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Air

Preparation of Fine Particulate Emission Inventories

Case Study Solution Handouts

APTI Course 419B

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HANDOUT 4-1

Case Study Number 4-1 Solution

Estimating PM_{10} and $PM_{2.5}$ Emissions from Locomotives

Question 1: Are the emission estimation methodologies the same for long haul and switchyard locomotives?
Answer: The activity data for both line-haul and switchyard locomotives are based on estimates of the gallons of distillate fuel oil consumed. However, the data provided for each requires that a different approach be used to estimate fuel consumption.

Question 2: What PM emission factors are applicable to locomotives?
Answer: The PM emissions factors that should be applied to the activity data are the same factors that were used in the NEI (listed in Table 4-9 of the Student Manual). In addition, it is assumed that 92% of PM_{10} is $PM_{2.5}$.

Question 3: What is the basis of the activity data for locomotives?
Answer: The activity data are based on an estimate of the gallons of distillate fuel oil consumed.

Question 4: What is the methodology for estimating PM_{10} and $PM_{2.5}$ emissions for line haul locomotives? For switchyard locomotives?
Answer: Since the activity data is based on gallons of fuel consumed and the emission factor is in terms of grams per gallon of fuel consumed, estimating emissions is based on using the available data to calculate fuel consumption.

In the case of line haul locomotives, traffic density can be estimated for each line segment by multiplying gross tonnage by the total miles of track. The next step in the emissions calculation process is to estimate the fuel consumption by multiplying the estimated traffic density by the fuel consumption index. The third step is to multiply the fuel consumption (gallons per year) by the PM_{10} emission factor (grams per gallon) to obtain a PM_{10} emission estimate. The fourth step is to apply a conversion factor to convert grams to tons of emissions. 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.

In the case of switchyard locomotives, the first step is to multiply the number of switch yard locomotives that was provided by the railroad company by EPA's default value for fuel consumed for both switchyard locomotives to obtain a fuel consumption estimate. The next step is to multiply the fuel consumption (gallons per year) by the PM_{10} emission factor (grams per gallon). The third step is to apply a conversion factor to convert grams to tons of emissions. 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.

Question 5: What is your estimate of the PM_{10} and $PM_{2.5}$ emissions from long-haul locomotives?
Answer: Line haul locomotive emissions are estimated for line segment 1 as follows:

Step 1: Calculate traffic density
15 million GT x 17 miles = 255 million gross ton miles

Step 2: Estimate fuel consumption
255 million gross ton miles x 0.00139 gal./gross ton-mile = 354,450 gallons/year

Step 3: Estimate emissions
354,450 gallons/year x 6.7 grams/gallon = 2,374,815 grams/year

Step 4: Convert units to tons
2,374,815 grams/yr ÷ 453.6 grams/pound = 5,235.5 pounds/year
5,235.5 pounds/year ÷ 2,000 pounds/ton = 2.62 tons of PM_{10}/year.

Step 5: Calculate $PM_{2.5}$ emissions
2.62 tons of PM_{10}/year x 0.92 = 2.4 tons of $PM_{2.5}$/year

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.

The following table 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.

Summary of Line Haul Emission Calculations

Line Segment	Gross Tonnage Million GT	Distance in Miles	Density Million GTM	Fuel Use in Gallons	PM_{10} 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

Question 6: What is your estimate of the PM_{10} and $PM_{2.5}$ emissions from switchyard locomotives?
Answer: Switchyard locomotive emissions are estimated as follows:

Step 1: Estimate fuel consumption
82,500 gal. fuel consumed/switchyard locomotive x 1.8 = 148,500 gallons/year

Step 2: Estimate emissions
148,500 gallons/year x 9.2 grams/gallon = 1,366,200 grams PM_{10}/year

Step 3: Convert units to tons

1,366,200 grams/yr ÷ 453.6 grams/pound = 3,011.9 pounds/year

3,011.9 pounds/year ÷ 2,000 pounds/ton = 1.51 tons of PM_{10}/year.

Step 4: Calculate $PM_{2.5}$ emissions

1.51 tons of PM_{10}/year x 0.92 = 1.39 tons of $PM_{2.5}$/year

The following table presents the collected data and the data that was calculated for each switchyard and the sum of total emissions for the entire inventory area.

