MEXICO EMISSIONS INVENTORY PROGRAM MANUALS

VOLUME V - AREA SOURCE INVENTORY DEVELOPMENT

FINAL

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and

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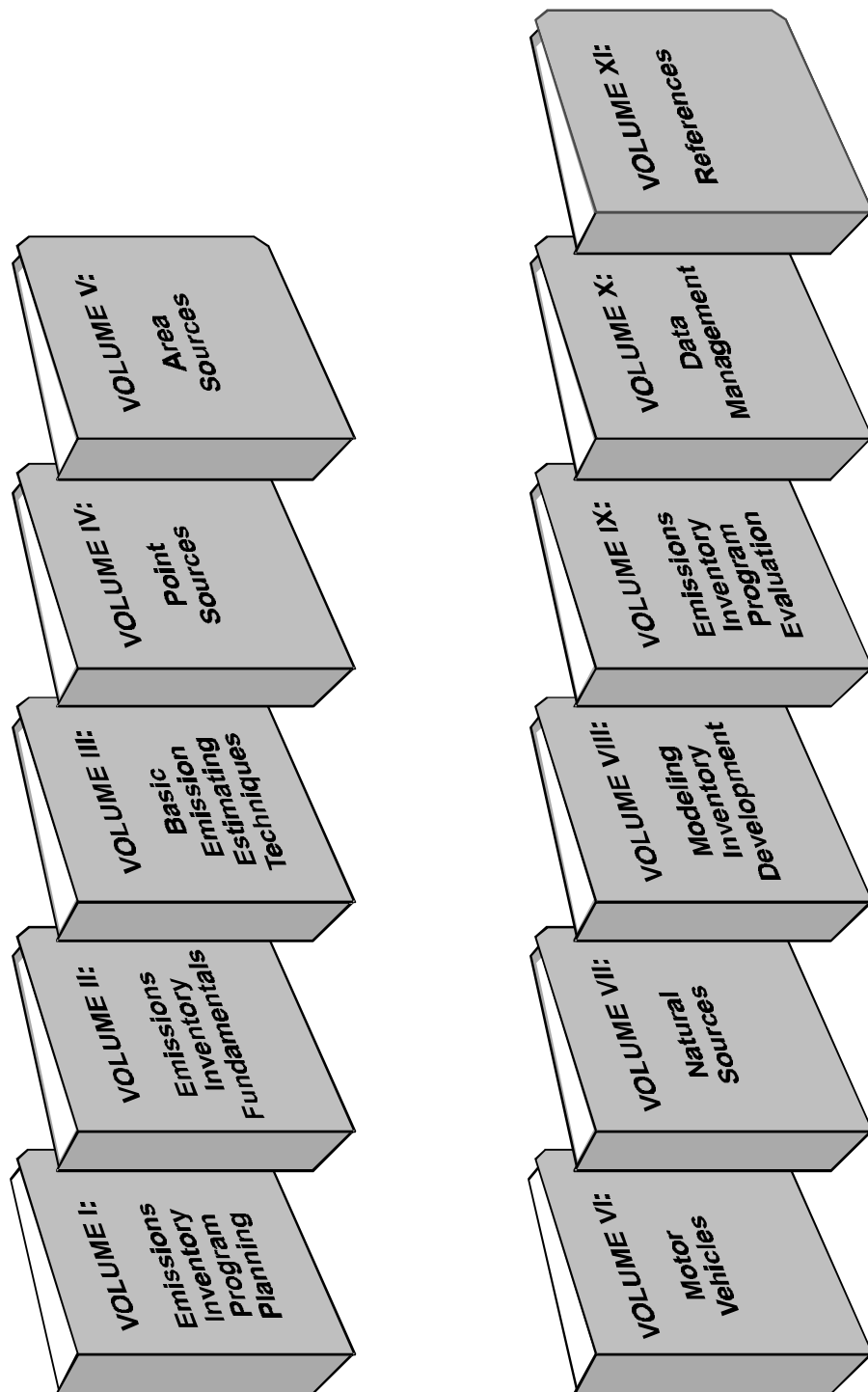Sacramento, CA 95827

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PREFACE

Air pollution can negatively impact public health when present in the atmosphere in sufficient quantities. Most rural areas rarely experience air quality problems, while elevated concentrations of air pollution are found in many urban environments. Recently, there has been an increasingly larger degree of urbanization and industrial activity throughout Mexico, resulting in air quality impairment for several regions.

Air pollution results from a complex mix of literally thousands of sources ranging from industrial smoke stacks and motor vehicles, to the individual use of grooming products, household cleaners, and paints. Even plant and animal life can play an important role in the air pollution problem. The complex nature of air pollution requires the development of detailed plans on a regional level that provide a full understanding of the emission sources and methods for reducing the health impacts associated with exposure to air pollution. Example air quality planning activities include:

- Application of air quality models;

- Examination of source attribution for emissions control where deemed necessary;

- Development of emission projections to examine possible changes in future air quality;

- Analysis of emission trends; and

- Analysis of emissions transport from one region to another.

Development of fundamentally sound emissions inventories is a key need for each of these air quality planning functions.

Developing emission estimates to meet air quality planning needs requires continual development and refinement; "one time" inventory efforts are not conducive to the air quality planning process. For lasting benefit, an *inventory program* must be implemented so that accurate emission estimates can be developed for all important geographic regions, refined over time, and effectively applied in the air quality planning and monitoring process. Consequently, a set of inventory manuals will be developed that can be used throughout the country to help coordinate the development of consistent emission estimates. These manuals are intended for use by local, state, and federal agencies, as well as by industry and private consultants. The purpose of these manuals is to assist in implementing the inventory program and in maintaining that program over time so that emissions inventories can be developed in periodic cycles and continually improved.

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VOLUME XI:
References

VOLUME X:
*Data
Management*

VOLUME IX:
*Emissions
Inventory
Program
Evaluation*

VOLUME VIII:
*Modeling
Inventory
Development*

VOLUME VII:
*Natural
Sources*

VOLUME VI:
*Motor
Vehicles*

VOLUME V:
*Area
Sources*

VOLUME IV:
*Point
Sources*

VOLUME III:
*Basic
Emission
Estimating
Techniques*

VOLUME II:
*Emissions
Inventory
Fundamentals*

VOLUME I:
*Emissions
Inventory
Program
Planning*

Figure 1. Mexico Emissions Inventory Program Manuals

The manuals cover inventory program elements such as estimating emissions, program planning, database management, emissions validation, and other important topics. Figure 1 shows the series of manuals that will be developed to support a complete inventory program. The main purpose of each manual or volume is summarized below.

Volume I—Emissions Inventory Program Planning. This manual addresses the important planning issues that must be considered in an air emissions inventory program. Program planning is discussed not as an "up-front" activity, but rather as an ongoing process to ensure the long-term growth and success of an emissions inventory program. *Key Topics*: program purpose, inventory end uses, regulatory requirements, coordination at federal/state/local levels, staff and data management requirements, identifying and selecting special studies.

Volume II—Emissions Inventory Fundamentals. This manual presents the basic fundamentals of emissions inventory development and discusses inventory elements that apply to multiple source types (e.g., point and area) to avoid the need for repetition in multiple volumes. *Key Topics*: applicable regulations, rule effectiveness, rule penetration,

pollutant definitions (excluding nonreactive volatile), point/area source delineation, point/area source reconciliation.

Volume III—Basic Emissions Estimating Techniques. This manual presents the basic methodologies used to develop emission estimates, including examples and sample calculations. Inventory tools associated with each methodology are identified and included in Volume XI (References). *Key Topics*: source sampling, emissions models, surveying, emission factors, material balance, extrapolation.

Volume IV—Emissions Inventory Development: Point Sources. This manual provides guidance for developing the point source emissions inventory. A cross-reference table is provided for each industry/device type combination (e.g., petroleum refining/combustion devices) with one or more of the basic methodologies presented in Volume III. *Key Topics*: cross-reference table, stack parameters, control devices, design/process considerations, geographic differences and variability in Mexico, quality assurance/quality control (QA/QC), overlooked processes, data references, data collection forms.

Volume V—Emissions Inventory Development: Area Sources (Includes Non-Road Mobile). This manual provides guidance for developing the area source emissions inventory. After the presentation of general area source information, a table is provided to cross-reference each area source category (e.g., asphalt application) with one or more of the basic methodologies presented in Volume III. Then, source category-specific information is discussed for each source category defined in the table. *Key Topics*: area source categorization and definition, cross-reference table, control factors, geographic differences and variability in Mexico, QA/QC, data references, data collection forms (questionnaires).

Volume VI—Emissions Inventory Development: Motor Vehicles. Because motor vehicles are inherently different from point and area sources, the available estimation methods and required data are also different. To estimate emissions from these complex sources,

models are the preferred estimation tool. Many of these models utilize extensive test data applicable to a given country or region. This manual focuses primarily on the data development phase of estimating motor vehicle emissions. *Key Topics*: available estimation methods, primary/ secondary/tertiary data and information, source categorization, emission factor sources, geographic variability within Mexico, QA/QC.

        Volume VII—Emissions Inventory Development: Natural Sources. This manual provides guidance for developing a natural source emissions inventory (i.e., biogenic volatile organic compounds [VOCs] and soil nitrogen oxide [NO_x]). In addition, this manual includes the theoretical aspects of emission calculations and discussion of specific models. *Key Topics*: source categorization and definition, emission mechanisms, basic emission algorithms, biomass determination, land use/land cover data development, temporal and meteorological adjustments, emission calculation approaches.

        Volume VIII—Modeling Inventory Development. This manual provides guidance for developing inventory data for use in air quality models and addresses issues such as temporal allocation, spatial allocation, speciation, and projection of emission estimates. *Key Topics*: definition of modeling terms, seasonal adjustment, temporal allocation, spatial allocation, chemical speciation, projections (growth and control factors).

        Volume IX—Emissions Inventory Program Evaluation. This manual consists of three parts: QA/QC, uncertainty analysis, and emissions verification. The QA/QC portion defines the overall QA/QC program and is written to complement source specific QA/QC procedures written into other manuals. The uncertainty analysis includes not only methods of assessing uncertainty in emission estimates, but also for assessing uncertainty in modeling values such as speciation profiles and emission projection factors. The emissions verification section describes various analyses that can be performed to examine the accuracy of the emission estimates. Examples include receptor modeling and trajectory analysis combined with specific data analysis techniques. *Key Topics*: description of concepts and definition of terms, inventory

review protocol, completeness review, accuracy review, consistency review, recommended uncertainty methodologies, applicable emission verification methodologies.

Volume X—Data Management. This manual addresses the important needs associated with the data management element of the Mexico national emission inventory program. *Key Topics*: general-purpose data management systems and tools, specific-purpose software systems and tools, coding system, confidentiality, electronic submittal, frequency of updates, recordkeeping, Mexico-specific databases, reports.

Volume XI—References. This manual is a compendium of tools that can be used in emission inventory program development. Inventory tools referenced in the other manuals are included (i.e., hardcopy documents, electronic documents, and computer models).

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ACRONYMS

ADT   average daily traffic

ANAFAPYT   Asociación Nacional de Fabricantes de Pinturas y Tintas (National Association of Paint and Ink Manufacturers)

ARB   Air Resources Board

ASA   Aeropuertos y Servicios Auxiliares (Airports and Auxiliary Services)

BOD   biological oxygen demand

Btu   British thermal unit

CANACINTRA   Cámara Nacional de la Industria de la Transformación (National Association of the Manufacturing Industry)

CANALAVA   Cámara Nacional de la Industria de Lavanderías (National Association of the Dry Cleaning Industry)

CE   control efficiency

CE-CERT   College of Engineering - Center for Environmental Research and Technology

CFC   chlorofluorocarbon

CH_4 methane

CICA   Centro de Información sobre Contaminación del Aire (Information Center on Air Pollution)

CICOPLAFEST   Comisión Intersecretarial para el Control del Proceso y Uso delos Plaguicidas, Fertilizantes y Substancias Tóxicas (Intersecretarial Commission for the Control of the Processing and Use of Herbicides and Pesticides, Fertilizers, and Toxic Substances)

cm   centimeter

CO   carbon monoxide

DDF   Departamento del Distrito Federal

DQO	data quality objective
EET	emissions estimating techniques
EF	emission factor
EIIP	Emission Inventory Improvement Program
FAA	Federal Aviation Administration
FAEED	Federal Aircraft Engine Emission Database
FNM	Ferrocarriles Nacionales de México (National Mexican Railways)
g	gram
gr	grain
GEM	Gobierno del Estado de México (Government of the State of Mexico)
GIS	Geographic Information System
ha	hectare
HC	hydrocarbon
HCFC	hydrochlorofluorocarbon
HDDV	heavy duty diesel vehicles
HDGV	heavy duty gasoline vehicles
HFC	hydrofluorocarbon
hp	horsepower
hr	hour
IC	internal combustion
IMP	Instituto Mexicano de Petróleo (Mexican Petroleum Institute)
INE	Instituto Nacional de Ecología (National Institute of Ecology)

INEGI	Instituto Nacional de Estadística, Geografía e Informática (National Institute of Statistics, Geography, and Information)
kcal	kilocalorie
kg	kilogram
km	kilometer
kph	kilometers per hour
lb	pound
LDDT	light duty diesel trucks
LDDV	light duty diesel vehicles
LDGT	light duty gasoline trucks
LDGV	light duty gasoline vehicles
LPG	liquefied petroleum gas
LTO	landing and takeoff
m^3	cubic meter
MC	motorcycle
Mg	megagram (i.e., 10^6 g = 1 metric ton)
mg	milligram
mm	milliliter
mm Hg	millimeters of mercury
mol	mole
mph	miles per hour
NA	not available

NFDR	National Fire Danger Rating
NH_3	ammonia
NMHC	non-methane hydrocarbons
NO	nitrogen monoxide
NO_2	nitrogen dioxide
NO_x	nitrogen oxides
N-P-K	nitrogen-phosphorus-potassium
O_2	oxygen
PEMEX	Petróleos Mexicanos
PM	particulate matter
$PM_{2.5}$	particulate matter of less than 2.5 microns aerodynamic diameter
PM_{10}	particulate matter of less than 10 microns aerodynamic diameter
POTW	publicly owned treatment works
ppmw	parts per million - weight
psi	pounds per square inch
psia	pounds per square inch absolute
QA	quality assurance
QC	quality control
RE	rule effectiveness
ROG	reactive organic gas
RP	rule penetration
RVP	Reid vapor pressure

S	saturation factor
S	sulfur
SAF	Seasonal Adjustment Factor
SAF	Society of American Foresters
SAGAR	Secretaría de Agricultura, Ganadería y Desarrollo Rural (Secretariat of Agriculture, Livestock, and Rural Development)
SCAQMD	South Coast Air Quality Management District
SCERP	Southwest Center for Environmental Research and Policy
SEMARNAP	Secretaría de Medio Ambientes, Recuros Naturals, y Pesca (Secretariat of the Environment, Natural Resources, and Fisheries)
SIMS	Surface Impoundment Modeling System
SNIFF	Sistema Nacional de Información de Fuentes Fijas (National Information System of Point Sources)
SO_2	sulfur dioxide
SO_x	sulfur oxides
SRM	Society for Range Management
THC	total hydrocarbons
TIM	time in mode
TOC	total organic compound
TOG	total organic gas
ton	English ton (i.e., 2,000 lbs)
UNAM	Universidad Nacional Autónoma de Mexico (National Autonomous University of Mexico)

U.S.   United States

USDA   United States Department of Agriculture

U.S. EPA   United States Environmental Protection Agency

VKT   vehicle kilometers traveled

VOC   volatile organic compound

vol   volume

wt   weight

yr   year

ZFN   Zona Fronteriza Norte (Northern Border Zone)

ZMCM   Zona Metropolitana de la Ciudad de México (Mexico
                 City Metropolitan Zone)

ZMG   Zona Metropolitana de Guadalajara (Guadalajara Metropolitan Zone)

ZMM   Zona Metropolitana de Monterrey (Monterrey Metropolitan Zone)

ZMVM   Zona Metropolitana de la Valle de México (Valley of Mexico Metropolitan
                 Zone)

1.0   INTRODUCTION

This manual provides guidance for developing an area and non-road mobile source emissions inventory (hereafter collectively referred to as area sources). Guidance is provided on inventory methods, including sources of activity data and applicable emission factors. General area and non-road mobile source information is presented, followed by a cross-reference table that associates each area source category with one or more of the basic emission estimating techniques (EETs) presented in Volume III of this document series, *Basic Emission Estimating Techniques*. The *Basic EETs Manual* explains and discusses each of the basic EETs, and provides sample calculations to illustrate their implementation.

Area sources represent the emissions from sources that are too numerous and dispersed to efficiently include in a point source inventory. Collectively, however, area sources are significant emitters of air pollutants, and such pollutants must be included in an emissions inventory to ensure completeness. Non-road mobile sources are included with stationary area sources primarily because the methods used to estimate area and non-road mobile emissions are very similar. In contrast, the inventory methodology applied to motor vehicles is significantly different, warranting presentation in a separate manual.

By definition, therefore, area sources are generally small and numerous. For example, gasoline stations and dry-cleaning establishments are often treated as area sources. Such facilities are typically not included in point source inventories because of the extensive effort that would be required to gather data and estimate emissions for each individual facility. One way to define area sources is based on emission level of an individual facility for a given pollutant (e.g., in the U.S., if *facility*-wide hydrocarbon emissions for any given pollutant are less than 10 tons per year, or less than 100 tons per year of oxides of nitrogen (NO_x), carbon monoxide (CO), or sulfur dioxide (SO_2), then it is considered an area source). The end-use of the inventory, the desired accuracy of the emissions, and the resources available for inventory development all contribute to

establishing the point/area source cutoff. If the cutoff is too high, many facilities will not be considered individually as point sources—and their emissions may be overlooked—or their emissions may be less accurately estimated. If the cutoff is too low, both the resources needed for contacting plants and the size of the point source database will increase significantly.

Rather than distinguishing between individual facilities and emitting devices—the method in a point source inventory—area source inventories place emissions from similar sources into *categories*. An area source inventory generally consists of the following broad categories:

- Stationary source fuel combustion (e.g., residential fuel combustion);

- Non-road mobile sources (e.g., trains and mobile equipment);

- Solvent use (e.g., small surface coating operations);

- Product storage and transport distribution (e.g., gasoline);

- Light industrial/commercial sources;

- Agriculture (e.g., feedlots, crop burning);

- Waste management (e.g., landfills); and

- Miscellaneous area sources (e.g., forest fires, wind erosion, unpaved roads).

Each of these categories is comprised of more specific source categories (e.g., organic solvent use includes commercial/consumer solvent use, dry cleaning, surface cleaning) that are defined by similar emission processes or a similarity in the methods that best estimate emissions. A comprehensive area source inventory may contain 150 or more individual source categories. For example, dry cleaning is typically represented by two or more source categories to account for the different solvents that are used (i.e., perchloroethylene versus petroleum-based solvents).

From an emissions estimating perspective, area source categories may be organized into the following four groups:

Primary Manufacturing Operations. Manufacturing facilities too small for inclusion in the point source inventory (e.g., tortilla or brick manufacturers) may be inventoried as area sources by surveying a subset of these facilities and extrapolating the results to the entire industry based on some surrogate that is assumed to be associated with emissions (e.g., number of employees, manufacturing level, etc.).

Key Process Operations. Other area source categories consist of process operations that are treated as a group with no attempt to identify the type of facility and products manufactured. Industrial degreasing is an example of this type of category. These emissions result from solvent use in vats, spray and wipe cleaning, or other operations at a wide variety of facilities, making it impractical to identify degreasing usage by industrial sector.

Non-Industrial Human Activities. The next group of area source categories include emissions that occur over broad geographic regions resulting from some form of human activity. Two examples include pesticide use and commercial/consumer solvents.

Non-Road Mobile Sources. Non-road mobile sources represent the last type of source. They are generally defined as having internal combustion engines and being mobile, but are not typically licensed for operation on public roads. The most obvious non-road mobile source categories are airplanes, locomotives, and commercial marine vessels. Other non-road categories consist of agricultural, construction, and recreational equipment. Examples include tractors, bulldozers, and boats.

The remainder of this manual is organized as follows:

- Section 2.0 presents guidance on preparing an area source inventory, including descriptions of emission sources and emission estimating techniques;

- Section 3.0 presents the area and non-road mobile source cross-reference table, linking emission estimation methods discussed in Volume III of the series, *Basic Emission Estimating Techniques*, with specific area source categories;

- Sections 4.0 through 11.0 present each area and non-road mobile source category, including a description of the source category, available emission factors, guidance on potential activity data sources, and a sample calculation.

  The various area and non-road mobile source categories are organized as follows:

  — Section 4.0 - Stationary Source Fuel Combustion,

  — Section 5.0 - Non-Road Mobile Sources,

  — Section 6.0 - Solvent Use,

  — Section 7.0 - Product Storage and Transport,

  — Section 8.0 - Light Industrial/Commercial Sources,

  — Section 9.0 - Agriculture,

  — Section 10.0 - Waste Management,

  — Section 11.0 - Miscellaneous Area Sources; and

- Section 12.0 contains references cited throughout this volume.

Please note that the activity data (e.g., population, fuel burned, solvent used, acreage, etc.) are generally <u>hypothetical values</u> that were specifically developed for the sample calculations. These values must be replaced by region-specific data in order to develop an area emissions inventory.

This manual presents the most recent recommended emission estimating methods for area sources in Mexico. As of March 1997, these methods are the most appropriate for use in Mexico. However, it is expected that this document will evolve in the future. As new Mexico-specific data and emission factors are developed, they should replace the information that is currently presented in this manual.

2.0 PREPARING AN AREA AND NON-ROAD MOBILE SOURCES EMISSIONS INVENTORY

This section introduces more of the concepts related to development of an area and non-road mobile source inventory. The *Basic EETs Manual* should be consulted for additional guidance on developing an inventory. In this section, area and non-road mobile emission sources are briefly described, planning and quality assurance/quality control (QA/QC) considerations are presented, emission estimating techniques (EETs) are discussed, and the need for adjustments to the emissions estimates is explained and illustrated. Lastly, discussions of reporting and data-coding procedures, geographic differences, and the causes of variability in emissions estimates are discussed.

2.1 Description of Emission Sources

For discussion purposes, area sources can be logically organized into the following general categories:

- Stationary source fuel combustion;

- Non-road mobile sources;

- Solvent use;

- Product storage and transport;

- Light industrial/commercial sources;

- Agriculture;

- Waste management; and

- Miscellaneous area sources.

Emissions from each source occur in a variety of ways. Fuel combustion can take place in a boiler, a fireplace, an internal combustion engine, or a non-road mobile source (e.g., locomotive, marine vessel, or aircraft). Emissions from solvent use occur through evaporation; emissions can be reduced by preventing evaporation or reducing the amount of solvent used. Product storage and transport emissions typically occur through evaporation (e.g., gasoline distribution, liquified petroleum gas [LPG] leaks). Emissions from light industrial/commercial processes occur from combustion (e.g., brick manufacturing), mechanical disturbance (e.g., building construction), or biological processes (e.g., bakeries). Emissions from agriculture occur from combustion (e.g., burning of crop residues), evaporation (e.g., pesticide application), mechanical disturbance (e.g., tilling) or biological processes (e.g., animal waste). Waste management emissions are caused by evaporation (e.g., publicly owned treatment works [POTWs]) and combustion (e.g., incineration). Emissions from miscellaneous area sources occur from combustion (e.g., forest fires, structure fires), mechanical disturbance (e.g., road dust), and biological processes (e.g., livestock ammonia [NH_3]).

A complete list of source categories can be found in Section 3.0 of this manual. Specific information regarding each source category is presented in Sections 4.0 through 11.0 of this manual.

2.2   Planning

Thorough planning at the beginning of the inventory process is essential for the development of a high quality inventory. The inventory scope is delineated in the planning phase. This includes identifying the following:

- End-uses of the inventory;

- Pollutants to be included;

- Geographic boundaries of the inventory region;

- Area and non-road mobile sources present in the inventory region;

- Area and non-road mobile sources to be included in the inventory; and

- EETs that will be used for each source category, including any adjustments that will be made.

These scope items should be clearly documented before any work begins on the emissions estimates. **The document that contains this information is called an inventory work plan.**

The purpose and intended use of an inventory are used to determine the data quality objectives (DQOs) for the inventory, as well as QA/QC requirements. DQOs are statements of the level of uncertainty a decision-maker is willing to accept. They ensure that the final inventory will be sufficient for its intended use. DQO statements must identify the end-use or intended purpose of the data, and the level of uncertainty anticipated in the emissions estimates. Hypothetical DQOs for an area source inventory may include completeness targets (e.g., "Include all sources believed to contribute more than 30,000 kg/year"), accuracy targets (e.g., "Reduce uncertainty of top three sources by conducting surveys to update emissions data"), and comparability items (e.g., "The inventory should include all sources in previously prepared inventory, and be prepared using comparable methods").

The pollutants to be included in the inventory depend on the end-use and purpose of the inventory. For example, in an ozone nonattainment area emissions inventory, reactive volatile organic compounds (VOCs), carbon monoxide (CO), and NO_x are included. In an inventory that will be used in a visibility study, additional pollutants are included, such as sulfur oxides (SO_x) and fine particulate ($PM_{2.5}$).

The geographic region that the inventory will cover also depends on the end-use of the inventory. Typically, an inventory will cover a discrete area that has a common air pollution problem and/or regulatory entity. An inventory can be developed for the whole country, an individual state, a metropolitan zone, or a municipality. For example the classification of regions done in 1991 by the National Institute of Ecology (INE) could be considered as the geographic boundaries for inventory development (see Table 2-1). These six regions were delineated by INE based on their air quality. These regions also have distinct environmental characteristics, different types of vegetation, and different climatic conditions.

Some examples of the geographic regions covered in an inventory include a study of air pollution control measures for the Monterrey Metropolitan Area (Radian International, 1996). This area comprises the city of Monterrey and the municipalities of Juárez, San Pedro, Santa Catarina, San Nicolas, Guadalupe, Apodaca, and Escobedo. The Departamento del Distrito Federal (DDF) has prepared annual inventories of reactive VOCs, NO_x, and CO for the Zona Metropolitana de la Ciudad de México (ZMCM) (DDF, 1995a and DDF, 1996a).

To determine the area and non-road mobile sources in the inventory region, a comprehensive list of source categories can be compiled from the information presented in Section 3.0 of this manual.

Several of the area source categories that may be included in an area source inventory pertain to emissions from small industrial facilities. Published data by Instituto Nacional de Estadística, Geografía e Informática (INEGI) or the Cámara Nacional de la Industria de la Transformación (CANACINTRA) can be used to determine the extent of these smaller facilities in a geographic region. For example, INEGI provides information on the geographic distribution of principal manufacturing industries by state and aggregated manufacturing value, as well as number of employees by state and industrial sector for some industries. CANACINTRA also publishes data on industrial facilities.

Table 2-1

States Included in Regions of Special Interest

REGION I	REGION II	REGION III	REGION IV	REGION V	REGION VI
Baja California	Aguascalientes	Nuevo León	Colima	Distrito Federal	Campeche
Baja California Sur	Chihuahua	San Luis Potosí	Guanajuato	Hidalgo	Chiapas
Nayarit	Coahuila	Tamaulipas	Guerrero	México	Oaxaca
Sinaloa	Durango		Jalisco	Morelos	Quintana Roo
Sonora	Zacatecas		Michoacán	Puebla	Tabasco
				Querétaro	Veracruz
				Tlaxcala	Yucatan

The sources to be included in the inventory should be prioritized based on their importance in the inventory. Resources should be allocated preferentially to the sources that are most important in meeting the end-uses of the inventory. High priority sources include those that are known to be significant contributors of air pollution; are known to be sources of specific, targeted pollutants (e.g., PM_{10}); or are most likely to impact air quality.

Section 3.0 presents the EETs for each area and non-road mobile source category. Selection of the EET for each area and non-road mobile source category also means identifying the agencies, such as PEMEX and the National Mexican Railways (FNM), that will need to be contacted for activity data and information. In the planning process, complementary point,

mobile, area, and biogenic inventory activities are also identified. Coordination is needed between these activities to ensure the completeness of the inventory and to make sure that the necessary inventory data are transferred from one group to another. For example, point source data are often needed to make adjustments in the emissions estimates for some area source categories.

Quality assurance/quality control (QA/QC) measures should also be delineated before any area or non-road mobile emissions are calculated. A good QA/QC program ensures that data collection, data handling, emission estimation, emission reporting, and documentation procedures are carefully planned and executed. A QA plan should be included as part of the inventory work plan to specify all QA/QC activities that will be followed.

2.3   Adjustments to Emission Estimates

While preparing the area source emissions estimates, or after the initial estimates have been prepared, the area source emissions estimates may need to be adjusted. Emissions estimates must often be adjusted to avoid double-counting with the point source inventory, to account for controls that are in place for some processes, to present emissions on a daily or seasonal basis rather than on an annual basis, or to adjust total organic compound (TOC) emissions if only reactive VOCs are needed for the inventory. **In general, adjustments should be made to the area source activity or emission factor data prior to calculation rather than to the emission estimate itself**. The methods used to make these adjustments are described below.

2.3.1   Point Source Adjustments

When a point source inventory and an area source inventory include emissions from the same process, the possibility of double-counting emissions exists. In these situations, the area source emission estimate should be adjusted. Certain area source categories such as commercial/consumer solvent use and architectural surface coating do not require any point

source adjustments. Others, such as fuel combustion, industrial processes, and solvent utilization, may share processes with point sources. **To avoid double counting, the point source activity is subtracted from the total activity for the source category**. The resulting area source emissions estimate is shown in the following equation:

$$\text{Area Source Activity} = \text{Total Activity of Source Category} - \text{Sum of Point Source Activity}$$

For example, if the area source emissions are calculated using employment, the number of employees at the point sources must be subtracted from the inventory region employment to give the area source employment. If the resulting area source activity is less than zero, the point source data should be reviewed for errors, and any errors found should be corrected. If area source activity is still less than zero, the area source activity is assumed to be equal to zero, with emissions only from point sources.

The point source adjustment is sometimes made by subtracting point source emissions from total source emissions, although this should be the method of last resort. If this method is used, make sure to use uncontrolled emissions (from total sources and point sources). Any emission control adjustments needed for the area sources should be made after the point source adjustment.

2.3.2   Emission Control Adjustments

Area source controls are less common than point source controls. Nonetheless, when they occur, they must be factored into the emission calculation.

Types of controls used for area sources include banning, product substitution, and changing work practices, as well as traditional end-of-pipe control

devices. Examples of banning as a method to control emissions include bans on agricultural burning, open burning, and release of open sewage. The use of product substitution to control emissions is particularly effective when solvent-based coatings are replaced with water-based coatings. Changing work practices is an effective way to prevent evaporation of solvents. Some examples include requiring that degreasing units have lids and that the lids be kept closed when not in use; that solvent-laden rags be kept in closed containers; and that automotive repair shops use gun cleaners with enclosed solvent reserve units. Add-on control devices are less commonly used on area sources than on point sources. However, emissions from some area sources could be easily reduced using control devices. Examples include gasoline distribution and landfills.

Control efficiency is the emission reduction efficiency, and is a percentage representing the amount of a source category's emissions that are controlled by a control device, process changes, or reformulation. As discussed in the *Basic EETs Manual*, the overall CE of a control device is a combination of the capture device efficiency and the control device efficiency. The capture device efficiency is the percentage of the emissions stream that is taken into the control device. The control device efficiency is the percentage of the air pollutant that is removed from the emission stream and not released to the atmosphere.

Rule effectiveness is an adjustment to the CE to account for failures and uncertainties that affect the actual performance of the control. For example, control equipment performance may be adversely affected by age of the equipment, lack of maintenance, or improper use. **A default value of 0.80 for RE is recommended if information cannot be acquired to determine the true value of RE**.

Rule penetration is the percentage of the area source category that is covered by the applicable regulation, or is expected to comply with the regulation. The RP value can be based on a percentage of the source that is regulated, a cutoff level, or regulation of an activity. **Both RE and RP are applied to entire source categories when calculating area source emission estimates**. RP is a measure of the extent to which a regulation covers a source

category. For example, regulations on gasoline underground tank filling may apply only to stations above a specified size cutoff, or to those built after a certain date.

The RP value must be estimated for each area source category; there is no default value that is feasible for all source categories. RP is calculated as:

$$\text{RP} = (\text{Uncontrolled emissions covered by regulation})/(\text{Total uncontrolled emissions}) \times 100$$

The following equation illustrates the effect of CE, RP, and RE on emissions estimates:

$$\text{Controlled emissions} = (\text{Uncontrolled emission factor}) \times (\text{activity data}) \times [(1-(CE)(RP)(RE)]$$

CE, RE, and RP are discussed in more detail in the Basic EETs manual.

2.3.3 Temporal Adjustments

Source activities for many categories fluctuate on a seasonal basis. Because emissions are generally a direct function of source activity, seasonal changes in activity levels should be examined. **For all categories, the seasonal variations in activity must be considered if seasonal or daily emissions are to estimated**. Emission factors for some categories may also be dependent on seasonal variables. The type of information needed to calculate emissions depends on the source category and the desired temporal resolution of the emissions estimates.

Some operations, such as architectural surface coating, are more active in the warmer months because of the warmer weather. Other sources such as residential heating will

exhibit activity only in colder months. Many other sources, such as processes associated with industrial facilities or commercial operations, will show no strong seasonal variability in activity throughout the year.

The best way to calculate daily or seasonal emission estimates is to obtain activity data that are specific for the season of interest. If this is not possible, an estimate of seasonal activity can be calculated using an adjustment factor applied to the annual activity.

Factors for making seasonal adjustments are often expressed as fractions. If the adjustment factor is expressed as a fraction, it is referred to as a seasonal adjustment factor (SAF). The equation below takes into consideration SAF for an ozone season emissions inventory:

$$\text{Ozone season emissions} = (\text{SAF}) \times (\text{Annual emissions estimate}) \tag{2-4}$$

If daily emissions are to be calculated, the activity days per week and weeks per year must be identified so they can be used in the emission equation. For most industrial sources, the number of days per week is five. For commercial and consumer activities, six or seven days are generally used. The following equation demonstrates adjustments to calculate a daily emissions estimate for a process with a uniform annual operation:

$$\text{Emissions per day} = (\text{Annual emissions})/[(\text{Operating days/week}) \times (\text{Operating weeks/year})] \tag{2-5}$$

A combination of the equations shown above is needed to estimate emissions for an ozone season day from a process that has annual operations that vary by season. This is shown in the following equation:

Ozone season day emissions = [(Annual emissions) $\times$ (SAF)]/[Operating days/week] $\times$ (Operating

Table 2-2 presents SAFs for ozone and carbon monoxide seasons and default activity days per week that are frequently used in the U.S. for estimating seasonal emissions. These factors are presented as examples; they will vary from area to area according to local conditions. If possible, Mexico-specific SAFs should be created, rather than relying on the U.S. SAFs presented in Table 2-2. SAFs are typically based upon local knowledge of source operations, engineering judgement, and surveying.

2.3.4   Adjustments for Non-reactive Compounds

Many different sources emit organic gases to the atmosphere. Collectively, the compounds that comprise hydrocarbon emissions are known as total organic gases (TOG). The concept of TOG includes all carbonaceous compounds except carbonates, metallic carbides, carbon monoxide, carbon dioxide and carbonic acid. From an air quality perspective, it is important to note that some of the TOG emitted to the atmosphere have limited, or no, photochemical reactivity and therefore do not participate in the formation of ozone. Nonphotochemically reactive compounds include:

- Methane;

- Ethane;

- Acetone;

Table 2-2

Area Source Seasonal Adjustment Factors and Days per Week
for the Peak Ozone and CO Seasons

Area Source	Seasonal Activity Factors		Activity Days Per Week
	Summer	Winter	
Gasoline Service Stations			
Tank Trucks in Transit	Seasonal variations in throughput vary from region to region. Use average temperature for a summer day where appropriate. Resort areas, in particular, may show marked seasonality in gasoline sales.		6
Tank Truck Unloading (Stage I)			6
Vehicle Fueling (Stage II)			7
Storage Tank Breathing Losses			7
Solvent Users			
Degreasing	0.25		6
Dry Cleaning	0.25		5
Surface Coatings			
Architectural	0.33		7
Auto Refinishing	0.25		5
Other Small Industrial	0.25		5
Graphic Arts	0.25		5
Cutback Asphalt Paving	Refer to local regulations and practices		
Pesticides	0.33		
Commercial/Consumer	0.25		7

Table 2-2

(Continued)

Area Source	Seasonal Activity Factors		Activity Days Per Week
	Summer	**Winter**	
Waste Management Practices			
Publicly Owned Treatment Works	0.35		7
Municipal Landfills	0.25		7
Stationary Source Fossil Fuel Use			
Residential	0.08	0.43	7
Commercial/ Institutional	0.15	0.35	6
Industrial	0.25	0.25	6
Solid Waste Disposal			
On-Site Incineration	0.25	0.25	7
Open Burning	Refer to local regulations and practices	Refer to local regulations and practices	7
Structure Fires	0.20	0.33	7
Agricultural and Forest Burning	Refer to local regulations	0.10	7
Wildfires	Refer to local fire conditions	0.05	7

- Perchloroethylene;

- Methylene chloride;

- Methyl chloroform (1,1,1-trichloroethane)

- Chlorofluorocarbons (CFCs);

- Hydrochlorofluorocarbons (HCFCs);

- Hydrofluorocarbons (HFCs); and

- Perfluorocarbons.

Chemicals considered to be photochemically reactive are termed reactive organic gases (ROG). By definition, therefore, ROG is a subset of TOG. This manual encourages the development of both TOG and ROG emission estimates. At first it may seem unnecessary to inventory TOG, but developing TOG emission estimates can facilitate a number of reporting functions for such things as greenhouse gases and air toxics. In addition, TOG emissions are better suited for use in three dimensional grid models used to simulate ozone formation and transport. Therefore, this manual presents hydrocarbon emission factors as TOG, but also provides the fraction of TOG that is ROG. Unless otherwise stated, all ROG/TOG fractions were obtained from the California Air Resources Board (ARB, 1991b).

2.4   **Reporting Emission Estimates and Data Coding**

Reporting and documentation are integral parts of the inventory development process. **The reporting methods and data coding procedures that will be used should be specified in the inventory work plan**. The level of detail reported for the inventory will depend primarily on the end-use of the inventory. For example, all of the information used to develop an inventory whose results will directly affect rulemaking activities should be well documented. Enough information should be reported so the emissions estimates can be reproduced by independent reviewers.

For other inventories, it may be sufficient to cite the data sources so that an interested reviewer can locate the specific data as needed. Guidance on the importance of reporting and documentation is provided in *Emission Inventory Improvement Program, Volume III* (U.S. EPA, 1996b) and *Example Documentation Report for 1990 Base Year Ozone and Carbon Monoxide State Implementation Plan Emissions Inventories* (U.S. EPA, 1992b).

For each area source emission estimate, it will be necessary to assign the source category a numerical code. This numerical code will facilitate the electronic data management of the emissions and sharing of emissions between different regions. This manual recommends the application of a 10-digit coding system. Each code is divided into segments: xx-xx-xxx-xxx. The first two digits of the code represent the following major categories:

- 21 - stationary source fuel combustion;

- 22 - mobile sources;

- 23 - industrial processes;

- 24 - solvent utilization;

- 25 - storage and transport;

- 26 - waste disposal;

- 27 - natural sources; and

- 28 - miscellaneous sources.

The next two digits provide an indication of the type of source. For example, all industrial fuel combustion inventoried under area sources would be 21-02-xxx-xxx. The remaining six digits describe the type of fuel and type of combustion device. For example, industrial liquefied petroleum gas (LPG) burned in all boiler types is 21-02-007-000 (the last three digits are listed as zeros because a specific combustion device has not been specified). Recommended numerical codes for each area source category are presented in Sections 4.0 through 8.0 with each emission

estimating methodology. A master list of the 10 digit codes is contained in Appendix V-A. In some instances, new codes were developed to accommodate Mexico-specific source categories. The Mexico-specific codes are marked with an asterisk (*) in Sections 4.0 through 11.0.

2.5   Geographic Differences and Causes of Variability

The methods used to estimate area and non-road mobile source emissions are generally more accurate on a large geographic scale than a small one. One important reason for this variability involves the use of per capita and per employee emission factors. **Emission factors relate the quantity of a pollutant released by a unit of activity. It is important to note that an average emission factor does not account for geographic variability in activity.** For example, dry-cleaning solvents are much more prevalent in urban areas than they are in rural areas.

For example, if per capita emission factors are used to estimate emissions and there are large regional differences in purchasing practices, product usage, or the use of commercial services such as dry-cleaning and auto body refinishing, they will not be taken into consideration using nationally-based per capita emission factors. The variability in emissions will only be reflected if the per capita emission factors are adjusted in some way. For example, it may be possible to conduct a survey and develop stratified per capita emission factors based on average household income to better represent activity from area and non-road mobile sources.

The use of nationally-based per employee emission factors also introduces uncertainty. These emission factors will overestimate emissions for operations that are very labor-intensive. Again, it may be possible to conduct a survey to develop per employee emission factors that represent the variability associated with the number of employees and production levels.

3.0 RECOMMENDED EMISSION ESTIMATING TECHNIQUES

Air pollutant emissions from area sources can be estimated by different emission estimating techniques (EETs). Volume III of this series, the *Basic EETs Manual*, describes each estimating technique in detail.

The techniques used to estimate area source emissions vary by source category. The selection of an EET requires consideration of the availability of data. If a large amount of data are needed to use a particular method, the costs may have to be weighed against the desired quality of the emissions estimate. For example, if the risks of adverse environmental effects from the source are high, more sophisticated and costly EETs may be necessary. Conversely, where risks are low, less expensive estimation methods may be acceptable. In some ways, the factors that drive selection of an EET for a given source category are identical to those that define the source categories to be included in the inventory (e.g., use of the inventory, costs, availability of data, etc.).

Table 3-1 recommends EETs for various area and non-road mobile source categories and identifies the pollutants that are emitted from each source category. The source categories and recommended EETs shown in Table 3-1 and discussed in Sections 4.0 through 11.0 should not be considered as definitive, but rather as general guidelines that should be adapted to the local conditions of the study area.

In Table 3-1, each applicable EET is given a ranking based on consideration of the emissions source, the availability of data, and the cost and quality of the emissions estimates. A rank of "1" indicates that a method is the most preferred. If a method does not have a ranking,

Table 3-1

Recommended Emission Estimating Techniques

Section Number	Area Source Category	Pollutants	Emission Factor	Survey/ Extrapolation	Emissions Model	Material Balance
4.1	Industrial and Commercial/ Institutional Fuel Combustion	TOG, NO$_x$, CO, PM, SO$_x$	1			
4.2	Residential Fuel Combustion (Commercial Fuels)	TOG, NO$_x$, CO, PM, SO$_x$	1			
4.3	Residential Fuel Combustion (Biomass or Waste-derived Fuels)	TOG, NO$_x$, CO, PM, SO$_x$	1			
5.1	Locomotives	TOG, NO$_x$, CO, PM, SO$_x$	1			
5.2	Commercial Marine Vessels	TOG, NO$_x$, CO, PM, SO$_x$	1			
5.3	Aircraft	TOG, NO$_x$, CO, PM, SO$_x$	1			
5.4	Other Non-Road Mobile Equipment	TOG, NO$_x$, CO, PM, SO$_x$	1			
5.5	Border Crossings	TOG, NO$_x$, CO, PM, SO$_x$			1	
5.6	Bus/Truck Terminals	TOG, NO$_x$, CO, PM, SO$_x$			1	
6.1	Industrial Surface Coating[a]	TOG	2	1		1

Table 3-1

(Continued)

Section Number	Area Source Category	Pollutants	Emission Factor	Survey/ Extrapolation	Emissions Model	Material Balance
6.2	Auto Body Refinishing[a]	TOG	2	1		1
6.3	Architectural Surface Coating[a]	TOG	2	1		1
6.4	Traffic Paints[a]	TOG	2	1		1
6.5	Industrial Surface Cleaning[a] (Degreasing)	TOG	2	1		1
6.6	Dry Cleaning	TOG	2	1		1
6.7	Graphic Arts[a]	TOG	2	1		1
6.8	Asphalt Application[a]	TOG	2	1		1
6.9	Commercial/ Consumer Solvent Use	TOG	1			
7.1	Gasoline Distribution	TOG	1			
7.2	Aircraft Refueling	TOG	1			
7.3	LPG Distribution	TOG		1		1
8.1	Bakeries	TOG	1			
8.2	Brick Manufacturing	TOG, NO_x, CO, PM, SO_x	2	1		
8.3	Construction Activities	PM	2		1	
8.4	Charbroiling	TOG, PM	1	1		
8.5	Street Vendors	TOG, PM	1	1		

Table 3-1

(Continued)

Section Number	Area Source Category	Pollutants	Emission Factor	Survey/ Extrapolation	Emissions Model	Material Balance
9.1	Pesticide Application[b]	TOG		1		1
9.2	Beef Cattle Feedlots	PM	1			
9.3	Agricultural Burning	TOG, CO, PM	1			
9.4	Fertilizer Application	NH_3	2	1		1
9.5	Animal Waste	NH_3	1			
9.6	Agricultural Tilling	PM	1			
10.1	On-Site Incineration	TOG, NO_x, CO, PM, SO_x	1			
10.2	Waste Management— Open Burning	TOG, NO_x, CO, PM, SO_x	1			
10.3	Wastewater Treatment	TOG	2		1	
10.4	Open Channel Sewage and Wastewater[b]	TOG, NH_3		1		1
11.1	Wildfires	TOG, NO_x, CO, PM, SO_x	1			
11.2	Structure Fires	TOG, NO_x, CO, PM	1			
11.3	Paved Road Dust	PM	2		1	

Table 3-1

(Continued)

Section Number	Area Source Category	Pollutants	Emission Factor	Survey/ Extrapolation	Emissions Model	Material Balance
11.4	Unpaved Road Dust	PM	2		1	
11.5	Wind Erosion	PM	2		1	
11.6	Domestic Ammonia Emissions[b]	NH$_3$		1		1

a   Emission estimates for solvent use categories can be developed using emission factors or by combining survey/extrapolation with material
    balance information obtained.
b   Emission estimates for these categories are developed by combining survey/extrapolation with material balance information obtained.
c   EETs for this category will vary based on the industries identified in the inventory area.

CO = carbon monoxide
LPG = liquified petroleum gas
NH$_3$ = ammonia
NO$_x$ = nitrogen oxides
PM = particulate matter
SO$_x$ = sulfur oxides
TOG = total organic gases

then it is not available for that source category. The basic EETs are summarized below with respect to area sources.

No single EET can be used to estimate emissions for all area sources. Volume III of this series, the *EETs Manual* should be consulted for a discussion on the selection and use of the different EETs, cost versus quality considerations, and a discussion of the advantages and disadvantages of the various EETs.

Census-Based Emission Factors. Emission factors relate the quantity of a pollutant released to a unit of activity. Emission factors can be either process-based or census-based. Process-based emission factors are normally used for point sources. Census-based

emission factors are commonly used for area sources. The use of census-based emission factors is an efficient method for dispersed and numerous emission source types that cannot be readily characterized by a knowledge of process rates, fuel consumption rates, and/or material feed rates. Compared to other EETs, the use of census-based emission factors is the most cost-effective choice, since census data are readily available for most emission inventory regions from the Instituto Nacional de Estadística, Geografía e Informática (INEGI). Most census-based emission factors, however, have been developed from U.S. data. Over time, these emission factors should be replaced with factors developed from Mexican data. As Mexican data are developed, census-based emission factors will provide a highly efficient method of calculating emissions.

Survey/Extrapolation. A survey questionnaire is the technique commonly used to gather point source inventory data. A survey approach can also be used to gather information needed to calculate area source emissions. For area sources, survey questionnaires are sent to a subset of facilities, and the results are extrapolated to the remaining facilities based on some surrogate that is related to emission levels. It is important to note here that while the survey/extrapolation method is rated higher than the use of emission factors in Table 3-1, the survey must be carefully planned and executed for this ranking to apply. If the survey is sent to a nonrepresentative subset of facilities, if the questions are not asked or answered correctly, or if the data received from respondents are not carefully handled (i.e., data entry errors), grossly inaccurate emissions estimates may result.

Emissions Models. Emissions models are designed to produce more accurate emissions estimates than an emission factor approach. However, emissions models have been developed for only a limited number of area source categories. The accuracy of the results of an emissions model are dependent not only on the quality of the input data, but on the assumptions underlying the model as well.

Material Balance. The material or mass balance approach is suitable for estimating emissions associated with solvent evaporation. In its simplest form, a material balance

approach assumes that all solvent consumed by a source evaporates. As shown in Table 3-1, the material balance approach for area sources is combined with survey results and extrapolated to an entire source category.

4.0 STATIONARY SOURCE FUEL COMBUSTION

Some small boilers, furnaces, space heaters, water heaters, and engines may be too small to be included in the point source inventory for a given inventory region. Therefore, these smaller stationary fuel combustion sources need to be included in the area source inventory effort. Inventory guidance for these sources are presented in the following subsections:

- Industrial and Commercial/Institutional Fuel Combustion;

- Residential Fuel Combustion (Commercial Fuels); and

- Residential Fuel Combustion (Biomass or Waste-Derived Fuels).

4.1   **Industrial and Commercial/Institutional Fuel Combustion**

SOURCE CODE: **DESCRIPTION:**

<u>Industrial</u>

21-02-001-000	Anthracite Coal
21-02-002-000	Bituminous/Subbituminous Coal
21-02-004-000	Distillate Oil: Total - Boilers & Internal Combustion (IC) Engines
21-02-004-001	Distillate Oil: All Boiler Types
21-02-004-002	Distillate Oil: All IC Engine Types
21-02-005-000	Residual Oil
21-02-006-000	Natural Gas: Total - Boilers & IC Engines
21-02-006-001	Natural Gas: All Boiler Types
21-02-006-002	Natural Gas: All IC Engine Types
21-02-007-000	Liquified Petroleum Gas (LPG)
21-02-008-000	Wood
21-02-009-000	Coke
21-02-010-000	Process Gas
21-02-011-000	Kerosene
21-02-012-000	Waste Oil

<u>Commercial/Institutional</u>

21-03-001-000	Anthracite Coal
21-03-002-000	Bituminous/Subbituminous Coal
21-03-004-000	Distillate Oil: Total - Boilers & IC Engines
21-03-004-001	Distillate Oil: All Boiler Types
21-03-004-002	Distillate Oil: All IC Engine Types
21-03-005-000	Residual Oil
21-03-006-000	Natural Gas: Total - Boilers & IC Engines
21-03-006-001	Natural Gas: All Boiler Types
21-03-006-002	Natural Gas: All IC Engine Types
21-02-007-000	LPG: Total - All Combustor Types
21-03-007-005	LPG: All Boiler Types
21-03-007-010	LPG: Asphalt Kettle Heaters
21-03-008-000	Wood
21-03-011-000	Kerosene: Total - All Combustor Types
21-03-011-005	Kerosene: All Boiler Types
21-03-011-010	Kerosene: Asphalt Kettle Heaters
21-03-012-000	Waste Oil: All Boiler Types
21-03-012-010	Waste Oil: Batch Asphalt Heaters

DESCRIPTION:

Industrial fuel combustion is the use of coal, oil, kerosene, natural gas, liquified petroleum gas (LPG), and wood for heating and power at industrial facilities. These fuels can be burned using a number of different equipment types including boilers, internal combustion (IC) engines, furnaces, heaters, and other heating units too small to be included in a point source inventory. Electric utilities are excluded from this category and should be inventoried as point sources. Commercial/institutional facilities are establishments that engage in retail and wholesale trade, hotels, restaurants, schools, hospitals, government buildings, etc. Note that this source category includes combustion emissions from Mexico-specific sources such as tortilla factories and public baths. The emissions from these facilities are not inventoried separately. Rather, the fuel consumption from all sources is aggregated to yield a total that is used in the emission calculation. This aggregation is done by fuel type because the emission factors vary by fuel. In addition, speciation of the emission estimates for use in a three dimensional grid model requires categorizing emissions by fuel type.

