CASE STUDY #1: INVENTORY PREPARATION PLAN AND QUALITY ASSURANCE PLAN

Part 1: Goal

The objective of this case study is to learn the principles of emissions inventory planning. The specific goals for this case study are:

- To develop an Inventory Preparation Plan/Quality Assurance Plan for a regional emissions inventory (EI) project for an Indian city, which includes:
  - Identifying sources to be included in the EI;
  - Identifying pollutants to be included in the EI;
  - Identifying various data requirements and sources; and
  - Identifying available estimation methods and select the most appropriate estimation method.
- To develop appropriate QA/QC procedures to achieve the data quality objectives determined for the emissions inventory.

Part 2: Problem Description

Bay City (a fictitious Indian city) is an industrialized region located in Western India and is one of the many developing cities in the country. Due to industrial growth and subsequent urbanization, the air pollution problems have started to become a harsh reality. This situation is occurring not only in Bay City, but also in the surrounding areas. Although the area is not yet exceeding any ambient air quality standards, there is a growing need to quantify the emissions generated within the area in anticipation of future air quality planning efforts that will include modeling of the ozone (O_3), PM_{10}, and $PM_{2.5}$ concentrations.

Most industrial point sources are located in the western part of the city. There are several sources for which an emissions inventory has never been developed, including two fertilizer manufacturing facilities (a urea plant and an ammonium phosphate plant). In addition, emissions previously have not been estimated for several smaller industries (usually classified as nonpoint sources) including three brick making that have small, open-furnace combustion processes using mainly wood waste for fuel and eight dry cleaning businesses. Another nonpoint source category for which emissions have never been estimated is domestic fuel combustion such as liquid propane gas (LPG) used for residential cooking.

Your team will develop an emissions inventory for these sources. This inventory should include annual estimates (in Mg) as well as O_3 season daily emissions (in kg/day) for each source. The O_3 season runs April through July. Some basic characteristics for these sources are summarized below under “Activity Data Section.”

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.

To ensure that this emissions inventory is developed correctly and that its data quality objectives are satisfied, an Inventory Preparation Plan/Quality Assurance Plan must first be developed. The Inventory Preparation Plan/Quality Assurance Plan will provide the air quality regulators in Bay City with the background necessary to effectively manage the development of the emissions inventory.

In this case study, your team will outline and describe the content of each part of the Inventory Preparation Plan/Quality Assurance Plan. It is not anticipated that you will do a significant amount of writing, but rather provide sufficient detail within an outline format to enable an external reviewer to assess the important features of how the inventory will be conducted including:

- Source category descriptions and emissions characterization;
- Methodologies to be used to estimate emissions, including data inputs;
- Data quality objectives necessary for a modeling inventory; and
- Level of detail of the results to be reported.

Activity Data Section:

Fertilizer Industry: Urea and Ammonium Phosphate Fertilizer Manufacturing

Operational schedule = 24 hr/day; 5 days/week; and 52 weeks/year
Operating conditions (urea production) = 190 ºC; retention time = 20 minutes
Amount of urea produced = 5 Mg/day (50% used in fertilizer production; 50% used in animal feed supplement)
Amount of ammonium phosphate produced = 8 Mg/day
Ammonia phosphate granules produced = 4 millimeters (mm) in diameter

The emission factors per Mg of urea produced are as follows:

Urea Manufacturing Operations	Uncontrolled PM emission factor (kg/Mg)[a]
Solution formation and concentration	0.0105
Fluidized bed prilling	3.1
Drum granulation	120
Rotary drum cooler	3.89
Bagging operations	0.095

Source: U.S. EPA, 1995 (AP-42, Table 8.2-1).
[a] PM_{10} Size fraction for Urea plants is 0.9600 and $PM_{2.5}$ Size fraction is 0.9500 (ARB, 1999).

