

Introduction to the Environmental Profession

Air Quality

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Presentation Road Map

- Define air pollution
- Discuss where air pollution comes from
- Projects you will likely be working on
 - Emission inventories
 - NSR Permitting
 - Operating Permits
 - Vapor intrusion, ambient monitoring, stack testing
- Work through some sample problems (easy but highlight common mistakes)



What Is Air Pollution?

- “Criteria pollutants”-Have a NAAQS
 - Carbon monoxide (CO), lead, nitrogen dioxide (NO₂), volatile organic compounds (VOC), ozone, particulate matter (PM₁₀ and PM_{2.5}), sulfur dioxide (SO₂)
- Toxic chemicals
 - Benzene, formaldehyde, asbestos, lead, chlorinated solvents, petroleum-related compounds, methane and many others
- Greenhouse gases
 - Carbon dioxide (CO₂), methane and others



National Ambient Air Quality Standards (NAAQS)

Pollutant	Averaging Period	NAAQS
CO	8-hour	9 ppm
CO	1-hour	35 ppm
Lead	Rolling 3-month	0.15 $\mu\text{g}/\text{m}^3$
NO ₂	1-hour	100 ppb
NO ₂	1-year	53 ppb
Ozone	8-hour	0.070 ppm
PM _{2.5}	1-year	12 $\mu\text{g}/\text{m}^3$
PM _{2.5}	24-hour	35 $\mu\text{g}/\text{m}^3$
PM ₁₀	24-hour	150 $\mu\text{g}/\text{m}^3$
SO ₂	1-hour	75 ppb



Particulate Matter Is Confusing

- Particulate Matter can be defined as either PM, PM10, PM2.5, or others
- PM
 - Total Particulate Matter, filterable component only
 - Sometimes referred to as Total Suspended Particulate (TSP) or Particulate Matter less than or equal to 30 microns in diameter (PM30)
- PM10(Primary)
 - Particulate Matter less than or equal to 10 microns in diameter
 - Includes the filterable and condensable fractions
- PM2.5(Primary)
 - Particulate Matter less than or equal to 2.5 microns in diameter
 - Includes the filterable and condensable fractions

What is Condensable Particulate Matter (CPM)?

- Particulate Matter that condenses immediately after leaving the stack or vent.
- Filterable PM
 - Solid or liquid material at stack temperature
- Condensable PM
 - Vapor or gas at stack temperature
 - Condenses to liquid or solid at stack exit
 - Can have both an organic and inorganic fraction
 - Added in entirety to both PM_{2.5}(Primary) and PM₁₀(Primary)

Sample Problem #1

- Estimate the PM10 emissions given the following information:
 - PM Emissions = 30 lb/hr
 - PM10(Filterable)/PM = 0.6 (gravimetric ratio)
 - Inorganic CPM = 0.33 lb/hr
 - Organic CPM = 0.1 lb/hr

Hint:

PM emissions do not include condensable particulate emissions

Sample Problem #1 (Solution)

- Estimate the PM10 emissions in lbs per hour given the following information:
 - PM Emissions = 30 lb/hr
 - PM10(Filterable)/PM = 0.6
 - Inorganic CPM = 0.33 lb/hr
 - Organic CPM = 0.1 lb/hr

Answer:

$$\text{PM10(Filt)} = 30 \text{ (lb-PM/hr)} * 0.6 \text{ (lb-PM10/lb-PM)} = 18 \text{ lb/hr}$$

$$\text{CPM (Total)} = 0.33 \text{ (lb-CPM(Inorg)/hr)} + 0.1 \text{ (lb-CPM(Org)/hr)} = 0.43 \text{ lb/hr}$$

$$\text{PM10 (Primary)} = 18 \text{ lb/hr} + 0.43 \text{ lb/hr} = \mathbf{18.43 \text{ lb/hr}}$$

