



National Pollutant Inventory

# **Emission Estimation Technique Manual**

**for**

**Sugar Milling  
and Refining**

**Version 1.1**

**10 August 2001**

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The manual was prepared in conjunction with Australian States and Territories according to the National Environment Protection (National Pollutant Inventory) Measure.

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**Erratum for Sugar Milling and Refining EET Manual (Version 1.1 - 10 August 2001).**

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2 Section 2.1	Alteration of process description.
7 Table 2	Emission factors updated from information from the sugar industry.
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**EMISSION ESTIMATION TECHNIQUES  
FOR  
SUGAR MILLING AND REFINING**

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## SUGAR MILLING AND REFINING

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## 1.0 Introduction

The purpose of all Emission Estimation Technique (EET) Manuals in this series is to assist Australian manufacturing, industrial and service facilities to report emissions of listed substances to the National Pollutant Inventory (NPI). This Manual describes the procedures and recommended approaches for estimating emissions from facilities engaged in raw and refined sugar manufacturing.

The sugar manufacturing activities covered in this Manual pertain to facilities primarily engaged in milling sugar cane and refining raw sugar.

EET MANUAL:                Sugar Milling and Refining

HANDBOOK:                Sugar Manufacturing

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This Manual was drafted by the Queensland Environmental Protection Agency on behalf of the Commonwealth Government. It has been developed through a process of national consultation involving State and Territory environmental authorities and key industry stakeholders. Particular thanks are due to the Sugar Research Institute and the Australian Sugar Milling Council for their comments, advice, and information.

Information from the emission estimation process will be made available both nationally and internationally as part of the public NPI database on the Internet.

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## 2.0 Processes and Emissions

The following section presents a brief description of the Sugar Industry and identifies likely sources of emissions.

### 2.1 Process Description

The processing of sugar from sugar cane takes place in two stages, namely milling and refining.

Seasonal sugar milling activities include the manufacturing of raw sugar (crystal and syrup) from sugar cane.

The predominant extraction method in Australia is the milling of shredded cane between rollers, which is then counter-currently contacted with water to ensure maximum possible extraction of juice. The other milling stages in sugar manufacturing include clarification, evaporation, crystallisation, separation and drying. Molasses is a by-product of the milling operation.

Sugar refining activities include the manufacture of white granulated sugar, brown sugar, liquid sugar and syrups from raw sugar. Icing sugar can be made by grinding white granulated sugar.

Refining is a further purification stage of raw crystal sugar which includes de-colourisation, crystallisation, separation and drying stages to produce sugars for consumption.

### 2.2 Emission Sources and Control Technologies

#### 2.2.1 Emissions to Air

Air emissions may be categorised as :

##### Point Source Emissions

These emissions are exhausted into a vent or stack and emitted through a single point source into the atmosphere. Table 1 highlights common air emissions of NPI-listed substances from sugar manufacturing processes.

**Table 1. Common Emissions to Air from Sugar Manufacturing**

Substances
Particulate Matter less than or equal to 10 microns in Aerodynamic diameter (PM <sub>10</sub> )
Ethanol (C <sub>2</sub> H <sub>6</sub> O)
Oxides of Nitrogen (NO <sub>x</sub> )
Carbon Monoxide (CO)
Sulfur Dioxide (SO <sub>2</sub> )

Other emissions that may occur from combustion processes using alternative fuels are as described in the *Combustion in Boilers Manual*.

Air emission control equipment, (e.g., dry and wet scrubbers), is installed to reduce the concentration of particulates before stack emission. Where emission factors from uncontrolled

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sources have been used in an emission estimation, the collection efficiency of the equipment needs to be considered. Guidance on applying collection efficiencies to emission factor equations is provided in later sections.

With regard to emission controls for PM<sub>10</sub>, in the absence of measured data, or knowledge of the collection efficiency for a particular piece of equipment, an efficiency of 90% should be used in the emission factor equation to calculate actual mass emissions. This default should only be used if there is no other available control efficiency.

## **Fugitive Emissions**

These are emissions that are not released through a vent or stack. Examples of fugitive emissions include dust from stockpiles, volatilisation of vapour from tanks, open vessels, or spills and materials handling. Emissions emanating from ridgeline roof-vents, louvres, and open doors of a building as well as equipment leaks, and leaks from valves and flanges are also examples of fugitive emissions. Emission factor EETs are the usual method for determining losses through fugitive emissions.

### **2.2.2 Emissions to Water**

Emissions of substances to water can be categorised as discharges to:

- Surface waters (e.g. lakes, rivers, dams, and estuaries);
- Coastal or marine waters; and,
- Stormwater.

Most facilities emitting NPI-listed substances to waterways are required by their relevant State or Territory environment agency to closely monitor and measure these emissions. This existing sampling data can be used to calculate annual emissions.