The emission factors per Mg of ammonia phosphate produced are as follows:

Ammonia Phosphate Manufacturing Operations	Controlled PM emission factor (kg/Mg)[a]	Controlled SO_2 emission factor (kg/Mg)
Reactor/Ammoniator- granulation	0.76	NA
Dryer/cooler	0.75	NA
Product sizing and material transfer	0.03	NA
Total plant emissions	0.34	0.04

Source: U.S. EPA, 1995 (AP-42, Table 8.5.3-1).
NA = Not applicable.
[a] PM_{10} is 85% of total PM and $PM_{2.5}$ is 30% of total PM, U.S. EPA, 1995 (Table B.2.2, Appendix B, AP-42).
[b] Assume that total plant emissions include fugitive emissions throughout the facility, and do not include emissions from the reactor, dryer, or product sizing and material transfer operations.

Brick Manufacturing

There are three brick kilns in the Bay City area that annually produce approximately 90,000 bricks each. The combustion material used for burns is mainly wood and sawdust. A study conducted in the year 2001 determined that an average brick kiln in the inventory region produces about 6,600 bricks per burn. The brick makers work 10 hours/day, 7 days/week, 52 weeks/year.

The emission factors per burn for brick manufacturing are as follows:

Pollutant	Emission Factor (lb/burn)
NO_x	10.46
CO	617.06
PM[a]	98.92
VOC	136.23

Source: El Paso Electric Company "Source Test Report for Testing on Brick Kiln" June 2002.
[a] Assume that PM = PM_{10} = $PM_{2.5}$ based on conversations with El Paso Electric representatives in charge of testing and emission factor development.

Dry Cleaning Facilities

Operational schedule = 8 hrs/day; 6 days/week; and 52 weeks/year
Weight of clothes cleaned = 200 kg/week/facility

Solvent data obtained from National Dry Cleaners Association (NDCA), 2001:

- Quantity of non-chlorinated dry cleaning solvent used in Bay City = 105,990 liters/year;
- Specific gravity of dry cleaning solvent = 0.78 at 60 °F; and
- VOC content in dry cleaning solvent = 450 g of VOC/liter of solvent.

Employees in dry cleaning facilities in Bay City are as follows:

Facility	Employees
Dry cleaner #1	8
Dry cleaner #2	14
Dry cleaner #3	22
Dry cleaner #4	16
Dry cleaner #5	20
Dry cleaner #6	10
Dry cleaner #7	9
Dry cleaner #8	29

Source: State Bureau of Economic Statistics, 2001, Bay City.

Domestic Fuel Combustion (Cooking)

The emission factors per 1,000 gallons of LPG are as follows:

Pollutant	LPG (lbs/1000 gallons)	
	Butane fraction	**Propane fraction**
CO	2.1	1.9
VOC	0.4	0.3
PM[a]	0.5	0.4
NO_x	15	14
SO_2	0.09S[b]	0.1S[b]

Source: U.S. EPA, 1995 (Chapter 1, Table 1.5-1, AP-42); English units, only
[a] Assume that total PM = PM_{10} = $PM_{2.5}$
[b] Sulfur content in fuel: S (LPG) = 0.18 gr./100 cu.ft.
Butane fraction of LPG = 60%

LPG usage in Bay City within the domestic/residential sector is estimated to be 980,564 liters (NFA, 2001).

Part 3: Planning

An Inventory Preparation Plan and Quality Assurance Plan 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 (for example, is Bay City in attainment with air pollution standards?);
- Inventory scope (for example, what geographic areas and populations will be covered? What are the pollutants of concern? What is the base year? And, what is the temporal resolution?);
- Data quality objectives;
- Inventory resources;
- Emissions estimation methodologies;

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

Student exercise: Each team will prepare an Inventory Preparation Plan outline and a Quality Assurance Plan outline.

<u>Inventory Preparation Plan Outline</u>:

1. Background and purpose of the inventory:

   A.

   B.

2. Inventory area status:

3. Inventory scope (area/facility, pollutants of concern, base year, temporal resolution):

   - Geographic area:
   - Pollutants:
   - Source Categories:
     - i. Point:
     - ii. Nonpoint:
   - Temporal resolution:

4. Data quality objectives:

   A..

   B.

5. Inventory resources:

   A. Team
   B. Overall project manager
   C. Team manager
   D. Data evaluator

6. Emissions estimation methodologies:

   List source categories in the inventory and identify source sector. Document why you chose to inventory as point or nonpoint.

