Module 2:

Emission Inventory Fundamentals

What is an Air Pollutant Emissions Inventory?

Inventory - a comprehensive listing by sources of air pollutant emissions in a geographic area during a specific time period.
Why Do We Need Air Emission Inventories?

- Public interest in clean air
- Fundamental Component of Air Quality Management Plan
  - To identify sources and problem areas
  - To establish a baseline for future planning
  - To develop air quality control plans and mitigation strategies
  - To establish regulations and permit conditions for industrial facilities and basis for emissions trading programs

Why Do We Need Air Emission Inventories?

- Fundamental Component of Air Quality Management Plan
  - To measure progress/changes over time to achieve cleaner air (track trends or progress toward air quality goals)
  - To determine compliance with environmental regulations
Why Do We Need Air Emission Inventories?

- To use in Modeling
  - Air quality modeling predict ambient concentration
  - Exposure modeling and risk assessments predict human health and ecological risks

- To help site ambient monitors

Why Do We Need Air Emission Inventories?

- Global Assessments
  - To understand the impact of air pollution from your country on other nations
  - To determine compliance with international treaties, for example, United Nations Framework Convention on Climate Change (UNFCCC)
What Do You Use Air Emission Inventories for in Your Country?

- Describe your country's air quality management program
  - Goals
  - Problems: Pollutants and sources
  - Reduction strategies (regulations, voluntary reductions, trading, etc.)
  - Implementation and Enforcement activities
  - Evaluation of results

- Describe how emission inventories are used in your air quality management program.

- Describe potential uses for emission inventories in your air quality management program.
Emission Inventory Characteristics

- Base year
- Geographic area
- Pollutants
- Source Categories
- Modeling parameters
- Spatial resolution
- Temporal resolution
- Speciation

Emission Inventory Characteristics: Base Year

- Base Year
  - Identifies the year for which emissions are estimated
  - Provides a benchmark for comparison with previous and future inventories compiled for different years
  - Provides a common basis for all the emission estimates
- Year is selected based on purpose of the inventory, regulatory requirements, and data availability
Emission Inventory Characteristics: Geographic Area

- Establishes geographic domain for the inventory
- Determines the sources to be included in the inventory based on their location
- Can be based on political boundaries (i.e., city, province, or country borders), air shed boundaries, or other (possibly arbitrary) considerations
- Is determined based on the purpose of the inventory
  - City-, district-, province-level, national analyses of air quality impacts (e.g., 100 to 500 km²) using modeling

Emission Inventory Characteristics: Pollutants

Pollutants selected based on the purpose of the inventory
- Particulate matter analysis: PM₁₀ and PM₂.₅, secondary aerosols
- Ozone analysis: NOₓ, VOC primarily (can include other carbon compounds)
- Visibility analysis
  - NOₓ, SOₓ, VOC, CO, PM₁₀, PM₂.₅, NH₃
  - Elemental and organic carbon (EC/OC)
Emission Inventory Characteristics: Pollutants

- Greenhouse gases assessment
  - CH₄, N₂O, CO₂
  - HFC’s, PCF’s, and SF6

- Ozone depleting substances (ODS)
  - CFC’s, HCFC’s, halons, CCl₄, methyl chloroform (C₂H₃Cl₃), methyl bromide (CH₃Br)

Emission Inventory Characteristics: Pollutants

- Air toxics analysis
  - Important to use CAS #s
  - Keep in mind that toxicity varies by chemical
    - Carcinogens
    - Non-carcinogens
  - Compound groups – Report individual compounds by CAS # for risk assessments
### Emission Inventory Characteristics: Pollutants

**Air toxics analysis: Compounds Groups**
- **Polycyclic Organic Matter:** "Includes organic compounds emitted from combustion sources with more than one benzene ring, and which have a boiling point greater than or equal to 100°C." Examples include polycyclic aromatic hydrocarbons (PAHs), chrysene, benzo(a)pyrene, and naphthalene.
- **Dioxins and Furans:** Compounds can be grouped by 2,3,7,8 TCDD Toxic Equivalents (TEQs). TEQs are multipliers for some dioxin and furan congeners to get to a common basis of toxicity.
- **Diesel PM:** Mixture of particles that is a component of diesel exhaust. Diesel PM has Cancer and noncancer health effects.
- **Cyanides**
- **Glycol ethers**
- **Xylenes and Cresols (ortho-, meta-, and para-)**
- **Metals:**
  - Antimony, Beryllium, Cadmium, Cobalt, Manganese, Selenium
  - Chromium: report as hexavalent and trivalent
  - Lead: report as Organic and inorganic
  - Mercury: report as Particulate, gaseous elemental, and gaseous divalent
  - Nickel: report as Nickel subsulfide and other nickel compounds