POLLUTANTS: TOG, CO, NO_x, SO_x, and PM

ROG:

For combustion sources, adjustments are necessary to account for non-reactive methane and ethane emissions. For most combustion categories, AP-42 provides emission factors for total organic compounds (TOC) and methane. Note that "TOC" in AP-42 is equivalent to "TOG." In these cases, these data should be used to develop an ROG emission factor (EF) (i.e., $EF_{ROG} = EF_{TOC} - EF_{CH4}$) and this ROG emission factor should be used to estimate ROG emissions. If the emission factor data available are not detailed enough to support this approach, then the ROG/TOG factors provided below may be used.

SOURCE CODE:	ROG/TOG:	DESCRIPTION:
Industrial		
21-02-001-000	NA	Anthracite Coal
21-02-002-000	NA	Bituminous/Subbituminous Coal
21-02-004-000	NA	Distillate Oil: Total - Boilers & IC Engines
21-02-004-001	82.8%	Distillate Oil: All Boiler Types
21-02-004-002	97.2%	Distillate Oil: All IC Engine Types
21-02-005-000	82.8%	Residual Oil
21-02-006-000	NA	Natural Gas: Total - Boilers & IC Engines
21-02-006-001	39.7%	Natural Gas: All Boiler Types
21-02-006-002	7.4%	Natural Gas: All IC Engine Types
21-02-007-000	64.6%	LPG
21-02-008-000	NA	Wood
21-02-009-000	NA	Coke

21-02-010-000	NA	Process Gas
21-02-011-000	NA	Kerosene
21-02-012-000	NA	Waste Oil

Commercial/Institutional

21-03-001-000	NA	Anthracite Coal
21-03-002-000	NA	Bituminous/Subbituminous Coal
21-03-004-000	NA	Distillate Oil: Total - Boilers & IC Engines
21-03-004-001	82.8%	Distillate Oil: All Boiler Types
21-03-004-002	97.2%	Distillate Oil: All IC Engine Types
21-03-005-000	82.8%	Residual Oil
21-03-006-000	NA	Natural Gas: Total - Boilers & IC Engines
21-03-006-001	39.7%	Natural Gas: All Boiler Types
21-03-006-002	7.4%	Natural Gas: All IC Engine Types
21-02-007-000	64.6%	LPG: Total - All Combustor Types
21-03-007-005	64.6%	LPG: All Boiler Types
21-03-007-010	64.6%	LPG: Asphalt Kettle Heaters
21-03-008-000	NA	Wood
21-03-011-000	NA	Kerosene: Total - All Combustor Types
21-03-011-005	NA	Kerosene: All Boiler Types
21-03-011-010	NA	Kerosene: Asphalt Kettle Heaters
21-03-012-000	NA	Waste Oil: All Boiler Types
21-03-012-010	NA	Waste Oil: Batch Asphalt Heaters

Note: An ROG/TOG ratio of "NA" indicates that no specific ROG/TOG ratio is available from the cited California Air Resources Board (ARB) reference. However, for "other" fuel types or combustion categories not specified in their reference, California ARB indicates that 69.9% may be used as a default value.

POINT SOURCE ADJUSTMENTS:

Emissions for this source category are estimated using emission factors and industrial and commercial/institutional fuel use (from PEMEX). Fuel used at industrial facilities included in the point source inventory should be subtracted from the total fuel used to develop an area source emissions estimate for industrial facilities. Unless specific information is known regarding commercial/institutional point sources, it can be assumed that all commercial/institutional facilities are area sources.

METHODOLOGY:

The amount of each type of fuel should be apportioned by type of combustion equipment for each fuel type. If information on specific types of combustion

equipment is not available, assumptions must be made about types of equipment present (if they can be reasonably supported), or the most conservative (highest) emission factors should be used.

Emission factors can be found in Chapter 1 of AP-42 (AP-42, 1995) and in Appendix V-B of this volume (Note: In AP-42, "TOG" is referred to as "TOC"). Sections in this chapter cover emissions from bituminous and subbituminous coal, anthracite coal, lignite, fuel oil, natural gas, LPG, wood waste, and waste oil.

The fuel used at point source facilities should be subtracted from the fuel amounts apportioned by equipment type:

$$\begin{pmatrix} \text{Area Source} \\ \text{Fuel Burned by} \\ \text{Equipment Type A} \end{pmatrix} = \begin{pmatrix} \text{Total Fuel} \\ \text{Burned by} \\ \text{Equipment Type A} \end{pmatrix} - \begin{pmatrix} \text{Point Source} \\ \text{Fuel Burned by} \\ \text{Equipment Type A} \end{pmatrix} \qquad (4.1\text{-}1)$$

Some emission factors will need to be adapted to local conditions, such as fuel sulfur or ash characteristics or fuel heat content. Refer to Volume IV of this manual series, *Emissions Inventory Development: Point Sources*, Section 3.1.1, Combustion Characteristics, for more information about fuel properties and operating conditions. A typical calculation multiplies the fuel characteristic by an emission coefficient:

$$\text{Emission Factor} = \text{Fuel Characteristic} \times \text{Emission Coefficient} \qquad (4.1\text{-}2)$$

Emission factors for each combustion equipment type are multiplied by the fuel burned by equipment type at area source facilities as shown below:

$$\text{Emissions} = \begin{pmatrix} \text{Area Source} \\ \text{Fuel Burned by} \\ \text{Equipment Type A} \end{pmatrix} \times \begin{pmatrix} \text{Emission Factor} \\ \text{for Equipment} \\ \text{Type A} \end{pmatrix} \qquad (4.1\text{-}3)$$

DATA NEEDED:

Data	Sources
Fuel used in inventory area, by type	PEMEX
Fuel use by equipment type (if available)	Survey or local information, PEMEX
Point source fuel use, by equipment type	SNIFF Database
Fuel characteristics, as needed	PEMEX
Emission factors by fuel type, equipment type	AP-42, 1995 (see Appendix V-B of this manual)

NOTES:

1.   The fuel usage data provided by PEMEX should be adjusted to reflect any local variations in types of fuel used. For example, if wood use is known to be high in the inventory area but no wood usage data are supplied by PEMEX, a survey should be conducted to determine local wood use or other sources of data should be evaluated. The Basic Emissions Estimating Techniques Manual describes the methodology for conducting a survey.

2.   If necessary, an assumption may be made that all industrial fuel (100 percent) is consumed at point source facilities, and all commercial/institutional fuel (100 percent) is consumed at area source facilities.

SAMPLE CALCULATIONS:

A.   In this example, 60,000 liters of diesel were used by the public baths in the Mexico City Metropolitan Zone (DDF, 1995a) in 1992. Information obtained from the SNIFF Database indicates that no public baths are considered to be point sources. Assume that the sulfur content of the fuel is 0.5 wt%. Emissions for SO_2 and CO are calculated using the following steps:

Steps for calculating SO_2 emissions:

1.   Subtract point source fuel use:

$$\begin{array}{c} \text{Area Source} \\ \text{Fuel Use} \end{array} = 60{,}000 \text{ liters} - 0 \text{ liters}$$

$$= 60{,}000 \text{ liters}$$

2.   Diesel fuel is similar to Number 2 distillate fuel. Therefore, the distillate
fuel emission factors from *AP-42, Section 1.3, Fuel Oil Combustion* should
be used (see Appendix V-B). The emission factor for SO_2 is a function of
a coefficient and the weight percent of sulfur content in the fuel:

$$\text{Sulfur Content} = 0.5 \% \text{ by Weight}$$

$$\begin{array}{c}\text{AP--42 Emission Factor} \\ \text{for } SO_2 \text{ (kg/10}^3 \text{ liters)}\end{array} = 17 \times 5\%$$

$$\begin{array}{c}\text{Emission Factor} \\ \text{for } SO_2 \text{ (kg/10}^3 \text{ liters)}\end{array} = 17 \times 0.5$$

$$= 8.5 \text{ kg/10}^3 \text{ liters}$$

3.   Emissions for SO_2 are then calculated as:

$$60,000 \text{ liters} \times 8.5 \text{ kg/10}^3 \text{ liters} = 510 \text{ kg } SO_2$$

Steps for calculating CO emissions:

1.   Point source subtraction is calculated above.

2.   The AP-42 emission factor is 0.6 kg/10^3 liters.

3.   Emissions for CO are then calculated as:

$$60,000 \text{ liters} \times 0.6 \text{ kg/10}^3 \text{ liters} = 36 \text{ kg CO}$$

B.   In this example, 67,030,000 liters of LPG were used by the tortilla factories
(tortillerias) in the Mexico City Metropolitan Zone (DDF, 1995a) in 1992.
Assume that information obtained from the SNIFF Database indicates that some of
these tortilla factories are already included in the point source inventory (and that
they use 12,000,000 liters of LPG). Emissions for CO are calculated using the
following steps:

1.   Subtract point source fuel use

Area Source LPG Use   =   67,030,000 liters - 12,000,000 liters
                           =   55,030,000 liters

2.   Determine the CO emission factor:

For LPG combustion, AP-42 presents emission factors for the combustion of butane and the combustion of propane (see Appendix V-B, Section 1.5). For emission calculating purposes, Mexican LPG is approximately 60% propane and 40% butane (PEMEX, 1996).

$$
\begin{aligned}
EF \quad &= \quad (60\% \times EF_{propane}) + (40\% \times EF_{Butane}) \\
&= \quad (60\% \times 0.2) + (40\% \times 0.3) \\
&= \quad 0.24 \text{ kg CO}/10^{3} \text{ liters}
\end{aligned}
$$

3.   Emissions for CO are then calculated as:

$(55{,}030{,}000 \text{ liters}) \times (0.24 \text{ kg}/10^{3} \text{ liters}) = 13{,}200 \text{ kg CO}$

4.2   Residential Fuel Combustion (Commercial Fuels)

SOURCE CODE: **DESCRIPTION:**

21-04-001-000	Anthracite Coal
21-04-002-000	Bituminous/Subbituminous Coal
21-04-004-000	Distillate Oil
21-04-005-000	Residual Oil
21-04-006-000	Natural Gas: Total
21-04-007-000	LPG
21-04-011-000	Kerosene

DESCRIPTION:

> The residential fuel combustion (commercial fuels) category is for the combustion of coal, oil, natural gas, and LPG used for heating of individual homes and apartment complexes. Non-commercially available fuels (e.g., wood, crop waste, waste oil, waste solvents, tires, etc.) are excluded from this category and should be inventoried as residential fuel combustion (biomass and waste-derived fuels). Additionally, emissions from leaks and evaporation from LPG storage and distribution systems should be inventoried as LPG distribution sources.
>
> In Mexico, diverse types of fuel are used domestically, principally for cooking food and in water heaters. Each year approximately 2 million tons of LPG are used for residential cooking and heating in Mexico City. (Sacramento Bee, 1995a). The Metropolitan Zone of the Valley of Mexico (ZMVM) is the largest LPG market in the world with the LPG consumption, at 70,000 barrels per day, almost the same as that of gasoline. The use of LPG for cooking and heating water in Mexico extends throughout all regions, and according to the data from INEGI, about 70% of the residential houses in Mexico use gas for cooking. However, in the city of Monterrey, Nuevo León, natural gas is the primary domestic fuel used and in Chiapas and Oaxaca wood and coal predominate.

POLLUTANTS: TOG, CO, NO_x, SO_x, and PM

ROG: For combustion sources, adjustments are necessary to account for methane and ethane emissions. For most combustion categories, AP-42 provides emission factors for TOC and methane. Note that "TOC" in AP-42 is equivalent to "TOG." In these cases, these data should be used to develop an ROG EF (i.e., $EF_{ROG} = EF_{TOC} - EF_{CH4}$) and this ROG emission factor should be used to estimate ROG emissions. If the emission factor data available are not detailed enough to support this approach, then the ROG/TOG factors provided below may be used.

SOURCE CODE: ROG/TOG: DESCRIPTION:

21-04-001-000	NA	Anthracite Coal
21-04-002-000	NA	Bituminous/Subbituminous Coal
21-04-004-000	NA	Distillate Oil
21-04-005-000	82.8%	Residual Oil
21-04-006-000	NA	Natural Gas: Total - All Combustor Types
21-04-007-000	64.6%	LPG: Total - All Combustor Types
21-04-011-000	NA	Kerosene: Total - All Combustor Types

Note: An ROG/TOG ratio of "NA" indicates that no specific ROG/TOG ratio is available from the cited California ARB reference. However, for "other" fuel types or combustion categories not specified in their reference, California ARB indicates that 69.9% may be used as a default value.

POINT SOURCE ADJUSTMENTS:

Emissions for this source category are generally not included in a point source inventory. Therefore, it is not expected that point source adjustments will be necessary. However, as illustrated in the example calculation, care must be taken to ensure that the fuel usage data correctly reflects <u>residential</u> usage and does not include any industrial or commercial usage.

METHODOLOGY:

The amount of each type of fuel combusted for domestic use needs to be determined for the inventory region. If the fuel usage statistics available do not directly correspond to the needs of the inventory effort (e.g., statewide statistics are available but the inventory region includes portion of multiple states; statewide statistics are available, but the inventory requires municipal-level emission estimates), then census data (e.g., population or housing) can be used to resolve this issue. The sample calculation presented below illustrates this procedure.

Emission factors can be found in Chapter 1 of AP-42 (AP-42, 1995) and in Appendix V-B of this volume (Note: In AP-42, "TOG" is referred to as "TOC"). Sections in Chapter 1 cover emissions from bituminous and subbituminous coal, anthracite coal, lignite, fuel oil, natural gas, LPG, wood waste, and waste oil. If AP-42 does not specifically provide "residential" emission factors for a given fuel type (e.g., LPG combustion), the commercial or institutional emission factors should be used.

Some emission factors will need to be adapted to local conditions, such as fuel sulfur or ash characteristics or fuel heat content. Refer to Volume IV in this series of manuals, *Emissions Inventory Development: Point Sources*, Section 3.1.1,

Combustion Characteristics, for more information about fuel properties and operating conditions. A typical PM or SO_x emission factor consists of a fuel characteristic (ash or sulfur content) multiplied by an emission coefficient (empirical constant):

$$\text{Emission Factor} = \text{Fuel Characteristic} \times \text{Emission Coefficient} \qquad (4.2\text{-}1)$$

For each fuel type, the quantity of fuel burned by residential sources are multiplied by the emission factors for each combustion equipment type as shown below:

$$\text{Emissions} = \begin{pmatrix} \text{Area Source} \\ \text{Fuel Burned by} \\ \text{Equipment Type A} \end{pmatrix} \times \begin{pmatrix} \text{Emission Factor} \\ \text{for Equipment} \\ \text{Type A} \end{pmatrix} \qquad (4.2\text{-}2)$$

DATA NEEDED:

Data	Sources
Fuel used in inventory area, by fuel type	PEMEX
Population or Housing Data	INEGI, 1993
Fuel characteristics, as needed	PEMEX
Emission factors by fuel type, equipment type	AP-42, 1995 (see Appendix V-B of this manual)

NOTES:

1. The fuel usage data provided by PEMEX should be adjusted to reflect any local variations in types of fuel used. For example, if coal use is known to be high in the inventory area but no coal usage data are supplied by PEMEX, other sources of data should be evaluated or a survey should be conducted to determine local coal use.

2. If fuel characteristics data are not available from PEMEX, the Mexican Official Norm NOM-086-ECOL-1994 have the following specifications for sulfur content of fuels that may be used as default values:

Fuel type	Maximum sulfur level (wt%)[a]	Typical sulfur value in 1995 (wt%)[b]
Magna sin	0.10	—
Magna sin (ZFN)	0.10	—
Magna sin (ZMCM) (a partir de 1998 también en la ZMM y ZMG)	0.10	0.048
Nova plus	0.15	—
Nova plus (ZMCM) (a partir de 1998 también en la ZMM y ZMG)	0.15	0.07
Diesel sin (ZMCM, ZMM y ZMG)	0.05	0.041
Diesel desulfurado	0.5	—
Diesel industrial	0.5	—
Gasóleo industrial	2.0	—
Combustóleo pesado	4.0	—
Combustóleo hidrotratado (ZMCM) (a partir del 1° de enero de 1988)	1.0	—
Combustible ligero (para zonas críticas)	2.0	—
Gas natural	0.32 dm^3/m^3	—
Gas licuado de petróleo (Gas L.P)	0.14 kg/mg	—
Turbosina	0.3	—

[a] Source: Norma Oficial Mexicana NOM-086-ECOL-1994
[b] Source: Programa para mejorar la calidad del aire en el Valle de México 1995-2000; DDF, GEM, SEMARNAP, SSa.; 1996.

3.   Detailed studies are not available on the efficiency of LPG combustion equipment that are used in Mexico, but, in general, the efficiency is low. In some cases, up to 20% of the hydrocarbons are released uncombusted, and these equipment tend to work with excess air, which reduces the thermal efficiency even more (DDF, et al, 1996). If available, Mexico-specific data should be used to adjust the AP-42 emission factors to reflect incomplete combustion.

SAMPLE CALCULATION:

This example shows how to calculate emissions from residential LPG combustion in Benito Juárez, a delegation of Mexico City, and is based on data obtained to develop the residential fuel combustion emissions for the Mexico City area source inventory (DDF, 1995a). Emissions for SO_2 and CO are calculated using the following steps:

1.   Determine the amount of residential LPG use in the ZMCM:

In Oficio GPASI-1511/93, PEMEX reported that the total amount of LPG consumed in the ZMCM in 1993 was 3830.31 x 10^3 cubic meters (m^3). Based on 1992 PEMEX figures, it was estimated that 80% of the total LPG use was for residential purposes. Therefore,

Total residential LPG use in ZMCM $= (3830.31 \times 10^3 \ m^3) \times (80\%)$
$$= 3064.25 \times 10^3 \ m^3$$

2.   Determine the amount of residential LPG use in Benito Juárez:

Delegation-specific fuel usage data were not obtained from PEMEX. Therefore, INEGI population data were used to disaggregate the ZMCM fuel usage data to the individual delegations. The total ZMCM population was 14,564,679 and the Benito Juárez population was 407,811. Therefore,

Total residential LPG use in Benito Juárez
$$= (3064.25 \times 10^3 \ m^3) \times (407,811 \ / \ 14,564,679)$$
$$= 85.799 \times 10^3 \ m^3$$
$$= 85,799 \times 10^3 \ liters$$

Note: It is preferable to use housing data if most of the fuel is used for heating. However, in this case, most of the LPG is used for cooking purposes, so population data are preferred.

3.   Determine the SO_2 emission factor:

The AP-42 emission factors for SO_2 are (0.011S and 0.012S. That is, they are a function of a coefficient (i.e., 0.011 and 0.012) and the sulfur content in the fuel (i.e., S, expressed in gr/100 ft^3). Based on the metric equivalent used by DDF (i.e., 0.009 g/100 m^3):

S(gr/100 ft^3) $= (0.009 \ g/100 \ m^3) \times (m^3/35.31 \ ft^3) \times (lb/453.6 \ g) \times (7000 \ gr/lb)$
$$= 0.0039 \ gr/100 \ ft^3$$

For LPG combustion, AP-42 presents emission factors for the combustion of butane and the combustion of propane (see Appendix V-B, Section 1.5). Therefore, the composition of the LPG used in the inventory region is needed to determine which set of emission factors to use (or whether to use a combination of the two). In highly industrialized countries, LPG is generally at least 95% propane. In Mexico, however, a mixture is sold in which propane predominates but which also contains an appreciable amount of butane, isobutane, propylene, and butylenes (DDF, et al., 1996). For emission estimating purposes, Mexican

LPG is approximately 60% propane and 40% butane (PEMEX, 1996). Therefore, if region-specific data are not obtained for Benito Juárez, the LPG emission factors could be calculated as follows:

$$EF_{(SO_x)(\text{Benito Juárez})} = (60\% \times EF_{\text{Propane}}) + (40\% \times EF_{\text{Butane}})$$
$$= (60\% \times 0.012S) + (40\% \times 0.011S)$$
$$= (0.6 \times 0.012 \times 0.0039) + (0.4 \times 0.011 \times 0.0039)$$
$$= 4.52 \times 10^{-5} \text{ kg } SO_x/1000 \text{ liters}$$

NOTE: Since "domestic" emission factors are not specified in this section of AP-42, "commercial" emission factors are used.

4.   Emissions for SO_2 are then calculated as:

$(85,799 \times 10^3 \text{ liters})$ times $(4.52 \times 10^{-5} \text{ kg}/10^3 \text{ liters}) = 3.9 \text{ kg } SO_2$

5.   Determine the CO emission factor:

As previously shown, if region-specific data are not obtained for Benito Juárez, the LPG emission factors could be calculated as follows:

$$EF_{CO(\text{Benito Juárez})} = (60\% \times EF_{\text{Propane}}) + (40\% \times EF_{\text{Butane}})$$
$$= (60\% \times 0.2 \text{ kg}/1000 \text{ liters}) + (40\% \times 0.3 \text{ kg}/1000 \text{ liters})$$
$$= 0.24 \text{ kg CO}/1000 \text{ liters}$$

6.   Emissions for CO are then calculated as:

$(85,799 \times 10^3 \text{ liters}) \times (0.24 \text{ kg}/10^3 \text{ liters}) = 20,600 \text{ kg CO}$

4.3   Residential Fuel Combustion (Biomass or Waste-Derived Fuels)

SOURCE CODE: **DESCRIPTION:**

21-04-008-000   Wood or Biomass
21-04-013-000*   Other Waste-Derived Fuels

*Proposed Mexico-specific code for source category not typically inventoried in the U.S.

DESCRIPTION: The residential fuel combustion (biomass and waste-derived fuels) category
includes the combustion of wood, biomass, manure, scrap materials, tires,
and other waste-derived fuels. These fuels are used for both residential
heating and cooking purposes. In most areas, recent regulations have
banned the burning of tires and other waste-derived materials which emit
strong odors and/or toxic pollutants. However, clandestine burning of
these materials is likely to occur in some areas.

Unlike the commercial fuels used in residential fuel combustion (described
in Section 4.2), biomass and other waste-derived fuels are usually not
distributed commercially (with the exception of commercial firewood).
Waste-derived fuels also tend to be used by the lower socioeconomic
classes of the population. For these reasons, assessing the amount of
biomass and other waste-derived fuels used in a region can be somewhat
problematic. The information presented below provides guidance
regarding how to estimate emissions from this category.

POLLUTANTS: TOG, CO, NO_x, SO_x, and PM_{10}

ROG: For residential wood combustion, ROG is 41.5% of TOG. ROG fractions have
not been developed for waste-derived fuels, although other biomass and scrap
material fuels probably have similar ROG fractions compared to residential wood
combustion.

POINT SOURCE ADJUSTMENTS: None.

METHODOLOGY:

The amount of each type of biomass and other waste-derived fuel combusted for
domestic use needs to be determined for the inventory region. The first step is to
estimate the fraction of households that use these types of fuels. The second step
is to determine the per household fuel use.

Ideally, the fraction of total households using biomass and other-derived fuels should be determined through region specific surveying. If survey information is not available, the number of households can be calculated from INEGI and other census statistics. INEGI or other census statistics identify the number of households that use commercial fuels (i.e., coal, oil, natural gas, and LPG). Subtracting the fraction of households using commercially available fuels from the total number of households results in the fraction of households using biomass and other waste-derived fuels. It is important to realize that INEGI and other census statistics may present information on the national or state level that might not be accurate at the local level. These situations warrant local level surveying.

After the number of households using biomass or other waste-derived fuels has been established, the next step is to determine the per household amount of fuel combustion. The amount of fuel used for cooking is likely to be similar in different regions. However, the amount of fuel used for heating is a function of local meteorological conditions. Obviously, cooler locations will tend to use more fuel for heating compared to warmer locations.

Once again, local surveying is the preferred method to be used to estimate per household fuel use. If local survey information is unavailable, INEGI statistics or local officials can be consulted for estimates of per household fuel use. However, because these fuels are not commercially available, it is unlikely that INEGI or local officials have compiled per household use statistics for these fuels.

Lacking information from surveying or statistical data, a rough estimate of per household fuel use for biomass and other waste-derived fuels can be made by using the concept of "fuel equivalence." Per household fuel use for coal, natural gas, LPG, and other commercially available fuels can be estimated by dividing total residential use of a commercially available fuel by the total number of households using that specific fuel. The derived per household fuel use for a certain commercial fuel has a given energy content. This energy content is "equivalent" to some amount of wood, rubber, or other waste-derived fuel. This calculation of biomass or waste fuels is shown in the following equation:

$$\text{Fuel}_{BW} = \text{Fuel}_{comm} \times \left(\frac{\text{EC}_{Comm}}{\text{EC}_{BW}} \right) \times \left(\frac{\text{Eff}_{comm}}{\text{Eff}_{BW}} \right) \qquad (4.3\text{-}1)$$

where: Fuel_{BW} =   Annual per household biomass/waste fuel usage (kg/yr);

Fuel_{Comm} =   Annual per household commercial fuel usage (kg/yr or liter/yr);

EC_{Comm} =   Energy content of commercial fuel (kcal/kg or kcal/liter);

EC_{BW}	=	Energy content of biomass/waste fuel (kcal/kg);
EFF_{Comm}	=	Efficiency of commercial fuel combustion; and
EFF_{BW}	=	Efficiency of biomass/waste fuel combustion.

The efficiencies of commercial fuel and biomass/waste fuel combustion are also included in Equation 4.3-1. However, due to variable and unknown efficiencies, these effects are often ignored. This method is approximate and should only be used when local surveying and census information is not available. This "fuel equivalence" method was used for the estimation of TOG and PM_{10} as a part of an air toxics inventory in Nogales, Sonora.

U.S.-based emission factors for residential wood combustion (fireplaces and woodstoves) can be found in Sections 1.9 and 1.10 of AP-42 (AP-42, 1995) and in Appendix V-B of this volume (Note: In AP-42, "TOG" is referred to as "TOC"). Mexico-specific emissions data for waste wood combustion have been developed by researchers at the University of Utah and Southwest Center for Environmental Research and Policy (SCERP) (Summit et al, 1996). These emissions data were derived from a limited number of source tests of a residential heater purchased in Ciudad Juárez using various waste wood fuels (U.S. pallets, Mexican pallets, and particle board). Emissions data for CO, total hydrocarbons (THC), and nitrogen monoxide (NO) are presented below in Table 4.3-1; emissions data for PM are still under development. It should be noted that there is a large amount of uncertainty associated with these emissions due to a limited number of source tests.

Table 4.3-1

CO, THC, and NO Emissions Data for Various Waste Wood Fuels

Fuel Type	CO (g/kg wood)	THC (g/kg wood)	NO (g/kg wood)[a]
U.S. Pallet	45 ± 4.5	3.0 ± 1.3	0.76 ± 0.19
Mexican Pallet	31 ± 7.5	2.3 ± 1.2	0.62 ± 0.040
Particle Board	66 ± 23	3.3 ± 1.8	3.5 ± 0.96

Source: Summit et al., 1996
[a] Emissions for NO only are available. It appears that data for NO_x was not developed. NO_x is the combination of NO and NO_2, expressed as NO_2.

U.S.-based emission factors for residential combustion of other types of refuse can be found in Section 2.5 of AP-42. Section 2.5 of AP-42 also includes emission factors for the open burning of crop wastes and tires that could be used to estimate emissions for the residential combustion of these fuels. The use of open burning emission factors, however, would be highly uncertain due to different combustion conditions.

It is recommended that Mexico develop Mexico-specific emission factors for the actual combustion practices and fuels being used. Until these Mexico-specific emission factors have been developed, it is recommended that the emission factors used in Table 4.3-1 be used, where applicable. If these factors are not applicable, then AP-42 emission factors found in Appendix V-B of this manual should be used.

For each fuel type, emissions are calculated by multiplying the quantity of fuel burned by its emission factor as shown below:

$$\text{Emissions} = \text{Fuel}_{\text{Total}} \times \text{EF} \tag{4.3-2}$$

DATA NEEDED:

Data	Sources
Number of households using biomass or waste-derived fuels	Survey or local information, INEGI
Per household fuel use	Survey or local information, INEGI, or "fuel equivalence" method
Emission factors by fuel type	AP-42, 1995 (see Appendix V-B) or Summit et al., 1996 (see above)

SAMPLE CALCULATION:

Local survey information indicates that in a metropolitan area containing 80,000 households, 1.5% of the households burn pallets. The survey information, however, does not indicate the average quantity of pallets burned by these households. A typical household using LPG uses 600 liters per year. Annual CO emissions for pallets used as residential fuels are calculated using the following steps:

1.   Calculate number of households using wood pallets as fuel:

   $80,000 \times 0.015 = 1,200$ households using pallets as fuel

2.   Calculate energy content of LPG:

   Assume that local LPG is 60% propane and 40% butane (rounded values from PEMEX, 1996). Also, assume that the energy content of butane is 6,790 kcal/liter and that the energy content of propane is 6,090 kcal/liter (AP-42, 1995)

$$(0.6 \times 6{,}090) + (0.4 \times 6{,}790) = 6{,}370 \text{ kcal/liter LPG}$$

3.   Calculate annual household use of pallets as fuel:

Assume that the energy content of pallet wood is 4,445 kcal/kg (Summit et al, 1996). Also assume that the combustion efficiencies for LPG and pallet wood are identical and can be ignored.

$$\left(\frac{600 \text{ liters LPG}}{\text{household}} \right) \times \left(\frac{6{,}370 \text{ kcal}}{\text{liters LPG}} \right) \times \left(\frac{1 \text{ kg wood}}{4{,}445 \text{ kcal}} \right) = \frac{860 \text{ kg wood}}{\text{household-yr}}$$

4.   Calculate annual CO emission:

$$\left(1{,}200 \text{ households} \right) \times \left(\frac{860 \text{ kg wood}}{\text{household-yr}} \right) \times \left(\frac{31 \text{ g CO}}{\text{kg wood}} \right) = 31{,}992 \text{ kg CO}$$

$$= 32.0 \text{ Mg CO}$$

5.0 NON-ROAD MOBILE SOURCES

Typically, only on-road motor vehicles (e.g., cars, trucks, buses, motorcycles) are included in the mobile source inventory for a given inventory region. Therefore, non-road mobile sources need to be included in the area source inventory effort. Inventory guidance for these sources are presented in the following subsections:

- Locomotives;

- Commercial Marine Vessels;

- Aircraft;

- Other Non-Road Mobile Equipment (includes Recreational, Construction, Industrial, Lawn and Garden, Farm, Light Commercial, Logging, and Airport Service Equipment);

- Border Crossings; and

- Bus/Truck Terminals.

5.1   Locomotives

SOURCE CODE: **DESCRIPTION:**

22-85-002-005   Line Haul Locomotives
22-85-002-010   Yard Locomotives

DESCRIPTION:

>   In Mexico, railway service is provided by a single, state company, Ferrocarriles
>   Nacionales de Mexico (FNM), which has two types of operations: line haul
>   (Foraneas) and yard or switch (Patio) operations. Line haul locomotives generally
>   travel between distant locations, such as from one city to another (including
>   intermodal freight service, mixed freight service, and passenger service) using
>   locomotives rated at 3,000 horsepower (hp). Yard locomotives are primarily
>   responsible for moving railcars within a particular railway yard, and use
>   locomotives rated at 1,800 hp.
>
>   There are two types of locomotives used in most railway systems: electric and
>   diesel-electric. Electric locomotives are powered by electricity generated at
>   stationary power plants and distributed by either a third rail or overhead system.
>   Emissions are produced only at the electrical generation plant, and are not covered
>   in a non-road inventory. Diesel-electric locomotives use a diesel engine and an
>   alternator or generator to produce the electricity required to power the traction
>   motors.

POLLUTANTS: TOG, CO, NO_x, SO_x, PM

ROG: ROG emissions are 97.2% of TOG for diesel combustion.

POINT SOURCE ADJUSTMENTS: None.

METHODOLOGY:

>   Emissions from line haul and yard locomotives must be calculated separately. In
>   this guidance, methods are provided for each of these operations. Note that only
>   emissions from diesel-electric locomotives are considered in this section.

Line Haul Operations

>   For this source category, emissions are estimated based on the amount of fuel
>   combusted.

If the line haul locomotives only travel within the inventory area, fuel consumption can be determined directly from the amount of fuel dispensed. However, line haul locomotives do not necessarily limit their travel to an inventory area, and therefore do not necessarily consume the fuel in the same location where the fuel is dispensed. The amount of fuel combusted in the area of interest must be first determined in order to estimate emissions.

It is recommended that fuel consumption be allocated by track length so the percentage of fuel consumed is based on the percentage of track length within the inventory area as noted in the following equation:

$$F_{ci} = F_{cn} \times \frac{TL_i}{TL_n} \tag{5.1-1}$$

where:

F_{ci}	=	Railroad fuel consumption for inventory area i (liter);
F_{cn}	=	National railroad fuel consumption (liter);
TL_i	=	Track length for inventory area i (km); and
TL_n	=	National railroad track length (km).

To estimate emissions, emission factors need to be applied to fuel consumption values, as noted in the following equation:

$$EL_{pi} = F_{ci} \times EF_{lp} \tag{5.1-2}$$

where:

EL_{pi}	=	Estimated annual emissions (kg) for pollutant p for inventory area i for long haul railroad operations;
F_{ci}	=	Railroad fuel consumption for inventory area i (liter/year); and
EF_{lp}	=	Emission factor for pollutant p (kg/liter) (from data table).

Track length data can be obtained from FNM, by measuring distance on local maps, or by using the U.S. Department of Transportation's Geographic Information System (GIS) study (*http://www.bts.gov/cgi-bin/gis/ntad-download.pl/mexrail*). If, for example, it has been estimated that 10 percent of the national track length runs within the inventory area, multiply the total national fuel consumption for the railroad by 0.10, in order to apportion the total fuel consumed in the inventory area.

DATA NEEDED - Line Haul Operations:

Data	Sources
National Railroad Fuel Data (1996): 652.4×10^6 liter/yr	Nava, 1996
National Track Length (1996): 20,447 km	Nava, 1996
Inventory Area Track Length	FNM, measurements from local maps, or GIS Data Base
Inventory Area Fuel Use	Calculated using Equation (5.1-1)

Emission Factors
       TOG   0.0025 kg/liter
       CO   0.0075 kg/liter
       NO_x 0.0591 kg/liter
       SO_2[a]   0.0043 kg/liter
       PM   0.0014 kg/liter
	U.S. EPA, 1992a

[a] SO_2 emissions are calculated based on an assumed fuel sulfur content of 0.25 percent by weight.

$$\left(\text{i.e.} \ \frac{0.863 \ \text{kg fuel}}{\text{liter fuel}} \times \frac{0.0025 \ \text{kg S}}{\text{kg fuel}} \times \frac{2 \ \text{kg SO}_2}{\text{kg S}} = \frac{0.004315 \ \text{kg SO}_2}{\text{liter fuel}} \right)$$

SAMPLE CALCULATION:

Calculate TOG emissions for Inventory Area A, which has 1,100 km of railroad. National track length in 1996 was 20,447 km and national railroad fuel consumption was 652.4 million liters. Fuel usage in the inventory area is:

$$= 652.4 \times 10^6 \ \text{liters} \left(\frac{1,100 \ \text{km}}{20,447 \ \text{km}} \right)$$
$$= 35.0 \times 10^6 \text{liters}$$

Estimated Emissions of TOG are:

$$= (35.0 \times 10^6 \ \text{liters}) \times (0.0025 \ \text{kg/liter})$$
$$= 87,500 \ \text{kg}$$
$$= 87.5 \ \text{Mg}$$

Yard Operations

Yard locomotive emissions are derived by multiplying the number of yard locomotives operating within the inventory area by the emissions generated by each unit during the year. The equation is:

$$EY_{pi} \ = \ NY_i \ \times \ EF_{yp} \qquad\qquad (5.1\text{-}3)$$

where: EY_{pi} =   Estimated annual emissions (kg) for pollutant p for inventory area i for yard railroad operations;

NY_i =   Number of yard locomotives that operate in inventory area i; and

EF_{yp} =   Yard locomotive emission factors for pollutant p (kg/year) (from the data table).

Because yard locomotives operate within the boundaries of the railway yard, it is possible to estimate the number of yard locomotives operating within the inventory area through interviews with the railway yard managers, who may maintain records of yard locomotive operations. If this approach proves unproductive, the number of yard locomotives can be determined by manually counting the units operating in each railway yard during a given day. This method is sufficient because the number of yard locomotives in operation each day remains relatively constant throughout the year.

The average annual emissions shown in the data table below were calculated based on the assumption that the average yard engine consumes 856 liters of fuel per day. Although these data were developed in the U.S., they are expected to be applicable to Mexico. Since yard locomotives can be assumed to operate 365 days a year (this assumes that when a yard engine is taken in for repairs it is replaced during that period), the average yard engine consumes 312,440 liters of fuel per year. The annual emission per yard locomotive were determined by multiplying the fuel consumption estimate (312,440 liter/year) by each emission factor in the data table.

DATA NEEDED - Yard Operations:

Data	Sources
Number of yard locomotives in operation in inventory area	Railway yard manager or actual count
Emission Factors TOG 1,893 kg/locomotive/yr CO 3,345 kg/locomotive/yr NO_x 18,873 kg/locomotive/yr SO_2[a] 1,395 kg/locomotive/yr PM 516 kg/locomotive/yr	U.S. EPA, 1992a

[a] SO_2 emissions are calculated based on an assumed fuel sulfur content of 0.25 percent by weight. See Note 3.

$$\left(\text{i.e. } \frac{0.004315 \text{ kg } SO_2}{\text{liter fuel}} \times \frac{323{,}312 \text{ liter fuel}}{\text{yr}} = \frac{1{,}395 \text{ kg } SO_2}{\text{locomotive/yr}} \right)$$

SAMPLE CALCULATION:

Inventory Area A has 21 yard locomotives in operation.

Calculated TOG emissions are:

= 21 × (1,893 kg/locomotive/yr)
= 39,753 kg
= 39.8 Mg

NOTES:

1.   For a locomotive inventory to be considered complete, emissions from both line haul and yard locomotives must be estimated.

2.   The emission factor of lbs SO_2/liter fuel will change with fuel density and sulfur content according to the following equation:

$$\text{emission factor} \left(\frac{\text{kg } SO_2}{\text{liter fuel}} \right) = \text{density of fuel} \left(\frac{\text{kg fuel}}{\text{liter fuel}} \right) \times \% \text{ of sulfur in fuel, expressed as a decimal} \left(\frac{\text{kg S}}{\text{kg fuel}} \right) \times \frac{2 \text{ kg } SO_2}{\text{kg S}}$$

$$\text{For example, } \frac{0.0043 \ 15 \text{ kg } SO_2}{\text{liter}} = \frac{0.863 \text{ kg}}{\text{liter}} \times \frac{0.0025 \text{ kg S}}{\text{kg}} \times \frac{2 \text{ kg } SO_2}{\text{kg S}}$$

3.   U.S. EPA 1992a, Section 6.0, Emissions from locomotives was used to convert emission factors from English to metric units. The emission factor for SO_2 presented for Yard Operations was obtained using an assumption of 322,312 liters/yr (85,410 gal/yr) fuel use per locomotive. Attention is called to this because U.S. EPA 1992a uses a slightly different fuel use per locomotive of 312,259 liters/yr (82,490 gal/yr) for all other listed pollutants.

5.2 Commercial Marine Vessels

SOURCE CODE: **DESCRIPTION:**

22-80-002-xxx   Marine Vessels: Diesel fuel
22-80-003-xxx   Marine Vessels: Residual fuel

DESCRIPTION:

Commercial marine vessels include all boats and ships used either directly or
indirectly in the conduct of commerce. These include vessels ranging in size from
7 meter charter boats to large tankers and military vessels which can exceed
300 meters in length. In spite of the large range of vessels represented by this
category, the majority of vessels in this category are powered either by diesel
engines (motor vessels) or steam turbines (steamships). Gasoline powered engines
are not typically used for commercial marine vessels. Gasoline powered
recreational boats are described in Section 5.4.

The predominant fuel used in all motor vessels and most steamships is oil, both
distillate and residual grades. In steamships, residual fuel such as heavy oil,
typically Number 6 or Bunker C, is used. Moderate speed diesel engines usually
require a blend of distillate and residual oil for satisfactory operation. Motor
vessels use diesel engines that require distillate oil. Other fuels are used, but only
to a limited extent. Wood, coal, and bagasse may be used in some very limited
applications.

POLLUTANTS: TOG, CO, NO_x, SO_x, PM

ROG: For motor vessels, ROG emissions are 97.2% of TOG (distillate); and for
steamships, ROG emissions are 82.8% of TOG (residual oil).

POINT SOURCE ADJUSTMENTS: None.

Two methods are available for estimating emissions from commercial marine
vessels. The first method is based on the quantity of fuel sold for marine use.
Emissions are estimated based on assumptions regarding the percentage of fuel
sold that is actually used within the port area, and the emission rate associated with
the use of the fuel. The second method attempts to provide a more accurate
estimate based on ship movement data. Both methods are described here.
Calculations need only be done using one method or the other, not both. The
method used will depend upon the availability of local data. Commercial marine
vessels used throughout the world are expected to have similar emission
characteristics. Although the data provided here are from U.S. references, these

data should provide reasonable emission estimates for marine vessels entering Mexican ports.

Fuel Sales Method

METHODOLOGY:

The fuel sales method assumes that 25 percent of the residual oil and 75 percent of the distillate oil sold in port is used there, and that all distillate oil is used by motor vessels and all residual oil is used by steamships. The total estimated quantities of residual and distillate oil used in port are:

$$
\begin{aligned}
Q_{ri} &= 0.25 \times Q_{rs} \text{ for residual, and} \\
Q_{di} &= 0.75 \times Q_{ds} \text{ for distillate}
\end{aligned}
\tag{5.2-1}
$$

where: Q_{ri} and Q_{di} = The quantities of residual and distillate oil, respectively, used in port i; and

Q_{rs} and Q_{ds} =   The total quantities of residual and distillate oil sold in the inventory area for marine use.

To estimate emissions, an emission factor is applied to the quantities Q_{ri} and Q_{di}. These emission factors, for motor vessels, are shown in the data table. Emission factors are given for two general categories of vessels, river and coastal. A river port supports vessels that travel throughout a given river basin; a coastal port supports vessels that travel in and across an ocean. To calculate emissions for motor vessels and steamships the following equation should be used:

$$
E_{ip} = \left(Q_{ri} \times EF_{rp} \right) + \left(Q_{di} \times EF_{dp} \right)
\tag{5.2-2}
$$

where: E_{ip} =   Quantity of emissions of pollutant p produced annually by vessels operating within area i waters;

Q_{ri} and Q_{di} =   Quantities of residual and distillate oil, respectively, used in port i; and

EF_{rp} and EF_{dp} =   Emission factors for pollutant p for residual and distillate oil, respectively

DATA NEEDED - Fuel Sales Method:

Data	Sources
Annual fuel usage (residual/diesel)	Local port authority or Dirección General de Puertos
Percentage of fuel used in port (25 percent for residual fuels and 75 percent for diesel fuel)	U.S. EPA, 1989

Emission Factors
   Steamships (Residual fuels)
      TOG[a]   0.463 kg/1000 liter
      ROG   0.383 kg/1000 liter (3.2 lb/10^3 gal)
      CO   negligible
      NO_x 4.362 kg/1000 liter (36.4 lb/10^3 gal)
      SO_x $19 \times$ % sulfur [kg/1000 liter] ($159 \times$ % sulfur [lb/10^3 gal])
      PM   1.198 kg/1000 liter (10 lb/10^3 gal)
 	
   Motor Vessels (Diesel fuels)
    River Vessels
       TOG   6.2 kg/1000 liter
       ROG   6.0 kg/1000 liter
       CO   12.0 kg/1000 liter
       NO_x 33.0 kg/1000 liter
       SO_x 3.2 kg/1000 liter
    Coastal Vessels
       TOG   6.2 kg/1000 liter
       ROG   6.0 kg/1000 liter
       CO   13.0 kg/1000 liter
       NO_x 32.0 kg/1000 liter
       SO_x 3.2 kg/1000 liter
	U.S. EPA, 1989

[a] TOG emission factor derived from the ROG emission factor and the ROG/TOG ratios presented earlier in this section.

SAMPLE CALCULATION—Fuel Sales Method:

       Coastal Port A dispenses 1 million liters of diesel for motor vessels and 459,000 liters of residual fuel for steamships annually.

Fuel used in the port is:

$$\text{Residual} \quad Q_{ri} = 0.25 \times Q_{rs}$$
$$= 0.25 \times 459{,}000 \ \text{liters}$$
$$= 114{,}750 \ \text{liters}$$

$$\text{Diesel} \quad Q_{di} = 0.75 \times Q_{ds}$$
$$= 0.75 \times 1{,}000{,}000 \ \text{liters}$$
$$= 750{,}000 \ \text{liters}$$

Estimated emissions for TOG are:

$$E_{ip} = (Q_{ri} \times EF) + (Q_{di} \times EF_{dp})$$
$$= 114{,}750 \ \text{liters} \ (0.463 \ \text{kg}/1{,}000 \ \text{liters}) + 750{,}000 \ \text{liters} \ (6.2 \ \text{kg}/1{,}000 \ \text{liters})$$
$$= 53.1 \ + \ 4{,}650 \ \text{kg}$$
$$= 4{,}703 \ \text{kg} \ = \ 4.7 \ \text{Mg}$$

Ship Movement Method

<u>METHODOLOGY:</u>

This method utilizes data concerning the number of vessels in various size categories that use a particular port, and assumptions about dockside activity and ship movements in and out of the harbor. This approach has two separate types of emissions associated with it:

- Underway emissions (i.e., emissions from vessels while in transit in the harbor); and

- Dockside emissions (i.e., emissions from vessels that are tied up at docks unloading or loading cargo).

The methods to estimate emissions from underway and dockside emissions are discussed below.

Underway Emissions

The first data element required is the number of vessels, by size category, using the port. Four size categories are of interest:

- Vessels with draft of less than 2 meters;

- Vessels with drafts greater than 2 meters or less than 4 meters;

- Vessels with drafts greater than 4 meters and less than 6 meters; and

- Vessels with drafts of 6 meters or more.

These data are used to compute emissions for vessels underway and at dockside.

Underway emissions occur while the vessel is entering, leaving, or maneuvering in port. Estimates of emissions produced by underway vessels can be developed based on the average travel time by vessels entering, maneuvering, and leaving the port, applying a fuel consumption factor to estimate fuel usage within the port, and applying an emission rate based on the quantity of fuel used.

Vessels with a draft of less than 6 meters (depth of water required for loaded vessel to operate in) are assumed to be powered by diesel engines using distillate fuels, while those vessels with a draft of 6 meters or more are assumed to be steam powered. Although large diesel powered vessels are capable of burning residual oil, it is assumed that distillate is used while underway or maneuvering in port. Further, it is assumed that all steamships use residual oil at all times.

To estimate average travel time, the distance between the outer limits of the study area and a theoretical centroid of activity within the port is determined. This distance is increased by 120 percent to account for maneuvering and leaving port and is divided by an assumed average speed in port of 13 km per hour to yield the estimated average underway travel time of each vessel using the port. This is:

$$\bar{t} = \frac{2.2d}{13} = 0.169\ d \tag{5.2-3}$$

where: $\bar{t}$ = Average travel time for vessels using the port (hr); and

   d = Distance in km between the outer limit of the study area and the assumed centroid of port activity.

Average travel time data can be applied to fuel consumption rates to estimate underway fuel consumption as noted in the following equation:

$$Q_{ijd} = \bar{t} \times FC_{jd} \times N_{jd} \tag{5.2-4}$$

where: Q_{ijd} = Underway fuel consumption for vessel type j (steamship, motor vessels) with draft d, for inventory area i (liter);

$\bar{t}$ = Average travel time (hr);

FC_{jd} = Fuel consumption rate for vessel type j and draft d (liter/hr); and
N_{ijd} = Number of vessels of vessel type j and draft d in inventory area i.

Fuel consumption rates for vessels operating in a Mexican port are provided in the data table. Different rates are given for motor vessels and steamships. To derive the distribution of motor vessels and steamships operating in a Mexican port, determine the relative number of U.S. and non-U.S. registered vessels visiting the port. Essentially all large U.S. registered vessels are steam powered, while most non-U.S. registered vessels are powered by diesel engines. From this information, the composite of motor vessels, and steamships can be approximated.

Once fuel use associated with underway operations has been computed, emissions can be calculated by applying emission factors from the data table. Emissions are calculated using the following equation:

$$E_{ijp} = Q_{ijd} \times EF_{jpd} \tag{5.2-5}$$

where: E_{ijp} = The quantity of emissions of pollutant p produced annually by category j vessels with draft d operating within area i waters;

Q_{ijd} = The quantity of fuel (residual or distillate), in liters, consumed by vessel type j with draft d; and

EF_{jpd} = The emission factor for pollutant p and vessel type j with draft d, from the data table.

DATA NEEDED - Ship Movement Method-Underway Emissions:

Data	Sources
Distance between outer limit of study area and assumed centroid of port activity	Measured with assistance of local port authority or Dirección General de Puertos
Travel time	Calculated using Equation 5.2-3
Type of vessel (Motor vessel or steamship) Draft of vessel Number of vessels for each type and draft	Local port authority or Dirección General de Puertos

Fuel consumption rates
  Motor Vessels
    Draft <2m   19 liter/hr (5 gal/hr)
    Draft ≥ 2 <4m   38 liter/hr (10 gal/hr)
    Draft ≥ 4 <6m   167 liter/hr (44 gal/hr)
    Draft ≥ 6m   484 liter/hr (128 gal/hr)
  Steamship
    Draft ≥ 6m   606 liter/hr (160 gal/hr)
	U.S. EPA, 1989

Fuel consumption for each type of vessel and draft	Calculated using Equation 5.2-4

Emission factors
  Motor Vessels
    Draft <2m   TOG[a]   6.30 kg/1000 liter
               ROG   6.12 kg/1000 liter (51.1 lb/10^3 gal)
               CO   5.67 kg/1000 liter (47.3 lb/10^3 gal)
               NO_x 46.65 kg/1000 liter (389.3 lb/10^3 gal)
               SO_x 3.24 kg/1000 liter (27 lb/10^3 gal)
    Draft ≥ 2 <4m TOG[a]   5.48 kg/1000 liter
               ROG   5.33 kg/1000 liter (44.5 lb/10^3 gal)
               CO   11.95 kg/1000 liter (99.7 lb/10^3 gal)
               NO_x 40.57 kg/1000 liter (338.6 lb/10^3 gal)
               SO_x 3.24 kg/1000 liter (27 lb/10^3 gal)
	U.S. EPA, 1989

Data			Sources
Motor Vessels			U.S. EPA, 1989
Draft ≥4 <6m	TOG[a]	2.07 kg/1000 liter	
	ROG	2.01 kg/1000 liter (16.8 lb/10^3 gal)	
	CO	7.45 kg/1000 liter (62.2 lb/10^3 gal)	
	NO_x	20.03 kg/1000 liter (167.2 lb/10^3 gal)	
	SO_x	3.24 kg/1000 liter (27 lb/10^3 gal)	
Draft ≥6m	TOG[a]	6.16 kg/1000 liter	
	ROG	5.99 kg/1000 liter (50 lb/10^3 gal)	
	CO	13.18 kg/1000 liter (110 lb/10^3 gal)	
	NO_x	32.35 kg/1000 liter	
	SO_x	3.24 kg/1000 liter (27 lb/10^3 gal)	
Steamship			
Draft ≥6m	TOG[a]	0.10 kg/1000 liter	
	ROG	0.08 kg/1000 liter (0.7 lb/10^3 gal)	
	CO	0.42 kg/1000 liter (3.5 lb/10^3 gal)	
	NO_x	6.69 kg/1000 liter (55.8 lb/10^3 gal)	
	SO_x	$19 \times \%$ sulfur [kg/1000 liter] ($159 \times \%$ sulfur [lb/10^3 gal])	
	PM	2.4 kg/1000 liter (20 lb/10^3 gal)	

[a]   TOG emission factor derived from ROG emission factor and ROG/TOG ratio presented earlier in this section.