   Urea Fertilizer Plant –

   Ammonium Phosphate Fertilizer Plant –

3 Brick kilns –

Dry cleaners –

Domestic fuel combustion for cooking –

Complete Tables 1 and 2.

Table 1. Point Source Emission Estimation Methodology

Plant/Process	**Pollutant**	**Methodology**	**Equation**	**Data needed**
Urea Fertilizer Plant: Solution formation and concentration Fluidized bed prilling Drum granulation Rotary drum cooler Bagging operations				Operation Data: Activity Data:
Ammonium Phosphate Fertilizer Plant: Reactor/ Ammoniator – granulation Dryer/Cooler Product sizing and material transfer Fugitive emissions				Operation Data: Activity Data:

Table 2. Nonpoint Source Emission Estimation Methodology

Source Category	**Pollutant**	**Methodology**	**Equation**	**Data needed**
Brick Manufacturing				Operation Data: Activity Data:
Dry Cleaners				Operation Data: Activity Data:

Domestic Fuel Combustion - Cooking				Operation Data: Activity Data:

7. Quality Assurance Plan

   - Introduction

   - DQOs

   -QA/QC staff

   - Summary of QA/QC

     Internal QC procedures

External QA/QC procedures

- Data Management Procedures

ATTACHMENT

INVENTORY PREPARATION PLAN AND QUALITY ASSURANCE PLAN FOR THE 2002 BAY CITY EMISSIONS INVENTORY

1.0 INTRODUCTION

This Inventory Preparation Plan and its Quality Assurance Plan describe procedures for developing point and nonpoint source emissions inventory for Bay City. The main elements of the Inventory Preparation Plan are:

- Background and purpose of the inventory;
- Inventory scope (i.e., geographic area, pollutants, source categories, and time intervals);
- Data quality objectives;
- Inventory resources;
- Emission estimating methodologies; and
- QAP.

2.0 BACKGROUND AND PURPOSE OF THE INVENTORY

There has been no previous emissions inventory for the city of Bay City. The purpose of this inventory development is to aid in policy making and to provide emission estimates for air modeling studies, primarily for ozone.

3.0 INVENTORY SCOPE

The inventory scope describes the geographical domain, pollutants, source categories, and time intervals of the estimates. The scope for this inventory is as follows:

- **Geographic area:** The city limits of Bay City.
- **Inventory region status:** Bay City is in attainment for all criteria pollutants.
- **Pollutants:** The pollutants to be inventoried are nitrogen oxides (NO_x), sulfur oxides (SO_x), volatile organic compounds (VOC), carbon monoxide (CO), and particulate matter (PM_{10} and $PM_{2.5}$).
- **Source categories:** The source categories covered in this inventory are:
    - Point sources (fertilizer plants); and

— Nonpoint sources (dry cleaners, brick manufacturing, and domestic fuel use).

- **Temporal resolution:** The emission inventory will be for the year 2002. Annual emissions (Mg) from point and nonpoint mobile sources will be estimated. Also, ozone seasonal daily emissions (kg/day) will be determined for the O_3 season (April-July).

4.0 DATA QUALITY OBJECTIVES

The following DQOs are established for the inventory:

- All significant sources of air pollution will be included; and
- 100% accuracy for all emission estimates.

5.0 INVENTORY RESOURCES

The emission inventories for Bay City, prepared using the methods described in Section 6.0, will be developed by a team consisting of [#] students. The overall project manager is [Instructor's name], and the overall emission inventory development task manager will be [student's name]. The task manager will serve as the primary decision-maker. [student's name] will serve as a data evaluator, whose responsibility will be to conduct internal quality control (QC) checks for the inventory. The other members on the team are [student's names].

6.0 EMISSION ESTIMATION METHODOLOGIES

This section describes the source categories and methodologies to be used to estimate emissions from each category. Two source category sectors will be included in the inventory – point sources and nonpoint sources.

6.1 Point Sources

Point sources are defined as industrial facilities that emit air pollutants and are located at specific stationary locations. The emissions may be either stack emissions and/or process-related fugitive emissions. The pollutants of concern for each point source include SO_2, PM_{10}, and $PM_{2.5}$. We will inventory the fertilizer plants as point sources because facility data exists.