Summary of Switchyard Emission Calculations

Switch Yard	EPA Estimated Yearly Fuel Consumption	Number of Switchyard Locomotives	Fuel Use in Gallons	PM_{10} 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

Question 7: Why does the railroad data on switchyards show fractions of switchyard locomotives in use in each switchyard?
Answer: 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, locomotives operating less than this are considered fractions of a locomotive. This explains why the data shows fractions of switchyard locomotives in use in each switchyard.

Question 8: Do emissions for each line segment and switchyard need to be calculated individually?
Answer: As shown in this case study, for both line haul and switchyard locomotives, emissions can be estimated individually for each line segment or switchyard and then added together to obtain a total for the inventory area OR total fuel consumption can be estimated for all line haul locomotives and switchyards in the study area. In the latter case, the emission factor is applied to the total fuel consumption to estimate total emissions for the inventory area. In the case study the approach of estimating emissions individually was used for estimating emissions from line haul locomotives. The approach of estimating fuel consumption for all locomotives before applying the emission factor was used for switchyard locomotives.

Question 9: How can PM_{10} and $PM_{2.5}$ emissions be estimated for locomotives of the smaller company that was not able to provide gross tonnage data?
Answer: 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 could be 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 could then be multiplied by the emission factor and the particle size multiplier to obtain emissions estimates for PM_{10} and $PM_{2.5}$.

For example, assuming the railroad consumes 25,000 gallons of fuel per year and 90 percent of the railroad's track lies within the inventory area, the inventory area fuel consumption is: 25,000 gal x 90 percent = 22,500 gal. PM_{10} emissions are then calculated by applying the emission factor to the estimated fuel consumption as follows: 22,500 gal/year x 0.0148 lbs/gal = 333 lbs/year = 0.17 tons/year. This can be added to the emission estimate for the larger railroad company to estimate total PM_{10} emissions for the entire inventory area.

HANDOUT 7-1

Case Study Number 7-1 Solution

Estimating PM_{10} and $PM_{2.5}$ Emissions from Unpaved Roads

Question 1: How is the PM emission factor for unpaved roads calculated?
Answer: Equation 7-8 of the Student Manual shows the AP-42 empirical equation that is used to calculate the unpaved road emission factor. Specifically,

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

where:
EF = size specific emission factor (tons per mile)
k = empirical constant
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 (lbs/VMT)

Question 2: What emissions from unpaved roads are accounted for by the emission factor?
Answer: 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.

Question 3: What is the basis of the activity data for unpaved roads?
Answer: 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. In this case study, the VMT data are provided by a local metropolitan planning organization.

Question 4: What is the methodology for estimating monthly PM_{10} emissions from unpaved roads?
Answer: The methodology involves first using the AP-42 emission factor equation to calculate an emission factor and then applying the VMT estimate for the study area to obtain a PM_{10} emissions estimate.

Question 5: What is the value for the empirical constant in the emission factor equation?

Answer: The empirical constant k in the emissions factor estimation equation is the NEI default value of 1.8 lb/VMT for PM_{10} and 0.27 lb/VMT for $PM_{2.5}$. These values are listed in Equation 7-8 of the Student Manual.

Question 6: What is the value for the default surface material moisture content?
Answer: Table 7-5 in the Student Manual lists the NEI default values for estimating PM emissions from unpaved roads. The default for surface material moisture content is 1 percent.

Question 7: How is mean vehicle weight considered in the estimation of PM emissions from unpaved roads?
Answer: The NEI estimated PM emissions from unpaved roads by using the pre-December 2003 AP-42 emission factor equation. This equation considers mean vehicle weight. However, the December 2003 AP-42 emission factor equation does not consider mean vehicle weight and therefore, it is not used in the calculation of PM emission in this case study.

