



National Pollutant Inventory

Emission Estimation Technique Manual

for

**Snack Foods Roasting
and Frying Industry**

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**EMISSION ESTIMATION TECHNIQUES
FOR
SNACK FOODS ROASTING AND FRYING INDUSTRY**

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SNACK FOODS ROASTING AND FRYING INDUSTRY

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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 snack foods roasting and frying.

EET MANUAL: Snack Foods Roasting and Frying Industry

HANDBOOK: Snack Foods and Prepared Meals

ANZSIC CODES : 2179

This Manual was drafted by the NPI Unit of the Queensland Department of Environment & 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 salted and roasted nuts and seeds industry and identifies likely sources of emissions.

2.1 Process Description

2.1.1 Salted and Roasted Nuts and Seeds

This industry encompasses a range of edible nuts and seeds processed primarily for human consumption. The salted and roasted nuts and seeds industry primarily includes establishments that produce salted, roasted, dried, cooked or canned nuts, or process grains and seeds for snack use. This industry does not encompass facilities that manufacture candy-coated nuts or those that manufacture peanut butter. The overall production of finished salted and roasted nuts and seeds has two primary components. Typically, nuts undergo post harvest processing such as hulling and shelling, either by the farmer on the farm, or by contractor companies either on the farm or at facilities near the farm, called crop preparation service facilities. The shelled nut or seeds are shipped to food processing plants to produce the final product.

Many of the post-harvest operations and processes are common to most of the nuts and seeds, including loading, precleaning, drying, screening, and hulling. Other operations specific to individual nuts and seeds include sizing, grading, skinning and oil or dry roasting. The processing of harvested nuts and seeds can produce particulate emissions primarily from the unloading, precleaning, hulling or shelling, and screening operations. In almond processing, all of the operations, except for unloading, are usually controlled to reduce the level of ambient particulate. The emissions from the unloading operation are usually uncontrolled.

In this handbook, the industry is divided in two sections, “Almond Processing” and “Peanut Processing”.

2.1.1.1 Almond Processing

Almonds are edible tree nuts. The nuts are harvested from orchards and transported to almond processing facilities, where the almonds are hulled and shelled. The function of an almond huller/sheller is to remove the hull and shell of the almond from the nut, or meat. Orchard debris, soil, and pebbles represent 10 to 25 percent of the field weight of material brought to the almond processing facility. Clean almond meats make up about 20 percent of the field weight. Processes for removing the debris and almond hulls and shells are potential sources of air emissions.

After almonds are collected from the field, they undergo two processing phases, post harvest processing and finishing processing. These phases are typically conducted at two different facilities. There are two basic types of almond post-harvest facilities: those that produce hulled, in-shell almonds as a final product (known as hullers), and those that

produce hulled, shelled, almond meats as a final product (known as huller/shellers). Almond precleaning, hulling, and separating operations are common to both types of facilities. The huller/sheller includes additional steps to remove the almond meats from their shells. A typical hulling operation is shown in Figure 1. A typical almond huller/sheller is depicted in Figure 2. The hulled, shelled almond meats are shipped to large production facilities, where the almonds may undergo further processing into various end products. Almond harvesting, along with precleaning, hulling, shelling, separating, and final processing operations, is discussed in more detail below.