6.1 Fertilizer Manufacturing

For most process sources, emissions will be calculated using the following general equation.

$$\mathbf{E = A \times EF}$$

Where:
E = emissions (kg/year);
A = activity level (activity units/year); and
EF = emission factor (kg/activity unit).

Estimating emissions from fertilizer plants employs the use of the above given equation. Emission factors for this point source category will be obtained from AP-42 (Table 8.2-1 for urea manufacturing and Table 8.5.3-1 for ammonium phosphate manufacturing).

Daily emissions will be calculated using daily production rates. Annual emissions will be calculated using daily production rates and days of operation per year.

Table 6.1 summarizes the point source emission estimation methods and data that will be needed to estimate emissions.

Table 6.1. Point Source Emission Estimation Methodology

Plant/Process	Pollutant	Methodology	Equation	Data needed
Urea Fertilizer Plant: Solution formation and concentration Fluidized bed prilling Drum granulation Rotary drum cooler	PM 2.5 PM10	Emission Factor and Activity Data	E_{daily} = EF x A E_{annual} = E_{daily} x days/week x weeks/yr PM10 E = 0.96 PM E PM2.5 E = 0.95 PM E E – emissions EF – emission factor A – Activity data (Mg urea produced/day) Emission Factors are for uncontrolled PM emissions	Operation Data: 5 days/week 52 week/year Amount urea produced in fertilizer operations at plant = 5 Mg/day x 0.5 = 2.5 Mg/day

Bagging operations			**EFs:** Solution formation and concentration EF = 0.0105 (kg/Mg) Fluidized bed prilling EF = 3.1 (kg/Mg) Drum granulation EF = 120 (kg/Mg) Rotary drum cooler EF = 3.89 (kg/Mg) Bagging operations EF = 0.095 (kg/Mg)	
Ammonium Phosphate Fertilizer Plant: Reactor/ Ammoniator – granulation Dryer/Cooler Product sizing and material transfer Fugitive emissions	PM2.5 PM10 SO2	Emission Factor and Activity Data	E_{daily} = EF x A E_{annual} = E_{daily} x days/week x weeks/yr PM10 E = 0.85 PM E PM2.5 E = 0.30 PM E E – emissions EF – emission factor A – Activity data (Mg ammonium phosphate produced/day) Emission Factors are for controlled PM and SO2 emissions **PM EFs:** Reactor/ Ammoniator Granulation EF = 0.76 (kg/Mg) Dryer/Cooler EF = 0.75 (kg/Mg) Product sizing and material transfer EF = 0.03 (kg/Mg) Fugitive emissions EF = 0.34 (kg/Mg) **SO2 EFs:** Fugitive emissions EF = 0.04 (kg/Mg)	Operation Data: 5 days/week 52 week/year Amount ammonium phosphate produced = 8 Mg/day

6.2 Nonpoint Sources

Nonpoint (or area) sources are defined as all stationary sources (both anthropogenic and nonanthropogenic) that are not included in the point source inventory. For the purpose of the Bay City nonpoint source inventory, a nonpoint source is defined as a stationary source of air pollution residing in the inventory region and not included in the point source inventory. We will inventory three categories in the nonpoint inventory – brick kilns, dry cleaners, and domestic fuel use in cooking. We will inventory brick kilns and dry cleaners as nonpoint because of a lack of facility data. We do not have data on individual residences for cooking and will inventory this category as nonpoint due to the number of individual residences in Bay City.

The nonpoint source inventory will include VOC, PM10, PM2.5, CO, NOx, and SO2 emissions for the base year. Annual emission estimates will be developed for the source categories listed in Table 6-2. Table 6-2 summarizes the methodology and activity data needed to estimate emissions for each nonpoint source. Table 6.3 summarizes the equations and data needed to estimate nonpoint emissions.

For the nonpoint source categories, emissions will be estimated using the U.S. EPA methodology. To the greatest extent possible, local activity data will be used for emission estimation. However, national- or state-level default values maybe used, if local-level activity data are unavailable.