Question 8: What is your estimate for the PM_{10} emission factor for unpaved roads in the hypothetical county?
Answer: Plugging the following values into Equation 7-8 of the Student Manual results in an emission factor of 0.0256 pounds per VMT for the month of June for the study area. Note: the value for C must be converted to lbs/VMT prior to using in the equation.

k (empirical constant)	1.8 lb PM_{10}/VMT
s (surface material silt content)	7.5 percent
M (surface material moisture content)	1 percent
S (mean vehicle speed)	35 miles per hour
C (emission factor for exhaust, brake wear, and tire wear)	0.2891 grams PM_{10}/VMT

Question 9: What is your estimate of the PM_{10} emissions from unpaved roads in the county for the month of June?
Answer: The monthly emission factor (0.0256 lbs/VMT) 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.

Question 10: How would $PM_{2.5}$ emissions be estimated if this case study required that an estimate of $PM_{2.5}$ be developed?
Answer: $PM_{2.5}$ emissions are calculated in the same manner as PM_{10} emissions, with the exception that the empirical constant (k) for $PM_{2.5}$ would be used instead of the empirical constant for PM_{10}.

Question 11: How would annual PM_{10} emissions from unpaved roads be calculated?
Answer: All of the monthly PM_{10} emission estimates are summed to obtain an annual PM_{10} emission estimate.

HANDOUT 7-2

Case Study Number 7-2 Solution

Estimating PM_{10} and $PM_{2.5}$ Emissions from Residential Construction Activities

Question 1: What PM emission factors are applicable to residential construction activities?
Answer: PM_{10} emission factors are those that were used in the NEI as shown in the following table (Table 7-9 of the Student Manual).

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

Question 2: What is the basis of the activity data for residential construction activities and how is it measured?
Answer: The number of acres disturbed per year is the activity data for residential construction. Unlike this case study, direct estimates of the number of acres disturbed are generally not available, therefore the value for this activity is usually estimated through the use of housing start data that is available from the Bureau of the Census.

Question 3: What is the methodology for estimating PM_{10} and $PM_{2.5}$ emissions from residential construction activities?
Answer: Equation 7-12 of the Student Manual shows the equation used for estimating PM_{10} emissions from one-unit structures without basements, as well as all two-unit structures. $PM_{2.5}$ emissions are estimated by assuming it accounts for 20 percent of PM_{10}.

Question 4: What is your estimate of the PM_{10} and $PM_{2.5}$ emissions from the residential construction activities in the county within the past year without accounting for rule effectiveness, rule penetration, soil moisture, and silt content?
Answer: Emissions must first be estimated individually for 1-unit houses, apartments, and duplexes using the emission factors and data specific to each of these types of dwellings and the following equation (Equation 7-12 in the Student Manual).

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

where:
EF = Emission factor
B = number of housing starts
f = buildings-to-acres conversion factor
m = duration of construction activity (months)

<u>For single unit houses:</u>
Emissions = 0.032 tons/acre/month x 251 bldg. x 0.184 acres/bldg. x 6 months = 8.87 tons

<u>For duplexes:</u>
Emissions = 0.032 tons/acre/month x 2 bldg. x 0.184 acres/bldg. x 6 months = 0.07 tons

<u>For apartments:</u>
Emissions = 0.11 tons/acre/month x 44 bldg. x 0.07 acres/bldg. x 12 months = 4.07 tons

Total PM_{10} emissions from all residential construction are determine by adding the emissions from the single housing units, apartments, and duplexes.

PM_{10} Emissions = 8.87 + 0.07 + 4.07 = 13.0 tons

$PM_{2.5}$ emissions are calculated by multiplying the PM_{10} emissions by 20 percent.

$PM_{2.5}$ Emissions = 0.2 x 13.0 tons = 2.6 tons

Question 5: What is your estimate of the PM_{10} and $PM_{2.5}$ emissions from the residential construction activities in the county within the past year accounting for control efficiency and rule penetration, but not for soil moisture and silt content?
Answer: Adjustments for controls efficiency and rule penetration can be made by multiplying the results for each type of housing category from above by (1-(CE/100)(RP/100)) as shown below. 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.

For single-unit houses:
8.87 tons x (1-(50/100)(75/100)) = 5.54 tons

For duplexes:
0.07 x (1-(50/100)(75/100)) = 0.04 tons

For apartments:
4.07 x (1-(50/100)(75/100)) = 2.54 tons

Adding these three estimates gives the total PM_{10} emissions from all types of construction adjusted for controls and rule penetration.

