CASE STUDY #2: POINT SOURCE - FOUNDRY

Part 1: Goal

The objective of this case study is to learn how to characterize, estimate, and report emissions for a point source category. The specific goals to be achieved by this case study are:

- To estimate emissions from a metallurgical source category;
- To use source test and monitoring data for estimating emissions;
- To document the inventory process so that the results can be duplicated.

Part 2: Problem Description

Although the air quality in the inventory region does not violate the air quality standards, industrial facilities can cause air quality problems in the region. In particular, emissions from a gray iron foundry need to be estimated. There have been no previous efforts to inventory this facility. This iron foundry emits air pollutants through stacks, processes, and fugitive emissions. Stack monitoring data are available for some sources located within the foundry.

An annual criteria pollutant emissions inventory (in Mg) for the year 2002 should be estimated for the foundry based upon equipment-level and fugitive source emissions. A brief IPP/QAP should be prepared. Also, the results (including methods, data, and assumptions used) should be documented to the extent that the results can be duplicated.

Note to the student: All of the activity data and their references provided in this case study are fictitious and made up for the sole purpose of demonstrating the emissions inventory methodology. However, the emission factors and their references are based on the actual references as provided.

<u>Operational Schedule</u>

The overall facility operational schedule during 2002 was as follows:

- 12 hours per day
- 5 days per week; and
- 52 weeks per year.

Materials Handling

The facility uses two enclosed conveyor belts to transport and load the raw material into open storage piles. The raw materials stored are coke (used as fuel) and pellet ore. One factor affecting air emissions during materials handling is the ambient wind speed. The average wind speed in the region is 8 km/hour (National Climatic Center, 2002). Characteristics of the materials handling equipment are as follows:

- Conveyor belt #1:
  Equipment ID: CONV-1
  Material loaded: Coke
  Throughput rate: 100 Mg/month
  Control device: Baghouse with fabric filter (95% efficiency)
  Capture efficiency: 85%
  Material moisture content = 7.8%

- Conveyor belt #2:
  Equipment ID: CONV-2
  Material loaded: Pellet ore
  Throughput rate: 80 Mg/month
  Control device: Baghouse with fabric filter (95% efficiency)
  Control efficiency: 95%
  Material moisture content = 2.2%

Particulate emissions from material handling operations can be calculated using the following equation (AP-42, Section 13.2.4):

$$EF = k \times 0.0016 \times [(U/2.2)^{1.3}/(M/2)^{1.4}]$$
$$E = EF \text{ x } A \text{ x } 12 \text{ month/year}$$

Where:

EF = Emission factor (kg/Mg of material);
k = Particle size multiplier (k = 0.35 for PM_{10} and 0.11 for $PM_{2.5}$);
U = Mean wind speed, meters per second (m/s); and
M = Material moisture content (%).
E = Emissions (Mg/Year)
A = Throughput (Mg/month)

$E = EF \times A$

Metal Melting

Solvent degreasing is carried out for scrap metal preparation. There is no heating for scrap preparation. The degreasing booths are uncontrolled. The total annual quantity of solvent used during 2002 for degreasing was 10,000 liters/year and the volatile content of the solvent is 450 g/liter. The equipment IDs for the boots are BOOTH-1 and BOOTH-2. (Assume equal solvent usage for both the degreasing booths.) VOC emissions from the degreasing operations can be calculated using material balance.

The facility has four electric arc furnaces for metal melting. All four furnaces are enclosed type and they exhaust emissions though a common stack. The furnaces are equipped with a baghouse filter to control particulate matter (PM) emissions. The capture and control efficiencies of the filter are 100% and 90%, respectively. Stack monitoring data are available for most pollutants (but not for VOCs). Characteristics of the furnaces are as follows:

- Equipment IDs: FUR-1; FUR-2; FUR-3; and FUR-4
  Annual production: 5,000 Mg of gray iron
  (Note that annual production for each furnace is not available. Per-furnace production may be assumed as 5,000/4 [1,250 Mg]).

- PM emissions were measured by stack sampling equipment
  Stack flow rate = 17,917.7 dscfm (dry standard cubic feet per minute)
  Volume of gas sampled = 41.1 dscf
  PM_{10} collected on filter = 0.0642 grams
  $PM_{2.5}$ collected on filter = 0.05 grams

  Emissions (kg/hr) = PM concentration (grains/dscf) × stack flow rate × 60 × (1/15,432.4)

  Where:
  PM concentration (grains/dscf) =
  (PM collected on filter/volume of gas sampled) × 15.43
  60 = 60 minutes/hour
  15,432 (grains) = 1 kg

- SO_2 emissions were measured with a continuous emissions monitoring system

Emissions (lb/hr) = (Pollutant concentration × MW × stack flow rate × 60)/(V×10^6)

Where:
SO_2 concentration = 0.75 ppmvd (parts/10^6)
MW = molecular weight of SO_2 = 64 lb/lb.mole
Stack flow rate = 17,917.7 dscfm
60 = 60 minutes/hour
V = volume of one mole of ideal gas at STP (68° F and 1 Atm.) = 385.5 ft^3/lb.mole

- NO_x and CO emissions were measured with a CEMS
  Emissions (lb/hr) = (Use above equation)
  NO_x concentration = 12 ppmvd (parts/10^6)
  MW of NO_2 = 46 lb/lb.mole
  CO concentration = 280 ppmvd
  MW of CO = 28 lb/lb.mole

- VOC emissions can be calculated using an emission factor of 0.09 kg VOC/Mg of iron (AP-42).