Table 6-2. Summary of Methods and Activity Data Needed to Estimate Nonpoint Source Emissions

Source Category	Pollutants	Source of Methodology and Emission Factors	Activity Data	Source of Activity Data
Dry Cleaning	VOC	Material balance	Solvent usage	Local/state census bureau
Brick Kilns	PM_{10}, $PM_{2.5}$, VOC, NO_x, and CO	El Paso Electric, 2002	Brick production data	Industry groups and brick kiln operators
Domestic Fuel Use	PM_{10}, $PM_{2.5}$, VOC, NO_x, SO_2, and CO	AP-42, Chapter 1.5	Fuel usage	National Fuel Agency

Table 6.3. Nonpoint Source Emission Estimation Methodology

Source Category	**Pollutant**	**Methodology**	**Equation**	**Data needed**
Brick Manufacturing	NOx CO PM2.5 PM10 VOC	Emission Factor and Activity Data	E_{annual} = EF x A E_{daily} = E_{annual} / (weeks/yr x days/week) E – emissions EF – emission factor A – Activity data (burns/yr) PM E = PM10 E = PM2.5 E **EFs:** NOx EF = 10.46 lb/burn CO EF = 617.06 lb/burn PM EF = 98.92617.06 lb/burn VOC EF = 136.23 lb/burn	A = # burns/yr = #bricks prod per year/(bricks/burn) = 270,000 (bricks/yr) / 6600 (bricks/burn) = 41 burns/yr Operation Data: 7 days/week 52 week/year
Dry Cleaners	VOC	Material Balance – Assume all solvent is emitted	Emissions (g/year) = Amount dry cleaning solvent used (liters/yr) x VOC content (g VOC/Liter solvent) E_{daily} = E_{annual} / (weeks/yr x days/week)	Activity Data: Dry cleaning solvent used = 105,990 liters/yr VOC content = 450 g/liter Operation Data: 6 days/week 52 week/year
Domestic Fuel Combustion - Cooking	CO VOC PM10 PM2.5	Emission Factor and Activity Data:	E_{annual} = EF x A LPG E_{annual} = (Butane E_{annual} x Butane fraction of LPG) + (Propane E_{annual} x Propane fraction of LPG) E_{daily} = E_{annual} / (days/yr)	LPG usage = 980,564 liters/yr x 264.7 gal/1000 liters = 259,555,700 gal/yr Butane fraction of LPG = 0.6

	NOx SO2		E – emissions EF – emission factor A – Activity data (1000 gallons LPG) PM E = PM10 E = PM2.5 E **EFs:** **Butane EFs:** NOx EF = 15 lb/1000 gal CO EF = 2.1 lb/1000 gal PM EF = 0.5 lb/1000 gal VOC EF = 0.6 lb/1000 gal SO2 EF = 0.09 lb/1000 gal x Sulfur content **Propane EFs:** NOx EF = 14 lb/1000 gal CO EF = 1.9 lb/1000 gal PM EF = 0.4 lb/1000 gal VOC EF = 0.5 lb/1000 gal SO2 EF = 0.10 lb/1000 gal x Sulfur content **Annual Emissions Equations for LPG** NOx LPG E_{annual} = (0.6 x 15 lb/1000 gal x A) + (0.4 x 14 lb/1000gal x A) CO LPG E_{annual} = (0.6 x 2.1 lb/1000 gal x A) + (0.4 x 1.9 lb/1000gal x A) PM LPG E_{annual} = (0.6 x 0.5 lb/1000 gal x A) + (0.4 x 0.4 lb/1000gal x A) VOC LPG E_{annual} = (0.6 x 0.4 lb/1000 gal x A) + (0.4 x 0.3 lb/1000gal x A) SO2 LPG E_{annual} = (0.6 x 0.09 lb/1000 gal x Sulfur content x A) + (0.4 x 0.1 lb/1000gal Sulfur content x A)	Propane fraction of LPG = 0.4 Sulfur content of fuel = 0.18 gr/100 cu ft. Operation Data: 365 days/yr

6.2.1 Dry cleaning

Emissions for the dry cleaning source category will be estimated by using a material balance. Only non-chlorinated dry cleaning solvents will be included. It is assumed that all solvent used in Bay City is emitted. VOC emissions will be calculated by multiplying the percentage of VOC in the solvent by the amount of non-chlorinated dry cleaning solvent used in Bay City.

