National Pollutant Inventory

Emission Estimation Technique Manual

for

Dairy Product Manufacturing

Environment Australia

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EMISSION ESTIMATION TECHNIQUES
FOR
DAIRY PRODUCT MANUFACTURING

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DAIRY PRODUCT MANUFACTURING

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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 dairy product manufacturing.

EET MANUAL:	Dairy Product Manufacturing
HANDBOOK:	Dairy Product Manufacturing
ANZSIC CODES	2121 Milk and Cream Processing 2122 Ice Cream Manufacturing 2129 Dairy Product Manufacturing (not elsewhere classified) and all codes in the 212 ANZSIC code group.

The ANZSIC codes above refer to the following activities:

Milk and Cream Processing
This class consists of facilities mainly engaged in filtering, and chilling fresh liquid whole milk or cream, or manufacturing, bottling or cartoning pasteurised liquid whole milk, flavoured liquid whole or skim milk, liquid skim milk, liquid standardised milk, cream, sour cream, cultured butter milk, or yoghurt.

Ice Cream Manufacturing
This class consists of facilities mainly engaged in manufacturing ice cream or frozen confectionery.

Dairy Product Manufacturing
This class consists of facilities mainly engaged in manufacturing butter, cheese, condensed, concentrated or evaporated milk, milk powder, and dairy products not elsewhere classified.

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.

2.0 Processes and Emissions

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

2.1 Process Description

The following processes are conducted in the dairy product manufacturing industry:

- milk processing including fresh milk;
- dairy product processing including UHT milk, evaporated milk, condensed milk, whey, protein powder, powdered milk;
- cheese manufacturing;
- ice-cream manufacturing;
- butter production; and
- yoghurt manufacture.

2.2 Emission Sources and Control Technologies

The following is a list of NPI substances that may be used by dairy product manufacturing facilities and can be emitted:

- phosphoric acid;
- hydrochloric acid;
- sulfuric acid;
- nitric acid; and
- chlorine.

In addition, there may also be emissions from fuel burning.

2.2.1 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 volatilisation of vapour from vats, open vessels, or spills and materials handling. Emissions emanating from 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.

Point Source Emissions

These emissions are exhausted into a vent or stack and emitted through a single point source into the atmosphere.

The major air emissions from the dairy product manufacturing industry are likely to be emissions from the burning of fuel on-site. The substances that may be emitted as a result of fuel burning are summarised below:

- Carbon Monoxide
- Sulfur Dioxide
- Oxides of Nitrogen
- Arsenic & compounds
- Beryllium & compounds
- Cadmium & Compounds
- Chromium (III) compounds
- Chromium (IV) compounds
- Copper & compounds
- Fluoride compounds
- Hydrochloric acid
- Lead & compounds
- Magnesium oxide fume
- Mercury & compounds
- Nickel & compounds
- Nickel carbonyl
- Nickel subsulfide
- Particulate Matter (PM_{10})
- Polychlorinated dioxins & furans
- Polycyclic aromatic hydrocarbons (PAHs)
- Total VOCs

The *Combustion in Boilers* EET Manual is available at the NPI Homepage and from your local Environment Protection Authority. This manual will assist you with estimating emissions from combustion processes.

Air emission control technologies, such as electrostatic precipitators, fabric filters or baghouses, and wet scrubbers, are commonly installed to reduce the concentration of particulates in process off-gases before stack emission. Where such emission abatement equipment has been installed, and where emission factors from uncontrolled sources have been used in emission estimation, the collection efficiency of the abatement equipment needs to be considered. Guidance on applying collection efficiencies to emission factor equations is provided in later sections.

With regards to emission controls for PM_{10} emissions (particulate matter with an equivalent aerodynamic diameter of 10 micrometres or less ie. $\leq 10\mu m)_{10}$, 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.

2.2.2 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 water can be calculated based on a mass balance or using emission factors.

The discharge of listed substances to a sewer does not require you to report to the NPI. However, leakage and other emissions (including dust) from a tailings storage facility are reportable. (See also Section Three of *The NPI Guide*.)

For the dairy product manufacturing industry, the majority of emissions will be to the sewer. Emissions to water need only be reported if your facility discharges effluent directly to a stream or water body.

Nitrogen and phosphorous are the main NPI-listed constituents of wastewater that need to be reported if wastewater is discharged into a water body.

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

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

In many instances dairy product manufacturing facilities irrigate with treated wastewater. Emissions of any NPI-listed substances contained in the wastewater must be reported *if* the threshold for that substance is triggered.

The following list indicates some of the NPI-listed substances contained in dairy effluent, which may need to be reported when wastewater is used for irrigation, as this constitutes an emission to land:

- chlorine; and
- ammonia (if it forms a constituent of the nitrogen component of wastewater).

3.0 Emission Estimation Techniques

Estimates of emissions of listed substances to air, water and land should be reported where the threshold is triggered. 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; and
- 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'.

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 the clean-up process.

The **usage** of each of the substances listed as Category 1 and 1a under the NPI must be estimated to determine whether the 10 tonnes (or 25 tonnes for VOCs) reporting threshold is exceeded. If the threshold is exceeded, **emissions** of these Category 1 and 1a substances must be reported for all operations/processes relating to the facility, even if the actual emissions of the substances are very low or zero.

3.1 Direct Measurement

You may wish to undertake 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 the 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 to 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^3 (dry standard). Annual emissions for NPI reporting can be calculated from this data. Stack 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.

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.

You should 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 emission estimations.