If no wastewater monitoring data exists, emissions to water can be calculated based on a mass balance or using emission factors.

An emission of ethanol to water should be reported only if the discharge is to a water course.

### **2.2.3 Emissions to Land**

Emissions of substances to land on-site include solid wastes, slurries, sediments, spills and leaks, storage, and distribution of liquids and may contain NPI-listed substances. These emission sources can be broadly categorised as:

- surface impoundments of liquids and slurries; and
- unintentional leaks and spills.



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### 3.0 Emission Estimation Techniques

Estimates of emissions of NPI-listed substances to air, water and land should be reported for each substance that triggers a threshold. The reporting list and detailed information on thresholds are contained in *The NPI Guide* at the front of this Handbook.

In general, there are four types of emission estimation techniques (EETs) that may be used to estimate emissions from your facility.

The four types described in *The NPI Guide* are:-

- sampling or direct measurement
- mass balance
- fuel analysis or other engineering calculations
- emission factors

Select the EET, (or mix of EETs), that is most appropriate for your purposes. For example, you might choose to use a mass balance to best estimate fugitive losses from pumps and vents, direct measurement for stack and pipe emissions, and emission factors when estimating losses from storage tanks and stockpiles.

If you estimate your emission by using any of these EET's, your data will be displayed on the NPI database as being of 'acceptable reliability'. Similarly, if your relevant environmental authority has approved the use of EETs that are not outlined in this handbook, your data will also be displayed as being of 'acceptable reliability'.

This Manual seeks to provide the most effective emission estimation techniques for the NPI substances relevant to this industry. However, the absence of an EET for a substance in this handbook does not necessarily imply that an emission should not be reported to the NPI. The obligation to report on all relevant emissions remains if reporting thresholds have been exceeded.

**You are able to use emission estimation techniques that are not outlined in this document. You must, however, seek the consent of your relevant environmental authority. For example, if your company has developed site specific emission factors, you may use these if approved by your relevant environmental authority.**

You should note that the EETs presented in this manual relate principally to average process emissions. Emissions resulting from non-routine events are rarely discussed in the literature, and there is a general lack of EETs for such events. However, it is important to recognise that emissions resulting from significant operating excursions and/or accidental situations (eg: spills) will also need to be estimated. Emissions to land, air and water from spills must be estimated and added to process emissions when calculating total emissions for reporting purposes. The emission resulting from a spill is the net emission, i.e. the quantity of the NPI reportable substance spilled, less the quantity recovered or consumed during clean up operations.

In determining emissions from fuel burning, please refer to the Combustion in Boilers EET Manual. Emissions from combustion engines are covered in the EET for Combustion Engines.

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### **3.1 Direct Measurement.**

You may wish to use direct measurement in order to report to the NPI, particularly if you already do so in order to meet other regulatory requirements. However, the NPI does not require you to undertake additional sampling and measurement. For sampling data to be adequate and able to be used for NPI reporting purposes it would need to be collected over a period of time and be representative of operations for the whole year.

#### **3.1.1 Sampling Data**

Stack sampling test reports often provide emissions data in terms of kg/hr or g/m<sup>3</sup> (dry standard). Annual emissions for NPI reporting can be calculated from this data. Stack tests for NPI reporting should be performed under representative (i.e. normal) operating conditions. You should be aware that some tests undertaken for a State or Territory license condition may require the test be taken under maximum emissions rating, where emissions are likely to be higher than when operating under normal operating conditions.

#### **3.1.2 Continuous Emission Monitoring System (CEMS) Data**

A continuous emission monitoring system provides a continuous record of emissions over time, usually by reporting pollutant concentration.

Once the pollutant concentration is known, emission rates are obtained by multiplying the pollutant concentration by the volumetric gas or liquid flow rate of that pollutant.

It is important to note that prior to using CEMS to estimate emissions, you should develop a protocol for collecting and averaging the data in order that the estimate satisfies your relevant environmental authority's requirement for NPI emissions estimations.

### **3.2 Mass Balance**

A mass balance identifies the quantity of substance going in and out of an entire facility, process, or piece of equipment. Emissions can be calculated as the difference between input and output of each listed substance. Accumulation or depletion of the substance within the equipment should be accounted for in your calculation.

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### 3.3 Engineering Calculations

An engineering calculation is an estimation method based on physical/chemical properties (e.g. vapour pressure) of the substance, and mathematical relationships (e.g. ideal gas law).

#### 3.3.1 Fuel Analysis

Fuel analysis is a particular type of engineering calculation and can be used to predict SO<sub>2</sub>, metals, and other emissions based on application of conservation laws, if fuel rate is measured. The presence of certain elements in fuels may be used to predict their presence in emission streams. This includes elements such as sulfur that may be converted into other compounds during the combustion process.