Dockside Emissions

Large vessels (those with a draft of 6 meters or more) produce emissions while dockside, since either auxiliary diesel generator systems or the main boilers are operated to supply power for the vessels' utilities. Further, the boilers on most steamships in port for less than 2 days are rarely shut down because of the relatively long time required to restart and prepare them for operation. To estimate the quantity of emissions produced by these vessels, an estimate of the average number of days in port must be developed and a fuel consumption rate determined. After the total quantity of fuel consumed in port is estimated, an emission factor is applied to derive the emission estimate.

The average duration of stay for large commercial vessels is from one to three days. An estimate for a particular port can be derived by inquiring to the port authority, or shipping company, or a default value of three days can be used.

The fuel consumption rates for steamships and motor vessels are assumed to be 7,192 liters per day of residual oil, and 2,490 liters per day of distillate oil, respectively. Again, it is assumed that all U.S. registered vessels are steamships and all non-U.S. registered vessels are motor vessels. Fuel used by each type of vessel while in port is calculated from:

$$Q_{ij} = N_{ij} \times D_{ij} \times f_{cj} \qquad\qquad (5.2\text{-}6)$$

where: Q_{ij} =   Total annual fuel consumption of residual or distillate oil, in area i, by type j vessels (steamships or motor vessels) (liters);

                 N_{ij} =   Total number of type j vessels using the port i;

                 D_{ij} =   Average duration of stay for vessel type j in area i (days); and

                 f_{cj} =   Fuel consumption rate for vessel type j (assumed to be 7,192 liters per day of residual oil for steamships and 2,498 liters per day of distillate oil for motor vessels).

Emissions produced by the ships while at dockside are:

$$E_{ijp} = Q_{ij} \times EF_{jp} \qquad\qquad (5.2\text{-}7)$$

where: E_{ijp} =   The quantity of emissions of pollutant p produced annually by category j vessels while at dockside in area i waters;

                 Q_{ij} =   The quantity of fuel, in 1,000 liters, consumed at dockside by vessel type j (1,000 liters); and

                 EF_{jp} =   The emission factor for pollutant p and vessel type j.

DATA NEEDED - Ship Movement Method-Dockside Emissions:

Data	Sources
Annual number and type (Motor vessels/Steamships) that visit port	Local port authority or Dirección General de Puertos
Average duration of stay (days)	Local port authority or Dirección General de Puertos

Fuel consumption rate
         Motor Vessels   2,498 liter/day (660 gal/day)
         Steamships   7,192 liter/day (1,900 gal/day)
	U.S. EPA, 1989

Fuel consumed	Calculated using Equation 5.2-6

Data	**Sources**

Emission factors
  Motor Vessels TOG[a] 7.27 kg/1000 liter
                  ROG 7.07 kg/1000 liter (59 lb/10^3 gal)
                  CO   5.27 kg/1000 liter (44 lb/10^3 gal)
                  NO_x 43.62 kg/1000 liter (364 lb/10^3 gal)
                  SO_x 3.24 kg/1000 liter (27 lb/10^3 gal)
                  PM   negligible
  Steamships   TOG[a] 0.46 kg/1000 liter
                  ROG 0.38 kg/1000 liter (3.2 lb/10^3 gal)
                  CO   negligible
                  NO_x 4.36 kg/1000 liter (36.4 lb/10^3 gal)
                  SO_x $19 \times$ % sulfur [kg/1,000 liters] ($159 \times$ % sulfur [lb/10^3 gal])
                  PM   1.20 kg/1000 liter of fuel (10 lb/10^3 gal)
	U.S. EPA, 1989

[a] TOG emission factor derived from ROG emission factor and ROG/TOG ratio presented earlier in this section.

SAMPLE CALCULATION—Ship Movement Method:

- The distance from the outer limit of the study area to the centroid of Port A is 30 km;

- Port A is visited by 10 motor vessels and 2 steamships weekly (520 motor vessels and 104 steam ships annually);

- All of the motor vessels have a draft between 2 and 4 meters - all steam ships have drafts greater than 6 meters; and

- Number of days vessels typically spent in port is 2.

Underway Emissions

Calculated travel time is:

$$\bar{t} = 0.169d$$

$$= 0.169 \text{ hr/km} \times 30 \text{ km}$$

$$= 5.07 \text{ hr}$$

Calculated fuel consumption is:

$$\text{Motor vessels} = (5.07 \text{ hr}) \ (38 \text{ liters/hr}) \ (520 \text{ vessels})$$

$$= 100,183 \text{ liters}$$

$$\text{Steamships} = (5.07 \text{ hr}) \ (606 \text{ liters/hr}) \ (104 \text{ vessels})$$

$$= 319,532 \text{ liters}$$

Estimated TOG emissions are:

$$\text{Motor vessel emissions} = (100,183 \text{ liters}) \ (5.48 \text{ kg TOG}/1,000 \text{ liters})$$

$$= 549 \text{ kg}$$

$$\text{Steamship emissions} = (319,532 \text{ liters}) \ (0.10 \text{ kg TOG}/1,000 \text{ liters})$$

$$= 32 \text{ kg}$$

$$\text{Total underway emissions} = \text{motor vessel emissions} + \text{steamship emissions}$$

$$= 549 \text{ kg} + 32 \text{ kg}$$

$$= 581 \text{ kg}$$

Dockside Emissions

Calculated fuel consumption is:

$$\text{Motor vessels}_{ij} = (520 \text{ vessels}) \ (2 \text{ days}) \ (2,498 \text{ liters/day})$$

$$= 2,597,920 \text{ liters}$$

$$\text{Steamships}_{ij} = (104 \text{ vessels}) \ (2 \text{ days}) \ (7,192 \text{ liters/day})$$

$$= 1,495,936 \text{ liters}$$

$$\text{Motor vessels emission} = (2,597,920 \text{ liters}) \ (7.27 \text{ kg TOG}/1,000 \text{ liters})$$

$$= 18,887 \text{ kg}$$

$$\text{Steamship emissions} = (1,495,936 \text{ liters}) \ (0.46 \text{ kg TOG}/1,000 \text{ liters})$$

$$= 688 \text{ kg}$$

Calculated TOG emissions are:

Total dockside
TOG emissions = Motor vessel emissions + Steamship emissions

= 18,887 kg + 688 kg

= 19,575 kg

Total TOG
emissions = Underway emissions + Dockside emissions

= 581 kg + 19,575 kg

= 20,156 kg

NOTES:

1.   The fuel use method combines underway and dockside activities in the estimate of fuel consumed in port. If the ship movement method is used to estimate emissions for this source, underway and dockside emissions must be calculated separately and combined to yield total emissions for commercial marine vessels.

2.   To identify seasonal variations in emissions, monthly tabulations of vessel activity must be obtained from the local port authority.

5.3   Aircraft

SOURCE CODE: **DESCRIPTION:**

22-75-000-000   Aircraft Total
22-75-001-000   Military
22-75-020-000   Commercial Total
22-75-050-000   Civil Aircraft

DESCRIPTION:

Civil aircraft include all categories of fixed and rotary wing craft from the smallest single engine, privately owned and operated, to the largest commercial aircraft. Within the civil category, there are three subcategories: commercial aircraft, air taxis, and general aviation aircraft. In the development of an emission inventory, it is necessary to account for the different types of aircraft using each airfield. Commercial aircraft are used in regularly scheduled flights. Air taxis also fly scheduled service carrying passengers and/or freight, but usually are smaller aircraft and operate on a more limited basis than the commercial carriers. General aviation includes all nonmilitary aircraft not used in scheduled service. Business aircraft support business travel, usually on an unscheduled basis. For the purpose of creating an emissions inventory, business aircraft are combined with general aviation aircraft because of their similar size, use frequency, and operating profiles. In this inventory guidance they are referred to simply as general aviation. Similarly, air taxis are treated much like the general aviation category because they are typically the same types of aircraft. Helicopters, or rotary wing aircraft, can be found in each of the categories. Their operation is distinct because they do not always operate from an airport, but may land and take off from a heliport at a hospital, police station, or similarly dispersed location.

Commercial aircraft typically are the largest source of aircraft emissions. Although they make up less than half of all aircraft in operation around a metropolitan area, their emissions usually represent a large percent of the total emissions because of their size and operating frequency. This will not hold true, of course, for a city with no major civil airports.

Pollutants are emitted from aircraft whenever the engines are operating. In the context of emission inventory development, however, concern is limited to those portions of the flight that occur between ground level and an altitude defined as the above ground level inversion height. Within this layer, the air is fairly stable, and emissions tend to diffuse rather than being transported away. As a result,

emissions occurring below the ground level inversion height have an effect on air quality at ground level owing to the mixing that occurs within the air cell.

Aircraft emissions are affected by the throttle power setting, that is, the percentage of maximum power that the engines are producing at a given time. However, the power setting is fairly predictable given the specific operating mode in which the aircraft is operating. For purposes of inventory development, five operating modes are of interest:

- Approach (30-40 percent throttle);

- Taxi/idle in (3-7 percent throttle);

- Taxi/idle out (3-7 percent throttle);

- Takeoff (100 percent throttle); and

- Climb out (85-90 percent throttle).

Collectively, these five modes form the landing and takeoff (LTO) cycle, which provides a basis for allocating aircraft emissions to a specific region. The emissions for a given mode are calculated based on the period of time an aircraft spends in the specified mode. This period of time is called the Time In Mode (TIM).

Duration in approach and climbout depends largely on the local meteorology. Since the period of interest is during operation of the aircraft within the air modeling zone, the inversion layer thickness determines how long the aircraft is in this zone. The inversion layer thickness is also known as the mixing height or mixing zone since the air in this layer is completely mixed and pollutants emitted anywhere within the layer will be carried down to ground level. When the aircraft is above the mixing layer, whether on descent or when climbing to cruising altitude, the emissions tend to disperse, rather than being trapped by the inversion, and have no ground level effect.

Taxi/idle time, whether from the runway to the gate (taxi/idle-in) or from the gate to the runway (taxi/idle-out), depends on the size and layout of the airport, the amount of traffic or congestion on the ground, and airport-specific operational procedures. Taxi/idle time is the most variable of the LTO modes. Taxi/idle time can vary significantly for each airport throughout the day, as aircraft activity changes, and seasonally, as general travel activity increases and decreases.

The takeoff period, characterized primarily by full-throttle operation, typically lasts until the aircraft reaches between 150 and 300 meters above ground level when the engine power is reduced and the climbout mode begins. This transition height is fairly standard and does not vary much from location to location or among aircraft categories.

Commercial aircraft used throughout the world are expected to have similar emission characteristics. Although the data provided here were developed in the U.S., these data should provide reasonable emission estimates for aircraft operating at Mexican airports.

POLLUTANTS: TOG, CO, NO$_x$, SO$_2$, PM

ROG: For jet aircraft, ROG emissions are 84.4% of TOG.
               For piston aircraft, ROG emissions are 96% of TOG.

POINT SOURCE ADJUSTMENTS: None.

METHODOLOGY:

The steps in the emission estimation methodology are basically the same for each aircraft classification and each location, though several factors used in creating an inventory are site specific. The steps are:

    1.   Identify all airports to be included in the inventory;

    2.   Determine the mixing height to be applied to the LTO cycle;

    3.   Define the fleet make-up for aircraft category using each airport;

    4.   Determine airport activity as the number of LTOs for each aircraft category;

    5.   Calculate emission rates from fuel flow rates and emission indexes for each category (presented later in this section);

    6.   Estimate a TIM for each aircraft category at each airport; and

    7.   Calculate emissions based on the airport activity, TIM, and aircraft emission factors.

The height of the mixing zone influences only the TIM for approach and climbout. This factor is significant primarily when calculating NO$_x$ emissions rather than

TOG or CO. If NO_x emissions are an important component of the inventory, specific data must be gathered on mixing heights. If NO_x emissions are not important, mixing height will have little effect on the results, and the default value of 900 meters can be used for more generalized results.

To define the fleet make-up and airport activity in Mexico, Airports and Auxiliary Services (ASA) or staff from the airport of interest should be contacted. It is necessary that the LTO data be collected for each aircraft type in the fleet.

The engines used on each aircraft type must be determined to select the emission factors for step 5. Table 5.3-1 lists aircraft and the corresponding engines used to power them. Many aircraft use only a single engine model, while others have been certified to use engines from two or three different manufacturers. When a single engine is listed for an aircraft model, emission data for that engine should be used. For aircraft with engines from more than one manufacturer, defining the specific engine mix used on the fleet of aircraft operating at a specific airport may be extremely difficult.

To develop a representative engine mix for aircraft with more than one engine model, the percentage of each model likely to be found on those aircraft in the U.S. fleet is shown adjacent to the engine model number in Table 5.3-1. The recommended procedure for compensating for the lack of detailed engine data is using the percentages shown in the table as weighing factors. For example, Boeing 757-200 cargo aircraft have been sold to U.S. airlines with Pratt & Whitney PW2040 engines as well as Rolls Royce RF.211-535E4 engines. The number of aircraft with each engine model is 15 and 43, respectively, to give the percentages shown in Table A of 26 and 74. These percentages can be used to divide the total LTOs for B 757-200 cargo aircraft into two groups representing the two engine types. This makes the inventory more representative than assigning a single engine for all cargo versions of B 757-200s, since the emission factors are different for each engine.

After identifying the engines included in the fleet, engine emission factors are used to calculate mass of emissions. For some of the engines shown in Table 5.3-1, emission factors have never been determined. For these engines it is necessary to use emission factors from an alternative engine. Table 5.3-2 lists alternative engines recommended by the engine manufacturers. For most of these engines, emission factors are available for a very similar engine, usually one of the same model and a related series. For a small number of engines there is no emissions data available and there are no suggested alternatives. In these instances there are three approaches available. First, the needed data may appear in the latest update of the Federal Aircraft Engine Emission Database (FAEED) [see http://www.epa.gov/oar/omswww/aviation.html].

Table 5.3-1

Aircraft Types and Engine Models

Aircraft[1]	Number of Engines	Engine Model (% of Aircraft) and Manufacturer[2]			
Commercial Aircraft					
Aerospatiale ATR-42	2	PW120(53)PWC	PW121(47)PWC		
Airbus A-300-B4	2	CF6-50(100)GE			
Airbus A-300-600	2	CF6-80C2A5(100)GE			
Airbus A-310-200	2	JT9D-7R4E1(100)PW			
Airbus A-310-300	2	PW4152(100)PW			
Airbus A-320-200	2	CFM56-5A(100)GE			
BEECH 18[3]	2	R-985-AN(100)PW[4]			
BEECH BH-C99	2	PT6A-36(100)PWC			
BEECH BH-1900	2	PT6A-65B(100)PWC			
Boeing B-707-300B	4	JT3D-3B(100)PW			
Boeing B-707-300C	4	JT3D-3B(100)PW			
Boeing B-727-100	3	JT8D-7(16)PW JT8D-7D(4)PW	JT8D-7A(4)PW JT8D-9(1)PW	JT8D-7A/7B(< 1)PW JT8D-9A(2)PW	JT8D-7B(73)PW
Boeing B-727-100[3]	3	JT8D-7A(6)PW	JT8D-7B(91)PW	JT8D-9(1)PW	JT8D-9A(2)PW
Boeing B-727-200	3	JT8D-7A(< 1)PW JT8D-15(26)PW JT8D-15B(< 1)PW	JT8D-7B(16)PW JT8D-15A(21)PW JT8D-17(3)PW	JT8D-9(20)PW JT8D-9A(9)PW JT8D-17A(1)PW	JT8D-17R(3)PW
Boeing B-737-100/200	2	JT8D-7B(19)PW JT8D-17(7)PW	JT8D-9A(39)PW JT8D-17A(1)PW	JT8D-15(10)PW	JT8D-15A(24)PW
Boeing B-737-200C	2	JT8D-7A(10)PW JT8D-17(32)PW	JT8D-9/9A(5)PW JT8D-17A(32)PW	JT8D-9A(16)PW	JT8D-15(5)PW
Boeing B-737-300	2	CFM56-3(100)GE[6]			
Boeing B-737-400	2	CFM56-3(100)GE			
Boeing B-747[3]	4	JT9D-7F(100)PW			
Boeing B-747F[3]	4	JT9D-7F(33)PW	JT9D-7Q(17)PW	JT9D-7R4G2(11)PW	JT9D-70A(39)PW
Boeing B-747SP	4	JT9D-7A(85)PW	JT9D-7A-SP(15)PW		
Boeing B-747-200	4	CF6-50(3)GE[6] JT9D-7A(55)PW	JT9D-7R4G2(3)PW JT9D-7AH(13)PW	JT9D-3A(7)PW JT9D-7F(5)PW	JT9D-7(1)PW JT9D-7Q(13)PW
Boeing B-747-400	4	PW4056(100)PW			

Table 5.3-1

(Continued)

Aircraft[1]	Number of Engines	Engine Model (% of Aircraft) and Manufacturer[2]		
Boeing B-757-200	2	RB.211-535E4(1)RR	PW2037(92)PW	PW2040(7)PW
Boeing B-757-200[3]	2	PW2040(26)PW	RB.211-535E4(74)RR	
Boeing B-767-200	2	CF6-80A2(59)GE	CF6-80C2B2(12)GE[7]	JT9D-7R4D(29)PW
Boeing B-767-300	2	CF6-80C2B6(100)GE[8]		
Brit. Air. Corp. BAC-111-200	2	Spey Mk 511(100)RR[9]		
Brit. Aero. BAe-146-1	4	ALF502R-5(100)Lyc		
Brit. Aero. BAe-146-2	4	ALF502R-5(100)Lyc		
Brit Aero. Concorde	4	Olympus 593 Mk610(100)RR		
Brit Aero. JETSTREAM 31	2	TPE 331-10UF(100)Grt[9]		
CESSNA 404[3]	2	TSIO-520-VB(100)Con[9]		
Convair CV-580	2	501D13H(100)All.[9]		
Convair CV-640[3]	2	Dart 542-4(100)RR		
de Havilland DASH-7	4	PT6A-50(100)PWC		
de Havilland DHC-6	2	PT6A-20(26)PWC	PT6A-27(74)PWC	
de Havilland DHC-8	2	PW120(17)PWC	PW120A(83)PWC	
deHavilland Twin Otter	2	PT6A-27(100)PW		
EMBRAER[10]	2	PW6A-34(100)PWC		
EMBRAER EMB-120	2	PW118(85)PWC	PW118A(15)PWC	
Fairchild F27	2	R. Da. 7(100)RR		
Fairchild FH-227	2	Dart 532-7(100)RR		
Fokker 100	2	Tay 620-15(75)RR	Tay 650(25)RR	
Fokker F-27 SERIES	2	Dart 514-7(15)RR Dart 532-7P(24)RR Dart 532-7R(29)RR	Dart 528-7E(10)RR Dart 532-7R(3)RR	Dart 532-7(5)RR Dart 535-7R(9)RR Dart 532-7N(3)RR Dart 536-7E(2)RR
Fokker F-28-100	2	Spey 555-15(100)RR		
Fokker F-28-4000/600	2	Spey 555-15H(12)RR	Spey 555-15P(88)RR	

Table 5.3-1

(Continued)

Aircraft[1]	Number of Engines	Engine Model (% of Aircraft) and Manufacturer[2]			
Grumman Goose	2	PT6A-27(100)PWC			
Lockheed L100 Hercules	2	501(100)All			
Lockheed L100 Hercules	2	501(100)All			
Lockheed L-100-30[3]	2	501D22A(100)All.[9]			
Lockheed L-188A/C	2	501D13(100)All.[9]			
Lockheed L-1011/100/200	3	RB.211-22B(99)RR	RB.211-524B4(1)RR		
Lockheed L-1011-500 TR	3	RB.211-524B4(100)RR			
McDonnell Douglas DC-6[3]	4	R2800(100)PW[9]			
McDonnell Douglas DC-6A[3]	4	R2800(100)PW[9]			
McDonnell Douglas CD-8-60	4	JT3D-3B(57)PW	JT3D-7(43)PW		
McDonnell Douglas DC-8-61[3]	4	JT3D-3B(100)PW			
McDonnell Douglas DC-8-62[3]	4	JT3D-3B(15)PW	JT3D-3BDL(21)PW	JT3D-7(64)PW	
McDonnell Douglas DC-8-63F[3]	4	JT3D-3B(24)PW	JT3D-7(42)PW	JT3D-735E4(7)PW	JT8D-7(27)PW
McDonnell Douglas DC-8-70	4	CFM56-2-C1(100)GE			
McDonnell Douglas CD-8-71	4	CFM56-2(100)GE			
McDonnell Douglas DC-9-10	2	JT8D-7(100)PW[9]			
McDonnell Douglas DC-9-15F	2	JT8D-7(15)PW	JT8D-7A(4)PW	JT8D-7A/7B(4)PW	JT8D-7B(77)PW
McDonnell Douglas DC-9-30	2	JT8D-9A(23)PW JT8D-17(1)PW	JT8D-7A(5)PW	JT8D-7B(68)PW	JT8D-15(3)PW

Table 5.3-1

(Continued)

Aircraft[1]	Number of Engines	Engine Model (% of Aircraft) and Manufacturer[2]			
McDonnell Douglas DC-9-40	2	JT8D-15(100)PW			
McDonnell Douglas DC-9-50	2	JT8D-17(87)PW	JT8D-17A(13)PW		
McDonnell Douglas DC-9-80[11]	2	JT8D-209(5)PW JT8D-217C(25)PW	JT8D-217(12)PW	JT8D-217A(36)PW	JT8D-219(22)PW
McDonnell Douglas DC-10-10	3	CF6-6(100)GE			
McDonnell Douglas DC-10-10[3]	3	CF6-6(100)GE			
McDonnell Douglas DC-10-30	3	CF6-50(100)GE			
McDonnell Douglas DC-10-30[3]	3	CF6-50(100)GE			
McDonnell Douglas DC-10-40	3	JT9D-20(100)PW			
McDonnell Douglas MD-11	2	CF6-80C2D1F(100)GE			
NAMC YS-11	2	Dart 542-10J(25)RR	Dart 542-10K(75)RR		
Saab SF-340A	2	CT7-5A( )GE[12]	CT-5A2( )GE[12]	CT7-7E( )GE[12]	
SHORT 360	2	PT6A-65AR(17)PWC	PT6A-65R(55)PWC	PT6A-67R(28)PWC	
Swearingen SWEAR-METRO 1	2	TPE 331-11U-611G()Grt[13]	PT6A-45R()PW[14]		
Swearingen METRO-2	2	TPE 331-1(100)GA			
General Aviation and Air Taxis					
Aerospatiale SN601 Corvette	2	JT15D-4(100)PWC			
Beech B99 Airliner	2	PT6A-27(100)PWC			
Bellanca 7GCBC Seaplane	1	0-320(100)Lyc			
Canadair CL-600 Challenger	2	ALF502L-2(100)Lyc			

Table 5.3-1

(Continued)

Aircraft[1]	Number of Engines	Engine Model (% of Aircraft) and Manufacturer[2]
Cessna Citation	2	JT15D-1(100)PW
Cessna 150	1	0-200(100)Con
Cessna 150	1	O-200(100)Con
Cessna Pressurized Skymaster	2	TS10-360C(100)Con
Cessna 337 Series	2	TSIO-360C(100)Con
Dassault Bregue Falcon 10	2	TFE731-2(100)Grt
Dassault Bregue Falcon 50	3	TFE731-3(100)Grt
Dassault Falcon 20	2	CF700-2D(100)GE
de Havilland DHC-6-300	2	PT6A-27(100)PWC
de Havilland Twin Otter	2	PT6A-27(100)PWC
Fairchild Pilatus PC6 Series	1	PT6A-27[15](100)PWC
Gates Learjet 24D	2	CJ610-6(100)GE
Gates Learjet 35,36	2	TPE 731-2(100)GE
Gates Learjet 35A/36A	2	TFE731-2-2B(100)Grt
Helio Aircraft HST-550A Stallion	1	PT6A-27(100)PWC
Israel Aircraft IAI 1124	2	TFE731-3(100)Grt
Learjet 31	2	TFE731-2(100)Grt
Mitsubishi MU-300 Series	2	JT15D-4(100)PWC
Piper Navajo Chieftain	2	T10-540(100)Lyc
Piper PA-18 Series	1	0-320[16](100)Lyc
Piper PA-42 Series	2	PT6A-41[17](100)PWC
Piper Warrior	1	0-320(100)Lyc

Table 5.3-1

(Continued)

Aircraft[1]	Number of Engines	Engine Model (% of Aircraft) and Manufacturer[2]
Rockwell International Shoreliner 75A	2	CF 700(100)GE
Shorts Skyvan-3	2	TPE-331-2(100)GA
Swearingen Merline IIIA	2	TPE-331-3(100)GA

[1]   Source of Aircraft, Type, and No. of Engines is Airport Activity Statistics of Certificated Route Air Carriers, U.S. Department of Transportation, Research and Special Programs Administration, Federal Aviation Administration, 1989. NTIS Report Number ADA 2290303, and the FAA Aircraft Engine Emission Database (FAEED), U.S. Department of Transportation, Federal Aviation Administration, Office of Environment and Energy, 1991. Source of number of aircraft is Census of U.S. Civil Aircraft, U.S. Department of Transportation, Federal Aviation Administration, Office of Management Systems, 1989.

[2]   Following the engine model is the percent of aircraft in parentheses which correspond to the particular engine and the engine manufacturer. GE engine data obtained from GE Aircraft Engines: Commercial Program Status, Volume 1, (General Electric, 1991, Cincinnati, Ohio) and Office of Combustion Technology, GE Aircraft Engines (One Newmann Way MD A309, Cincinnati, Ohio 45215-6301, 513/774-4438). Corresponding percents of aircraft refer to U.S. commercial and government aircraft in operation as of 12/31/90. P&W, P&WC, and RR engine data obtained from Turbine-Engined Fleets of the World's Airlines 1990 (Exxon Corporation, supplement to Air World, Volume 42, Number 2, 1990). Corresponding percents of aircraft refer only to U.S. airlines. Engine Manufacturers: Con - Teledyne/Continental, GE - General Electric, Grt - Garrett AiResearch, Lyc - Avco/Lycoming, PW - Pratt & Whitney, PWC - Pratt & Whitney Canada, RR - Rolls Royce.

[3]   All Cargo Services.

[4]   Percent of aircraft assumed 100%.

[5]   Refers to B-737-300 and -500 aircraft.

[6]   Refers to B-747-200, -300, and SR aircraft.

[7]   Refers to B-767-200ER aircraft. GE combined the number of aircraft in operation of B-767-200ER and -300ER aircraft. It is assumed that an equal distribution between the two aircraft models exists.

[8]   Refers to B-767-300ER aircraft. GE combined the number of aircraft in operation of B-767-200ER and -300ER aircraft. It is assumed that an equal distribution between the two aircraft models exists.

[9]   Source of engine information is Modern Commercial Aircraft, Green, W., J. Mowinski, and G. Swanborough, 1987. Percent of aircraft assumed 100%.

[10]   Assumed EMB-100 aircraft.

[11]   Assumed MD-80 aircraft.

[12]   Source of engine information is Modern Commercial Aircraft. Percent of aircraft unknown.

[13]   Source of engine information is Modern Commercial Aircraft. Engine refers to METRO III aircraft. Percent of aircraft unknown.

[14]   Source of engine information is Modern Commercial Aircraft. Engine refers to METRO IIIA aircraft. Percent of aircraft unknown.

[15]   Engine refers to a PC6/B2H2 aircraft.

[16]   Engine refers to a PA-18-150 Super aircraft.

[17]   Engine refers to PA-42 Cheyenne aircraft.

Source: U.S. EPA, 1992a.

Table 5.3-2

Alternative Source of Emission Data for Some Aircraft Engines[1]

Manufacturer	Engine Model	Recommended Source for Emissions Data[2]
GE	CF6-6	CF6-6D
	CF6-50	CF6-50E/C1/E1/C2/E2
	CT7-5A	CT7-5
	CT7-5A2	CT7-5
	CT7-7E	CT7-5
GE (SCNECMA)	CFM56-2	CFM56-2B
	CFM56-2-C1	CFM56-2B
	CFM56-5A	CFM56-5A1
P&W	JT3D series	Contact manufacturer[3]
	JT8D-7D	JT8D-7/7A/7B
	JT8D-15B	JT8D-15
	JT9D-3A	Contact manufacturer
	JT9D-7A-SP	JT9D-7F/7A
	JT9D-7AH	JT9D-7F/7A
	JT9D-20	JT9D-7F/7A
	JT9D-70A	JT9D-70/59/7Q
	PW4060	PW4460
RR	RB211-535E5	Contact manufacturer[4]
	RB211-535F5	Contact manufacturer
	TRENT 600 series	Contact manufacturer
	TRENT 700 series	Contact manufacturer
	SPEY MK506	Contact manufacturer
	SPEY MK555-15	SPEY MK555
	SPEY MK555-15P	SPEY MK555
	SPEY MK555-15H	SPEY MK555

Table 5.3-2

(Continued)

Manufacturer	Engine Model	Recommended Source for Emissions Data[2]
RR (Continued)	SPEY MK512	Contact manufacturer
	TAY MK651	Contact manufacturer
	Dart 514-7	Dart RDa7
	Dart 528-7E	Dart RDa7
	Dart 532-7	Dart RDa7
	Dart 532-7N	Dart RDa7
	Dart 532-7P	Dart RDa7
	Dart 532-7R	Dart RDa7
	Dart 535-7R	Dart RDa7
	Dart 536-7E	Dart RDa7
	Dart 542-4	Dart RDa10
	Dart 542-10J	Dart RDa10
	Dart 542-10K	Dart RDa10
	Dart 552-7R	Dart RDa7

[1] FAA Aircraft Engine Emission Database does not identify these alternative emission factors. A manual adjustment to the database output may be required.

[2] As recommended by engine manufacturers.

[3] For information, contact the Office of Certification & Airworthiness, Commercial Engine Business, United Technologies Pratt & Whitney, 400 Main Street, East Hartford, Connecticut 06108, 203/565-2269.

[4] For information, contact <u>Manager Project Combustion</u>, Rolls Royce Place. P.O. Box 31, Derby DE2 99J England. Telephone - 0332 242424.

Source: U.S. EPA, 1992a.

Table 5.3-3

Model Emission Rates - Civil Aircraft Engine[1]

Model-Series Manufacturer[2]	Mode	Power Setting	Fuel Flow (kg/min)	Emission Indexes (kg/1000 kg of fuel)				
				TOG	CO	NO_x	SO_2[3]	PM
501D22A[4] All.	Takeoff	100%	17.96	0.28	2.04	8.88	0.54	—
	Climbout	85%	16.62	0.89	2.06	9.22	0.54	—
	Approach	30%	8.62	1.96	5.10	7.49	0.54	—
	Taxi/Idle	7%	4.61	17.61	43.61	3.52	0.54	—
0-200[4] Con.	Takeoff	100%	0.34	20.81	974.1	4.87	0.11	—
	Climbout	85%	0.34	20.81	974.10	4.87	0.11	—
	Approach	40%	0.20	33.22	1187.84	1.14	0.11	—
	Taxi/Idle	7%	0.06	29.00	644.42	1.58	0.11	—
TS10-360C[4]	Takeoff	100%	1.01	9.17	1081.95	2.71	0.11	—
	Climbout	85%	0.75	9.55	960.80	4.32	0.11	—
	Approach	40%	0.46	11.31	995.08	3.77	0.11	—
	Taxi/Idle	7%	0.09	138.26	592.17	1.91	0.11	—
CF6-6D GE	Takeoff	100%	104.16	0.30	0.50	40.00	0.54	—
	Climbout	85%	85.86	0.30	0.50	32.60	0.54	—
	Approach	30%	29.03	0.70	6.50	11.40	0.54	—
	Taxi/Idle	7%	10.37	21.00	54.20	4.50	0.54	—
CF6-45 GE	Takeoff	100%	127.56	0.10	1.00	30.60	0.54	—
	Climbout	85%	106.20	0.10	1.30	26.60	0.54	—
	Approach	30%	36.30	0.70	8.20	10.50	0.54	—
	Taxi/Idle	7%	12.12	32.70	59.20	3.90	0.54	—

Table 5.3-3

(Continued)

Model-Series Manufacturer[2]	Mode	Power Setting	Fuel Flow (kg/min)	Emission Indexes (kg/1000 kg of fuel)				
				TOG	CO	NO$_x$	SO$_2$[3]	PM
CF45A/A2 GE	Takeoff	100%	121.62	0.09	0.43	25.45	0.54	—
	Climbout	85%	99.78	0.14	0.54	21.61	0.54	—
	Approach	30%	635.52	0.35	5.01	9.36	0.54	—
	Taxi/Idle	4%	9.78	2.72	24.04	3.40	0.54	—
CF6-50E/C1/E1/C2/E2 GE	Takeoff	100%	145.68	0.60	0.50	36.50	0.54	—
	Climbout	85%	115.50	0.70	0.50	29.60	0.54	—
	Approach	30%	39.85	1.00	5.70	9.70	0.54	—
	Taxi/Idle	3%	10.09	49.30	81.30	2.40	0.54	—
CF6-80A GE	Takeoff	100%	128.70	0.29	1.00	29.80	0.54	—
	Climbout	85%	107.70	0.29	1.10	25.60	0.54	—
	Approach	30%	36.90	0.47	3.10	10.30	0.54	—
	Taxi/Idle	4%	9.00	6.29	28.20	3.40	0.54	—
CF6-80A1 GE	Takeoff	100%	128.70	0.29	1.00	29.80	0.54	—
	Climbout	85%	107.70	0.29	1.10	25.60	0.54	—
	Approach	30%	36.90	0.47	3.10	10.30	0.54	—
	Taxi/Idle	4%	9.00	6.29	28.20	3.40	0.54	—
CF6-80A2 GE	Takeoff	100%	135.24	0.30	1.00	29.60	0.54	—
	Climbout	85%	113.10	0.37	1.10	25.60	0.54	—
	Approach	30%	38.46	0.45	2.80	10.30	0.54	—
	Taxi/Idle	4%	9.00	6.28	28.20	3.40	0.54	—

Table 5.3-3

(Continued)

Model-Series Manufacturer[2]	Mode	Power Setting	Fuel Flow (kg/min)	Emission Indexes (kg/1000 kg of fuel)					
				TOG	CO	NO_x	SO_2[3]	PM
CF6-80A3 GE	Takeoff	100%	135.24	0.30	1.00	29.60	0.54	—
	Climbout	85%	113.10	0.37	1.10	26.60	0.54	—
	Approach	30%	38.46	0.45	2.80	10.80	0.54	—
	Taxi/Idle	4%	9.00	6.28	28.20	3.40	0.54	—
CF6-80C2A1 GE	Takeoff	100%	144.00	0.08	0.56	32.22	0.54	—
	Climbout	85%	117.18	0.09	0.54	24.85	0.54	—
	Approach	30%	38.16	2.00	2.19	9.76	0.54	—
	Taxi/Idle	7%	11.94	9.19	42.24	3.99	0.54	—
CF6-80C2A2 GE	Takeoff	100%	127.02	0.14	0.58	27.90	0.54	—
	Climbout	85%	104.70	0.11	0.56	20.71	0.54	—
	Approach	30%	34.80	0.25	3.04	9.52	0.54	—
	Taxi/Idle	7%	11.34	10.74	46.65	3.91	0.54	—
CF6-80C2A3 GE	Takeoff	100%	147.42	0.08	0.59	34.44	0.54	—
	Climbout	85%	120.18	0.10	0.57	25.45	0.54	—
	Approach	30%	38.94	0.21	2.15	10.01	0.54	—
	Taxi/Idle	7%	12.12	9.21	42.18	3.96	0.54	—
CFM56-2A GE (SNECMA)	Takeoff	100%	67.38	0.03	0.90	21.05	0.54	—
	Climbout	85%	55.62	0.04	1.00	17.18	0.54	—
	Approach	30%	20.70	0.10	3.40	8.62	0.54	—
	Taxi/Idle	7%	7.92	1.17	24.90	4.12	0.54	—

Table 5.3-3

(Continued)

Model-Series Manufacturer[2]	Mode	Power Setting	Fuel Flow (kg/min)	Emission Indexes (kg/1000 kg of fuel)				
				TOG	CO	NO_x	SO_2[3]	PM
CFM56-2B GE (SNECMA)	Takeoff	100%	60.12	0.05	0.90	19.06	0.54	—
	Climbout	85%	50.22	0.08	0.90	16.30	0.54	—
	Approach	30%	19.32	0.10	3.70	8.14	0.54	—
	Taxi/Idle	7%	7.38	1.67	29.50	3.66	0.54	—
CFM56-3 GE (SNECMA)	Takeoff	100%	61.20	0.04	0.90	18.50	0.54	—
	Climbout	85%	50.58	0.05	0.90	16.00	0.54	—
	Approach	30%	20.28	0.10	3.50	8.40	0.54	—
	Take/Idle	7%	7.26	1.83	31.00	3.90	0.54	—
CFM56-3B GE (SNECMA)	Takeoff	100%	68.40	0.04	0.90	20.70	0.54	—
	Climbout	85%	55.80	0.05	0.90	17.30	0.54	—
	Approach	30%	21.60	0.08	3.10	8.70	0.54	—
	Taxi/Idle	7%	7.80	1.25	27.00	4.10	0.54	—
CFM56-3B4 GE (SNECMA)	Takeoff	100%	52.80	0.04	0.90	16.60	0.54	—
	Climbout	85%	43.80	0.05	1.10	14.50	0.54	—
	Approach	30%	16.20	0.11	4.20	8.00	0.54	—
	Taxi/Idle	7%	6.60	3.33	38.50	3.90	0.54	—
CFM56-3C GE (SNECMA)	Takeoff	100%	70.80	0.04	0.90	20.17	0.54	—
	Climbout	85%	58.20	0.04	1.00	17.15	0.54	—
	Approach	30%	20.40	0.09	3.20	8.88	0.54	—

Table 5.3-3

(Continued)

Model-Series Manufacturer[2]	Mode	Power Setting	Fuel Flow (kg/min)	Emission Indexes (kg/1000 kg of fuel)				
				TOG	CO	NO$_x$	SO$_2$[3]	PM
CFM56-5A1 GE (SNECMA)	Takeoff	100%	64.77	0.23	0.83	28.03	0.54	—
	Climbout	85%	52.80	0.23	0.87	23.10	0.54	—
	Approach	30%	18.00	0.40	2.47	9.48	0.54	—
	Taxi/Idle	7%	6.60	1.53	18.00	4.36	0.54	—
TFE 731-2 Grt	Takeoff	100%	12.30	0.11	1.39	15.25	0.54	—
	Climbout	85%	10.38	0.13	2.03	13.08	0.54	—
	Approach	30%	4.02	4.26	22.38	5.90	0.54	—
	Taxi/Idle	7%	1.44	20.04	58.60	2.82	0.54	—
TFE 731-3 Grt	Takeoff	100%	13.50	0.06	1.13	19.15	0.54	—
	Climbout	85%	11.16	0.07	1.62	16.02	0.54	—
	Approach	30%	4.32	1.41	15.56	6.92	0.54	—
	Taxi/Idle	7%	1.56	9.04	47.70	3.72	0.54	—
TPE 331-3[6] Grt	Takeoff	100%	3.46	0.11	0.76	12.36	0.54	1.75
	Climbout	90%	3.09	0.15	0.98	11.86	0.54	1.47
	Approach	30%	1.89	0.64	6.96	9.92	0.54	2.40
	Taxi/Idle	7%	0.85	79.11	61.52	2.86	0.54	2.95
ALF 502L-2 Lyc	Takeoff	100%	24.00	0.02	0.40	13.43	0.54	—
	Climbout	85%	19.41	0.02	0.30	12.03	0.54	—
	Approach	30%	7.03	0.18	3.97	6.47	0.54	—
	Taxi/Idle	7%	2.86	6.65	45.63	3.38	0.54	—

Table 5.3-3

(Continued)

Model-Series Manufacturer[2]	Mode	Power Setting	Fuel Flow (kg/min)	Emission Indexes (kg/1000 kg of fuel)				
				TOG	CO	NO$_x$	SO$_2$[3]	PM
ALF 502R-3 Lyc	Takeoff	100%	20.86	0.06	0.43	11.20	0.54	—
	Climbout	85%	17.28	0.05	0.50	9.94	0.54	—
	Approach	30%	6.16	0.29	8.43	6.15	0.54	—
	Taxi/Idle	7%	2.59	6.51	44.67	3.30	0.54	—
ALF 502R-5 Lyc	Takeoff	100%	21.49	0.06	0.30	13.53	0.54	—
	Climbout	85%	17.73	0.05	0.25	10.56	0.54	—
	Approach	30%	6.21	0.22	7.10	13.53	0.54	—
	Taxi/Idle	7%	2.45	5.39	40.93	3.78	0.54	—
0-320[4] Lyc	Takeoff	100%	0.67	11.78	1077.44	2.19	0.11	—
	Climbout	85%	0.50	12.38	989.51	3.97	0.11	—
	Approach	40%	0.35	19.25	1221.51	0.95	0.11	—
	Taxi/Idle	7%	0.07	36.92	1077.00	0.52	0.11	—
D-36 MKB	Takeoff	100%	38.04	0.00	0.50	26.00	0.54	—
	Climbout	85%	31.98	0.00	0.40	22.00	0.54	—
	Approach	30%	12.66	0.00	2.70	9.00	0.54	—
	Taxi/Idle	7%	0.00	5.40	20.70	5.50	0.54	—
NK-86 NPO	Takeoff	100%	121.14	0.00	1.30	13.60	0.54	—
	Climbout	85%	99.00	0.00	1.70	10.00	0.54	—
	Approach	30%	34.32	0.00	5.00	3.80	0.54	—

Table 5.3-3

(Continued)

Model-Series Manufacturer[2]	Mode	Power Setting	Fuel Flow (kg/min)	Emission Indexes (kg/1000 kg of fuel)				
				TOG	CO	NO_x	SO_2[3]	PM
IAE V2500 PW	Takeoff	100%	66.78	0.10	0.55	37.13	0.54	—
	Climbout	85%	55.44	0.11	0.55	30.82	0.54	—
	Approach	30%	20.04	0.15	0.77	13.45	0.54	—
	Taxi/Idle	7%	7.44	0.22	7.76	5.91	0.54	—
JT3D-7[4] PW	Takeoff	100%	75.26	0.50	0.90	12.70	0.54	—
	Climbout	85%	61.90	0.40	1.90	9.60	0.54	—
	Approach	30%	23.31	2.10	19.50	5.30	0.54	—
	Taxi/Idle	7%	7.66	123.00	138.99	2.20	0.54	—
JT8D-7/7A/7B PW	Takeoff	100%	59.35	0.40	1.50	17.10	0.54	—
	Climbout	85%	48.68	0.50	2.00	13.50	0.54	—
	Approach	30%	17.16	1.60	10.50	5.50	0.54	—
	Taxi/Idle	7%	7.75	10.60	35.50	2.70	0.54	—
JT8D-9/9A PW	Takeoff	100%	62.40	0.47	1.24	17.92	0.54	—
	Climbout	85%	50.76	0.47	1.66	14.21	0.54	—
	Approach	30%	17.88	1.73	9.43	5.64	0.54	—
	Taxi/Idle	7%	7.92	10.00	34.50	2.90	0.54	—
JT8D-11 PW	Takeoff	100%	67.26	0.40	1.20	18.90	0.54	—
	Climbout	85%	54.82	0.45	1.90	14.60	0.54	—
	Approach	30%	20.04	1.40	9.40	5.80	0.54	—

Table 5.3-3

(Continued)

Model-Series Manufacturer[2]	Mode	Power Setting	Fuel Flow (kg/min)	Emission Indexes (kg/1000 kg of fuel)				
				TOG	CO	NO_x	SO_2[3]	PM
JT8D-15[7] PW	Takeoff	100%	70.68	0.25	0.72	19.12	0.54	—
	Climbout	85%	56.70	0.25	1.01	15.01	0.54	—
	Approach	30%	20.42	1.57	9.12	5.97	0.54	—
	Taxi/Idle	7%	8.86	10.33	33.88	3.01	0.54	—
JT8D-15A PW	Takeoff	100%	66.90	0.25	1.08	18.10	0.54	—
	Climbout	85%	53.73	0.33	1.20	13.90	0.54	—
	Approach	30%	18.72	0.65	2.90	6.60	0.54	—
	Taxi/Idle	7%	8.23	2.29	12.43	3.10	0.54	—
JT8D-17[7] PW	Takeoff	100%	74.70	0.66	0.75	19.30	0.54	—
	Climbout	85%	59.82	0.75	1.01	15.26	0.54	—
	Approach	30%	21.24	1.86	8.13	6.23	0.54	—
	Taxi/Idle	7%	8.82	9.57	29.56	3.29	0.54	—
JT8D-17A PW	Takeoff	100%	70.38	0.25	1.07	19.10	0.54	—
	Climbout	85%	56.06	0.30	1.16	14.30	0.54	—
	Approach	30%	19.82	0.64	2.88	6.70	0.54	—
	Taxi/Idle	7%	8.41	2.02	12.46	3.20	0.54	—
JT8D-17AR PW	Takeoff	100%	81.90	0.21	0.93	24.50	0.54	—
	Climbout	85%	62.82	0.27	1.08	16.00	0.54	—
	Approach	30%	21.45	0.55	2.68	8.00	0.54	—

Table 5.3-3

(Continued)

Model-Series Manufacturer[2]	Mode	Power Setting	Fuel Flow (kg/min)	Emission Indexes (kg/1000 kg of fuel)				
				TOG	CO	NO_x	SO_2[3]	PM
JT8D-17R PW	Takeoff	100%	85.02	0.21	0.95	25.30	0.54	—
	Climbout	85%	66.18	0.27	1.03	17.60	0.54	—
	Approach	30%	22.53	0.53	2.54	8.40	0.54	—
	Taxi/Idle	7%	9.30	0.95	9.43	3.30	0.54	—
JT8D-209 PW	Takeoff	100%	71.46	0.35	1.03	22.80	0.54	—
	Climbout	85%	58.97	0.50	1.40	19.00	0.54	—
	Approach	30%	21.55	1.69	4.37	8.80	0.54	—
	Taxi/Idle	7%	7.82	4.03	14.10	3.50	0.54	—
JT8D-217/217A/217C PW	Takeoff	100%	79.20	0.28	0.80	25.70	0.54	—
	Climbout	85%	64.68	0.43	1.23	20.60	0.54	—
	Approach	30%	23.00	1.60	4.17	9.10	0.54	—
	Taxi/Idle	7%	8.23	3.33	12.27	3.70	0.54	—
JT8D-219 PW	Takeoff	100%	81.24	0.27	0.73	27.00	0.54	—
	Climbout	85%	65.10	0.42	1.20	20.80	0.54	—
	Approach	30%	22.90	1.59	4.07	9.13	0.54	—
	Taxi/Idle	7%	8.06	3.48	12.63	3.60	0.54	—
JT9D-7[4] PW	Takeoff	100%	122.03	0.05	0.20	29.40	0.54	—
	Climbout	85%	99.74	0.10	0.50	21.40	0.54	—
	Approach	30%	35.14	1.00	9.60	7.80	0.54	—

Table 5.3-3

(Continued)

Model-Series Manufacturer[2]	Mode	Power Setting	Fuel Flow (kg/min)	Emission Indexes (kg/1000 kg of fuel)				
				TOG	CO	NO_x	SO_2[3]	PM
JT9D-7F(modV)/ 7A(modV) PW	Takeoff	100%	130.03	0.30	0.40	46.00	0.54	—
	Climbout	85%	105.84	0.30	0.40	34.40	0.54	—
	Approach	30%	37.42	0.50	2.90	7.80	0.54	—
	Taxi/Idle	7%	13.14	26.00	54.00	3.10	0.54	—
JT9D- 7R4D/7R4D1 PW	Takeoff	100%	123.30	0.15	0.51	38.50	0.54	—
	Climbout	85%	100.68	0.12	0.48	32.00	0.54	—
	Approach	30%	45.56	0.13	1.36	9.80	0.54	—
	Taxi/Idle	7%	12.32	1.25	10.00	4.10	0.54	—
JT9D-7R4E/ E1(A1500) PW	Takeoff	100%	127.08	0.16	0.57	41.60	0.54	—
	Climbout	85%	103.44	0.13	0.53	34.20	0.54	—
	Approach	30%	39.17	0.13	1.23	10.40	0.54	—
	Taxi/Idle	7%	13.26	1.11	8.27	4.10	0.54	—
JT9D-7R4E1(H) (A1-600) PW	Takeoff	100%	133.08	0.15	0.67	36.90	0.54	—
	Climbout	85%	109.74	0.13	0.67	29.70	0.54	—
	Approach	30%	38.40	0.22	1.46	8.50	0.54	—
	Taxi/Idle	7%	13.23	3.35	14.00	3.50	0.54	—
JT9D-7R4G2 PW	Takeoff	100%	145.74	0.15	0.74	41.30	0.54	—
	Climbout	85%	112.80	0.14	0.63	32.10	0.54	—
	Approach	30%	39.54	0.18	1.40	8.80	0.54	—

Table 5.3-3

(Continued)

