level of the point source adjustment that is used to calculate the nonpoint source activity is an issue when surrogate activity data (e.g., employment and housing populations) is used to allocate total state activity to the county level. For example, the EIIP method recommends using employment for specific SIC codes to allocate total statewide natural gas combustion to the county level for fuel combustion at industrial and commercial institutions. However, summing the point source throughput for a given county and subtracting it from the total activity for the county may produce negative results, indicating the point source consumption fuel use is higher than that calculated for the nonpoint sources. This can be an artifact of the allocation data that was used. The preferred approach is to sum up the point source fuel throughput consumption on the state level and subtract it from the total consumption for the state prior to doing the county-level allocation. It is also preferable to obtain activity data such as employment data for the point sources included in the inventory. In this way it is possible to make point source adjustments to the surrogate allocations to account for the amount of employment that is associated with the point sources.

5.5.2 QA/QC

It is also recommended that the county level nonpoint source estimates be reviewed for reasonableness after the adjustment has been made. Adjustments should be based on the experience of the agency personnel. For example, if the allocation method places nonpoint source activity in a county for which it is known that there is no activity, that county should be excluded from the allocation. Also, if all of a county's activity is covered by the point source emission inventory, the nonpoint source emissions should be zero.

5.5.3 CERR Reporting

If the point emission inventory includes sources with emissions below the CERR point emission inventory reporting thresholds, the emissions for these small sources can be included in the nonpoint source emissions. However, in this case it is important to avoid double counting in the nonpoint source inventory. This can be done by subtracting the total point source activity from the total state activity before rolling up the small point source data to add to the inventory. In this way the emissions for the small point sources in the area are not double counted.

5.6 ADDITIONAL MATERIALS

A suggested reading list for preparing point source inventories for fine PM is listed in Table 5-1.

Table 5-1. Reading List

Stationary Source Control Techniques Document for Fine Particulate Matter, EPA/OAQPS, Oct. 1998 (http://www.epa.gov/ttn/oarpg/t1/meta/m32050.html)
Emission Inventory Guidance for Implementation of Ozone and Particulate Matter National Ambient Air Quality Standards (NAAQS) AND Regional Haze Regulations, EPA, OAQPS (http://www.epa.gov/ttn/chief/eidocs/publications.html)
Introduction to Stationary Point Source Emission Inventory Development, EIIP Vol. 2, Chapter 1, May 2001
How to Incorporate Effects of Air Pollution Control Device Efficiencies and Malfunctions into Emission Inventory Estimates, EIIP Vol. 2, Chapter 12, July 2000

Review Exercises

1. _______ particulate matter is particles that are directly emitted as a solid or liquid at stack or release conditions and captured on the filter of a stack test train.
   a. Condensable
   b. Primary
   c. Secondary
   d. Filterable

2. Which of the following should **not** be reported in a particulate matter emission inventory?
   a. Primary PM
   b. Secondary PM
   c. Secondary PM precursors
   d. Filterable PM

3. What should be reported if it cannot be determined whether the emissions represent the $PM_{2.5}$ or PM_{10} size fraction?
   a. total primary PM
   b. filterable total primary PM and condensable PM, individually.
   c. both a and b
   d. None of the above

4. Which EPA test method is designed for measuring PM_{10} filterable?
   a. Method 5
   b. Method 201/201A
   c. Method 17
   d. Preliminary Method 4

5. In estimating particle size, which of the following sources of particle size data should be consulted first?
   a. AP-42
   b. Appendix B-1
   c. Appendix B-2
   d. State and local data

6. Which of the following can be used to estimate $PM_{2.5}$ emissions based on the PM_{10} emissions?
   a. AP-42
   b. FIRE
   c. The PM Calculator
   d. CHIEF

7. The best approach to calculating a total nonpoint source activity level is to base it on _______.
   a. activity data
   b. emissions data
   c. geographical location
   d. population data

8. The geographical level of the point source adjustment is important when _______ data is used to allocate total state activity to the county level.
   a. employment
   b. population
   c. square mileage
   d. All of the above

9. Adjustments made to the county level nonpoint source estimates should be based on _______.
   a. data obtained from the sources
   b. the experience of the agency personnel
   c. data obtained from surveys
   d. All of the above

10. What is he appropriate action when the point source inventory includes sources with emissions below the CERR reporting thresholds?
   a. Nothing
   b. Include those sources in the nonpoint source inventory
   c. Include those sources in both the nonpoint source and pint source inventories
   d. Create a special category for these sources in the point source inventory

Review Answers

1. d. Filterable

2. c. Secondary PM precursors.

3. c. both a and b.

4. b. Method 201/201A

5. d. State and local data

6. c. The PM Calculator

7. a. activity data

8. d. All of the above

9. b. the experience of the agency personnel

10. b. Include those sources in the nonpoint source inventory

Chapter 6: Nonpoint Sources

LESSON GOAL

Demonstrate, through successful completion of the chapter review exercises, a general understanding of the approach for identifying nonpoint sources for inclusion in an emissions inventory; the methodologies for estimating emissions from nonpoint sources; and the reconciliation of fugitive emissions data with ambient data.

STUDENT OBJECTIVES

When you have mastered the material in this chapter, you should be able to:

1. Identify the different sources of data for identifying nonpoint sources for inclusion in an emissions inventory.
2. Explain PM one pagers and identify the information that they contain.
3. Identify typical nonpoint source categories of PM emissions.
4. Describe the general methodology for estimating PM emissions from nonpoint sources.
5. Explain the concepts of rule effectiveness and rule penetration.
6. Explain the mechanisms that lead to the disparity between fugitive emissions data and ambient data.
7. Explain the issues with modeling fugitive dust with both Gaussian and grid models.

Chapter 6: Nonpoint Sources

6.1 OVERVIEW

A nonpoint source is any source that is a stationary source that is not included in the point source inventory. It should be noted that for emission inventory development purposes, EPA has traditionally used the term "area sources" to refer to stationary air pollutant emission sources that are not inventoried at the facility-level. The Consolidated Emissions Reporting Rule (CERR) specifies reporting thresholds for point and area sources of criteria air pollutants, which vary depending on the pollutant and the attainment status of the county in which the source is located (see http://www.epa.gov/ttn/chief/cerr/index.html). The Clean Air Act (CAA) also includes a specific definition of area sources of Hazardous Air Pollutants (HAPs) for the purpose of identifying regulatory applicability. In particular, the CAA defines an area HAP source as "any stationary source . . . that emits or has the potential to emit considering controls, in the aggregate, less than 10 tons per year of any HAP or 25 tons per year of any combination of HAPs." Sources that emit HAPs above these thresholds are categorized as "major sources." To reduce confusion between these two sets of area source definitions, EPA has adopted the term "nonpoint" to refer to all criteria air pollutant and HAP stationary emission sources that are not incorporated into the point source component of the NEI.

Throughout this Chapter there are references to CHIEF, EIIP chapters, EIIP One-pagers, and the PM2.5 Resource Center. Table 6-1 lists the web site address for each of these references.

Table 6-1. Web Address for References Cited in this Chapter

Reference	Web Address
CHIEF	www.epa.gov/ttn/chief
EIIP Chapters	www.epa.gov/ttn/chief/eiip/techreport/volume03/index.html
EIIP One-pagers	www.epa.gov/ttn/chief/eiip/pm25inventory/areasource.html
PM2.5 Resource Center	www.epa.gov/ttn/chief/eiip/pm25inventory/index.html

6.1.1 Identifying Nonpoint Sources

Volume III of the EIIP Area Source Guidance lists the PM fine categories for which the EIIP guidance is available (see Table 6-2). AP-42 and existing emission inventories also can help identify nonpoint source categories that are sources of fine PM and ammonia emissions. Specific existing inventories include the National

Emissions Inventory, the Toxics Release Inventory, and any inventories developed through the efforts of a regional planning organization or state and local agencies.

Table 6-2. Key Chapters of Volume III of the EIIP Area Source Guidance for Sources of PM Emissions

Chapter	Topic
2	Residential Wood Combustion
16	Open Burning
18	Structure Fires
24	Conducting Surveys for Area Source Inventories

The EIIP also has "area source category method abstracts" for charbroiling, vehicle fires, residential and commercial/institutional coal combustion, fuel oil and kerosene combustion, and natural gas and liquefied petroleum gas combustion.

The PM2.5 Resource Center, which is available on the CHIEF website contains "PM one-pagers," which contain an overview of the NEI methods and summarize nonpoint source NEI methods for specific categories of PM_{10}, $PM_{2.5}$, and ammonia. These overviews provide the source category name and SCC, the pollutants of most concern, current NEI method, and how state, locals, and tribal agencies can improve on the NEI method, uncertainties and shortcomings. They also contain activity variables used to calculate the emissions, current variables and assumptions used in the methods, suggestions for improving the variables, and where to find additional information and guidance for the categories. The open burning categories covered by the one-pagers include residential yard waste for leaves, household waste, residential, nonresidential, and road construction land clearing waste, structure fires, wildfires and prescribed burning, and managed or slash burning. Fugitive dust categories covered by the one-pagers include paved and unpaved roads, residential construction, and mining and quarrying. One-pagers also exist for residential combustion (i.e., fireplaces, woodstoves, and other residential home heaters that burn natural gas or fuel oil).

6.1.2 Typical Source Categories

Table 6-3 identifies typical area source categories grouped by fugitive dust sources of filterable PM emissions, open burning nonpoint source categories of carbonaceous fine PM, external and internal fuel combustion nonpoint sources of carbonaceous fine PM, and ammonia nonpoint sources.

Table 6-3. Typical Nonpoint Source Categories

Source Category	Typical Source Categories
Fugitive Dust	Construction Mining and Quarrying Paved and Unpaved Roads Agricultural Tilling Beef Cattle Feed Lots
Open Burning	Open Burning (residential municipal solid waste, yard waste, and land clearing debris) Structure Fires Prescribed Fires Wildfires Agricultural Field Burning
Fuel Combustion	Residential Wood Combustion Other Residential Fuel Combustion Industrial Fuel Combustion Commercial/Institutional Fuel Combustion
Ammonia	Animal Husbandry Agricultural Fertilizer Application Agricultural Fertilizer Manufacturing Waste Water Treatment

Figure 6-1 shows the relative contribution of the nonpoint particulate matter source categories based on the 2001 National Emissions Inventory. Figure 6-2 shows similar data for the ammonia source categories.

Figure 6-1. PM2.5 Emissions in the 2001 NEI

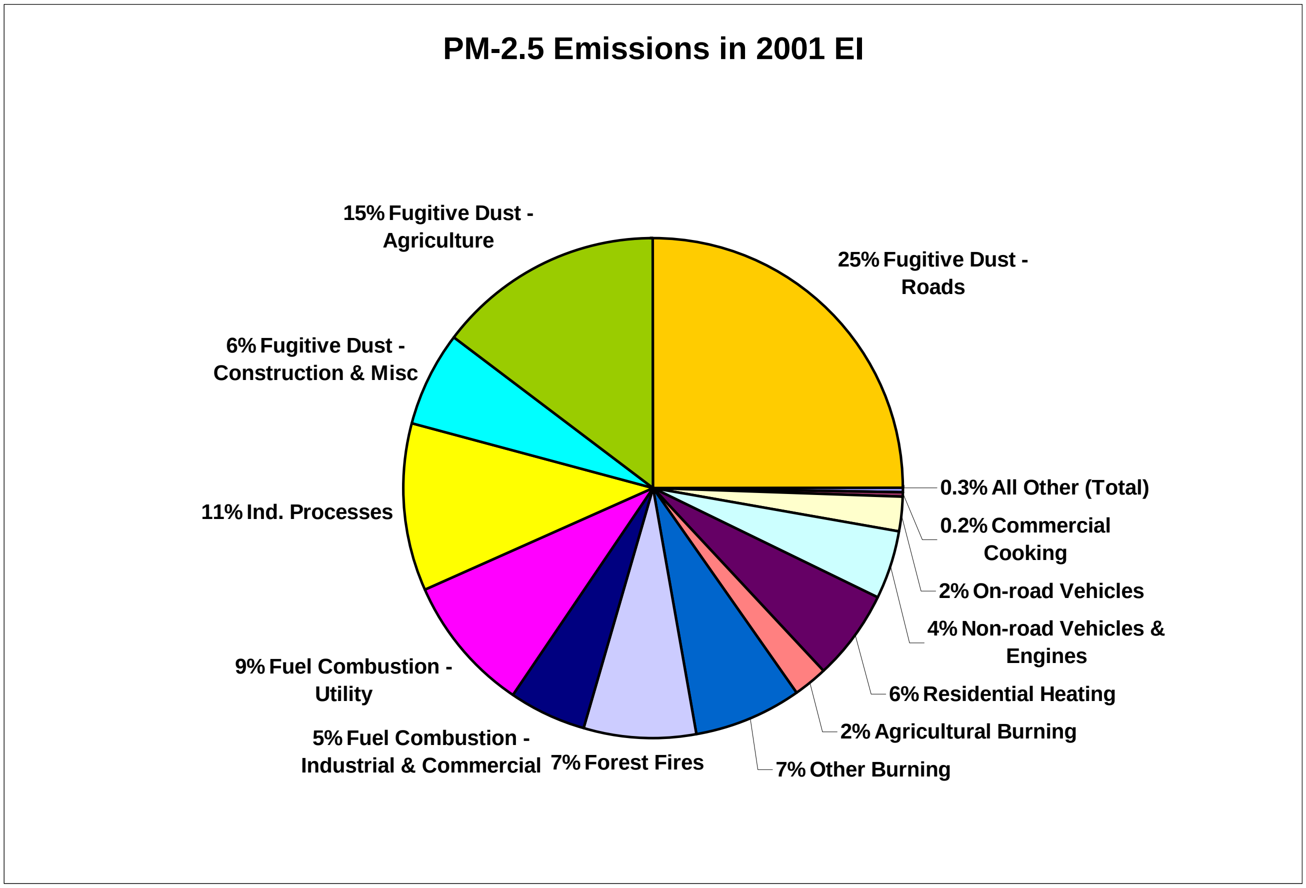
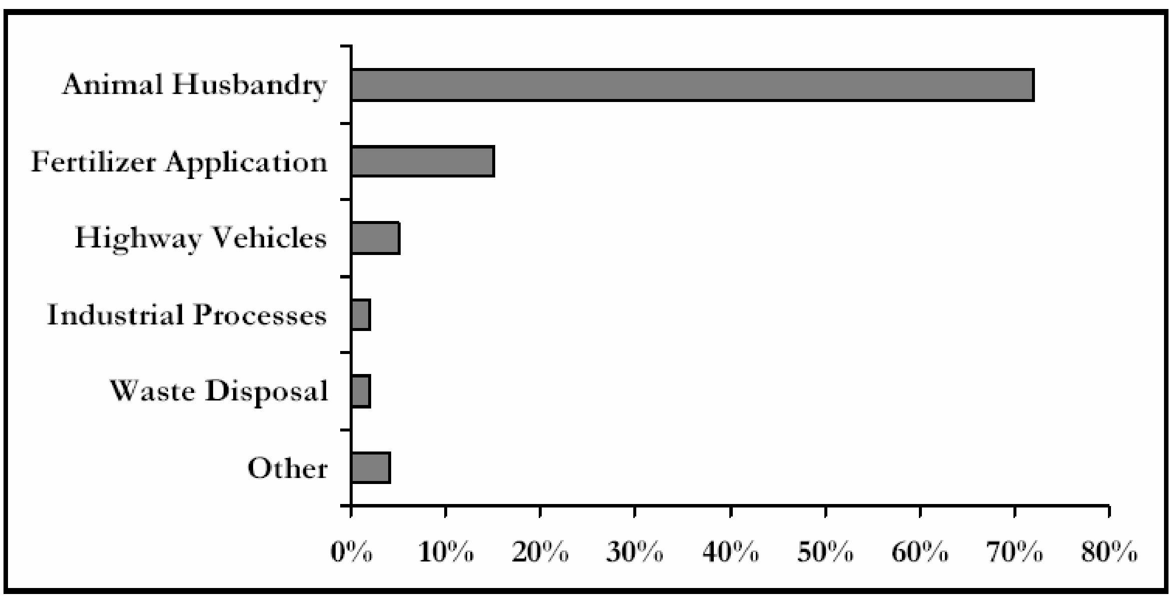


Figure 6-2. NH3 National Emissions



6.1.3 Estimating Emissions

Nonpoint source inventories are prepared and reported by the 10-digit SCC source classification code. Also, actual emissions, not allowable or potential emissions are reported for the NEI. EPA's master list of SCCs are available on the CHIEF website at www.epa.gov/ttn/chief/codes/index.html#scc. This is a dynamic list that can be updated (with EPA's approval) to add SCCs. For example, SCCs should be added if there are several subcategories within a general nonpoint source category and a state or local agency is estimating emissions at that level.