### Emission Inventory Characteristics: Source Categories

- **Anthropogenic (man-made) and Natural sources may be included in an inventory.**
- **Anthropogenic Sources include:**
  - Stationary Point and Nonpoint sources
  - Mobile Onroad and Nonroad sources
- **Natural sources include:**
  - Biogenic emissions from vegetation
  - Geogenic emissions from soil, volcanoes, and geothermal activities
- **Wildfires and wind erosion are classified as either anthropogenic or natural by different countries**
- **Indoor and Other source categories**
Point Sources

- Emissions may be released from large or small point sources. Examples include electrical generating facilities, chemical manufacturing plants, secondary metal smelters, etc.
- Emissions may be released from:
  - Equipment leaks,
  - Transfer of materials from one location to another, or
  - Emissions stacks or vents

Point Source Considerations

- May be defined based on
  - Point source cutoffs / thresholds (e.g., 12 metric tons per year NOx)
  - Regulations or laws (e.g., all petroleum refineries are point sources)
  - Location or regulatory jurisdiction (e.g., regulated by city, state, or federal government)

- Detail needed:
  - Plant, unit, process, stack (emission release point)
  - Pollutants
  - Operation schedule (for example, 7 days a week, 24 hr/day)
  - Location, stack parameters, control device info, Process description (for example, SCC), Facility description (for example, NAICS code)
Nonpoint Sources

- Stationary industrial, commercial, institutional facilities and businesses that are too small or numerous to be categorized as a point source
  > Examples: dry cleaners, gasoline stations

- Nonpoint sources emit over a geographic “area” versus point sources that emit over a geographic “point”
  > Examples: residential cooking and heating, wind erosion of vacant lots and agricultural lands, dust from vehicle travel over paved and unpaved roads, consumer solvent use, wildfires

Nonpoint Source Considerations

- May be defined based on:
  > Thresholds
  > Regulations

- Detail needed:
  > County level
  > Pollutants
  > Process description (for example, SCC)

- Includes source categories that overlap with point source inventory
  > Point source inventories often include small sources such as dry cleaners and gas stations
  > Due to differences in source type definitions and inventory procedures used, the potential for double counting of point and nonpoint source emissions exists
  > As required, point source contributions to some nonpoint source categories must be removed from nonpoint inventories
Mobile Sources

- Pollutants
  - \( \text{VOC}, \text{PM}, \text{CO}, \text{Lead}, \text{NO}_x, \text{SO}_2 \)
  - Greenhouse Gases: \( \text{CO}_2, \text{N}_2\text{O}, \text{CH}_4 \)
  - 20 volatile organic and metal air toxics
  - Diesel particulate matter and diesel exhaust organic gases
- Includes Onroad and Nonroad Sources

Mobile Sources: Onroad

Onroad - Vehicles found on roads and highways.
- Fuel types - Vehicles may operate on any fuel, including petrol, diesel, propane, methanol, and electricity
- Vehicle classifications depend on methodology used to estimate emissions:
  - Passenger vehicles, trucks and vans
  - Heavy duty trucks with trailers
  - Buses and motor homes
  - Taxis
  - Two and three-wheeled vehicles designed for onroad use
- Emission Types include:
  - Exhaust emissions
  - Evaporative emissions
Mobile Sources: Nonroad

Nonroad - Mobile sources not found on roads
- Specific categories of nonroad sources vary between inventories
  - Aircraft (may be included in nonpoint sources)
  - Locomotives (may be included in nonpoint sources)
  - Boats and other marine vessels (may be included in nonpoint sources)
  - 2/4 stroke engines in construction, industrial, and agricultural equipment, lawn and garden equipment, etc.