Daily emissions will be calculated using annual emissions divided by number of days per year of operation. For purposes of this case study, it is assumed that dry cleaners operate the same number of days each month throughout the year.

6.2.2 Brick manufacturing

For brick kilns, emissions will be calculated using the following general equation.

$$\mathbf{E = A \times EF}$$

Where:
E = emissions (kg/year);
A = activity level (activity units/year); and
EF = emission factor (kg/activity unit).

Emission factors for brick kilns will be obtained from "Source Test Report for Testing on Brick Kiln," (El Paso Electric Company, 2002). Annual emissions will be based upon annual production rate. Daily emissions will be based upon annual emissions divided by number of facility operational days per year (365).

6.2.3 Domestic fuel use

Emissions for domestic fuel use category will be calculated by using equation 6.2.3 along with annual fuel consumption data for LPG, the primary fuel used for cooking in Bay City. Daily emissions will be calculated assuming 365 days per year usage of LPG.

7.0 QUALITY ASSURANCE PLAN (QAP)

This QAP describes the quality assurance goals and procedures for the Bay City Emissions Inventory. To the extent possible, based on currently available data, the inventory must be complete with respect to all point and nonpoint sources. In addition to completeness, it is important to minimize the uncertainty associated with the base year emissions estimates.

This emission inventory will be developed based on relevant guidance material (EIIP, CORINAIR, AP-42, etc.) and according to the methodologies discussed in Section 6.0 of this IPP. The objectives of QAP are to ensure completeness and minimize uncertainty in the base year emissions inventory. How representative the inventory is of actual emission sources and conditions are also critical, and will be assessed in a number of ways. Emission factor and activity data usage will be evaluated to assure that they correspond to the associated source categories.

7.1 Data Quality Objectives (DQOs)

The 2002 Bay City Emissions Inventory will provide supporting data for air pollution policy building in Bay City. The following steps are established to help ensure the accuracy of the emission estimates:

- Accuracy checks: All the equations and calculations will be checked for accuracy, and any errors will be corrected.
- Completeness checks:
  - The list of pollutants and source categories listed in Section 6.0 of this IPP will be compared against all of the inventory documents to make certain that emissions are estimated for all the specified pollutants and source categories. Any errors will be corrected.
  - The entire inventory will be reviewed to confirm that the annual emissions are estimated for all relevant point, and nonpoint source categories.
- Representativeness:
  - The emission factors and activity data will be reviewed for appropriateness and to make sure that they are current for the source categories for all of the inventoried source categories.

7.2 QA/QC Staff

[Student's name] will serve as the QA/QC program coordinator. In this capacity, [he/she] will assure that the inventory DQOs are achieved. The QA program coordinator and the project team will first check that there is adequate management and supervision of work. They will also confirm that written procedures for data gathering, data assessment, calculation of emission estimates, QC of emission estimates, and reporting are developed and implemented.

7.3 Summary of QA/QC Procedures

For the Bay City Emissions Inventory, internal QA checks will be applied at two key points in the inventory development process:

- When calculations are complete; and
- When the inventory data are complied into a final report.

7.4 Data Management Procedures

Data management procedures include establishing and implementing procedures for:

- Data coding and recording;
- Data tracking;
- Correcting data;
- Reviewing emission estimates: In all cases, the data evaluator(s) will review the proposed emission estimation methods prior to the development of the inventory to verify the approach. All the calculations will be checked by the generator and another team member will check a minimum of 10% of the calculations.
- Correcting calculation errors: If no questionable data or calculation errors are identified, the data evaluator will sign of the calculation sheet as final. If corrections are needed, the calculation sheet will be returned to the team member who developed the estimates, with a flag indicating that corrective action is needed. Any adjustments made to the calculations will be documented. The data evaluator will again review the calculations to verify that the appropriate adjustments have been made.

- Data reporting: The data will be documented in a manner that will allow reconstruction of all inventory development activities. Any adjustments made to the data received prior to development of the emission estimates will be documented and justified. Adjustments made following QC of the estimates will also be documented.