Emissions from nonpoint sources are calculated by multiplying the activity data with the emission factor, control efficiency data, rule effectiveness, and rule penetration. It should be noted that EPA guidance specifically excludes applying default RE/RP assumption values for PM inventories. It is highly recommended that the EIIP methods be followed since these were developed with state and local input and they reflect the most current standardized procedures for preparing emission inventories. The EIIP provides preferred and alternative methods for collecting activity data and the use of emission factors, and contains suggested improvements on existing inventory methods. Equation 6-1 is a summary of the emission estimation equation.

Equation 6-1. Nonpoint Source Emission Estimation Equation

$$C_A = (EF_A)*(Q)*[(1-(CE))(RP)(RE)]$$

where: C_A = Controlled nonpoint source emissions of pollutant A
EF_A = Uncontrolled emission factor for pollutant A
Q = Category activity
CE = % Control efficiency/100
RP = % Rule penetration/100
RE = % Rule effectivenss/100

Activity data is obtained from various published sources of data or surveys. However, the use of use national, regional and state level activity data requires allocation to the counties using county-level surrogate indicator data. As a result, the use of a survey is the preferred approach to obtain the local estimates of activity (i.e., a bottom-up approach, rather than a top-down approach).

Emission factors for PM and ammonia can be obtained from FIRE and AP-42. Alternatively, the emission factor ratio or particle size multiplier approach can be used. This involves calculating the $PM_{2.5}$ emissions from the PM_{10} emissions using the ratio of $PM_{2.5}$ to PM_{10} emission factors in AP-42. However, the use of state, local, and tribal emission factors are preferred over any other approach because they are always specific.

Control efficiency is the percentage value representing the amount of a source category's emissions that are controlled by a control device, process change, reformulation, or a management practice. They typically are represented as the weighted average control for a nonpoint source category.

Rule effectiveness (RE) is an adjustment to the control efficiency to account for failures and uncertainties that affect the actual performance of the control method. Rule penetration (RP) represents the percentage of the nonpoint source category that is covered by the applicable regulation or is expected to be complying with the regulation.

6.1.4 Spatial and Temporal Allocation

The available national, regional, or state-level activity data often require allocation to counties or subcounties using surrogate indicators. As such, state, local, and tribal agencies should review emission estimates developed in this manner for representativeness. The available temporal profiles to estimate seasonal, monthly, or daily emissions for specific categories may be limited so states are encouraged to reflect local patterns of activity in their emission inventories. For example, residential home heating emissions from fuel oil combustion can be allocated to the county level by using the number of households in each county in the state.

6.1.5 EI Development Approaches

The approaches that are available to state, local, and tribal agencies for developing an emissions inventory include developing an emissions inventory following the EIIP procedures; comparing the state, local, tribal activity data and assumptions to the NEI defaults and replacing the defaults, as necessary; or using the NEI default estimates.

The triage approach to improving the emissions inventory involves considering the importance of each NEI category and examining the potential impact on air quality, considering emissions, receptor modeling, and other available information. Improvements should be made to those categories that are determined to be important using the suggestions and references provided in this training course. This includes reviewing the available guidance and deciding what approaches are doable in the near term and longer term.

6.2 RECONCILING FUGITIVE DUST EMISSIONS WITH AMBIENT DATA

As discussed in Chapter 1, the main sources of crustal materials are unpaved roads, agricultural tilling, construction, and wind-blown dust. There is a huge disparity between the crustal data in an emissions inventory and the ambient air quality data. The amount of crustal material on the ambient filters is much less than one would expect given the large estimates of fugitive dust emissions in the NEI. This apparent anomaly is explained by the fact that fugitive dust has a low transportable fraction.

The data presented in Figure 6-3 show that $PM_{2.5}$ inventories in the States included in the VISTAS area have fugitive dust in the 20-40% range. The rest of PM in the inventory is from sources that are primarily carbonaceous. Comparing this data with the data presented in Figure 6-4 shows that the ratio of crustal $PM_{2.5}$ emissions to total carbonaceous matter emissions does not match with the ratio of crustal to total carbonaceous $PM_{2.5}$ based on the ambient data.

Figure 6-3. Fugitive Dust Emissions in VISTAS States

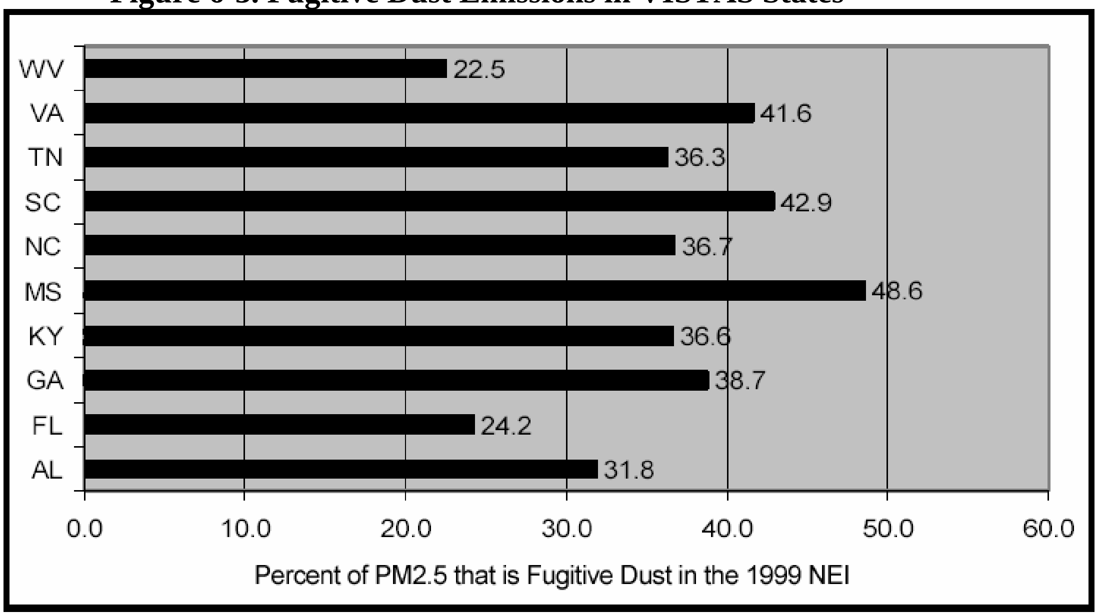
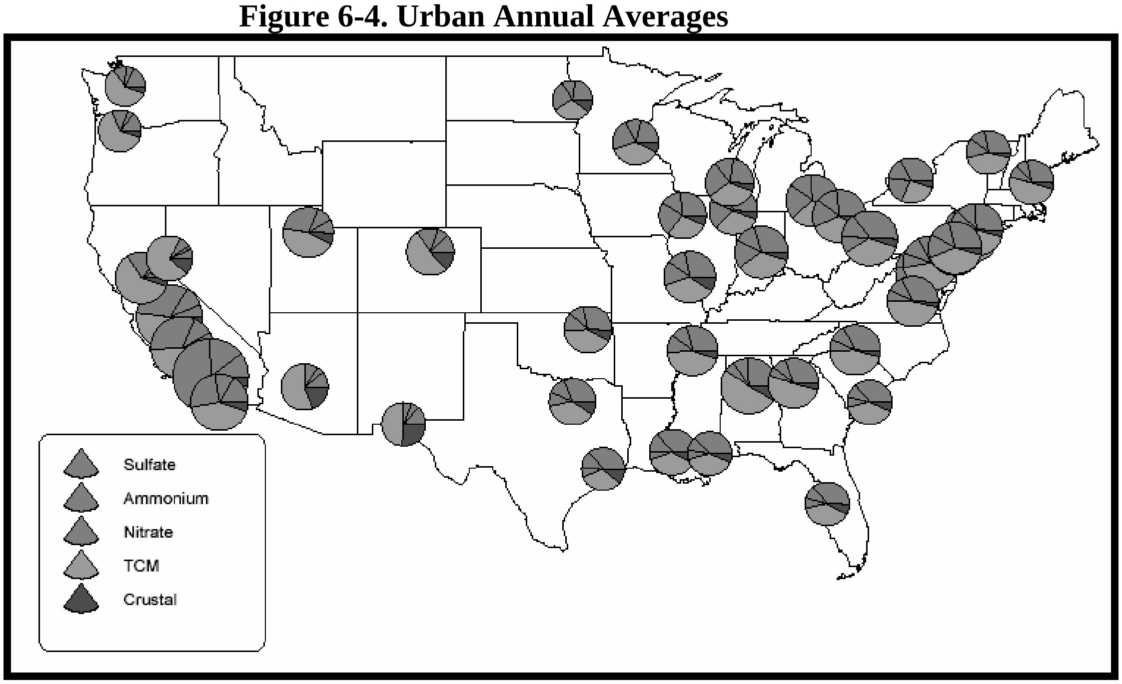


Figure 6-4. Urban Annual Averages



6.2.1 Fugitive Dust Removal Processes

In the process of developing models the concept of a stilling zone underneath the canopy of vegetation was recognized. Within the stilling zone (the bottom three-fourths of the height of the vegetation) the air is very still and it lends itself to gravitational settling and impaction and filtration by the vegetation.

In the western part of the country it is common to see wind breaks. These are basically a row of trees or other tall vegetation designed to slowdown the wind speed on the leeward side of the downwind side. The overall objective is to prevent the wind from catching the soil and picking it up and eroding it. Another important feature of windbreaks is the entrapment effect involving the transmittance of dust through a wind break. Research shows that the dust that goes through a wind break is about the same as the optical transmittance of light through a wind break and the remainder is trapped in the windbreak.

6.2.2 Capture and Transport Fraction

Capture fraction is the portion of fugitive dust emissions that are removed by nearby surface cover and transport fraction is the portion that is transported out of the source area. The capture fraction plus the transport fraction together sum to the fugitive dust emissions inventory.

Figure 6-5 shows a graph that plots a capture fraction value (from zero to 1) and the type of vegetation qualitatively described as going from densely forested to barren. The test data plotted on this graph suggest that there is a relationship between the amount of vegetation and the capture fraction. This data suggest that tall leafy dense vegetation has a high capture fraction and the short sparse scattered vegetation has a low capture fraction. This conceptual model has yet to be integrated with air quality models, but it does allow one to assign capture fractions to different types of vegetation as shown in Table 6-4.

Figure 6-5. Capture Fraction Conceptual Model

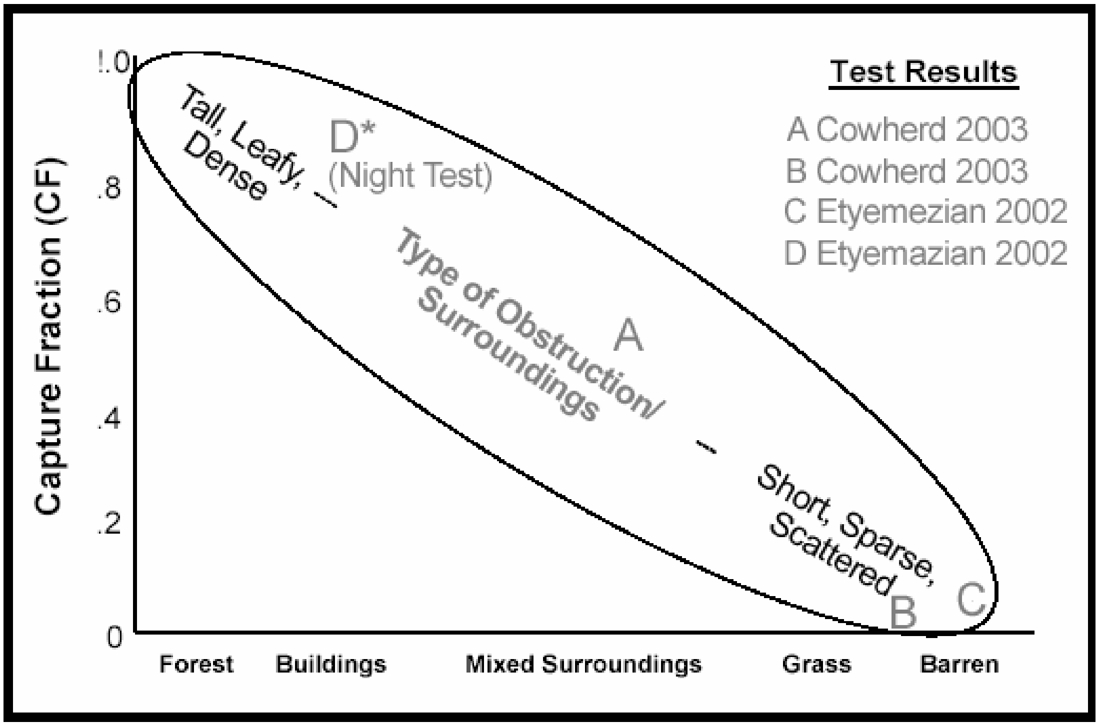


Table 6-4. Capture Fraction Estimates

Surface Cover Type	CF (Estimated)
Smooth, Barren or Water	0.03 – 0.1
Agricultural	0.1 – 0.2
Grasses	0.2 – 0.3
Scrub and Sparsely Wooded	0.3 – 0.5
Urban	0.6 – 0.7
Forested	0.9 – 1.0

By using land use databases that contain data on the fractional land use in six different areas (barren and water, agriculture, grass, urban, scrub and sparse vegetation, and forest) it is possible to do a computation of the capture fraction. As shown in Table 6-5, the capture fraction for a given area is the summation of capture fraction by land use type times the county fractional land use amount. The transport fraction is equal to one minus the capture fraction. For example, the transport fraction from the source in Churchill County, Nevada is much higher than the amount that gets away from the source in

Oglethorpe County, Georgia. The main difference is the amount of trees in those two areas. In general, the transport fraction is fairly low in those areas of the country that are very heavily forested, or in cities with a lot of buildings.

Table 6-5. Example Capture Fraction Calculations

Land Use Type	**Barren & Water**	**Agriculture**	**Grass**	**Urban**	**Scrub & Sparse Vegetation**	**Forest**	**CF**	**TF**
CF	.03	.15	.2	.6	.3	.95		
Fractional Land Use in Churchill Co., NV	.33	.03	.2.	0	.36	.05	0.23	0.77
Fractional Land Use in Oglethorpe Co., GA	0	.1	.14	0	0	.76	0.76	0.24

6.2.3 Modeling Issues

There are modeling issues associated with using this approach to account for different transport characteristics of dust in different parts of the country. Gaussian models actually have removal mechanisms built in to them to accommodate capture fraction through the use of empirical coefficients. Unfortunately, there is limited data and guidance on how to apply these coefficients, so they are rarely used.