Iron Refining

Magnesium is added to molten metal to produce ductile iron at this facility. The equipment/process ID for iron refining is FUG-1.

Particulate emissions from iron refining and magnesium treatment can be calculated using the following emission factors:

Operation	PM[a] Emission Factor (kg/Mg)
Iron refining	2
Magnesium treatment	0.2

Source: U.S. EPA, 1995 (Table 12.10-6, AP-42).
[a] PM_{10} size fraction to be 49% of total PM and $PM_{2.5}$ size fraction to be 24% of total PM (Table 12.10-8, AP-42).

Mold and Core Production

Two sand handling units operate at the facility. Each unit handles 3,000 Mg of sand annually. The operations involved are sand shakeout, sand handling, and baking (core making). The sand handling equipment IDs are SAND-1 and SAND-2.

Emission factors for the above described mold and core production operations are as follows:

Operations	PM[a] Emission Factor (kg/Mg)
Shakeout	1.6
Sand handling	1.8
Baking	0.6

Source: U.S. EPA, 1995 (Table 12.10-6, AP-42).
[a] PM_{10} size fraction to be 70% of total PM and $PM_{2.5}$ size fraction to be 42% of total PM (Table 12.10-8, AP-42).

Casting and Finishing

Casting and finishing involves pouring of metal into the casts and finishing processes. The equipment/process ID for casting and finishing is FUG-2. Emission factors for calculating emissions from casting and finishing operations are as follows:

Operation	PM[a] Emission Factor (kg/Mg)
Pouring	2.1
Finishing	0.05

Source: U.S. EPA, 1995 (Table 12.10-6, AP-42).
[a] PM_{10} size fraction to be 49% of total PM and $PM_{2.5}$ size fraction to be 24% of total PM (Table 12.10-8, AP-42).

Part 3: Planning

A brief Inventory Preparation Plan/Quality Assurance Plan for the gray iron foundry emissions inventory should be prepared. The contents of the Inventory Preparation Plan/Quality Assurance Plan are outlined as follows:

- Background and purpose of the inventory;
- Inventory area status;
- Inventory scope (area/facility, pollutants of concern, base year, temporal resolution);
- Data quality objectives;
- Inventory resources;
- Emissions estimation methodologies; and

- QA/QC procedures
  - Internal QC procedures;
  - External QA/QC procedures (to be conducted in Step 6 by exchanging solutions with another group, and completing the QA Checklist).

Part 4: Solution

The solution to this case study has three parts: the Inventory Preparation Plan/Quality Assurance Plan, and the emissions calculations and documentation.

Solution – IPP/QAP

The contents of the Inventory Preparation Plan/Quality Assurance Plan should be based upon the outline provided in Part 3, above. Time limitations will dictate the level of detail that can be included in the Inventory Preparation Plan/Quality Assurance Plan. An example of the minimum level of detail that should be included in the Inventory Preparation Plan/Quality Assurance Plan for this case study is as follows:

- Background and purpose of the inventory – There have been no previous efforts to develop emission estimates for this facility. The basis for this point source inventory is to aid in policy making by the local air quality regulating agency

- Inventory area status – attainment vs. nonattainment status;

- Inventory scope:
  1. Inventory area/facility: Gray iron foundry;
  2. Pollutants of concern: NO_x, SO_x, CO, VOC, PM_{10}, and $PM_{2.5}$;
  3. Sources: Materials handling (2 conveyors), metal melting (4 furnaces), iron refining (fugitive emissions), mold and core production (2 sand handling units), casting and finish (fugitive emissions); and
  4. Temporal resolution: Annual emissions for the year 2002.

- Data quality objectives:
  1. The inventory should include all the sources listed; and
  2. Emission estimates should be 100% correct.

- Inventory resources:
  1. Team
  2. Overall project manager
  3. Team manager

4. Data evaluator

- Emissions estimation methodologies – Emission factors and activity data; stack monitoring data.