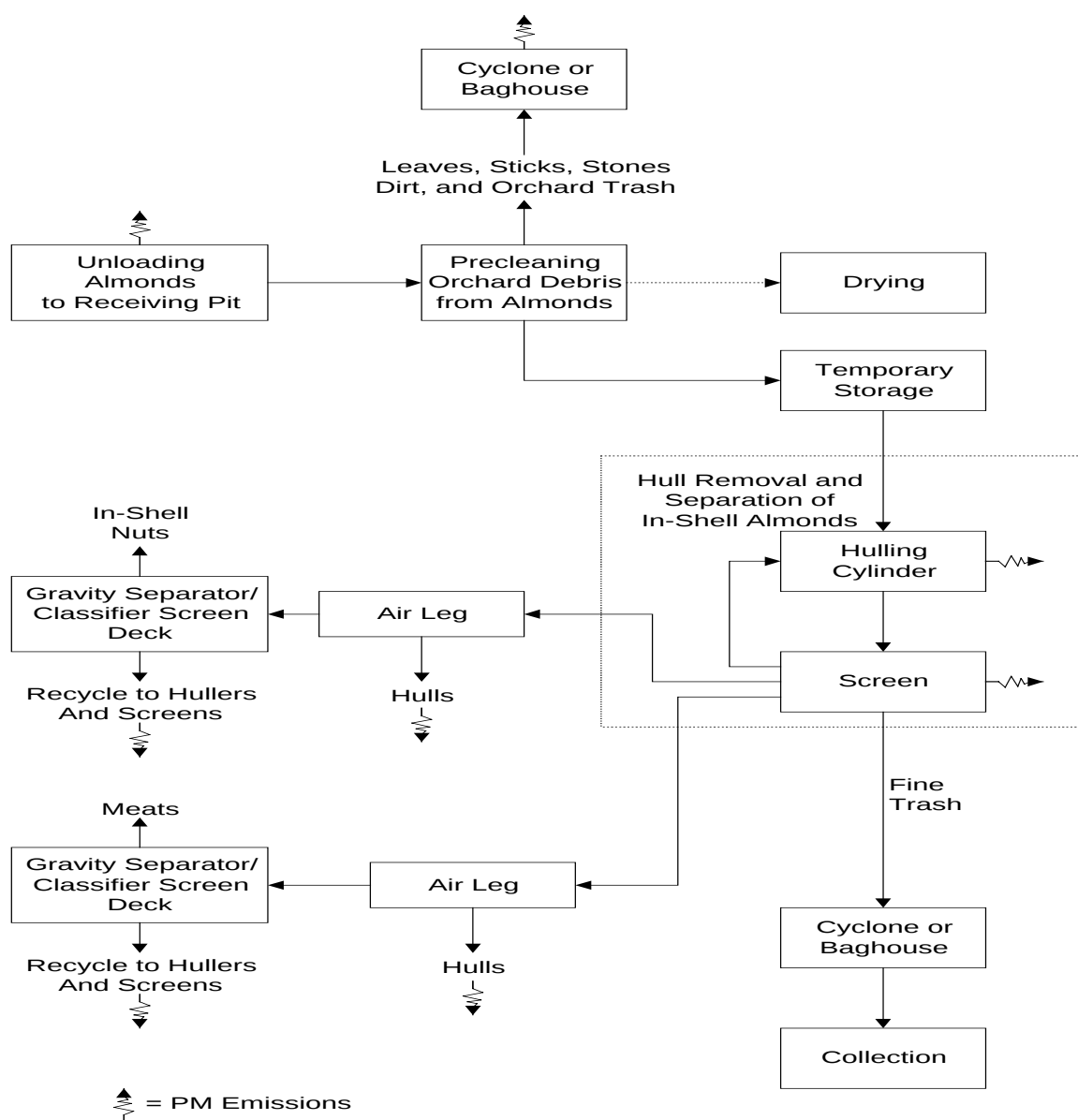


Figure 1 - Representative Almond Hulling Process Flow Diagram

Source: USEPA, AP 42, Section 9.10.2.1, 1995

Almond harvesting and processing is a seasonal industry. However, the beginning and duration of the season vary with the weather and with the size of the crop. Almonds are harvested either manually, by knocking the nuts from the tree limbs with a long pole, or mechanically, by shaking them from the tree. Typically the almonds remain on the ground for seven to ten days to dry. The fallen almonds are then swept into rows. Mechanical pickers gather the rows for transport to the almond huller or huller/sheller. A portion of the material in the gathered rows includes orchard debris, such as leaves, grass, twigs, pebbles and soil. The fraction of debris is a function of farming practices (tilled versus untilled), field soil characteristics, and age of the orchard, and it can range from less than 5 to 60 percent of the material collected. On average, field weight yields 12 percent debris, 50 percent hulls, 14 percent shells, and 23 percent clean almond meat and pieces, but these ratios can vary substantially from farm to farm.

The almonds are delivered to the processing facility and are dumped into a receiving pit. The almonds are transported along screw conveyors, and in bucket elevators to a series of vibrating screens. The screens selectively remove orchard debris, including leaves, soil, and pebbles. A destoner removes stones, dirt clods, and other large debris. A detwigger removes twigs and small sticks. The air streams from the various screens, destoners, and detwiggers are ducted to cyclones or fabric filters for particulate matter removal. The recovered soil and fine debris, such as leave and grass, are disposed of by spreading on surrounding farmland. The recovered twigs may be chipped and used as fuel for co-generation plants. The precleaned almonds are transferred from the precleaner by another series of conveyors and elevators to storage bins to await further processing. (In some instances, the precleaned almonds may be conveyed to a dryer before storage. However, field drying is used in most operations).

Almonds are conveyed on belt and bucket conveyors to a series of hulling cylinders or shear rolls, which crack the almond hulls. Hulling cylinders are typically used in almond huller facilities. Series of shear rolls are generally used in hullers/shellers. The hulling cylinders have no integral provision for aspiration of shell pieces. Shear rolls, on the other hand, do have integral aspiration to remove shell fragments from loose hulls and almond meats. The cracked almonds are then discharged to a series of vibrating screens or a gravity table, which separates hulls and unhulled almonds from the in-shell almonds, almond meats and fine waste. The remaining unhulled almonds pass through additional hulling cylinders or shear rolls and screen separators. The number of passes and the combination of equipment vary among facilities. The hulls are conveyed to a storage facility and sold as an ingredient in the manufacture of cattle feed. The fine waste is ducted to a cyclone or fabric filter for collection and disposal.

In a hulling facility, the hulled, in-shell almonds are separated from any remaining hull pieces in a series of air legs (counter-flow forced air gravity separators) and are then graded, collected, and sold as finished product, along with an inevitable small percentage of almond meats. In the huller/sheller, the in-shell almonds continue through more shear rolls and screen separators.

As the in-shell almonds make additional passes through sets of shear rolls, the almond shells are cracked or sheared away from the meat. More sets of vibrating screens separate the shells from the meat and small shell pieces. The separated shells are aspirated and collected in a fabric filter or cyclone, and then conveyed to storage for sale as fuel for co-generation plants. The almond meats and small shell pieces are conveyed on vibrating

conveyor belts and bucket elevator to air classifiers, or air legs, that separate the small shell pieces from the meats. The number of these air separators varies among facilities.