Model-Series Manufacturer[2]	Mode	Power Setting	Fuel Flow (kg/min)	Emission Indexes (kg/1000 kg of fuel)					
				TOG	CO	NO$_x$	SO$_2$[3]	PM	
JT9D-7R4H1/H2 PW	Takeoff	100%	150.72	0.15	0.74	45.20	0.54	—	
	Climbout	85%	119.94	0.14	0.63	34.20	0.54	—	
	Approach	30%	43.36	0.18	1.39	8.90	0.54	—	
	Taxi/Idle	7%	14.72	1.48	11.63	3.80	0.54	—	
JT9D-70/59/7Q PW	Takeoff	100%	146.51	0.20	0.20	31.60	0.54	—	
	Climbout	85%	119.98	0.20	0.20	25.60	0.54	—	
	Approach	30%	40.82	0.30	1.70	7.80	0.54	—	
	Taxi/Idle	7%	14.22	12.00	53.00	3.00	0.54	—	
PW2037 PW	Takeoff	100%	92.28	0.05	0.40	31.10	0.54	—	
	Climbout	85%	75.96	0.06	0.41	24.80	0.54	—	
	Approach	30%	23.94	0.21	2.30	10.30	0.54	—	
	Taxi/Idle	7%	8.46	2.26	23.10	4.40	0.54	—	
PT2040 PW	Takeoff	100%	109.32	0.03	0.20	47.70	0.54	—	
	Climbout	85%	86.88	0.04	0.20	27.70	0.54	—	
	Approach	30%	29.58	0.18	2.60	11.00	0.54	—	
	Taxi/Idle	7%	9.30	2.36	23.60	4.40	0.54	—	
PW2041 PW	Takeoff	100%	115.02	0.03	0.20	37.00	0.54	—	
	Climbout	85%	92.16	0.04	0.20	29.00	0.54	—	
	Approach	30%	31.02	0.16	2.50	11.00	0.54	—	

Table 5.3-3

(Continued)

Model-Series Manufacturer[2]	Mode	Power Setting	Fuel Flow (kg/min)	Emission Indexes (kg/1000 kg of fuel)				
				TOG	CO	NO_x	SO_2[3]	PM
PW4056/4156 PW	Takeoff	100%	140.52	0.06	0.44	28.10	0.54	—
	Climbout	85%	115.80	0.01	0.57	22.90	0.54	—
	Approach	30%	39.48	0.13	2.00	11.60	0.54	—
	Taxi/Idle	7%	12.48	1.92	21.86	4.80	0.54	—
PW4152 PW	Takeoff	100%	130.62	0.13	0.12	26.90	0.54	—
	Climbout	85%	107.10	0.16	0.17	22.70	0.54	—
	Approach	30%	35.58	0.15	1.09	11.10	0.54	—
	Taxi/Idle	7%	10.62	0.74	12.76	4.90	0.54	—
PW4158 PW	Takeoff	100%	148.86	0.09	0.40	30.20	0.54	—
	Climbout	85%	120.28	0.02	0.54	23.70	0.54	—
	Approach	30%	40.92	0.14	1.88	11.80	0.54	—
	Taxi/Idle	7%	12.66	1.78	20.99	4.80	0.54	—
PW4460 PW	Takeoff	100%	158.82	0.10	0.37	32.80	0.54	—
	Climbout	85%	125.10	0.03	0.51	24.70	0.54	—
	Approach	30%	42.18	0.14	1.78	12.00	0.54	—
	Taxi/Idle	7%	12.78	1.66	20.32	4.90	0.54	—
JT15D-1 PWC	Takeoff	100%	8.88	0.01	2.65	7.60	0.54	—
	Climbout	85%	7.44	0.01	3.50	6.77	0.54	—
	Approach	30%	3.06	4.43	40.50	3.44	0.54	—

Table 5.3-3

(Continued)

Model-Series Manufacturer[2]	Mode	Power Setting	Fuel Flow (kg/min)	Emission Indexes (kg/1000 kg of fuel)				
				TOG	CO	NOx	SO2[3]	PM
JT15D-4 PWC	Takeoff	100%	10.18	0.09	2.10	9.23	0.54	—
	Climbout	85%	8.58	0.19	3.18	8.56	0.54	—
	Approach	30%	3.54	5.15	32.00	5.29	0.54	—
	Taxi/Idle	7%	1.56	40.00	97.00	2.63	0.54	—
PT6A-27[6] PWC	Takeoff	100%	3.21	0.00	1.01	7.81	0.54	—
	Climbout	90%	3.03	0.00	1.20	7.00	0.54	—
	Approach	30%	1.62	2.19	23.02	8.37	0.54	—
	Taxi/Idle	7%	0.87	50.17	64.00	2.43	0.54	—
PT6A-41[4] PWC	Takeoff	100%	3.86	1.75	5.10	7.98	0.54	—
	Climbout	90%	3.57	2.03	6.49	7.57	0.54	—
	Approach	30%	2.06	22.71	34.80	4.65	0.54	—
	Taxi/Idle	7%	1.11	101.63	115.31	1.97	0.54	—
Dart RDa7 RR	Takeoff	100%	10.68	1.00	3.20	5.60	0.54	—
	Climbout	85%	9.42	1.10	3.50	4.50	0.54	—
	Approach	30%	4.89	3.00	33.30	0.90	0.54	—
	Taxi/Idle	7%	3.10	23.90	91.40	0.70	0.54	—
Dart RDa10 RR	Takeoff	100%	12.78	0.00	2.20	4.30	0.54	—
	Climbout	85%	10.20	0.00	3.00	3.90	0.54	—
	Approach	30%	4.74	0.00	23.20	2.20	0.54	—

Table 5.3-3

(Continued)

| Model-Series Manufacturer[2] | Mode | Power Setting | Fuel Flow (kg/min) | Emission Indexes (kg/1000 kg of fuel) | | | | |
				TOG	CO	NO$_x$	SO$_2$[3]	PM
M45H-01 RR	Takeoff	100%	29.88	0.75	6.20	11.50	0.54	—
	Climbout	85%	24.96	0.74	7.90	9.30	0.54	—
	Approach	30%	8.76	7.40	51.00	3.60	0.54	—
	Taxi/Idle	7%	3.18	59.50	178.40	1.50	0.54	—
OLYMPUS 593 MK610 RR	Takeoff	100%	381.90	2.90	29.00	9.50	0.54	—
	Climbout	65%	139.74	1.70	19.90	9.30	0.54	—
	Descent	15%	41.10	22.00	73.20	2.50	0.54	—
	Approach	34%	70.26	11.40	52.90	3.50	0.54	—
	Taxi/Idle	7%	25.26	33.40	100.10	1.70	0.54	—
RB.211-22B RR	Takeoff	100%	111.96	0.36	2.48	34.32	0.54	—
	Climbout	85%	92.52	0.39	4.14	25.63	0.54	—
	Approach	30%	33.18	7.73	26.38	8.05	0.54	—
	Taxi/Idle	7%	13.62	65.37	93.17	2.70	0.54	—
RB.211-524B/B2/ B3/B4 RR	Takeoff	100%	142.98	0.52	1.83	47.00	0.54	—
	Climbout	85%	116.34	0.40	2.82	33.00	0.54	—
	Approach	30%	41.58	4.98	20.00	9.75	0.54	—
	Taxi/Idle	7%	16.32	50.60	82.20	3.53	0.54	—
RB.211-524C2 RR	Takeoff	100%	148.80	0.00	0.66	41.90	0.54	—
	Climbout	85%	121.20	0.22	1.63	32.30	0.54	—
	Approach	30%	44.40	4.42	18.90	10.40	0.54	—

Table 5.3-3

(Continued)

Model-Series Manufacturer[2]	Mode	Power Setting	Fuel Flow (kg/min)	Emission Indexes (kg/1000 kg of fuel)				
				TOG	CO	NO_x	SO_2[3]	PM
RB.211-524D4[7] RR	Takeoff	100%	146.11	0.02	0.53	56.97	0.54	—
	Climbout	85%	117.01	0.42	1.15	41.06	0.54	—
	Approach	30%	43.08	4.68	16.44	9.68	0.54	—
	Taxi/Idle	7%	17.46	45.11	71.87	4.12	0.54	—
RB.211-524G RR	Takeoff	100%	157.20	2.28	0.59	58.71	0.54	—
	Climbout	85%	124.80	1.46	0.43	40.54	0.54	—
	Approach	30%	42.00	1.14	1.01	9.56	0.54	—
	Taxi/Idle	7%	15.60	3.28	13.74	4.63	0.54	—
RB.211-524H RR	Takeoff	100%	163.80	1.00	0.90	65.80	0.54	—
	Climbout	85%	130.20	0.60	0.40	46.30	0.54	—
	Approach	30%	42.60	0.30	1.00	10.30	0.54	—
	Taxi/Idle	7%	15.60	0.50	11.70	4.80	0.54	—
RB.211-535C RR	Takeoff	100%	108.00	0.25	0.70	33.71	0.54	—
	Climbout	85%	88.20	0.14	0.27	24.89	0.54	—
	Approach	30%	32.40	0.44	0.84	6.37	0.54	—
	Taxi/Idle	7%	12.00	1.44	18.79	3.44	0.54	—
RB.211-535E4 RR	Takeoff	100%	111.60	0.69	1.01	52.70	0.54	—
	Climbout	85%	90.60	0.94	1.23	36.20	0.54	—
	Approach	30%	34.20	1.33	1.71	7.50	0.54	—

Table 5.3-3

(Continued)

Model-Series Manufacturer[2]	Mode	Power Setting	Fuel Flow (kg/min)	Emission Indexes (kg/1000 kg of fuel)				
				TOG	CO	NO_x	SO_2[3]	PM
SPEY MK511 RR	Takeoff	100%	53.34	0.98	1.81	23.27	0.54	—
	Climbout	85%	43.56	1.32	2.06	19.18	0.54	—
	Approach	30%	16.74	7.23	20.30	7.94	0.54	—
	Taxi/Idle	7%	7.14	56.73	97.96	1.48	0.54	—
SPEY MK511-8 RR	Takeoff	100%	53.46	0.09	0.12	22.70	0.54	—
	Climbout	85%	43.56	0.12	0.63	17.30	0.54	—
	Approach	30%	16.68	0.18	2.65	7.20	0.54	—
	Taxi/Idle	7%	7.62	3.69	31.77	3.60	0.54	—
SPEY MK555[8] RR	Takeoff	100%	33.34	0.74	0.41	19.61	0.54	—
	Climbout	85%	27.27	1.27	0.16	15.07	0.54	—
	Approach	30%	10.28	5.43	17.96	6.12	0.54	—
	Taxi/Idle	7%	5.33	71.84	74.68	2.26	0.54	—
TAY MK620-15/ MK611-8 RR	Takeoff	100%	45.60	0.80	0.70	21.10	0.54	—
	Climbout	85%	37.80	0.30	0.80	16.80	0.54	—
	Approach	30%	13.80	0.90	3.90	5.70	0.54	—
	Taxi/Idle	7%	6.60	3.40	24.10	2.50	0.54	—
TAY MK650[9] RR	Takeoff	100%	52.44	0.40	1.70	19.80	0.54	—
	Climbout	85%	42.90	0.40	2.00	16.50	0.54	—
	Approach	30%	15.24	0.90	6.50	4.60	0.54	—

Table 5.3-3

(Continued)

[1] SOURCE: ICAO Engine Exhaust Emissions Databank. (ICAO Committee on Aviation Environmental Protection, Working Group Meeting, Mariehamn, Aland., October 1989), unless otherwise noted.

[2] MANUFACTURERS: All. - Allison, Con - Teledyne/Continental, GE - General Electric, Grt - Garrett AiResearch, Lyc - Avco/Lycoming, PW - Pratt & Whitney, PWC - Pratt & Whitney Canada, RR - Rolls-Royce.

[3] SO_2 emissions based on national average sulfur content of aviation fuels from Aviation Turbines Fuels, 1989, Dickson, Cheryl L. and Paul W. Woodward, March, 1990. NIPER Report Number NIPER-164 PPS, National Institute for Petroleum and Energy Research, ITT Research Institute, Bartlesville, Oklahoma.

[4] Source of data is AP-42, Compilation of Air Pollutant Emission Factors, Volume II: Mobile Sources, U.S. Environmental Protection Agency, Ann Arbor, Michigan, September, 1985. (Aircraft data from February 1980).

[5] Source of engine data is General Electric Office of Combustion Technology, GE Aircraft Engines, One Newmann Way MD A309, Cincinnati, Ohio 45215-6301, 513/774-438.

[6] Source of data is AP-42. Source of Particulate data is AP-42 Reference 4 (M. Platt, et al., The Potential Impact of Aircraft Emissions upon Air Quality, APTD-1085, U.S. Environmental Protection Agency, Research Triangle Park, NC, December 1971). The indicated reference does not specify series number for this model engine.

[7] Source of engine data is ICAO, ICAO Engine Exhaust Emissions Databank. Data are sales weighted averages of two versions of this engine. The basis is 93% high emission combustors and 7% low emission combustors.

[8] Source of engine data is ICAO, ICAO Engine Exhaust Emissions Databank. Data are sales weighted averages of two versions of this engine. The basis is 77% high emission combustors and 23% low emission combustors.

[9] Source of engine data is Rolls Royce Combustion Research Department, Rolls Royce plc. P.O. Box 31, Derby DE2 88J England. Telephone - 0332 242424.

The Federal Aviation Administration (FAA) should be contacted for the latest version of the data base. Second, for an aircraft with several potential engine types, where no emissions data are available for one engine, the recommended procedure is to reallocate the market share among the engines for which data is available. Third, if emission rate information (fuel consumption and emission index) for an engine model still cannot be located the engine manufacturer should be contacted directly.

After the engine types have been identified, fuel flow rates and emission indexes can be found in Table 5.3-3. Emission indexes are given for specific fuel flow rates which are representative of the power settings used during the different operating modes. The emission index multiplied by the fuel flow rate yields an emission rate.

Step 6 is to specify a time-in-mode for each aircraft type. Take-off time is fairly standard for commercial aircraft and represents the time for initial climb from ground level to about 150 meters. The default take-off time for calculating emissions is 0.7 minutes (42 seconds) and, unless more specific data are available, should be used in this methodology. The time in the approach and climbout modes depends on mixing height. As mentioned earlier, a default mixing height of 900 meters was assumed for calculating an approach time of 4 minutes and a climbout time of 2.2 minutes, which can be used if specific information on mixing height is not available. The procedure for adjusting these times to correspond to a different mixing height is shown below.

The mode most likely to vary by time for each specific airport is taxi/idle time. Total taxi/idle time for a very congested airport can be as much as three or four times longer than for an uncongested airport. Taxi/idle-in time typically is shorter than taxi/idle-out time because there are usually fewer delays for aircraft coming into a gate than for aircraft lining up to takeoff. For a large congested airport the taxi/idle-out time can be three times longer than taxi/idle-in time. Taxi/idle time also may vary by aircraft type. For example, wide-body jets may all use special gates at the terminal that place them further from the runway than narrow-body jets or small regional commuter aircraft so their taxi/idle-in and taxi/idle-out times are longer. Because of the variation in taxi/idle time, it is important to get data specific to the airports of interest in the inventory. Commercial airlines must keep track of their taxi/idle time at each airport for different aircraft types so that their flight schedules reflect anticipated daily and seasonal variations. Therefore, the airlines' Flight Operations departments at their headquarters locations are the best source of data for taxi/idle time by aircraft type at a particular airport. Since all airlines using a particular airport will experience similar taxi/idle times, it is only necessary to get information from a single source. If taxi/idle times are not available for a particular airport, Table 5.3-4 lists default values of taxi/idle

Table 5.3-4

Default Time-in-Mode for Various Aircraft Categories

Aircraft	Time-in-Mode (minutes)					
	Taxi/ Idle-out	Takeoff	Climbout	Approach	Taxi/ Idle-in	Total	Source
Commercial Carrier							
Jumbo, long and medium range jet	19.0	0.7	2.2	4.0	7.0	32.9	AP-42, 1985
Turboprop	19.0	0.5	2.5	4.5	7.0	33.5	AP-42, 1985
Transport-piston	6.5	0.6	5.0	4.6	6.5	23.2	AP-42, 1985
General Aviation							
Business jet	6.5	0.4	0.5	1.6	6.5	15.5	AP-42, 1985
Turboprop	19.0	0.5	2.5	4.5	7.0	33.5	AP-42, 1985
Piston	12.0	0.3	5.0	6.0	4.0	27.3	AP-42, 1985
Helicopter	3.5	—	6.5	6.5	3.5	20.0	AP-42, 1985

periods, as well as other modes, for different aircraft classifications. For commercial aircraft, this information is based on data collected prior to 1971 at large airports during periods of congestion. For the inventory calculations, taxi/idle-in and taxi/idle-out time are added together to get a total time for the taxi/idle mode.

The final step in the procedure is to calculate total emissions for each aircraft type and to sum them for a total commercial aircraft emission rate. The following series of equations illustrates the calculation.

Adjust Approach and Climbout TIM to Represent Local Conditions

These equations adjust the TIMs, which are based on a default mixing height of 900 meters, to an airport specific value based on the local mixing height.

Equation 5.3-1 assumes the climbout mode begins with the transition from takeoff to climbout at 150 meters and continues until the aircraft exits the mixing layer.

$$TIM_{App} = TIM_{App-Def} \left(\frac{H}{900} \right)$$

$$TIM_{Clm} = TIM_{Clm-Def} \left(\frac{H-150}{750} \right)$$

(5.3-1)

where: TIM_{App} =   Actual time in approach mode (minutes);

                $TIM_{App-Def}$ =   Default time in approach mode (minutes) (see Table 5.3-4);

                H =   Mixing height used in air quality modeling for time and region of interest;

                TIM_{Cln} =   Actual time in climbout mode (minutes); and

                $TIM_{Clm-Def}$ =   Default time in climbout mode (minutes) (see Table 5.3-4).

If the detailed estimation procedure is being followed based on specific aircraft and engines, airport specific estimates on TIM might be used if available from airport officials. These data likely vary quite widely because of the many different types of services provided by this aircraft category. Otherwise, the estimation procedure is based on the default TIMs from Table 5.3-4. Emissions should be calculated separately for the different aircraft categories.

Calculate Emissions for Each Aircraft Type

$$E_{ij} = \Sigma \; [(TIM_{jk}) \times \left(FF_{jkL}/1{,}000 \right) \times (EL_{ijkL}) \times (NE_j)]$$

(5.3-2)

where: E_{ij} =   Total emissions of pollutant i, produced by aircraft type j for one LTO cycle (kg);

                TIM_{jk} =   Time in mode for mode k (takeoff, climbout, approach, taxi/idle), in minutes, for aircraft type j;

                FF_{jkL} =   Fuel flow for mode k, for engine L used on aircraft type j (kg/minute) (from Table 5.3-3);

                EL_{ijkL} =   Emission index for pollutant i in mode k for aircraft type j for engine L (kg/1,000 kg fuel) (from Table 5.3-3); and

                NE_{j} =   Number of engines used on aircraft type j (from Table 5.3-1).

To estimate emissions, the following equation should be used:

$$E_{aij} = E_{ij} \times LTO_{j} \hspace{3cm} (5.3\text{-}3)$$

where: E_{aij} =   Total emissions of pollutant i for aircraft type j (kg);

                E_{ij} =   Total emissions of pollutant i, produced by aircraft type j for one LTO (kg); and

                LTO_{j} =   Number of LTOs for aircraft type j.

To estimate total emissions from aircraft activity, the emissions for each aircraft are then summed.

Alternative Approach for General Aviation and Air Taxis

In some cases LTO data on general aviation and air taxis may not be reported in the detail required to use the above method.

A rough estimate of emissions for each aircraft category can be made using emission indices based on a representative fleet mix. The following indices were calculated based on 1988 U.S. fleet data for general aviation aircraft:

        TOG   0.179 kg per LTO
        CO   5.449 kg per LTO
        NO_x 0.029 kg per LTO
        SO_2 0.005 kg per LTO

Because air taxis have fewer of the smallest engines in their fleet and more turboprop and turbojet engines, their emission factors are somewhat different:

        TOG   0.376 kg per LTO
        CO   12.76 kg per LTO
        NO_x 0.072 kg per LTO

SO$_2$ 0.007 kg per LTO

These emission factors may then be applied to the following equation to estimate emissions:

$$E_{ij} = EF_{ij} \times LTO_{ij} \qquad\qquad (5.3\text{-}4)$$

where: E_{ij} =   Total emissions of pollutant i, in kg, produced by aircraft type j;
               EF_{ij} =   Emission factor for pollutant i, in kg of pollutant per LTO
                                        for aircraft type j; and
               LTO_j =   LTO cycle for aircraft type j.

DATA NEEDED:

Data	Sources
LTO Data by Aircraft Type	ASA and local airport operation
Aircraft Engine Data	FAA, 1991
Number of Engines	Air World, 1990
Engine Model and Manufacture	FAA, 1991
Market Share	Air World, 1990
Fuel Flow	FAA, 1991
Emission Index	FAA, 1991
Mixing Height	Sosa, 1995
Time-in-Mode Data	Local Airport Operators

SAMPLE CALCULATION:

- Airport A is served twice a week by airline B using a Boeing B-757-200, annually LTOs = 104
  Boeing B-757-20: 2 engines
  26 percent of the market share use Pratt & Whitney engine DW2040 and 74 percent of market share use Rolls Royce engine RB.211-535 E4.

- Ceiling height for Airport A is 800 meters

$$TIM_{App} = TIM_{App-DEF} \times \left(\frac{H}{900} \right)$$

$$= 4 \times \left(\frac{800}{900} \right)$$

$$= 3.6 \text{ min.}$$

$$TIM_{Clm} = TIM_{Clm-Def} \times \left(\frac{H-150}{750} \right)$$

$$= 2.2 \times \left(\frac{800-150}{750} \right)$$

$$= 1.9 \text{ min.}$$

Time data for taxing in/out of the airport is provided by the airport operations; 25 minutes.

•   To calculate emissions of TOG:

$$E_{ij} = \Sigma \; [(TIM_{jk}) \times (EF_{jk}/1,000) \times (EL_{ijk}) \times (NE_j)]$$

PW2040 Engine

Approach	=	(3.6) (29.58/1000) (0.18) (2)	= 0.038 kg
Climbout	=	(1.9) (86.88/1000) (0.04) (2)	= 0.013 kg
Taxi	=	(25) (9.30/1000) (2.36) (2)	= 1.097 kg
Take off	=	(0.7) (109.32/1000) (0.03) (2)	= 0.005 kg
Total	=	Approach + Climbout + Taxi + Takeoff	
	=	0.038 + 0.013 + 1.097 + 0.005 = 1.153 kg/LTO	

RB.211.535E4 Engine

Approach	=	(3.6) (34.20/1000) (1.33) (2)	= 0.327 kg
Climbout	=	(1.9) (90.60/1000) (0.94) (2)	= 0.324 kg
Taxi	=	(25) (11.40/1000) (2.85) (2)	= 1.625 kg
Take off	=	(0.7) (111.60/1000) (0.69) (2)	= 0.108 kg

$$\text{Total} \quad = \quad \text{Approach} + \text{Climbout} + \text{Taxi} + \text{Take off}$$

$$= \quad 0.327 + 0.324 + 1.625 + 0.108 = 2.384 \text{ kg/LTO}$$

Combined Engines

26% (PW2040) + 74% (RB.211-535E4)

0.26 (1.153) + 0.74 (2.384) = 2.064 kg/LTO

Emissions

$$E_{aij} = E_{ij} \times LTO_{j}$$

$$= 2.064 \text{ kg/LTO} \times 104 \text{ LTOs}$$

$$= 214.66 \text{ kg}$$

5.4   Other Non-Road Mobile Equipment

<u>**SOURCE CODE:**</u>   <u>**DESCRIPTION:**</u>

22-60-000-000	All Off-Highway Vehicles: Gasoline, 2-Stroke
22-60-001-xxx	Recreational Vehicles: Gasoline, 2-Stroke
22-60-002-xxx	Construction Equipment: Gasoline, 2-Stroke
22-60-003-xxx	Industrial Equipment: Gasoline, 2-Stroke
22-60-004-xxx	Lawn and Garden Equipment: Gasoline, 2-Stroke
22-60-005-xxx	Farm Equipment: Gasoline, 2-Stroke
22-60-006-xxx	Light Commercial: Gasoline, 2-Stroke
22-60-007-xxx	Logging Equipment: Gasoline, 2-Stroke
22-60-008-xxx	Airport Service Equipment: Gasoline, 2-Stroke
22-65-000-000	All Off-Highway Vehicles: Gasoline, 4-Stroke
22-65-001-xxx	Recreational Vehicles: Gasoline, 4-Stroke
22-65-002-xxx	Construction Equipment: Gasoline, 4-Stroke
22-65-003-xxx	Industrial Equipment: Gasoline, 4-Stroke
22-65-004-xxx	Lawn and Garden Equipment: Gasoline, 4-Stroke
22-65-005-xxx	Farm Equipment: Gasoline, 4-Stroke
22-65-006-xxx	Light Commercial: Gasoline, 4-Stroke
22-65-007-xxx	Logging Equipment: Gasoline, 4-Stroke
22-65-008-xxx	Airport Service Equipment: Gasoline, 4-Stroke
22-70-000-000	All Off-Highway Vehicle: Diesel
22-70-001-xxx	Recreational Vehicles: Diesel
22-70-002-xxx	Construction Equipment: Diesel
22-70-003-xxx	Industrial Equipment: Diesel
22-70-004-xxx	Lawn and Garden Equipment: Diesel
22-70-005-xxx	Farm Equipment: Diesel
22-70-006-xxx	Light Commercial: Diesel
22-70-007-xxx	Logging Equipment: Diesel
22-70-008-xxx	Airport Service Equipment: Diesel
22-82-005-xxx	Recreational Boats: Gasoline, 2-Stroke
22-82-010-xxx	Recreational Boats: Gasoline, 4-Stroke
22-82-020-xxx	Recreational Boats: Diesel

<u>**DESCRIPTION**</u>**:**

In addition to the nonroad categories noted in earlier sections of this document, there are additional nonroad sources that include motorized equipment and

vehicles that normally are not operated on public highways. There are eight categories of these other nonroad sources:

- Recreational Vehicles;

- Construction Equipment;

- Industrial Equipment;

- Lawn and Garden Equipment;

- Farm Equipment;

- Light Commercial Equipment;

- Logging Equipment; and

- Airport Service Equipment.

Some examples of the specific types of equipment included in these general categories are presented in Table 5.4-1.

POLLUTANTS: TOG, CO, NO_x, PM, SO_x

ROG: The ROG/TOG factors provided below may be used. Note that an ROG/TOG ratio of "NA" indicates that no specific ROG/TOG ratio is available from the cited CARB reference. However, based on the available data, it appears that it would be reasonable to use an ROG/TOG ratio of 96.0% for gasoline equipment exhaust and 97.2% for diesel equipment exhaust as a default values. ROG is 100% of TOG for crank, evaporative, and refueling emissions.

SOURCE CODE	ROG/TOG	DESCRIPTION
22-60-000-000	NA	All Off-Highway Vehicles: Gasoline, 2-Stroke
22-60-001-xxx	96.0%	Recreational Vehicles: Gasoline, 2-Stroke
22-60-002-xxx	NA	Construction Equipment: Gasoline, 2-Stroke
22-60-003-xxx	96.0%	Industrial Equipment: Gasoline, 2-Stroke
22-60-004-xxx	NA	Lawn and Garden Equipment: Gasoline, 2-Stroke
22-60-005-xxx	96.0%	Farm Equipment: Gasoline, 2-Stroke

Table 5.4-1

Other Nonroad Mobile Source Categories

Category	

Recreational Vehicles
    Recreational Boats
    Motorcycles
    Snowmobiles
    All Terrain Vehicles (ATV)
    Minibikes
    Golf Carts
	Construction Equipment
	    Asphalt Pavers
	    Plate Compactors
	    Rollers
	    Scrapers
	    Trenchers
	    Bore/Drill Rigs
	    Cement and Mortar Mixers
	    Cranes

Industrial Equipment
    Aerial Lifts
    Forklifts
    Sweepers/Scrubbers
    Mobile Refrigerators
    Auxiliary Engines
    Portable Well Drilling
     Equipment
	Lawn and Garden Equipment
	    Lawn Mowers
	    Trimmers/Edgers
	    Leaf Blowers
	    Chain Saws
	    Wood Splitters
	    Chippers/Stump Grinders

Farm Equipment
    Combines
    Balers
    Harvesters
    General purpose
    Machines
    Tractors
	Light Commercial Equipment
	    Pumps
	    Generators
	    Air Compressors
	    Gas Compressors
	    Welders
	    Pressure Washers

Logging Equipment
    Chain Saws
    Shredders
    Skidders
    Fellers/Bunchers
	Airport Service Equipment
	    Airport Support Equipment
	    Terminal Tractors

22-60-006-xxx	96.0%	Light Commercial: Gasoline, 2-Stroke
22-60-007-xxx	NA	Logging Equipment: Gasoline, 2-Stroke
22-60-008-xxx	NA	Airport Service Equipment: Gasoline, 2-Stroke
22-65-000-000	NA	All Off-Highway Vehicles: Gasoline, 4-Stroke
22-65-001-xxx	96.0%	Recreational Vehicles: Gasoline, 4-Stroke
22-65-002-xxx	NA	Construction Equipment: Gasoline, 4-Stroke
22-65-003-xxx	96.0%	Industrial Equipment: Gasoline, 4-Stroke
22-65-004-xxx	NA	Lawn and Garden Equipment: Gasoline, 4-Stroke
22-65-005-xxx	96.0%	Farm Equipment: Gasoline, 4-Stroke
22-65-006-xxx	96.0%	Light Commercial: Gasoline, 4-Stroke
22-65-007-xxx	NA	Logging Equipment: Gasoline, 4-Stroke
22-65-008-xxx	NA	Airport Service Equipment: Gasoline, 4-Stroke
22-70-000-000	NA	All Off-Highway Vehicle: Diesel
22-70-001-xxx	97.2%	Recreational Vehicles: Diesel Boats
22-70-002-xxx	NA	Construction Equipment: Diesel
22-70-003-xxx	97.2%	Industrial Equipment: Diesel
22-70-004-xxx	NA	Lawn and Garden Equipment: Diesel
22-70-005-xxx	97.2%	Farm Equipment: Diesel
22-70-006-xxx	97.2%	Light Commercial: Diesel
22-70-007-xxx	NA	Logging Equipment: Diesel
22-70-008-xxx	NA	Airport Service Equipment: Diesel

POINT SOURCE ADJUSTMENTS: None.

METHODOLOGY:

Emissions from most nonroad mobile sources are calculated using the following equation:

$$\text{Emissions}_p = N_e \times hr_e \times hp_e \times LF_e \times EF_{p,e} \qquad (5.4\text{-}1)$$

where:

Emissions_p	=	emissions of pollutant, p (kg/yr);
N_e	=	equipment population of equipment type, e;
hr_e	=	annual hours of use for equipment type, e;
hp_e	=	average rated horsepower for equipment type, e;
LF_e	=	typical load factor for equipment type, e; and
$EF_{p,e}$	=	emission factor for pollutant, p, and equipment type, e (g/hp-hr).

Emissions from most types of recreational equipment and marine equipment are calculated using different equations. For some types of recreation equipment (all terrain vehicles [ATVs], minibikes, off-road motorcycles, and golf carts), the estimation equation is:

$$\text{Emissions}_p = N_e \times hr_e \times EF_{p,e} \tag{5.4-2}$$

where: Emissions_p = emissions of pollutant, p (kg/yr);
N_e = equipment population of equipment type, e;
hr_e = annual hours of use for equipment type, e; and
$EF_{p,e}$ = emission factor for pollutant, p, and equipment type, e (g/hr).

For recreational marine equipment, the estimation equation is:

$$\text{Emissions}_p = N_e \times \text{Fuel}_e \times EF_{p,e} \tag{5.4-3}$$

where Emissions_p = emissions of pollutant, p (kg/yr);
N_e = equipment population of equipment type, e;
Fuel_e = annual fuel use (gal/yr); and
$EF_{p,e}$ = emission factor for pollutant, p, and equipment type, e (g/hr).

Where possible, local Mexico-specific activity data (i.e., equipment population, hours of use, equipment horsepower, etc.) should be obtained. U.S.-based emission factors, as well as U.S. default activity data, are presented in Appendix V-C. The following tables are presented in Appendix V-C:

- Table 2-04 - Average rated horsepower estimates;

- Table 2-05 - Typical operating load factor estimates;

- Table 2-06 - Annual use estimates;

- Table 2-07a - Diesel equipment emission factors;

- Table 2-07b - 4-Stroke gasoline equipment emission factors (not adjusted for in-use effects);

- Table 2-07c - 4-Stroke gasoline equipment emission factors (adjusted for in-use effects);

- Table 2-07d - 2-Stroke gasoline equipment emission factors (not adjusted for in-use effects); and

- Table 2-07e - 2-Stroke gasoline equipment emission factors (adjusted for in-use effects).

The source of these emission factors and activity data is the U.S. EPA's *Nonroad Engine and Vehicle Emission Study* (U.S. EPA, 1991b). These U.S.-based emission factors and activity data have limited applicability in Mexico and should only be used if no other data are available.

A couple things should be noted about these tables. First of all, activity data presented in Tables 2-04, 2-05, and 2-06 are given for Inventory A and Inventory B. Inventory A activity data were developed solely by U.S. EPA contractors, while Inventory B activity data incorporated addition information from manufacturer associations. Thus, Inventory B activity data is preferred over Inventory A activity data. Also, the emission factors presented in Tables 2-07b and 2-07d are based upon emissions data from new engines, while the emission factors presented in Tables 2-07c and 2-07e represent in-use effects including engine malfunctions, improper maintenance, and engine wear. Therefore, the emission factors presented in Tables 2-07c and 2-07e are preferred over the emission factors in Tables 2-07b and 2-07d.

DATA NEEDED:

Data	Sources
Equipment population	Local agencies or surveys
Hours of use	Local agencies or surveys; U.S. default values (Appendix V-C, Table 2-06)
Average rated horsepower	Local agencies or surveys; U.S. default values (Appendix V-C, Table 2-04)
Load factor	Local agencies or surveys; U.S. default values (Appendix V-C, Table 2-05)
Fuel use (recreational marine only)	Local agencies or surveys; U.S. default values (Appendix V-C, Table 2-06)
Emission factors	U.S. emission factors (Appendix V-C, Table 2-07a through 2-07e);

NOTES:

1.   Volume II of the fourth edition of AP-42 (AP-42, 1985) included information on the estimation of emissions from nonroad mobile sources, but this information is outdated. The information presented

in the *Nonroad Engine and Vehicle Emission Study*, along with more recent emissions test data, is currently being incorporated into a fifth edition of Volume II of AP-42. It is unclear when this document will be available.

2.   TOG emission factors are <u>not</u> presented in Appendix V-C, Tables 2-07a through 2-07e. Hydrocarbon (HC) emission factors are presented for exhaust, crank, evaporative, and refueling emissions. Elsewhere in the *Nonroad Engine and Vehicle Emission Study*, it is explained that HC is equivalent to volatile organic compounds (VOC). Because methane and ethane are excluded from VOC, then VOC is essentially the same as ROG. Thus, the emission factors presented in Appendix V-C, Tables 2-07a through 2-07e are equivalent to ROG. TOG emission factors can be obtained using the ROG emission factors and the ROG/TOG ratios of 96.0% for gasoline equipment exhaust and 97.2% for diesel equipment exhaust. This is demonstrated in the sample calculation. For crank, evaporative, and refueling emissions, there is virtually no methane and ethane included, so the ROG and TOG are equivalent.

SAMPLE CALCULATION:

Assume that a certain inventory region has 50 4-stroke gasoline welders, 30 diesel pumps, and 15 diesel cranes. Calculate total TOG emissions.

1.   Determine hours of use:
                Based on local surveys, it has been estimated that the welders are used 100 hours per year, the pumps are used 200 hours per year, and the cranes are used 600 hours per year.

2.   Determine average rated horsepower:
                Because local survey information is unavailable, determine average rated horsepower from Table 2-04 in Appendix V-C.

                Welders - 19.0 hp
                Pumps - 23.0 hp
                Cranes - 194.0 hp

3.   Determine typical operating load factors:

Once again, local survey information is unavailable, so operating load factors taken from Table 2-05 in Appendix V-C.

Welders - 51%
Pumps - 74%
Cranes - 43%

4.   Calculate emission factors
Diesel emission factors are taken from Table 2-07a and 4-stroke gasoline emission factors from Table 2-07c. Exhaust emission factors must be converted from ROG to TOG. For all other emissions, ROG is equivalent to TOG.

$$\text{Welders Exhaust} = \left(\frac{19.95 \text{ g ROG}}{\text{hp-hr}} \right) \left(\frac{1}{0.96} \right) = \frac{20.78 \text{ g TOG}}{\text{hp-hr}}$$

$$\text{Crank} = \frac{3.14 \text{ g TOG}}{\text{hp-hr}}$$

$$\text{Evaporative} = \frac{9.75 \text{ g TOG}}{\text{hp-hr}}$$

$$\text{Refueling} = \frac{1.72 \text{ g TOG}}{\text{hp-hr}}$$

Total = 20.78 + 3.14 + 9.75 + 1.72 = 35.39 g TOG/hp-hr

$$\text{Pumps Exhaust} = \left(\frac{1.20 \text{ g ROG}}{\text{hp-hr}} \right) \left(\frac{1}{0.972} \right) = \frac{1.235 \text{ g TOG}}{\text{hp-hr}}$$

$$\text{Crank} = \frac{0.02 \text{ g TOG}}{\text{hp-hr}}$$

$$\text{Evaporative} = \text{Not applicable}$$

$$\text{Refueling} = \frac{0.003 \text{ g TOG}}{\text{hp-hr}}$$

Total = 1.235 + 0.02 + 0.003 = 1.26 g TOG/hp-hr

$$\text{Crane Exhaust} = \left(\frac{1.26 \text{ g ROG}}{\text{hp-hr}} \right) \left(\frac{1}{0.972} \right) = \frac{1.296 \text{ g TOG}}{\text{hp-hr}}$$

$$\text{Crane} = \frac{0.03 \text{ g TOG}}{\text{hp-hr}}$$

$$\text{Evaporative} = \text{Not applicable}$$

$$\text{Refueling} = \frac{0.003 \text{ g TOG}}{\text{hp-hr}}$$

$$\text{Total} = 1.296 + 0.03 + 0.003 = 1.33 \text{ g TOG/hp-hr}$$

Total = 1.296 + 0.03 + 0.003 = 1.33 g TOG/hp-hr

5.   Calculate emissions

$$\text{Welders} = 50 \left(\frac{100 \text{ hr}}{\text{yr}} \right) (19.0 \text{ hp}) (0.51) \left(\frac{35.39 \text{ g}}{\text{hp-hr}} \right) = 1{,}715 \text{ kg/yr}$$

$$\text{Pumps} = 30 \left(\frac{200 \text{ hr}}{\text{yr}} \right) (23.0 \text{ hp}) (0.74) \left(\frac{1.26 \text{ g}}{\text{hp-hr}} \right) = 129 \text{ kg/yr}$$

$$\text{Cranes} = 15 \left(\frac{600 \text{ hr}}{\text{yr}} \right) (194.0 \text{ hp}) (0.43) \left(\frac{1.33 \text{ g}}{\text{hp-hr}} \right) = 999 \text{ kg/hr}$$

$$\text{Total emissions} = 1{,}715 + 129 + 999 = 2{,}843 \text{ kg TOG/yr}$$

$$= 2.8 \text{ Mg TOG/yr}$$

5.5   Border Crossings

SOURCE CODE: **DESCRIPTION:**

22-01-001-900*   Light Duty Gasoline Vehicles (LDGV)
22-01-060-900*   Light Duty Gasoline Trucks (LDGT)
22-01-070-900*   Heavy Duty Gasoline Vehicles (HDGV)
22-01-080-900*   Motorcycles (MC)
22-30-001-900*   Light Duty Diesel Vehicles (LDDV)
22-30-060-900*   Light Duty Diesel Trucks (LDDT)
22-30-070-900*   Heavy Duty Diesel Vehicles (HDDV)

* Proposed Mexico-specific codes for source category not typically inventoried in the U.S.

DESCRIPTION:

This section specifically covers emissions from border crossings. This category is of primary interest in the U.S.-Mexico border region. Vehicles (both U.S. and Mexican) often line up for extended periods of time (up to 1 hour) while waiting to enter the United States and pass through customs inspections. Vehicles in the queue typically do not turn off their engines, but idle while they inch forward in line. This emissions category is also applicable for vehicles entering Mexico (although the idling time appears to be shorter compared to vehicles entering the United States) and any other vehicles that idle at other checkpoints. The methodology described below is similar to that described for bus terminals (see Section 5.6).

Because these idling emissions are emitted by on-road motor vehicles, an argument could be made that idling emissions should be included as a mobile source. However, unlike typical mobile source emissions, the location of idling emissions from border crossings is very well defined (i.e., the road segment directly in front of the border crossing). Also, the latest versions of the mobile source emission factor models (MOBILE5a, PART5, and related modified versions) can only be used to estimate emissions from moving vehicles. For these reasons, idling emissions at border crossings should be treated as area sources.

POLLUTANTS: TOG, CO, NO_x, SO_x, PM_{10}

ROG: For non-catalyst gasoline vehicles, ROG is 92.4% of TOG.
                            For catalyst gasoline vehicles, ROG is 85.2% of TOG.
                            For diesel vehicles, ROG is 95.7% of TOG (ARB, 1993).

POINT SOURCE ADJUSTMENTS: None.

METHODOLOGY:

> As mentioned above, the latest versions of MOBILE5a and PART5 do not provide any idling emission factors. Earlier versions of MOBILE provided some idling emission factors. However, these emission factors represented standard test conditions (stabilized operating mode, 75 °F, and 9.0 psi RVP fuel). Because U.S. EPA has been unable to develop a satisfactory algorithm to account for variations in operating mode, ambient temperature, and fuel RVP, the direct calculation of idling emission factors has been disabled in MOBILE5a while idling emissions data are being collected.
>
> U.S. EPA has provided an interim methodology for estimating idling emissions using MOBILE5a (U.S. EPA, 1993). This methodology can be used to estimate vehicle emissions at border crossings and in other idling situations. It is assumed that this methodology is valid for PART5 and any MOBILE models that have been modified for use in Mexico (i.e., MOBILE-MCMA, MOBILE-MMAp, MOBILE-Juárez, etc.). A MOBILE model will be used to estimate TOG, CO, and NO_x emissions. A PART5 model will be used to estimate PM_{10} emissions. SO_x emissions will be estimated by using a simple fuel balance.
>
> In the U.S. EPA interim methodology, idling emission rates are calculated using exhaust emission factors from a MOBILE run set at the lowest allowable vehicle speed (2.5 miles per hour [mph] for MOBILE5a and PART5 and 4 kilometers per hour [kph] for Mexico-specific modified MOBILE models). The lowest allowable speed is used because it contains the largest percentage of idling time of any of the speed cycles used by the MOBILE model. After running the MOBILE model, exhaust emission factors for TOG, CO, and NO_x will be calculated in units of grams per mile or grams per kilometer. To convert these emission factors to idling emission factors in units of grams per hour, multiply by 4 kph (or 2.5 mph). The resulting idling emission factors should not include any non-exhaust emissions. For more information on running the MOBILE and PART5 models, consult the Motor Vehicle Manual of this series and/or the MOBILE and PART5 User's Guides (U.S. EPA, 1994; U.S. EPA, 1995).
>
> At border crossings, idling vehicles will consist of a mixture of U.S. and Mexican vehicles. Consequently, MOBILE5a would need to be used for the U.S. vehicle fraction and a Mexico-specific MOBILE model would need to be used for the Mexican vehicle fraction. MOBILE-Juárez (Radian, 1996) is the most recent Mexico-specific MOBILE model. It is the current recommended model to estimate emissions from idling Mexican vehicles. However, the

MOBILE model will continue to evolve in Mexico; in the future, INE staff should be contacted to identify the most current MOBILE model.

United States Customs officials maintain vehicle counts of all vehicles that enter into the United States. However, these statistics do not provide U.S. and Mexico vehicle fractions. Also, these statistics do not include a distribution of vehicles into different vehicle classification (i.e., LDGV, HDDV, etc.) The Mexico/U.S. vehicle fraction will have to be determined through a survey at the border crossing(s). The distribution of vehicle classifications can also be determined through the border crossing survey and/or local or regional vehicle registration data.

Finally, the length of idling time is required. U.S. Customs officials can make a rough estimate of this, but a survey should be conducted to assess this duration. Sufficient surveying is important to determine a representative idling time, Mexico/U.S. vehicle fraction, and vehicle distribution. All of these data can vary significantly by hour, by day, and by season.

Given the data listed above, the equation to estimate emissions from idling vehicles is:

$$
\begin{aligned}
\text{Emissions} = &\sum (\text{Vehicles}_{\text{Total}} \times \text{VF}_{\text{Mexico}} \times \text{VC}_{\text{Mexico,v}} \times \text{EF}_{\text{Mexico,v}} \times 4.0 \times \text{T}_{\text{Idle}}) \\
+ &\sum (\text{Vehicles}_{\text{Total}} \times \text{VF}_{\text{US}} \times \text{VC}_{\text{US,v}} \times \text{EF}_{\text{US,v}} \times 2.5 \times \text{T}_{\text{Idle}})
\end{aligned}
\tag{5.5-1}
$$

where:

	$\text{Vehicles}_{\text{Total}}$	=	Total number of vehicles passing through the border crossing;
	$\text{VF}_{\text{Mexico}}$, VF_{US}	=	Fraction of vehicles that are from Mexico or the U.S.;
	$\text{VC}_{\text{Mexico,v}}$, $\text{VC}_{\text{US,v}}$	=	Fraction of Mexico and U.S. vehicles in each vehicle class, v;
	$\text{EF}_{\text{Mexico,v}}$, $\text{EF}_{\text{US,v}}$	=	Emission factor for Mexico and U.S. vehicle in each vehicle class, v, taken from MOBILE- and/or PART5-based emission factor model;
	4.0 (2.5)	=	Factor used to convert grams per kilometer (grams per mile) emission factor to grams per hour emission factor; and
	T_{Idle}	=	Average time spent idling in queue at border crossing.

DATA NEEDED:

Data	Sources
MOBILE5a and PART5 Emission Factor Model Input Parameters	Description of needed data and available sources can be found in the Motor Vehicle Manual (Volume VI of this series).
Vehicle Counts	U.S. Customs officials and other local officials.
Mexico/U.S. Vehicle Fractions	Site-specific survey.
Distribution of Vehicle Classifications	Site-specific survey or local vehicle registration data.
Idling Time	Site-specific survey or U.S. (and Mexican) Customs officials.

NOTES:

1.   Care must be taken to prevent double counting of emissions that are already included as mobile source emissions. Overall VMT from vehicle counts should not need adjustment for double counting. Overall VMT from fuel sales, however, should be adjusted for double counting. Also, there is some question on how "real" the emission estimates become when the speed drops to 4 kph.

SAMPLE CALCULATION:

In 1995, an estimated 800,000 vehicles passed from Mexico into the United States through a particular border crossing. For this example, emissions will not be estimated for those vehicles passing from the United States into Mexico. Survey results indicated an average idling time of 12 minutes per vehicle. Of the vehicles entering the United States, 62% are Mexican vehicles with the remaining vehicles being U.S. vehicles. Seventy percent of U.S. vehicles and 75% of Mexican vehicles are LDGVs. The remaining vehicles are LDGTs. Calculate annual NO_x emissions from these idling vehicles.

1.   From MOBILE runs, the following hypothetical fleet average NO_x emission factors were calculated:

U.S. LDGVs: 2.4 g/mile
U.S. LDGTs: 3.2 g/mile
Mexico LDGVs: 2.7 g/mile
Mexico LDGTs: 3.6 g/mile

2. Multiplying these emission factors by 2.5 mph gives the following idling emission factors:

U.S. LDGVs:	6.0 g/hour
U.S. LDGTs:	8.0 g/hour
Mexico LDGVs:	6.75 g/hour
Mexico LDGTs:	9.0 g/hour

3. The number of vehicles for each category is calculated using vehicle fractions and vehicle class fractions.

   U.S. LDGVs: 800,000 vehicles $\times$ 0.38 $\times$ 0.70 = 212,800 vehicles
   U.S. LDGTs: 800,000 vehicles $\times$ 0.38 $\times$ 0.30 = 91,200 vehicles
   Mexico LDGVs: 800,000 vehicles $\times$ 0.62 $\times$ 0.75 = 372,000 vehicles
   Mexico LDGTs: 800,000 vehicles $\times$ 0.62 $\times$ 0.25 = 124,000 vehicles

4. The total NO_x emissions are then calculated:

   (212,800 vehicles $\times$ 0.2 hours $\times$ 6.0 g/hour) + (91,200 vehicles $\times$ 0.2 hours $\times$ 8.0 g/hour) + (372,000 vehicles $\times$ 0.2 hours $\times$ 6.75 g/hour) + (124,000 vehicles $\times$ 0.2 hours $\times$ 9.0 g/hour)
   = 255.4 kg + 145.9 kg + 502.2 kg + 223.2 kg
   = 1.13 Mg NO_x

5.6   Bus/Truck Terminals

SOURCE CODE: DESCRIPTION:

22-01-070-900*   Heavy Duty Gasoline Vehicles (HDGV)
22-30-070-900*   Heavy Duty Diesel Vehicles (HDDV)

* Proposed Mexico-specific codes for source category not typically inventoried in the U.S.

DESCRIPTION:

This section addresses emissions from bus/truck terminals. In Mexico, buses
and trucks often line up for extended periods of time while waiting to load
and/or unload passengers or cargo. Vehicles in the queue typically do not turn
off their engines, but idle while they inch forward in line. The methodology
described below is similar to that described for border crossings (see Section
5.5).

Because these idling emissions are emitted by on-road motor vehicles, an
argument could be made that idling emissions should be included as a mobile
source. However, unlike typical mobile source emissions, the location of idling
emissions from bus/truck terminals is very well defined (i.e., the road segments
or stations that make up the bus/truck terminal). Also, the latest versions of the
mobile source emission factor models (MOBILE5a, PART5, and related
modified versions) can only be used to estimate emissions from moving
vehicles. For these reasons, idling emissions at bus/truck terminals should be
treated as area sources.

POLLUTANTS: TOG, CO, NO$_x$, SO$_x$, PM$_{10}$

ROG: For non-catalyst gasoline vehicles, ROG is 92.4% of TOG.
For catalyst gasoline vehicles, ROG is 85.2% of TOG.
For diesel vehicles, ROG is 95.7% of TOG.

POINT SOURCE ADJUSTMENTS: None.

METHODOLOGY:

As discussed in Section 5.5 above, the latest versions of MOBILE5a and
PART5 do not provide any idling emission factors. Earlier versions of
MOBILE provided some idling emission factors. However, these emission
factors represented standard test conditions (stabilized operating mode, 75 °F,
and 9.0 psi RVP fuel). Because U.S. EPA has been unable to develop a

satisfactory algorithm to account for variations in operating mode, ambient temperature, and fuel RVP, the direct calculation of idling emission factors has been disabled in MOBILE5a while idling emissions data are being collected.

U.S. EPA has provided an interim methodology for estimating idling emissions using MOBILE5a (U.S. EPA, 1993). This methodology can be used to estimate vehicle emissions at bus/truck terminals and in other idling situations. It is assumed that this methodology is valid for PART5 and any MOBILE models that have been modified for use in Mexico (i.e., MOBILE-MCMA, MOBILE-MMAp, MOBILE-Juárez, etc.). A MOBILE model will be used to estimate TOG, CO, and NO_x emissions. A PART5 model will be used to estimate PM_{10} emissions. SO_x emissions will be estimated by using a simple fuel balance.