Mobile Source Considerations

- Contribution by source category varies geographically
- May be defined by regulations
- Detail needed:
  - County level
  - Pollutants
  - Process description (for example, SCC)
Natural Sources

- Natural biological and geological phenomenon which generate air emissions (nonanthropogenic)
- Biogenic emissions:
  - VOC emissions from vegetation
- Geogenic emissions:
  - NO$_x$ emissions from soil (denitrification)
  - SO$_x$ emissions from volcanoes and geothermal activity
- May include wind erosion, wildfires

Indoor Sources

- Indoor air can become contaminated from numerous sources
- Indoor air can have significantly higher concentrations of air pollutants than outdoor air
Other Types of Sources

There are a number of other important sources of air pollutants that aren’t so easy to categorize or count:

- Accidental releases
- Long-range transport of air pollutants
- Historical background (for example, carbon tetrachloride)

Emission Inventory Characteristics:
What is Air Quality Modeling?

Determination of ambient air concentrations and deposition of pollutants by mathematically simulating their “fate & transport” in the atmosphere.
### Emission Inventory Characteristics: Why Model?

- Too costly to monitor for every pollutant everywhere
  - However, limited monitoring data are needed to confirm modeling results
- To predict what will happen...
  - New source
  - New strategies
  - Future Growth
- Can tell you what sources are contributing to the ambient air concentrations – includes transport from other areas
- Can help you decide where to put monitors

### Emission Inventory Characteristics: Modeling Inventories

- Modeling inventories have more specific requirements than other more general tracking inventories
- Modeling inventories need
  - Geographically resolved emissions (gridded or specific dimensions) – spatial allocation of emissions
  - Hourly time resolution – temporal allocation of emissions
  - Pollutant species (“model species”) to meet needs of AQ model chemical/physical algorithms
    - Risk assessors want modeled species to match health effects data
  - Quality Assurance/Quality Control of data
  - All sources represented
    - Anthropogenic, Biogenic (grid models)
Basic Types of Models

- Eulerian (grid): Observer "watches the plume go by"
- Lagrangian (plume/puff): Observer "follows along with the plume"

Comparison of Basic Model Types

<table>
<thead>
<tr>
<th>Grid (Eulerian)</th>
<th>Gaussian (Lagrangian)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(examples: CMAQ, CAMX, REMSAD, UAM)</td>
<td>(examples: ISCST3, AERMOD)</td>
</tr>
<tr>
<td>Photochemical criteria pollutants (Ozone, PM), Air toxics, Mercury</td>
<td></td>
</tr>
<tr>
<td>Long range transport</td>
<td>Near source (50km)</td>
</tr>
<tr>
<td>Atmospheric Chemistry: Secondary formation</td>
<td>Atmospheric Chemistry: Linear decay</td>
</tr>
<tr>
<td>Concentrations uniform within grid cells.</td>
<td>Captures concentrations gradients at fine scales - receptors at any point in space</td>
</tr>
<tr>
<td>Grid cells 36, 12, and 4km</td>
<td>Can run to get impacts of one source or groups of sources without having to consider all sources</td>
</tr>
<tr>
<td>Requires all sources (including biogenics) - sources not additive</td>
<td>Can be Easy to run (e.g., for single source)</td>
</tr>
<tr>
<td>Complex to run</td>
<td>Captures concentrations gradients at fine scales - receptors at any point in space</td>
</tr>
<tr>
<td>Concentrations uniform within grid cells.</td>
<td></td>
</tr>
</tbody>
</table>
Challenges in Preparing an Inventory For Modeling

- Different air quality models have different emission needs
  > Gaussian vs. Grid
- Inventory information doesn’t match those needs
- As inventory information evolves -- emission model processors must keep up with the changes
- Terminology can be different from inventory to processor to air quality model

Inventory preparers should understand the inventory and its use in specific air quality models.