The almond meats are then conveyed to a series of gravity tables or separators (classifier screen decks), which sorts the meats by lights, middlings, goods and heavies. Lights, middlings, and heavies, which still contain hulls and shells, are returned to various points in the process. Goods are conveyed to the finished meats box for storage. Any remaining shell pieces are aspirated and sent to shell storage.

The almond meats are now ready either to be sold as raw product or for further processing, typically at a separate facility. The meats may be blanched, sliced, diced, roasted, salted or smoked. Small meat pieces may be ground in to meal or pastes for bakery products. Almonds are gradually heated and roasted in a rotating drum. They are heated slowly to prevent the skin and outer layers from burning. Roasting time develops the flavour and affects the colour of the meats. To obtain almonds with a light brown colour and a medium roast requires a 250 kg roaster fuelled with natural gas and for about 1.25 hours at 118 °C.

2.1.1.2 Peanut Processing

The initial step in processing is harvesting, which typically begins with the mowing of mature peanut plants. Then the peanut plants are inverted by specialised machines called peanut inverters, which dig, shake, and place the peanut plants, with the peanut pods on top, into windrows for field curing. After open-air drying, mature peanuts are picked up from the windrow with combines that separate the peanut pods from the plants using various thrashing operations. The peanut plants are deposited back onto the fields and the pods are accumulated in hoppers. Some combines dig and separate the vines and stems from the peanut pods in one step, and peanuts harvested by this method are cured in storage. Some small producers still use traditional harvesting methods, ploughing the plants from the ground and manually stacking them for field curing.

Harvesting is normally followed by mechanical drying. Moisture in peanuts is usually kept below 12 percent, to prevent aflatoxin moulds from growing. This low moisture content is difficult to achieve under field conditions without overdrying vines and stems, which reduces combine efficiency (less foreign materials is separated from the pods). On-farm dryers usually consist of either storage trailers with air channels along the floor or storage bins with air vents. Fans blow heated air (approximately 35 °C) through the air channels and up through the peanuts. Peanuts are dried to moisture of roughly 7 to 10 percent.

Local peanut mills take peanuts from the farm to be further cured (if necessary), cleaned, stored, and processed for various uses (oil production, roasting, peanut butter production, etc.). Major process steps include processing peanuts for in-shell consumption and shelling peanuts for other uses.

In-Shell Processing

Some peanuts are processed for in-shell roasting. Figure 3 presents a typical flow diagram for in-shell peanut processing. Processing begins with separating foreign material (primarily soil, vines, stems and leaves) from the peanut pods using a series of screens and blowers. The pods are then washed in wet coarse sands that remove stains and discolouration. The sand is then screened from the peanuts for reuse. The nuts are then dried and powdered with talc or kaolin to whiten the shells. Excess talc/kaolin is shaken from the peanut shells.

Shelling

A typical shelled peanut processing flow diagram is shown in Figure 4. Shelling begins with separating the foreign material with a series of screens, blowers and magnets. The cleaned peanuts are then sized with screens (size graders). Sizing is required so that peanut pods can be crushed without also crushing the peanut kernels.