In the U.S. EPA interim methodology, idling emission rates are calculated using exhaust emission factors from a MOBILE run set at the lowest allowable vehicle speed (4 kilometers per hour [kph] for Mexico-specific modified MOBILE models). The lowest allowable speed is used because it contains the largest percentage of idle time of any of the speed cycles used by the MOBILE model. After running the MOBILE model, exhaust emission factors for TOG, CO, and NO_x will be calculated in units of grams per kilometer. To convert these emission factors to idling emission factors in units of grams per hour, multiply by 4 kph. The resulting idling TOG emission factor should not include any non-exhaust emissions. For more information on running the MOBILE and PART5 models, consult the Motor Vehicle Manual (Volume VI of this series) and/or the MOBILE and PART5 User's Guides (U.S. EPA, 1994; U.S. EPA, 1995). MOBILE-Juárez (Radian, 1996) is the most recent Mexico-specific MOBILE model. It is the current recommended model to estimate emissions from idling Mexican vehicles. However, the MOBILE model will continue to evolve in Mexico; in the future, INE staff should be contacted to identify the most current MOBILE model.

Finally, the length of idling time is needed to estimate emissions. Bus/truck terminal employees might be able to estimate this, but a survey may be needed to determine accurate durations. It is important that sufficient surveying be conducted to determine representative idling time and vehicle distribution. All of these data can vary significantly by hour, by day, and by season.

Given the data listed above, the equation to estimate emissions from idling vehicles is:

$$\text{Emissions} = \sum (\text{Vehicles}_{\text{Total}} \times VC_{\text{Mexico},v} \times EF_{\text{Mexico},v} \times 4.0 \times T_{\text{Idle}}) \qquad (5.6\text{-}1)$$

where:	Vehicles$_{\text{Total}}$	=	Total number of vehicles passing through the bus/truck terminal;
	VC_v	=	Fraction of vehicles in each vehicle class, v;
	EF_v	=	Emission factor for vehicle in each vehicle class, v, taken from MOBILE- and/or PART5-based emission factor model;
	4.0	=	Factor used to convert grams per kilometer emission factor to grams per hour emission factor; and
	T_{Idle}	=	Average time spent idling in queue at the bus/truck terminal.

DATA NEEDED:

Data	Sources
MOBILE5a and PART5 Emission Factor Model Input Parameters	Description of needed data and available sources can be found in the Motor Vehicle Manual (Volume VI of this series).
Vehicle Counts	Bus/truck terminal employees or other local officials.
Distribution of Vehicle Classifications	Site-specific survey.
Idling Time	Site-specific survey, bus/truck terminal employees, or frequent terminal users

NOTES:

1.   Care must be taken to prevent double counting of emissions that are already included as mobile source emissions. Overall VMT from vehicle counts should not need adjustment for double counting. Also, there is some question on how "real" the emission estimates become when the speed drops to 4 kph.

EXAMPLE CALCULATION:

In 1995, an estimated 20,000 vehicles passed through a particular bus terminal. Survey results indicate an average waiting time of 15 minutes per vehicle.

Forty percent of vehicles are HDGVs and the remaining vehicles are HDDVs. Calculate annual NO_x emissions from these idling vehicles.

1. Assume that from the latest MOBILE model, the following NO_x emission factors were calculated:

   HDGVs: 2.8 g/km
   HDDVs: 13.3 g/km

2. Multiplying these emission factors by 4.0 kph gives the following idle emission factors:

   HDGVs: 11.2 g/hour
   HDDVs: 53.2 g/hour

3. The number of vehicles for each category is calculated using the total number of vehicles and vehicle class fractions:

   HDGVs: 20,000 vehicles $\times$ 0.40 = 8,000 vehicles
   HDDVs: 20,000 vehicles $\times$ 0.60 = 12,000 vehicles

4. The total NO_x emissions are then calculated:

   (8,000 vehicles $\times$ 0.25 hours $\times$ 11.2 g/hour) +
   (12,000 vehicles $\times$ 0.25 hours $\times$ 53.2 g/hour)
   = 22.4 kg + 159.6 kg
   = 182 kg
   = 0.18 Mg NO_x

6.0   SOLVENT USE

Many solvent use activities may be too small or too numerous to be included in the point source inventory for a given inventory region. Therefore, these smaller solvent evaporation sources need to be included in the area source inventory effort. Inventory guidance for these sources are presented in the following subsections:

- Industrial Surface Coating;

- Auto Body Refinishing;

- Architectural Surface Coating;

- Traffic Paint;

- Industrial Surface Cleaning (Degreasing);

- Dry Cleaning;

- Graphic Arts;

- Asphalt Application; and

- Commercial/Consumer Solvent Use.

6.1   Industrial Surface Coating

SOURCE CODE: **DESCRIPTION:**

24-01-010-xxx	Textile Products
24-01-015-xxx	Factory Finished Wood
24-01-020-xxx	Wood Furniture
24-01-025-xxx	Metal Furniture
24-01-030-xxx	Paper
24-01-035-xxx	Plastic Products
24-01-040-xxx	Metal Cans
24-01-045-xxx	Metal Coils
24-01-050-xxx	Miscellaneous Finished Materials
24-01-055-xxx	Machinery and Equipment
24-01-060-xxx	Large Appliances
24-01-065-xxx	Electronic and Other Electrical
24-01-070-xxx	Motor Vehicles
24-01-075-xxx	Aircraft
24-01-080-xxx	Marine
24-01-085-xxx	Railroad
24-01-090-xxx	Miscellaneous Manufacturing
24-01-100-xxx	Industrial Maintenance Coatings
24-01-200-xxx	Other Special Purpose Coatings
24-01-990-xxx	All Surface Coating Categories

DESCRIPTION:

Surface coating operations consist of applying a thin layer of coating such as paint, varnish, lacquer, or paint primer to an object for decorative or protective purposes. There are a number of steps involved in the coating process. Surface coatings are applied during the manufacture of a wide variety of products, including furniture, cans, automobiles, airplanes and other transportation equipment, machinery, appliances, flat wood, wire, and other miscellaneous products. In addition, coatings are used in maintenance operations at industrial facilities.

Solvents contained in the surface coatings evaporate as the coating is applied and dries. Although residual solvents may remain in the coating after the coating has dried, and some of the coating will not be used and will be disposed of in facility wastewater or sent to a landfill, most inventory efforts assume that all of the coating solvents evaporate into the air.

Emissions from surface coating operations can be reduced by the use of water-based coatings, the use of filters, condensation systems, afterburners, and more efficient application processes in which less solvent is applied.

POLLUTANTS: TOG

ROG: ROG emissions are 98.8% of TOG.

POINT SOURCE ADJUSTMENTS:

Surface coating operations may occur at large facilities that may be inventoried as point sources. Therefore, the emission calculation procedure for area source estimates must be adjusted to prevent double counting with the point source estimates. If per employee emission factors are used, employment at the point source facilities should be subtracted from the total inventory area employment. If employment data are not available, then the point emissions can be subtracted from total emissions.

METHODOLOGY:

Emissions from this source can be calculated using one of two methods.

Method 1: The first method uses a per capita emission factor developed for Mexico City (DDF, 1995b).

The calculation using the per capita emission factor is:

$$\text{Annual TOG Emissions} = (\text{Population}) \times (\text{Emission Factor}) \tag{6.1-1}$$

If any industrial surface coating facilities are included in this point source inventory, their emissions should be removed from this estimate to yield an area source emission estimate.

Method 2: The second method uses per employee emission factors that are based on national averages from the U.S. These U.S.-based per employee emission factors have limited applicability in Mexico and should only be used if no other Mexico-specific data are available. The use of the per employee emission factors requires collection of data on the number of people employed within certain industries. A brief industry description is provided in the table in the **DATA NEEDED** portion of this section. After local or regional industries are matched to the groupings in the table, the employment for point source facilities in those groups must be subtracted from the total number of people

employed in each industrial category. The remaining number is the area source employment. Emissions are then calculated as:

$$\begin{array}{c} \text{Annual TOG} \\ \text{Emissions} \end{array} = \left(\begin{array}{c} \text{Area Source} \\ \text{Industry Group} \\ \text{Employment} \end{array} \right) \times \left(\begin{array}{c} \text{Emission} \\ \text{Factor} \end{array} \right) \qquad (6.1\text{-}2)$$

Emission factors for both of these methods are provided in the **DATA NEEDED** portion of this section.

DATA NEEDED:

Data		Sources
Per Capita Emission Factor Method:		
Population		INEGI
TOG Emission Factor	1.28 kg/person/yr	DDF, 1995b
Per Employee Method:		
Employment by Industry Type		SNIFF Database, CANACINTRA, INEGI
TOG Emission Factor		U.S. EPA, 1991a
Factory Finished Wood	59 kg/employee/yr (131 lb/employee/yr)	
Metal Furniture and Fixtures	428 kg/employee/yr (944 lb/employee/yr)	
Electrical Insulation	132 kg/employee/yr (290 lb/employee/yr)	
Metal Cans	2,735 kg/employee/yr (6,029 lb/employee/yr)	
Miscellaneous Finished Metal (sheet, strip and coil)	1,305 kg/employee/yr (2,877 lb/employee/yr)	
Machinery and Equipment	35 kg/employee/yr (77 lb/employee/yr)	
Appliances	210 kg/employee/yr (463 lb/employee/yr)	
Motor Vehicles (new)	360 kg/employee/yr (794 lb/employee/yr)	
Other Transportation (includes aircraft and railroad)	16 kg/employee/yr (35 lb/employee/yr)	
Marine	140 kg/employee/yr (308 lb/employee/yr)	

NOTES:

1.   The emission factor for industrial surface coatings was developed by DDF (1995b), based on information on national product sales (for 1993) provided by ANAFAPYT (National Association of Paint and Ink Manufacturers).

2.   The per capita emission factor was developed by multiplying the total volume of paint by 0.45 to reflect that the average paint is estimated to contain 45% solvent.

3.   Adjustments to both the per capita and the per employee emission factors may be needed to reflect local conditions, and, over time, to reflect changes in coating usage and composition.

4.   The emission estimates calculated using the per employee factors will need to be linked to industrial codes in SNIFF to facilitate reconciliation with the point source inventory.

5.   An alternative to the emission factors presented above is to survey a representative number of surface coating operations. Results from the survey should then be scaled up to the entire inventory area.

   •   The section on surveys in Volume III, *Basic Emission Estimating Techniques*, should be reviewed before conducting a survey.

   •   The entire population of facilities must be identified, but only a representative sample of these facilities will be surveyed.

Surveys should request information that can be used to calculate emissions using the material balance method (see *Basic Emission Estimating Techniques*). A survey should request the following information:

   •   Name and location of the facility;

   •   Name of the person filling out the survey, or the person who can be contacted for further questions;

   •   Number of employees at the facility;

   •   Type of product coated at the facility (e.g., wood or metal furniture, household appliances, machinery, boats);

   •   Kilograms of surface coatings used at the facility (if amounts of coatings are recorded as liters, then it will be necessary to collect information on the coating density to calculate the weight), weight for each type of coating used; and

   •   Chemical constituents in each coating.

If this method is done properly, the results will be much more accurate than the results from the first method. However, this method requires more effort and expense. If this method is not done correctly, the results may be less accurate than using emission factors.

SAMPLE CALCULATION:

For example, total annual TOG emissions from industrial surface coatings in a state with a population of 1,250,000 are:

$$(1{,}250{,}000 \text{ persons}) \times (1.28 \text{ kg/person/yr}) = 1{,}600{,}000 \text{ kg/yr}$$

$$= 1{,}600 \text{ Mg/yr}$$

If there are large facilities that have surface coating operations in the inventory area, and they have been inventoried as point sources, then the emissions assigned to those facilities need to be subtracted from the total calculated above. For example, if the point source emissions are:

- 124 Mg per year for Facility A;

- 83 Mg per year for Facility B; and

- 17 Mg per year for Facility C.

Then:

$$\begin{array}{l} \text{Area Source} \\ \text{Emissions} \end{array} = 1{,}600 \text{ Mg} - (124 \text{ Mg} + 83 \text{ Mg} + 17 \text{ Mg})$$

$$= 1{,}376 \text{ Mg/yr}$$

Calculations needed for the second method are similar. However, in this case, subtracting the employment at point sources from the total employment should result in a more accurate emission estimate. For example,

- Total employment at metal furniture and fixture factories in the inventory area is 623; and

- Point source employment at two metal furniture factories is 479.

Then:

$$\begin{array}{l} \text{Area Source} \\ \text{Employment} \end{array} = 623 - 479$$

$$= 144 \text{ metal furniture factory employees}$$

Area source emissions are then calculated as:

$$\text{Area Source Emissions} = (144 \text{ employees}) \times (428 \text{ kg/employee/yr})$$

$$= 61,632 \text{ kg/yr}$$

$$= 61.6 \text{ Mg/yr}$$

6.2   Auto Body Refinishing

<u>SOURCE CODE</u>: 24-01-005-000

<u>DESCRIPTION</u>:

> Auto body refinishing is the repair and restoration of automobile, light truck, and other vehicle bodies. Refinishing operations occur subsequent to those at original equipment manufacturer assembly plants. Coating of new vehicles is not included in this source category, but falls under the industrial surface coating source category in a point source inventory. Most auto body refinishing jobs are performed as part of collision repair and involve only portions of a vehicle. Painting may take place in a spray booth.

> Auto body refinishing operations can range in size from large production shops with many employees to very small operations where an individual works part time. In some instances, the large operations may be inventoried as point source facilities.

> Emissions occur during surface cleaning, filling and priming, painting, and cleanup. Emissions from refinishing operations are influenced by the solvent content of the product, transfer efficiency of the spray equipment used to apply the coatings, and cleanup practices. Controls can include using lower solvent coatings, increased transfer efficiency for spray equipment, and enclosed cleaning devices.

<u>POLLUTANTS</u>: TOG

<u>ROG</u>:   ROG emissions are 98.8% of TOG.

<u>POINT SOURCE ADJUSTMENTS</u>:

> Auto body refinishing may take place at point source facilities. Uncontrolled emissions that have been calculated for point source facilities should be subtracted from the uncontrolled emissions total to yield an estimate of area source emissions.

<u>METHODOLOGY</u>:

Annual TOG Emissions = (Population) $\times$ (Emission Factor)   (6.2-1)

DATA NEEDED:

Data	Sources
Population	INEGI
TOG emission factor 0.14 kg/person/yr	DDF, 1995b

NOTES:

1.   The emission factor shown for auto body refinishing was developed by
      DDF (1995b) based on information on national solvent content and
      product sales (for 1993) provided by ANAFAPYT (National Association
      of Paint and Ink Manufacturers).

2.   The emission factor was developed by multiplying the total volume of
      paint by 0.45 to reflect that the average paint is estimated to contain
      45% solvent.

3.   Adjustments to this per capita emission factor may be needed to reflect
      local conditions. Additional adjustments over time may be required
      because substitution of compounds contained in auto body refinishing
      may alter the non-reactive fraction.

SAMPLE CALCULATION:

For example, total annual TOG emissions from auto body refinishing use in the
state of Colima (population 428,510) are:

$$(428{,}510 \text{ persons}) \times (0.14 \text{ kg/person/yr}) = 59{,}991 \text{ kg/yr}$$

$$= 59.99 \text{ Mg/yr}$$

6.3   Architectural Surface Coating

SOURCE CODE: 24-01-001-000

DESCRIPTION:

Architectural surface coatings are used by painting contractors and individuals to protect and enhance building interior and exterior surfaces. Architectural surface coating involves spreading a thin layer of coating such as paint, paint primer, varnish, or lacquer to architectural surfaces, and the use of solvents for thinning and cleanup. This category does <u>not</u> include auto refinishing, traffic paint application, industrial surface coating, industrial maintenance coatings, or paints used in graphic arts applications. Because emissions from this category will be distributed throughout the inventory area and will not occur repeatedly at a single place during an inventory period, this category should be treated only as an area source.

TOG that are used as solvents in the coatings are emitted during application of the coating and as the coating dries. Control techniques involve either the substitution of products or the reformulation of products. Alternative products include low solvent content coatings, waterborne coatings, and powder coatings.

POLLUTANTS: TOG

ROG: ROG emissions are 94.5% of TOG for water-based architectural coatings, 96.8% of TOG for oil-based architectural coatings, and 69.9% of TOG for thinners/clean-up solvents used with architectural coatings.

POINT SOURCE ADJUSTMENTS: None.

METHODOLOGY:

Annual TOG Emissions = (Population) $\times$ (Emission Factor)   (6.3-1)

DATA NEEDED:

Data	Sources
Population	INEGI
TOG Emission Factor 1.36 kg/person/yr	DDF, 1995b

NOTES:

1. The emission factor shown for architectural surface coatings was developed by DDF (1995b) based on information on solvent content and product sales (for 1993) provided by ANAFAPYT (National Association of Paint and Ink Manufacturers).

2. The emission factor was developed by multiplying the total volume of paint by 0.45 to reflect that the average paint is estimated to contain 45% solvent.

3. Adjustments to this per capita emission factor may be needed to reflect local conditions. Additional adjustments over time may be required because substitution of compounds contained in architectural surface coatings may alter the non-reactive fraction.

SAMPLE CALCULATION:

For example, total annual TOG emissions from architectural surface coating use in the state of Colima (population 428,510) are:

$$(428{,}510 \text{ persons}) \times (1.36 \text{ kg/person/yr}) = 582{,}774 \text{ kg/yr}$$

$$= 582.77 \text{ Mg/yr}$$

6.4   Traffic Paint

SOURCE CODE: 24-01-008-000

DESCRIPTION:

Traffic paint application is the painting of centerlines, edge stripes, directional markings, parking lot markings, and paved and unpaved surfaces to improve traffic flow. Traffic markings can include solvent- and water-based paints, which are usually applied with a spray, or in the form of thermoplastics or preformed tapes that are epoxied to the road surface. Traffic paints are applied by maintenance crews and traffic paint contractors during road construction and repairs. Because emissions from this category will be scattered throughout the inventory area and will not occur repeatedly at a single place during an inventory period, this category should be treated only as an area source.

Factors such as climatic conditions, the durability of the paint, pavement type, traffic density, and position of the marking will determine how often the paint will need to be re-applied, and thereby influence emissions. Control techniques involve the substitution or reformulation of products. Alternative formulations include water-based paints, thermoplastics, permanent markers, and preformed tapes.

POLLUTANTS: TOG

ROG: ROG emissions are 98.8% of TOG.

POINT SOURCE ADJUSTMENTS: None.

METHODOLOGY:

Annual TOG Emissions = (Population) $\times$ (Emission Factor)   (6.4-1)

DATA NEEDED:

Data		Sources
Population		INEGI, 1993
TOG emission factor	0.04 kg/person/yr	DDF, 1995b

NOTES:

1. The emission factor shown for traffic paint application was developed by DDF (1995b) based on information on solvent content and product sales (for 1993) provided by ANAFAPYT (National Association of Paint and Ink Manufacturers).

2. The emission factor was developed by multiplying the total volume of paint by 0.45 to reflect that the average paint is estimated to contain 45% solvent.

3. Adjustments to this per capita emission factor may be needed to reflect local conditions. Additional adjustments over time may be required because substitution of compounds contained in traffic paint application may alter the non-reactive fraction.

SAMPLE CALCULATION:

For example, total annual TOG emissions from traffic paint application use in the state of Colima (population 428,510) are:

$$(428{,}510 \text{ persons}) \times (0.04 \text{ kg/person/yr}) = 17{,}140 \text{ kg/yr}$$

$$= 17.14 \text{ Mg/yr}$$

6.5   Industrial Surface Cleaning (Degreasing)

SOURCE CODE: **DESCRIPTION:**

24-15-000-xxx	All Processes/All Industries
24-15-005-xxx	Furniture and Fixtures
24-15-010-xxx	Primary Metal Industries
24-15-015-xxx	Secondary Metal Industries
24-15-020-xxx	Fabricated Metal Products
24-15-025-xxx	Industrial Machinery and Equipment
24-15-030-xxx	Electronic and Other Electrical Processes
24-15-035-xxx	Transportation Equipment
24-15-040-xxx	Instruments and Related Products
24-15-045-xxx	Miscellaneous Manufacturing
24-15-050-xxx	Transportation Maintenance Facilities
24-15-055-xxx	Automotive Dealers
24-15-060-xxx	Miscellaneous Repair Services
24-15-065-xxx	Auto Repair Services

DESCRIPTION:

Surface cleaning operations involve the use of solvent liquids or solvent vapors to remove water-insoluble contaminants such as grease, oils, waxes, carbon deposits, fluxes, and tars from metal, plastic, glass, and other surfaces. This process takes place in a large variety of manufacturing, scientific, and repair operations. Solvent cleaning operations involve the use of a number of different solvents and different solvent cleaning procedures.

Solvent cleaning equipment can be categorized as:

- Batch cold cleaning machines -- these machines are batch loaded and liquid solvent is sprayed, dipped, or brushed onto the surfaces that are to be cleaned.

- Batch vapor cleaning machines -- these machines are batch loaded, and the materials to be cleaned are exposed to vaporized solvent. The condensing solvent flushes the contaminants from the surfaces to be cleaned.

- In-line cleaning machines -- these machines are loaded on a continual basis and are often custom made for large-scale operations. An in-line solvent cleaning machine may use liquid solvent or vapor solvent.

- Cleanup solvent use -- this process involves wiping a surface with the solvent and a rag, mop, or sponge.

POLLUTANTS: TOG

ROG: ROG emissions are 100% of TOG for petroleum solvents and 0% of TOG for synthetic solvents. If chemical speciation data are available for the inventory region, the ROG/TOG ratio should be adjusted accordingly. If only the total amount of surface cleaning solvents is known, then it may be estimated that ROG emissions are 60% of TOG emissions (U.S. EPA, 1991a).

POINT SOURCE ADJUSTMENTS:

Solvent cleaning operations may occur at large facilities that may be inventoried as point sources. Therefore, the emission calculation procedure must be adjusted to prevent double counting with the point source estimates. If per employee emission factors are used, employment at the point source facilities should be subtracted from the total inventory area employment. If employment data are not available, then the point emissions can be subtracted from total emissions.

METHODOLOGY:

Emissions from this source can be calculated using one of two emission factors. The second method, which uses a per capita emission factor, should be used only as a last resort.

Method 1: The first group of emission factors, derived in the U.S., are based on the number of employees for facilities that typically have solvent cleaning operations. These U.S.-based per employee emission factors have limited applicability in Mexico and should only be used if no other data are available. The use of per employee emission factors requires collection of data on the number of people employed within certain industries. A brief industry description is provided in the following table under **DATA NEEDED**. After local or regional industries are matched to the groupings in the table, the employment for point source facilities in those groups must be subtracted from the total number of people employed in each industrial category. The remaining number is the area source employment.

$$\begin{pmatrix} \text{Annual} \\ \text{Emissions} \end{pmatrix} = \begin{pmatrix} \text{Area Source} \\ \text{Industry Group} \\ \text{Employment} \end{pmatrix} \times \begin{pmatrix} \text{Emission} \\ \text{Factor} \end{pmatrix} \qquad (6.5\text{-}1)$$

Method 2: The second group of emission factors, also derived in the U.S., are based on population (U.S. EPA, 1991a). These U.S.-based per capita emission factors have limited applicability in Mexico and should only be used if no other data are available. The calculation using the per capita emission factor is:

$$\text{Annual Emissions} = (\text{Population}) \times (\text{Emission Factor}) \tag{6.5-2}$$

If any solvent cleaning operations are included in the point source inventory, their emissions should be removed from this estimate to yield an area source emission estimate.

Per employee and per capita emission factors are provided in the **DATA NEEDED** portion of this section. If information is available on the specific solvent cleaning operations in the geographic region of interest, emission factors for only those operations should be used. If information is not available on the types of cleaning operations, the "solvent cleaning (total)" emission factor should be used.

DATA NEEDED:

Data		Sources
Per Employee Method:		
Employment by Industry Type		SNIFF Database, CANACINTRA, INEGI
TOG Emission Factors Solvent Cleaning (total)	65 kg/employee/yr	U.S. EPA, 1991a

Batch Cold Cleaning
    Auto Repair
    Manufacturing
	
	122 kg/employee/yr
	11 kg/employee/yr	

Batch Vapor and In-line Machines
    Electronics and Electrical
    Other
	
	68 kg/employee/yr
	22 kg/employee/yr	

Data		Sources
Per Capita Emission Factor Method:		
Population		INEGI
TOG Emission Factors Solvent Cleaning (total)	3.27 kg/person/yr	U.S. EPA, 1991a
Batch Cold Cleaning Auto Repair Manufacturing	 1.13 kg/person/yr 0.50 kg/person/yr	
Batch Vapor and In-line Machines Electronic and Electrical Other	 0.50 kg/person/yr 1.13 kg/person/yr	

NOTES:

1. Adjustments to both the per capita and the per employee emission factors may be needed to reflect local conditions, and, over time, to reflect changes in solvent usage and composition.

2. The emission estimates calculated using the per employee factors will need to be correctly linked to SNIFF to facilitate reconciliation with the point source inventory.

3. An alternative to using the emission factors presented above is to a survey a representative number of surface cleaning operations. Results from this the survey then must be scaled up to the entire inventory area. See the **NOTES** portion of the Industrial Surface Coating section (Section 6.1) for an outline of the survey procedure. Surveying procedures are also contained in the *Basic Emissions Estimating Technique* manual.

SAMPLE CALCULATION:

Per Employee Method

Calculations needed for both methods are similar. However, in the first method, subtraction of the point source employment from the total employment should result in a more accurate emission estimate. For example,

- Total employment at manufacturing plants that use cleaning in the inventory area is 623; and

- Point source employment at two equipment manufacturing factories that use cold cleaning in their process is 379.

Then:

$$\begin{array}{l}\text{Area Source} \\ \text{Employment}\end{array} = 623 - 379$$

$$= 244 \text{ manufacturing factory employees}$$

Emissions are calculated as:

$$\begin{array}{l}\text{Area Source} \\ \text{TOG Emissions}\end{array} = (244 \text{ employees}) \times (11 \text{ kg/employee/yr})$$

$$= 2{,}684 \text{ kg/yr}$$

$$= 2.7 \text{ Mg/yr}$$

The same procedure is used if there are other point source surface cleaning operations in the inventory area.

Per Capita Method

If the second method is used, total annual TOG emissions from surface cleaning in a state with a population of 1,250,000 are:

$$(1{,}250{,}000 \text{ persons}) \times (3.27 \text{ kg/person/yr}) = 4{,}087{,}500 \text{ kg/yr}$$

$$= 4{,}087.5 \text{ Mg/yr}$$

If there are large facilities that use cold cleaning processes in the inventory area, and they have been inventoried as point sources, then the emissions assigned to those facilities need to be subtracted from the total calculated above. For example, if the point source emissions are:

- 178 Mg per year for Facility A;

- 123 Mg per year for Facility B; and

- 56 Mg per year for Facility C.

Then:

$$\text{Area Source} \atop \text{Emissions} = 4,087.5 \text{ Mg} - (178 \text{ Mg} + 123 \text{ Mg} + 56 \text{ Mg})$$

$$= 3,730.5 \text{ Mg/yr}$$

6.6   Dry Cleaning

SOURCE CODE: DESCRIPTION:

24-20-000-000	All Processes, All Solvent Types
24-20-000-055	All Processes, Perchloroethylene
24-20-000-370	All Processes, Special Naphthas
24-20-000-999	All Processes, Other Solvents
24-20-010-000	Commercial/Industrial Cleaners, All Solvent Types
24-20-010-055	Commercial/Industrial Cleaners, Perchloroethylene
24-20-010-370	Commercial/Industrial Cleaners, Special Naphthas
24-20-010-999	Commercial/Industrial Cleaners, Other Solvents

DESCRIPTION:

The dry cleaning industry is a service industry for the cleaning of clothing, draperies, leather goods, and other fabric items. Dry cleaning operations use halogenated or petroleum distillate organic solvents for cleaning. Dry cleaners can range in size from large industrial plants, which are typically treated as point sources, to very small operations with one unit, which may only be used intermittently. Commercial plants are the intermediate size between the two extremes.

Dry cleaning typically uses the following solvents: perchloroethylene, 1,1,1-trichloroethane, trichlorofluoroethane (CFC-113), as well as Stoddard solvent and other petroleum solvents. Perchloroethylene, trichloroethane, and CFC-113 are not considered photochemically reactive and should not be included in an inventory for ozone precursors.

Emissions occur from dry cleaning facilities when the solvents evaporate during the process, from leaks in the equipment, and from solvent recovery or disposal systems. Emissions can be controlled by using add-on control devices such as refrigerated condensers, reducing fugitive emissions from equipment leaks, and minimizing evaporation from solvent storage containers.

POLLUTANTS: TOG

ROG: As mentioned above, perchloroethylene, 1,1,1-trichloroethane, and CFC-113 are not considered photochemically reactive and should not be included in an inventory for ozone precursors. Only dry cleaning processes that use petroleum solvents will have ROG emissions. Therefore, ROG emissions are 100% of TOG for petroleum solvents and 0% of TOG for synthetic solvents. If only the

total amount of dry cleaning solvents is known, then it may be estimated that ROG emissions are 58% of TOG emissions (U.S. EPA, 1991a).

POINT SOURCE ADJUSTMENTS:

Industrial dry cleaning facilities may be inventoried as point sources. Therefore, the area source emission calculation procedure must be adjusted to prevent double counting with the point source estimates. If per employee emission factors are used, employment at the point source facilities should be subtracted from the total inventory area employment. If employment data are not available, then the point emissions can be subtracted from total emissions.

METHODOLOGY:

Emissions from this source can be calculated using one of two emission factors. Emission factors for halogenated and petroleum solvent emissions are provided in the **DATA NEEDED** portion of this section.

Method 1: The first method uses per employee emission factors (based on national averages from the U.S.). These U.S.-based per employee emission factors have limited applicability in Mexico and should only be used if no other data are available. Emissions and reactivity of TOG emissions vary by the type of solvent used in the different types (sizes) of dry cleaning facilities (industrial, commercial, or small).

The use of per employee emission factors requires collection of data on the number of people employed by dry cleaning facilities that use either halogenated solvents (perchloroethylene, trichloroethane, or CFC-113) or petroleum solvents. Because small facilities are assumed to use only halogenated solvents, employees in these facilities should be excluded from the employment total if an inventory for ROG is being prepared. After employment data for dry cleaning facilities have been collected, the employment at point source facilities is subtracted from the total number of people employed. The resulting number of employees represents the area source employment. Emissions are then calculated as:

$$\text{Annual Emissions} = \left(\begin{array}{c} \text{Area Source Dry} \\ \text{Cleaning Employment} \end{array} \right) \times (\text{Emission Factor}) \qquad (6.6\text{-}1)$$

Method 2: The second emission factor is based on population calculated from national average solvent use in the U.S. (U.S. EPA, 1991a). These U.S.-based per capital emission factors have limited applicability in Mexico and should only be used if no other data are available.

The calculation using the per capita emission factor is:

$$\text{Annual Emissions} = (\text{Population}) \times (\text{Emission Factor}) \tag{6.6-2}$$

If any dry cleaning operations are included in the point source inventory, their emissions should be removed from this estimate to yield an area source emission estimate.

DATA NEEDED:

Data			Sources
Per Employee Method:			
Employment in Dry cleaning Facilities			SNIFF Database, CANALAVA[a], INEGI
TOG Emission Factor			U.S. EPA, 1991a
Dry cleaning (total)		1,043 kg/employee/yr (2,300 lb/employee/yr)	
Halogenated solvents		445 kg/employee/yr (980 lb/employee/yr)	
Small facilities		24 kg/employee/yr (52 lb/employee/yr)	
Commercial/industrial facilities		544 kg/employee/yr (1,200 lb/employee/yr)	
ROG Emission Factor			
Petroleum solvents		816 kg/employee/yr (1,800 lb/employee/yr)	
Per Capita Emission Factor Method:			
Population			INEGI
TOG Emission Factor			U.S. EPA, 1991a
Dry cleaning (total)		0.86 kg/person/yr (1.9 lb/person/yr)	
Halogenated solvents		0.37 kg/person/yr (0.81 lb/person/yr)	
Small facilities		0.005 kg/person/yr (0.01 lb/person/yr)	
Commercial/industrial facilities		0.36 kg/person/yr (0.80 lb/person/yr)	
ROG Emission Factor			U.S. EPA, 1991a
Petroleum solvents		0.50 kg/person/yr (1.1 lb/person/yr)	

[a] Information from CANALAVA may be available only for Chamber members.

NOTES:

1.   The per capita and per employee factors presented here are based on U.S. national solvent use averages, not on data specific to Mexico. More accurate estimates should be made with emission factors developed from data specific to the dry cleaning industry in Mexico obtained from CANALAVA.

2.   Adjustments to both the per capita and the per employee emission factors may be needed to reflect local variation, and over time, to reflect changes in solvent usage and composition.

3.   The emission estimates calculated using the per employee factors will need to be correctly linked to SNIFF to facilitate reconciliation with the point source inventory.

4.   An alternative to the emission factors presented above is a survey of a representative number of dry cleaning operations. Results from this survey should then be scaled up to the entire inventory area. See the **NOTES** portion of the Industrial Surface Coating section (Section 6.1) for an outline of the survey procedure. Surveying procedures are also contained in the *Basic Emissions Estimating Techniques* Manual.

SAMPLE CALCULATION:

Calculations needed for both methods are similar. However, in the first method, subtracting the employment at point sources from the total employment should result in a more accurate emission estimate. For example,

•   Total employment at dry cleaning plants that use halogenated solvents in the inventory area is 990; and

•   Point source employment at Facilities A, B, and C totals 170.

Then:

Area Source Employment = 990 – 170

$\qquad\qquad$ = 820 halogenated solvent dry cleaning employees

Emissions are then calculated as:

$$\begin{array}{l} \text{Area Source} \\ \text{TOG Emissions} \end{array} = (820 \text{ employees}) \times (445 \text{ kg/employee/yr})$$

$$= 364{,}900 \text{ kg/yr}$$

$$= 364.9 \text{ Mg/yr}$$

If the second method is used, total annual TOG emissions from facilities using halogenated solvents in a state with a population of 1,250,000 are:

$$(1{,}250{,}000 \text{ persons}) \times (0.37 \text{ kg/person/yr}) = 462{,}500 \text{ kg/yr}$$

$$= 462.5 \text{ Mg/yr}$$

If there are large facilities that use halogenated solvents for dry cleaning in the inventory area, and they have been inventoried as point sources, then the emissions assigned to those facilities need to be subtracted from the total calculated above. For example, if the point source emissions are:

- 32 Mg per year for Facility A;

- 11.2 Mg per year for Facility B; and

- 23 Mg per year for Facility C.

Then:

$$\text{Area Source Emissions} = 462.5 \text{ Mg} - (32 \text{ Mg} + 11.2 \text{ Mg} + 23 \text{ Mg})$$

$$= 396.3 \text{ Mg/yr}$$

6.7   Graphic Arts

SOURCE CODE: DESCRIPTION:

24-25-000-xxx   All Processes
24-25-010-xxx   Lithography
24-25-020-xxx   Letterpress
24-25-030-xxx   Rotogravure
24-25-040-xxx   Flexography

DESCRIPTION:

Graphic arts includes operations that are involved in the printing of newspapers, magazines, books, and other printed materials. Printing may be performed on various substrates (e.g., coated or uncoated paper, metal, or fabric). The difference between printing on paper coating is that printing always involves the application of ink by a printing press. The four basic operations used in graphic arts in the U.S. are web lithography, rotogravure, web letterpress, and flexography. Screen printing and manual or sheet-fed techniques are less common. Lithography is characterized by a planographic image carrier (i.e., the image and nonimage areas are on the same plane). In gravure printing, the image area is engraved (i.e., "intaglio") relative to the surface of the image carrier. In letterpress, the image area is raised, and the ink is transferred to the substrate directly from the image surface. Flexography also uses an image area above the surface of the plate, but flexography uses a rubber image carrier, whereas letterpress uses a metal or plastic one.

Printing inks vary widely in composition, but all consist of three major components: pigments, binders, and solvents. The majority of solvent use in graphic arts operations is consumed in printing ink formulations, with lesser amounts of solvents used for equipment cleaning or as a component in fountain solutions for dampening systems in lithographic printing. The solvents evaporate from the inks into the atmosphere during the drying process. Although residual solvents may remain in the printed product after the ink has dried, and some of the inks will not be used and will be disposed of in facility wastewater or to a landfill, most inventory efforts conservatively assume that all of the ink solvents evaporate into the air.

Emissions from graphic arts operations can be reduced by the use of water-based inks, more efficient application processes in which less ink is applied, filters, condensation systems, and afterburners.

POLLUTANTS: TOG

ROG: ROG emissions are 100% of TOG.

POINT SOURCE ADJUSTMENTS:

> Graphic arts operations may occur at large facilities that may be inventoried as point sources. Therefore, the emission calculation procedure must be adjusted to prevent double-counting with the point source estimates.

METHODOLOGY:

> The calculation using the per capita emission factor is:

$$\text{Annual TOG Emissions} = (\text{Population}) \times (\text{Emission Factor}) \qquad (6.7\text{-}1)$$

> If any large graphic arts facilities are included in the point source inventory, their emissions should be removed from this estimate to yield an area source emission estimate.
>
> Note that this U.S.-based per capita emission factor has limited applicability in Mexico and should only be used if no other data are available.

DATA NEEDED:

Data	Sources
Per Capita Emission Factor Method:	
Population	INEGI
TOG Emission Factor (for all types of graphic arts operations) 0.59 kg/person/yr (1.3 lb/person/yr)	U.S. EPA, 1991a

NOTES:

1. The fifth edition of AP-42 (AP-42, 1995) presents a per capita emission factor of 0.4 kg non-methane volatile organic compound (VOC)/person/yr. However, this emission factor is based on 1981 data and, therefore, the 1991 U.S. EPA guidance is considered to be more current.

2. It may soon be possible to develop a Mexico-specific per capita emission factor for graphic arts based on information on product sales available from the

National Association of Paint and Ink Manufacturers (ANAFAPYT) and population estimates as summarized below:

Per capita EF   =   (total annual inks usage, liters) $\times$ (DDF adjustment factor for growth from data year to inventory year) $\times$ (percentage of ink solvent) $\times$ (average ink density, g/liter)/(population)   (6.7-2)

DDF has already developed some Mexico-specific per capita emission factors for various surface coating categories using this approach (DDF, 1995b).

3.   Adjustments to per capita emission factors may be needed to reflect local conditions and to reflect changes in ink usage and composition over time.

4.   An alternative to the emission factor approach presented above is to survey a representative number of graphic arts operations. Results from the survey should then be scaled up to the entire inventory area. See the **NOTES** portion of the Industrial Surface Coating Section (Section 6.1) for an outline of the survey procedure. Surveying procedures are also contained in the *Basic Emissions Estimating Techniques* Manual.

SAMPLE CALCULATION:

For example, total annual TOG emissions from graphic arts in a state with a population of 1,250,000 are:

(1,250,000 persons) x (0.59 kg/person/yr) = 737,500 kg/yr
 = 737.5 Mg/yr

If there are large graphic arts facilities in the inventory region that have been inventoried as point sources, then the emissions assigned to those facilities need to be subtracted from the total calculated above. For example, if the point source emissions are:

•   12 Mg/yr for Facility A; and

•   15 Mg/yr for Facility B;

Then:

Area Source Emissions = (Total Emissions) - (Point Emissions)
= 737.5 - (12 + 15)
= 710.5 Mg/yr

6.8   Asphalt Application

SOURCE CODE: DESCRIPTION:

24-61-021-000   Cutback Asphalts
24-25-022-000   Emulsified Asphalt

DESCRIPTION:

Asphalt surfaces and pavements are composed of compacted aggregate and an asphalt binder. The aggregate transmits the load from the surface to the base course, takes the abrasive wear of traffic, and provides a nonskid surface. The binder holds the aggregate together and prevents movement or loss of aggregate. This source category addresses hydrocarbon emissions from the evaporation of these binders.

Asphalt binders may be asphalt cement or liquified asphalts. Asphalt cement is the residue of distillation processes. There are two types of liquified asphalts: cutback asphalts and emulsified asphalts. Cutback asphalts are asphalt cement thinned or "cutback" with volatile petroleum distillates, and they are generally categorized as rapid cure, medium cure, and slow cure. Asphalt characterization is based on the solvent used as a diluent and the corresponding time needed for curing (i.e., gasoline or naphtha is used as a diluent for rapid cure, whereas kerosene and other low volatility fuel oils are used for medium and slow cure). Emulsified asphalts use a blend of water and emulsifier (i.e., soap) instead of solvent diluent, and they rely on water evaporation or ionic bonding to cure.

TOG emissions result from the evaporation of the petroleum distillate solvent used to liquify the asphalt cement. The type and quantity of diluent used are the two major variables affecting the total VOC emissions and the time over which emissions occur. Long-term emissions can be estimated by assuming that 95 wt% of the diluent evaporates from rapid cure, 70 wt% from medium cure, and 25 wt% from slow cure (U.S. EPA, 1995a). Some of the diluent appears to be permanently retained in the road surface after application.

POLLUTANTS: TOG

ROG: ROG emissions are 100% of TOG.

POINT SOURCE ADJUSTMENTS:

Asphalt batch plants may be inventoried as point sources. Emissions that have been calculated for these point source facilities may include TOG estimates for emissions from the diluents during mixing or material handling. If this is the case, these diluent emissions should be subtracted from the emissions total in order to estimate area source emissions.

METHODOLOGY:

To calculate emissions, required data include the total amount of each type of asphalt applied in the inventory region and the type and amount of diluent used in each region. Since the amount of diluent in the asphalt is usually provided in percent by volume, the general emission estimating equations are:

Density of the asphalt = (density of asphalt cement) $\times$ (vol% asphalt cement) + (density of asphalt diluent) $\times$ (vol% asphalt diluent)   (6.8-1)

Volume of asphalt applied = (mass of asphalt applied) / (density of the asphalt)   (6.8-2)

Total volume of diluent = (volume of asphalt applied) $\times$ (vol% diluent)   (6.8-3)

Total mass of diluent = (total volume of diluent) $\times$ (diluent density)   (6.8-4)

Total TOG emissions = (Total mass of diluent) $\times$ (% of diluent evaporated based on cure type)   (6.8-5)

If the amount of diluent in the asphalt is provided in percent by weight, then the general emission estimating equations are simply:

Total mass of diluent = (mass of asphalt applied) $\times$ (wt% diluent density)   (6.8-6)

Total TOG emissions = (Total mass of diluent) $\times$ (% of diluent evaporated based on cure type)   (6.8-7)

DATA NEEDED:

Data	Sources
Amount of each type of asphalt applied in the inventory region	Municipal agency (e.g., *Dirección General de Obras Públicas* in Mexico City)
Physical properties of the asphalt (asphalt cement and diluent)	Municipal agency (e.g., *Dirección General de Obras Públicas* in Mexico City)
TOG Emission Factor (i.e., wt% evaporated) 95 wt% for rapid cure 70 wt% for medium cure 25 wt% for slow cure	AP-42

NOTES:

1.   If region-specific physical properties for asphalt are not available, the following default values may be used:

Physical Property	Default Value	Source
wt% diluent in asphalt	0.34 wt% (Mexico City) 6.2 wt% (all other areas of Mexico)	DDF, 1996b
diluent density	0.7 kg/liter (naphtha, rapid cure) 0.8 kg/liter (medium cure) 0.9 kg/liter (slow cure)	AP-42
asphalt cement density	1.1 kg/liter 1.1 - 1.5 kg/liter	AP-42 CRC, 1985, p. F-1

2.   If the amount of asphalt applied is only available for a portion of the inventory region, these available data should be used to develop a per capita emission factor to be used together with population data to develop emission estimates for the other portion of the region as shown in the Sample Calculation. DDF has used this approach to develop emission estimates for asphalt application in the Mexico City Metropolitan Zone (ZMCM)(DDF, 1996b).

SAMPLE CALCULATION:

Local records show that 10,000 kg of rapid cure cutback asphalt was applied in a given area during the year. This asphalt is reported to be 45 vol% naphtha. Assuming that the density of naphtha is 0.7 kg/liter and the density of the asphalt cement is 1.1 kg/liter, calculate the annual TOG emissions.

1.   Density of the asphalt =   (density of asphalt cement) × (vol% asphalt cement) + (density of asphalt diluent) × (vol% asphalt diluent)

                             =   (1.1 kg/liter) x (55 vol%) + (0.7 kg/liter) x (45 vol%)
                             =   0.92 kg/liter

2.   Volume of asphalt applied = (mass of asphalt applied) / (density of the asphalt)

                             =   (10,000 kg) / (0.92 kg/liter)
                             =   10,870 liters

3.   Total volume of diluent =   (volume of asphalt applied) × (vol% diluent)

                             =   (10,870 liters) × (45 vol%)
                             =   4,891 liters

4.   Total mass of diluent =   (total volume of diluent) x (diluent density)

                             =   (4,891 liter) × (0.7 kg/liter)
                             =   3,424 kg

5.   Total TOG emissions =   (Total mass of diluent) × (% of diluent evaporated based on cure type)

                             =   (3,424 kg) × (95% evaporation for rapid cure)
                             =   3,253 kg TOG/yr

If there are large asphalt batch plants in the inventory region that have been inventoried as point sources, then the diluent emissions reported by those facilities need to be subtracted from the total calculated above. For example, if the point source emissions are:

- 500 kg TOG/yr for Facility A (400 kg from diluent, 100 kg from combustion); and

- 300 kg TOG/yr for Facility B (250 kg from diluent, 50 kg from combustion);

Then:

Area Source Emissions   = (Total Emissions) - (Point Emissions)
                                             = $3{,}253 - (400 + 250)$
                                           = 2,603 kg TOG/yr

6.9   Commercial/Consumer Solvent Use

<u>**SOURCE CODE:**</u>   <u>**DESCRIPTION:**</u>

<u>Consumer</u>
24-65-000-000   All Consumer Products
24-65-100-000   Personal Care Products
24-65-200-000   Household Products
24-65-300-000   Aerosol Products
24-65-400-000   Automotive Aftermarket Products
24-65-600-000   Adhesives and Sealants
24-65-800-000   Household Pesticides
24-65-900-000   Miscellaneous Products

<u>Commercial</u>
24-61-000-000   Total Commercial Products
24-61-600-000   Adhesives and Sealants
24-61-800-000   Commercial Pesticides

<u>**DESCRIPTION:**</u>

Hydrocarbons are ingredients of consumer and commercial products which serve as propellants, aid in product drying (through evaporation), act as co-solvents and cleaning agents, and are emitted during product use. Typically these hydrocarbon sources are large in number, highly dispersed, and individually emit relatively small amounts of TOG. Commercial and consumer products which release TOG include aerosols, household products, personal care products, automotive aftermarket products, adhesives and sealants, and commercial and household pesticides.

Solvents contained in consumer and commercial products are primarily released during product use. Residual amounts of solvent may remain in discarded product packaging, enter the municipal solid waste stream, and be disposed of in landfills. Solvents from these products may also enter the wastewater treatment system through use and disposal. Most inventory efforts assume that all TOG in consumer and commercial products volatilize to the air.

Typical TOG constituents that are released to the atmosphere from this source category include special naphthas, alcohols and various chloro- and fluorocarbons. Approximately 31% of the TOG released from these products is considered non-photochemically reactive (AP-42, 1995).

POLLUTANTS: TOG

ROG: ROG emissions are estimated to be 69% of TOG.

POINT SOURCE ADJUSTMENTS: None.

METHODOLOGY:

Annual TOG Emissions = (Population) × (Emission Factor)   (6.9-1)

DATA NEEDED:

Data	Sources
Population	INEGI
ROG Emission Factors	
Aerosol Products 0.046 kg/person/yr	DDF, 1995b
Household Products 0.36 kg/person/yr	U.S. EPA, 1996a
Personal Care Products 1.05 kg/person/yr	U.S. EPA, 1996a
Automotive Aftermarket Products 0.61 kg/person/yr	U.S. EPA, 1996a
Adhesives and Sealants 0.26 kg/person/yr	U.S. EPA, 1996a
Commercial/Household Pesticides 0.81 kg/person/yr	U.S. EPA, 1996a
Miscellaneous Products 0.03 kg/person/yr	U.S. EPA, 1996a
TOTAL ROG 3.17 kg/person/yr	
TOG Emission Factors	
Aerosol Products 0.067 kg/person/yr	DDF, 1995b
Household Products 0.52 kg/person/yr	U.S. EPA, 1996a
Personal Care Products 1.52 kg/person/yr	U.S. EPA, 1996a
Automotive Aftermarket Products 0.88 kg/person/yr	U.S. EPA, 1996a
Adhesives and Sealants 0.38 kg/person/yr	U.S. EPA, 1996a
Commercial/Household Pesticides 1.17 kg/person/yr	U.S. EPA, 1996a
Miscellaneous Products 0.04 kg/person/yr	U.S. EPA, 1996a
TOTAL TOG 4.58 kg/person/yr	

NOTES:

1.   The TOG emission factors have been developed from the referenced ROG emission factors and estimating that ROG emissions are 69% of the TOG.

2.   The emission factor shown for aerosol products was developed by DDF (1995b) based on information on solvent content and product sales (for

1993) provided by ANAFAPYT (National Association of Paint and Ink Manufacturers).

3.   Adjustments to these per capita emission factors may be needed over time because substitution of compounds contained in commercial/ consumer products may alter the non-reactive fraction of compounds.

SAMPLE CALCULATION:

For example, total annual TOG emissions from consumer and commercial solvent use in the state of Colima (population 428,510) are:

$$(428,510 \text{ persons}) \times (4.58 \text{ kg/capita/yr}) = 1,962,576 \text{ kg/yr}$$

$$= 1,963 \text{ Mg/yr}$$

7.0 PETROLEUM PRODUCT STORAGE AND TRANSPORT

The various emission points associated with petroleum product storage and transport are generally considered too numerous to be included in the point source inventory for a given inventory region. Therefore, these smaller evaporation sources need to be included in the area source inventory effort. Inventory guidance for these sources are presented in the following subsections:

- Gasoline Distribution (includes gasoline tank trucks in transit, tank truck unloading [Stage I], underground tank breathing, and vehicle refueling [Stage II] and spillage);

- Aircraft Refueling; and

- Liquified Petroleum Gas (LPG) Distribution.

7.1   Gasoline Distribution

<u>**SOURCE CODE**</u>:   <u>**DESCRIPTION**</u>:

25-01-060-000	Gasoline Service Stations: All Processes
25-01-060-050	Stage I: Total
25-01-060-051	Stage I: Submerged Filling
25-01-060-052	Stage I: Splash Filling
25-01-060-053	Stage I: Balanced Submerged Filling
25-01-060-100	Stage II: Total
25-01-060-101	Stage II: Displacement Loss/Uncontrolled
25-01-060-102	Stage II: Displacement Loss/Controlled
25-01-060-103	Stage II: Spillage
25-05-030-120	Truck Transportation: Gasoline
25-01-060-200	Underground Tank: Total
25-01-060-201	Underground Tank: Breathing and Emptying

<u>**DESCRIPTION**</u>:

In the gasoline distribution industry, gasoline is transported from refineries by tanker trucks to bulk plants and terminals, and ultimately to service stations. The procedures discussed below relate directly to the emissions that occur during the transportation and distribution of gasoline from bulk plants and terminals to service stations.

Evaporative emissions occur at all points in the gasoline distribution process. Those operations generally thought of as area sources are gasoline dispensing stations (service stations) and gasoline tank trucks in transit. Bulk terminals and gasoline bulk plants, which are intermediate distribution points between refineries and outlets, should be inventoried as point sources.