PM_{10} Emissions = 5.54 + 0.04 + 2.54 = 8.1 tons

Alternatively, the control and rule penetration adjustments can be applied to the aggregate PM_{10} emissions from all types of construction as follows:

13 tons x (1-(50/100)(1-75/100)) = 8.1 tons

$PM_{2.5}$ Emissions = 8.1 tons x 0.2 = 1.6 tons

Question 6: What is your estimate of the PM_{10} and $PM_{2.5}$ emissions from the residential construction activities in the county within the past year accounting for control efficiency, rule penetration, and soil moisture?
Answer: Adjustments for soil moisture content are made by applying the following formula (Equation 7-13 of the Student Manual):

Moisture Level Corrected Emissions = Base Emissions x (24/PE)

Where: PE = Precipitation Evaporation value for the county

Therefore, corrected PM_{10} emissions are equal to 8.1 tons x 24/6 = 32.4 tons

Corrected $PM_{2.5}$ emissions are equal to 1.6 tons x 24/6 = 6.4 tons

Question 7: What is your estimate of the PM_{10} and $PM_{2.5}$ emissions from the residential construction activities in the county within the past year accounting for control efficiency, rule penetration, and silt content (but not soil moisture)?
Answer: Emissions are adjusted for the dry silt content in the soil of the area being inventoried by using the following equation (Equation 7-14 of the Student Manual).

Silt Content Corrected Emissions = Base Emissions x (s/9%)

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

Therefore, corrected PM_{10} emissions are equal to 8.1 tons x 4.45 = 36 tons

Corrected $PM_{2.5}$ emissions are equal to 1.6 tons x 4.45 = 7.1 tons

Question 8: What is your estimate of the PM_{10} and $PM_{2.5}$ emissions from the residential construction activities in the county within the past year accounting for control efficiency, rule penetration, soil moisture, and silt content?
Answer: Emissions are adjusted for both soil moisture content and silt content by applying the appropriate adjustments to the base emissions (already corrected for controls and rule penetration) as follows:

$$\text{Corrected Emissions} = \text{Base Emissions} \times 24/PE \times (s/9\%)$$

Therefore, corrected PM_{10} emissions are equal to 8.1 tons x 24/6 x 40/9 = 144.2 tons

Corrected $PM_{2.5}$ emissions are equal to 1.6 tons x 24/6 x 40/9 = 28.5 tons

Question 9: Explain the significance of the adjustments that are made for soil moisture content and silt content.
Answer: These adjustments have a significant effect on the emissions since the case study area represents a relatively dry area.

HANDOUT 7-3

Case Study Number 7-3 Solution

Estimating PM_{10} and $PM_{2.5}$ Emissions from Road Construction Activities

Question 1: What PM emission factors are applicable to road construction?
Answer: The PM_{10} 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}. (See page 7-18 of the Student Manual)

Question 2: What is the basis of the activity data for road construction?
Answer: The number of acres disturbed is the activity data indicator for road construction. It is based on State level expenditure data for capital outlay for six road construction classifications. To obtain the activity data in terms of acres disturbed it is necessary to convert the expenditure data to mileage and then to acreage. Conversion factors are available from the NEI to convert dollars to miles and then to convert to acres disturbed per mile of road activity (See Table 7-10 in the Student Manual).

Question 3: What is the methodology for estimating PM_{10} and $PM_{2.5}$ emissions from road construction?
Answer: Equation 7-16 of the Student Manual shows the basic emission formula used for calculating PM_{10} emissions from road construction. This involves multiplying the emission factor by the activity data (converted to an acres basis) and the duration of the project. $PM_{2.5}$ emissions are assumed to be 20 percent of the PM_{10} emissions.

Adjustments for controls and rule penetration can be made by multiplying the results from Equation 7-16 by (1-(CE/100)) and (1-(RP/100)), respectively.

Finally, adjustments are applied for soil moisture content and silt content using Equation 7-13 and Equation 7-14 in the Student Manual, respectively.