Emission Inventory Characteristics: Modeling Point Sources

- Inventory Perspective: Emissions occur at a facility – at a known location
- AQ Model Perspective:
  > Gaussian AQ Model Perspective: Point sources are vertical stacks
  > Grid Model Perspective: Point sources allocated into grid cell based on lat/lon, and vertically allocated based on plume rise, some can be treated with plume-in-grid algorithm
- Key inventory elements
  > Facility/Process/Stack-Level emissions, by pollutant
  > Geographic coordinates
  > Emission release point parameters
    - Stack heights
    - Stack diameters
    - Flow rates
    - Temperatures
  > Source Category Information
  > Temporal information (start/end, seasonal throughput)
  > Control Information (for projections)
Emission Inventory Characteristics: Modeling Nonpoint and Nonroad Sources

- Non-point and Nonroad emissions treated similarly
- Inventory-perspective: county-level emissions
- AQ model perspective: non-stack
  - Gaussian AQ model perspective: flux or "area" source
  - Grid AQ model perspective: distributed evenly across grid cell, all in first layer
- Key inventory elements
  - Category-Level Emissions (process/industrial category), by pollutant
  - Province, City
  - Source Category Information
  - Temporal information (start/end, seasonal throughput)
  - Control information (projections)

Emission Inventory Characteristics: Modeling Onroad Sources

- National Inventory-perspective: county-level emissions
- AQ model perspective: non-stack
  - Gaussian AQ model perspective: flux or "area" source can be gridded or provided as elongated rectangles
  - Grid AQ model perspective: distributed evenly across grid cell, all in first layer
- Key inventory elements
  - Category-Level Emissions (vehicle type/road class), by pollutant
    - Emission process should be included for grid models
  - Province, City
  - For local scale analysis, you can create a link-based inventory by running MOBILE6 model using link-specific activity
The Big Picture for Modeling

- Prepare Mass Inventory
- Format Inventory for Emission Processor
- Emission Processor Input (Emissions & Other Data)
- Emissions Processor
- Other Air Quality Model Inputs
- Air Quality Model
- Modeling Results

Functions of Emissions Processor in Modeling

- Spatial Allocation – proper resolution
- Temporal Allocation – hourly
- Pollutant Speciation – model species
- Quality Assurance/Quality Control
- Emission Projections (optional)
Emission Inventory Characteristics: Spatial Resolution

- Establishes the detail of the geographic location of the sources
- Determined based on the purpose of the inventory
  - National-level analysis => Single national estimate for each major source type and pollutant
  - Modeling inventory => Source-specific emissions allocated based on location coordinates, source-category emissions allocated based on "grids" (e.g., 1 to 50 km²)
- Basis varies between point sources and what is used for nonpoint and mobile sources
- Modeling inventories have more specific requirements than general tracking inventories
Modeling Domain Example:
China Air Quality Modeling

Modeling: Spatial Allocation of County-level Emissions to Grid

Concept:
• Use surrogates to allocate county level emissions for county-level sources.
• Example: use population data to allocate consumer product emissions

This Grid cell gets 3/20 of Orange county’s consumer product emissions
Emission Inventory Characteristics: Temporal Resolution

- Describes the variability of emissions over time
- Determined based on the purpose of the inventory
  > Resolution can be annual, seasonal, monthly, daily, hourly, or less
  > Modeling inventory => can be hourly or by second

Emission Inventory Characteristics: Temporal Resolution - Modeling

- Typically from annual (inventory) to what model needs

<table>
<thead>
<tr>
<th>Model</th>
<th>Resolution</th>
</tr>
</thead>
<tbody>
<tr>
<td>EMS-HAP/ASPEN</td>
<td>3-hour time blocks (every day is treated the same)</td>
</tr>
<tr>
<td>EMS-HAP/ISCST3</td>
<td>24-hourly, 4 season, 3 day type factors</td>
</tr>
</tbody>
</table>

- Model Processors uses temporal profiles
  Example: temporal profile for aircraft emissions for summer weekday

Hour of the Day

0  5  10  15  20

0  1  2  3  4 x 10^{-7}
**Temporal Resolution Example:**

- A supplemental boiler at a factory is used for increased production in the months of December - February (90 days/year) and emits 500 metric tons/year of CO.
- Calculate annual operation in seconds:
  \[= 90 \text{ days} \times 10 \text{ hours/day} \times 3,600 \text{ seconds/hour}\]
  \[= 3.24 \times 10^6 \text{ seconds}\]
- Calculate CO emissions in grams/second (g/s):
  \[= \frac{(500 \text{ Mg} \times 10^6 \text{ grams})}{3.24 \times 10^6} \]
  \[= 154.3 \text{ g/s}\]