The basic equation used in fuel analysis emission calculations is the following:

$$E_i = Q_f * \text{pollutant concentration in fuel } i \text{ ( } MW_p \div EW_f \text{)} \quad (1)$$

where:

$E_i$	=	emissions of pollutant $i$
$Q_f$	=	fuel use (kg/hr)
$MW_p$	=	molecular weight of pollutant emitted (kg/kg-mole)
$EW_f$	=	elemental weight of pollutant in fuel (kg/kg-mole)

For instance, SO<sub>2</sub> emissions from oil combustion can be calculated based on the concentration of sulfur in the oil. This approach assumes complete conversion of sulfur to SO<sub>2</sub>. Therefore, for every kilogram of sulfur (EW = 32) burned, two kilograms of SO<sub>2</sub> (MW = 64) are emitted. The application of this EET is shown in Example 1:

#### Example 1 - Calculating SO<sub>2</sub> Emissions

This example shows how SO<sub>2</sub> emissions can be calculated from oil based on fuel analysis results and the fuel flow information from a sugar mill. In addition to bagasse, oil may be used as a fuel source in starting up the boiler. The facility is assumed to consume 150 tonnes per year.

$E_{SO_2}$  = may be calculated using Equation (1)

Seasonal usage = 150 tonnes

Weight percent sulfur in oil = 1.17

$$\begin{aligned} E_{SO_2} &= Q_f * \text{pollutant concentration in fuel} * (MW_p \div EW_f) \\ &= (150,000) * (1.17 \div 100) * (64 \div 32) \\ &= 3510 \text{ kg/yr} \end{aligned}$$

#### 3.4 Emission Factors

An emission factor is a tool that is used to estimate emissions to the environment. In this Manual, it relates the quantity of substances emitted from a source to some common activity associated with those emissions. Emission factors are obtained from US, European, and Australian sources and are usually expressed as the weight of a substance emitted, divided by

the unit weight, volume, distance, or duration of the activity emitting the substance (e.g. kilograms of particulate matter (PM<sub>10</sub>) emitted per tonne of bagasse burned).

Emission factors are used to estimate a facility's emissions by the general equation:

$$E_{kpy,i} = [A * OpHrs] * EF_i * [1 - (CE_i/100)] \quad (2)$$

where :

$E_{kpy,i}$	=	emission rate of pollutant i, kg/yr
A	=	activity rate, t/hr
OpHrs	=	operating hours, hr/yr
$EF_i$	=	uncontrolled emission factor of pollutant i, kg/t
$CE_i$	=	overall control efficiency for pollutant i, %

Emission factors developed from measurements for a specific process may sometimes be used to estimate emissions at other sites. Should a company have several processes of similar operation and size, and emissions were measured from one process source, an emission factor could be developed and applied to similar sources. As previously mentioned, it is advisable to have the emission factor reviewed and approved by State or Territory environment agencies prior to its use for NPI estimations.

### 3.4.1 Industry-wide Emission Factors

**Table 2. Emission Factors for Particulate Matter (PM<sub>10</sub>) from Sugar Refining**

Emission Source	Emission Factor (kg/t)	Emission Factor Rating Code*
Granular Carbon Regeneration Furnace	0.0066	E

Units are kg of substance emitted/tonne of raw sugar processed.

\* See Section 4.4

**Table 3. Emission Factors for Particulate Matter (PM<sub>10</sub>) from Bagasse Handling<sup>1</sup>**

PM <sub>10</sub>	Emission Factor (kg PM <sub>10</sub> /t cane crushed)	Emission Factor Rating Code*
Bagasse Stockpile (carting)	$2.72 \times 10^{-3}$	U
Bagasse Dust (crushing)	$5.67 \times 10^{-3}$	U

<sup>1</sup> Sugar Research Institute (1998)

Units are kg of substance emitted / tonne of cane crushed.

\* See Section 4.4

An example of the use of the emission factors in Tables 2?? and 3?? are in Example 2??.

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### Example 2 - Using Emission Factors

Table 2 shows that 0.0066 kg of particulate matter (PM<sub>10</sub>) is emitted from sugar refining in the granular carbon regeneration furnace, for each tonne of raw sugar processed. It is assumed that the facility operates 24 hours/day, 200 days/year, which is equivalent to

$$\begin{aligned} \text{EF}_{\text{particulate matter}} &= 0.0066 \text{ kg/t} \\ \text{Activity rate} &= 150,000 \text{ tonnes/yr} \\ \text{PM}_{10} \text{ Emissions/year} &= \text{EF}_{\text{PM}_{10}} * \text{Activity rate} \\ &= 0.0066 \text{ kg/tonne} * 150,000 \\ &= 990 \text{ kg/yr} \end{aligned}$$

**Table 4. Emission Factors for VOCs<sup>1</sup>**

VOC	Emission Factor (kg/t)	Emission Factor Rating Code*
Ethanol	0.065 (to air)	U
Ethanol	0.6 (to water)	U

<sup>1</sup> Sugar Research Institute (1998)

Units are kg of substance emitted / tonne of raw sugar produced.