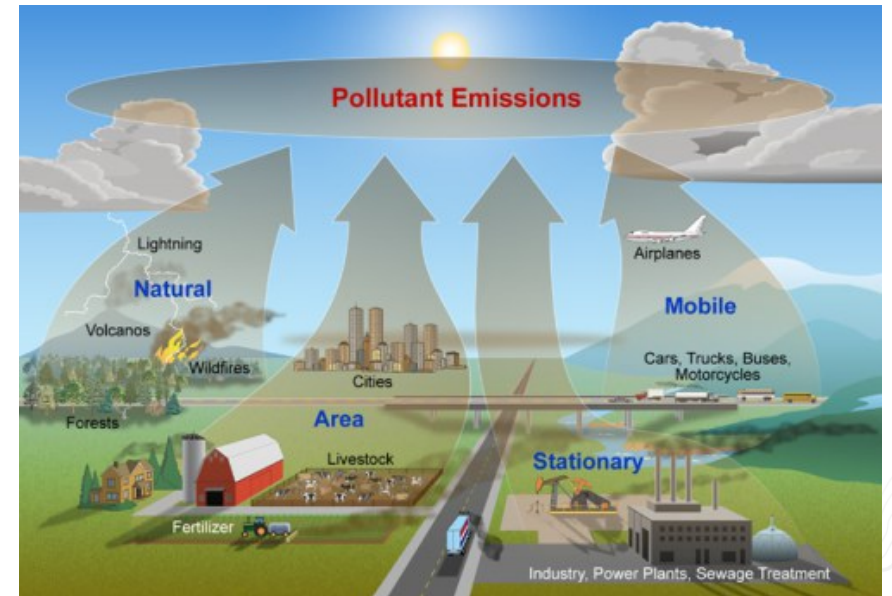
Where Does Air Pollution Come From?

- Combustion sources: CO, NO_x, SO₂, VOC, greenhouse gases
 - Utility and industrial coal, oil and natural gas boilers; natural gas engines; stationary and mobile engines (cars and trucks)
- Chemical volatilization and decomposition of organic material: VOCs, formaldehyde, methane, many others
 - Surface coatings (paints, primers), solvents, degreasers, fuels, building materials
 - Contaminated soil and groundwater
 - Landfills and decomposition of wood debris
- Mining, crushing and grinding operations: particulate matter, lead and other metals
 - Mines, quarries, rock crushers



Emission Inventory

- Emission inventories are the starting point for almost all air projects
- Detailed quantification of air emissions from facility or geographic area
- Useful for many purposes
 - Determine amount of emission reduction needed
 - Demonstrate compliance with an air regulatory requirement
 - Other reasons, e.g., support Environmental Impact Assessments, ISO certification or business decisions /marketing



How do we estimate emissions?

$$ER = P * EF * (100-CE)/100$$

ER = Emission Rate

P = Production Rate (i.e. Maximum Hourly Design Rate)

EF = Emission Factor

CE = Control Efficiency (%)



- Emission factors relate the quantity of a pollutant to an industrial activity (i.e. lbs of SO₂ emitted per ton of coal burned)
- Using the MHDR for P will calculate the maximum hourly emission rate
- The potential annual emissions can then be calculated assuming 8,760 hours of operation per year

Sample Problem #2

- Estimate the maximum hourly NOX emissions from a propane burner given the following information:
 - MHDR = 10 MMBTU/hr
 - EF = 13 lb-NOX/Mgal-Propane
 - Uncontrolled

Hint:

For English units (gal, BTU, cubic feet) M=Thousand, MM=Million

Propane Heating Value = 94,000 BTU/gal

Sample Problem #2 (Solution)

- Estimate the maximum hourly NOX emissions from a propane burner given the following information:
 - MHDR = 10 MMBTU/hr
 - EF = 13 lb-NOX/Mgal-Propane
 - Uncontrolled

Answer:

$$\begin{aligned} \text{MHDR} &= 10 \text{ (MMBTU/hr)} / 94,000 \text{ (BTU/gal)} * 10^6 \text{ (BTU/MMBTU)} \\ &= 106 \text{ gal/hr (Maximum Propane Burned)} \end{aligned}$$

$$\begin{aligned} \text{ER} &= 0.106 \text{ (Mgal/hr)} * 13 \text{ (lb-NOX/Mgal)} * (100-0)/100 \\ &= \mathbf{1.38 \text{ lb-NOX/hr}} \text{ (Maximum Hourly NOX Emission Rate)} \end{aligned}$$

Emission factors can come from many sources

- Emission factors can be obtained from published documents (AP42, WebFIRE), stack tests, CEM data, models, mass balance, ...
- AP42 is the primary compilation of EPA emission factors
- WebFIRE is EPA's online emission factor database
- The emission factors are generally consistent between AP42 and WebFIRE, but there can be differences (Check both!)
- Links to AP42 and WebFIRE can be found at www.epa.gov/chief
- Select the method that you believe will give the most accurate results

Sample Problem #3

- Calculate an SO₂ emission factor for coal combustion in units of lb-SO₂ per ton of coal (Dry Basis) given the following information:
 - Coal Sulfur Content = 0.5% by weight, Dry Basis
 - Assume 95% of the fuel sulfur is converted to SO₂