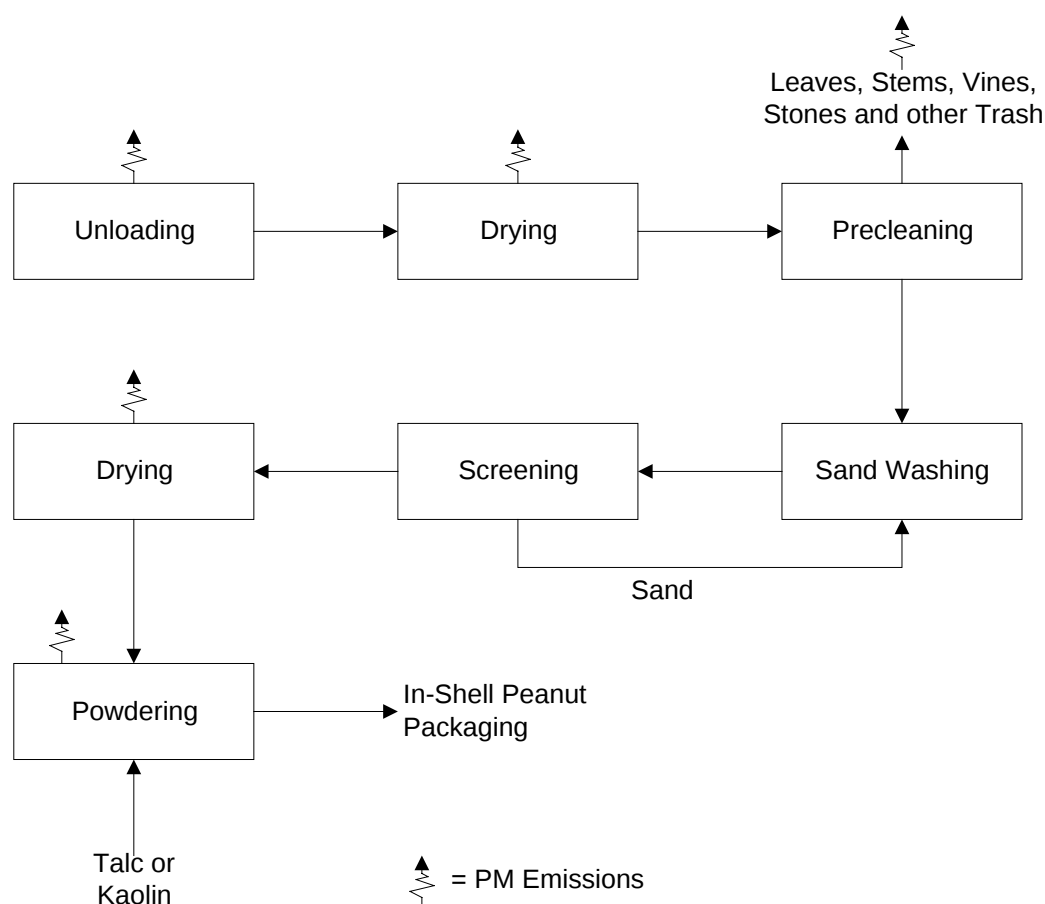


Figure 3 - Typical In-Shell Peanut Processing Flow Diagram

Source: USEPA, AP 42, Section 9.10.2.2, 1995

Next, shells of the sized peanuts are crushed, typically by passing the peanuts between the rollers that have been adjusted for peanut size. The gap between rollers must be narrow enough to prevent damage to the kernels. A horizontal drum, with a perforated and ridged bottom and a rotating beater, is also used to hull peanuts. The rotating beater crushed the peanuts against the bottom ridges, pushing both the shells and peanuts through the perforations. The beater can be adjusted for different sizes of peanuts, to avoid damaging the peanut kernels. Shells are aspirated from the peanut kernels as they fall from the drum. The crushed shells and peanut kernels are then separated with oscillating shaker screens and air separators. The separation process also removes undersized kernels and split kernels.