Question 4: What is your estimate of the PM_{10} and $PM_{2.5}$ emissions from the road construction activities in the county within the past year without accounting for rule effectiveness, rule penetration, soil moisture, and silt content?
Answer: In solving this problem, it must be recognized that the State expenditures for capital outlay on road construction during the last 12 months are not given. However, since the total miles of road construction are given, the State expenditures are not needed. In short, the total number of miles of road construction that is given is the product of the values $ and f1 in Equation 7-16 of the Student Manual, thereby allowing this problem to be solved without knowing the State expenditures or the dollars-to-miles conversion factor.

Consequently, the answer is the product of the emission factor, the miles of road construction, the miles-to-acre conversion factor, and the duration of the road construction activity, as shown below.

PM_{10} Emissions = EF x m x f2 x d

Where: EF = emission factor (tons PM_{10}/acre month)
m = 12.3 miles
f2 = miles-to-acre conversion factor
d = duration (months)

PM_{10} Emissions = 0.42 tons/acre month x 12.3 miles x 9.8 acres/mile x 12 months = 607.5 tons

The value of f2 is obtained from Table 7-10 of the Student Manual. The value of f2 for urban collectors is 9.8. The value for the emission factor is obtained from Equation 7-16 in the Student Manual.

$PM_{2.5}$ emissions are calculated by multiplying the PM_{10} emissions by 20 percent.

$PM_{2.5}$ Emissions = 0.2 x 607.5 tons = 121.5 tons

Question 5: What is your estimate of the PM_{10} and $PM_{2.5}$ emissions from the road construction activities in the county within the past year accounting for control efficiency and rule penetration, but not accounting for soil moisture and silt content?
Answer: Adjustments for controls efficiency and rule penetration can be made by multiplying the results from Equation 7-16 by (1-(CE/100)(RP/100)) as shown below.

PM_{10} Emissions = 607.5 tons x (1-(50/100)(1-75/100)) = 379.7 tons

$PM_{2.5}$ Emissions = 379.7 tons x 0.2 = 75.9 tons

Question 6: What is your estimate of the PM_{10} and $PM_{2.5}$ emissions from the road construction activities in the county within the past year accounting for control efficiency, rule penetration, and soil moisture?
Answer: Adjustments for soil moisture content are made by applying the following formula (Equation 7-13 of the Student Manual):

Moisture Level Corrected Emissions = Base Emissions x (24/PE)

Where: PE = Precipitation Evaporation value for the county

Therefore, corrected PM_{10} emissions are equal to 379.7 tons x 24/6 = 1,518.8 tons
Corrected $PM_{2.5}$ emissions are equal to 75.9 tons x 24/6 = 303.6 tons

Question 7: What is your estimate of the PM_{10} and $PM_{2.5}$ emissions from the road construction activities in the county within the past year accounting for control efficiency, rule penetration, and silt content (but not for soil moisture)?
Answer: Emissions are adjusted for the dry silt content in the soil of the area being inventoried by using the following equation (Equation 7-14 of the Student Manual).

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

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

Therefore, corrected PM_{10} emissions are equal to 379.7 tons x 4.45 = 1,689.7 tons
Corrected $PM_{2.5}$ emissions are equal to 75.9 tons x 4.45 = 337.8 tons

Question 8: What is your estimate of the PM_{10} and $PM_{2.5}$ emissions from the road construction activities in the county within the past year accounting for control efficiency, rule penetration, soil moisture, and silt content?
Answer: Emissions are adjusted for both soil moisture content and silt content by applying the appropriate adjustments to the base emissions (already corrected for controls and rule penetration) as follows:

$$\text{Corrected Emissions} = \text{Base Emissions} \times 24/PE \times (s/9\%)$$

Therefore, corrected PM_{10} emissions are equal to 379.7 tons x 24/6 x 40/9 = 6,750 tons
Corrected $PM_{2.5}$ emissions are equal to 75.9 tons x 24/6 x 40/9 = 1,350 tons
Alternatively, $PM_{2.5}$ emissions can be calculated by applying the 20 percent value directly to the corrected PM_{10} emissions as follows: 6,750 tons of PM_{10} x 0.2 = 1,350 tons of $PM_{2.5}$.