**Emission Inventory Characteristics: Speciation**

- Disaggregates inventory pollutants into individual chemical components or groups.
- Determined based on the inventory purpose:
  - Visibility analysis: elemental carbon/organic carbon
  - Ozone analysis: Aromatics, paraffins, VOCs, etc.
  - Air toxic risk assessment:
- Speciation tools exist on EPA's web site (see http://www.epa.gov/ttn/chief/emch/speciation/index.html) – only applicable for VOC and PM modeling; not appropriate for air toxics.
Air Toxics Speciation: Modeling Metal Compounds

- Specific metal HAPs should be reported in the inventory, if available
- Model mass of metal only
  > For example, Emission modelers compute the mass of manganese in manganese oxide
- Specific compound may be needed for risk assessment or chemistry considerations in model
  > For example, To determine whether it is hexavalent chromium or trivalent chromium, is it nickel subsulfide?
- For mercury, if exact chemical compounds not known, provide amount of mass as "divalent particulate," "divalent gas," and "elemental"
  > These three are "model species" in numerous grid models (for example, REMSAD, CMAQ)
  > Ideally, emissions should be broken out by specific chemical and by specific form (gas vs. particulate)

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Air Toxics Speciation for Modeling Example

Example: Manganese Coarse and Fine Pollutant Groups

<table>
<thead>
<tr>
<th>Inventory Species</th>
<th>Model Species</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manganese nitrate</td>
<td>Manganese coarse</td>
</tr>
<tr>
<td>Manganese dioxide</td>
<td>Manganese fine</td>
</tr>
<tr>
<td>Manganese tetroxide</td>
<td></td>
</tr>
<tr>
<td>Manganese napthenate</td>
<td></td>
</tr>
<tr>
<td>Manganese &amp; compounds</td>
<td></td>
</tr>
<tr>
<td>Manganese</td>
<td></td>
</tr>
<tr>
<td>Manganese tallate</td>
<td></td>
</tr>
<tr>
<td>Manganese sulfate</td>
<td></td>
</tr>
</tbody>
</table>

- Remove non-manganese mass
- Partition into coarse and fine particulate matter
Emissions Inventory Development Approaches

- Top-Down approach
- Bottom-Up approach
Top-Down Approach

- Methodology:
  > General emission factors combined with high level (national) activity data (e.g., emission factor x national coal consumption) to estimate emissions in country or region
  > National- or regional-level emissions estimates scaled to the inventory domain based on surrogate data (geographic, demographic, economic data)
- Typically used when:
  > Local data are not available
  > The cost to gather local information is prohibitive
  > The end use of the data does not justify the cost
- Advantages: Requires minimum resources
- Disadvantages:
  > Emissions generally have high level of uncertainty
  > Loss of accuracy in emission estimates

Bottom-Up Approach

- Methodology
  > Uses source-specific data (for point sources) and category-specific data at the most refined spatial level (for nonpoint and mobile sources)
  > Emission estimates for individual sources (and source categories) are summed to obtain domain-level inventory
- Typically used when:
  > Source/category-specific activity or emissions data are available
  > End use of inventory justifies the cost of collecting site-specific data (e.g., for ozone control strategy demonstration)
- Advantages: Results in more accurate estimates than a top-down approach
- Disadvantages: Requires more resources to collect site-specific information than a top-down approach
Emission Estimation Techniques

How Do I Choose Emission Estimation Methods?

- Choice of methods depends on:
  - Pollutant and source category priorities
  - Intended use of the inventory
  - Resources
  - Availability of data
  - Compromise between method accuracy and cost to implement
Source Category Estimation Methods

- **Point Source Methods**
  - Continuous Emission Monitor (CEM)
  - Source tests
  - Material balance
  - Emission factor x activity factors
  - Fuel analysis
  - Emission estimation models
  - Engineering judgment

- **Nonpoint Source Methods**
  - Surveys and questionnaires
  - Material balance
  - Emission factor x activity factors
  - Emission models

- **Mobile**
  - Emission models

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Estimation Methods: A Continuous Emission Monitoring (CEM) System

- Sampling is continuous
- CEMs measure and record actual emissions during the time period the monitor is operating and the data produced can be used to estimate emissions for different operating periods.
- CEMs can be required by permit conditions for some pollutants

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Opacity Monitor

Sampling Interface

Analyzers

Data Acquisition System
Estimation Methods: A Continuous Emission Monitoring (CEM) System

Short term emission measurements typically taken from a stack or vent

- Includes:
  - Individual test at facility
  - Testing at similar facilities
  - Pooled source testing