Grid models on the other hand are not equipped to handle particle transport. One issue with grid models is that they tend to remix particles within the lowest layer during each time step and this results in an underestimation of the removal by gravitational settling. Within a time step of the model particles have had a chance to settle down, but not settle out. In the next time step they are remixed into the whole lower mixing cell, so they may never get out. Also, in the initial grid (i.e., grids no smaller than 4 km square) removal processes, even gravitational settling, are ignored. This is a very significant omission unless the grid is very small. However, modeling very small grids is not really practical.

6.2.4 Summary

Transport fractions should not be used to reduce the emission inventory nor with Gaussian models. They can be used with grid models with the proper caveats. Because there are other issues with the inventory, there will not be instantaneous agreement between the fugitive dust emissions and the ambient data. For example, there are issues with applying the unpaved road factors properly. The transport fraction concept is evolving and over time grid model modifications could eliminate the need for this approach.

Crustal material is a relatively small part of $PM_{2.5}$ in the ambient air. Fugitive dust is released near the ground and surface features often capture the dust near its source. Finally, the capture/transport fraction concept provides a useful way to account for near source removal when used with grid models. This area of research offers many opportunities to improve model performance.

Review Exercises

1. Which of the following is a source for obtaining information for identifying nonpoint sources for inclusion in an emissions inventory?
   a. EIIP Area Source Guidance
   b. AP-42
   c. Toxics Release Inventory
   d. All of the above

2. Which of the following is **not** found in the PM one-pagers for specific categories of nonpoint sources?
   a. An overview of the NEI methods
   b. National emission estimates
   c. Approaches for improving the NEI results
   d. Activity variables

3. Typical fugitive dust categories of _______ emissions include construction, mining, paved and unpaved roads, agricultural tilling, and beef cattle feed lots.
   a. ammonia
   b. carbonaceous fine PM
   c. filterable PM
   d. All of the above

4. Which type of emissions are reported for PM in the NEI?
   a. Actual
   b. Allowable
   c. Potential
   d. All of the above

5. Which of the following data is used in estimating emissions from nonpoint sources?
   a. control efficiency
   b. rule effectiveness
   c. rule penetration
   d. All of the above

6. _______ represents the percentage of the nonpoint source category that is covered by an applicable regulation.
   a. Rule effectiveness
   b. Control efficiency
   c. Rule penetration
   d. Activity data

7. The area that comprises the bottom three-fourths of the height of vegetation underneath a canopy of vegetation is called the _______ zone.
   a. dropout
   b. inversion
   c. laminar
   d. stilling

8. The _______ fraction is the portion of fugitive dust emissions that are removed by nearby surface cover.
   a. capture
   b. transport
   c. suspended
   d. trapped

9. Transport fractions can be used _______ with the proper caveats.
   a. to reduce the emissions inventory
   b. with Gaussian models
   c. with grid models
   d. All of the above

Review Answers

1. d. All of the above

2. b. National emission estimates

3. c. filterable PM

4. a. Actual

5. d. All of the above

6. c. Rule penetration

7. d. stilling

8. a. capture

9. c. with grid models

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Chapter 7: Fugitive Dust Area Sources

LESSON GOAL

Demonstrate, through successful completion of the chapter review exercises, a general understanding of the methods used in the NEI to estimate PM emissions from agricultural tilling, paved and unpaved roads, and construction activities.

STUDENT OBJECTIVES

When you have mastered the material in this chapter, you should be able to:

1. Explain how PM emissions are calculated for agricultural tilling operations.
2. Identify methods for improving the NEI emissions for agricultural tilling operations.
3. Explain how PM emissions are calculated for paved and unpaved roads.
4. Identify methods for improving the NEI emissions for paved and unpaved roads.
5. Explain how PM emissions are calculated for residential, commercial, and road construction activities.
6. Identify methods for improving the NEI emissions for residential, commercial, and road construction activities.

Chapter 7: Fugitive Dust Area Sources

This Chapter addresses fugitive dust emissions from the following area sources: agricultural tilling, paved roads, unpaved roads, and residential, commercial, and road construction activities.

7.1 AGRICULTURAL TILLING

7.1.1 NEI Method

The SCC that is contained in the National Emissions Inventory for agricultural tilling emissions is 2801000003. For this category the NEI contains estimates of filterable PM_{10} and $PM_{2.5}$. There are no condensibles associated with this category.

The activity data for the NEI was obtained from the Conservation Technology Information Center (CTIC), which publishes a national crop residue management survey every two years that contains county level activity data. The NEI used the data from the 1998 survey. This database provides acres of crops tilled in each county by crop type and by tilling method. The five tilling methods included in the database include no till, mulch till, rich till, zero to 15% residue, and 15-30% residue.

The emission factor in the NEI is expressed as the mass of the total suspended particulate per acre tilled. The emission factor is comprised of a constant of 4.8 pounds per acre pass of PM, the silt content of the surface soil, the number of tillings per year, which is broken into conservation and conventional use, and the particle size multiplier to calculate the PM_{10} or the $PM_{2.5}$ from the PM emissions.

The silt content values that are used for various soil types in the NEI are listed in Table 7-1. These soil types are assigned to counties by using the USDA surface soil and county level maps to match the soil types to counties.

Table 7-1. NEI Silt Content Values

Soil Type	Silt Content (%)
Silt Loam	52
Sandy Loam	33
Sand	12
Loamy Sand	12
Clay	29
Clay Loam	29
Organic Material	10-82
Loam	40

Table 7-2 shows the number of tillings that are assumed by crop type for both conservation and conventional use. The no till, mulch till, and ridge till methods come from the county level inventory from the CTIC and are grouped into the conservation use category. The acres reported for the zero to 15 percent residue and the 15 to 30 residue are grouped into the conventional use category. As can be seen from the data in Table 7-2, the conventional use category has more tilling passes per acre than the conservation use.

Table 7-2. Number of Tillings in NEI

Crop	Conservation Use	Conventional Use
Corn	2	6
Spring Wheat	1	4
Rice	5	5
Fall-Seeded Small Grain	3	5
Soybeans	1	6
Cotton	5	8
Sorghum	1	6
Forage	3	3
Permanent Pasture	1	1
Other Crops	3	3
Fallow	1	1

Equation 7-1 presents the equation that is used in the NEI for calculating total PM emissions from agricultural tilling operations.

Equation 7-1. Agricultural Tilling Emission Estimation Equation

$$E = c*k*s^{0.6}*p*a$$

where:
E = PM emissions, lbs per year
c = constant 4.8 lbs/acre-pass
k = dimensionless particle size multiplier (PM_{10} = 0.21; $PM_{2.5}$ = 0.042)
s = silt content of surface soil (%), defined as the mass fraction of particles smaller than 75 μm diameter found in soil to a depth of 10 cm
p = number of passes or tillings in a year
a = acres of land tilled

This equation has been used to estimate PM emissions from agricultural operations in the NEI prior to 1999. Since 1999 the number of acres tilled for each of the five tillage types has been estimated based on a linear interpolation of national level data available for 1998, 1999 and 2002. Using 1998 as the basis, national growth factors were developed by tillage type for 1998, 1999 and 2002. These growth factors were applied to county level emissions for 1998 to estimate county level emissions for 1999 and 2002. Finally, the NEI emission calculation assumed no controls.

7.1.2 Improving the NEI

One way to improve upon the NEI method is to use crop-specific acreage and tilling practice data from the state or local agency or tribal authority. In addition, if State or local emission factors exist, they should be used. Another improvement is to perform a field study to determine the local silt content percentage of the surface soil. The silt values that are used in the NEI are based on limited data and represent averages for the entire country. Local or state conditions may exist that warrant improving the NEI silt content values. Finally, the development of crop calendars to determine the time and frequency of the activities (e.g., land preparation, planting and tilling) will be an improvement over the NEI data.

7.1.3 CARB Case Study

This case study is based on the report "Computing Agricultural PM_{10} Fugitive Dust Emissions Using Process Specific Rates and GIS" by Patrick Gaffney and Hong Yu and presented at the National Emissions Inventory Conference in San Diego during April 2003 (download from the CHIEF web site).

The California Air Resources Board (CARB) prepared a statewide PM_{10} inventory for land preparation activities and harvest activities at the county level. The goals were to obtain current crop-specific acreage data, develop crop-specific temporal profiles or crop calendars, and to develop emission factors for all crops.

In developing the inventory CARB obtained county level crop-specific acreage data from the California Department of Food and Agriculture. This department generates the crop data every year by county, and it includes over 200 crops and 30 million acres.

CARB also developed crop calendars for the 20 most important crop types with importance based on the acreage and the potential emissions associated with each crop type. The crop calendars were used to define the temporal periods of farming operation activities for each of the crop types. Figure 7-1 is an example of a crop calendar for corn. These types of calendars are very informative in terms of identifying when specific activities occur. As an example, stubble disking for corn occurred in November and December with one pass across the field. In contrast, the NEI assumes these emissions are annual and does not apply any temporal adjustments.

Figure 7-1. Example Crop Calendar for Corn

Farming Operations	Crop Cycles Per Year	Passes Per Crop Cycle	Fraction of Acreage Per Cycle	Passes During Month											
				Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Land Preparation															
Stubble Disc	1	1	1.0												
Finish Disc	1	1	1.0												
List & Fertilize	1	1	1.0												
Mulch Beds	1	1	1.0												
Planting	1	1	1.0												
Cultivation	1	2	1.0												
Harvesting	1	1	1.0												

Prior to preparing the statewide PM_{10} inventory for land preparation activities and harvest activities CARB used the AP-42 tilling emission factor of 4.0 lbs PM_{10}/acre-pass for all land preparation activities. For harvesting, CARB only estimated emissions for three crop types for which emission factors were available. In order to improve over the past approach CARB conducted field testing over a seven year period to develop emission factors for several different types of activities that are crop specific and operation specific.

These new data allowed CARB to develop the crop calendar that was discussed above.

Table 7-3 presents the land preparation emission factors that CARB developed for five different types of activities. These emission factors were used as surrogates for other land preparation activities such as wheat cutting where specific factors were not available.

Table 7-3. Land Preparation Emission Factors

Land Preparation	(lbs PM_{10}/acre-pass)
Root Cutting	0.3
Discing, Tilling, Chiseling	1.2
Ripping, Subsoiling	4.6
Land Planning & Floating	12.5
Weeding	0.8

Table 7-4 presents the harvest emission factors that CARB developed for three types of crops. These factors were assigned to over 200 crop types and adjusted using a division factor that was developed in consultation with the agricultural industry within the state. For example, wheat harvesting was assigned to another crop type, and then adjusted with a division factor. These adjusted factors were considered to be the upper limit of the emission factors for other crop types.

Table 7-4. Harvest Emission Factors

Harvest	(lbs PM_{10}/acre-pass)
Cotton Harvest	3.4
Almond Harvest	40.8
Wheat Harvest	5

7.2 PAVED ROADS

7.2.1 NEI Method

The SCC that is contained in the National Emissions Inventory for paved road emissions is 2294000000. For this category the NEI contains emission estimates for PM_{10} and $PM_{2.5}$.

7.2.1.1 Activity Data

The activity data used for the NEI for paved roads is vehicle miles traveled (VMT) on paved roads. Paved road VMT is estimated by subtracting the state and road type-level unpaved road VMT from the total state road type-level VMT. It is important to note that because the Federal Highway Administration uses different methodologies to calculate unpaved road VMT and total paved road VMT, there are a few instances (principally in western states) where the unpaved road VMT is higher than the total VMT. In this case, the unpaved VMT is simply reduced to equal the total VMT, and the paved roads are assumed to be zero.

The NEI estimates monthly paved road VMT by applying temporal allocation factors that were developed for the 1985 NAPAP study to the annual paved road VMT estimate.

7.2.1.2 Emission Factors

The December 2003 version of the emission factor equation in AP-42 only estimates PM emissions from resuspended road surface material. PM emissions from vehicle exhaust, brake wear, and tire wear are estimated using EPA's MOBILE6 model and are subtracted from the emission factor equation. Equation 7-2 presents the formula for calculating the paved road emission factor for all vehicle classes. It should be noted that the NEI used the pre-December 2003 version of the emission factor equation for estimating paved road emissions.

Equation 7-2. Paved Road Emission Factor Equation

$$PAVED = PSDPVD*(PVSILT/2)^{0.65}*(WEIGHT/3)^{1.5} - C$$

where:
PAVED = paved road dust emission factor for all vehicle classes combined (grams per mile)
PSDPVD = base emission factor for particles of less than 10 microns in diameter (7.3 g/mi for PM_{10})
PVSILT = road surface silt loading
WEIGHT = average weight of all vehicle types combined (tons)
C = emission factor for 1980's vehicle fleet exhaust, brake wear, and tire wear

The road surface silt loading varies according to the 12 functional roadway classifications that are contained in the NEI. For example, the silt loading for county maintained class roads is one gram per square meter. However for road types with an average daily traffic volume (ADTV) of less than 5,000 vehicles per day the silt loading is 0.2 grams per square meter. For road types exceeding the 5,000 ADTV the silt loading is 0.04 grams per square meter. The national average vehicle weight is 6,360 pounds. It should be noted that the fleet average emission factor includes PM from reentrained dust, tailpipe exhaust, brake wear, and tire wear.

Since the amount of fugitive dust emissions is a function of the amount of rain, the NEI makes an adjustment for precipitation. This is accomplished by multiplying the emission factor by a rain correction factor that is calculated by the formula in Equation 7-3. The precipitation data for the NEI was taken from one meteorological station representative of an urban area for each state. In this manner, the NEI developed emission factors on a monthly basis at the state and the road type level for the average vehicle fleet.

Equation 7-3. Precipitation Adjustment Equation

$$\text{Correction Factor} = 1- (p/4N)$$

where: p = the number of days during the averaging period with greater than 0.01 inches of precipitation
n = the number of days within the averaging period (e.g., 365 for annual)

7.2.1.3 Emission Calculations

Equation 7-4 shows the formula used in the NEI to calculate PM_{10} emissions from paved roads from resuspended road surface material. PM emissions from vehicle exhaust, brake wear, and tire wear are estimated using EPA's MOBILE6 model. $PM_{2.5}$ are estimated by multiplying the PM_{10} emissions by a particle size multiplier of 0.25.

Equation 7-4. Paved Road Emission Calculation Equation

$$EM_{s,r,m} = VMT_{s,r,m} * EF_{s,r,m}$$

where: EM = PM_{10} emissions (tons/month)
VMT = vehicle miles traveled (miles/month)
EF = emission factor (tons/mile)
S = State
R = road type class
M = month

Equation 7-5 shows the equation for allocating the monthly paved road emissions at the state level to the county level.

Equation 7-5. County Level Allocation Equation

$$PVDEMIS_{X,Y} = PVDEMIS_{ST,Y} * VMT_{X,Y} / VMT_{ST,Y}$$

where: $PVDEMIS_{X,Y}$ = paved road PM emissions (tons) for county x and road type y
$PVDEMIS_{ST,Y}$ = paved road PM emissions (tons) for the entire state and road type y
$VMT_{X,Y}$ = total VMT (10^6 miles) in county x and road type y
$VMT_{ST,Y}$ = total VMT (10^6 miles) in entire State for road type y

7.2.1.4 Controls

The NEI methodology assumes that controls are only in place for urban and rural roads in serious PM non-attainment areas and for urban roads in moderate PM non-attainment areas. A control efficiency of 79% is applied in these areas. This value corresponds to vacuum sweeping on paved roads twice per month. There is also an accounting of rule penetration that varies by road type and the non-attainment area classification.

