National Pollutant Inventory

# Emission Estimation Techniques Manual

**for**

# Bread Manufacturing
# Version 1.1

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## Disclaimer

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

While reasonable efforts have been made to ensure the contents of this manual are factually correct, the Commonwealth does not accept responsibility for the accuracy or completeness of the contents and shall not be liable for any loss or damage that maybe occasioned directly or indirectly through the use of, or reliance on, the contents of this manual.

## Erratum for Bread Manufacturing Emission Estimation Technique (EET) Manual (Version 1.1 – 12 May 2003)

| Page | Outline of alteration |
|---|---|
| Table 2 Page 7 | The ethanol and Total VOC emissions have been decreased based on test work completed on Australian facilities and work undertaken on UK facilities that have a similar process to that used in Australia. |
| Appendix I | Has been removed as the emission factor it derived based on broad assumptions has been updated based on plant measurements and work undertaken on similar baking processes in the UK. |

**EMISSION ESTIMATION TECHNIQUES**
**FOR**
**BREAD MANUFACTURING**

## TABLE OF CONTENTS


**DISCLAIMER ........ I**

**ERRATUM FOR BREAD MANUFACTURING EMISSION ESTIMATION TECHNIQUE (EET) MANUAL (VERSION 1.1 – 12 MAY 2003) ........ II**

**1. INTRODUCTION ........ 1**

**2. PROCESSES AND EMISSIONS ........ 2**

**2.1 Process Description ........ 2**
**2.2 Reporting Thresholds ........ 2**
**2.3 Emission Sources ........ 3**
2.3.1 Emissions to Air ........ 3
2.3.2 Emissions to Water ........ 4
2.3.3 Emissions to Land ........ 4

**3. EMISSION ESTIMATION ........ 5**

**3.1 Direct Measurement ........ 6**
3.1.1 Sampling Data ........ 6
3.1.2 Continuous Emission Monitoring System (CEMS) Data ........ 6
**3.2 Mass Balance ........ 6**
**3.3 Engineering Calculations ........ 6**
**3.4 Emission Factors ........ 7**
3.4.1 Industry-wide Emission Factors ........ 7
3.4.2 Meeting the Threshold for Ethanol ........ 8
3.4.3 Predictive Emission Monitoring (PEM) ........ 10

**4. EMISSION ESTIMATION TECHNIQUES: ACCEPTABLE RELIABILITY AND UNCERTAINTY ........ 11**

**4.1 Direct Measurement ........ 11**
**4.2 Mass Balance ........ 11**
**4.3 Engineering Calculations ........ 11**
**4.4 Emission Factors ........ 12**

**5. REFERENCES ........ 13**

## BREAD MANUFACTURING

## LIST OF FIGURES AND TABLES


**Figure 1. Typical Baking Process 3**

**Table 1. Air Emissions from Bread Baking 4**

**Table 2. Emission Factors for Ethanol from Bread Manufacturing 7**

**Table 3. Emission Factors for Nitrogen to Water [a] 8**

**Example 1. Calculating Ethanol Emissions Using Emission Factors 8**

**Example 2. Determining Ethanol Emissions from Bread Baking 9**

# 1. 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 bread manufacturing.

The bread baking activities covered by this Manual apply to facilities primarily engaged in the manufacturing of bread.

| | |
|---|---|
| EET MANUAL: | Bread Manufacturing |
| HANDBOOK: | Bakery Product Manufacturing |
| ANZSIC CODES : | 216 Series |

This Manual was drafted by the NPI Unit of the Queensland Department of Environment and Heritage 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.

# 2. Processes and Emissions

The following section presents a brief description of the bread manufacturing industry and identifies likely sources of emissions.

## 2.1 Process Description

The bread manufacturing activities covered by this Manual include facilities involved in the blending of flour and other ingredients, and cooking by dry heat to produce bread and related products containing yeast.

Bread is leavened by yeast and baked using one of two processes: the straight-dough process, or the sponge-dough process. The predominant process used in Australia is the straight-dough process. This involves mixing the ingredients together that are then fermented and baked.

Substances such as ethanol and other volatile organic compounds (VOCs) are emitted from bread during the fermentation stage. Stoichiometric equations outlining this process may be found in Appendix I.