Table1. Emission Estimation Methodology: Uncontrolled Emissions

Process	**Pollutant**	**Methodology**	**Equation**	**Data needed**
Materials Handling: 2 Conveyor belts	$PM_{2.5}$ PM_{10}	Emission Factor and Activity Data	EF = k x 0.0016 x $[(U/2.2)^{1.3}/(M/2)^{1.4})]$ E = EF x A x 12 month/year EF = Emission factor (kg/Mg of material) k = Particle size multiplier (k = 0.35 for PM_{10} and 0.11 for $PM_{2.5}$) U = Mean wind speed, meters per second (m/s) M = Material moisture content (%) E = Emissions (Mg/Year) A = Throughput (Mg/month)	U M A
Metal Melting: Degreasing – 2 booths	VOC	Material Balance	E = S x VOC E = Emissions (g/year) S = Solvent used (liters/year) VOC = VOC content of solvent (g/liter)	S VOC
Metal Melting: 4 Electric Arc Furnaces	PM	Source test	E = (PM test/V) x FR x 60 x (1kg/1000g) E = Emissions (kg/hr) PM test = PM collected on filter (g) V = volume of gas sampled (dscm) FR = flow rate (dscmm)	PM test V FR
Metal Melting: 4 Electric Arc Furnaces	SO2 NOx CO	CEM	E = (P conc x MW x FR x 60)/(24.07 m3/kg-mole x 10^6) E = Emissions (kg/hr) P conc = pollutant concentration (ppmv) MW = molecular weight of pollutant (kg/kg-mole) FR = stack flow rate (dscmm)	P conc MW FR
Metal Melting: 4 Electric	VOC	Emission Factor and Activity Data	E = EF x A E = Emissions (kg/yr)	A

Arc Furnaces			EF = emission factor =0.09 kg/Mg Iron produced A = Mg iron produced /yr	

Process	**Pollutant**	**Methodology**	**Equation**	**Data needed**
Iron Refining Iron Refining Magnesium treatment	PM	Emission Factor and Activity Data	E = EF x A x 0.49 for PM_{10} E = EF x A x 0.24 for $PM_{2.5}$ E = Emissions (kg/yr) EF = emission factor EF = 2 kg/Mg for iron refining EF = 0.2 kg/Mg for magnesium treatment A = Mg material/yr	A
Mold and Core Production: Shakeout Sand handling – 2 units Baking	PM	Emission Factor and Activity Data	E = EF x A x 0.70 for PM_{10} E = EF x A x 0.42 for $PM_{2.5}$ E = Emissions (kg/yr) EF = emission factor EF = 1.6 kg/Mg for shakeout EF = 1.8 kg/Mg for sand handling EF = 0.6 kg/Mg for baking A = Mg material /yr	A
Casting and Finishing: Pouring Finishing	PM	Emission Factor and Activity Data	E = EF x A x 0.49 for PM_{10} E = EF x A x 0.24 for $PM_{2.5}$ E = Emissions (kg/yr) EF = emission factor EF = 2.1 kg/Mg for pouring EF = 0.05 kg/Mg for finishing A = Mg material /yr	A

What units have hourly emissions that need to be converted? What is equation to convert hourly emissions to annual?

For Electric Arc Furnaces emissions of PM, SO2, CO and NOx, convert hourly emissions to annual emissions by using operational data for facility.

Emissions (kg/yr) = emissions (kg/hr) x 12 (hrs/day) x 5 (days/week) x 52 (weeks/yr) = 3120 (hr/yr) x emissions (kg/hr)

What is equation to calculate controlled emissions?

For controlled emissions, use capture and control efficiency data.

Controlled emissions = Uncontrolled emissions (1 – (CapEff x ConEff))

Cap Eff – Capture efficiency expressed as a fraction

Con Eff – Control efficiency expressed as a fraction

Complete Table 2 to calculate controlled emissions.

Table 2. Control Emissions Data

Process	**Unit**	**Pollutant**	**Control Equipment**	**Capture Efficiency (%)**	**Control Efficiency (%)**	**Equation**
Materials Handling	Coke	PM	Baghouse with fabric filter	85	95	Controlled emissions = Uncontrolled emissions x (1- (0.95 x 0.85))
Materials Handling	Pellet	PM	Baghouse with fabric filter	100	95	Controlled emissions = Uncontrolled emissions x (1- (1 x 0.95))
Metal Melting		PM	Baghouse	100	95	Controlled emissions = Uncontrolled emissions x (1- (1 x 0.95))

- QA/QC procedures – Internal QC steps should be briefly outlined in the Inventory Preparation Plan, and could include:
    1. Checking emission calculations for errors;
    2. Checking emission factors to ensure the appropriateness of the factors used; and
    3. Documenting all the assumptions made during emission calculations.

Solution - Calculations

See attached spreadsheet.

Part 5: Documentation

Due to time limitations, it is not possible to develop a complete emissions inventory report. However, an outline or annotated outline can be developed which contains the following elements:

- Description of the source category (i.e., gray iron foundries);
- Explanation of the methods used for data collection, and sources of data collected (e.g., source tests for some sources);
- Explanation of the assumptions made in data collection and in the data analysis phase (e.g., assume equal production for each furnace);
- Emission estimation methods;
- Emission factors and their sources;
- Emission calculations and assumptions;
- Internal QC checks implemented and results of external QA including findings and corrections made and;
- Results (e.g., tables, pie charts) and analysis (e.g., comparisons/controls) among sub-categories.

Part 6: Quality Assurance

Have students exchange all documentation and conduct external QA audit using the QA checklist.

Part 7: Discussion of Results

Review the following with the students:

- The external QA checklist;
- The content of the inventory report; and
- The emission calculations and results.

ATTACHMENT

SOLUTION FOR
POINT SOURCE – FOUNDRY CASE STUDY
(SPREADSHEET)