Sampling can be infrequent
(1 stack test every 5 years)
> Estimation Methods: Source Sampling
Estimation Methods: Source Sampling

- Emission rates generally reported as concentrations which must be converted to mass units for use in emission inventories
- Summarize emissions for each pollutant in terms of:
  - Mass loading rate
  - Emission factor
  - Flue gas concentration
- Results depend upon air pollution control device performance and design
- Screening measurements can be indicators of emissions, potential compliance issues
Estimation Methods: Fuel Analysis

- Used to predict emissions based on the application of conservation laws
- \[ E = Q_f \times \text{Pollutant in fuel} \times \left( \frac{\text{MW}_p}{\text{MW}_f} \right) \]
  where:
  \[ Q_f \] throughput of the fuel, mass rate (e.g. lb/hr)
  \[ \text{MW}_p \] molecular weight of pollutant emitted (lb/lb-mole)
  \[ \text{MW}_f \] molecular weight of pollutant in fuel (lb/lb-mole)

Estimation Methods: Emissions Models

- Used when
  > Calculations are very complex
  > Combination of parameters has been identified that affect emissions, but individually, do not provide a direct correlation
- Used to calculate emission factors or mass emissions for specific source categories
  > Examples: Mobile exhaust and evaporative emissions, storage tank evaporation and breathing losses, VOCs from wastewater treatment facilities
- Generally require that a significant amount of information be known about the source(s) being estimated
  > Examples: meteorological conditions in the source area, tank capacity and color, amount and chemical make-up of wastes treated
- Mechanistic and multivariate models
Emissions Models

U.S. EPA models include:

- **TANKS** - volatile liquid storage tanks
  ([http://www.epa.gov/ttn/chief/software/tanks/index.html](http://www.epa.gov/ttn/chief/software/tanks/index.html))
- **WATER9** - wastewater treatment
  ([http://www.epa.gov/ttn/chief/software/water/index.html](http://www.epa.gov/ttn/chief/software/water/index.html))
- **MOBILE6** – onroad motor vehicles
  ([http://www.epa.gov/otaq/mobile.htm](http://www.epa.gov/otaq/mobile.htm))
- **LandGEM** - landfills
  ([http://www.epa.gov/ttn/catc/products.html#software](http://www.epa.gov/ttn/catc/products.html#software))

Emission Factors

- **Definition:** a ratio that relates the quantity of a pollutant released to a unit of activity
- **Allow development of**
  generalized estimates of typical emissions from source categories or individual sources within a category
- **Estimates the rate at which a pollutant is released to the atmosphere as a result of some process**
Types of Emission Factors

**Process-Based Emission Factors**
- Natural Gas Boiler
  - kg/10^6 m^3
- Vapor Degreaser
  - kg/hr/m^2
- Battery Manufacturing
  - kg/10^3 batteries

**Census-Based Emission Factors**
- Per Capita
  - kg/person/yr
- Per Employee
  - kg/employee/yr

Published Sources of Emission Factors

- U.S. AP-42 Compilation of Air Pollutant Emission Factors
- U.S. Emissions Inventory Improvement Program, EIIP
- U.S. Factor Information REtrieval (FIRE) Data System
  [http://www.epa.gov/ttn/chief/software/fire/index.html](http://www.epa.gov/ttn/chief/software/fire/index.html)
- European Environment Agency – CORINAIR
- Intergovernmental Panel on Climate Change (IPCC) database
  [http://www.ipcc-nggip.iges.or.jp/](http://www.ipcc-nggip.iges.or.jp/)
# Calculating Emissions Using Emission Factors

- Emissions = $EF \times AD \times (1 – CE/100)$
  - $EF = \text{emission factor}$
  - $AD = \text{activity data (throughput)}$
  - $CE = \text{overall control efficiency (\%) = } (\text{CAP} \times \text{CON})/100$
    - $\text{CAP} = \% \text{ of the emissions stream captured by the control}$
    - $\text{CON} = \% \text{ of pollutant removed from the emissions stream}$
  - Activity data
    - Process weight rates = Mg/year, kg/hour, liter/hour
    - Fuel consumption rates = BTU/year, kJ/hour
    - Can be expressed in terms of production rates