7.2.2 Improving the NEI

One method to improve the NEI is to obtain VMT data for both paved and unpaved roads. This is preferable to the NEI approach of subtracting the unpaved road VMT from the total VMT.

Also, local registration data may be available that represents the average weight of the vehicles. This is preferable to the use of the NEI default value, particularly since this variable is weighted most heavily.

Another option is to perform sampling to refine the value used for silt content. However, this can be resource intensive and should only be used if enough samples can be collected to give a good representation of the roads in the inventory area.

7.3 UNPAVED ROADS

7.3.1 NEI Method

The SCC that is contained in the National Emissions Inventory for unpaved road emissions is 2296000000. For this category the NEI contains emission estimates for PM_{10} and $PM_{2.5}$. There is no condensable material so the PM filterable (PM-FIL) is equivalent to PM primary (PM-PRI).

7.3.1.1 Activity Data

The activity data used by the NEI for unpaved roads is state level unpaved road VMT data that is available from the Federal Highway Administration. This data is allocated to counties by population. Due to the availability of specific activity for the local classes this calculation is done differently for urban and rural local functional classes (i.e., county maintained road types) than it is for the state and federally maintained roads.

Equation 7-6 shows the equation for calculating the vehicle mile traveled by road type.

Equation 7-6. Unpaved VMT Calculation Equation

$$\text{Unpaved VMT}_{\text{Roadtype}} = \text{Mileage}_{\text{Roadtype}} * \text{ADTV} * \text{DPY}$$

where: Unpaved $VMT_{Roadtype}$ = road type specific unpaved VMT (miles/year)
$Mileage_{Roadtype}$ = total number of miles of unpaved roads by functional class (miles)
ADTV = Average daily traffic volume (vehicle/day)
DPY = number of days per year

The non-local functional classes of roads tracked by the Federal Highway Administration include rural minor collector, rural major collector, rural minor arterial, rural other principal arterial, urban collector, urban minor arterial, and urban other principal arterial. Because there are no estimates of average daily traffic volume for the non-local roads, it is estimated from local urban and rural VMT and mileage data for the local roads (see Equation 7-7).

Equation 7-7. ADTV Calculation Equation

$$ADTV = VMT/Mileage$$

where: ADTV = average daily traffic volume for State and federally maintained roadways
VMT = urban/rural VMT on county-maintained roadways (miles/year)
Mileage = urban/rural state-level roadway mileage of county-maintained roadways (miles)

The total state unpaved VMT by road type is calculated by adding the non-local functional class VMT to local functional class VMT. The total state unpaved VMT is temporally allocated by month using NAPAP temporal allocation factors.

7.3.1.2 Emission Factor

Similar to the AP-42 emission factor equation for paved roads, the unpaved road emission factor equation only estimates PM emissions from resuspended road surface material. PM emissions from vehicle exhaust, brake wear, and tire wear are estimated separately, using EPA's MOBILE6, and are subtracted out of the emission factor equation. It should be noted that the vehicle exhaust, brake wear, and tire wear component is relatively much less for unpaved roads than for paved roads.

Equation 7-8 shows the AP-42 empirical equation that is used to calculate the unpaved road emission factor. It has some of the same variables as the paved road equation, but they are weighted differently. For example, there is more weight given to surface material silt content.

Equation 7-8. Unpaved Road Emission Factor Equation

$$EF = [k*(s/12)*(S/30)^{0.5}]/[(M/0.5)^{0.2}] - C$$

where: EF = size specific emission factor (pounds per VMT)

k = empirical constant (1.8 lb/VMT for PM10-PRI, 0.27 for PM2.5-PRI)
s = surface material silt content (%)
M = surface material moisture content (%)
S = mean vehicle speed (mph)
C = emission factor for 1980's vehicle fleet exhaust, brake wear, and tire wear

Table 7-5 summarizes the NEI default emission factor input values and the source of the values. The web address for the surface materials silt content values links to a database for unpaved roads that provides all the supporting documentation that was used, including a database of state level silt content. It should be noted that the calculation of unpaved road emissions in the NEI used the pre-December 2003 AP-42 emission factor equation. This equation considers mean vehicle weight and, therefore, it is listed in Table 7-5. Also, it should be noted that the precipitation data is obtained from one meteorological station that is representative of rural areas since unpaved road activity is expected to be occurring in rural areas.

Table 7-5. NEI Default Emission Factor Input Values

Input	Source of Values
Surface Material Silt Content(s)	Average state-level sources available at **ftp://ftp.epa.gov/EmisInventory/finalnei99ver2/criteria/documentation/xtra_sources/**
Mean Vehicle Weight (W)	National average value of 2.2 tons (based on typical vehicle mix)
Surface Material Moisture Content (M_{dry})	1 percent
Number of days exceeding 0.01 inches of precipitation (p)	1. Precipitation data from one meteorological station in state is used to represent all rural areas of the state 2. Local climatological data available from National Climactic Data Center at **http://www.ncdc.noaa.gov/oa/ncdc.html**

7.3.2 Improving the NEI

Short of developing independent estimates, the NEI defaults should be reviewed for representativeness. Also, local data should be used when possible for the activity and emission factor. If resources are limited, the focus should be on collecting data that represents local precipitation as well as actual local VMT estimates.

7.3.3 Case Study

This case study examines developing a PM_{10} inventory for unpaved roads in a hypothetical county. The method is to develop a local inventory using county level data where available, and filling in the gaps with NEI default data. In this case study, daily VMT data was provided by a local metropolitan planning organization, and VMTs were calculated using TransCAD GIS-based modeling software.

The emission factor input values for surface material silt content were obtained from samples taken on dirt roads in the county for which the inventory was conducted. Default values were used for the mean vehicle weight value and the surface material moisture content. The number of days that were exceeding the precipitation threshold of 0.01 inches was obtained from a local meteorological station. The inventory is a county level inventory with a temporal resolution of monthly.

Equation 7-9 shows the AP-42 empirical equation that is used to calculate the unpaved road emission factor with the actual values for the variables in the equation.

Equation 7-9. Unpaved Road Emission Factor Equation

$$EF = [k*(s/12)*(S/30)^{0.5}]/[(M/0.5)^{0.2}] - C$$

where:
EF = size specific emission factor (tons per mile)
k = empirical constant = 1.8 lb/VMT
s = surface material silt content = 7.5%
M = surface material moisture content = 1%
S = mean vehicle speed = 35mph
C = emission factor for 1980's vehicle fleet exhaust, brake wear, and tire wear = 0.001 lbs/VMT

Plugging these values into the equation results in an emission factor of 0.025 pounds per VMT for the month of June in the study area. This monthly emission factor is applied to the monthly VMT estimate of 2.964 million miles per month for the study area to obtain an estimate of PM_{10} emissions of 37.9 tons per month for the month of June. All of the monthly emission estimates are summed to obtain an annual PM_{10} emission estimate.

7.4 CONSTRUCTION

7.4.1 Overview

The SCCs that are contained in the National Emissions Inventory for the construction category are shown in Table 7-6. The NEI contains emission estimates for PM_{10} and $PM_{2.5}$ and there are no condensibles, so PM-PRI is equal to PM-FIL. The relative contribution of these three different types of construction to the 1999 NEI is listed in the last column of Table 7-6.

Table 7-6. SCCs for Construction

Category	SCCs	% Contribution
Residential	2311010000	5
Commercial	2311020000	40
Road	2311030000	55

7.4.2 Residential Construction

7.4.2.1 NEI

The NEI uses the number of acres disturbed per year as the activity data for residential construction. Since direct estimates of the number of acres disturbed are generally not available, the value for this activity is estimated through the use of housing start data that is available from the Bureau of the Census. These data are available as regional monthly housing unit start values. Data is also available at a national level for housing unit starts for the various classifications of housing. These classifications include 1-unit houses, 2-unit houses, 3-4 unit houses, and 5+ unit housing. These housing classifications are important because there are different numbers of acres disturbed for each type of housing. The regional housing unit starts for each of these categories is estimated using the fraction that is available at a national level as shown in Equation 7-10.

Equation 7-10. Regional Housing Unit Starts Estimation Equation

$$\text{Regional HS} = \text{Total Regional HS} * (\text{National HS by Category}/\text{Total National HS})$$

where: HS = Housing Starts

Since these regional housing starts are on a monthly basis they are summed to obtain an annual total. The next step is to allocate these regional housing starts data to the county level. This is accomplished by using data on the annual number of building permits in each county for each housing unit classification. It should be noted that the building permit data should not be used to estimate housing starts but only to allocate housing starts to the county. This is because many times a building permit is issued but the dwelling is never constructed. In short, the housing start data is a more accurate estimate of what is really being constructed.

Also, the regional housing start data actually represents the number of units that were started. However, the number of structures is a better activity indicator of the number of acres that are disturbed. For example, the activity data for an apartment building with multiple units should reflect the structure as a whole (i.e., the number of acres disturbed in the building of the structure and not for each unit). Table 7-7 shows the correlation between residential structure starts and housing unit starts.

Table 7-7. Relationship Between Housing Units and Residential Housing Structures

Housing Unit Starts	Residential Structure Starts
1-unit	1 unit per structure
2- unit	2 units per structure
3-4 unit	3.5 units per structure
5+ unit	Region specific units per structure as calculated from building permits data

Equation 7-11 shows the equation for estimating the number of county residential housing structure starts based on the regional number of structure starts.

Equation 7-11. Residential of Structure Starts Estimation Equation

County SS = Regional SS*(County Bldg. Permits/Regional Bldg. Permits)

where: SS = Structure Starts

The number of acres disturbed and the duration of the construction activity vary depending on the size and type of the structure. The assumed values for both acres disturbed and duration are listed in Table 7-8. The basis behind these assumptions can be found in *Estimating Particulate Emissions from Construction Operation*, 1999.

Table 7-8. Assumed Values for Residential Construction

Type of Structure	Acres Disturbed	Duration of Construction
1-unit	¼ acre per building	6 months
2-unit	1/3 acre per building	6 months
Apartments	½ acre per building	1 year

The number of apartment structures is estimated by adding the number of 3-4 unit buildings and the number of 5+ unit buildings. Also, the number of 1-unit houses needs to be estimated separately for houses with a basement and those without a basement. This is because building a house with a basement requires that additional dirt be moved and this must be accounted for in the emission factor equation. The number of 1-unit houses without basements is estimated by multiplying the regional number of 1-unit structures by the regional percentage of one-family houses with basements and subtracting the product from the total number of 1-unit houses.

The amount of dirt moved for 1-unit houses with basements is estimated by multiplying the assumed average basement depth of 8 feet by the assumed value of 2,000 square feet of dirt moved per structure. An additional 10 percent is added to this value to account for footings and other back-filled areas adjacent to the basement.

Table 7-9 shows the emission factor data that the NEI uses to estimate the emissions on an acre-per-month basis. Also, $PM_{2.5}$ is assumed to be 20% of PM_{10}.

Table 7-9. NEI PM_{10} Residential Construction Emission Factors

Housing Category	Emission Factor (tons/acre/month)
1-unit housing with basement	0.011 (plus 0.059 tons/cubic yard of on-site cut/fill)
1-unit housing without basement	0.032
2-unit housing	0.032
Apartments	0.11

Equation 7-12 shows the equation that NEI uses to estimate PM_{10} emissions from 1-unit residential structures with basements and Equation 7-13 shows the equation used for one-unit structures without basements, as well as all two-unit structures. The same equation is used for apartments with the exception that the emission factor of 0.11 tons/acre/month is used instead of the 0.032 tons/acre/month value.

Equation 7-12. PM_{10} Emission Estimation Equation for 1-unit Residential Structures with Basements

$$\text{Emissions} = (EF*B*f*m) + 0.059 \text{ tons } PM_{10}/1000 \text{ cubic yards of cut/fill}$$

where: EF = Emission factor (0.011 tons PM_{10}/acre/month)
B = number of housing starts with basements
f = buildings-to-acres conversion factor (1/4 acre per building)
m = duration of construction activity (months)

Equation 7-13. PM_{10} Emission Estimation Equation for 1-Unit Residential Structures without Basements and 2-Unit Residential Structures

$$\text{Emissions} = (EF*B*f*m)$$

where: EF = Emission factor (0.032 tons PM_{10}/acre/month)
B = number of housing starts with basements
f = buildings-to-acres conversion factor (1/4 acre per building)
m = duration of construction activity (months)

Controls in PM_{10} non-attainment areas are accounted for by applying a control efficiency of 50% for both PM_{10} and $PM_{2.5}$ emissions for all PM_{10} nonattainment areas. There is no adjustment made for attainment areas. The 50% value represents best available control methods on fugitive dust construction activities in the nonattainment counties.

In addition to accounting for the control measures, other adjustments are applied to the emission estimates for all three construction categories. These adjustments are for soil moisture content and silt content. Emissions are adjusted for soil moisture content by using average Precipitation Evaporation (PE) values according to Thornthwaite's Precipitation Evaporation Index. Equation 7-14 shows the formula for making this adjustment. This adjustment accounts for precipitation and humidity in a certain area and, as can be seen in the equation, the higher the PE the smaller the adjustment.

Equation 7-14. Soil Moisture Level Adjustment

$$\text{Moisture Level Corrected Emissions} = \text{Base Emissions} * (24/PE)$$

where: PE = Precipitation Evaporation value for county

Emissions are adjusted for the dry silt content in the soil of the area being inventoried. Equation 7-15 shows the formula for making this adjustment.

Equation 7-15. Silt Content Adjustment

$$\text{Silt Content Corrected Emissions} = \text{Base Emissions} * (s/9\%)$$

where: s = % dry silt content in soil for area being inventoried

7.4.2.2 Improving the NEI

Obtaining local data for new housing starts, or permits for additions or modifications to existing homes would be an improvement over the use of the NEI defaults. Another improvement is to develop a buildings-to-acres conversion factor for acres disturbed per construction unit as well as obtaining data on the seasonality of residential construction practices. Finally, obtaining local information on soil moisture content, silt content, and control efficiencies would be an improvement over the NEI default values.

7.4.2.3 Case Study

This case study demonstrates the approach for developing an inventory for residential construction at the county level in a PM nonattainment area. In this example, local officials provided data that represent actual housing unit starts for single unit houses, duplexes, and apartment buildings. Also, it should be noted that none of the houses in the inventory included basements, and local control information was assumed to be provided.

Table 7-10 shows a summary of the data that were used in the case study. It should be noted that some of the NEI default values are used, such as duration, controls, rule penetration, precipitation evaporation, and silt content.

Table 7-10. Data for Residential Construction Case Study

	Single Family Houses (No Basement)	Duplexes	Apartments
Housing Structure Starts (B)	251	2	44
Acres Disturbed per building (f)	0.184	0.184	0.07
Duration (m) (months)	6	6	12
CE	50	50	50
RE	100	100	100
RP	75	75	75
PE	6	6	6
s (%)	40	40	40

Plugging this data into the emission estimation equation (Equation 7-16) yields the emissions for the county for each type of residential construction as shown in Table 7-12. The emissions calculated with Equation 7-16 need to be corrected for soil moisture content and silt content using Equations 7-14 and 7-15, respectively. Table 7-11 shows both the base and corrected emissions. These adjustments have a significant effect since the case study area represents a relatively dry area.