HANDOUT 9-1

Case Study Number 9-1 Solution

Estimating PM_{10} Emissions from Residential Wood Combustion

Question 1: What PM_{10} emission factors are applicable to residential wood combustion?
Answer: The PM_{10} emission factors used in the NEI for fireplaces without inserts are obtained from Houck, J.E. et al, *Review of Wood Heater and Fireplace Emission Factors*. The PM_{10} emission factors for woodstoves and fireplaces with inserts are obtained from AP-42. The values are listed in the Notes section at the end of this case study.

Question 2: What is the methodology for estimating PM_{10} emissions from residential wood combustion?
Answer: Although the emission factors and usage patterns are different for the various types of wood combustion units, the emission estimation methodology is basically the same.

The first step in estimating emissions from residential wood combustion is to determine the number of residential wood combustion units within the county. Data on the number of homes with wood combustion units are obtained from the results of the Residential Wood Combustion survey that was conducted in the study area. This data must be scaled up to reflect the entire county population as opposed to the surveyed population. In addition, these data need to be adjusted to account for the fact that some homes have more than one wood combustion unit (multiply by 1.17).

The next step is to use the survey data to estimate the amount of wood burned in each residential combustion unit. This is done by converting the wood consumption data from the survey to an annual basis. Specifically, the weekly wood consumption data is multiplied by the number of weeks in the winter heating season to obtain a winter heating consumption value and then apportioning based on the seasonal percentages applied to the climate zone (Table 9-7 of the Student Manual). The wood consumption values for each season are added together to obtain an annual consumption number.

Once the annual wood consumption for residential wood combustion units in the entire county is calculated, the next step is to apply emission factors to determine county emissions from residential wood combustion units. Because the emission factors and usage patterns are different for the various types of residential wood combustion units, it is necessary to perform these calculations separately for each.

Question 3: What is your estimate of the PM_{10} emissions from residential wood combustion in the county within the past year without accounting for rule effectiveness or rule penetration?

Answer:

For Fireplaces without Inserts

Step 1 – Scale up the survey data to reflect the number of homes with fireplaces without inserts in the county.

110 homes/500 homes x 380,000 homes in the county = 83,600 homes

Step 2 – Adjust the data to account for the fact that some homes have more than one wood combustion unit (multiply by 1.17).

83,600 homes x 1.17 fireplaces/home = 97,812 fireplaces without inserts

Step 3 – Estimate the amount of wood burned seasonally in all fireplaces without inserts.

¼ cord/fireplace without insert/week x 13 weeks/winter heating season = 3.25 cords/ fireplace without insert/winter heating season

Step 4 – Apportion the winter heating season wood consumption based on the seasonal percentages applied to the climate zone.

Because the county is located in Climate Zone 4 (from Table 9-7 in the Student Manual), 70 percent of the annual wood consumed is consumed in the winter season. Therefore, wood usage can be calculated on an annual basis as follows:

0.7 x annual wood usage = 3.25 cords/winter heating season

Solving for annual wood usage = 4.64 cords/year

Step 5 – Estimate total wood consumption for the entire county.

The seasonally adjusted annual value for wood consumption can be multiplied by the number of fireplaces without inserts in the county to obtain a countywide, annual wood consumption estimate.

4.64 cords/ fireplace without insert/year x 97,812 fireplaces without inserts = 453,848 cords/year

Step 6 – Estimate emissions emitted from all fireplaces without inserts in the county.

Once the annual wood consumption for residential wood combustion units in the entire county is calculated, the next step is to apply emission factors to determine county emissions from residential wood combustion units. However, since the emission factors are in the units of pounds of particulate per ton of wood burned, it is necessary to convert the annual wood consumption value from cords per year to tons per year.

$$453{,}848 \text{ cords/year} \times 128 \text{ ft}^3\text{/cord} = 58.1 \text{ million ft}^3\text{/year}$$

$$58.1 \text{ million ft}^3\text{/year} \times 23.9 \text{ pounds/ ft}^3 \times 1 \text{ ton/2000 pounds} = 694{,}295 \text{ tons/year}$$

$$694{,}295 \text{ tons/year} \times 23.2 \text{ lbs. } PM_{10}\text{/ton wood burned} = 16.1 \text{ million pounds } PM_{10}\text{/year}$$

$$16.1 \text{ million pounds } PM_{10}\text{/year} \times 1 \text{ ton/2000 pounds} = 8{,}050 \text{ tons } PM_{10}\text{/year}$$

<u>For Fireplaces with Inserts</u>

Step 1 – Scale up the survey data to reflect the number of homes with fireplaces with inserts in the county.