# Estimate VOC Emissions from Industrial Fuel Combustion

- Given:
  - Quantity of fuel used = 10,000,000 liters/year
  - VOC emission factor = 88 kg/10⁶ m³
  - CAP = 80% and CON = 90%
- Estimate overall control efficiency
  - $CE = (80 \times 90)/100 = 72\%$
- Convert fuel used in liters/year to m³
  - $10,000,000/1,000 = 10,000 \text{ m}^3$
- Calculate annual emissions
  - Emissions = $EF \times AD \times (1 – CE/100)$
  - $88 \text{ kg/10}^6 \text{ m}^3 \times (10,000 \text{ m}^3/10^6) \times (1 – 72/100) = 0.25 \text{ kg/year}$
Surveying

- Questionnaires are used to collect activity, controls, and emissions data from specific source types, categories
- Can be used to either:
  > Collect all information including emissions estimates and necessary data fields
  > Collect activity data and information about facility and its operations
    - If emissions are not included as part of survey, agency develops emission estimates using activity data collected by survey and emission factor data or source test data

Surveying

- Surveys can be conducted by various means
  > Workshops
  > Telephone
  > Internet
  > Visits to individual facilities by survey staff
- Keys to successful surveys
  > Well planned field effort
  > Well trained survey staff
  > Efficiently designed survey instrument
  > Quality assurance of data at various steps in the process
Point Source Survey Process

Develop Questionnaire

Industrial Plant 1

Industrial Plant 2

Industrial Plant 3

Survey All Facilities

Complete Questionnaires for Each Point Source

Estimate Facility Emissions for Surveyed Point Sources

Survey Elements

- Cover Letter
- Questionnaire Instructions
  - Clarity of Instructions
    - Questionnaire responses must provide both the descriptive information desired and the correct numerical data
    - Units of measurement, method of calculations and conversions, and code number instructions should be put on the questionnaire itself and not explained in the instructions
  - Questionnaire Design
    - General Approach
      - Pollutants, Source Categories Coverage
      - Emissions-Based vs. Use or Production Approach
      - Minimize length of questionnaire
      - Clear statement from which the respondent can determine whether the questionnaire is applicable
    - Tiered Approach
- Check the effectiveness of questionnaire
Estimation Methods: Material Balance

Used:

• When source test data, emission factors, or other developed methods are not available
• Where accurate measurements can be made of all process parameters
• For processes where material does not react to form secondary products or does not undergo significant chemical change
• For processes like solvent degreasing operations, and surface coating operations

Estimation Methods: Material Balance

• Approach considers all inputs of a material and all possible fates for the material after passing through the process, including direct air emissions, fugitive air emissions, solid and liquid waste streams, and residual product content
  > Uses measurements of various components of a process to determine air emissions:

  \[
  \text{Air emissions} = \text{input} - \text{liquid emissions} - \text{solid wastes} - \text{products} - \text{by products} - \text{recycled material}
  \]

• Commonly used to estimate emissions from solvent usage based on contents of various solvents
  > Solvent degreasing operations
  > Surface coating operations
Examples of Material Balance

VOC Emission
Fresh Solvent
Solid Waste
Waste Solvent
Assume all solvents in paint are evaporated

Sulfur Dioxide (SO₂) Emissions
Sulfur (S) in Fuel
Paint VOCs
Assume all sulfur in a fuel is converted to SO₂ during the combustion process

Assume waste solvent is sent to a reprocessor and solid waste is sent to a treatment facility

Estimation Methods: Engineering Judgment (Extrapolation)

• Last resort to be used only if none of the methods described can be used to generate accurate emission estimates
• Provides an “order of magnitude” estimate with significant uncertainty
• Scaling emissions estimates to create another inventory using scaling parameters
  > Production quantity
  > Material throughput
  > Land area
  > Number of employees
  > Population
Summary: Emission Inventory Fundamentals

- Inventories are the fundamental building blocks of any air quality management program and are used for a variety of purposes.
- Inventory characteristics (e.g., year, pollutants, sources, spatial and temporal resolution) are determined by the uses of the inventory.
- Modeling inventories have more specific requirements than more general tracking inventories.
- Emission Inventories can be developed using a top-down or bottom-up approach.
- A variety of emission estimation methods exist and are determined by the inventory uses, pollutant and source category priorities, resources, and data available.

Questions or Comments?