Area sources of TOG from the transportation and distribution of gasoline involve the following types of emissions:

•   Breathing losses

-        Evaporation of gasoline from the tank truck during transportation of the gasoline from the bulk plant/terminal to the service station or other dispensing outlet;

-        Evaporation of gasoline from the empty tank truck on the return trip from the service station within an inventory area to the bulk plant/terminal; and

- Evaporation of gasoline from the underground storage tank(s) or the lines going to the gasoline dispensing outlet (pumps) when standing and not in use.

- Working losses

    - Evaporation of gasoline during the transfer of gasoline from the tank truck to underground storage at the service station (often referred to as "Stage I");

    - Evaporation of gasoline during the transfer of gasoline from the pump to vehicles (often referred to as "Stage II");

    - Spillage of gasoline (and subsequent evaporation) during either delivery activity, above. This loss is made up of contributions from prefill and postfill nozzle drip and from spit-back and overflow from the filler pipe of the vehicle's fuel tank during filling; and

    - Evaporation of gasoline from the underground storage tank or the lines going to the pumps during transfer of gasoline.

POLLUTANTS: TOG

ROG: For gasoline, the fraction of the total emissions that is methane or ethane is negligible; therefore, ROG emissions are estimated to be 100% of TOG. For diesel fuels, methane and ethane constitute 15% of total TOG evaporative emissions, so ROG emissions are estimated to be 85% of TOG.

POINT SOURCE ADJUSTMENTS:

Gasoline distribution activities may occur at large facilities that may be inventoried as point sources. Emissions that have been calculated for point source facilities must be subtracted from the emissions total in order to estimate area source emissions.

METHODOLOGY:

The most accurate approach to estimate area source gasoline distribution emissions is to acquire gasoline consumption data, which is then multiplied by a number of emission factors to determine evaporative losses. Gasoline distribution and consumption statistics are collected and maintained by PEMEX.

The flow of gasoline through the inventory area should be mapped to gasoline consumption. The best approach is to develop a chart showing overall gasoline flow within the inventory area, from the point of entry, through bulk storage, to service stations and vehicle loading operations. Construction of this flowchart provides a valuable overview of the gasoline distribution system and facilitates detection of gross anomalies in the distribution data. Care should be taken that all gasoline consumed in the inventory area is accounted for, including that dispensed at marinas, airports, military bases, and government motor pools.

Tank Truck Unloading

Emissions from tank truck unloading are affected by whether the service station tank is equipped for submerged, splash, or balance filling. Therefore, information must be obtained on the fraction of stations using each filling method. A survey of several service stations in the area will produce an estimate of the number of stations employing each filling method. PEMEX is another source of information on station characteristics.

Tank truck unloading losses occur as hydrocarbon vapors in "empty" cargo tanks are displaced to the atmosphere by the liquid being loaded into the tanks. These vapors are a composite of (1) vapors formed in the empty tank by evaporation of residual product from previous loads, (2) vapors transferred to the tank in vapor balance systems as product is being unloaded, and (3) vapors generated in the tank as the new product is being loaded.

In the splash loading method, the fill pipe dispensing the gasoline is lowered only part way into the cargo tank. Significant turbulence and vapor/liquid contact occur during the splash loading operation, resulting in high levels of vapor generation and loss. If the turbulence is great enough, liquid droplets will be entrained in the vented vapors.

A second method of loading is submerged loading. Two types are the submerged fill pipe method and the bottom loading method. In the submerged fill pipe method, the fill pipe extends almost to the bottom of the tank. In the bottom loading method, a permanent fill pipe is attached to the tank bottom. During most of submerged loading by both methods, the fill pipe opening is below the liquid surface level. Liquid turbulence is controlled significantly during submerged loading, resulting in much lower vapor generation than encountered during splash loading.

One control measure for vapors displaced during gasoline loading is called "vapor balance" or Stage I vapor control, in which the vapors displaced during product

unloading return to the tank truck cargo compartment. The control efficiency of the recovery units range from 90 to over 99 percent.

Emissions from loading gasoline (or any petroleum liquid) can be estimated (with a probable error of ±30 percent) using the following expression:

$$EF_{tu} = 12.46 \ \frac{SPM}{T} \qquad\qquad (7.1\text{-}1)$$

where: EF_{tu} = Loading loss, lbs per 1,000 gallons of liquid loaded;
  S = Saturation factor (see Table 7.1-1). The saturation factor, S, represents the expelled vapor's fractional approach to saturation, and it accounts for the variations observed in emission rates from the different unloading and loading methods;
  P = True vapor pressure of liquid loaded, pounds per square inch absolute (psia) (see Table 7.1-2);
  M = Molecular weight of vapors, pounds per pound-mole (lb/lb-mole) (see Table 7.1-2); and
  T = Temperature of bulk liquid loaded, °R (°F + 460).

To estimate emissions, the emission factor for tank truck unloading is applied to the total fuel dispensed, as noted in the following equation:

$$E_{tu} = EF_{tu} \times F \qquad\qquad (7.1\text{-}2)$$

where: E_{tu} = Total emissions from tank truck unloading (kg/year);
  EF_{tu} = Emission factor for tank truck unloading (kg/liter); and
  F = Fuel dispensed (liters/year).

Table 7.1-1

Saturation Factors (S) For Calculating Petroleum Liquid Loading Losses

Cargo Carrier	Mode of Operation	S Factor
Tank trucks and rail tank cars	Submerged loading: clean cargo tank	0.50
	Submerged loading: dedicated normal service	0.60
	Submerged loading: dedicated vapor balance service	1.00
	Splash loading: clean cargo tank	1.45
	Splash loading: dedicated normal service	1.45
	Splash loading: dedicated vapor balance service	1.00
Marine vessels[a]	Submerged loading: ships	0.2
	Submerged loading: barges	0.5

[a]   For products other than gasoline and crude oil.

Source: AP-42, 1995a, Section 5.2.

Note: the saturation factor reflects the degree to which the vented vapors are saturated, relative to equilibrium conditions. That is, S = 1.00 represents vented vapors at equilibrium conditions. If liquid droplets are entrained in the vented vapors, S > 1.0.

Table 7.1-2

Properties (M$_V$ and P$_{VA}$) of Selected Petroleum Liquids

Petroleum Liquid	Vapor Molecular Weight at 60°F, M$_V$ (lb/lb-mole)	True Vapor Pressure, P$_{VA}$ (psia)							
		40°F	50°F	60°F	70°F	80°F	90°F	100°F
Gasoline RVP 13	62	4.7	5.7	6.9	8.3	9.9	11.7	13.8
Gasoline RVP 10	66	3.4	4.2	5.2	6.2	7.4	8.8	10.5
Gasoline RVP 7	68	2.3	2.9	3.5	4.3	5.2	6.2	7.4
Crude Oil RVP 5	50	1.8	2.3	2.8	3.4	4.0	4.8	5.7
Jet naphtha (JP-4)	80	0.8	1.0	1.3	1.6	1.9	2.4	2.7
Jet kerosene	130	0.0041	0.0060	0.0085	0.011	0.015	0.021	0.029
Distillate Fuel Oil No. 2	130	0.0031	0.0045	0.0074	0.0090	0.012	0.016	0.022
Residual Oil No. 6	190	0.00002	0.00003	0.00004	0.00006	0.00009	0.00013	0.00019

Source: AP-42, 1995a, Section 7.1. Where possible, values for these properties for Mexican petroleum derivatives should be obtained from PEMEX.

DATA NEEDED:

Data	Sources
Fuel consumption dispensed	PEMEX
TOG Emission factors[a] Calculated using Equation 7.1-1 or Submerged filling: 880 mg/liter of fuel Splash filling: 1,380 mg/liter of fuel Balanced submerged filling: 40 mg/liter of fuel	AP-42, 1995

[a] Factors are for TOG as well as ROG because the methane and ethane content of gasoline vapors is negligible.

SAMPLE CALCULATION-TANK TRUCK UNLOADING:

Assume that in the inventory region, 100,000 m^3 of gasoline (RVP = 10 psia) are unloaded from tank trucks at service stations in a given year. Assume that all the service station tanks are equipped for submerged filling and that the tank trucks are operated in dedicated normal service. Finally, assume that the average loading temperature is 21°C.

1.   Determine the saturation factor, S.

       Use Table 7.1-1 for submerged loading dedicated normal service, S = 0.6.

2.   Determine the true vapor pressure and the vapor molecular weight.

       Use Table 7.1-2. For RVP = 10 psia, the default value for vapor molecular weight is 66 lb/lb-mole.

       The average loading temperature is 21°C or 70°F. Therefore, the default value for the true vapor pressure is 6.2 psia.

3.   Determine the emission factor, using equation 7.1-1:

$$EF_{tu} = 12.46 \; \frac{SPM}{T}$$

$$= 12.46 \times \left[\frac{(0.6) \; (6.2) \; (66)}{(70 \; + \; 460)} \right]$$

$$= 5.77 \; lb/1000 \; gal$$

$$= 0.69 \; kg/1000 \; liters$$

$$= 0.69 \; kg/m^3$$

4.   Determine the TOG emissions from these tank truck unloading operations using equation 7.1-2:

$$E_{tu} = EF_{tu} \times F$$

$$E_{tu} = (0.69 \; kg/m^3) \times (100,000 \; m^3)$$
$$= 69,000 \; kg \; TOG = 69 \; Mg \; TOG$$

Underground Tank Breathing

A second source of vapor emissions from service stations is underground tank breathing. Breathing losses occur daily and are attributable to gasoline evaporation and barometric pressure changes. The frequency with which gasoline is withdrawn from the tank, allowing fresh air to enter to enhance evaporation, also has a major effect on the quantity of these emissions. An average breathing emission rate is 120 mg/liter of throughput.

To estimate emissions, the emission factor for tank breathing is applied to the total fuel dispensed, as noted in the following equation:

$$E_b = EF_b \times F \tag{7.1-3}$$

where: E_b = Total underground tank breathing emissions (mg/year);
              EF_b = Emission factor for tank breathing (mg/liter); and
              F = Fuel dispensed (liter/year).

DATA NEEDED:

Data	Sources
Fuel Dispensed	PEMEX
TOG Emission factor[a] 120 mg/liter of fuel dispensed	AP-42, 1995

[a] Factor is for TOG as well as ROG because the methane and ethane content of gasoline vapors is negligible.

SAMPLE CALCULATION - UNDERGROUND TANK BREATHING:

As in Sample Calculation #1, assume that 100,000 m^3 of gasoline are dispensed from service stations in the inventory region in a given year. Use equation 7.1-3 to determine the TOG emissions from underground tank breathing:

$$E_b = EF_b \times F$$

$$EF_b = (120 \text{ mg/liters}) \times (1 \text{ kg}/10^6 \text{ mg}) \times (1000 \text{ liters/m}^3) = 0.120 \text{ kg/m}^3$$

$$E_b = (0.120 \text{ kg/m}^3) \times (100,000 \text{ m}^3)$$

$$= 12,000 \text{ kg TOG}$$

$$= 12 \text{ Mg TOG}$$

Gasoline Tank Trucks In Transit

Breathing losses from tank trucks during the transport of gasoline are caused by leaking delivery trucks, pressure in the tanks, and thermal effects on the vapor and on the liquid. A worst case situation arises if a poorly sealed tank has been loaded with gasoline and pure air becomes saturated. During the vaporization process, pressure increases and venting occurs.

Because some gasoline is delivered to bulk plants, rather than delivered directly to service stations from bulk terminals, the amount of gasoline transferred in any area may exceed the total gasoline consumption due to the additional trips involved. Therefore, transit emissions involve not only end consumption, but also gasoline transport from outside the inventory area to the intermediate bulk plants, and should be based on total gasoline transferred rather than on consumption. For example, if gasoline sales in an area are 300 million liters per year, and 50 million liters of this goes through bulk plants, then 350 million

liters is the amount transported by tank trucks and is the appropriate figure to use to estimate transit losses. In the U.S., a default assumption of 25 percent is applied if site-specific data cannot be obtained. In other words, gasoline distribution in an area could be multiplied by 1.25 to estimate gasoline transportation (AP-42, 1991a). This U.S.-based default value has limited applicability in Mexico and should only be used if no other data are available.

To estimate emissions the emission factor for tank trucks in transit is applied to the total fuel transferred, as noted in the following equation:

$$E_{tt} = EF_{tt} \times F_t \tag{7.1-4}$$

where: E_{tt} = Total emissions from tank trucks in transit (mg/year);
EF_{tt} = Emission factor for tank trucks in transit (mg/liter); and
F_t = Fuel in transit through inventory area, including through bulk plants (liter/year).

DATA NEEDED:

Data	Sources
Fuel transferred into and through inventory area	PEMEX
TOG Emission factors[a] Tank truck loaded with product 0-1 mg/liter transported Tank truck returning with vapor 0-13 mg/liter transported	AP-42, 1995

[a] Factors are for TOG as well as ROG because the methane and ethane content of gasoline vapors is negligible.

NOTES:

1.   The U.S. EPA default (25 percent) used for gasoline transit through bulk plants is meant to correct for gasoline going through bulk terminals. A more accurate adjustment can be created using data from the bulk terminals in the inventory area.

SAMPLE CALCULATION - GASOLINE TANK TRUCKS IN TRANSIT:

As in the previous sample calculations, assume that 100,000 m^3 of gasoline are delivered to service stations in the inventory region in a given year. Assume that the amount delivered to bulk plants is unknown.

1. Determine the total amount of gasoline in transit.

    Since the amount delivered to bulk plants is unknown, use the U.S. default value of 25 percent.

    $$F_t = F_{\text{service station}} + F_{\text{bulk plants}}$$
    $$= F_{\text{service stations}} + 0.25 F_{\text{service stations}}$$
    $$= 1.25 \times 100,000 \text{ m}^3$$
    $$= 125,000 \text{ m}^3 \text{ gasoline}$$

2. Determine the TOG emissions from gasoline tank trucks in transit and loaded with product using equation 7.1-4.

    $$E_{tt} = EF_{tt} \times F_t$$
    $$EF_{tt} = (0.5 \text{ mg/liters}) \times (1 \text{ kg}/10^6 \text{ mg}) \times (1000 \text{ liters/m}^3)$$
    $$= 0.0005 \text{ kg/m}^3$$
    $$E_{tt} = (0.0005 \text{ kg/m}^3) \times (125,000 \text{ m}^3)$$
    $$= 62.5 \text{ kg TOG}$$

3. Determine the TOG emissions from gasoline tank trucks in transit and returning with vapor.

    $$E_{tt} = EF_{tt} \times F_t$$
    $$EF_{tt} = (6.5 \text{ mg/liters}) \times (1 \text{ kg}/10^6 \text{ mg}) \times (1000 \text{ liters/m}^3)$$
    $$= 0.0065 \text{ kg/m}^3$$
    $$E_{tt} = (0.0065 \text{ kg/m}^3) \times (125,000 \text{ m}^3)$$
    $$= 812.5 \text{ kg TOG}$$

Vehicle Refueling (Stage II) and Spillage

Vehicle refueling emissions come from vapors displaced from the automobile tank by dispensed gasoline and from spillage. The quantity of displaced vapors depends on gasoline temperature, auto tank temperature, gasoline Reid vapor pressure (RVP), and dispensing rate. Equation 7.1-5 can be used to estimate uncontrolled displacement losses from vehicle refueling for a particular set of conditions.

$$264.2 \ [(-5.909) - 0.0949 \ (\Delta T) + 0.0884 \ (T_D) + 0.485 \ (\qquad\qquad (7.1\text{-}5)$$

where:
EF_r = TOG emission factor for vehicle refueling (mg/liter);
ΔT = Difference between temperature of fuel in vehicle tank and temperature of dispensed fuel, °F;
T_D = Temperature of dispensed fuel, °F; and
RVP = Reid vapor pressure, psia.

It is estimated that the uncontrolled emissions from the vapors displaced during vehicle refueling average 1,320 mg/liter of dispensed gasoline (AP-42, 1995). This U.S.-based average value has limited applicability in Mexico and should only be used if no other data are available.

Spillage loss is made up of contributions from prefill and postfill nozzle drip and from spit-back and overflow from the vehicle's fuel tank filler pipe during filling. The amount of spillage loss can depend on several variables, including service station business characteristics, tank configuration, and operator refueling techniques. An average spillage loss is 80 mg/liter of dispensed gasoline (AP-42, 1995). The U.S.-based average value has limited applicability in Mexico and should only be used if no other data are available.

To estimate emissions, the emission factor for vehicle refueling is applied to the total fuel dispensed, as noted in the following equation:

$$E_{rs} = EF_{rs} \times F \qquad\qquad (7.1\text{-}6)$$

where:
E_{rs} = Emissions associated with vehicle refueling and spillage (kg/year);
EF_{rs} = Emission factors for refueling and spillage (mg/liter); and
F = Fuel dispensed (liter/year).

DATA NEEDED:

Data	Sources
Fuel dispensed	PEMEX
TOG Emission factors[a] Refueling Emissions Equation 7.1-5 or Uncontrolled: 1320 mg/liter of fuel Controlled: 132 mg/liter of fuel Spillage 80 mg/liter of fuel	AP-42, 1995

[a] Factors are for TOG as well as ROG because the methane and ethane content of gasoline vapors is negligible.

SAMPLE CALCULATION - VEHICLE REFUELING AND SPILLAGE

Assume again that 100,000 m^3 of gasoline (RVP = 10 psia) are dispensed in the inventory region in a given year. Assume that the temperature of the dispensed fuels is 15°C and the temperature of the fuel in the vehicle tank is about 21°C. Finally assume that the U.S.-based average value for spillage loss is applicable.

1.   Determine the TOG emission factor for vehicle refueling, using equation 7.1-5.

$$EF_r = 264.2 \ [(-5.909) - 0.0949 \ (\Delta T) + 0.0884 \ (T_D) + 0.485 \ (RVP)]$$

$$= 264.2 \ [(-5.909) - 0.0949 \ (70°F - 59°F) + 0.0884 \ (59°) + 0.485 \ (10)]$$

$$= 822 \ \text{mg/liter}$$

$$= 0.822 \ \text{kg/m}^3$$

2.   Determine the TOG emission factor for spillage.

$$EF_s = 80 \ \text{mg/liter}$$

$$= 0.080 \ \text{kg/m}^3$$

3.   Determine the TOG emissions from vehicle refueling and spillage, using equation 7.1-6.

$$E_{rs} = EF_{rs} \times F$$

$$EF_{rs} = (0.822 \text{ kg/m}^3) + (0.080 \text{ kg/m}^3)$$

$$= 0.902 \text{ kg/m}^3$$

$$E_{rs} = (0.902 \text{ kg/m}^3) \times (100,000 \text{ m}^3)$$

$$= 90,200 \text{ kg TOG}$$

$$= 90.2 \text{ Mg TOG}$$

7.2   Aircraft Refueling

SOURCE CODE: **DESCRIPTION:**

22-75-900-000   Refueling: All Fuels

DESCRIPTION:

Gasavión and Turbosina are the most common types of aircraft fuels used in Mexico. Emissions occur when vapor-laden air in a partially empty fuel tank is displaced to the atmosphere when the tank is refilled. The quantity of vapor displaced depends on the fuel temperature, fuel vapor pressure, aircraft fuel tank temperature, and fuel dispensing rate.

Commercial and general aviation aircraft may not contribute enough emissions to be treated as point sources. Their refueling emissions exhibit regional, seasonal, and temporal variations determined by the concentration of air traffic at the airports in the study area (typically located close to urban areas), the airlines' daily schedules, and the travel seasons.

POLLUTANTS: TOG

ROG: ROG emissions are estimated to be 100% of TOG since it is assumed that the fraction of methane and ethane are negligible.

POINT SOURCES:

Some large airports that are point sources may have reported refueling emissions. If so, the emissions included in the point source inventory must be subtracted from the emissions total in order to estimate area emissions.

METHODOLOGY:

Emissions from aircraft refueling can be estimated using fuel sales data by type of fuel multiplied by the corresponding fuel emission factors. Regional, state, and national fuel consumption data are available from PEMEX and ASA. Local fuel sales data may also be obtained either from local airport officials or by apportioning regional-level fuel sales to airports based on flight activities. Emission factors can be developed using the following equation (AP-42, 1995):

$$EF_a = 12.46 \times \frac{SPM}{T} \tag{7.2-1}$$

where: EF_a = Emission factor in lbs TOG per 1000 gallons fuel throughput;
           S   = Saturation factor of 1.45 (from Table 7.1-1);
           P   = True vapor pressure of fuel in psia (Table 7.1-2);
           M   = Molecular weight of vapors in lb/lb mol (Table 7.1-2); and
           T   = Temperature of bulk liquid loaded °R.

To estimate emissions the emission factor for aircraft refueling, the aircraft emission factor is applied to the total aircraft fuel dispensed, as noted in the following equation:

$$E_a = EF_a \times F_a \tag{7.2-2}$$

where: E_a = Total emissions from aircraft refueling (mg/year);
           EF_a = Emission factor for aircraft refueling (mg/liter); and
           F_a = Aircraft fuel dispensed in inventory areas (liter/year).

DATA NEEDED:

Data	Sources
Aircraft fuel dispensed in inventory area	PEMEX, ASA
TOG Emission factor Equation 7.2-1	AP-42, 1995

SAMPLE CALCULATION:

Assume that 100,000 m^3 of turbosina are used to refuel aircraft in the inventory region in a given year. Assume that the physical properties of turbosina are similar to jet kerosene in the U.S. Finally, assume that average loading temperature is 21°C.

1.   Determine the vapor molecular weight and the true vapor pressure.

       Use Table 7.1-2. For jet kerosene, the default value for vapor molecular weight is 130 lb/lb-mol.

The average loading temperature is $21°C$ or $70°F$.
Therefore, the default value for the true vapor pressure is 0.011 psia.

2.   Determine the emission factor, using equation 7.2-1:

$$EF_a = 12.46 \ \frac{SPM}{T}$$

$$= 12.46 \times \left[\frac{(1.45)\ (0.011)\ (130)}{(70\ +\ 460)} \right]$$

$$= 0.0487 \ lb/1000 \ gal$$

$$= 0.0058 \ kg/1000 \ liter$$

$$= 0.0058 \ kg/m^3$$

3.   Determine the TOG emissions from these aircraft refueling operations, using equation 7.2-2:

$$E_a = EFa \times F_a$$

$$= (0.0058 \ kg/m^3) \times (100,000 \ m^3)$$

$$= 580 \ kg \ TOG$$

$$= 0.58 \ mg \ TOG$$

7.3   Liquified Petroleum Gas Distribution

<u>SOURCE CODE</u>:   **<u>DESCRIPTION</u>:**

25-01-210-210*   LPG Storage
25-05-000-210*   LPG Transport

*Proposed Mexico-specific codes for source category not typically inventoried in the U.S.

<u>DESCRIPTION</u>:

In addition to the emissions from the combustion of LPG, emissions due to leaks and evaporation from the storage and distribution systems, represent an important source of pollution that should be considered when developing an area emissions inventory. The Mexican Petroleum Institute (IMP) and researchers from the University of California have identified LPG leaks as a potentially significant source of hydrocarbons emissions. Though some LPG is used by the industrial and commercial/services sectors, in Mexico, LPG is predominately used domestically, principally for cooking food and heating water. This source category addresses emissions from all LPG distribution.

The Metropolitan Zone of the Valley of Mexico (ZMVM) is the largest LPG market in the world with the LPG consumption at 70,000 barrels per day, almost the same as that of gasoline (DDF et al, 1996). The use of LPG for cooking and heating water in Mexico extends throughout all regions, and according to the data from INEGI, about 70% of the residential houses in Mexico use LPG for cooking. Only Chiapas and Oaxaca have less than 50%, where wood and coal predominate.

The distribution and storage of LPG for domestic use in Mexico is principally done via 20-40 kg portable cylinders which are sold from distributor trucks. The empty tanks are collected and refilled at specialized centers. Another form of domestic LPG distribution is done via stationary tanks, usually 300 kg in size, which are filled at the home by special trucks equipped with fill pipes. In Mexico City, 32 independent companies make an estimated 200,000 deliveries a day. Five million steel tanks are installed in the millions of urban homes where they are hooked up with pipes and tubes that may or may not be properly maintained. (Sacramento Bee, 1995a).

LPG, in highly industrialized countries, is primarily made up of propane (at least 95%). In Mexico, a mixture is sold in which propane predominates (60%) but which also contains an appreciable amount of butane, isobutane, propylene, and butylenes (PEMEX, 1996). Since the butanes and olefins are more

photochemically reactive than propane, the high photochemical reactivity of Mexico's LPG also contributes to its potential significance as an emission source.

POLLUTANTS: TOG

ROG: ROG emissions are 98.4% of TOG (PEMEX, 1996).

POINT SOURCE ADJUSTMENTS:

Emissions for this source category are generally not included in a point source inventory. However, if any bulk distribution centers are inventoried as point sources, emission from these facilities should be subtracted from the total emissions in order to estimate area source emissions.

METHODOLOGY:

The amount of LPG consumed needs to be determined for the inventory region. If the LPG usage statistics available do not directly correspond to the needs of the inventory effort (e.g., statewide statistics are available but the inventory region includes portion of multiple states; statewide statistics are available, but the inventory requires municipal-level emission estimates), then census data (e.g., population or housing) can be used to apportion the regional data to the smaller geographic area. The sample calculation for residential fuel combustion (commercial fuels) illustrates this procedure.

The expected form of the emission calculation is:

Emissions TOG =   (volume of LPG used) $\times$ (LPG density) $\times$ (7.3-1)
(EF [expressed as %leakage])

DATA NEEDED:

Data	Sources
Total LPG usage in inventory area	PEMEX
Population or Housing Data	INEGI
LPG leakage emission factor - 3.6%	PEMEX, 1996
LPG chemical composition, density	PEMEX

NOTES:

1. The emission factor is based on a study completed for the Metropolitan Zone of Mexico City (PEMEX, 1996):

$$EF = \text{total LPG emissions/total LPG usage}$$

$$= (76,414 \text{ tons/yr})/(2,136,000 \text{ tons/yr})$$

$$= 3.6\%$$

2. If specific LPG density data are not available, the value from AP-42, 507 g/liter, may be used as a default value (included in Appendix V-B of this document).

3. The high photochemical reactivity of the LPG used in Mexico, combined with the large LPG consumption, means that two types of process changes are being considered. The elimination of a significant part of the leaks in residential and commercial installations, or the enrichment of the LPG with propane. However, there is some risk associated with propane. Because propane has higher bottled pressure than other LPG components, the propane-enriched reformulated LPG would also have a higher bottled pressure than the LPG that is currently used. As a result, it would be necessary to verify that the receiving containers are in good shape and able to withstand the pressure of the new formulation (DDF, et al, 1996).

SAMPLE CALCULATION:

This example shows how to calculate emissions from LPG distribution leaks in the Metropolitan Zone of Mexico City (ZMCM) and is based on fuel usage data obtained to develop fuel combustion emissions for the Mexico City area source inventory (DDF, 1995a). If possible region-specific data should be obtained. In lieu of region-specific data, the following information can be used.

TOG emissions are calculated using the following steps:

1. Determine the amount of LPG use in the ZMCM:

In Oficio GPASI-1511/93, PEMEX reported that the total amount of LPG consumed in the ZMCM in 1993 was 3830.31×10^3 m^3. Based on 1992

PEMEX figures, it was estimated that 13% of the total LPG was used by industry, 7% by commercial/services, and 80% for residential purposes.

2.　Determine the LPG distribution emission factor:

From the PEMEX study, the emission factor is 3.6%.

3.　Emissions for TOG are then calculated as:

$$E_{TOG} = (3830.31 \times 10^6 \text{ liters/yr}) \times (507 \text{ g/liter}) \times (3.6\%)$$
$$= 69,911 \text{ Mg/yr}$$

8.0 LIGHT INDUSTRIAL/ COMMERCIAL SOURCES

Some light industrial or commercial activities may be too small or too numerous to be included in the point source inventory for a given inventory region. Therefore, these smaller sources need to be included in the area source inventory effort. Inventory guidance for these sources are presented in the following subsections:

- Bakeries;

- Brick Manufacturing;

- Construction Activities;

- Traffic Markings;

- Charbroiling; and

- Street Vendors.

8.1   Bakeries

SOURCE CODE: 23-02-050-000

DESCRIPTION:

Yeast fermentation in bakeries produces hydrocarbon emissions. Other
emissions from bakeries due to fuel combustion are not covered in this section;
they should be calculated as part of the commercial fuel use category. Bakeries
that produce baked goods that are not yeast-leavened will not produce any
organic gases from yeast fermentation.

Hydrocarbon emissions from bakeries consist primarily of ethanol that is
produced during yeast fermentation. Ethanol is emitted during the fermentation
and rising process, as well as during baking. Emissions are from a biological
process, and, as is typical with biological processes, emission are dependant on
a number of variables, such as the length of rising time for the yeast, the
amount of fermentable sugars in the dough and the temperature of fermentation.
For an area source inventory, the effort required to collect data about these
details is very time consuming compared to the magnitude of emissions.

POLLUTANTS: TOG

ROG: ROG emissions are 100% of TOG.

POINT SOURCE ADJUSTMENTS:

Any bakery included in the point source inventory should be identified, and
emission from the yeast fermentation should be subtracted from emissions
calculated using the methods described here.

METHODOLOGY:

Emission from this source are calculated using a per capita emission factor
developed for the U.S. (Adams, 1992). This source contains a range of
emission factors for straight-dough and sponge-dough yeast leavening processes:

Process	Emission Factor (kg TOG/Mg Bread)	Source
Straight-Dough	0.5 kg/Mg	Adams, 1992
Sponge-Dough	5 to 8 kg/Mg	Adams, 1992

Most bakeries use sponge-dough for yeast leavening. So the emission factor was taken from this category. As emission estimates will be higher and thus more conservative with sponge-dough than straight-dough, the lower end of the range of emission factors was chosen. A per capita bread consumption rate of 28.02 kg bread/person was used to determine the following per capita emission factor (source: U.S. Department of Commerce, International Trade Administration).

$$\frac{5 \text{ kg TOG}}{\text{Mg bread}} \times \frac{1 \text{ Mg}}{1{,}000 \text{ kg}} \times \frac{28.02 \text{ kg bread}}{\text{person} - \text{yr}} = 0.14 \frac{\text{kg TOG}}{\text{person} - \text{yr}}$$

This U.S.-based emission factor has limited applicability in Mexico and should only be used if no other data are available.

The calculation using the per capita emission factor is:

$$\text{Annual Emissions} = (\text{Population}) \times (\text{Emission Factor}) \qquad (8.1\text{-}1)$$

DATA NEEDED:

Data	Sources
Per capita method:	
Population	INEGI
TOG emission factor 0.14 kg/person-yr	Adams, 1992

NOTES:

1. If national data for production of yeast leavened baked goods are available, then a Mexico specific emission factor can be developed for this source category. To do this, an emission rate per kilogram of bread baked emission factors (5 kg TOG/Mg bread produced) could be used to estimate national emissions from the source category, and the resulting emissions then apportioned by the total national population. It is important to remember, however, that the use of per capita emission factors do not reflect local variations, and bread production data should be for the year of the inventory or similar to that year. Information on production may be available from the Cámara Nacional de la Industria Panificadora. Emissions should be calculated by the following methods:

$$\text{TOG emissions} = \frac{5 \text{ kg TOG}}{\text{Mg bread produced}} \times \frac{\text{Mg bread produced}}{\text{yr}} \qquad (8.1\text{-}2)$$

2.   The emission estimates calculated using the bread production method will need to be correctly linked to SNIFF to facilitate reconciliation with the point source inventory.

SAMPLE CALCULATION:

For example, emissions from bakeries in a state with a population of 1,250,000 are:

$$(1{,}250{,}000 \text{ persons}) \times (0.14 \text{ kg/person-yr}) = 175{,}000 \text{ kg/yr}$$

$$= 175 \text{ Mg/yr}$$

If there are large bakeries in the inventory area, and they have been inventoried as point sources, then the emissions assigned to those facilities need to be subtracted from the total calculated above. For example, if the point source emissions are:

•   32 Mg per year for Facility A;

•   11.2 Mg per year for Facility B; and

•   23 Mg per year for Facility C.

Then:

$$\text{Area Source Emissions} = 175 \text{ Mg} - (32 \text{ Mg} + 11.2 \text{ Mg} + 23 \text{ Mg})$$
$$= 108.8 \text{ Mg/yr}$$

8.2   Brick Manufacturing

SOURCE CODE: 23-05-090-000*   Brick Manufacturing

*Proposed Mexico-specific code for source category not typically inventoried in the U.S.

DESCRIPTION:

> Numerous small brick kilns are located in some portions of northern Mexico. For example, there are an estimated 200-300 kilns in Ciudad Juárez. Many of these units are domestic operations, making it impractical to include them in point source inventories. Wood is the predominant fuel used to fuel domestic brick kilns. Some use of other waste-derived materials, such as trash or waste solvents, has been reported. In addition, in the Ciudad Juárez area, efforts are being made to try and convince some domestic operators to use LPG.

POLLUTANTS: TOG, CO, NO_x, SO_x, PM

ROG: Adjustment factors for ROG are dependent upon the fuel type. See Sections 4.1 and 4.2 for fuel combustion ROG/TOG adjustment factors.

POINT SOURCE ADJUSTMENTS:

> Larger industrial brick manufacturing facilities may be included in a point source inventory. Care should be taken to ensure that there is no double-counting of emissions in the area source inventory.

METHODOLOGY:

> The amount of each type of fuel combusted in small brick manufacturing kilns needs to be determined for the inventory region. A special survey effort should be conducted to obtain data on the number of kilns, number of bricks produced per kiln, and the types and amounts of fuels they are consuming.
>
> Emission factors can be found in Chapter 1 of AP-42 (AP-42, 1995) and are included in Appendix V-B of this volume (Note: in AP-42, "TOG" is often referred to as "TOC"). Sections in Chapter 1 cover emissions from commercial fuels, wood, and waste oil. Section 2.5 of AP-42 also includes emission factors for the open burning of crop wastes and tires that could be used to estimate emissions from brick kilns. The use of open burning emission factors, however, would be highly uncertain due to different combustion conditions.

For each fuel type, the quantity of fuel burned by small brick manufacturing kilns is then multiplied by the appropriate emission factors as shown below:

$$\text{Emissions} = \begin{pmatrix} \text{Area Source} \\ \text{Fuel Burned by} \\ \text{Equipment Type A} \end{pmatrix} \times \begin{pmatrix} \text{Emission Factor} \\ \text{for Equipment} \\ \text{Type A} \end{pmatrix} \qquad (8.2\text{-}1)$$

DATA NEEDED:

Data	Sources
Fuel used in inventory region, by fuel type	Survey; engineering judgement (default)
Number of brick kilns in inventory region	Survey; engineering judgement (default)
Fuel characteristics (heat content, wood moisture content)	AP-42, 1995, Appendix A; Technical Handbook (e.g., Marks Mechanical Handbook—see data presented in the sample calculation)
Emission factors by fuel type	AP-42, 1995

NOTES:

1. If region-specific fuel usage quantities are not available, it may be assumed that an average kiln produces 16,000 bricks/day and that it takes approximately 5000 Btu (1260 kcal) to fire one 2.2 kg (4.8 lb) brick (Valenzuela, 1996). Then, for each fuel, usage quantities may be estimated as follows:

$$\text{Amount of fuel burned} = \frac{(\text{\# kilns/day}) \times (16,000 \text{ bricks/kiln/day}) \times (5,000 \text{ kcal/brick})}{(\text{fuel heat content [kcal/fuel unit]})}$$

$$(8.2\text{-}2)$$

2. For regions where brick manufacturing is a significant activity, it is strongly recommended that a survey be conducted of a representative sample of typical operations. Results from this sample should then be

scaled up to the entire inventory area. See the *Basic Emissions Estimating Techniques* Manual for an outline of the survey procedure.

SAMPLE CALCULATION:

This example is based on calculations developed to estimate emissions from brick manufacturing in the Ciudad Juárez area (Valenzuela, 1996).

(1)   Determine the amount of each fuel burned in the brick kilns:

For this example, it is assumed that an average kiln produces 16,000 bricks/day and that it takes approximately 5,000 Btu (1260 kcal) to fire one 2.2 kg (4.8 lb) brick (Valenzuela, 1996). If 10 kilns are fired with yellow pine, then, the quantity of fuel may be estimated as follows:

Amount of yellow pine burned = (# kilns) $\times$ (16,000 bricks/kiln/day) $\times$ (1,260 kcal/brick) / (fuel heat content [kcal/fuel unit])

$$= (10 \text{ kilns/day}) \times (16,000 \text{ bricks/kiln/day}) \times (1260 \text{ kcal/brick}) / (3720 \text{ kcal/kg})$$

$$= 54,194 \text{ kg/day of yellow pine}$$

where the yellow pine fuel content was calculated as follows *(using data from Marks Mechanical Handbook)*:

12% moisture (dry) yellow pine weighs 3,240 lb/cord
50% moisture (green) yellow pine weighs 4,770 lb/cord

12% moisture (dry) yellow pine - 26×10^6 Btu/cord
50% moisture (green) yellow pine - 23.7×10^6 Btu/cord

Assume wood moisture is 25% on the average; then by interpolation:

25% moisture pine weighs 3,764 lbs/cord
25% moisture pine - 25.2×10^6 Btu/cord

or $(25.2 \times 10^6 \text{ Btu/cord})/(3764 \text{ lbs/cord}) = 6,695$ Btu/lb of pine

(2)   Identify appropriate emission factors:

Use emission factors from AP-42, Section 1.9-4 developed for residential fireplaces (i.e., wood burning):

$$PM_{10} \qquad 17.3 \text{ g/kg}$$
$$CO \qquad 126.3 \text{ g/kg}$$
$$SO_x \qquad 0.2 \text{ g/kg}$$
$$NO_x \qquad 1.3 \text{ g/kg}$$
$$TOG \qquad 114.5 \text{ g/kg}$$

$$
\begin{aligned}
E_{PM10} \; &= \; (54,194 \text{ kg/day of pine}) \times (17.3 \text{ g/kg}) / (1,000 \text{ g/kg}) \\
&= \; 938 \text{ kg PM}_{10}/\text{day}
\end{aligned}
$$

$$
\begin{aligned}
E_{CO} \; &= \; (54,194 \text{ kg/day of pine}) \times (126.3 \text{ g/kg}) / (1,000 \text{ g/kg}) \\
&= \; 6,845 \text{ kg CO/day}
\end{aligned}
$$

$$
\begin{aligned}
E_{SO2} \; &= \; (54,194 \text{ kg/day of pine}) \times (0.2 \text{ g/kg}) / (1,000 \text{ g/kg}) \\
&= \; 11 \text{ kg SO}_x/\text{day}
\end{aligned}
$$

$$
\begin{aligned}
E_{NOx} \; &= \; (54,194 \text{ kg/day of pine}) \times (1.3 \text{ g/kg}) / (1,000 \text{ g/kg}) \\
&= \; 70 \text{ kg NO}_x/\text{day}
\end{aligned}
$$

$$
\begin{aligned}
E_{TOG} \; &= \; (54,194 \text{ kg/day of pine}) \times (114.5 \text{ g/kg}) / (1,000 \text{ g/kg}) \\
&= \; 6,205 \text{ kg VOC/day}
\end{aligned}
$$

8.3   Construction Activities

SOURCE CODE: 23-11-000-000

DESCRIPTION:

Building, road, and other construction activities are a potentially significant source of fugitive PM emissions. These emissions can be generated through a variety of activities, including land clearing, drilling and blasting, ground excavation, earth moving, and actual building construction. Emissions due to construction activities vary by site due to different levels of activity, operations, and meteorological conditions.

This section focuses solely on fugitive PM emissions generated by construction activities. Exhaust and evaporative emissions from construction equipment and vehicles are addressed in Section 5.4 of this manual.

POLLUTANTS: PM_{10}

ROG: Not Applicable

POINT SOURCE ADJUSTMENTS:

None.

METHODOLOGY:

Because of potentially significant differences in Mexican construction practices, it is recommended that Mexico-specific data be collected through surveys. These data can then be used in the development of a multivariate model for Mexican construction activities. Until these data are collected, it is recommended that U.S. emission factors be used to estimate emissions from construction activities.

Until a multivariate emissions model can be developed using Mexico-specific data, the following equation can be used to estimate fugitive dust emissions from overall regional construction activities:

$$\text{Emissions} = \text{Area} \times \text{Time} \times \text{EF} \qquad\qquad (8.3\text{-}1)$$

where: Emissions   =
            Total annual fugitive (PM_{10}) dust emissions;

Area   =
Total area of specific construction site;
Time   = Total duration of construction activities; and
EF   =
Fugitive dust (PM_{10}) emission factor.

Table 8.3-1 presents overall uncontrolled PM_{10} emission factors for seven
construction sites located in California and Nevada, as well as the resulting
geometric mean. A description of the type and level of construction activity at
each of the seven sites is also included.

Table 8.3-1

Summary of Uncontrolled PM_{10} Emission Rates Estimated for Construction Sites[a]

Site	Overall Uncontrolled PM_{10} Emission Factor (Mg/hectare/month)	Construction Type and Activity Level
A	0.072	Industrial - Moderate Activity (trenching, prepaving, small-scale earthmoving)
B	0.72	Residential - Moderate to Heavy Activity (trenching, earthmoving, drilling/blasting, compaction)
C	0.18	Residential - Moderate to Heavy Activity (trenching, prepaving, trucking of road base)
D	0.0087	Residential - Low to Moderate Activity (framing, landscaping)
E	0.90	Residential - Heavy Activity (earthmoving, hauling, stockpiling)
F	0.96	Residential - Heavy Activity (earthmoving)
G	0.76	Commercial - Moderate to Heavy Activity (trenching, trucking of fill material)
Geometric Mean	0.25	

[a] Table derived from MRI, 1996 (pg. 3-2, Table 2; pg. 4-2, Table 3)

It is recommended that the geometric mean emission factor (0.25 Mg
PM_{10}/hectare-month) be used. However, other emission factors from the table
could be used if the specific construction activity is similar to those included in
the table. Because these emission factors represent construction activities in the
United States, caution should be exercised when these emission factors are

applied in Mexico. Different construction practices and levels of mechanization in Mexico might introduce considerable uncertainty into the emissions estimates.

The emissions estimating methodology presented above is most applicable for regional construction emissions. If emissions need to be estimated for individual sites, then an alternative methodology is presented in AP-42, Table 13.2.3-1 (summarized in MRI, 1996 [pgs. 2-3 through 2-5, Table 1]). This methodology provides different emission factors for several different construction operations (i.e. bulldozing, compacting, land clearing, etc.). These emission factors will provide a more accurate estimate of emissions than the emission factors presented in Table 8.4-1, but more detailed, site-specific data must be collected.

DATA NEEDED:

Data	Sources
Construction Area	Local authorities or the Cámara Nacional de la Industria de la Construcción
Construction Duration	Local authorities or the Cámara Nacional de la Industria de la Construcción
Emission Factor	Table 8.3-1
Site Specific Data (see AP-42, Table 13.2.3-1)	Construction site personnel

SAMPLE CALCULATION:

In 1995, local officials indicated that there were 120 hectares of construction activity. These officials estimated that these areas were under construction for a average period of 2.5 months. The total estimated annual PM_{10} emissions for 1995 are calculated below.

1.   Assuming a wide variety of construction types, the geometric mean emission factor of 0.25 Mg/hectare-month seems to be most appropriate.

2.   Total PM_{10} emissions:

120 hectares $\times$ 2.5 months $\times$ 0.25 Mg PM_{10}/hectare-month
= 75 Mg PM_{10}

8.4   Charbroiling

SOURCE CODE: 23-02-002-000

DESCRIPTION:

> Charbroiling refers to the cooking of meat (typically beef or chicken) over an open flame in which grease is allowed to drip down onto the open flame. This category is limited to commercial charbroiling; charbroiling in the form of residential barbecues is thought to be extremely limited. In Mexico, charbroiling is limited to small-scale restaurants and street vendors. Small-scale restaurants are discussed in this section; street vendors are addressed in Section 8.5. Based upon observations in Nogales, Sonora, beef is usually cooked using LPG and chicken is typically cooked using charcoal.

> The primary pollutant of concern for charbroiling is PM_{10}. Virtually all of the PM_{10} emitted from charbroiling is of sub-micron size. Also, a significant amount of the PM emitted consists of organic carbon.

> Emissions from charbroiling are dependent upon a number of variables, such as type of fuel used, type of meat charbroiled, fat content of meat, flame temperature. However, until recently, the effects of these variables were not very well quantified. The existing emissions data were primarily limited to charbroiled hamburgers cooked over a natural gas flame, which is a significant fraction of charbroiling that occurs within the United States. Researchers at the University of California Riverside's CE-CERT (College of Engineering Center for Environmental Research and Technology) have recently completed work for the South Coast Air Quality Management District (SCAQMD) which examines the effects of meat type of type on emissions. Preliminary results from this research are presented in Table 8.4-1.

POLLUTANTS: TOG and PM_{10}

ROG: ROG emissions are approximately 100% of TOG (Welch, 1997).

POINT SOURCE ADJUSTMENTS:

> With the exception of an industrial meat-cooking facility, emissions from this source category would not be included in a point source inventory. In general, therefore, point source adjustments should not be necessary.

METHODOLOGY:

It is thought that emission factors based on the amount of meat charbroiled are most reliable. Consequently, it is necessary to develop an estimate of the amount of meat charbroiled.

The equation used to estimate emissions from charbroiling is:

$$\text{Emissions}_m = N_m \times A_m \times EF_m \qquad\qquad (8.4\text{-}1)$$

where:

Emissions$_m$	=	Emissions for meat type, m;
N_m	=	Number of charbroiling operations for meat type, m;
A_m	=	Average amount of meat charbroiled for meat type, m at each charbroiling operation; and
EF_m	=	Emission factor for meat type, m.

The first step in estimating charbroiler emissions is to determine the number of charbroilers. Local health officials might be able to provide some information relating to the number of restaurants with charbroilers. Because these restaurants usually are concentrated in shopping and commercial districts, rough restaurant counts could be derived from informal surveying.

The amount of meat charbroiled and other related information (fuel use, cooking practices, meat characteristics, etc.) should be estimated through local surveys. Cultural and socio-economic differences between different regions makes the application of another region's survey data highly uncertain.

Table 8.4-1 presents recently developed charbroiling emission factors. These emission factors may not exactly represent actual charbroiling operations, but emission factors are still somewhat limited. Further refinement and development of charbroiling emission factors is expected in the future.

Table 8.4-1

Charbroiling Emission Factors[a]

Meat Type	PM$_{10}$[b] (g/kg meat)	TOG[c] (g/kg meat)	Comments
Beef	32.7	3.9	25% fat hamburgers
Chicken	10.4	1.8	Butterflied whole chicken
Fish	3.2	0.4	Atlantic salmon fillets

[a]   All emission factors based upon source testing of under-fired charbroilers using natural gas (SCAQMD, 1997).
[b]   Virtually all PM$_{10}$ has an aerodynamic diameter < 2.5 m or less (Welch, 1997).
[c]   Original emission factors were for ROG. However, measured methane was near detection limits, so TOG is nearly equivalent to ROG (Welch, 1997)

DATA NEEDED:

Data	Sources
Number of charbroilers	Local health officials or survey data
Average amount of meat charbroiled	Local survey data
Type and amount of fuel	Local survey data
Emission factors	Table 8.4-1 of this section; also see Note 1

SAMPLE CALCULATION:

A certain metropolitan area has 80 restaurants that each charbroil an average of 60 kg of beef per day. Charbroiling operations are assumed to occur on every day of the year. Calculate the annual PM emissions.

80 restaurants $\times$ 60 kg meat/day $\times$ 365 days/yr
       $\times$ 32.7 g PM$_{10}$/kg meat $=$ 57,290 kg PM$_{10}$ $=$ 57.3 Mg PM$_{10}$/yr

NOTES:

1. Charbroiling emissions are mainly dependent upon the flame temperature at the flame-meat interface. Higher flame temperatures result in higher emissions. Although the CE-CERT research did not examine the effects of different fuels, previous research on residential barbecues has indicated that fuels with higher flame temperatures (i.e., natural gas or propane) have higher emissions than fuels with lower flame temperatures (i.e., charcoal) (Welch, 1997).

8.5   Street Vendors

SOURCE CODE: 23-02-002-005*

*Proposed Mexico-specific code for source category not typically

DESCRIPTION:

>Street vendors sell a variety of food products in commercial and shopping districts. Street vendors typically sell their food products out of portable carts that are moved from place to place. Many of the street vendor operations do not produce emissions. However, some street vendors charbroil meat which can be a significant source of TOG and PM_{10}. LPG appears to be the fuel of choice for street vendor charbroiling. For a more detailed discussion of charbroiling, refer to Section 8.4.

POLLUTANTS: TOG and PM_{10}

ROG: ROG emissions are approximately 100% of TOG (Welch, 1997).

POINT SOURCE ADJUSTMENTS: None

METHODOLOGY:

>The methodology used to estimate emissions from street vendor charbroiling is identical to that for general restaurant charbroiling. See Section 8.4 for details.

DATA NEEDED:

Data	Sources
Number of street vendor charbroilers	Local health officials or survey data
Average amount of meat charbroiled	Local survey data
Type and amount of fuel	Local survey data
Emission factors	Table 8.4-1 of Section 8.4; also see Note 1 of Section 8.4

SAMPLE CALCULATION:

A certain metropolitan area has 140 street vendors that each charbroil an average of 25 kg of beef per day. Charbroiling operations are assumed to occur on every day of the year. Assuming the beef PM_{10} emission factor presented in Table 8.4-1, calculate the annual PM emissions.

140 street vendors $\times$ 25 kg meat/day $\times$ 365 days/yr
$\times$ 32.7 g PM/kg meat $=$ 41,774 kg PM $=$ 41.8 Mg PM_{10}/yr

9.0 AGRICULTURE

Most agricultural emission sources may be too small or too numerous to be included in the point source inventory for a given inventory region. Therefore, these sources need to be included in the area source inventory effort. Inventory guidance for these sources are presented in the following subsections:

- Pesticide Application;

- Beef Cattle Feedlots;

- Agricultural Burning;

- Fertilizer Application;

- Animal Waste; and

- Agricultural Tilling.

9.1　　Pesticide Application

SOURCE CODE:　　24-61-850-000

DESCRIPTION:

Pesticides are used to kill or retard the growth of insects, weeds, or other pests. Most air emissions from pesticide use primarily occur because of the volatile nature of the active ingredients, carrier solvents, and other chemicals in pesticide formulations. Volatilization of pesticides can occur both during application and for some time after application. Some pesticide formulations are dusts, granules, or powders. These dry formulations can result in particulate emissions. However, particulate emission factors have not been developed due to insufficient data. The following discussion is limited to emissions due to hydrocarbon-based pesticide volatilization.

Volatile pesticides usually are applied as liquid formulations, such as solutions, emulsions, or aerosols. In general, volatile pesticides consist of an "active" ingredient and various "inert" ingredients. The terms "active" and "inert" do not refer to photochemical activity; rather, they are a measure of compound toxicity. The active and inert fractions can vary depending upon the specific type of pesticide application.