30 homes/500 homes x 380,000 homes in the county = 22,800 homes

Step 2 – Adjust the data to account for the fact that some homes have more than one wood combustion unit (multiply by 1.17).

22,800 homes x 1.17 fireplaces/home = 26,676 fireplaces with inserts

Step 3 – Estimate the amount of wood burned seasonally in all fireplaces with inserts.

¼ cord/fireplace with insert/week x 13 weeks/winter heating season = 3.25 cords/ fireplace with insert/winter heating season

Step 4 – Apportion the winter heating season wood consumption based on the seasonal percentages applied to the climate zone.

Because the county is located in Climate Zone 4 (from Table 9-7 in the Student Manual), 70 percent of the annual wood consumed is consumed in the winter season. Therefore, wood usage can be calculated on an annual basis as follows:

0.7 x annual wood usage = 3.25 cords/winter heating season

Solving for annual wood usage = 4.64 cords/year

Step 5 – Estimate total wood consumption for the entire county.

The seasonally adjusted annual value for wood consumption can be multiplied by the number of fireplaces with inserts in the county to obtain a countywide, annual wood consumption estimate.

4.64 cords/ fireplace with insert/year x 26,676 fireplaces with inserts = 123,777 cords/year

Step 6 – Estimate emissions emitted from all fireplaces with inserts in the county.

Once the annual wood consumption for residential wood combustion units in the entire county is calculated, the next step is to apply emission factors to determine county emissions from residential wood combustion units. However, since the emission factors are in the units of pounds of particulate per ton of wood burned, it is necessary to convert the annual wood consumption value from cords per year to tons per year.

123,777 cords/year x 128 ft^3/cord = 15.8 million ft^3/year

15.8 million ft^3/year x 23.9 pounds/ ft^3 x 1 ton/2000 pounds tons/year = 189,329 tons/year

189,329 tons/year x 30.6 lbs. PM_{10}/ton wood burned = 5.8 million pounds PM_{10}/year

5.8 million pounds PM_{10}/year x 1 ton/2000 pounds = 2,897 tons PM_{10}/year

<u>For Woodstoves</u>
Step 1 – Scale up the survey data to reflect the number of homes with woodstoves in the county.

40 homes/500 homes x 380,000 homes in the county = 30,400 homes

Step 2 – Adjust the data to account for the fact that some homes have more than one wood combustion unit (multiply by 1.17).

30,400 homes x 1.17 woodstove/home = 35,568 woodstoves

Step 3 – Estimate the amount of wood burned seasonally in all woodstoves.

1/8 cord/woodstove/week x 13 weeks/winter heating season = 1.625 cords/ woodstove/winter heating season

Step 4 – Apportion the winter heating season wood consumption based on the seasonal percentages applied to the climate zone.

Because the county is located in Climate Zone 4 (from Table 9-7 in the Student Manual), 70 percent of the annual wood consumed is consumed in the winter season. Therefore, wood usage can be calculated on an annual basis as follows:

0.7 x annual wood usage = 1.625 cords/winter heating season

Solving for annual wood usage = 2.32 cords/year

Step 5 – Estimate total wood consumption for the entire county.

The seasonally adjusted annual value for wood consumption can be multiplied by the number of woodstoves in the county to obtain a countywide, annual wood consumption estimate.

2.32 cords/ woodstove/year x 35,568 woodstoves = 82,518 cords/year

Step 6 – Estimate emissions emitted from all woodstoves in the county.

Once the annual wood consumption for residential wood combustion units in the entire county is calculated, the next step is to apply emission factors to determine county emissions from residential wood combustion units. However, since the emission factors are in the units of pounds of particulate per ton of wood burned, it is necessary to convert the annual wood consumption value from cords per year to tons per year.