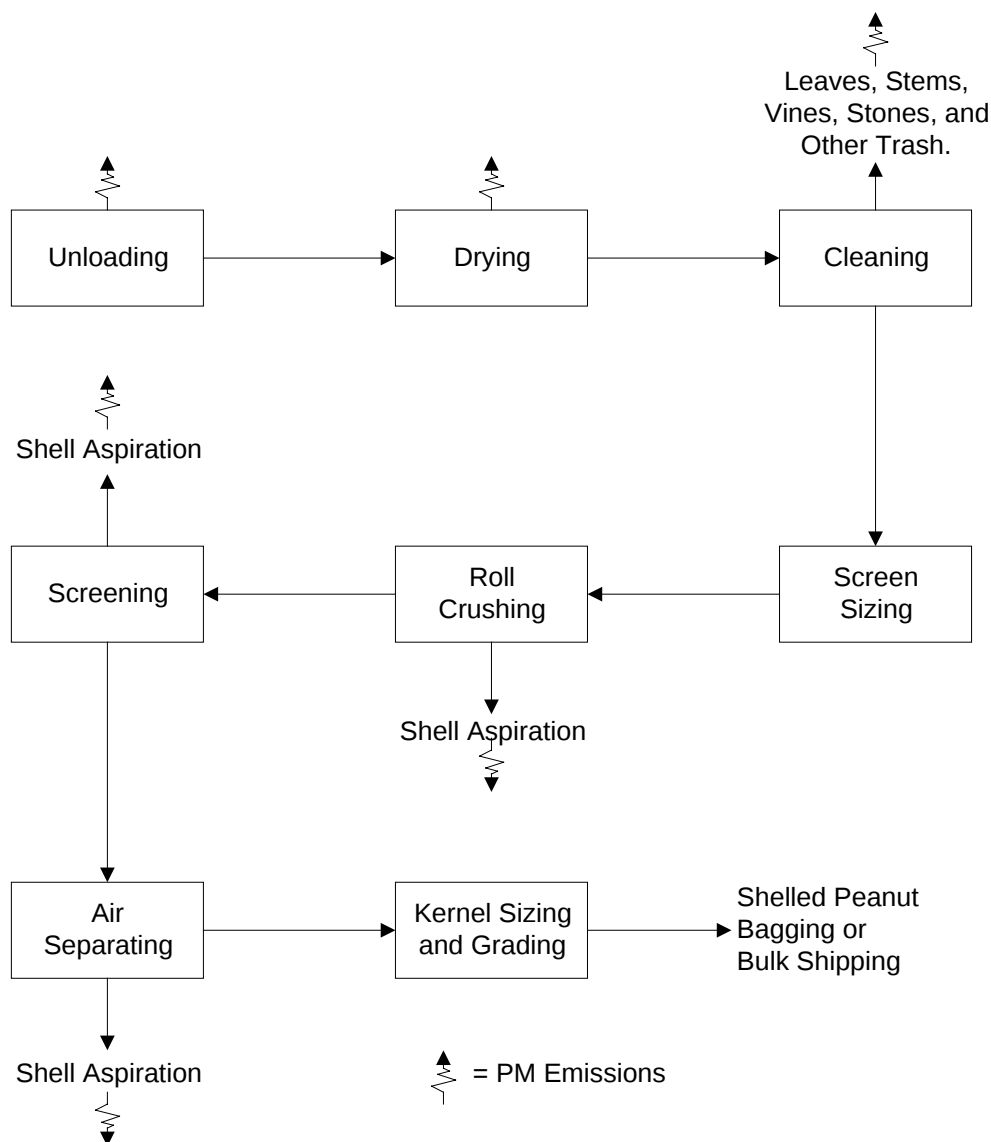


Figure 4 - Typical Shelled Peanut Processing Flow Diagram

Source: USEPA, AP 42, Section 9.10.2.2, 1995

Following crushing and hull/kernel separation, peanut kernels are sized and graded. Sizing and grading can be done by hand, but most mills use screens to size kernels and electric eye sorters for grading. Electric eye sorters can detect discoloration and can separate peanuts by colour grades. The sized and graded peanuts are bagged for shipment

to end users, such as peanut butter plants and nut roasters. Some peanuts are shipped in bulk in rail hopper cars.

Roasting

Roasting imparts the typical flavour associated with peanuts. During roasting, amino acids and carbohydrates react to produce tetrahydrofuran derivatives. Roasting also dries the peanuts further and causes them to turn brown as peanut oil stains the peanut cell walls. Typical peanut roasting is shown in Figure 5. There are two primary methods for roasting peanuts, dry roasting and oil roasting.

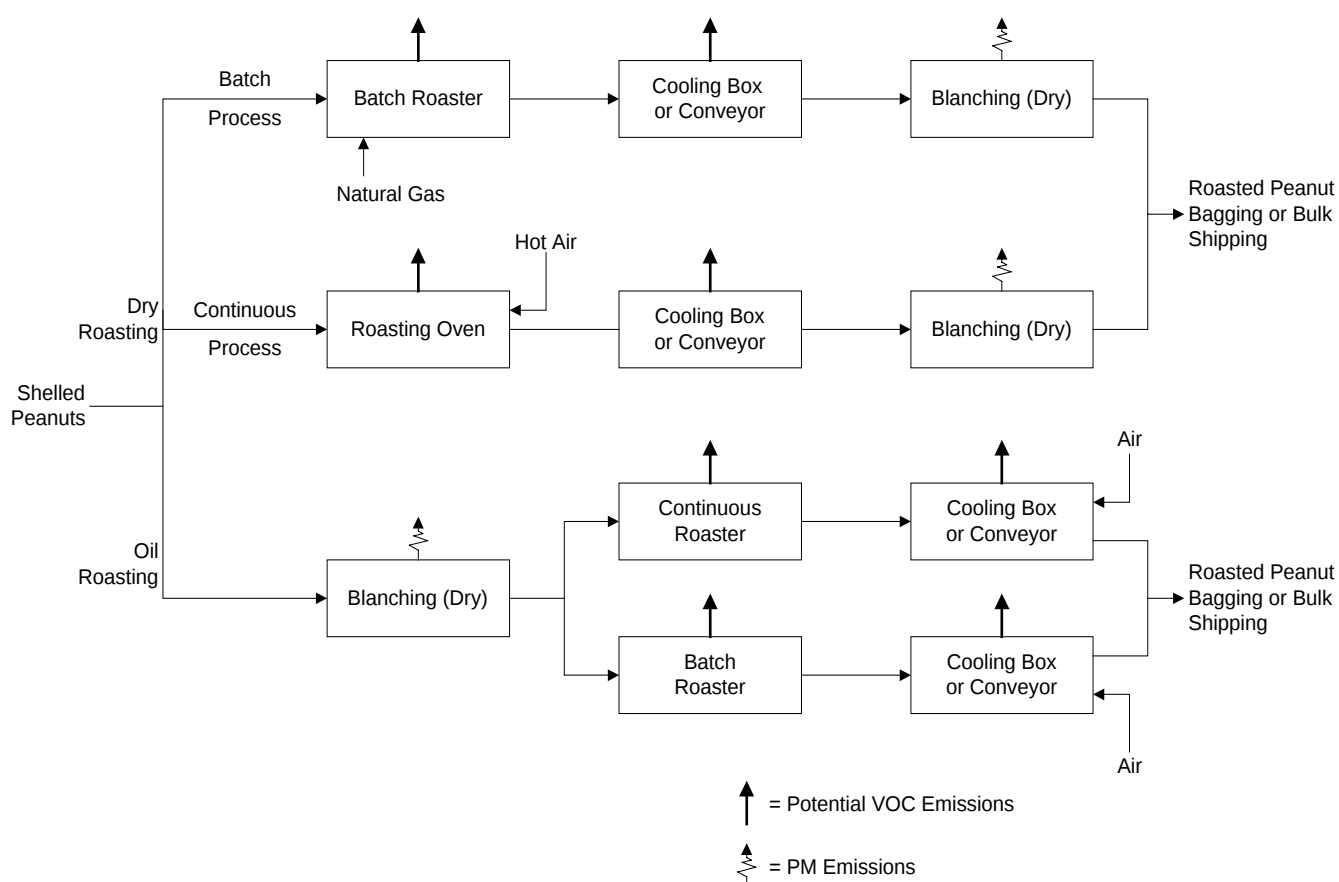


Figure 5 - Typical Shelled Peanut Roasting Flow Diagram

Source: USEPA, AP-42, Section 9.10.2.2, 1995

Dry Roasting

Dry roasting is either a batch or continuous process. Batch roasters offer the advantage of adjusting for different moisture contents of peanut lots from storage. Batch roasters are generally natural gas-fired revolving ovens (drum-shaped). The rotation of the oven continuously stirs the peanuts to produce an even roast. Oven temperatures are approximately 430 °C for 40 to 60 minutes. Actual roasting temperatures and times vary with the condition of the peanut batch and the desired end characteristics.