Estimating Emissions from Wastewater Irrigation

Many dairy factories irrigate wastewater to farmland after varying degrees of treatment. If effluent is used for irrigation, it is possible to estimate emissions to land from the average concentration of particular pollutants in the effluent, and the average volume of wastewater irrigated to land per year. This method may be particularly useful for estimating emissions of chlorine and ammonia, which may be constituents in the wastewater stream. Adjustments may need to be made for any ammonia released to air during irrigation.

The basic equation for performing this calculation is illustrated below.

Equation 1

$$E_{kpy,i} = (C_i * V) / 1\,000)$$

where

$E_{kpy,i}$ = emission of pollutant i , kg/year
C_i = concentration of pollutant i in the wastewater, mg/L
V = volume of wastewater irrigated per year, m^3/year
1000 = conversion factor (1 000 000 mg/kg) / (1000L/m^3)

Example 1 - Using Sampling Data

This example illustrates how emissions to land of chlorine from wastewater used for irrigation, can be calculated from sampling data that may be available from on-site monitoring.

From a dairy operation, 100 000 m^3 of wastewater was used for irrigation in one year. The average concentration of chlorine in this wastewater is 1 mg/L.

From Equation 1

$$E_{kpy,chlorine} = C_{chlorine} * V$$

Using the information from the dairy operation,

$$E_{kpy,chlorine} = (1 \text{ mg/L} * 100\,000 \text{ m}^3\text{/year}) / 1\,000$$
$$= 100 \text{ kg/year.}$$

Therefore, from this dairy operation, 0.1 tonne per year of chlorine is emitted to the land via irrigation. This effluent is irrigated over a large area, say 200 hectares.

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).

3.3.1 Fuel Analysis

Fuel analysis is an example of an engineering calculation and can be used to predict SO_2, 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:

Equation 2

$$E_{kpy,i} = Q_f * \text{pollutant concentration in fuel} * (MW_p / EW_f) * OpHrs$$

where:

$E_{kpy,i}$ = emissions of pollutant i, kg/yr
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
OpHrs= operating hours, hr/yr

Pollutant concentration in fuel is measured as weight fraction. This approach assumes complete conversion of sulfur to SO_2. Therefore, for every kilogram of sulfur (EW = 32) burned, two kilograms of SO_2 (MW = 64) are emitted. The application of this emission estimation technique is shown in Example 2.

Example 2 - Using Fuel Analysis

This example illustrates how SO_2 emissions can be calculated from coal combustion based on fuel analysis results and the fuel flow information from a dairy product manufacturing facility. The facility is assumed to operate 1500 hours per year.

$E_{kpy,SO2}$ = may be calculated using Equation 2

Fuel flow = 2000 kg/hr
Weight percent sulfur in fuel = 0.5

$$\begin{aligned} E_{kpy,SO2} &= Q_f * \text{pollutant concentration in fuel} * (MW_p / EW_f) * OpHrs \\ &= (2000) * (0.5/100) * (64/32) * 1500 \\ &= 20.0 kg/hr * 1500 hr/yr \\ &= 30\ 000 kg/yr \end{aligned}$$

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 (eg. kilograms of particulate matter emitted per tonne of dry cheese produced).

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

Equation 3

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

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, %.

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 are measured from one process source, an emission factor can be developed and applied to similar sources. As previously mentioned, you are required 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 following emissions factors may be used to assist with the estimation of PM_{10} emissions from cheese manufacturing.

Table 1 - PM_{10} Emission Factors for Natural & Processed Cheese Manufacture[a]

Source	Controlled Emission Factor (kg/tonne) [b]	Emission Factor Rating
Cheese Dryer	1.62	D
Whey Dryer	0.78	D

[a] USEPA AP-42, Section 9.6.1, 1997
[b] Units are kg of PM_{10} emitted per tonne of dry product produced.

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.

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 regards to accuracy.

Several techniques are available for calculating emissions from dairy product manufacturing facilities. The technique chosen is dependent on available data, available 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

Use of stack and/or workplace health and safety sampling data is likely to be a relatively accurate method of estimating air emissions from dairy product 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 production.

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 dairy product manufacturing facility using mass balance appears to be a straightforward approach to emission estimations. However, it is likely that few Australian dairy product 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 often result in large deviations of total facility emissions. Because emissions from specific materials are typically below 2 percent of gross consumption, an error of only ± 5 percent in any one step of the operation can significantly skew emission estimations.

4.3 Engineering Calculations

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

Use of emission equations to estimate emissions from dairy product 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 Manual. 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

5.0 References

Griffith University. 1996. *Industrial Water and Waste Water Treatment - Study Guide Part Two.* Brisbane, Queensland.

National Pollutant Inventory Homepage
http://www.npi.gov.au

USEPA. July 1997. *Compilation of Air Pollutant Emission Factors, Volume 1: Stationary Point and Area Sources, fourth edition, AP-42. Section 9.6.1 Natural and Processed Cheese.* United States Environmental Protection Agency, Office of Air Quality Planning and Standards. Research Triangle Park, NC, USA.
http://www.epa.gov/ttn/chief/ap42.html

The following Emission Estimation Technique Manuals referred to in this Manual are available at the NPI Homepage and from your local environmental protection agency (see the front of the *NPI Guide* for details):

- Emission Estimation Technique Manual for Combustion in Boilers;
- Emission Estimation Technique Manual for Combustion Engines; and
- Emission Estimation Technique Manual for Sewage & Wastewater Treatment.