In the sponge-dough process, that is less commonly used in Australia, only part of the ingredients is initially mixed and allowed to ferment, with the remainder added to the mix and fermented just prior to baking. The bulk of dark rye bread, biscuit production and all cake manufacturing involves the use of chemical leavening agents rather than yeast. Figure 1 outlines the basic bread making process.

The manufacture of biscuits and cakes (while bread-related) uses chemical leavening agents rather than yeast. Biscuit making does not generate ethanol emissions, but emissions from fuel burnt in the ovens may still trip thresholds. In this case, please refer to the EET Manual for Combustion in Boilers to determine whether you need to report emissions from combustion processes.

## 2.2 Reporting Thresholds

Facilities are required to report to the NPI is they exceed NPI reporting thresholds. Reporting thresholds are detailed in the NPI Guide on the Internet (www.npi.gov.au).

For the reporting of estimated ethanol emissions to the NPI the amount of bread that needs to be produced in 13.4 million kilograms per year. This is equivalent to approximately 19.1 million 700g loaves of bread per year. See Example 2 for details of how this was derived.

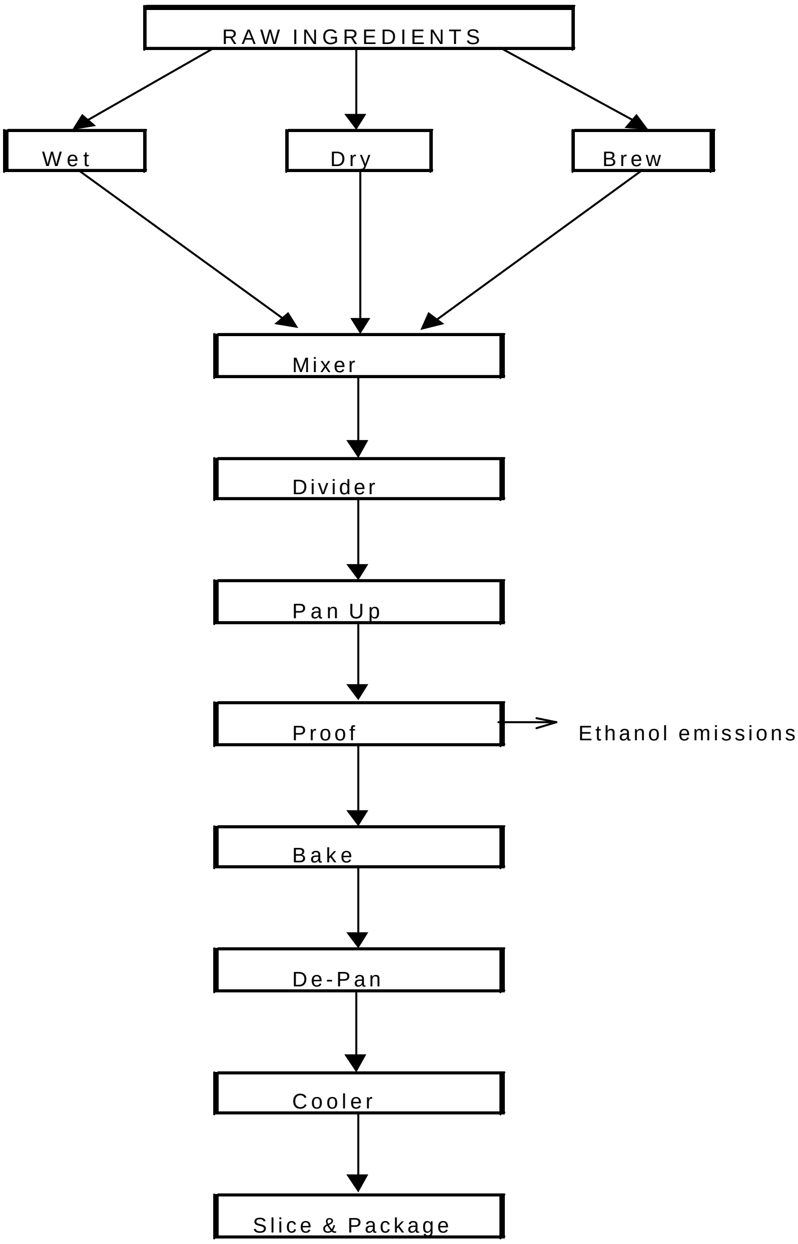


**Figure 1. Typical Baking Process**

*Queensland Department of Environment and Heritage, 1998*

## 2.3 Emission Sources

### 2.3.1 Emissions to Air

Air emissions may be categorised as :

**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 vats or open vessels, and material 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.