Continuous dry roasters vary considerably in type. Continuous roasting reduces labour, ensures a steady flow of peanuts for other processes (packaging, candy production, peanut butter production etc.), and decreases spillage. Continuous roasters may move peanuts through an oven by a conveyor or by gravity feed. In one type of roaster, peanuts are fed along a conveyor into a stream of countercurrent hot air, which roasts the peanuts. In this system, the peanuts are agitated to ensure that the air passes around the individual kernels to promote an even roast.

Dry roasted peanuts are cooled and blanched. Cooling occurs in cooling boxes or on conveyors when large quantities of air are blown over the peanuts immediately following roasting. Cooling is necessary to stop the roasting process and maintain a uniform quality. Blanching removes the skin of the peanut as well as dust, moulds, and other foreign material. There are several blanching methods including dry, water spin and air impact.

Dry blanching is used primarily in peanut butter production, because it removes the kernel hearts, which affect peanut butter flavour. Dry blanching heats the peanuts to approximately 138 °C for 25 minutes to crack and loosen the skins. Screening is used to separate the hearts from the cotyledons (peanut halves).

Spin blanching uses steam to loosen the skins of the peanuts. Steaming is followed by spinning the peanuts on revolving spindles, as the peanuts move, one by one, down a grooved conveyor. The spinning removes the peanut skins.

Air impact blanching uses a horizontal drum (cylinder) in which the peanuts are placed and rotated. The inner surface of the drum has an abrasive surface that aids in the removal of the skins as the drum rotates. Inside the drum are jets that blow the peanuts counter to the rotation of the drum creating air impact, which loosens the skin. The combination of air impacts and the abrasive surface of the drum result in skin removal. Either batch or continuous air impact blanching can be conducted.

Oil Roasting

Oil roasting is also done on a batch or continuous basis. Before roasting, the peanuts are blanched to remove the skins. Continuous roasters move the peanuts on a conveyor through a long tank of heated oil. In both batch and continuous roasters, oil is heated to temperatures of 138 to 143 °C, and roasting times vary from 3 to 10 minutes depending on desired characteristics and peanut quality. Oil roaster tanks have heated elements on the sides to prevent charring the peanuts on the bottom. Oil is constantly monitored for quality, and frequent filtration, neutralisation, and replacement are necessary to maintain quality. Coconut oil is preferred, but oils such as peanut and cottonseed are frequently used.

Cooling also follows oil roasting, so that a uniform roast can be achieved. Cooling is achieved by blowing large quantities of air over the peanuts either on conveyors or in cooling boxes.

2.1.2 Snack Chip Deep Fat Frying

Vegetables and other raw foods are cooked by industrial deep fat frying and are packaged for later use by consumers. The batch frying process consists in immersing the food in the cooking oil until it is cooked and then removing it from the oil. When the raw food is immersed in hot cooking oil, the oil replaces the naturally occurring moisture in the food as it cooks. Batch and continuous processes may be used for deep fat frying. In the contiguous frying method, the food is moved through the cooking oil on a conveyor. Potato chips are one example of a food prepared by deep fat frying. Other examples include corn chips, tortilla corn chips and multigrain chips.

Figure 6 provides general diagrams for the deep fat frying process for potato chips and other snack chips. The differences between the potato chip process and other snack chip processing operations are also shown. Some snack food processes (eg tortilla chips) include a toasting step. Because the potato chip processes represent the largest industry segment, they are discussed here as a representative example.

In the initial preparation, dirt, decayed potatoes, and other debris are first removed in cleaning hoppers. The potatoes go next to washers, then to abrasion, steam and lye peelers. Abrasion is the most popular method. Preparation is either in batch or continuous, depending on the number of potatoes to be peeled.

The next step is slicing, which is performed by a rotary slicer. Potato slice widths vary with the condition of the potatoes and with the type of chips being made. The potato slices move through rotating reels where high-pressure water separates the slices and removes starch from the cut surfaces. The slices are then transferred to the rinse tank for final rinsing.

Next, the surface moisture is removed by one or more of the following methods: perforated revolving drum, sponge rubber-covered squeeze roller, compressed air systems, vibrating mesh belt, heated air, or centrifugal extraction.

The partially dried chips are then fried. Most producers use a continuous process, in which the slices are automatically moved through the fryer on a mesh belt. Batch frying, which is used for a smaller quantity of chips, involves placing the chips in a frying kettle for a period of time and then removing them. A variety of oils may be used for frying chips, with cottonseed, corn and peanut oils being the most popular. Canola and soybean oils are also used. Animal fats are rarely used in this industry.