Equation 7-16. Emission Estimation Equation for Residential Construction

Emissions = (EF*B*f*m) * (1- (CE/100)(RP/100))

Table 7-11. Summary of Case Study Emissions

	Emissions (tons/year)	Corrected Emissions (tons/year)
Single family houses	5.54	98.49
Duplexes	0.04	0.71
Apartments	2.54	45.16
	Total	144.36

Annual PM10-PRI emissions for each type of residential construction are added together to obtain total annual emissions.

7.4.3 Commercial Construction

7.4.3.1 NEI

Similar to the residential construction category, the NEI uses the number of acres disturbed each year as the activity representing fugitive dust emissions from commercial construction. The NEI developed a top-down inventory by using national level activity data on the dollar value of commercial construction. These data were then allocated to the county level.

The allocation of the national level expenditure data was performed by using two data sources: *Annual Average Employment for SIC 154*, Data Series ES202, Bureaus of Labor Statistics, 1999 and *Annual Average Employment for SIC 154*, *MarketPlace 3.0*, Dunn & Bradstreet, 1999. Two data sources were used because there were some data missing in the first database, and the Dunn & Bradstreet database was used to fill in the gaps. Specifically, the county proportion of the state total from the Dunn & Bradstreet database was applied to the state total from the BLS data base to estimate employment for counties where data were missing.

The dollar value activity data were converted to acres disturbed using a conversion factor of 1.6 acres/10^6 dollars. This conversion factor was applied to the estimated county-level construction valuation data.

The PM10-PRI emission factor for commercial construction is 0.19 tons per acre month. The $PM_{2.5}$ is assumed to be 20% of the PM_{10}.

Equation 7-17 shows the emission formula used in the NEI for calculating the PM emissions from commercial construction.

Equation 7-17. Emission Estimation Equation for Commercial Construction

$$\text{Emissions} = (EF*\$*f*m)$$

where: EF = Emission factor (0.19 tons PM_{10}/acre/month)
$ = dollars spent on nonresidential construction (millions)
f = dollars-to-acres conversion factor
m = duration of construction activity (assumed 11 months)

The emissions calculated from Equation 7-17 are adjusted to reflect control measures that are in place in PM_{10} non-attainment areas. In addition to accounting for the control measures, adjustments are applied for soil moisture content and silt content using Equation 7-14 and Equation 7-15, respectively.

7.4.3.2 Improving the NEI

Improving the NEI results can be done by obtaining local information on number of acres disturbed per construction event or per construction dollar spent. Also information on location, average duration, and seasonality of commercial construction practices would be an improvement over the NEI default values. Finally, local information on soil moisture content, silt content, and control efficiency would result in improved emission estimates.

7.4.4 Road Construction

7.4.4.1 NEI

The NEI uses the number of acres disturbed as the activity data indicator for road construction. State level expenditure data for capital outlay for six road construction classification are available. These classifications include:

Interstate, urban
Interstate, rural
Other arterial, urban
Other arterial, rural
Collectors, urban
Collectors, rural

Because some of the activities that are included in the total state level expenditure data do not contribute to PM emissions, it was necessary to remove the expenditures for these activities. These activities include minor widening, resurfacing, bridge rehabilitation, safety, traffic operation and control, and environmental enhancement and other.

To obtain the activity data in terms of acres disturbed it was necessary to first convert the expenditure data to mileage and then to acreage. The NEI estimated the miles of new road constructed by applying conversion factors of $4 million dollars per mile of interstate, and $1.9 million dollars per mile for other arterial and collector roads. These conversion factors were based on information obtained from the North Carolina Department of Transportation. The NEI then applied the conversion factors in Table 7-12 to convert to acres disturbed per mile of road activity level.

Table 7-12 Road Construction Conversion Factors

Classification	Conversion Factor (acres/mile)
Interstate, urban	15.2
Interstate, rural	15.2
Other arterial, urban	15.2
Other arterial, rural	12.7
Collectors, urban	9.8
Collectors, rural	7.9

The estimated acres disturbed are summed across all of the road types to estimate the total acres disturbed. The NEI allocates these state-level estimates of acres disturbed to the county-level by using housing start data. This is the same data that was developed for the residential construction category. This assumes that new road development is directly proportional to new housing starts.

The PM10-PRI emission factor for road construction is 0.42 tons per acre month. The $PM_{2.5}$ is assumed to be 20% of the PM_{10}.

Equation 7-18 shows the emission formula used in the NEI for calculating the PM emissions from road construction.

Equation 7-18. Emission Estimation Equation for Road Construction

$$\text{Emissions} = (EF*\$*f1*f2*d)$$

where: EF = Emission factor (0.42 tons PM_{10}/acre/month)
$ = State expenditures for capital outlay on road construction
f1 = dollars-to-miles conversion factor
f2 = miles-to-acres conversion factor
d = duration of roadway construction activity (assumed 12 months)

The emissions calculated from Equation 7-18 are adjusted to reflect control measures that are in place in PM_{10} non-attainment areas. In addition to accounting for the control measures, adjustments are applied for soil moisture content and silt content using Equation 7-14 and Equation 7-15, respectively.

7.4.4.2 Improving the NEI

Obtaining information on location and timing of road construction practices in the area is one way of improving on the NEI results. Also, obtaining local data on the number of miles constructed and the number of acres disturbed per project or per mile of road constructed is better than using the NEI default values that are based on expenditure data. Also, local data on the duration of the projects and information on private road construction activity (not included in the NEI) would represent improvements. Finally, obtaining information for making adjustments for soil moisture content, silt content, and control efficiency would be an improvement over the NEI default values.

7.4.4.3 Case Study

This hypothetical case study involves developing a local inventory using available county level inventory data and filling the data gaps with the NEI default data. In this case study the county officials have provided estimates of the miles of roadway constructed in the county. Also, the study assumes that all roads fall into the urban collectors category. Table 7-13 shows a summary of the data that were used in the case study.

Table 7-13. Data for Road Construction Case Study

Miles of roadway constructed	12.3 miles
f2 (urban connector)	9.8 acres/mile
Duration	12 months
CE	50
RE	100
RP	75
PE	6
s (%)	40

Plugging this data into Equation 7-18 and applying the control and rule penetration adjustments results in an estimated 379.70 tons per year. Correcting this base emissions value for soil moisture and silt content results in a corrected emissions of 6,750 tons of PM10-PRI per year.

Review Exercises

1. Which of the following variables is not included in the NEI emissions methodology for estimating emissions from agricultural tilling operations?
   a. silt content of soil
   b. acres of land tilled
   c. control measures
   d. number of passes

2. Which of the following would be an improvement over the NEI emissions methodology for estimating emissions from agricultural tilling operations?
   a. use of corn calendars
   b. performing a field study to determine silt content
   c. use of crop-specific acreage
   d. All of the above

3. In the paved roads category, the NEI contains emission estimates for ______________.
   a. PM_{10}
   b. $PM_{2.5}$
   c. Condensable PM
   d. A and B

Deleted: ¶

4. Which of the following is used as the activity data for paved roads in the NEI?
   a. total miles of road
   b. vehicle miles traveled
   c. road type class
   d. average vehicle weight

5. The assumed control measure for paved roads in the NEI is _______.
   a. wetting of the road
   b. the use of dust suppression materials such as oil
   c. vacuum sweeping
   d. All of the above

6. Which of the following sources of emissions from unpaved roads are estimated by EPA's MOBILE6.2 model?
   a. vehicle exhaust
   b. tire wear
   c. brake wear
   d. All of the above

7. In estimating the amount of dirt moved for 1-unit houses with basements, an additional _______ percent is added to the amount of dirt removed for the basement to account for footings and other back-filled areas adjacent to the basement.
   a. 5
   b. 10
   c. 15
   d. 20

8. A _______ Precipitation Evaporation value represents high precipitation and humidity and results in a _______ adjustment to the base emissions estimate.
   a. larger, larger
   b. smaller, larger
   c. larger, smaller
   d. smaller, smaller

9. Which of the following activities need to be removed from State-level road construction expenditures when developing an activity level for road construction activities?
   a. Resurfacing
   b. Bridge rehabilitation
   c. Minor road widening
   d. All of the above

10. Which construction category requires a two-step conversion to obtain the activity data of number of acres disturbed?
    a. commercial
    b. residential
    c. road
    d. All of the above

Review Answers

1. c. control measures

2. d. All of the above

3. d. A and B

4. b. vehicle miles traveled

5. c. vacuum sweeping

6. d. All of the above

7. b. 10

8. c. larger, smaller

9. d. All of the above

10. c. road

Chapter 8: Ammonia Emissions From Animal Husbandry

LESSON GOAL

Demonstrate, through successful completion of the chapter review exercises, a general understanding of the issues associated with estimating ammonia emissions from animal husbandry operations and some of the efforts that are being undertaken to address these issues.

STUDENT OBJECTIVES

When you have mastered the material in this chapter, you should be able to:

1. Explain the problems that have been identified with the ammonia emission estimates in the NEI.

2. Explain the six-step process for improving the ammonia emissions estimates from animal husbandry operations.

3. Explain the concept of manure management trains.

4. Identify the improvements that are being made to the NEI for the animal husbandry category.

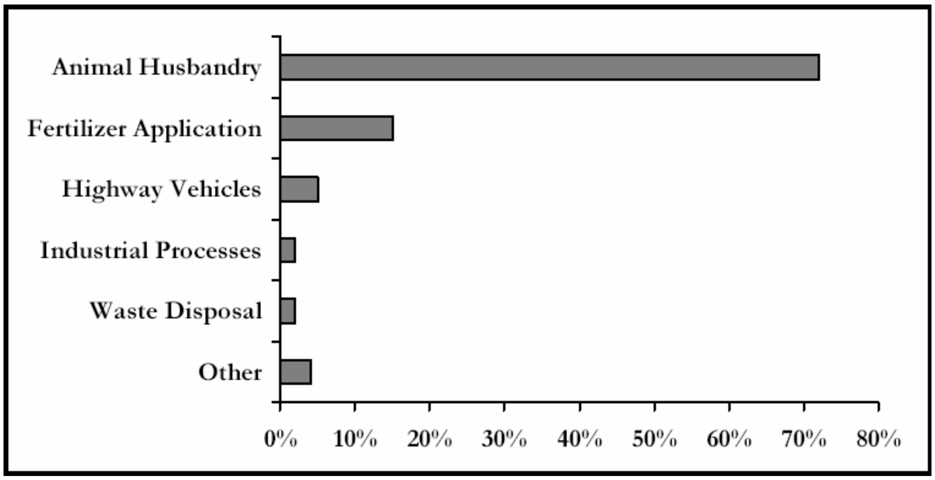
5. Explain the differences between the 1999 NEI and the 2002 NEI with respect to ammonia emissions from animal husbandry operations.

Chapter 8: Ammonia Emissions From Animal Husbandry

8.1 OVERVIEW

Almost 5 million tons a year of ammonia are emitted nationally and as shown in Figure 8-1 animal husbandry is the largest contributor to ammonia emissions nationally.

Figure 8-1. NH_3 – Precursor to Ammonium Sulfate and Nitrate



In addition to being the largest contributor to ammonia emissions nationally, it is important to address ammonia emissions from animal husbandry because inverse modeling suggests that ammonia emissions may be overestimated. Inverse modeling involves doing a complete chemical transformation and transport modeling of an area and accounting for all of the ammonia through transformation and deposition processes. Comparing these results to the ammonia that has been found in the ambient air indicates that ammonia may be overestimated nationally. The interim improvements described in Section 8.2 below address many of these shortcomings.

Additionally, problems with the current NEI have been identified. For example, there are probable errors in the emission factor selections, especially for beef. Also, the NEI does not use information on variability of emissions due to different manure handling practices within a given animal industry, nor does it make total use of the National Agricultural Statistic Service (NASS) data on different animal populations by weight. The NEI also does not take temperature into account, which would greatly increase the temporal variation in ammonia emissions.

Moreover, EPA's water emission effluent guidelines project has provided some new information on animal production and waste handling practices. Also, the National Academy of Sciences, at the behest of the agricultural community, has reviewed EPA's inventory work, and recommended a long-term data-gathering effort.

8.2 IMPROVING THE NEI

EPA has recently prepared a report that provides a basis for making interim improvements to the NEI. It provides improved data on populations, practices, and emissions. It is the beginning of a switch-over to a process-based framework that is a consistent and transparent way of estimating emissions that would allow for partial updating as better data becomes available. This technique provides a lot of motivation and a structure for making data-collection improvements. It also provides an opportunity to educate users about the data limitations and the proper use of the data. The goal is for the higher animal production states to begin to adopt and offer improvements to the NEI using this new method.

Table 8-1 lists the six steps that comprise this new methodology for estimating ammonia emissions from animal husbandry operations. Each of these six steps is addressed in detail in the following paragraphs.

Table 8-1. Overview of New Estimation Methodology

Step 1	Estimate Animal Populations
Step 2	Identify Manure Management Trains (MMT)
Step 3	Estimate Amount of Nitrogen Excreted
Step 4	Identify Emission Factors
Step 5	Estimate Ammonia Emissions
Step 6	Estimate Future Ammonia Emissions

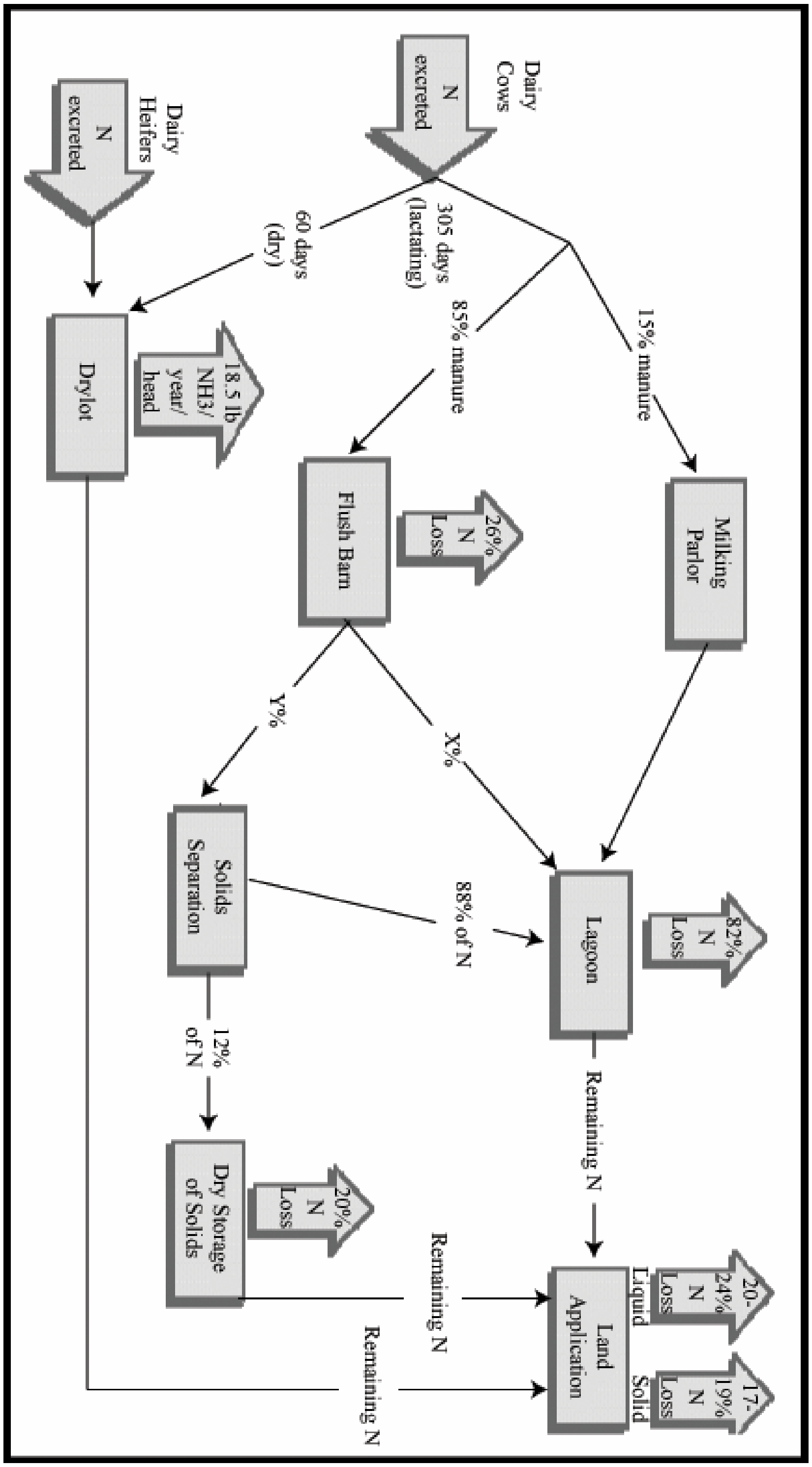
Step 1

The first step in this process is estimating average animal populations by animal group, state, and county. This step uses the 2002 NASS data for state-level populations, and the 1997 census of agricultural to apportion the state-level NASS data to the county level. However, there are some privacy issues with regard to animal populations. For example, a county with only one large facility would create an industrial privacy issue since that facility will not want their competition to know how many animals they are raising.