**Point Source Emissions**

These emissions are exhausted into a vent or stack and emitted through a single point source into the atmosphere. An air emissions control device such as a carbon adsorption unit, scrubber, baghouse, or afterburner may be added to the stack prior to the atmospheric release. Table 1 highlights common air emissions from bread baking processes.

**Table 1. Air Emissions from Bread Baking**

| Substance |
| --- |
| Ethyl Acetate |
| Ethanol |
| Total VOCs (including non-NPI listed VOCs) |

### 2.3.2 Emissions to Water

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

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

Because of the significant environmental hazards posed by emitting toxic substances to water, 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 process water can be calculated based on a mass balance or using emission factors.

The discharge of listed substances to a sewer or tailings dam does not require you to report to the NPI (See also Section Three of *The NPI Guide*).

### 2.3.3 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 listed substances. These emission sources can be broadly categorised as :

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

## 3. Emission Estimation

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 EETs, 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 emission estimation techniques 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 Manual does not necessarily imply that an emission should not 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, ie. the quantity of the NPI reportable substance spilled, less the quantity recovered or consumed during clean up operations.

## 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, such as workplace health and safety issues. 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 representative of operations for the whole year.

### 3.1.1 Sampling Data

Sampling test reports often provide emissions data in terms of kg/hr or $g/m^3$ (dry standard). Annual emissions for NPI reporting can be calculated from this data. Sampling tests for NPI reporting should be performed under representative (ie. 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.

## 3.3 Engineering Calculations

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

## 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 (eg. kilograms of ethanol emitted per tonne bread produced).

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

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

where :

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

The emission factors in Table 2 have been derived using the fermentation reaction that occurs as bread rises. These calculations may be found in Appendix I .

**Table 2. Available Emission Factors for Ethanol from Bread Manufacturing**

| Substance Emitted | Emission Factors (kg/tonne of bread produced) | Emission Factor Rating Code[3] |
|---|---|---|
| Ethanol[1] | 8.3E-01 | U |
| Total VOCs[2] | 8.32E-01 | U |

Notes
1. Reference 2 – Goodman Fielder
2. References 3 and 4 (Tilly and USEPA respectively)
3. Emission factor rating codes are discussed in Section 4.4.
4. Scientific notation is used; e.g. 7.38E-02 represents 7.38 x 10-2 or 0.0738.

Wastewater from baking operations may contain nitrogen. The following emission factors are only applicable if wastewater is discharged directly to a water body:

**Table 3. Emission Factors for Nitrogen to Water[1]**

| Process Emission Categories | Emission Factors for Total Nitrogen to Water[2] (kg/tonne of bread produced) | Emission Factor Rating Code[3] |
|---|---|---|
| Bread | 4.0E-03 | U |
| Rusk | 4.0E-03 | U |
| Dry Pastry | 5.0E-03 | U |
| Wet Pastry | 5.0E-02 | U |

Notes

1. Reference 1 – Economopoulos
2. Reporting nitrogen emissions is only required when the emissions flow directly into a stream or waterbody.
3. Emission factor rating codes are discussed in Section 4.4.
4. Scientific notation is used; e.g. 7.38E-02 represents 7.38 x 10-2 or 0.0738.

**Example 1. Calculating Ethanol Emissions Using Emission Factors**

Table 2 shows that for bread baking, the ethanol emission factor is 0.83 kg ethanol emitted / tonne of bread baked.

Emission reduction efficiency for ethanol is effectively zero, with all ethanol produced emitted to air. (Therefore, CE = 0)

Assuming a bakery produces 20 million loaves of bread per year, with each loaf averaging 700 g, emissions can be estimated by using Equation (1).

$$E_{kpy,ethanol} = A \times EF_{ethanol} \times [1 - (CE / 100)]$$

$$= (2.0E{+}07 \text{ loaves / year} \times 700 \text{grams / loaf} \times 0.83 \text{ kg ethanol / tonne of bread} \times 1.0E{-}06 \text{ tonne / gram}) * [1 - (0 / 100)]$$

$$= 11{,}600 \text{ kg / year emitted.}$$

Since the threshold of 10 tonnes of ethanol used per year has been exceeded, this facility is required to report to the NPI its emissions of ethanol, which in this example, is 11,600 kg per year.