\* See Section 4.4

### 3.4.2 Predictive Emission Monitoring (PEM)

Predictive emission monitoring is based on developing a correlation between pollutant emission rates and process parameters. A PEM allows facilities to develop site-specific emission factors, or emission factors more relevant to their particular process.

Based on test data, a mathematical correlation can be developed which predicts emissions using various parameters.

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## 4.0 Emission Estimation Techniques: Acceptable Reliability and Uncertainty

This section is intended to give a general overview of some of the inaccuracies associated with each of the techniques. Although the National Pollutant Inventory does not favour one emission estimation technique over another, this section does attempt to evaluate the available emission estimation techniques with regard to accuracy.

Several techniques are available for calculating emissions from sugar manufacturing facilities. The technique chosen is dependent on available data, and resources, and the degree of accuracy sought by the facility in undertaking the estimate.

**In general, site-specific data that is representative of normal operations is more accurate than industry-averaged data, such as the emission factors presented in Section 3.4.1. of this Manual.**

### 4.1 Direct Measurement

The use of stack and/or workplace health and safety sampling data is likely to be a relatively accurate method of estimating air emissions from sugar manufacturing facilities. However, collection and analysis of samples from facilities can be very expensive, and especially complicated where a variety of NPI-listed substances are emitted, and where most of these emissions are fugitive in nature. Sampling data from a specific process may not be representative of the entire manufacturing operation, and may provide only one example of the facility's emissions.

To be representative, sampling data used for NPI reporting purposes needs to be collected over a period of time and to cover all aspects of the production of sugar. In the case of CEMS, instrument calibration drift can be problematic and uncaptured data can create long-term incomplete data sets. However, it may be misleading to assert that a snapshot (stack sampling) can better predict long-term emission characteristics. It is the responsibility of the facility operator to properly calibrate and maintain monitoring equipment and the corresponding emissions data.

### 4.2 Mass Balance

Calculating emissions from a sugar manufacturing facility using mass balance appears to be a straightforward approach to emission estimation. However, few Australian industrial facilities consistently track material usage and waste generation with the overall accuracy needed for application of this method. Inaccuracies associated with individual material tracking or other activities inherent in each material handling stage can result in large deviations for total facility emissions. Because emissions from specific materials are typically below 2 percent of gross consumption, an error of only  $\pm 5$  percent in any one step of the operation can significantly skew emissions estimations.

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### 4.3 Engineering Calculations

Theoretical and complex equations or *models* can be used for estimating emissions from sugar manufacturing processes. However, the use of emission equations to estimate emissions from sugar manufacturing facilities is a more complex and time-consuming process than the use of emission factors. Emission equations require more detailed inputs than the use of emission factors, but they do provide an emission estimate that is based on facility-specific conditions.

### 4.4 Emission Factors

Every emission factor has an associated emission factor rating (EFR) code. This rating system is common to EETs for all industries and sectors and therefore, to all Industry Handbooks. They are based on rating systems developed by the United States Environmental Protection Agency (USEPA), and by the European Environment Agency (EEA). Consequently, the ratings may not be directly relevant to Australian industry. Sources for all emission factors cited can be found in Section 5.0 of this document. The emission factor ratings will not form part of the public NPI database.

When using emission factors, you should be aware of the associated EFR code and what that rating implies. An A or B rating indicates a greater degree of certainty than a D or E rating. The less certainty, the more likely that a given emission factor for a specific source or category is not representative of the source type. These ratings notwithstanding, the main criterion affecting the uncertainty of an emission factor remains the degree of similarity between the equipment/process selected in applying the factor, and the target equipment/process from which the factor was derived.

The EFR system is as follows :

A	-	Excellent
B	-	Above Average
C	-	Average
D	-	Below Average
E	-	Poor
U	-	Unrated

In addition to the EFR code, the accuracy of emission factors is thoroughly dependent upon the degree of similarity between the reference source and the emission source being estimated.

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## 5.0 Glossary of Technical Terms and Abbreviations

Term	Definition
C	Concentration
EF	Emission Factor
NO <sub>x</sub>	Oxides of Nitrogen
NPI	National Pollutant Inventory
PAHs	Polycyclic Aromatic Hydrocarbons
PM <sub>10</sub>	Particulate Matter less than or equal to 10 microns in Aerodynamic diameter
VOCs	Volatile Organic Compounds



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