Step 2

The second step is using Manure Management Trains (MMT) for each animal group to estimate the distribution of the animal population. Fifteen manure management trains have been identified. Figure 8-2 shows an advanced manure management train, one of several such trains for the dairy industry. This manure management train begins with the amount of nitrogen excreted by dairy cows. The train traces the manure through the different handling options and shows how much is handled in different ways. The train also shows the nitrogen and ammonia emissions at the various handling points. For example, there is nitrogen loss in the flush barn and the lagoon, and ammonia loss in the dry lot. There are other trains that provide similar information for other farm industries. These trains characterize a type of industry, and the general way that manure would be handled in a facility.

Figure 8-2. NH3 - Example Manure Management Train



Some of the variables that affect the different trains include the way the animals are housed, the waste storage methods, and the land application methods that are used. For example, the non-feedlot outdoor confinement (e.g., pasture) is one of the trains for swine, dairy, and beef. The MMTs represent different pathways for the escape of ammonia into the air. In applying the MMT approach to estimate the 2002 ammonia inventory, the mix of MMTs is assumed to vary by state, but not within a state. Animal population is allocated among the applicable trains. For example, in a given state 20% of the hogs may be handled using manure management train 3, another 60% may be using manure management train 7, and the rest of them may be using manure management train 14. Finally, it should be noted that the final stage on every train is land application.

Step 3

The third step is estimating the amount of nitrogen excreted from the animals using each type of MMT. This step involves looking at typical animal weights and data on the amount of nitrogen per thousand kilos of live weight. The data on the nitrogen amounts can be obtained from NRCS *Agricultural Waste Management Field Handbook*. Another useful source of information is land grant university researchers and local agricultural extension agents. It is important to include experts in the agricultural industry in the inventory development efforts.

Step 4

Step four involves identifying or developing the emission factors for each component of each manure management train. Some of these factors are in pounds per animal, and some are percent air release of the input ammonia. These factors are used to determine the amount of ammonia that goes to the next stage of the manure train process. Under this approach, the air emissions could never be higher than the original manure content. Also, using this approach sets the stage for applying temporal profiles and process-related variables such as moisture and rainfall.

Step 5

The next step involves applying this methodology to estimate annual ammonia emissions from each animal group by MMT. This includes tracking the ammonia release through each manure management train for each animal type for each county and calculating ammonia releases to the air and transfers to the next stage. This whole process assumes no air emission controls at this time, but control assumptions could be added later. Emissions are summed up to animal type and county, but the database is preserved with full detail for transparency so that changes and improvements can be made.

Step 6

The last step involves estimating ammonia emissions for future years.

Other improvements that are being made to the NEI for animal husbandry operations are to incorporate emission estimates for sheep, ducks, goats, and horses. Additional data sources are being examined to provide recently available data on manure production and excretion rates by animal type and weight. Finally, EPA is examining ways to better address special, seasonal, and regional differences in emissions.

8.3 COMPARISON OF THE 1999 AND 2002 AMMONIA NEIs

A comparison of the 1999 NEI version 3 with the 2002 NEI version 1 shows that there are some significant differences in the ammonia emissions (See Table 8-2). As shown on this chart, about half of the emissions from all animals come from calves and cattle. Also, total ammonia emissions from animal husbandry operations decreased significantly from 3.4 million in 1999 to 2.3 million in 2002.

Table 8-2. NH_3 – Comparison of '99 and '02 NEIs

Animal Group	1999 NEI			2002 NEI		
	Population	**Emission Factor lb/head/yr**	**Emissions Tons/year**	**Population**	**Emission Factor lb/head/yr**	**Emissions Tons/year**
Cattle and Calves Composite	100,126,106	50.5	2,476,333	100,939,728	23.90	1,205,493
Hogs and Pigs Composite	63,095,955	20.3	640,100	59,987,850	14.32	429,468
Poultry and Chickens Composite	1,754,482,225	0.394	345,325	2,201,945,253	0.60	664,238
TOTAL	1,917,704,286	N/A	**3,461,758**	2,362,863,831	N/A	**2,299,199**

Review Exercises

1. Which of the following statements about ammonia emissions from animal husbandry operations is false?
   a. Animal husbandry operations are the largest emitter of ammonia nationally.
   b. Inverse modeling suggests that ammonia emissions may be underestimated.
   c. There are probable errors in some of the ammonia emission factors in the NEI.
   d. The NEI does not take temperature into account in estimating ammonia emissions.

2. The _______ characterize(s) the general way manure is handled by a specific facility.
   a. NASS data
   b. NEI
   c. MMT
   d. All of the above3. Improvements are being made to the NEI to account for ammonia emissions from ______.
   a. sheep
   b. ducks
   c. goats
   d. All of the above

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¶

4. Which type of livestock emits the most ammonia on a per animal basis?
   a. cattle
   b. pigs
   c. poultry
   d. horses

5. Which type of livestock emits the most ammonia on a yearly basis?
   a. cattle
   b. pigs
   c. poultry
   d. horses

Review Answers

1. b. Inverse modeling suggests that ammonia emissions may be underestimated.

2. c. MMT

3 d. All of the above

4 a. cattle

5 a. cattle

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Chapter 9: Combustion Area Sources

LESSON GOAL

Demonstrate, through successful completion of the chapter review exercises, a general understanding of the methodologies for calculating emissions from residential wood combustion, residential and land clearing debris burning, agricultural field burning, and wildland fires.

STUDENT OBJECTIVES

When you have mastered the material in this chapter, you should be able to:

1. Explain the method used in the MANE-VU study to estimate emissions from residential wood combustion sources.
2. Explain the method used in the NEI for calculating emissions from residential wood combustion sources.
3. Identify the difference between the MANE-VU method and NEI method for estimating emissions from residential wood combustion sources.
4. Explain the method used in the NEI for estimating emissions from residential open burning.
5. Identify the different types of residential open burning.
6. Identify ways in which the NEI method for estimating emissions from residential open burning can be improved.
7. Explain the method used in the NEI for estimating emissions from land clearing debris burning.
8. Identify ways in which the NEI method for estimating emissions from land clearing debris burning can be improved.

9. Explain the general method for estimating emissions from agricultural field burning.

10. Explain the general method for estimating emissions from wildland fires.

11. Identity some of the efforts underway to improve the methods for estimating emissions from wildland fires.

Chapter 9: Combustion Area Sources

This Chapter covers three types of combustion area sources: residential wood combustion, residential/land clearing debris burning, agricultural field burning, and wildland fires.

9.1 RESIDENTIAL WOOD COMBUSTION

9.1.1 MANE-VU Emissions Inventory

The MANE-VU View Regional Planning Organization conducted a residential wood combustion survey to develop an emissions inventory for the year 2002. The approach of using a survey is the EIIP preferred method for this category. The objective of the MANE-VU project is to prepare a 2002 inventory based on a survey of household equipment usage and wood consumption patterns. The survey method is a stratified random sampling approach. The data collected for each household consists of wood consumption at the equipment level for both real wood and artificial logs, the type of real wood, and the temporal activity to calculate monthly, weekly, and daily emissions.

9.1.1.1 Sampling Frame

The sampling was designed to address major sources of variability in wood consumption activity. These sources of variability include the location and type of housing, the heating demand expressed as heating degree days (HDD), and the availability of wood.

Housing data from the 2000 census was used to stratify the sample by four categories: urban, suburban, rural single family, and other homes. The other homes category includes multi-family units such as apartments, condominiums, and mobile homes. The rural single-family category was stratified into forested versus non-forested areas using USGS-GIS data. Total annual heating degree days were used to further stratify the sample into three zones: low, medium and high.

Table 9-1 is a sample frame shown in a grid. Within each cell the number 61 is the minimum sample size that was determined based on calculations for the precision desired from the survey. The numbers in parentheses represent the number of surveys that were actually collected or completed. Surveys for which the respondents did not categorize correctly were removed from the sample.

Table 9-1. Sample Frame

Geographic Zone	Rural-Forested		Rural Non-Forested		Suburban		Urban	
	Single-Family	Other	Single-Family	Other	Single-Family	Other	Single-Family	Other
High HDD	**Cell 1** 61 (173)	**Cell 2** 61 (64)	**Cell 3** 61 (87)	**Cell 4** 61 (66)	**Cell 5** 61 (61)	**Cell 6** 61 (72)	**Cell 7** 61 (69)	**Cell 8** 61 (69)
Low HDD	**Cell 9** 61 (150)	**Cell 10** 61 (62)	**Cell 11** 61 (118)	**Cell 12** 61 (69)	**Cell 13** 61 (76)	**Cell 14** 61 (67)	**Cell 15** 61 (75)	**Cell 16** 61 (62)
Med HDD	**Cell 17** 61 (87)	**Cell 18** 61 (60)	**Cell 19** 61 (91)	**Cell 20** 61 (64)	**Cell 21** 61 (71)	**Cell 22** 61 (60)	**Cell 23** 61 (63)	**Cell 24** 61 (68)

9.1.1.2 Survey Instrument

The survey instrument is a questionnaire developed to gather the activity data on indoor equipment (fireplaces, woodstoves, pellet stoves, furnaces, and boilers), and outdoor equipment (fire pits, barbeques, fireplaces, and chimineas). A pilot survey was conducted to test the questionnaire. Based on the pilot survey, questions were rephrased to clarify the questions in order to collect the information that was needed to characterize the activity. The survey was conducted using computer-assisted telephone interviewing with over 1,900 surveys being completed across all 24 cells.

9.1.1.3 Data Reduction

After completion, the surveys were quality assured to make sure that the data collected made sense. Also, the user fraction (i.e., the fraction of the total household population that burns wood in indoor and outdoor equipment), the annual activity (i.e., cords of wood by equipment and wood types), and temporal data were summarized for each cell. Finally, statistical analyses were conducted to identify significant differences between cells for the user fraction and annual activity.

9.1.1.4 Results and Observations

Table 9-2 is the same as Table 9-1 with the exception that the grid cells have the fraction of indoor wood burning equipment on a percentage basis. In some cases the fractions add up to more than 100% because some houses were using more than one piece of equipment. It should be noted that the rural forested areas within a high heating demand zone has a higher diversity of equipment and more households are using wood burning equipment than the urban areas.

Table 9-2. Sample Frame

Geographic Zone	Rural-Forested		Rural Non-Forested		Suburban		Urban	
	Single-Family	**Other**	**Single-Family**	**Other**	**Single-Family**	**Other**	**Single-Family**	**Other**
High HDD	**Cell 1** FP=34 WS=67 F/B=21 PS=**4**	**Cell 2** FP=75 WS=75 F/B=0 PS=0	**Cell 3** FP=43 WS=76 F/B=7 PS=0	**Cell 4** FP=33 WS=67 F/B=0 PS=0	**Cell 5** FP=36 WS=64 F/B=**18** PS=0	**Cell 6** FP=0 WS=0 F/B=0 PS=0	**Cell 7** FP=80 WS=30 F/B=0 PS=0	**Cell 8** FP=100 WS=0 F/B=**50** PS=0
Low HDD	**Cell 9** FP=60 WS=65 F/B=5 PS=2	**Cell 10** FP=100 WS=0 F/B=0 PS=0	**Cell 11** FP=61 WS=54 F/B=**4** PS=4	**Cell 12** FP=50 WS=50 F/B=0 PS=0	**Cell 13** FP=70 WS=35 F/B=0 PS=5	**Cell 14** FP=67 WS=0 F/B=0 PS=33	**Cell 15** FP=90 WS=10 F/B=0 PS=0	**Cell 16** FP=100 WS=0 F/B=0 PS=**20**
Med HDD	**Cell 17** FP=55 WS=66 F/B=7 PS=7	**Cell 18** FP=60 WS=60 F/B=0 PS=0	**Cell 19** FP=59 WS=45 F/B=0 PS=9	**Cell 20** FP=100 WS=0 F/B=0 PS=**25**	**Cell 21** FP=81 WS=27 F/B=**8** PS=4	**Cell 22** FP=50 WS=50 F/B=0 PS=0	**Cell 23** FP=100 WS=0 F/B=0 PS=0	**Cell 24** FP=0 WS=0 F/B=0 PS=0

FP = Fireplace; WS = Woodstove; F/B = Furnace/Boiler; PS = Pellet Stove
Totals do not always add to 100 since some respondents use more than one type of equipment. Values in **bold** are derived from responses that were identified as wood consumption outliers (equipment could be mis-categorized by respondent).

Another observation is that rural areas have a higher percentage of stoves and furnaces and boilers than urban areas. Urban and suburban areas have a lower diversity of equipment types and a higher percentage of fireplaces than rural areas. With respect to heating demand, rural areas have a higher percentage of stoves and furnaces in the higher HDD zone, and rural areas have a higher percentage of fireplaces in the lower HDD zone.

For indoor equipment, because of the sample size of the survey, it was hard to find households that burned wood in urban areas. However, the urban sample size was not increased (due to budget constraints and priorities) to obtain a representative sample for three instead of two HDD zones. As a result, emissions were not calculated for each piece of indoor equipment in urban areas. Rather, in order to maintain precision, the equipment and fuel-based survey results were used to estimate average emissions (pound of $PM_{2.5}$ per household per year) and a household-based statistical model was used to estimate emissions for each cell for indoor equipment.

Because there was enough data collected to maintain the sample frame precision, emissions were estimated for outdoor equipment using the survey results. The emissions are the product of the fraction of outdoor equipment users per cell, the annual activity, and the emission factor. This is the first attempt to estimate emissions from outdoor wood burning equipment at the household level and is a tremendous improvement over the NEI, which only includes indoor equipment.

9.1.1.5 Emission Inventory Development

Emissions were estimated for all criteria pollutants and precursors, and several dozen toxic air pollutants. They were estimated at the census track level and summed to the county, state and region. Emissions were temporally allocated to support modeling using profiles that were developed from the survey.