### 3.4.2 Meeting the Threshold for Ethanol

For the National Pollutant Inventory, a bakery is required to report ethanol emissions arising from the fermentation reactions where the emissions exceed 10 tonnes per year, since the emission of ethanol is considered coincidental production. Equation (2) should be used to determine whether a bakery meets this 10 tonnes per year for ethanol, while Equation (3) converts total annual bread production into the number of loaves per year required to meet the threshold.

$$P_{Bread} = 10 \text{ tonnes} / EF_{ethanol} * 1\,000 \quad (2)$$

where:

$P_{Bread}$ = annual bread production in tonnes/year
10 tonnes = the emission threshold for ethanol

$EF_{ethanol}$ = emission factor for ethanol, kg/tonne
1 000 = conversion factor, kg to tonnes

$$L_{bread} = P_{bread} / ML_{Bread} \quad (3)$$

where:

$L_{bread}$ = number of loaves per year to meet ethanol reporting threshold, loaves/year
$P_{bread}$ = bread production rate, kg/year
$ML_{Bread}$ = mass of an average loaf of bread, kg

Example 2 illustrates the application of Equations (2) and (3). Calculations are based on the assumption that the average loaf of bread weighs 700g. This figure should be adjusted where a facility produces bread of a different weight average.

**Example 2 . Determining Ethanol Emissions from Bread Baking**

The emission factor given in section 3.4.1 is used for this calculation.

$EF_{ethanol}$ = 0.83 kg ethanol emitted / tonne of bread produced

Using Equation (2):

$P_{Bread}$ = (10 tonnes ethanol/year) / $EF_{ethanol}$ * 1,000
= 10 tonnes / (0.75 kg ethanol/tonne bread) * 1,000
= 12,000 tonnes of bread per year

Using Equation (3), it is now possible to determine how many loaves of bread per year must be produced to meet the 10 tonne threshold:

$L_{bread}$ = $P_{bread}$ / $ML_{Bread}$

= $\frac{12{,}000{,}000 \text{ kg of bread}}{0.7 \text{ kg /loaf of bread}}$

= 17.1 million loaves per year

Therefore, 17.1 million loaves of bread per year, (or approximately 47,000 loaves per day) must be produced to trigger the threshold for ethanol.

### 3.4.3 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.

# 4. 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 regards to accuracy.

Several techniques are available for calculating emissions from bread 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 sampling data is likely to be a relatively difficult method of estimating air emissions from bread manufacturing facilities. Collection and analysis of samples from facilities can be very expensive, and especially complicated where a variety of NPI-listed substances are emitted and 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 cover all aspects of the production of bread.

## 4.2 Mass Balance

Calculating emissions from a bread manufacturing facility using mass balance appears to be a straightforward approach to emission estimation. However, it is necessary to account for the reaction that occurs as the bread rises. In addition, few Australian bread manufacturing facilities are likely to 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.

## 4.3 Engineering Calculations

Theoretical and complex equations or *models* can be used for estimating emissions from bread manufacturing processes.

Use of emission equations present in Appendix I to estimate emissions from bread baking facilities is a more complex and time-consuming process than the use of the emission factors in Table 2. Both methods are an acceptable method of determining ethanol emissions from bread baking, however the emission factors are easier to apply as they are based purely on the amount of bread baked.

### 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.

# 5. References


1. Economopoulos A. P. 1993. *Assessment of Sources of Air, Water, and Land Pollution. A Guide to Rapid Source Inventory Techniques and their use in Formulating Environmental Control Strategies. Part One: Rapid Inventory Techniques in Environmental Pollution.* World Health Organisation, Geneva, Switzerland.

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3. Tilly K. 1998. Personal communication from, Environment Protection Authority, Melbourne, Australia to Tim Powe, National Pollutant Inventory Unit, Queensland Department of Environment, 30 March 1998.

4. USEPA. October 1992. *VOC / PM Speciation Data System - Version 1.50.* United States Environmental Protection Agency, Office of Air Quality, Planning and Standards. Research Triangle Park, NC, USA.