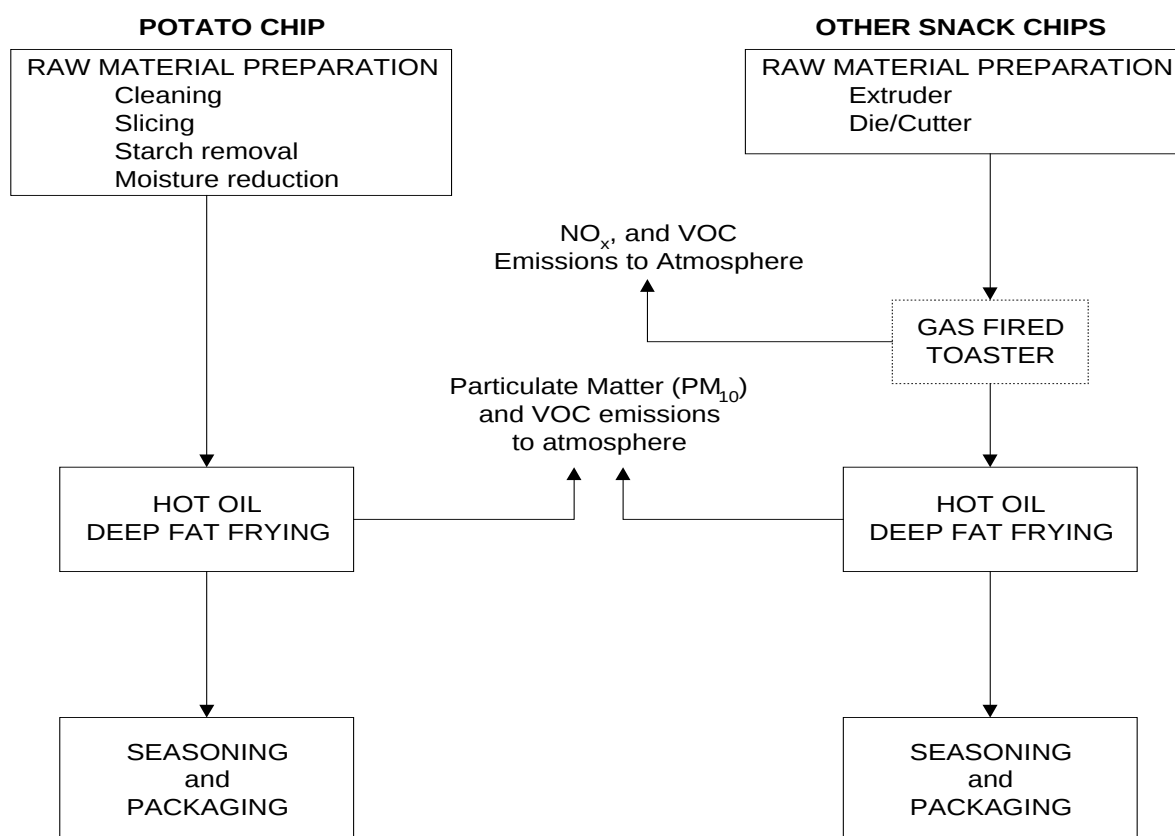


Figure 6 - Generalised Deep Fat Frying Process for Snack Foods

Source: USEPA, AP 42, Section 9.13.3, 1995

As indicated in Figure 6, the process for other snack chips is similar to that for potato chip frying. Typically the raw material is extruded and cut before entering the fryer. In some cases, the chips may be toasted before frying.

2.2 Emission Sources and Control Technologies

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 dust from stockpiles, volatilisation of vapour from vats, 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.

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 from snack foods roasting and frying. The *Combustion in Boilers* EET Manual, along with other Manuals in this series, is available from State and Territory environment agencies. The *Combustion in Boilers* EET Manual is designed to provide guidance on estimating emissions from combustion sources such as combustion of natural gas, oil, LPG or coal which may be of particular relevance to the snack foods roasting and frying industry.

Table 1 - Common Air Emissions from Snack Foods Roasting and Frying Processes

Substances
Particulate Matter (PM ₁₀)
Volatile Organic Compounds (VOCs)
Chlorine (Cl ₂) *

Source: Queensland Department of Environment and Heritage, 1998

* Chlorine is a common substance used for cleaning / disinfection purposes, hence a possible emission source

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 PM₁₀ emissions, (particulate matter with an equivalent aerodynamic diameter of 10 micrometres or less ie. $\leq 10\mu\text{m}$), 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 process 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*.)

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; and
- unintentional leaks and spills

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; 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 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, ie. the quantity of the NPI reportable substance spilled, less the quantity recovered or consumed during clean up operations.

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 parts per million (ppm) or grams per cubic metre (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.

This Section shows how to calculate emissions in kg/hr based on stack sampling data, and how to convert this to an annual emissions figure. Calculations involved in determining particulate emissions are used as an example, although the same calculations are applicable for most of the substances listed on the NPI. Use Equation 1 to calculate concentrations of particulate matter and use Equation 2 to calculate the hourly emission of particulate matter in kg/hr .