9.1.1.6 Lessons Learned

The survey instrument for regional surveys should be tailored to suit the usage patterns on rural and suburban and urban areas. It is difficult to find wood burners in the urban areas, and the sample size may need to be increased to locate these sources. For indoor equipment, to keep resources manageable, the use of statistically derived emissions based model (household level) instead of an equipment specific method should be considered. The concern with this MANE-VU approach, however, is that it aggregates emissions for different types of wood burning equipment, which should be disaggregated in order to conduct a control strategy analysis.

9.1.1.7 Documentation

Documentation for the MANE-VU project can be obtained at www.manevu.org/pubs/index.asp. This contains the work plan, including the equations for calculating the sampling precision.

9.1.2 NEI

The NEI categorizes fireplaces into four SCCs and woodstoves into three SCCs as shown in Table 9-3. A description of the equipment associated with each SCC is also included in Table 9-3.

Table 9-3. NEI SCCs for Residential Wood Combustion

SCC	Combustion Source
	FIREPLACES
2105008001	Without Inserts
2104008002	With Inserts; Non-EPA Certified
2104008003	With Inserts; Non-Catalytic, EPA Certified
2104008004	With Inserts; Catalytic, EPA Certified
	WOODSTOVES
2104008010	Non-EPA Certified

2104008030	Catalytic, EPA Certified
2104008050	Non-Catalytic, EPA Certified

The pollutants included in the NEI for residential wood combustion include PM_{10} primary, $PM_{2.5}$ primary, NO_X, CO, SO_X, and HAPs. The emission factors that are used for residential wood combustion represent primary emissions. There is no breakout of the filterable and condensable portions of the emission factor for this category.

9.1.2.1 Emission Factors

The emission factors used in the NEI for fireplaces without inserts (pounds pollutant per ton of dry wood) are obtained from AP-42 except for PM and CO which are obtained from Houck, J.E. et al, *Review of Wood Heater and Fireplace Emission Factors*. The $PM_{2.5}$ emission factor is assumed to be the same as the PM_{10} primary emission factor. The emission factors for all pollutants from woodstoves and fireplaces without inserts are obtained from AP-42.

9.1.2.2 Emission Estimation Methodology

The NEI developed separate national wood consumption estimates and, therefore emission estimates, for fireplaces with inserts, fireplaces without inserts, and woodstoves to account for the different emission factors and different usage patterns. The methodology is different for fireplaces without inserts than it is for fireplaces with inserts and woodstoves. As such, these are discussed separately in the following sections.

9.1.2.2.1 Fireplaces without Inserts

The first step in estimating emissions from fireplaces without inserts is to determine the number of homes with fireplaces in the United States. These data can be obtained from the US Department of Census (DOC). These data need to be adjusted to account for the fact that some homes have more than one fireplace (multiply by 1.17) and for the fact that not every home burns wood (74% burn wood, 26% burn gas).

After making the adjustments to account for multiple fireplaces and those that burn wood, the number of fireplaces not being used (42% not used) and the number of fireplaces with inserts are subtracted. Fireplaces with inserts are treated in the same manner as woodstoves and are discussed in section 9.1.2.2.2.

Based on DOC data the NEI separated fireplaces without inserts into 2 categories; those used for heating and those used for aesthetics. The amount of wood burned in each device is determined by assuming wood consumption rates of 0.656 cords burned /unit/year for fireplaces used for heating and 0.069 cords/unit/year for fireplaces used for aesthetics. In 1997, EPA estimated that 2.94 million cords of wood were burned in the former and 0.483 million cords of wood were burned in the latter.

Once the national wood consumption for fireplaces without inserts is calculated it is necessary to allocate it to 1 of 5 climate zones based on temperature, and demographics/population (i.e., the number of single-family home). Within each climate zone, wood consumption is allocated to individual counties.

Table 9-4 shows the climate zones defined by the ranges of heating degree day and cooling degree day values as well as the amount of national consumption that is allocated to each zone.

Table 9-4. Climate Zones

Climate Zone	Percent of Wood Consumed
1 (>7000 HDD)	36
2 (5500-7000 HDD)	19
3 (4000-5499 HDD)	21
4 (<4000 HDD and <2000 CDD)	15
5 (<4000 HDD and >2000 CDD)	9

The census data classifies counties as either urban or rural. A county is classified as urban if 50 percent of the county's population is located in cities and towns and it is classified as rural if less than 50 percent of the population is located in cities and towns. The total wood consumption for all the urban counties are summed for each climate zone, and the same is done for the rural counties. The data is adjusted if the percentage proportion between urban and rural areas does not match the percentage in the number of units that are reported in the 2001 census. This data is shown in Table 9-5. For example, if the total wood consumption for woodstoves in climate zone 1 is 60 percent for rural and 40 percent for urban, then each urban and rural county within zone 1 receives a percent increase or decrease in cordwood consumption to obtain the correct percent split to reach the 65 percent rural and 35 percent urban split for zone 1.

Table 9-5. Urban/Rural Apportionment Data

Type	Rural	Urban
Woodstoves	65%	35%
Fireplaces with Inserts	43%	57%
Fireplaces without Inserts	27%	73%

Finally, AP-42 factors are used to determine county emissions from fireplaces without inserts.

9.1.2.2.2 Fireplaces with Inserts and Woodstoves

The first step in estimating emissions from fireplaces with inserts and woodstoves is to determine the number of woodstoves and inserts in the United States. These data are obtained from the DOC and are adjusted for the fact that some homes have more than one stove. Also, units used for main heating purposes are considered different from units that are used for other heating purposes (e.g., aesthetic).

The total cords of wood consumed by the residential section for 1997 are obtained from the Energy Information Administration (EIA). Since this value does not include consumption for aesthetic purposes, it is necessary to subtract the cords of wood used in fireplaces for aesthetic purposes.

Using the same approach that was used for fireplaces without inserts, the national wood consumption for fireplaces with inserts and for woodstoves is allocated to 1 of 5 climate zones (see Table 9-4). Within each climate zone, the wood consumption is allocated to the individual counties using the relative percent of detached single family homes in the county to the total number of detached single family homes in the entire climate zone.

After allocating to the climate zones, the wood consumption in each zone is summed and compared the urban and rural split. The total is adjusted until the desired split is achieved. For woodstoves, the split is 69 percent rural and 31 percent urban. For inserts, the split is 50/50. For example, if the total wood consumption for woodstoves in climate zone 1 was 60 percent for rural 40 percent fir urban, then each urban and rural county with that zone would receive a percent increase or decrease in cordwood consumption to obtain the correct percent split to reach the 69 percent rural and 31 percent urban split.

Wood consumption for woodstoves and fireplaces with inserts are allocated to one of the three SCCs as shown in Table 9-6. Fireplaces without inserts are recorded on one SCC, so there is no need to allocate to SCCs.

Table 9-6. Apportionment for Woodstoves and Fireplaces with Inserts

Type of Device	Percent of Total Wood Consumption
Non-Certified	92
Certified Non-Catalytic	5.7
Certified Catalytic	2.3

Once the amount of wood consumed per residential wood combustion type is obtained, AP-42 emission factors are used to calculate emission estimates.

9.1.2.3 Seasonal Adjustment

When the NEI method was developed the seasonal activity was allocated by climate zone. The seasonal throughput percentages assigned to each climate zone are listed in Table 9-7. Zone five is the warmest zone, so all the activity was placed into the winter category. Summer has no activity with the NEI default method, and the activity is distributed across the seasons for zones two, three and four.

Table 9-7. Apportionment for Woodstoves and Fireplaces with Inserts

Climate Zone	Winter	Spring	Summer	Fall
5	100	0	0	0
4	70	15	0	15
3	50	25	0	25
2	40	30	0	30
1	33.33	33.33	0	33.33

9.1.2.4 Improving the NEI

One approach to improving on the NEI method is to conduct a local survey, or allocating emissions within the seasons. It is preferable to use local data and the preferred collection method is to do a local or statewide survey. The EIIP provides an alternative method that uses the bureau census data and the EIA data method. Any assumptions other than 100% for rule effectiveness and rule penetration should be incorporated into the emissions estimation methodology since the NEI method does not account for the effect of state and local rules. Finally, the residential wood combustion section of the EIIP series (Chapter 2 of Volume III) contains information on conducting a survey.

9.1.3 Comparison of the MANE-VU and NEI

The MANE-VU inventory is a bottom-up methodology and the NEI is top down. MANE-VU provides better estimates by geographic area and census. It also accounts for differences in housing type (single versus multi-family homes). MANE-VU provides better estimates of usage patterns based on heating demand, and it includes outdoor equipment not included in the NEI estimates. It also provides some temporal data that can be used to allocate emissions.

9.2 Residential/Land Clearing Debris Burning

9.2.1 Residential Open Burning

Residential open burning includes household waste burning and yard waste burning, which includes brush waste and leaf waste.

9.2.1.1 NEI

Table 9-8 lists the SCCs and the pollutants for residential open burning that are included in the NEI.

Table 9-8. Residential Opening Buring SCCs and Pollutants

Category	SCCs	Pollutants
Residential Municipal Solid Waste Burning	2610030000	PM_{10}, $PM_{2.5}$, CO, NO_x, VOC, SO_2, 32 HAPs
Residential Leaf Burning	2610000100	PM_{10}, $PM_{2.5}$, CO, VOC, 6 HAPs
Residential Brush Burning	2610004000	PM_{10}, $PM_{2.5}$, CO, VOC, 6 HAPs

The first step in developing activity data for residential municipal solid waste is to estimate the rural population by county by applying percentages of rural and urban population from the census data. The second step is to multiply the rural population by a per capita household waste factor of 3.37 pounds per person per day. Once the total waste generated is estimated, the amount of waste burned is estimated by assuming that 28% of the household waste generated is burned. The final step is to account for burning bans. Ideally this is done by knowing exactly which areas have instituted a burning ban and the time period over which the ban applies. However, the NEI assumes that if a county has an urban population that exceeds 80% of the total population the amount of waste burned is zero.

The activity data for yard waste is estimated in a similar manner to household waste using a per capita waste factor for yard waste generation of 0.54 pounds per person per day. However, since different types of yard waste materials have different emission factors it is necessary to estimate the percentage of total yard waste that corresponds to leaf, brush, and grass waste. The NEI assumed that 25% was leaf waste, 25% was brush waste, and 50% was grass waste. The amount of waste burned is estimated by assuming that 28% of the total leaf and brush waste is burned and that 0% of the grass waste is burned. One additional adjustment is made to the amount of yard waste burned to try to account for the variation in vegetation among the counties. This is done by using an estimate of the percent of the forested acres per county that was obtained from the biogenic emissions land cover database from the Biogenic Emission Inventory System (BEIS) as shown in Table 9-9. For example, if the BEIS data indicates that a county has less than 10% forested acres, the NEI assumes that there is no yard waste generated.

Table 9-9. Vegetation Adjustment Values

Percent Forested Acres per County	Adjustment for Yard Waste Generated
< 10	Zero out
>=10 and <50	Multiply by 50%
>=50	Assume 100%

The final step is to account for burning bans in the same manner that was used for household waste. Once the activity data is estimated, emissions are calculated by the use of Equation 9-1. A 100% CE is assumed for counties that have an urban population greater than 80% of the total population. The NEI also assumes that RE and RP are 100% for these areas. The NEI assumes that all other counties are uncontrolled.

Equation 9-1. Emission Estimation Formula for Household and Yard Waste Burning

$$E = A*EF*(1-CE*RP*RE)$$

where: E = Controlled emissions (lbs pollutant/year)
A = Activity (tons of waste burned/year)
EF = Emission factor (lbs/ton waste burned)
CE = % Control efficiency/100
RP = % Rule penetration/100
RE = % Rule effectiveness/100

There is an EIIP document for open burning and it contains an alternative approach for estimating emissions for yard waste. This approach involves obtaining records of burning permits or violations and data (or assumptions) on typical volumes and material composition.

9.2.1.2 Improving the NEI

The open burning EIIP (Volume III, Chapter 16) contains alternative methods for estimating activity data for this category. Another approach is to use the NEI methodology coupled with state or local estimates of the per capita waste generation and the amount or percentage of waste burned. Also, state/local data on the months when yard waste is burned would be an improvement since the NEI does not make any temporal adjustment for yard waste burning. Some of the sources for this type of information include the Solid Waste agency, the Air

Agency, the Health Department, the Solid Waste Management agency, and through the use of local surveys.

The NEI can also be improved by obtaining better estimates of control measures that are applied to open burning. This involves identifying the rules that limit or prohibit open burning and the organization that enforces those rules (e.g., fire marshal, health department). For areas that have burning prohibitions, a rule effectiveness survey can be performed to estimate the compliance rate with the rule. This is critical in rural areas where there are few complaints about open burning. Also, rule penetration is critical since many open burning rules have exemptions that are listed (e.g., firefighting training activities, recreational campfires). Rule penetration is also important for seasonal bans.

9.2.1.3 Case Study

This case study examines the development of a 2002 residential open burning inventory for the MANE-VU states. This was developed by a multi-state Regional Planning Organization and followed the procedures in the EIIP document (i.e., conducting a survey) to obtain activity data.

A survey instrument was developed to collect data on the number of households that burn waste, the burn frequency, the amount burned, and the seasonal nature of the burning. Three separate surveys were performed for residential municipal solid waste, brush waste and leaf waste. The data collected from these surveys were used to estimate emissions for each survey area and to estimate default activity data for those areas not included in the surveyed areas.

Equation 9-2 shows the equation that was used to estimate the amount of waste burned based on the data collected from the surveys.

Equation 9-2. Equation for Estimating Mass of Waste Burned

$$Wt = HH * Bt * M$$

where: Wt = Mass of waste burned per time period
HH = Number of households that burn
Bt = Number of burns per time period
M = Mass of waste burned

In addition to collecting data to estimate activity data, a control database was developed that established area-specific control efficiency, rule effectiveness, and rule penetration. Because rule effectiveness and rule penetration can vary significantly depending on enforcement and the rule applicability, a rule effectiveness survey was conducted to determine the level of compliance with the state or local open burning prohibitions. This data was also used to estimate default RE values for use in the non-surveyed areas.

Using the activity data and the control information, emissions were estimated for all criteria pollutants and precursors as well as for several HAPs. The emissions were estimated at the census track level and then summed to the county, state, and regional level. Finally, the data on the occurrence of the burning activities were used to temporally allocate the emissions to support modeling using profiles that were developed from the survey.

A number of lessons were learned from conducting the survey including that separate surveys should be performed in targeted areas where leaf burning is significant. In addition, household waste and yard waste surveys should be performed separately simply to reduce the length of the survey. Another lesson learned is that a larger sample may have allowed for greater geographic distinction. In addition, a regional survey provides greater consistency that allows for easier comparison of emission estimates from different areas. Finally, better accounting of controls results in a decrease of the NEI emissions.

9.2.2 Land Clearing Debris Burning

Land clearing debris burning is covered under SCC 2610000500. The NEI contains emission estimates for PM_{10}, $PM_{2.5}$, CO, VOC, and 6 HAPs from this category.

9.2.2.1 NEI

The activity data for this category is the same as that used for the construction category (i.e., the number of acres disturbed for the different types of construction categories). A loading factor is applied to the number of acres disturbed to produce an estimate of the amount of material that is being burned. Weighted county-specific loading factors were developed based on the acres of hardwood, softwoods, and grasses. The average loading factors (Table 9-10) are multiplied by the percent contribution of each type of vegetation class to the total county land area. The average loading factors for hardwood and softwoods were adjusted by an additional 1.5 to account for the mass of tree below the surface. It should be noted that the emission factors presented in Table 9-10 reflect this adjustment.