The volatility of active ingredients can also be quite variable. Volatilization is typically assumed to occur during the first 30 days after application. After approximately 30 days, degradation and surface runoff become the primary removal mechanisms for pesticides. Laboratory and field research indicates that active ingredient volatility appears to be dependent on three major parameters: the physical and chemical properties of the active ingredient, local meteorological conditions, and soil adsorption. Additional discussion about the effects of these three parameters can be found in Section 9.2.2.3 of AP-42 (AP-42, 1995).

Most pesticides are not applied at full concentration (i.e., direct application of the pure form of the active ingredient); rather, the active ingredient is mixed with an inert "carrier". Sometimes, water is used as the carrier for liquid pesticide formulations. However, many of the inert carriers used in pesticides are volatile organic liquids and gases. It is assumed that 100 percent of the volatile inert carriers volatilize within 30 days of application.

In addition to the synthetic organic pesticides described above, petroleum distillates are sometimes used in weed, fungus, and insect control applications.

When petroleum distillates are used, it is assumed that 100 percent of the distillates volatilize.

POLLUTANTS: TOG

ROG: ROG emissions are 100% of TOG.

POINT SOURCE ADJUSTMENTS:

None.

METHODOLOGY:

For synthetic organic pesticides,

$$\text{Emissions}_i = (\text{Usage}_i \times \%\text{active}_i \times \text{EF}_i) + (\text{Usage}_i \times \%\text{inert}_i \times \%\text{V}_i) \qquad (9.1\text{-}1)$$

where:

	Emissions_i	=	Total annual TOG emissions from pesticide, i;
	Usage_i	=	Total annual usage of pesticide, i;
	$\%\text{active}_i$	=	Percentage of active ingredients in pesticide, i;
	EF_i	=	Emission factor for active ingredients in pesticide, i;
	$\%\text{inert}_i$	=	Percentage of inert ingredients in pesticide, i (100% - $\%\text{active}_i$); and
	$\%\text{V}_i$	=	Volatile content of inert fraction of pesticide, i.

The emission factor used in the above equation depends upon the vapor pressure of the specific active ingredients and the method of pesticide application. Emission factors for surface application and soil incorporation are presented in Table 9.1-1. Emission factors are not available for aerial application of pesticides. Current research indicates that volatilization is small compared to drift effects in aerial applications.

For petroleum distillates,

$$\text{Emissions}_i = \text{Usage}_i \qquad (9.1\text{-}2)$$

Table 9.1-1

Uncontrolled Emission Factors for Pesticide Active Ingredients[a]

Type of Application	Vapor Pressure Range (mm Hg at 20 to 25 °C)[b]	Emission Factor (kg/Mg)[c]
Surface Application	1×10^{-4} to 1×10^{-6}	350
	$> 1 \times 10^{-4}$	580
Soil Incorporation	$< 1 \times 10^{-6}$	2.7
	1×10^{-4} to 1×10^{-6}	21
	$> 1 \times 10^{-4}$	52

[a] Table modified from AP-42, Table 9.2.2-4.
[b] Vapor pressures of some specific active ingredients can be found in AP-42, Table 9.2.2-1. For other active ingredients, pesticide reference materials should be consulted.
[c] Emission factors expressed as equivalent weight of active ingredients volatilized per unit weight of active ingredients applied.

The above method provides an accurate estimate of emissions from pesticide application.
However, if the data listed in the table below are not available, a conservative, but less
accurate, method can be used. The conservative approach is to assume that 100 percent of the
applied pesticide volatilizes. This will result in an overestimation of emissions, but it is a
reasonable alternative method if detailed data are not available.

DATA NEEDED:

Data	Sources
Annual Pesticide Usage (by specific formulation)	Local SAGAR/CICOPLAFEST office
Method of Application	Local SAGAR/CICOPLAFEST office
Types of Active Ingredients in Formulation	Pesticide container, pesticide manufacturer, end-use formulator, or local distributor. Active ingredients for common trade name pesticides provided in AP-42, Table 9.2.2-2. Also, *Farm Chemicals Handbook - 1992*. (Meister, 1992)
Vapor Pressures of Active Ingredients	Some vapor pressures provided in AP-42, Table 9.2.2-1. Additional vapor pressures in Wauchope et al., 1992.
Type of Formulation (e.g., emulsion, solution, granules, etc)	Pesticide container, pesticide manufacturer, end-use formulator, or local distributor.
Percentage of Active and Inert Ingredients	Pesticide container, pesticide manufacturer, end-use formulator, or local distributor.
Volatile Content of Inert Ingredients	Pesticide manufacturer or end-use formulator. Also, estimated average volatile contents provided in AP-42, Table 9.2.2-3.

SAMPLE CALCULATION:

5,000 kg of Lazo® have been surface applied to cropland for weed control, and an estimate is desired of the total quantity of emissions within 30 days after application.

1.   The active ingredient in Lazo® is alachlor (AP-42 [Table 9.2.2-2] or *Farm Chemicals Handbook - 1992*). The pesticide container states that the formulation is an emulsion consisting of 41% active ingredient and 59% inert ingredient.

2.   Total quantity of active ingredient applied:

$0.41 \times 5,000$ kg = 2,050 kg of alachlor applied

3.   From AP-42, Table 9.2.2-1, the vapor pressure of alachlor is 1.4×10^{-5} millimeters (mm) mercury between 20 and 25 °C. From AP-42, Table 9.2.2-4, this corresponds to an emission factor of 350 kg active ingredient volatilized per Mg of active ingredient applied. So, the total quantity of active ingredient volatized is given by:

   2.05 Mg $\times$ (350 kg/Mg) = 718 kg of alachlor volatilized within 30 days of application

4.   From AP-42, Table 9.2.2-3, it can be determined that the average volatile content of the inert portion of emulsions (emulsible concentrates) is 56 percent.

   Total quantity of emissions from inert ingredients:

   5,000 kg $\times$ 0.59 $\times$ 0.56 = 1,652 kg of volatile inert ingredients (100% of the volatile inert ingredients is assumed to volatilize within 30 days of application)

5.   The total quantity of emissions during the 30 days after application is the sum of emission from active ingredients and inert ingredients. In this example, the emissions are:

   718 kg (active ingredients) + 1,652 kg (volatile inert ingredients) = 2,370 kg

9.2   Beef Cattle Feedlots

SOURCE CODE: 28-05-001-000

DESCRIPTION:

Beef cattle feedlots and stock yards are areas used for fattening or holding cattle prior to marketing or transfer to another location. The fattening process typically consists of feeding cattle a high energy ration of feed grains for a period of four or five months. Feedlots and stock yards can be a significant source of fugitive particulate matter. The primary generation mechanism is cattle movement over soil dust and dried manure. Vehicle traffic and wind action in the vicinity of the feedlot can also contribute to particulate emissions. Similar emissions are <u>not</u> expected to occur when cattle are put out to pasture for grazing because there will be minimal concentrated manure accumulation and disturbed surface area.

Ammonia emissions are also generated by beef cattle through the anaerobic decomposition of manure on feedlot surfaces, as well as volatilization from urine. Ammonia emissions from beef cattle will be addressed in the section on livestock waste (Section 9.5).

POLLUTANTS: PM_{10}

ROG: Not Applicable.

POINT SOURCE ADJUSTMENTS: None.

METHODOLOGY:

Feedlot emissions can be estimated using the following equation based on feedlot throughput:

$$\text{Emissions} = \text{Throughput}_{\text{Cattle}} \times \text{EF}_{\text{Throughput}} \qquad (9.2\text{-}1)$$

where: | Emissions | = | Total annual PM_{10} emissions;
           | $\text{Throughput}_{\text{Cattle}}$ | = | Annual cattle throughput; and
           | $\text{EF}_{\text{Throughput}}$ | = | PM_{10} emission factor based on annual throughput.

Alternatively, feedlot emissions can be estimated using the following equation based on feedlot capacity:

$$\text{Emissions} = \text{Cattle} \times \text{Days} \times \text{EF}_{\text{Capacity}} \qquad\qquad (9.2\text{-}2)$$

where: Emissions   =   Total annual PM_{10} emissions;
           Cattle   =   Average number of cattle present in feedlot;
           Days   =   Annual number of days that cattle are in feedlot;
           EF_{Capacity} = PM_{10} emission factor based on average capacity.

DATA NEEDED:

Data	Sources
PM_{10} Emission Factor[a] 12.0 Mg/1000 head throughput (13.0 tons/1,000 head throughput)	AP-42, 1985
PM_{10} Emission Factor[a] 62.4 kg/day-1000 head capacity (134.4 lbs/day-1,000 head capacity)	AP-42, 1985
Annual Cattle Throughput	SAGAR, INEGI, or local feedlots
Average Number of Cattle in Feedlot	SAGAR, INEGI, or local feedlots
Number of Days Cattle are in Feedlot	SAGAR, INEGI, or local feedlots

[a]   AP-42 emission factors are actually given for PM. Air Resource Board (ARB) documents indicate that 48% of PM from beef cattle feedlots is PM_{10} (ARB, 1995).

NOTES:

1.   All emission factors assume that no housekeeping measures for air pollution control are implemented. Normal housekeeping measures to prevent unacceptable quantities of manure typically are used at most feedlots and stockyards.

2.   Current emission factors are highly uncertain. U.S. EPA is currently conducting research on this source category. Improved emission factors should be available in the future, but none were available as of March 1997. Improved emission factors will eventually be presented in Section 9.4.1 of AP-42.

SAMPLE CALCULATION:

A beef cattle feedlot indicated an annual throughput of 23,200 head of cattle.

1.   Total amount of PM_{10} emissions for this feedlot:

      23,200 head $\times$ (12.0 Mg/1,000 head throughput) = 278 Mg PM_{10}

9.3   **Agricultural Burning**

SOURCE CODE: 28-01-500-000

DESCRIPTION:

Agricultural burning refers to the burning of field crops, wood, and leaves associated with agricultural activities. In Mexico, agricultural burning is mainly limited to the burning of crop remains in order to prepare the agricultural fields for new crops. Agricultural burning is permitted in Mexico, provided that prior notification has been given to SEMARNAP or SAGAR. All agricultural burning should conform with NOM-EM-003-SEMARNAP/ SAGAR-1996.

Emissions from agricultural burning are dependent upon several different factors. Some primary factors include type of crop, fuel loading (how much organic material per unit of land area), and type of burning (headfire or backfire). Headfires are started at the upwind side of a field and allowed to progress in the direction of the wind; backfires are started at the downwind side of a field and forced to progress in a direction against the wind. Other factors that can affect emissions include moisture content and arrangement of the organic material to be burned. Additional discussion concerning these factors can be found in Section 2.5.2.3 of AP-42 (AP-42, 1995).

POLLUTANTS: TOG, CO, and PM

ROG: ROG emissions are 72.2% of TOG.

POINT SOURCE ADJUSTMENTS: None.

METHODOLOGY:

$$\text{Emissions}_c = \text{Area}_c \times \text{Fuel Load}_c \times \text{EF}_c \qquad\qquad (9.3\text{-}1)$$

where: Emissions_c =   Total annual emissions from crop type, c;
Area_c =   Total area burned of crop type, c;
Fuel Load_c =   Average fuel loading for crop type, c; and
EF_c =   Emission factor for crop type, c.

The Secretary of Agriculture, Livestock, and Rural Development (SAGAR) keeps statistics on the amount of area cultivated for various crops. This information can be obtained from the state level SAGAR offices. INEGI also

compiles and publishes some of this agricultural information. However, SAGAR currently does not have any information on the amount or method of agricultural burning that occurs. As NON-EM-003-SEMARNAP/SAGAR-1996 is implemented, it is expected this type of information will become available from SAGAR. Until that time, this type of information will need to be collected on the local level.

The emission factor used in the above equation mainly depends upon the crop type and the type of burning. Emission factors for agricultural burning can be found in Table 2.5-5 of AP-42. The following types of burning are given: unspecified field crops, specific field crops (headfire, backfire, and independent of headfire/backfire), vine crops, weeds, orchard crops, and forest residues. These groups are broken down further into specific crop types (e.g., orchard crops include avocado, citrus, fig, olive, etc.). Table 2.5-5 of AP-42 also includes different fuel loading factors for each crop type.

It must be noted that the agricultural burning emission factors and fuel loading factors presented in AP-42 were developed in the United States. Mexican agricultural practices that are significantly different and other factors may result in different emission factors and fuel loading factors. An example of different fuel loading factors <u>within</u> the United States can be found in footnote "i" of Table 2.5-5 of AP-42. The sugar cane fuel loading factor for Louisiana is given as 8-13.6 Mg/hectare, while the fuel loading factor for Hawaii is given as 30-48 Mg/hectare. These fuel loading factors are significantly different due to differences in climate and/or agricultural practices. Instead of relying upon the fuel loading factors presented in AP-42, Mexico-specific fuel loading factors should be developed whenever possible. This will require performing field studies to determine the amount (i.e., weight) of crop residue present per unit of land area.

DATA NEEDED:

Data	Sources
Agricultural Area Burned (by crop type)	Local data collection
Fuel Loading Factor	Local data collection, U.S. values presented in AP-42, Table 2.5-5
Emission Factor	AP-42, Table 2.5-5

NOTES:

1. Particulate emission factors are presented as total particulate. Research has indicated that particulate matter from most agricultural burning is in the submicrometer range. Therefore, total particulate can be assumed to be equivalent to PM_{10}.

2. TOG emission factors are presented separately as non-methane TOG and methane emission factors. The overall TOG emission factor can be calculated by adding the non-methane TOG and methane emission factors together.

SAMPLE CALCULATION:

Local officials indicate that approximately 75% of the 120 hectares of melon fields are burned after harvest. Calculate the amount of CO emissions from this agricultural burning.

1. Total area burned:

    120 hectares $\times$ 0.75 = 90 hectares of fields burned

2. From Table 2.5-5 of AP-42, the fuel loading factor for melons (vine crops) is 5.6 Mg/hectare. However, this agricultural region practices more concentrated cultivation. Consequently, a hypothetical region-specific fuel loading factor of 7.8 Mg/hectare will be used.

3. The CO emission factor for vine crops from Table 2.5-5 of AP-42 is 26 kg/Mg of agricultural waste.

4. Total CO emissions:

    90 hectares $\times$ (7.8 Mg waste/hectare) $\times$ (26 kg/Mg waste)
    $\qquad$ = 18,252 kg CO
    $\qquad$ = 18.3 Mg CO

9.4   Fertilizer Application

SOURCE CODE: **DESCRIPTION:**

28-01-700-001   Anhydrous Ammonia
28-01-700-002   Aqua Ammonia (Ammonia in Solution)
28-01-700-003   Nitrogen Solutions
28-01-700-004   Urea
28-01-700-005   Ammonium Nitrate
28-01-700-006   Ammonium Sulfate
28-01-700-007   Ammonium Thiosulfate
28-01-700-008   Other Straight Nitrogen
28-01-700-009   Ammonium Phosphates
28-01-700-010   N-P-K (Nitrogen[N]-Phosphorus[P]-Potassium[K] Mixtures)

DESCRIPTION:

> Fertilizers are used extensively to add or replenish nutrients that are depleted or
> otherwise missing from agricultural soil. Because of the large number of soil
> and crop types, many different types of fertilizers have been formulated. After
> application, the nitrogen-based fertilizers release ammonia to the atmosphere.
> The amount of ammonia emissions is dependent upon the type of fertilizer
> applied and is typically expressed as some percent of the nitrogen content of the
> fertilizer.

> The development of ammonia emission factors for fertilizer application is still in
> its beginning stages. Some generalized emission factors have been developed,
> however, there are many influencing factors that have not been adequately
> addressed in these generalized emission factors. These influencing factors
> include meteorological conditions, soil properties, application technique (surface
> or subsurface), and application cycles.

POLLUTANTS: NH_3

ROG: Not applicable

POINT SOURCE ADJUSTMENTS: None.

METHODOLOGY:

Ammonia emissions from fertilizer application can be estimated using the following equation:

$$Emissions_f \;=\; Use_f \times \%N_f \times EF_f \tag{9.4-1}$$

where:

	$Emissions_f$	=	Total annual NH_3 emissions for fertilizer type, f;
	Use_f	=	Total annual use of fertilizer type, f;
	$\%N_f$	=	Nitrogen content of fertilizer type, f; and
	EF_f	=	Emission factor for fertilizer type, f.

DATA NEEDED:

Data	Sources
Annual Fertilizer Usage (by fertilizer type)	Local SAGAR/CICOPLAFEST Office
Nitrogen Content (by fertilizer type)	Local SAGAR/CICOPLAFEST Office
NH_3 Emission Factors Anhydrous Ammonia 12 kg NH_3/Mg total N Aqua Ammonia 12 kg NH_3/Mg total N Nitrogen Solution 30 kg NH_3/Mg total N Urea 187 kg NH_3/Mg total N Ammonium Nitrate 25 kg NH_3/Mg total N Ammonium Sulfate 97 kg NH_3/Mg total N Ammonium Thiosulfate 30 kg NH_3/Mg total N Other Straight Nitrogen 30 kg NH_3/Mg total N Ammonium Phosphates 48 kg NH_3/Mg total N N-P-K 48 kg NH_3/Mg total N	Battye et al., 1994

NOTES:

1. U.S. EPA is currently developing fertilizer application ammonia emission factors. As of March 1997 these factors were unavailable. These factors will eventually be presented in Section 9.2.1 of AP-42. It is expected that some of the emission factors presented above will be included in the AP-42 documentation.

SAMPLE CALCULATION:

It has been reported that 42 Mg of N-P-K have been applied to melon fields in a certain region. The N-P-K fertilizer has a total nitrogen content of 32%. What are the resultant NH_3 emissions?

1. Total NH_3 emissions from N-P-K fertilizer:

    (42 Mg N-P-K) $\times$ (0.32 Mg total N/Mg N-P-K) $\times$
    (48 kg NH_3/Mg total N) = 645 kg NH_3

9.5   Animal Waste

SOURCE CODE: DESCRIPTION:

Cattle and Calves
28-05-020-001   Beef cows
28-05-020-002   Milk cows
28-05-020-003   Heifers (Beef cow replacements)
28-05-020-004   Heifers (Milk cow replacements)
28-05-020-005   Heifers (Other)
28-05-020-006   Steers
28-05-020-007   Bulls
28-05-020-008   Calves

Hogs and Pigs
28-05-025-011   Breeding sows (> 50 kg)
28-05-025-011   Breeding sows (20-50 kg)
28-05-025-021   Market hogs (< 27.2 kg)
28-05-025-022   Market hogs (27.2-54.0 kg)
28-05-025-023   Market hogs (54.1-81.2 kg)
28-05-025-024   Market hogs (> 81.3 kg)

Chickens
28-05-030-001   Mother animals (> 6 months)
28-05-030-002   Laying hens (> 18 weeks)
28-05-030-003   Mother animals (< 6 months)
28-05-030-004   Laying hens (< 18 weeks)
28-05-030-005   Other chickens
28-05-030-006   Broilers

Other Poultry
28-05-035-001   Ducks
28-05-035-002   Turkeys
28-05-035-003   Turkeys (< 7 months)
28-05-035-004   Turkeys (> 7 months)
28-05-035-005   Turkeys (fryer-roaster)

Miscellaneous Farm Animals
28-05-040-000   Sheep and Lambs
28-05-045-001   Goats
28-05-045-004   Rabbit
27-10-020-030   Horses

DESCRIPTION:

Livestock and other domesticated farm animals are a significant source of ammonia emissions. In some locations, they constitute the largest single source of ammonia emissions. Ammonia emissions from livestock animals result from the conversion of excreted nitrogen to ammonia and its subsequent volatilization. It is thought that nitrogen contained in livestock urine is easily converted to and emitted as ammonia. In contrast, ammonia emissions from manure typically require considerable decomposition.

The magnitude of livestock ammonia emissions is dependent upon many factors. These factors include type of livestock, animal size and weight, manure storage practices, nitrogen content of livestock feed, and meteorology. In additional, there are a large number of environmental factors that govern the rate of manure decomposition. Because livestock ammonia emissions are dependent upon a wide range of environmental variables, it is quite difficult to establish an accurate set of emission factors. The emission factors presented below represent current recommended emission factors for regional-scale emission inventories.

Additional emission factors for specialized livestock sources (i.e. dairies, slaughterhouses, etc.) have been developed. Two references for these are presented in the **NOTES**.

POLLUTANTS: NH_3

ROG: Not Applicable

POINT SOURCE ADJUSTMENTS: None.

METHODOLOGY:

Ammonia emissions from livestock and other domesticated farm animals can be estimated using the following equation:

$$\text{Emissions}_a = \text{Population}_a \times \text{EF}_a \times \text{RT}_a \tag{9.5-1}$$

where: Emissions_a =   Total annual NH_3 emissions for animal type, a;
           Population_a =   Total livestock population for animal type, a; and
           EF_a = NH_3 emission factor for animal type, a; and
           RT_a =   Livestock residence time for animal type, a, as a fraction of a year.

DATA NEEDED:

Data	Sources
Livestock Populations	Local SAGAR office. INEGI statistics may also be useful.
Livestock Residence Time	Local SAGAR office.
Emission Factors	Battye et. al, 1994

Emission Factors (continued within same cell):

Beef Cows	39.7 kg NH_3/head-yr
Milk Cows	39.7 kg NH_3/head-yr
Heifers (Beef Cow Replacements)	15.2 kg NH_3/head-yr
Heifers (Milk Cow Replacements)	13.0 kg NH_3/head-yr
Heifers (Other)	13.0 kg NH_3/head-yr
Steers	8.2 kg NH_3/head-yr
Bulls	27.9 kg NH_3/head-yr
Calves	5.2 kg NH_3/head-yr
Breeding Sows (> 50 kg)	16.1 kg NH_3/head-yr
Breeding Sows (20-50 kg)	5.2 kg NH_3/head-yr
Market Hogs (< 27.2 kg)	7.0 kg NH_3/head-yr
Market Hogs (27.2-54.0 kg)	7.0 kg NH_3/head-yr
Market Hogs (54.1-81.2 kg)	11.0 kg NH_3/head-yr
Market Hogs (> 81.3 kg)	11.0 kg NH_3/head-yr
Chickens (Mother Animals > 6 months)	0.60 kg NH_3/head-yr
Chickens (Laying Hens > 18 weeks)	0.31 kg NH_3/head-yr
Chickens (Mother Animals < 6 months)	0.27 kg NH_3/head-yr
Chickens (Laying Hens < 18 weeks)	0.17 kg NH_3/head-yr
Other Chickens	0.18 kg NH_3/head-yr
Broilers	0.17 kg NH_3/head-yr
Ducks	0.12 kg NH_3/head-yr
Turkeys	0.86 kg NH_3/head-yr
Turkeys (< 7 months)	0.89 kg NH_3/head-yr
Turkeys (> 7 months)	1.3 kg NH_3/head-yr
Turkeys (fryer-roaster)	0.86 kg NH_3/head-yr
Sheep and Lambs	3.4 kg NH_3/head-yr
Goats	6.4 kg NH_3/head-yr
Rabbits	2.8 kg NH_3/head-yr
Horses	12.2 kg NH_3/head-yr

NOTES:

1.   Specialized ammonia emission factors have been developed for southern California dairies (Schmidt and Winegar, 1996). Per animal emission factors were developed for individual unit processes, as well as overall

dairy averages. It is uncertain how applicable these emission factors would be for Mexican dairies.

2.   Specialized ammonia emission factors have been developed for U.S. beef and chicken processing plants (Radian, 1995). Emission factors are given in terms of number of animals processed per day, amount of meat processed per day, amount of discharged wastewater, and amount of effluent ammonia or BOD (biological oxygen demand). It is uncertain how applicable these emission factors would be for Mexican meat processing plants.

SAMPLE CALCULATION:

A certain region has a year-round livestock population of 25,000 beef cows and 5,000 bulls. For three months of the year, 15,000 sheep are brought into the region for grazing. Calculate the total NH_3 emissions.

1.   Total emissions from 25,000 beef cows:

25,000 beef cows $\times$ (39.7 kg NH_3/head-yr) $\times$ 1.0 = 992,500 kg NH_3/yr

2.   Total emissions from 5,000 bulls:

5,000 bulls $\times$ (27.9 kg NH_3/head-yr) $\times$ 1.0 = 139,500 kg NH_3/yr

3.   Total emissions from 15,000 sheep:

15,000 sheep $\times$ (3.4 kg NH_3/head-yr) $\times$ 0.25 = 12,750 kg NH_3/yr

4.   Total livestock emissions:

992,500 kg NH_3/yr + 139,500 kg NH_3/yr + 12,750 kg NH_3/yr
= 1,144,750 kg NH_3 = 1,145 Mg NH_3

9.6   Agricultural Tilling

SOURCE CODE: 28-01-000-003

DESCRIPTION:

Fugitive dust from agricultural operations can be a significant contributor of PM_{10} emissions in some rural areas. Agricultural operations are typically divided into three classifications: soil preparation, soil maintenance, and crop harvesting. The agricultural tilling source category focuses primarily on soil preparation. Soil preparation includes such operations as plowing, harrowing, leveling, and dicing.

POLLUTANTS: PM_{10}

ROG: Not applicable

POINT SOURCE ADJUSTMENTS: None.

METHODOLOGY:

To estimate emissions from agricultural tilling, the following equation derived from AP-42 and the Air Resources Board's *Emission Inventory Procedural Manual* (ARB, 1995) is used:

$$\text{Emissions}_c = 5.38(s)^{0.6} \times k \times HP_c \times \text{Area}_c \qquad (9.6\text{-}1)$$

where: Emissions_c =   Annual PM_{10} emissions for crop type, c;
            $5.38(s)^{0.6}$ =   Base emission factor (kg PM/hectare-pass);
            k   =   Particle size multiplier (0.21 for PM_{10} from AP-42);
            s   =   Silt content (%) - (see **NOTE** #2);
            HP_c =   Number of hectare-passes per hectare for crop type, c; and
            Area_c =   Total cultivated area for crop type, c.

The first term of the equation is taken from Section 11.2.2 of the 4th Edition of AP-42 (AP-42, 1993). This term is used to estimate emissions from a specific operation.

The second term of the equation (the number of hectare-passes per hectare) is used to account for the multiple tilling operations that are used for most crop

types. The number of hectare-passes per hectare is calculated by multiplying
the number of typical tilling operations by the percent of agricultural land that is
actually tilled. For most types of field crops, 100% of the land is tilled.
However, for orchard crops, a smaller fraction (5-20%) of the area is tilled.
Table II of Section 7.4 in ARB's *Emission Inventory Procedural Manual*
presents some typical values for the number of tilling operations and the percent
of cultivated area actually tilled for various crop types. These values, however,
represent California agricultural practices. Because Mexican agricultural
practices might be significantly different, it is recommended that Mexico-
specific data be developed.

Although a default value (18%) is available for the silt content, region-specific
data are highly desirable. Appendices C.1 and C.2 of AP-42 provide
procedures for determining silt content.

DATA NEEDED:

Data	Sources
Silt Content of Soil	Site specific measurements, INEGI, or Instituto de Geología of the Universidad Nacional Autónoma de Mexico (UNAM)
Agricultural Area Under Cultivation	SAGAR or local agricultural officials
Number of Yearly Operations	SAGAR or local agricultural officials; California values presented in Emission Inventory Procedural Manual
Percentage of Land Area Tilled	SAGAR or local agricultural officials; California values presented in Emission Inventory Procedural Manual

NOTES:

1. The methodology presented above (particularly the $5.38(s)^{0.6}$ factor) is
    based on limited data. U.S. EPA is currently revising its methodology
    for estimating emissions from agricultural tilling. When completed, this
    methodology will appear in Section 9.1 of the 5th Edition of AP-42.

2. The default value for silt content is 18%. Equation 8.12-1 is valid for
    silt contents ranging from 1.7% to 88%.

3.   Some researchers believe that agricultural tilling emissions are not solely a function of silt content as described above. Instead, they believe there are other parameters that would better describe the emission mechanisms for agricultural tilling. Data collection and statistical analysis for new emission factors are currently being conducted by research personnel at the Crocker Nuclear Laboratory at the University of California at Davis (Ashbaugh, 1996).

4.   Current research indicates that agricultural tilling emissions vary depending upon the type of crop and tilling implement. For instance, concentrations of respirable dust (50% of the particles have an aerodynamic diameter of 4 microns or less) sampled at the implement level revealed that soil ripping results in concentrations that are 31 times greater than for dicing of corn stubble. Also, concentrations from dicing of wheat stubble is 7.5 times greater than that for dicing of corn stubble. Agricultural tilling emissions may also be influenced by various environmental factors such as soil moisture and wind speed. Further research is currently being conducted in an attempt to try and quantify these factors (Clausnitzer and Singer, 1996).

SAMPLE CALCULATION:

A certain agricultural area has a soil silt content of 20%. The two main crops produced in this region are cotton and oranges. There are 110 hectares of cotton and 35 hectares of oranges. It is determined from local agricultural practices that 100% of the land used for cotton is tilled 5 times per year and that 15% of the land used for oranges is tilled 3 times per year. What are the annual PM_{10} emissions?

1.   Hectare passes per hectare for cotton are:

$5 \times 100\% = 5$

2.   Hectare passes per hectare for oranges are:

$3 \times 15\% = 0.45$

3.   Annual PM_{10} emissions from cotton are:

$5.38 \, (20)^{0.6}$ (kg PM_{10}/hectare-pass) $\times \, 0.21 \times 5$ (hectare-pass/hectare) $\times \, 110$ hectares $= 3{,}750$ kg

4.   Annual PM_{10} emissions from oranges are:

$5.38 \ (20)^{0.6} \ (\text{kg PM}_{10}/\text{hectare-pass}) \times 0.21 \times 0.45 \ (\text{hectare-pass/hectare}) \times 35 \ \text{hectares} = 107 \ \text{kg}$

5.   Total annual PM_{10} emissions from agricultural tilling are:

$3{,}750 \ \text{kg} + 107 \ \text{kg} = 3{,}856 \ \text{kg PM}_{10} = 3.86 \ \text{Mg PM}_{10}$

10.0 WASTE MANAGEMENT

Some waste management emission sources may be too small or too numerous to be included in the point source inventory for a given inventory region. Therefore, these sources need to be included in the area source inventory effort. Inventory guidance for these sources are presented in the following subsections:

- On-Site Incineration;

- Open Burning;

- Wastewater Treatment; and

- Open Channel Sewage and Wastewater.

10.1   On-Site Incineration

SOURCE CODE: DESCRIPTION:

26-01-000-000   All Categories
26-01-020-000   Commercial/Institutional
26-01-030-000   Residential

DESCRIPTION:

On-site incineration is the <u>confined</u> burning of trash and other refuse. Open
burning of these materials is addressed in Section 10.2 of this manual.
Municipal waste, hazardous waste, or industrial incinerators are usually
classified as point sources and fall under federal jurisdiction. These incinerators
will not be addressed in this section. Only commercial, institutional, and
residential on-site incineration devices are included in this section. Direct
statistics related to on-site incineration are not readily available in Mexico
because it is not a widespread activity. However, the material balance method
described below can be used to estimate emissions.

POLLUTANTS: TOG, CO, NO_x, SO_x, and PM_{10}

ROG: ROG emissions are 75% of TOG.

POINT SOURCE ADJUSTMENTS:

Emissions from on-site incineration should be adjusted downward to account for
any incineration point sources (i.e., municipal incinerators, etc.) within the
region. This is done by subtracting the waste that goes to these sources from
the overall incinerated waste stream. INE or other government agencies should
have information on incineration point sources.

METHODOLOGY:

The first step in estimating emissions from on-site incineration is to perform a
solid waste material balance. In general, a solid waste material balance is in the
form of:

$$\sum \text{Waste}_{\text{Generated}} = \sum \text{Waste}_{\text{Disposed}} \tag{10.1-1}$$

where: $\Sigma \text{Waste}_{\text{Generated}}$ =   Total amount of waste generated; and

                    $\text{Waste}_{\text{Disposed}}$ =   Total amount of waste disposed.

The total amount of waste generated is usually calculated by multiplying a per capita waste generation rate by the inventory area population. This is mathematically represented below.

$$\sum \text{Waste}_{\text{Generated}} = \text{Population} \times \text{Waste}_{\text{per capita}} \qquad (10.1\text{-}2)$$

According to INE, the 1994 per capita waste generation rate for the entire country of Mexico was 0.893 kg/person-day (INE, 1994). Regional socioeconomic differences will result in higher or lower waste generation rates for different regions. For example, it has been estimated that the waste generation rate for Nogales, Sonora is approximately 0.8 kg/person-day (Monroy, 1996). It is recommended that local officials be contacted to obtain an appropriate waste generation rate.

The total amount of disposed waste is given by the following equation:

$$\sum \text{Waste}_{\text{Disposed}} = \text{Waste}_{\text{Landfill}} + \text{Waste}_{\text{Recycle}} + \text{Waste}_{\text{Incinerator}} + \text{Waste}_{\text{Open Burn}} + \text{Waste}_{\text{Other}} \qquad (10.1\text{-}3)$$

where: $\text{Waste}_{\text{Landfill}}$ =   Total amount of waste sent to sanitary landfill;

                    $\text{Waste}_{\text{Recycle}}$ =   Total amount of recycled waste;

                    $\text{Waste}_{\text{Incinerator}}$ =   Total amount of waste sent to an incinerator;

                    $\text{Waste}_{\text{Open Burn}}$ =   Total amount of waste consumed through open refuse burning; and

                    $\text{Waste}_{\text{Other}}$ =   Total amount of waste "disposed" of through other means (i.e., abandonment, etc.)

Rearranging Equations 10.1-1, 10.1-2, and 10.1-3 results in the following equation which gives the amount of waste combusted in incinerators. As indicated above, this amount of waste must be further adjusted for point source incinerators:

$$\text{Waste}_{\text{Incinerator}} = (\text{Population} \times \text{Waste}_{\text{per capita}}) - \text{Waste}_{\text{Landfill}} - \text{Waste}_{\text{Recycle}} - \text{Waste}_{\text{Open Burn}} - \text{Waste}_{\text{Other}} \qquad (10.1\text{-}4)$$

INE has estimated that approximately 70% of the waste generated in Mexican cities ends up being collected and sent to the sanitary landfill. Other areas may have different fractions of the overall waste stream sent to the landfill.

The amount of overall waste that is recycled is probably small for most areas of Mexico. For example, it has been estimated that 1.3% of the total generated waste in Nogales, Sonora was recycled in 1990 (Monroy, 1996). However, it is expected that the amount of recycling will increase in the future as the practice of recycling expands worldwide.

Local officials will need to be consulted concerning the amount of waste that is disposed of by open burning and other means.

After estimating the amount of waste sent to incinerators, the amount of waste sent to point source incinerators must be subtracted. After that, emissions can be calculated using the following equation:

$$\text{Emissions}_i = \text{Waste}_{\text{Incinerator}} \times \text{EF}_i \qquad\qquad (10.1\text{-}5)$$

where:

Emissions_i	=	Total annual emissions for pollutant, i;
$\text{Waste}_{\text{Incinerator}}$	=	Total waste incinerated (adjusted for point source incinerators); and
EF_i	=	Emission factor for pollutant, i.

Some emission factors for on-site incinerators are presented below in Table 10.1-1.

Table 10.1-1

Uncontrolled Emission Factors for On-Site Incinerators Other than Municipal Waste[a]

Combustor Type		TOC[b] (kg/Mg)	CO (kg/Mg)	NO$_x$ (kg/Mg)	PM (kg/Mg)	SO$_2$ (kg/Mg)
Commercial/ Institutional	Multiple Chamber	1.5	5.0	1.5	3.5	1.25
	Single Chamber	75	10	1.0	7.5	1.25
Residential	Without Primary Burner	50	150	0.5	17.5	0.25
	With Primary Burner	1.0	0	1.0	3.5	0.25

[a]   Emission factors taken from Table 2.1-12 of AP-42. Additional emission factors for other non-municipal waste incinerators can be found there.

[b]   Expressed as methane.

DATA NEEDED:

Data	Sources
Population	INEGI or local officials
Per Capita Waste Generation Rate (default - 0.893 kg/person-day)	INE, INEGI, or local officials
Amount of Waste Disposed in Landfill (default - 70% of total waste)	INE or local officials
Amount of Waste Recycled	Local officials
Amount of Waste Disposed by Open Burning	Local officials
Amount of Waste Disposed by Other Means (abandonment, etc.)	Local officials
Amount of Waste Disposed by Point Source Incinerators	INE or local facilities
Emission Factors	Table 10.1-1 of this manual or Table 2.1-12 of AP-42

SAMPLE CALCULATION:

A certain municipality has a population of 160,000 people. Local officials have indicated that the per capita waste generation factor is slightly lower than the national average (0.85 kg/person-day). Local officials also indicate that 65% of the total waste is landfilled, 3% is recycled, 10% is disposed through open burning, and the remainder is incinerated. Five percent is abandoned or dumped. A municipal waste incinerator within the municipality incinerates 5,500 Mg of waste yearly. Calculate annual CO emissions from on-site incineration assuming that all waste is burned in a commercial single chamber combustor.

1.   Total annual waste generated:

160,000 people $\times$ (0.85 kg/person-day) $\times$ 365 days = 49,640,000 kg
$$= 49,640 \text{ Mg}$$

2.   Total annual waste that is landfilled:

49,640 Mg $\times$ 0.65 = 32,266 Mg

3.   Total annual waste that is recycled:

49,640 Mg x 0.03 = 1,489 Mg

4.   Total annual waste that is disposed through open burning:

49,640 Mg $\times$ 0.10 = 4,964 Mg

5.   Total annual waste that is abandoned or dumped:

49,640 Mg $\times$ 0.05 = 2,482 Mg

6.   Total annual waste that is incinerated:

49,640 Mg - 32,266 Mg - 1,489 Mg - 4,964 Mg
       - 2,482 Mg = 8,439 Mg

7.   Total annual waste that is incinerated (adjusted for point source incinerators):

8,439 Mg - 5,500 Mg = 2,939 Mg

8.   Total CO emissions:

$$2{,}939 \text{ Mg waste} \times (10 \text{ kg CO/Mg waste}) = 29{,}390 \text{ kg CO/yr}$$
$$= 29.4 \text{ Mg CO/yr}$$

10.2   Waste Management - Open Burning

SOURCE CODE: **DESCRIPTION:**

26-10-000-000   All Categories
26-10-010-000   Industrial
26-10-020-000   Commercial/Institutional
26-10-030-000   Residential

DESCRIPTION:

In some areas, open burning is the preferred method of disposal of solid waste. The confined burning of waste materials is addressed under on-site incineration (Section 10.1). Large scale agricultural burning is not included in this section; the methodology for agricultural burning can be found in Section 9.3. Large open burning dumps are usually classified as point sources and will not be addressed in this section.

Direct statistics related to open refuse burning are somewhat limited. Mexican law states that open burning will only be permitted in zones under Federal jurisdiction when it occurs with permission from SEMARNAP for training firefighting personnel. In such a request, the type and quantity of fuel that will be burned should be provided. The practice of small-scale open refuse burning without permission from SEMARNAP, however, also seems to be prevalent. The effects of local rules and regulations should also be considered when estimating emissions from open burning. The material balance method described below can be used to estimate emissions.

POLLUTANTS: TOG, CO, NO_x, SO_x, and PM_{10}

ROG: ROG emissions are 38.7% of TOG.

POINT SOURCE ADJUSTMENTS:

Emissions from open refuse burning should be adjusted downward to account for any open burning point sources (i.e., large open burning dumps, etc.) within the region. This is done by subtracting the waste that goes to these sources from the overall incinerated waste stream. Local officials should have information on these point sources.

METHODOLOGY:

The first step in estimating emissions from open refuse burning is to perform a solid waste material balance. In general, a solid waste material balance is in the form of:

$$\sum \text{Waste}_{\text{Generated}} = \sum \text{Waste}_{\text{Disposed}} \tag{10.2-1}$$

where: $\Sigma\text{Waste}_{\text{Generated}}$ =   Total amount of waste generated; and
                $\text{Waste}_{\text{Disposed}}$ =   Total amount of waste disposed.

The total amount of waste generated is usually calculated by multiplying a per capita waste generation rate by the inventory area population. This is mathematically represented below.

$$\sum \text{Waste}_{\text{Generated}} = \text{Population} \times \text{Waste}_{\text{per capita}} \tag{10.2-2}$$

According to INE, the 1994 per capita waste generation rate for the entire country of Mexico was 0.893 kg/person-day (INE, 1994). Regional socioeconomic differences will result in higher or lower waste generation rates for different regions. For example, it has been estimated that the waste generation rate for Nogales, Sonora is approximately 0.8 kg/person-day (Monroy, 1996). It is recommended that local officials be contacted to obtain an appropriate waste generation rate.

The total amount of disposed waste is given by the following equation:

$$\sum \text{Waste}_{\text{Disposed}} = \text{Waste}_{\text{Landfill}} + \text{Waste}_{\text{Recycle}} + \text{Waste}_{\text{Incinerator}} + \text{Waste}_{\text{Open Burn}} + \text{Waste}_{\text{Other}}$$

$$\tag{10.2-3}$$

where: $\text{Waste}_{\text{Landfill}}$ =   Total amount of waste sent to sanitary landfill;
               $\text{Waste}_{\text{Recycle}}$ =   Total amount of recycled waste;
               $\text{Waste}_{\text{Incinerator}}$ =   Total amount of waste sent to an incinerator;
               $\text{Waste}_{\text{Open Burn}}$ =   Total amount of waste consumed through open refuse burning; and
               $\text{Waste}_{\text{Other}}$ =   Total amount of waste "disposed" of through other means (i.e., abandonment, etc.)

Rearranging Equations 10.2-1, 10.2-2, and 10.2-3 results in the following equation which gives the amount of waste combusted in open burning.

$$\text{Waste}_{\text{Open Burn}} = (\text{Population} \times \text{Waste}_{\text{per capita}}) - \text{Waste}_{\text{Landfill}} - \text{Waste}_{\text{Recycle}} - \text{Waste}_{\text{Incinerator}} - \text{Waste}_{\text{Other}}$$

(10.2-4)

INE has estimated that approximately 70% of the waste generated in Mexican cities ends up being collected and sent to the sanitary landfill. Other areas may have different fractions of the overall waste stream sent to the landfill.

The amount of overall waste that is recycled is probably small for most areas of Mexico. For example, it has been estimated that 1.3% of the total generated waste in Nogales, Sonora was recycled in 1990 (Monroy, 1996). However, it is expected that the amount of recycling will increase in the future as the practice of recycling expands worldwide.

Local officials will need to be consulted concerning the amount of waste that is disposed of by incineration and other means.

After estimating the amount of waste combusted by open burning, then emissions can be calculated using the following equation:

$$\text{Emissions}_i = \text{Waste}_{\text{Open Burn}} \times \text{EF}_i \qquad (10.2\text{-}5)$$

where:
Emissions_i	=	Total annual emissions for pollutant, i;
$\text{Waste}_{\text{Open Burn}}$	=	Total waste burned (adjusted for point source incinerators); and
EF_i	=	Emission factor for pollutant, i.

Emission factors for typical municipal refuse can be found in Table 10.2-1. The open burning of organic or agricultural refuse is addressed in Section 9.3 of this manual. Specialized discussion concerning the open burning of automobile components, tires, and agricultural plastic film are presented in Sections 2.5.2.2, 2.5.2.3, and 2.5.2.4 of AP-42 (AP-42, 1995).

Table 10.2-1

Emission Factors for Open Burning of Municipal Refuse Municipal Waste[a]

Source	TOG (kg/Mg)[b]		CO (kg/Mg)	NO$_x$ (kg/Mg)	PM[c] (kg/Mg)	SO$_2$ (kg/Mg)
	Methane	Non-methane				
Municipal Refuse	6.5	15	42	3	8	0.5

[a]   Emission factors taken from Table 2.5-1 of AP-42.
[b]   TOG emission factors are presented separately as non-methane TOG and methane emission factors together.
[c]   Particulate emission factors are presented as total particulate. Although not stated, it seems reasonable to assume that a significant fraction of PM is PM$_{10}$.

DATA NEEDED:

Data	Sources
Population	INEGI or local officials
Per Capita Waste Generation Rate (default - 0.893 kg/person-day)	INE, INEGI, or local officials
Amount of Waste Disposed in Landfill (default - 70% of total waste)	INE or local officials
Amount of Waste Recycled	Local officials
Amount of Waste Disposed by Incineration	Local officials and facilities
Amount of Waste Disposed by Other Means (abandonment, etc.)	Local officials
Emission Factors	Table 10.2-1

SAMPLE CALCULATION:

A certain municipality has a population of 140,000 people. Local officials have indicated that the per capita waste generation factor is lower than the national average (0.75 kg/person-day). Local officials also indicate that 60% of the total waste is landfilled, 2% is recycled, 10% is disposed through incineration (municipal and on-site), 5% is abandoned or dumped, and the remainder is open-burned. Calculate annual NO$_x$ emissions from open burning assuming that all waste generated is typical municipal waste.

1.   Total annual waste generated:

        140,000 people $\times$ (0.75 kg/person-day) $\times$ 365 days = 38,325,000 kg
                                                                                = 38,325 Mg

2.   Total annual waste that is landfilled:

        38,325 Mg $\times$ 0.60 = 22,995 Mg

3.   Total annual waste that is recycled:

        38,325 Mg x 0.02 = 767 Mg

4.   Total annual waste that is disposed of through incineration:

        38,325 Mg $\times$ 0.10 = 3,833 Mg

5.   Total annual waste that is abandoned or dumped:

        38,325 Mg $\times$ 0.05 = 1,916 Mg

6.   Total annual waste that is disposed of through open burning:

        38,325 Mg - 22,995 Mg - 767 Mg - 3,833 Mg
                - 1,916 Mg = 8,814 Mg

7.   Total NO_x emissions:

        8,814 Mg waste $\times$ (3 kg NO_x/Mg waste) = 26,442 kg NO_x/yr
                                                                        = 26.4 Mg NO_x/yr

10.3   Wastewater Treatment

SOURCE CODE: **DESCRIPTION:**

26-30-000-000   All Categories/Composite
26-30-010-000   Industrial/Composite
26-30-020-000   Public Owned/Composite
26-30-030-000   Residential or Subdivision Owned/Composite

DESCRIPTION:

Various industrial processes generate wastewater streams that contain organic compounds. These streams typically undergo collection, contaminant treatment, and/or storage steps before they are discharged into either a receiving body of water or a municipal treatment plant (also called publicly owned treatment works [POTWs] in the U.S.) for further treatment. During some of these operations, the wastewater is open to the atmosphere and organic compounds may be emitted into the air.

In addition to industrial wastewater, POTWs may also treat water from residential, institutional, or commercial facilities, water that enters the sewer system from the ground and/or storm water runoff. These other types of wastewater generally do not contain significant levels of TOG. In the U.S., if the actual annual industrial wastewater contribution to the POTWs of an inventory region is not known, then 16% of the total annual flow (i.e., the national average) is recommended as a default value. This U.S.-based default value has limited applicability in Mexico and should only be used if no other data are available.

The effluent from the wastewater treatment plant must meet federal, state, and municipal quality standards before it is discharged into a receiving body of water. The size and degree of treatment of wastewater streams will depend on the volume and degree of contamination of the wastewater and on the extent of contaminant removal desired.

POLLUTANTS: TOG

ROG: Most of the non-reactive hydrocarbons that should be excluded are halogenated organics. If chemical-specific wastewater concentration data are available, the TOG emissions can be adjusted to exclude the halogenated organic portion.

For example, if the TOG emissions are 100 Mg/yr, the sum of the halogenated organic compound concentrations is 40 ppmw and the TOC concentration is 500 ppmw, then:

Non-reactive portion = (40 ppmw) / (500 ppmw) = 8%

ROG emissions   = (TOG emissions) x (ROG fraction)
                     = (100 Mg/yr) x (1 - 0.08)
                     = 92 Mg/yr

POINT SOURCE ADJUSTMENTS:

Wastewater treatment may occur at large facilities that may be inventoried as point sources. Ideally, the total volume of wastewater treated at point sources should be subtracted from the total volume of wastewater treated in the inventory region and the resulting "total volume of wastewater treated at area sources" should be used in the emissions calculations. If only emissions data are available for the point source facilities, then these emissions must be subtracted from the total emissions calculated using the methods described here to yield the final area source emissions estimate.

METHODOLOGY:

The amount of industrial wastewater treated needs to be determined for the inventory region. If the statistics available do not directly correspond to the needs of the inventory effort (e.g., statewide statistics are available but the inventory region includes portion of multiple states; statewide statistics are available, but the inventory requires municipal-level emission estimates), then census data (e.g., population or housing) or other available statistics can be used to disaggregate the totals to the inventory region. For example, population data might be used for municipal wastewater treatment and the number of industrial facilities or industrial revenues might be used for industrial wastewater treatment. The sample calculation for residential fuel combustion (commercial fuels) (Section 4.2) illustrates this procedure.

The emission factor developed must relate the mass of pollutant emitted to the amount of wastewater treated (e.g., kg TOG/liter). Then, the equation for uncontrolled TOG emissions is simply:

$$\text{Emissions}_{TOG} = \text{(volume of wastewater treated)} \times \text{EF}_{TOG} \qquad (10.3\text{-}1)$$

As an alternative, a much more rigorous approach using an emissions model such as CHEMDAT8 or WATER8 may be applied. See Section 4.1.4 of *Basic*

Emission Estimating Techniques (Volume III of this series) for more information on these computer models, the emission model equations, and data requirements. Also, Section 4.2.8 (i.e., Tratamiento de Aguas Residuales) of the documentation for the development of an area source inventory for the Mexico City Metropolitan Area (DDF, 1995a) provides more detailed information on how a older emissions model (i.e., the Surface Impoundment Modeling System [SIMS]) has previously been used in Mexico to develop area source emission estimates from wastewater treatment. However, U.S. EPA no longer supports this model.

DATA NEEDED:

Data	Sources
Quantity of industrial wastewater treated in the inventory region	Federal agency: *Comisión Nacional del Agua* State or local agency: (e.g., *Dirección General de Construcción y Operación Hidráulica*, Mexico City)
Emission factor 1.3×10^{-5} kg TOG/liter (1.1×10^{-4} TOG lb/gal)	U.S. EPA, 1991a

NOTES:

1.   The information about wastewater treatment plants by regions in the country can be found in the *Comisión Nacional del Agua* (National Water Commission), a source of information for municipal wastewater treatment plants. The Commission is the federal agency that compiles information about use and discharge to federal bodies of water.

2.   The only currently published emission factor is 1.3×10^{-5} kg/liter (1.1×10^{-4} lb/gal) (U.S. EPA, 1991a). This emission factor is based on the reported total industrial flow discharged to POTWs in the U.S. in 1984 which was 1.6×10^{12} gallons and a national VOC emissions estimate from POTWs of 78,540 Mg/yr. This VOC emissions estimate was based on the annual VOC loadings reported for raw POTW influent and an assumption, supported by research, that in the event of heavy chemical loading, 85% of all volatile pollutants discharged to wastewater treatment systems are stripped to the ambient air. That is:

$$\text{EF}_{\text{VOC}} = (78540 \text{ Mg/yr}) (10^6 \text{ g/Mg}) / (453.6 \text{ g/lb}) / (1.6 \text{ x } 10^{12} \text{ gal/yr})$$
$$= 1.1 \text{ x } 10^{-4} \text{ lbs VOC/gal}$$

This U.S.-based emission factor has limited applicability in Mexico and should only used if no other data are available.