Hint:

Dry Basis – Excludes the moisture content of the coal

Sometimes sulfur content will be expressed on a Dry Mineral Matter Free (DMMF) basis-also excludes the ash component

Sometimes coal will be tracked “as-received”-Includes moisture and ash

Sample Problem #3 (Solution)

- Calculate an SO₂ emission factor for coal combustion in units of lb-SO₂ per ton of coal (Dry Basis) given the following information:
 - Coal Sulfur Content = 0.5% by weight, Dry Basis
 - Assume 95% of the fuel sulfur is converted to SO₂

Answer:

$$\text{EF} = 0.5/100 \text{ (lb-S/lb-Dry Coal)} * 0.95 \text{ (lb-S to SO}_2\text{/lb-S)}$$
$$* 64/32 \text{ (lb-SO}_2\text{/lb-S)} * 2000 \text{ (lb-Dry Coal/ ton-Dry Coal)} =$$

19 lb-SO₂/ton-Coal(Dry)-Burned

New Source Review

- Pre-construction permitting required for new equipment, modifications that increase air emissions significantly
- There are three types of New Source Review (NSR) Permits
 1. Prevention of Significant Deterioration (PSD)
 - Required for major new sources or major source making a major modification
 - Located in areas that are in attainment with the National Ambient Air Quality Standards (NAAQS)
 2. Nonattainment NSR
 - Required for major new sources or major source making a major modification
 - Located in areas that are **NOT** in attainment with the National Ambient Air Quality Standards (NAAQS)
 3. Minor source permits

New Source Review

- What is a major source?
 - Potential-to-Emit any NAAQS Pollutant > 250 ton/year
 - Potential-to-Emit any NAAQS Pollutant > 100 ton/year and on a list of 28 source categories specifically listed in the regulation
 - Fossil fuel-fired steam electric plant >250 MMBTU/hr heat input,
 - Coal cleaning plants (with thermal dryers),
 - Portland cement plant,
 - 25 other facility types
- What is a major modification?
 - Significant net increase in emissions at a major source (10 ton/yr PM_{2.5}, 40 ton/yr SO₂, NO_X, VOC, etc.)

New Source Review

- Permit Requirements - New Major Source or Major Modification at Existing Major Source
 1. Control Technology Analysis Required
 - Best Available Control Technology (BACT) in Attainment Area
 - Lowest Achievable Emission Rate (LAER) in Nonattainment Area
 2. Dispersion modeling required (NAAQS and Increment)
 3. Additional Impact (visibility, vegetation, growth)
 4. Impact analysis for nearby “Class 1” areas: certain national parks and wilderness areas (e.g., Mingo, Hercules-Glades)
 5. Ambient monitoring may be required (Pre or Post Construction)
 6. Emission off-sets required in nonattainment areas
 7. Public participation required

Best Available Control Technology (BACT) Analysis

- BACT must be applied to each NSR regulated pollutant that has the potential to be emitted in significant quantities
- A five step “top down” approach is used to determine BACT
 1. Identify all potential control technologies
 2. Eliminate technically infeasible options
 3. Rank remaining technologies by control effectiveness
 4. Evaluate most effective controls
 5. Select BACT
- Controls can be eliminated for economic reasons
- Energy and environmental impacts can also be considered

Sample BACT Analysis

Control Technology	Control Efficiency (%)	Technically Feasible?	Cost Effectiveness (\$/ton)	Cost Effective?	Selected as BACT?
Option #1	99	Yes	\$25,000	No	No
Option #2	90	No			No
Option #3	75	Yes	\$3,000	Yes	Yes
Option #4	50	Yes			

Option 2 was determined to be technically infeasible and eliminated
Cost Effectiveness = (Annualized Control Cost) / (Emission Reduction)

Borderline Cost Effectiveness Range, Approx. \$5,000-\$15,000/ton

Assumes Option #3 does not have significant environmental or energy impacts

Sample Problem #4

- Calculate the cost effectiveness in \$ per ton of emission reduction for a baghouse controlling PM_{2.5} given the following information:
 - PM_{2.5}(Primary) Emissions = 200 ton/yr
 - Condensable Fraction = 20%
 - Baghouse Control Efficiency = 99% (PM_{2.5} Filterable)
 - Annualized Cost = \$500,000/year (Total)

Hint:

Assume the condensable fraction is not controlled by the baghouse

Sample Problem #4 (Solution)