Table 9-10 Fuel Loading Factors

Fuel Type	Fuel Loading (tons/acre)
Hardwood	99
Softwood	57
Grass	4.5

Equation 9-3 shows the formula for developing the loading factors.

Equation 9-3. Equation for Estimating Fuel Loading Factor

$$L_w = F_h*L_h + F_s*L_s + F_g*L_g$$

where: L_w = County-specific weighted loading factor
F_h = Fraction of county acres classified as hardwoods

L_h = Average loading factor for hardwoods
F_s = Fraction of county acres classified as softwoods
L_s = Average loading factor for softwoods
F_g = Fraction of county acres classified as grasses
L_g = Average loading factor for grasses

Emissions are estimated from the activity data as shown by Equation 9-4. This formula multiplies the activity data, the number of acres of land, and the county-specific loading factor. Since the loading factor does not vary by the types of construction, the number of acres cleared for all three types of activities (residential, commercial, and road construction) are summed before the loading factor is applied. The NEI assumes that all the fuel loading on the land cleared is burned and that no controls or bans are in place.

Equation 9-4. Equation for Estimating Emissions from Land Clearing Debris Burning

$$E = A * LF * EF$$

where: E = Emissions (lbs pollutant/year)
A = Number of acres cleared per county
LF = County-specific loading factor (tons/acre)
EF = Emission factor (lbs pollutant/ton)

9.2.2.2 Improving the NEI

The NEI does not take into account data on burning practices or controls, so a good place to begin to improve the NEI is to review the EIIP section on open burning. The EIIP methods rely on a direct measure of mass of waste or debris burned, which may be obtainable from local officials that track this activity for permitting purposes. Also, obtaining a better estimate of the acres cleared for the fugitive dust construction category would improve the inventory for the land clearing debris burning category. Other approaches for improving the NEI include:

- Developing an improved loading factor.
- Identifying specific counties with burning bans.
- Specifying counties where wastes are burned.
- Obtaining state or local estimates of the percentage or amount of waste burned per construction event (the NEI assumes that the fuel loading associated with the land that is cleared is being burned).

9.2.2.3 Case Study

This case study involves a study for the Northern Virginia area that performed a RE survey to determine the level of compliance with rules for land clearing debris burning and residential waste burning. The objective of the study was to develop a defensible RE value for use in the State Implementation Plan. Current EPA guidelines requires the application of an 80% rule effectiveness.

The study reviewed the existing conditions of the open burning rules to determine the time period of the ban and the exemptions that apply. A survey of local open burning officials responsible for tracking and enforcing open burning rules was conducted. The survey form was derived from an EPA questionnaire that is available from the rule effectiveness guidance. Responses to the questions on the survey were assigned a specific point value that adds up to a maximum of 100 points. This point value is considered equivalent to the RE percentage value. If all the questions were answered with the highest rating, an RE value of 100% was assigned. The RE values were analyzed by county as well as for the five-county region and a regional RE value of 93% was estimated. Although not done in this case study, separate RE values could be developed for urban and rural area in cases where there are significantly different population densities.

Some of the lessons learned from this case study are that the local officials tend to defer to the county or state level officials for enforcing the open burning rules. Also, in developing an annual emissions inventory, it is important to note that RE may be high only for the time period that the ban is in effect. In this case, the duration of the ban (RP) needs to be taken into account if it is less than annual or seasonal. Also it is important to account for when the ban is taking place and if it overlaps with when the activity occurs. For example, a ban in place for the summer months for brush waste burning will have minimal impact if the majority of the brush burning occurs in the fall.

9.3 Agricultural Field Burning

9.3.1 Introduction

Agricultural burns create particulate matter pollution and their inventory is important to the overall particulate matter air quality analysis. The SCC for agricultural burning is 2801500000 and EPA encourages States to inventory both PM10 and PM2.5-PRI. Since agricultural burning is a combustion process, both condensibles and filterables are included in the PM-PRI estimate.

EPA develops emission estimates for most source categories in the NEI and then the States submit any improved information that they have for those particular categories. However, for agricultural burning EPA does not at this time prepare an estimate of emissions from agricultural burning. In this case EPA encourages each State to develop their own inventories and submit them. In 1999 ten States (Alabama, California, Delaware, Georgia, Idaho, Kansas, Maine, Oregon, Texas, and Utah) developed their own agricultural burning inventory. In general, these States developed the inventories by characterizing the activity or acres of the crop burned, the loading factor, the ton of biomass of vegetation per acre burned, and the emission factor in terms of pounds of $PM_{2.5}$ per ton.

9.3.2 Case Study

This case study involves wheat stubble burning and uses county-specific data. The activity data that was obtained are the acres of wheat burned by month. This was obtained from burn permits that are usually issued by the county fire department. Also, the fuel loading for wheat stubble was obtained from the county agricultural extension office. The emission factors are from a study done by CARB (Jenkins, B.M. et al., *Atmospheric Pollutant Emission Factors from Open Burning of Agricultural and Forest Biomass by Wind Tunnel Simulations*, Volume 2, Results, Cereal Crop Residues, California Air Resources Board Project Number A932-126). The emission factors are 8.82 pounds per tons of wheat stubble burned for PM_{10} and 8.34 for $PM_{2.5}$. The spatial resolution for this inventory is the county and the temporal resolution is monthly. Equation 9-5 shows the formula for calculating PM2.5-PRI emissions using the data for the month of June. This calculation would be repeated for each month during the burning season and summed to give an annual emissions estimate. It should be noted that if the number of acres burned per fire is larger than 100 acres; the specific latitude and longitude of the fire should also be obtained.

Equation 9-5. Equation for Estimating Emissions from Agricultural Burning

$$E = A * LF * EF$$

where: E = Emissions (lbs pollutant/month) = 16,263
A = Number of acres burned per month = 1,950
LF = Loading factor (tons/acre) = 1
EF = Emission factor (lbs pollutant/ton) = 8.34

9.3.3 Improvements

EPA encourages all states to develop their own agricultural burning inventory. For fires larger than 100 acres EPA suggests that they be located at a specific latitude and longitude and the stop and start date and time of the fire be recorded. Smaller fires should be lumped into overall monthly acreage like in the previous case study example. Obtaining information on agricultural burning requires coordination with the burners and the permitting authorities. In order to develop an agricultural burning inventory, states needs to build a system and a relationship with the burners and permitting authorities. Chances are pretty good that the first time a State tries to obtain this information they will find that records are not kept or are not kept in a way that can easily be understood.

The local acres of crops burned are obtained from burn permits or from a survey of county agricultural extension offices or perhaps a combination of both. It is important that States verify that the burns actually occurred. Often a burner will get a permit to burn a lot more acreage than they actually are able to burn in a particular day. In many cases a burner is limited by the weather or other factors that keep them from burning the acreage that they are permitted to burn. Finally, States need to obtain local fuel loading data. This is preferably obtained from the local county agricultural extension office or the local Natural Resources Conservation Service Center. This is highly preferable to using the national defaults that are available in Chapter 2.5 of AP-42.

9.4 Wildland Fires

Fires have become a major issue in both visibility impairment and in creating high concentrations of $PM_{2.5}$ that could result in health problems. The problems have been mainly in the West, but also wildfires from the Southeast, the Central States, Canada, and Mexico have become a concern. EPA's wildland burning inventory includes both wild and managed burns. The typical agencies that burn are the National Park Service, the United States Forest Service, the Bureau of Land Management, the United States Fish and Wildlife Service, State & Tribal Forests, and private burners. Wildland fires are categorized into two types: wildfires and managed or prescribed burns. Prescribed burns are those burns that are ignited intentionally for habitat improvement of the wildlife; for managing the overall under growth and understoring of the forest; and to reduce the risk of wildfires later on by removing the fuels from the forested area.

9.4.1 NEI

The approach used to estimate wildfire emissions in the NEI is a very rudimentary approach. It should be noted that this discussion focuses on the technique for estimating emissions from wildfires; however, emissions from prescribed or managed fires are estimated in a similar fashion. The pollutants that are included in the NEI inventory for wildland fire emissions are PM_{10}, $PM_{2.5}$, NOx, CO, VOC, SO_2, and about 30 HAPS. The emissions factors for estimating fire emissions, the fuel regional loading factors, and the fuel consumption factors are found in AP-42. The technique is to merge the factor and fuel loading and fuel consumption information with annual activity data obtained at either the state or regional level from the main burning agencies. Most of the federal burners keep fairly good records of the burns that they conduct mostly because these fires end up being watched and/or fought by personnel. Some states also provide burn data as do some private burners.

The data obtained from the burners is at the state level or regional level and it is allocated to the state or county level using the amount of forested area in a state. In other words, since the NEI does not have data on the exact location of the fires, the amount of acreage that was burned during a year in a particular state is allocated across the state to the forested lands.

The NEI allocates the emissions annually and the emissions processor allocates the emissions diurnally and monthly. This allocation is important because certain areas of the country have different fire seasons and fire seasons are different for prescribed burns and managed burns.

9.4.2 Improving the NEI

In order to improve wild land fire emissions, national and regional databases and models must be improved. Fires need to be treated as events (i.e., specify the area burned, when it was burned, and where it occurred). In addition, large fires need to be entered into the databases as point sources with a particular location (lat/long) and a start date, end date, and the time of day. National regional models and databases need to be developed and refined to improve the pre-burn fuel loading information. The information in AP-42 is very general, very dated, and averaged over large regions of the country. Finally, the use of fuel consumption models needs to be to refined and expanded and guidance on estimating the impact of mitigation measures on emissions needs to be provided.

There is a Memorandum of Understanding (MOU) in effect between the EPA, Department of Interior, and the United States Department of Agriculture to develop a fire events database. It is a broad scope MOU that covers fire management activities including ways to improve the national databases. There is a similar effort (NEISGEI) being conducted at Washington University in St. Louis. There currently exists a database for recording fire events in the Pacific NW called the B-RAINS system. Although these types of projects are moving toward real time data collection, quality assurance and data sharing, there is much more work needed in these areas.

EPA is also investigating the potential use of satellites to improve wildland fire inventories. EPA has funded a report entitled *Overview of Using Satellites in AQ Management*. There is also collaboration going on with NASA to take advantage of their skills in aerial surveillance with satellites. There are several interagency groups working on the use of satellites including the National Interagency Fire Center (a jointly funded effort of all the Federal burners) in Boise, Idaho, the Missoula Fire Research Center, and Salt Lake City. Another project includes CAMFER, which is a project underway at University of California Berkeley.

9.4.3 Emission Estimation Tools and Inventories

EPA recently published a report entitled *Fire Emission Estimation Methods* (available on the CHIEF web site) that contains a lot of good background information on wildland fire emission estimation. In addition, there is a lot of ongoing work to improve emission estimation tools for wildland fires. The US Forest Service has ongoing work on the development of fuel consumption and fire behavior models at the Fire Sciences Lab in Missoula and also at the Pacific NW Research Station in Corvallis. Also, there is also a lot of emission factor testing occurring in the Fire Sciences Lab in Missoula.

There is also collaboration going on between all the different burn agencies, EPA, and the Regional Planning Organizations (RPO). The Western Regional Air Partnership (WRAP) conducts a fire emissions joint forum and EPA and the burn agencies participate in that forum. There is a RPO project to refine the 2002 wildland fire emissions inventory. There was a national fire emissions workshop held in May of 2004 that focused on the latest ideas and methodologies for estimating fire emissions. Also, the US Forest Service with assistance and funding from EPA is developing a geographic coverage of the fuel types and fuel conditions for burning at a 1km resolution. A map of the country that will be useful in GIS systems will be developed out of this project. Finally there will be further work on developing an emissions model that will estimate fire emissions in real time using real time meteorological data. Output from this model will be fed directly into the grid models for estimating ambient air concentrations associated with fire emissions.

The emissions model that is under development is the Wildlands Fire Emissions Model. It will interface with SMOKE and OpEMs (the emissions model that is under development by the RPO), and the CMAQ modeling system. The user will need to input fire locations, durations, and size of the fire (i.e., the blackened area of the fire). The model components, which will be drawn from the Blue Sky system being developed in the Pacific NW, are:

1. A fuel loading default that will use either the national fire danger rating system or, as it becomes available, the FCC map.
2. Fuel moisture will be calculated using actual metrological data for the period during, and immediately before the fire. This is a significant improvement over the past and an important improvement since fuel moisture is critical in determining the amount of fuel that will burn and the emissions from that fuel.
3. Fuel consumption models are being built into the model. Both the CONSUME / FOFEM are such models that have recently been improved significantly. The CONSUME model is developed in the Corvallis lab and the FOFEM has been developed by the Missoula Fire Lab. These models compliment each other and have strengths and weakness that, when used together properly, give a pretty good handle on fuel consumption.
4. The emission heat release and plume rise is being handled through the EPM model and the modified Briggs plume rise equation. There is an improvement to the EPM model called FAR, which is about to be released in beta test form.

The output of the model will be a gridded hourly emission estimate and plume characteristics. The output will be able to be interfaced with grid models to provide a regional scale estimate of the effects of fires. For instance, this new wildland fire model will be able to estimate the NOx plume from a wildland fire and the effects of that increased NOx on ozone formation. The integration, testing, and release of the model are anticipated for late 2004.

Review Exercises

1. The NEI methodology for residential wood combustion made adjustments to the national number of fireplaces to account for _______.
   a. fireplaces that burn gas
   b. fireplaces without inserts
   c. fireplaces used for aesthetic purposes
   d. All of the above

2. Which type of residential wood combustion is not allocated to different SCCs?
   a. woodstoves
   b. fireplaces with inserts
   c. fireplaces without inserts
   d. All of the above

3. The NEI methodology for residential municipal solid waste burning assumes that if a county has an urban population that exceeds _______ percent of the total population, the amount of waste burned is zero.
   a. 50
   b. 75
   c. 80
   d. 90

4. The NEI methodology for residential municipal solid waste burning assumes that _______ percent of household waste generated is burned.
   a. 18
   b. 28
   c. 38
   d. 48

5. The land clearing debris burning load factors for _______ are adjusted by an additional 1.5 to account for the mass below the surface.
   a. hardwoods and grasses
   b. softwoods and grasses
   c. hardwoods and softwoods
   d. All of the above

6. The activity data for land clearing debris burning is the same that is used for the _______ category.
   a. agricultural burning
   b. unpaved roads
   c. agricultural tilling
   d. construction

7. Which of the following variables are not used in the NEI to estimate emissions from land clearing debris burning?
   a. number of acres cleared
   b. county-specific loading factor
   c. emission factor
   d. rule effectiveness

8. For which of the following categories did the NEI not develop a methodology?
   a. agricultural field burning
   b. agricultural tilling
   c. wood stoves
   d. land clearing debris burning

9. Which of the following is **not** a source of variability in wood consumption activity in the MANE-VU study?
   a. type of housing
   b. heating degree days
   c. moisture content of wood
   d. availability of wood

10. Current EPA guidance for State Implementation Plans specifies that a rule effectiveness of ______ percent should be applied to waste burning in nonattainment areas.
    a. 50
    b. 75
    c. 80
    d. 85

11. In estimating emissions from wildland fires, the data obtained from the burners is allocated to the state or county level using ______ .
    a. the number of burn permits issued
    b. the number of acres burned
    c. the amount of forested land in a state
    d. All of the above

Review Answers

1. d. All of the above

2. c. fireplaces without inserts

3. c. 80

4. b. 28

5. c. hardwoods and softwoods

6. d. construction

7. d. rule effectiveness

8. a. agricultural field burning

9. c. moisture content of wood

10. c. 80

11. c. the amount of forested land in a state

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