82,518 cords/year x 128 ft^3/cord = 10.5 million ft^3/year

10.5 million ft^3/year x 23.9 pounds/ ft^3 x 1 ton/2000 pounds tons/year = 126,220 tons/year

126,220 tons/year x 34.6 lbs. PM_{10}/ton wood burned = 4.4 million pounds PM_{10}/year

4.4 million pounds PM_{10}/year x 1 ton/2000 pounds = 2,184 tons PM_{10}/year

<u>Total</u>
Total emissions for residential wood combustion in the county are obtained by adding the estimates for fireplaces without inserts, fireplaces with inserts, and woodstoves.

8,050 tons PM_{10}/yr + 2,897 tons PM_{10}/yr + 2,184 tons PM_{10}/yr = 13,131 tons PM_{10}/yr

Question 4: What is your estimate of the PM_{10} emissions from residential wood combustion in the county within the past year accounting for rule effectiveness and rule penetration?
Answer: Adjustments for rule effectiveness and rule penetration can be made by multiplying the total countywide emissions by (1-(RE/100)(RP/100)) as shown below.

13,131 tons PM_{10}/yr x (1-((100/100)(75/100))) = 3,283 tons PM_{10}/yr

Question 5: If the residential wood combustion survey failed to collect data on the amount of wood burned, how could emissions from fireplaces without inserts be calculated?

Answer: If the survey failed to collect data on the amount of wood consumed in the various residential wood combustion units, data from the US Department of Census (DOC) would need to be used to estimate wood consumption rates for the county. However, because the DOC data separates fireplaces without inserts into 2 categories, those used for heating and those used for aesthetics, it is necessary to separate the number of homes that use fireplaces without inserts for heating and those that use them for aesthetic purposes. In order to do this, the survey would need to have collected data on what the fireplaces is used for (heating or 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.

Question 6: How would you propose to estimate $PM_{2.5}$ emissions from residential wood combustion in the county?

Answer: The $PM_{2.5}$ emission factor is assumed to be the same as the PM_{10} primary emission factor.

HANDOUT 9-2

Case Study Number 9-2 Solution

Estimating PM_{10} and $PM_{2.5}$ Emissions from Agricultural Field Burning

Question 1: What is the basis of the activity data for agricultural burning?
Answer: The activity data that is used to estimate emissions from agricultural burning is the number of acres of the crop burned.

Question 2: What does the loading factor represent?
Answer: The loading factor represents the tons of biomass of vegetation per acre burned, and is used to convert the acres of biomass burned into a mass loading value. The mass loading is needed because the emission factor is in terms of pounds of PM per ton of biomass burned.

Question 3: What is the methodology for estimating PM_{10} emissions from agricultural burning operations?
Answer: The following equation (Equation 9-5 in the Student Manual) shows the formula for calculating PM emissions from agricultural burning.

$$E = A * LF * EF$$

Where: E = Emissions (lbs pollutant/month)
A = Number of acres burned per month
LF = Loading factor (tons/acre)
EF = Emission factor (lbs pollutant/ton)

Question 4: What is your estimate of the PM_{10} emissions from wheat stubble burning in the county for the month of June?
Answer:

$$\text{Emissions} = 1{,}950 \text{ acres x } 1 \text{ tons/acre x } 8.82 \text{ lbs } PM_{10}\text{/ton} = 17{,}199 \text{ lbs } PM_{10}$$

$$17{,}199 \text{ lbs } PM_{10} \text{ x } 1 \text{ ton/2000 lbs} = 8.6 \text{ tons } PM_{10}$$

Question 5: How would $PM_{2.5}$ emissions be estimated if this case study required that an estimate of $PM_{2.5}$ be developed?
Answer: The same equation that was used for PM_{10} is used for $PM_{2.5}$, with the exception that the $PM_{2.5}$ emission factor is plugged into the equation.

$$\text{Emissions} = 1{,}950 \text{ acres x } 1 \text{ tons/acre x } 8.34 \text{ lbs } PM_{2.5}\text{/ton} = 16{,}263 \text{ lbs } PM_{2.5}$$

$$16{,}262 \text{ lbs } PM_{2.5} \text{ x } 1 \text{ ton/2000 lbs} = 8.1 \text{ tons } PM_{2.5}$$

Question 6: How would annual PM_{10} emissions from agricultural burning be calculated?
Answer: The formula in Equation 9-5 of the Student Manual is used to calculate emissions for each month during the burning season. These monthly totals are then summed to give an annual emissions estimate.