- Calculate the cost effectiveness in \$ per ton of emission reduction for a baghouse controlling PM_{2.5} given the following information:
 - PM_{2.5}(Primary) Emissions = 200 ton/yr
 - Condensable Fraction = 20%
 - Baghouse Control Efficiency = 99% (PM_{2.5} Filterable)
 - Annualized Cost = \$500,000/year (Total)

Answer:

ER (Reduction) = 200 (ton/yr) * 0.8 (ton-Filterable/ton) * 0.99 = 158.4 ton/yr

Cost Effectiveness = 500,000 (\$/yr) / 158.4 (ton/yr) = **\$3,157/ton**

Dispersion Modeling Analysis

- Used to ensure that the proposed source/modification will not cause a violation of the NAAQS or increment standards
- Dispersion modeling provides estimate of the ambient concentration at a future (or maximum) emission level
- Model the source first and compare to Significant Impact Levels (SILs)
- Must include background and nearby sources for NAAQS comparison

Pollutant	Averaging Period	Class II Increment Standard
PM _{2.5}	Annual	4 µg/m ³
PM _{2.5}	24-hour	9 µg/m ³
PM ₁₀	Annual	17 µg/m ³
PM ₁₀	24-hour	30 µg/m ³
SO ₂	Annual	20 µg/m ³
SO ₂	24-hour	91 µg/m ³
SO ₂	3-hour	512 µg/m ³
NO ₂	Annual	25 µg/m ³

Sample NAAQS Modeling Analysis

Pollutant/ Averaging Period	New Source Impact ($\mu\text{g}/\text{m}^3$)	Nearby Source Impact ($\mu\text{g}/\text{m}^3$)	Background Concentration ($\mu\text{g}/\text{m}^3$)	Total Predicted Impact ($\mu\text{g}/\text{m}^3$)	NAAQS ($\mu\text{g}/\text{m}^3$)
Scenario 1 – Permit could be issued					
PM10/24-hour	3	120	54	177	150
Scenario 2 – Permit could NOT be issued					
PM10/24-hour	7	120	54	181	150

PM10/24-hour Average Significant Impact Level (SIL) = $5 \mu\text{g}/\text{m}^3$

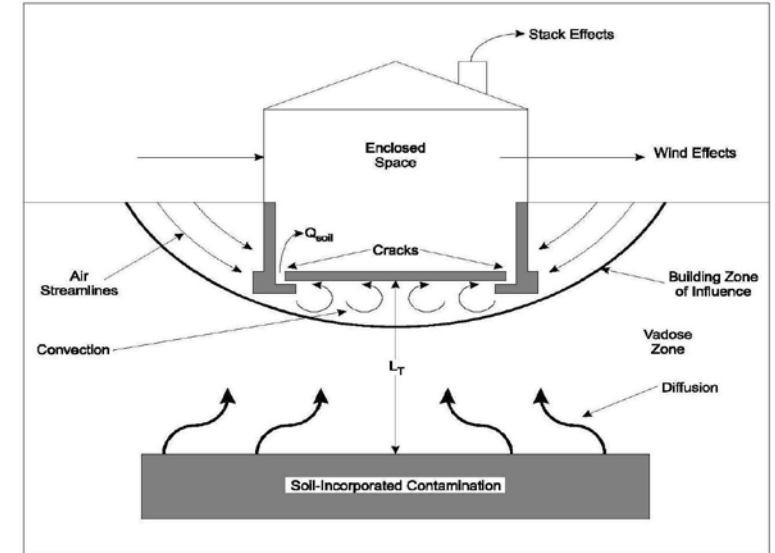
Operating Permits

- Operating permits are compilation of all air requirements that apply to a source
 - Title V operating permits for major sources
 - Basic state (minor) operating permits for smaller sources
- Operating permits must be renewed every 5 years



Vapor Intrusion Evaluation/Mitigation

- Migration of VOCs from the subsurface into overlying structures
- Drivers include recent state and federal regulations and property development (financing, insurance, attorneys)
- Projects could include sample collection, vapor intrusion evaluation and mitigation
- Wide range of projects. Single family homes to large office towers. Individual properties to large EPA Superfund Sites.