SAMPLE CALCULATION:

1.   Determine the amount of wastewater treated. Assume that the total amount of wastewater treated in the inventory region is $2,500 \times 10^6$ liters/yr. Since the amount of <u>industrial</u> wastewater treated is not known, the U.S. default of 16% is used:

$$(2,500 \times 10^6 \text{ liters/yr}) \times (16\%) = 400 \times 10^6 \text{ liters/yr}$$

2.   Determine the TOG emissions

For example, the total annual TOG emissions from a state that treats 400×10^6 liters/yr of industrial wastewater are:

$$(400 \times 10^6 \text{ liters/yr}) \times (1.3 \times 10^{-5} \text{ kg TOG/liter}) \qquad = 5200 \text{ kg/yr}$$
$$= 5.2 \text{ Mg/yr}$$

3.   Subtract point source emissions, if necessary

If there are large wastewater treatment plants in the inventory region that have been inventoried as point sources, then preferably, the total volume of wastewater treated at point sources should be subtracted from the total volume of wastewater treated in the inventory region and the resulting "total volume of wastewater treated at area sources" should be used in the emissions calculations. For example, if the point source throughputs are:

•   10 million liters/yr for Facility A; and

•   20 million liters/yr for Facility B;

Then:

$$[(400) - (10 + 20)] \times 10^6 \text{ liters/yr} \times (1.3 \times 10^{-5} \text{ kg TOG/liter}) = 4810 \text{ kg/yr}$$
$$= 4.8 \text{ Mg/yr}$$

If only emissions data are available for the point source facilities, then the emissions assigned to those facilities need to be subtracted from the total

calculated for the inventory region. For example, if the point source emissions are:

- 100 kg/yr for Facility A; and

- 150 kg/yr for Facility B;

Then:

Area Source Emissions   = (Total Emissions) - (Point Emissions)
                                            = 5200 - (100 + 150)
                                            = 4950 kg/yr
                                            = 4.95 Mg/yr

10.4　Open Channel Sewage and Wastewater

SOURCE CODE:　　　　DESCRIPTION:

26-30-090-000*　　　　　Wastewater Treatment

*Proposed Mexico-specific code for source category not typically inventoried in the U.S.

DESCRIPTION:

In some areas of Mexico, open channels may be used to conduct human sewage and/or industrial wastewaters. For example, Ciudad Juárez, with around 1 million people, has no sewage systems and diverts about 55 million gallons of raw sewage each day into open unlined channels that flow along the Rio Grande (*Sacramento Bee*, 1995b). These canals, streams, rivers, and ditches, are sources of emissions to the atmosphere from the decomposition of organic material and the evaporation of hydrocarbons present in the discharges.

POLLUTANTS:　　TOG and NH_3.

ROG:　　Industrial wastewaters may include chlorofluorocarbons (CFCs) or other organic compounds that are not considered reactive and that should be excluded from ROG inventory efforts.

POINT SOURCE ADJUSTMENTS:

Open channel sewage and wastewater sources are not generally included in a point source inventory. No adjustments should be necessary.

METHODOLOGY:

Further studies are needed to develop a methodology for estimating volatile hydrocarbon emissions from the decomposition of organic material and emissions in open channels. U.S. EPA is currently funding at least one such effort through the Centro de Informacion sobre Contaminacion del Aire (CICA). CICA Project No. 2, *Emission Estimation Techniques for Unique Source Categories in Mexicali, Mexico,* will present and evaluate specific methodologies for developing emission factors for open wastewater ditches/canals. It is expected that the draft report for this project will be complete by April 1997 and might be available to the public on the CICA Home Page at (*http://www.epa.gov/oar/oaqps/cica/*).

Data to support a simple mass balance approach (e.g., total amount of wastewater, concentrations of pollutants to be inventoried) may be available in some regions. However, the methodology likely would need to account for the effects of decomposition, since this chemical reaction will both destroy some chemical species originally discharged into the open channels and create other byproducts. It is interesting to note that a Rice University study suggests that in some cases it is possible that the human waste may not decompose because the concentration levels of industrial chemicals kill the bacteria in the water (*http://www.rice.edu/projects/TELRC/Colonias/file5.html*).

DATA NEEDED:

Data	Sources
General information on length and conditions of open channels	Municipal agencies (e.g., Mexico City - *Dirección General de Construcción y Operación Hidráulica* of the Government of the Federal District).
Number of houses and occupants by availability and type of drainage	INEGI (e.g., 1990 Census report)
Amount of wastewater generated per capital (potentially developed from amount of wastewater treated and number of people serviced by existing wastewater treatment facilities).	Local wastewater treatment facilities

NOTES:

1.   To be determined.

SAMPLE CALCULATION:

To be determined.

11.0 MISCELLANEOUS AREA SOURCES

Some miscellaneous emission sources may be too small or too numerous to be included in the point source inventory for a given inventory region. Therefore, these sources need to be included in the area source inventory effort. Inventory guidance for these sources are presented in the following subsections:

- Wildfires;

- Structure Fires;

- Paved Road Dust;

- Unpaved Road Dust;

- Wind Erosion; and

- Domestic Ammonia Emissions.

11.1   Wildfires

SOURCE CODE: 28-10-001-000

DESCRIPTION:

Wildfires occur naturally in Mexico, but another significant cause of wildland fire emissions are intentionally-ignited fires intended to promote the growth of grass for cattle grazing. The use of prescribed fires to manage forest ecosystems is not practiced in Mexico. Most fires occur in central and southern Mexico during the January through May time period. These fires are set not only on range land, but also in forested areas. By June, the fire season ends as the summer rains begin. An exception to this is Baja California, where brush fires occur much as they do in California.

Because fires tend to occur during the cooler part of the year, they usually do not burn very hot. This results in mostly ground fires, rather than crown fires. In addition, the fires tend to be small, though numerous. This is particularly true for public lands, where more fires are set than on private lands. Statistics on the amount of acres burned per year are maintained by SEMARNAP.

POLLUTANTS: TOG, CO, and PM_{10}

ROG: ROG emissions are 45% of TOG.

POINT SOURCE ADJUSTMENTS: None.

METHODOLOGY:

The basic equation for estimating wildfire emissions is:

$$\text{Emissions}_i = EF_i \times L \times C \times A \qquad (11.1\text{-}1)$$

where:

Emissions$_i$	=	total emissions of pollutant i;	
EF$_i$	=	emission factor for pollutant i (g/kg);	
L	=	fuel loading (kg/ha);	
C	=	percent of fuel loading that is consumed by the fire; and	
A	=	land area burned (ha).	

Fuel loading values are site-specific estimates of the oven-dry mass of vegetative fuels that are available for consumption by a fire. Ideally, these are further defined in terms of fuel size

class, such as fine fuels (those 0-1" in diameter), small fuels (those between 1" and 3" in diameter), large woody fuels (those greater than 3" in diameter), live vegetation, and duff (partially decomposed litter). Each fuel component has different propensity to burn in a fire and equilibrates its moisture content with the surrounding environment at a different rate.

The amount of available fuel actually consumed by a fire is a complex function of many variables, but the main parameters are the fuel moisture content, fuel size class distribution and arrangement, ambient windspeed, and fire intensity. Consumption models, such as CONSUME, exist for many fuel types in the U.S. (Ottmar et al., 1993). If such consumption models are unavailable, then the conservative assumption can be made that 100% of the available fuel is consumed (i.e., C = 1.0).

Ideally, consumption estimates are derived separately for fuel consumed in the flaming and smoldering phases of combustion. This distinction is important because each phase of combustion occurs with a characteristic combustion efficiency (η). Complete combustion efficiency ($\eta = 1.00$) produces only water, carbon dioxide, and a small amount of inorganic pollutants. In practice, however, complete combustion never occurs. Smoldering combustion is very inefficient and produces a higher proportion of pollutants in comparison to flaming combustion. In general, the emission factors presented in this section are a function of the combustion efficiency. For detailed emission estimates, separate estimates for flaming and smoldering emissions should be performed because flaming phase emissions, although "cleaner", can be transported long distances when contained in a strongly buoyant plume from a large fire, while smoldering phase emissions are "dirtier" and very important for assessing local impacts. Emissions management can be practiced by limiting smoldering phase combustion, which can be achieved by: 1) scheduling ignitions to take advantage of fuel moisture to limit the duration of smoldering combustion; and 2) aggressive mop-up after the flaming phase to extinguish smoldering fires.

Estimated total fuel consumption (after summing together both flaming and smoldering phases) is given in Table 11.1-1 for a variety of western U.S. fuels. These fuels (or similar species) also extend down into Mexico, so the total fuel consumption values are expected to be representative of conditions in Mexico. The values for fuel consumption presented in Table 11.1-1 are actually the products of the L and C terms from equation 11.1-1. The fuel consumption estimates are given for a "dry" fire weather scenario (use for wildfires in severely dry conditions), a "normal" fire weather scenario (use for prescribed burning or wildfires in moderately dry conditions), and a "wet" weather scenario (use for prescribed burning or wildfires under moister conditions). The fuel combustion estimates in Table 11.1-1 were obtained by assigning standard vegetation classifications from the Society of American Foresters (SAF) and the Society for Range Management (SRM) to one of the National Fire Danger Rating (NFDR) system fuel models (Deeming and Cohen, 1982). For each vegetation classification presented in Table 11.1-1, the specific NFDR model (T, F, L, H, or C) used for fuel combustion estimates is identified. Also, for each specific model, the fuel loading and resulting fire intensity has been identified as either low, medium, or high (Hardy et al., 1997).

The data presented in Table 11.1-1 mainly represent vegetation in an early mature level of development. Vegetation stands in earlier or later stages of development will have different loadings.

As mentioned earlier, the species presented in Table 11.1-1 ar those that are found both in the U.S. and Mexico. Data presented in Table 11.1-1 are not appropriate for native Mexico species, particularly for those species found in the tropical areas of the country. Also included in Table 11.1-1 are average $PM_{2.5}$ emission factors for each fuel/weather scenario, calculated from average PM_{10} emission factors (Hardy et al., 1997) by a regression model developed by Ward et al. (1993).

Table 11.1-1.

Total Fuel Consumption, PM$_{2.5}$ Emission Factors and Combustion Efficiency Estimates for Some Representative Western U.S. Fuels

Fuel[a]	Fire Weather Scenario	Total Fuel Consumption (kg/ha)	PM$_{2.5}$ Emission Factor (g/kg)	Fire-Average Combustion Efficiency η
Antelope Bitterbrush-Bluebunch Wheatgrass: SRM104, T, M	Dry	2,317	6.99	0.90
	Normal	2,317	6.99	0.90
	Wet	2,317	6.78	0.90
Blue Oak-Digger Pine: SAF250, F, H	Dry	2,317	6.95	0.90
	Normal	2,197	6.65	0.91
	Wet	1,877	5.55	0.93
Blue Oak Woodland: SRM201, L, M	Dry	819	8.09	0.89
	Normal	799	8.09	0.89
	Wet	799	7.75	0.89
Chamise Chaparral: SRM206, F, M	Dry	2,317	6.99	0.90
	Normal	2,317	6.99	0.90
	Wet	2,317	6.78	0.91
Interior Douglas fir: SAF210, H, L	Dry	7,749	9.32	0.87
	Normal	7,050	9.36	0.87
	Wet	4,553	8.81	0.88
Interior Ponderosa Pine: SAF237, T, H	Dry	5,772	8.52	0.88
	Normal	5,292	8.52	0.88
	Wet	3,715	7.75	0.89

Table 11.1-1

(Continued)

Fuel[a]	Fire Weather Scenario	Total Fuel Consumption (kg/ha)	PM$_{2.5}$ Emission Factor (g/kg)	Fire-Average Combustion Efficiency η
Juniper-Pinyon Woodland: SAF412, L, M	Dry	1,038	7.20	0.90
	Normal	1,038	7.20	0.90
	Wet	1,038	6.95	0.90
Lodgepole Pine: SAF218, H, H	Dry	4,993	7.46	0.90
	Normal	4,733	7.50	0.90
	Wet	4,074	7.58	0.90
Mesquite: SAF242, T, M	Dry	2,396	6.99	0.90
	Normal	1,358	5.81	0.92
	Wet	1,138	4.45	0.94
Ponderosa Pine-shrubland: SRM109, T, M	Dry	7,649	8.26	0.89
	Normal	7,130	8.43	0.88
	Wet	5,372	8.05	0.89
Ponderosa Pine-grassland: SRM110, C, H	Dry	5,951	9.45	0.87
	Normal	5,432	9.41	0.87
	Wet	3,415	8.14	0.89
White Fir: SAF211, H, M	Dry	7,968	9.28	0.87
	Normal	7,269	9.36	0.87
	Wet	4,813	8.98	0.87

[a] Basis for fuel consumption (vegetation classification, NFDR model used, assumed fire intensity [high, medium, or low]).

Additional emission factors for wildland fuels are presented in Table 11.1-2. These data are based on measured emissions from some representative U.S. fuels (Ward et al., 1993). The interrelationships among the emitted pollutants enable calculation of the emission factor from either the combustion efficiency or the PM$_{2.5}$ data in Table 11.1-1.

Table 11.1-2.

Emission Factor Algorithms

Pollutant (EF)	Emission Factor Algorithm	Units	Uncertainty
Carbon monoxide (CO)	$961 - (\eta \times 984)$	g/kg	$\pm\, 10\%$
Methane (CH$_4$)	$42.7 - (\eta \times 43.2)$	g/kg	$\pm\, 20\%$
Nonmethane hydrocarbons (NMHC)	$0.76 + (EF_{CH4} \times 0.616)$	g/kg	$\pm\, 25\%$
TOG	$EF_{CH4} + EF_{NMHC}$	g/kg	$\pm\, 25\%$
PM$_{10}$	$1.18 \times EF_{PM2.5}$	g/kg	$\pm\, 25\%$

DATA NEEDED:

Data	Sources
Land area burned	SEMARNAP
Fuel loading and consumption	Mexico specific data; Table 11.1-1
Emission factors	Mexico specific data; Table 11.1-2

NOTES:

1. The information presented in Tables 11.1-1 and 11.1-2 is not intended to be exhaustive; rather, representative values are presented. If further detailed information is required, the references cited in this section should be consulted.

2. Fuel loading values for Mexico have not yet been developed. The fuel loading depends on the age and distribution of species for each site burned; this is best determined from vegetative biomass inventories of representative sites. Until these values are available, fuel models from other regions, such as the United States, may be used to estimate Mexican fuel loading. Refer to Table 11.1-1 for U.S. fuel loading data that may be utilized in lieu of Mexico-specific data.

3.   Fuel consumption data for Mexico have not yet been developed. The fuel consumption in flaming and smoldering phases of the fire is best determined from pre- and post-burn vegetative biomass inventories.

4.   Emission factors for Mexican vegetative biomass have not yet been developed. Until these data are available, fuel models from other regions, such as the United States, may be used to estimate emission factors for Mexican vegetation fires. Refer to Tables 11.1-1 and 11.1-2 for U.S. emission factors that may be utilized in lieu of Mexico-specific values.

5.   Radian is currently working with Ernesto Alvarado and Roger Ottmar of the USDA Forest Service, Pacific Northwest Research Station (206-553-7815) to develop fuel loading data and appropriate emission factors for use in Mexico.

SAMPLE CALCULATION:

Given a 120 hectare prescribed burn of interior Douglas fir during the early spring, estimate CO emissions.

1.   Determine the fuel consumption for the 120 hectare fire (assume early spring conditions are represented by the "wet" consumption data in Table 11.1-1):

A = 120 ha;
$(L \times C)$ = 4,553 kg/ha;

120 ha burned $\times$ 4,553 kg fuel consumed / ha = 546,360 kg fuel consumed

2.   Next estimate the carbon monoxide emission factor from the appropriate equation in Table 11.1-2. The combustion efficiency estimate (η) is used from Table 11.1-1:

EF_{CO} = 961 - (0.88 $\times$ 984) = 95.08 g CO / kg fuel consumed

3.   Finally, estimate the total emissions from the fire using the derived emission factor for carbon monoxide and the fuel consumption from step 1:

$$546{,}360 \text{ kg fuel} \times \left(\frac{95.08 \text{ g CO}}{\text{kg fuel}} \right) = 51{,}948 \text{ kg CO}$$

$$= 51.9 \text{ Mg CO}$$

11.2   Structure Fires

SOURCE CODE: 28-10-030-000

DESCRIPTION:

Like other combustion sources, structure fires generate TOG, CO, NO_x, and PM emissions. However, unlike many other combustion sources, building fires are unintentional. Consequently, the amount of material burned can be difficult to determine.

To estimate emissions from structure fires, it is first necessary to estimate the amount of material combusted. This includes both structural materials and building contents. Typical values for residential buildings in the United States are included in this section, however, it is thought that values in Mexico may be drastically different due to structural differences (i.e., U.S. homes are predominantly built out of wood, while Mexican homes tend to be built out of brick and other non-wood materials). Mexico-specific values are desirable and should be developed.

POLLUTANTS: TOG, CO, NO_x, and PM

ROG: ROG emissions are 69.9% of TOG.

POINT SOURCE ADJUSTMENTS: None

EQUATIONS:

$$\text{Emissions}_p = \text{Fires} \times \%\text{Loss} \times (\text{CM}_{\text{Building}} + \text{CM}_{\text{Content}}) \times \text{EF}_p \qquad (11.2\text{-}1)$$

where:

Emissions_p	=	Total annual emissions for pollutant, p;
Fires	=	Total annual number of fires;
%Loss	=	Average percent structural loss;
$\text{CM}_{\text{Building}}$	=	Amount of combustible material from building itself;
$\text{CM}_{\text{Content}}$	=	Amount of combustible material from building contents; and
EF_p	=	Emission factor for pollutant, p.

The average percent structural loss must be estimated, because most structure fires do not consume 100% of the available combustible material. Many structure fires are extinguished

before the structure has been completely consumed. In California, the average percent structural loss has been estimated to be 7.3%. This could be used as a default value for Mexico, but a Mexico-specific estimate is desirable.

In the United States, the average residential home has 1,200-1,500 ft^2 (111-139 m^2) of floor space with 10-12 tons (9.1-10.9 Mg) of combustible structural materials. These statistics probably do not accurately describe residential homes in Mexico. Specifically, the widespread brick, cinder block, and adobe houses in Mexico would probably have much lower amounts of combustible structural materials in them.

In the United States, values have been determined for the combustible contents per square foot for different functional areas of the average home. These values are presented in Table 11.2-1 (CARB, 1995).

Table 11.2-1

Combustible Contents for Different Functional Areas in the United States

Functional Area	Origin of Fires (%)	Combustibles (lbs/ft^2)	Combustibles (kg/m^2)	Weighted Average (lbs/ft^2)
Bedroom	28.96	10.4	50.8	3.01
Sleeping Area	0.20	10.4	50.8	0.02
Dining Area	2.20	7.2	35.2	0.16
Kitchen	53.92	6.8	33.2	3.67
Bathroom	6.32	7.0	34.2	0.44
Laundry	8.08	7.2	35.2	0.58
Office	0.17	7.9	38.6	0.01
Other	0.13	9.6	46.9	0.01
Total	100.00	—	—	7.90

A weighted average of 7.90 lbs/ft^2 (38.6 kg/m^2) of combustible contents has been estimated for the United States by using the fire occurrence distribution for different functional areas and multiplying by the combustible content loading in each functional area. This value might not be accurate for Mexico; in which case, a Mexico-specific combustible content loading would need to be estimated.

DATA NEEDED:

Data	Sources
Number of Fires	Local fire department
Average Percent Structural Loss	Local fire department or national fire protection association; U.S. default values.
Amount of Combustible Structural Material	INEGI, national fire protection association, or national builders association; U.S. default values.
Amount of Combustible Building Contents	INEGI, national fire protection association, or national builders association; U.S. default values.
TOG Emission Factor[a] 6.95 kg/Mg (13.9 lbs/ton)	ARB, 1995
CO Emission Factor[a] 84 kg/Mg (168 lbs/ton)	ARB, 1995
NO$_x$ Emission Factor[b] 2.0 kg/Mg (4.0 lbs/ton)	ARB, 1995
PM Emission Factor[a] 5.4 kg/Mg (10.8 lbs/ton)	ARB, 1995

[a] TOG, CO, and PM emission factors obtained from tests on the burning of model wood buildings.
[b] NO$_x$ emission factor assumed to be similar to that listed in AP-42 for municipal refuse.

SAMPLE CALCULATION:

A municipality reported 1,100 fires in 1995. The percent structural loss in this municipality was estimated to be approximately 14%. Most of the houses in this municipality were constructed out of brick or cinder block, so the amount of combustible building material was estimated to be only 2.5 Mg per house. It was also estimated that there are 25 kg of combustible contents per square meter with the typical house measuring 90 m^2. The values used in this example calculation are for illustrative purposes only. The values are not intended to represent conditions in Mexico and should not be used in emission estimates.

1.   Total amount of combustible contents per house:

$$(25 \text{ kg/m}^2) \times 90 \text{ m}^2 = 2,250 \text{ kg}$$
$$= 2.25 \text{ Mg}$$

2.   Total CO emissions:

1,100 fires $\times$ 0.14 $\times$ (2.5 Mg + 2.25 Mg) $\times$ (84 kg CO/Mg burned)
= 61,446 kg CO = 61.4 Mg CO

11.3   Paved Road Dust

SOURCE CODE: **DESCRIPTION**:

22-94-000-000   All paved roads
22-94-005-000   Interstate/arterial
22-94-010-000   All other public roads
22-94-015-000   Industrial roads

DESCRIPTION:

As motor vehicles move over paved road surfaces, dust that has either settled or been carried onto the paved surface is entrained by the turbulent wake of the vehicle and emitted as particulate matter. Currently, emissions are estimated as a function of the silt loading of the paved surface and the mean weight of the vehicles traveling over the surface. Silt loading, in turn, is a function of the road type. Roads with high traffic volumes typically have lower silt loadings than roads with small traffic volumes. Silt is defined as the material that passes through a 200-mesh screen using method ASTM-C-136.

Additional research is underway to possibly refine the current method used to estimate emissions. Additional updates to this section will be made as new information becomes available. Check with INE to identify the most current estimation method.

POLLUTANTS: PM_{10}

ROG: Not applicable.

POINT SOURCE ADJUSTMENTS: None.

METHODOLOGY:

The following empirical equation is used to develop a region-specific emission factor:

$$EF \; = \; k \left(\frac{sL}{2} \right)^{0.65} \left(\frac{W}{3} \right)^{1.5} \tag{11.3-1}$$

where: EF   = particulate matter emission factor;
        k   = particle size multiplier (g/VKT);
        sL   = road surface silt loading (g/m^2); and
        W   = mean vehicle weight (Mg).

Based on data collected in the U.S., silt loadings have been found to have significant spatial and temporal variation. For roads with high average daily traffic (ADT), a frequency distribution of the available data yields a size loading value of 0.4 g/m^2 for the 50th percentile and 7 g/m^2 for the 90th percentile. Similar data for low-ADT roads are 2.5 and 25 g/m^2, respectively. For a freeway, the mean silt loading drops to 0.02 g/m^2 (the 90th percentile value is not available).

In addition, this equation is most applicable for the following conditions:

        Silt loading: 0.02 to 400 g/m^2;
        Mean vehicle weight: 1.8 to 38 Mg; and
        Mean vehicle speed: 16 to 88 kilometers/hour.

Applying this equation in regions with parameters outside of these ranges will result in highly uncertain estimates. Paved road dust emissions are estimated by using the following equation.

$$\text{Emissions}_p = \text{EF}_p \times \text{VKT}_p \qquad (11.3\text{-}2)$$

where: Emissions_p =   Annual PM_{10} emissions from paved road dust;
        EF_p =   Paved road dust emission factor; and
        VKT_p =   Annual paved road VKT.

DATA NEEDED:

Data	Sources
Vehicle Kilometers Traveled (VKT)	Obtain from motor vehicle emissions modeling calculations. See also Motor Vehicle Emissions Manual.
Particle Size Multiplier (k): 4.6 g/VKT for PM$_{10}$	U.S. EPA, 1995
Silt Loading	Local samples (preferably by type of road)
Mean Vehicle Weight	Analysis of motor vehicle fleet, see motor vehicle emissions data for characteristics of the fleet

NOTES:

1. Methods for determining region-specific silt data can be found in Appendices C.1 and C.2 of AP-42.

2. If region-specific silt loading data can not be developed, the tables in Appendix V-D of this manual may be consulted. Appropriate data from this table can be extrapolated to other regions, if needed.

3. If needed, a default mean vehicle weight of 2.2 Mg can be used.

SAMPLE CALCULATION:

For a defined geographic region, the following daily estimates of traffic activity were developed: 1.1 million VKT for freeways, 500,000 VKT for high-ADT roads, and 175,000 VKT for low-ADT roads. Using default values, a first order approximation of the PM$_{10}$ emissions are:

$$\text{Freeways} = (1{,}100{,}000)\ (4.6)\ \left(\frac{0.02}{2}\right)^{0.65}\left(\frac{2.2}{3}\right)^{1.5}(10^{-6})\ (365)$$

$$= 58.1 \text{ Mg/yr}$$

$$\text{High-ADT roads} = (500{,}000)\ (4.6)\ \left(\frac{0.4}{2}\right)^{0.65}\left(\frac{2.2}{3}\right)^{1.5}(10^{-6})\ (365)$$

$$= 185.2 \text{ Mg/yr}$$

$$\text{Low-ADT roads} = (175{,}000) \; (4.6) \left(\frac{2.5}{2}\right)^{0.65} \left(\frac{2.2}{3}\right)^{1.5} (10^{-6}) \; (365)$$

$$= 213.3 \text{ Mg/yr}$$

$$\text{Total emissions} = 58.1 + 185.2 + 213.3$$

$$= 456.5 \text{ Mg/yr}$$

11.4   Unpaved Road Dust

SOURCE CODE: DESCRIPTION:

22-96-000-000   All unpaved roads
22-96-005-000   Public unpaved roads
22-96-010-000   Industrial unpaved roads

DESCRIPTION:

As motor vehicles move over unpaved surfaces, silt contained within the road
surface is entrained by the turbulent wake of the vehicle and emitted as
particulate matter. As vehicles pass over the surface, the force of the wheels on
the surface grinds the road material into smaller particles, thereby partially
replenishing the silt content of the road.

Emissions are estimated as a function of traffic volume, silt content of the
unpaved surface, speed of the vehicles, mean number of wheels and mean
weight of the vehicles traveling over the surface, and the number of days with
precipitation greater than 0.254 mm. Road silt content, defined as particles less
than 75 micrometers in size, varies spatially and by road type (e.g., gravel
roads have different silt contents than dirt roads). The silt content of a road is
determined by measuring the proportion of the loose dry surface dust that passes
through a 200-mesh screen using the method ASTM-C-136.

POLLUTANTS: PM_{10}

ROG: Not applicable.

POINT SOURCE ADJUSTMENTS: None.

METHODOLOGY:

The following empirical equation is used to develop a site specific emission
factor:

$$EF = k\,(1.7) \left(\frac{s}{12} \right) \left(\frac{S}{48} \right) \left(\frac{W}{2.7} \right)^{0.7} \left(\frac{w}{4} \right)^{0.5} \left(\frac{365-p}{365} \right) \tag{11.4-1}$$

where: EF   =   emission factor (kg/VKT);
              k   =   particle size multiplier (dimensionless);
              s   =   silt content of road surface material (%);
              S   =   mean vehicle speed (km/hr);
              W   =   mean vehicle weight (Mg);
              w   =   mean number of wheels; and
              p   =   number of days with precipitation > 0.25 mm

Prior studies in the U.S. have found that the silt loading of unpaved roads varies significantly. For example, on dirt roads, silt content values of 1.6% to 68% have been observed, with a mean value of 12%. Whenever possible, it is desirable to obtain local samples and measure the silt content.

In addition, the empirical equation presented above is most applicable for the following conditions:

          Silt content: 4.3 to 20%;
          Mean vehicle weight: 2.7 to 142 Mg;
          Mean vehicle speed: 21 to 64 km/hr and
          Mean number of wheels: 4 to 13.

Applying this equation in regions with parameters outside these values may result in highly uncertain estimates. Unpaved road dust emissions are estimated by using the following equations.

$$\text{Emissions}_u = \text{EF}_u \times \text{VKT}_u \tag{11.4-2}$$

where: Emissions_u =   Annual PM_{10} emissions from unpaved road dust;
              EF_u =   Unpaved road dust emission factor; and
              VKT_u =   Annual unpaved road VKT.

DATA NEEDED:

Data	Sources
Vehicle Kilometers Traveled (VKT)	Local vehicle usage data. See also Motor Vehicle Emissions Manual
Particle Size Multiplier (k): 0.36	U.S. EPA, 1995
Silt Content	Local samples (preferably by type of road)
Mean Vehicle Weight	Analysis of motor vehicle fleet, see motor vehicle emissions modeling data for characteristics of the fleet
Vehicle Speed	Observation of local speeds
Mean Number of Wheels	Analysis of motor vehicle fleet, see motor vehicle emissions modeling data for characteristics of the fleet

NOTES:

1.   Methods for determining site-specific silt data can be found in Appendices C.1 and C.2 of AP-42.

2.   If site specific silt loading data cannot be developed, the following default values can be used. Rural gravel road: 5.0% to 13%, with a mean value of 8.9%. Rural dirt road: 1.6% to 68%, with a mean value of 12%. Municipal unpaved road: 0.4% to 13%, with a mean value of 5.7%. Additional values can be found in AP-42 for industrial roads.

3.   As a default, a mean vehicle weight of 2.2 Mg can be used.

SAMPLE CALCULATION:

For a defined geographic region, the annual VKT for municipal unpaved roads is an estimated 2.3 million VKT. It is further estimated that 80% of this VKT occurs on gravel roads and 20% on rural dirt roads. Speeds on the gravel road average 20 km/hour, while speeds on the dirt road average 10 km/hour. Annually, there are 20 days with precipitation greater than > 0.25 mm. Using default values, a first order approximation of the PM_{10} emissions is:

$$\text{avel Roads} = (2.3 \times 10^6 \text{ VKT}) \ (0.80) \ (0.36) \ (1.7) \left(\frac{8.9}{12}\right) \left(\frac{20}{48}\right) \left(\frac{2.2}{2.7}\right)^{0.7} \left(\frac{5}{4}\right)^{0.5} \left(\frac{365-20}{365}\right) (10^-$$

$$= 319 \text{ Mg}$$

$$\text{Dirt Roads} = (2.3 \times 10^6)\,(0.20)\,(0.36)\,(1.7)\left(\frac{12}{12}\right)\left(\frac{10}{48}\right)\left(\frac{2.2}{2.7}\right)^{0.7}\left(\frac{4}{4}\right)^{0.5}\left(\frac{365-20}{365}\right)(10^{-3})$$

$$= 48 \text{ Mg}$$

Total emissions = 319 + 48
$$\phantom{\text{Total emissions }} = 367 \text{ Mg/yr}$$

11.5   Wind Erosion

SOURCE CODE: 27-30-100-000

DESCRIPTION:

During periods of high wind events, small dust particles may be entrained by
the wind and emitted to the atmosphere as particulate matter. These emissions
are typically associated with disturbed land, such as agricultural fields under
cultivation, or large construction sites. In addition, emissions may result from
vacant lots, road shoulders that contain loose dirt, and from unpaved roads.
Natural lands that have not been disturbed are considered negligible sources of
windblown dust. Sources that are not periodically disturbed also gradually lose
their ability to emit windblown dust.

POLLUTANTS: PM_{10}

ROG: Not applicable.

POINT SOURCE ADJUSTMENTS: None.

METHODOLOGY:

The current emission estimating technique for this category is based on a
modified version of the soil erodibility equation developed by the U.S.
Department of Agriculture (U.S. EPA, 1977). The following equation presents
the modified USDA approach.

$$E_s = (FS) \ I \ C \ K \ L \ V \tag{11.5-1}$$

where: E_s = suspended PM emission factor (tons/acre/year);
                 FS   = fraction of total wind erosion losses measured as suspended PM;
                 I   = soil erodibility (tons/acre/year);
                 C   = climatic factor (dimensionless);
                 K   = surface roughness factor (dimensionless);
                 L   = unsheltered field width factor (dimensionless); and
                 V   = vegetative cover factor (dimensionless).

Fraction of Wind Erosion Loss - FS

This term represents the fraction of wind erosion losses that would be measured
as suspended particulate. A certain amount of soil "creeps" along the ground
and is not suspended in the atmosphere as an emission source. A value of 2.5%

is typically assumed for agricultural land, while 3.8% is used for unpaved roads and other areas. Of the suspended amount, approximately 50% is PM_{10}.

Soil Erodibility- I

The soil erodibility factor is a function of the soil texture or soil type. The soil type is obtained from soil maps of the area. An inventory region may have one or more soil types, and therefore have different degrees of soil erodibility in different parts of the region. Because of lack of information on the area boundaries of the soil types, the soil erodibility factor is generally based on the predominant soil type in the inventory region. Table 11.5-1 lists soil erodibility factors (I) for 12 predominant soil types.

Climatic Factor - C

The climatic factor, C, is dependent on wind speed and soil surface moisture. The rate of soil movement varies directly with the wind velocity and inversely with the soil surface moisture. The climatic factor is calculated from the following equation:

$$C = \frac{(.345)\ V^3}{\left[115\ \sum_{i=1}^{12}\left(\frac{PM_i}{TM_i\ -\ 10}\right)^{\frac{10}{9}}\right]^2}$$

(11.5-2)

where: V   = mean annual wind velocity (mph), corrected to 30 feet;
            PM   = monthly precipitation in inches; and
            TM   = average monthly temperature in degrees Fahrenheit
                   (set equal to $28.4°$ if below $28.4°$).

The climatic factor, more than the other factors in the windblown dust equation, quickly becomes less exact as an averaged value is applied to smaller areas and shorter time spans. It is also important to note that, given equivalent values for the other parameters, a 100 mph wind entrains 125 times as much particulate in an hour as a 20 mph wind. A year with severe wind storms can therefore have wind blown dust emissions four or five times greater than those of a year with no such storms.

Wind velocity is also an important parameter for developing temporally resolved emission estimates. The mean wind velocity cannot be used for this purpose because it is cubed in the equation.

Table 11.5-1

Soil Erodibility Factors for Various Soil Textural Classes

Predominant Soil Textural Class	Erodibility, I, tons/acre/yr
Sand[a]	220
Loamy sand[a]	134
Sandy loam[a]	86
Clay	86
Silty clay	86
Loam	56
Sandy clay loam[a]	56
Sandy clay[a]	56
Silt loam	47
Clay loam	47
Silty clay loam	38
Silt	38

[a] Very fine, fine, or medium sand

Source: U.S. EPA, 1977

The following example demonstrates this point.

Area A: Wind speed = 10 mph over 100% of time period
Area B: Wind speed = 40 mph over 25% of time period
                     0 mph over 75% of time period

Both areas have a numeric mean wind speed of 10 mph. In equation 11.5-2, the wind speed term for Area A has the value:

$$(10 \text{ mph})^3 \times 100\% = 1{,}000$$

While the wind speed term for Area B is:

((40 mph)^3 x 25%) + ((0 mph)^3 x 75%) = 16,000

Thus, while both areas have the same mean wind speed, Area B would actually suffer 16 times as much wind erosion as Area A. For this reason, the U.S. Soil Conservation Service weights its short term C factors with the fraction of the wind's annual mean energy velocity during the time period in question. The mean energy velocity (V_e) for a time period during which "n" measurements of the wind velocity (V) are taken at equal intervals is given as:

$$V_e = \left(\frac{\sum_{i=1}^{n} (V_i)^3}{n} \right)^{\frac{1}{3}}$$

(11.5-3)

In calculating the wind blown dust emissions from California's South East Desert Air Basin, the U.S. EPA estimated the emissions resulting from each measured wind speed separately (Ono and Bird, 1987). This method is mathematically analogous to using the mean energy velocity. The mean energy velocity weighting technique should be used just as the U.S. Soil Conservation Service does if temporally resolved estimates are required.

In addition, neglecting the effects of irrigation in arid regions results in a C factor as much as an order of magnitude high for some crop types. The preferred method is to modify the C factor of each region for each crop. This involves gathering data on the average quantity of irrigation water required to raise each crop in each soil and temperature area. This irrigation water is added to the rainfall value used to calculate the C factor.

Surface Roughness Factor - K

The surface roughness factor, K, accounts for the resistance of wind blowing over ridges, furrows, or large clods in a field. For regional areas, K is a function of crop type, because field preparation techniques are relatively uniform for a specified crop. Values of K are listed in Table 11.5-2. Since Table 11.5-2 lists only a limited number of field crops, some of the crops must be assigned the same value as the ones on the list, based on the type of crop.

For unpaved roads, the value of K is set equal to 1.0 (i.e., there are minimal ridges/furrows on unpaved roads).

Unsheltered Field Width Factor - L

Soil erosion across a field is directly related to the unprotected width of the field in the prevailing wind direction. Knowing the unsheltered width of the field (L), and the surface erodibility (IK), the L factor is obtained using the graph on Figure 11.5-1 (U.S. EPA, 1977). Values of L for common field crops are listed in Table 11.5-2.

A similar situation exists for unpaved roads. The actual value of L varies with the angle of the wind to the road. Over the long term, it can be assumed that L for a given road surface in the prevailing wind direction varies continually. To assess an average effective distance factor, it may be assumed that in the long term, wind direction is equally distributed for all roads. Any error in this assumption is offset by the probable assumption that roads are distributed in all different directions. With these assumptions, L becomes a function of IK as shown below:

IK	Average L
40	0.29
60	0.32
80	0.34

Vegetative Cover Factor - V

Vegetative cover such as crop residue (stubble or mulch) on agricultural fields during periods other than the primary crop season greatly reduces wind erosion of the soil. The V factor is the fractional amount of annual soil loss which results when the field has vegetative cover. It is estimated from Figure 11.5-2 (U.S. EPA, 1977). The amount of vegetative cover, V, is the amount in pounds of air-dried residue left on a field per acre. Values of V for common field crops are obtained from Table 11.5-2.

Knowing the values of I, K, C, L, and V, the V factor is obtained from Figure 11.5-2.

For unpaved roads, V is equal to 1.0.

Figure 11.5-1. Effect of Field Length on Relative Emission Rate (not available).

Table 11.5-2

Values of K, L, and V for Common Field Crops

Crop	K	L, ft	V, lb/acre
Alfalfa	1.0	1,000	3,000
Barley	0.6	2,000	1,100
Beans	0.5	1,000	250
Corn	0.6	2,000	500
Cotton	0.5	2,000	250
Grain hays	0.8	2,000	1,250
Oats	0.8	2,000	1,250
Peanuts	0.6	1,000	250
Potatoes	0.8	1,000	400
Rice	0.8	1,000	1,000
Rye	0.6	2,000	1,250
Safflower	1.0	2,000	1,500
Sorghum	0.5	2,000	900
Soybeans	0.6	2,000	250
Sugar beets	0.6	1,000	100
Vegetables	0.6	500	100
Wheat	0.6	2,000	1,350

Source: U.S. EPA, 1977
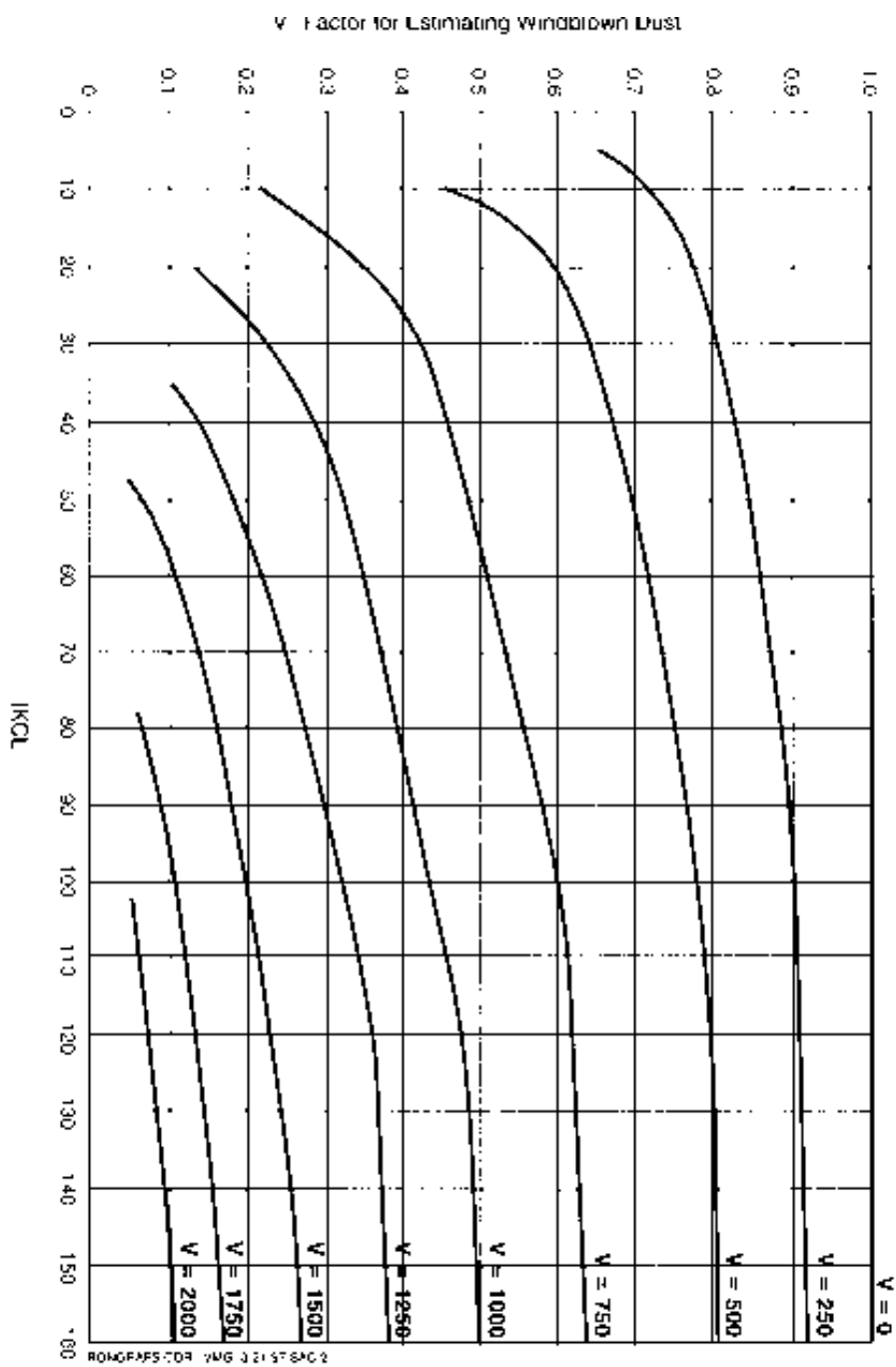
Figure 11.5-2. Effect of Vegetative Cover on Relative Emission Rate

DATA NEEDED:

Data	Sources
Meteorological Data	1. National Institute of Statistics, Geography and Computer Science (INEGI) 2. National Meteorological and Atmospheric Science Center at the National University (UNAM) 3. Servicio Meterológico Nacional dependiente de la Comisión National del Agua.
Crop Acreage	SAGAR, INEGI

NOTES:

1.   The emission estimating technique presented here is thought to provide highly uncertain, and possibly misleading results. The U.S. EPA is currently sponsoring the development a new methodology for this emission source.

SAMPLE CALCULATION:

Determine the windblown dust emissions from an area that has 1,000 acres of tomatoes under cultivation. The soil for this area has been determined to be sandy loam. The climatic factor (C) is calculated to be 0.30 (including irrigation).

From Table 11.5-1, the erodibility (I) is 86 tons/acre/yr. From Table 11.5-2, the values of (K), (L), and (V) are taken for vegetables:

- K = 0.6;
- L = 500 ft; and
- V = 100 lb/acre.

The product of (IK) is 52. Using this value of (IK) and (L) of 500 feet yields an (L) value of 0.57 based on the information presented in Figure 11.5-1.

To determine (V), first calculate the product of (IKCL). This value is 8.9. From Figure 11.5-2, read V as approximately 0.85. From these data, the annual suspended particulate emissions per acre are:

$$
\begin{aligned}
E_s &= FS \; I \; CK \; L \; V \\
&= (0.025)\,(86)\,(0.30)\,(0.6)\,(0.57)\,(0.85) \\
&= 0.19 \text{ tons/acre/year}
\end{aligned}
$$

The annual emissions of PM_{10} are:

$$
\begin{aligned}
EE &= (\text{Area})\,(E_s)\,(0.50) \\
&= (1{,}000)\,(0.19)\,(0.50) \\
&= 95 \text{ tons/year of } PM_{10}
\end{aligned}
$$

11.6   Domestic Ammonia Emissions

SOURCE CODE: **DESCRIPTION:**

27-10-020-020	Dogs
27-10-020-010	Cats
28-10-010-000	Human Respiration
28-10-010-000	Human Perspiration
28-10-010-000	Household Ammonia Use
28-10-060-000	Cigarette Smoke
28-10-010-000	Diapers
28-10-010-000	Human Waste - Homeless
28-10-010-000	Human Waste - Other

DESCRIPTION:

This category consists of various domestic ammonia (NH_3) sources, including
pet waste, human perspiration and respiration, household ammonia use,
cigarette smoke, and untreated human waste. Individually, emissions from
these sources are relatively small. Collectively, however, emissions from these
sources can be significant.

POLLUTANTS: NH_3

ROG: Not Applicable.

POINT SOURCE ADJUSTMENTS: None.

METHODOLOGY:

For ammonia emissions from pets (dogs and cats), emission estimates can be
made using the following equation:

$$\text{Emissions}_p = \text{Population} \times \text{PR}_p \times \text{EF}_p \qquad\qquad (11.6\text{-}1)$$

where: Emissions_p =   Annual emissions for pet type, p;
            Population   =   Total population within region;
            PR_p =   Pet ratio (number of pets per 1,000 people) for pet
                                            type, p; and
            EF_p =   Emission factor for pet type, p.

Typical U.S. pet ratios are given in Table 11.6-1. These are the only data readily available. To the extent possible, Mexico-specific data should be developed and used to replace these values.

Table 11.6-1

Typical Pet Ratios for Various Regions

Type of Region	Pet Ratio - Dogs (pets/1,000 people)	Pet Ratio - Cats (pets/1,000 people)	Reference
Urban (> 800,000 inhabitants)	122	83	Coe et al, 1996
Suburban (200,000-800,000 inhabitants)	167	111	
Rural (< 200,000 inhabitants)	220	133	

For ammonia emissions from cigarette smoking, emissions can be estimated using the following equation:

$$\text{Emissions} = \text{Cigarettes} \times \text{EF} \qquad\qquad (11.6\text{-}2)$$

where: Cigarettes   =   Number of cigarettes sold within the region.

For all other types of ammonia sources, emissions can be estimated using the following equation:

$$\text{Emissions}_s = \text{Population}_s \times \text{EF}_s \qquad\qquad (11.6\text{-}3)$$

where: Emissions_s =   Annual emissions from source type, s;
                    Population_s =   Applicable population within region for source type, s (Overall population for human perspiration and respiration, household ammonia use, and human waste [other]; homeless population for human waste [homeless]; and infants under 3 years of age for diapers); and
                    EF_s =   Emission factor for source type, s.

DATA NEEDED:

Data	Sources
Overall Population	INEGI
Homeless Population	INEGI or local officials
Population (under age of 3 years)	INEGI
Pet Ratio	Table 11.6-1
Number of Cigarettes Sold	INEGI or local officials
Emission Factors: Dogs 2.49 kg/head-yr Cats 0.82 kg/head-yr Cigarettes 5.2 mg/cigarette Human Perspiration 0.25 kg/person-yr Human Respiration 0.0016 kg/person-yr Household Ammonia Use 0.023 kg/person-yr Diapers (Cloth) 3.13 kg/infant-yr Diapers (Disposable) 0.16 kg/infant-yr Human Waste (Homeless) 4.99 kg/person-yr Human Waste (Other) 0.023 kg/person-yr	Radian, 1991

NOTES:

1. The pet ratios presented in Table 11.6-1 are based upon dog and cat population studies performed in California during the 1970s. These pet ratios might not be applicable for Mexico. New statistics for Mexico can be obtained from either veterinary offices or through surveys. See the Basic Emission Estimating Techniques Manual for the survey methodology.

2. The use of disposable diapers has increased significantly in Mexican cities and urban areas; cloth diapers are still used considerably in rural areas.

SAMPLE CALCULATION:

Estimate the total annual ammonia emissions from a municipality of 175,000 people (defined as a rural area in Table 11.6-1).

Assume that 15% of the population smokes (average of 20 cigarettes/day). Assume that infants make up 3% of the population and all of them wear disposable diapers. Finally, assume that there are no homeless people.

Dogs: The pet ratio for rural areas is 220 dogs per 1,000 people.

$$\text{Emissions} = (175{,}000 \text{ people}) \left(\frac{220 \text{ dogs}}{1{,}000 \text{ people}} \right) \left(\frac{2.49 \text{ kg NH}_3}{\text{dogs-yr}} \right) = 95{,}865 \text{ kg}$$

Cats: The pet ratio for rural areas is 133 cats per 1,000 people.

$$\text{Emissions} = (175{,}000 \text{ people}) \left(\frac{133 \text{ cats}}{1{,}000 \text{ people}} \right) \left(\frac{0.82 \text{ kg}}{\text{cat-yr}} \right) = 19{,}086 \text{ kg}$$

Cigarettes:

$$\text{Emissions} = (175{,}000 \text{ people}) (0.15) \left(\frac{20 \text{ cigarettes}}{\text{day}} \right) \left(\frac{365 \text{ days}}{\text{yr}} \right) \left(\frac{5.2 \text{ mg}}{\text{cigarette}} \right) = 996 \text{ kg}$$

Human Perspiration:

$$\text{Emissions} = (175{,}000 \text{ people}) \left(\frac{0.25 \text{ kg}}{\text{person-yr}} \right) = 43{,}750 \text{ kg}$$

Human Respiration:

$$\text{Emissions} = (175{,}000 \text{ people}) \left(\frac{0.0016 \text{ kg}}{\text{person-yr}} \right) = 280 \text{ kg}$$

Household Ammonia Use:

$$\text{Emissions} = (175,000 \text{ people}) \left(\frac{0.023 \text{ kg}}{\text{person} - \text{yr}} \right) = 4,025 \text{ kg}$$

Diapers (Disposable):

$$\text{Emission} = (175,000 \text{ people}) (0.03) \left(\frac{0.16 \text{ kg}}{\text{person} - \text{yr}} \right) = 840 \text{ kg}$$

Human Waste (Other):

$$\text{Emission} = (175,000 \text{ people}) \left(\frac{0.023 \text{ kg}}{\text{person} - \text{yr}} \right) = 4,025 \text{ kg}$$

Total Ammonia Emissions = $95,865 + 19,086 + 996 + 43,750 + 280 + 4,025 + 840 + 4,025$
= 168,867 kg/yr
= 168.9 Mg/yr

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APPENDIX V-A

AREA SOURCE CATEGORY CODES

APPENDIX V-B

INDUSTRIAL, COMMERCIAL, INSTITUTIONAL
FUEL COMBUSTION EMISSION FACTORS
(FROM AP-42)

APPENDIX V-C

NON-ROAD MOBILE EQUIPMENT ACTIVITY DATA
AND EMISSION FACTORS

APPENDIX V-D

PAVED ROAD SAMPLING DATA
(FROM AP-42)