Other Air Projects

- Ambient air monitoring
 - Used to measure actual ambient pollutant concentrations at specific time, location
 - Compliments the modeling analyses (validation/verification)
 - Monitor siting using dispersion modeling is generally required
- Stack testing
 - Used to measure in-stack pollutant concentrations
 - Used to verify compliance with permitted emission limits and develop emission factors for inventories



Sample Problem #5

- Calculate the potential annual NOX emissions from the propane burner in Problem #2 limited to 5,000 hours of operation per year:
 - Max. Hourly ER = 1.38 lb-NOX/hour
 - Burner limited to 5,000 hours per year
 - The operational limit is federally enforceable

Hint:

Must use the maximum hourly emission rate for each hour of operation

Sample Problem #5 (Solution)

- Calculate the potential annual NOX emissions from the propane burner in Problem #2 limited to 5,000 hours of operation per year:
 - Max. Hourly ER = 1.38 lb-NOX/hour
 - Burner limited to 5,000 hours per year
 - The operational limit is federally enforceable

Answer:

$$\text{ER} = 1.38 \text{ (lb-NOX/hr)} * 5,000 \text{ (hr/yr)} / 2000 \text{ (lb/ton)} = \mathbf{3.45 \text{ ton/yr}}$$

Sample Problem #6

- Calculate the actual annual NOX emissions from the propane burner in Problem #2 given the following actual production data:
 - 2016 Annual Propane Consumption = 495 Mgal/year
 - EF = 13 lb-NOX/Mgal-Propane
 - Annual emissions are needed in tons/year

Hint:

Multiply the annual propane consumption by the emission factor
2,000 pounds per short-ton

Sample Problem #6 (Solution)

- Calculate the actual annual NOX emissions from the propane burner in Problem #2 given the following actual production data:
 - 2016 Annual Propane Consumption = 495 Mgal/year
 - EF = 13 lb-NOX/Mgal-Propane
 - Annual emissions are needed in tons/year

Answer:

$$ER = 495 \text{ (Mgal/yr)} * 13 \text{ (lb-NOX/Mgal)} / 2000 \text{ (lb/ton)} = \mathbf{3.22 \text{ ton/yr}}$$

93% of their potential emissions at 5,000 hours per year

Sample Problem #7

- Calculate the actual lead emissions from a furnace in lbs per hour given the following information:
 - Stack Test Exit Concentration = 0.0001 gr-Lead/dscf
 - Stack gas flow rate = 50,000 scfm
 - Stack gas moisture content = 8%

Hint:

When “gr” is used with English units, usually means grains

7,000 grains = 1 lb

dscf = Dry Standard Cubic Feet

Sometimes g/dscm is used-grams per dry standard cubic meter (Be Careful!)

Sample Problem #7 (Solution)

- Calculate the actual lead emissions from a furnace in lbs per hour given the following information:
 - Stack Test Exit Concentration = 0.0001 gr-Lead/dscf
 - Stack gas flow rate = 50,000 scfm
 - Stack gas moisture content = 8%

Answer:

$$\text{Dry Flow} = 50,000 \text{ (scf/min)} * 0.92 \text{ (dscf/scf)} = 46,000 \text{ dscfm}$$

$$\text{ER} = 46,000 \text{ (dscf/min)} * 0.0001 \text{ (gr/dscf)} / 7000 \text{ (gr/lb)} * 60 \text{ (min/hr)} =$$

0.039 lb/hr (lead)

Sample Problem #8

- Calculate the potential lead compound emissions from an ore crusher in lbs per year, given the following information:
 - MHDR = 300 ton/hr (ore crushed)
 - Ore lead content = 5%, by weight
 - The lead in the ore exists predominantly as a sulfide (PbS)

Hint:

Calculating the “metal compound” emissions (includes the mass of the sulfide)

EF(from AP42) = 0.0054 lb-PM/ton-Stone-Crushed (Section 11.19.2)

MW(Pb) = 207, MW(PbS)=239

Sample Problem #8 (Solution)

- Calculate the potential lead compound emissions from an ore crusher in lbs per year, given the following information:
 - MHDR = 300 ton/hr (ore crushed)
 - Ore lead content = 5%, by weight
 - The lead in the ore exists predominantly as a sulfide (PbS)

Answer:

$$\begin{aligned} \text{EF} &= 0.0054 \text{ (lb-PM/ton)} * 5/100 \text{ (lb-Pb/lb-PM)} * 239/207 \text{ (lb-PbS/lb-Pb)} \\ &= 0.00031 \text{ lb-PbS/ton-Ore-Crushed} \end{aligned}$$

$$\begin{aligned} \text{ER} &= 300 \text{ (ton/hr)} * 0.00031 \text{ (lb-PbS/ton)} * 8,760 \text{ (hr/yr)} = \\ &815 \text{ lb/yr (lead compounds as PbS)} \end{aligned}$$

Contact

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Questions?