Equation 1

$$C_{\text{PM}} = C_f / V_{\text{m,STP}}$$

where:

$$\begin{aligned} C_{\text{PM}} &= \text{concentration of PM or gram loading, g}/\text{m}^3 \\ C_f &= \text{filter catch, g} \\ V_{\text{m,STP}} &= \text{metered volume of sample at STP, m}^3 \end{aligned}$$

Equation 2

$$E_{PM} = C_{PM} * Q_d * 3.6 * [273 / (273 + T)]$$

where:

E_{PM}	=	hourly emissions of PM, kg / hr
C_{PM}	=	concentration of PM, g / m ³
Q_d	=	stack gas volumetric flow rate, m ³ / s
T	=	stack gas temperature, °C

The information from some stack tests may be reported in kilograms of particulate matter per cubic metre of exhaust gas (wet). Use Equation 3 to calculate the dry particulate emissions in kg / hr.

Equation 3

$$E_{PM} = Q_a * C_{PM} * 3.6 * \left(1 - \frac{\text{moist}_R}{100}\right) * \left[\frac{273}{273 + T}\right]$$

where:

E_{PM}	=	hourly emissions of PM in kilograms per hour, kg / hr
Q_a	=	actual (ie. wet) cubic metres of exhaust gas per second, m ³ / s
C_{PM}	=	concentration of PM or gram loading, g / m ³
3.6	=	3600 seconds per hour multiplied by 0.001 kilograms per gram
moist_R	=	moisture content, %
273	=	273 K (0°C)
T	=	stack gas temperature, °C

Total suspended particulates (TSP) are also referred to as total particulate matter (total PM). To determine PM₁₀ from total PM emissions, a size analysis may need to be undertaken. The weight PM₁₀ fraction can then be multiplied by the total PM emission rate to produce PM₁₀ emissions. Alternatively, assume that 100% of PM emissions are PM₁₀; ie assume that all particulate matter emitted to air has an equivalent aerodynamic diameter of 10 micrometres or less ie. ≤10µm.

To calculate moisture content use Equation 4.

Equation 4

Moisture percentage = 100 % * weight of water vapour per specific volume of stack gas / total weight of the stack gas in that volume.

$$moist_R = \frac{100\% * \left(\frac{g_{moist}}{1000 * V_{m,STP}} \right)}{\left(\frac{g_{moist}}{1000 * V_{m,STP}} \right) + \rho_{STP}}$$

where

$moist_R$ = moisture content, %
 g_{moist} = moisture collected, g
 $V_{m,STP}$ = metered volume of sample at STP, m³
 ρ_{STP} = dry density of stack gas sample, kg / m³ at STP
{if the density is not known a default value of 1.62 kg / m³ may be used. This assumes a dry gas composition of 50% air, 50% CO₂}

Example 1 - Calculating Moisture Percentage

A 1.2m³ sample (at STP) of gas contains 410g of water. To calculate the moisture percentage use Equation 4.

$$moist_R = \frac{100\% * \left(\frac{g_{moist}}{1000 * V_{m,STP}} \right)}{\left(\frac{g_{moist}}{1000 * V_{m,STP}} \right) + \rho_{STP}}$$

$$\begin{aligned} g_{MOIST} / 1000 * V_{m,STP} &= 410 / (1000 * 1.2) \\ &= 0.342 \\ moist_R &= 100 (0.342 / (0.342 + 1.62)) \\ &= 17.4\% \end{aligned}$$

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.

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.

Most food processing industries however, will not be required to use this method of EET for the reporting of substances.

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 SO₂ and metal 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, which may be converted into other compounds during the combustion process.

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

Equation 5

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

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 element in fuel, kg / kg-mole
OpHrs	=	operating hours, hr / yr

For instance, SO₂ emissions from oil combustion can be calculated based on the concentration of sulfur in the oil. This approach assumes complete conversion of sulfur to

SO₂. Therefore, for every kilogram of sulfur (EW = 32) burned, two kilograms of SO₂ (MW = 64) are emitted. The application of this EET is shown in **Example 2**.

Example 2 - Using Fuel Analysis Calculations

This example illustrates how SO₂ emissions can be calculated from oil combustion based on fuel analysis results and the fuel flow information from a processing facility. The facility is assumed to operate 1500 hours per year.

E_{kpy,SO_2} = may be calculated using Equation 5.

Fuel flow = 2 000 kg / hr

Weight percent sulfur in fuel = 1.17

$$\begin{aligned} E_{kpy,SO_2} &= Q_f * \text{pollutant concentration in fuel} * (MW_p / EW_f) * \text{OpHrs} \\ &= (2\,000) * (1.17 / 100) * (64 / 32) * 1500 \\ &= 46.8\text{kg/hr} * 1\,500\text{ hr/yr} \\ &= 70\,200\text{ kg/yr} \end{aligned}$$

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.

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

Equation 6

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

where :

$$\begin{aligned} E_{kpy,i} &= \text{emission rate of pollutant i, kg / yr} \\ A &= \text{activity rate, t / hr} \\ \text{OpHrs} &= \text{operating hours, hr / yr} \\ EF &= \text{uncontrolled emission factor of pollutant i, kg / t} \\ CE_i &= \text{overall control efficiency of pollutant i, \%} \end{aligned}$$

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. 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

Table 2 presents emission factors for total PM emissions resulting from almond processing.

Table 2 - Emission Factors for Almond Processing^{a, b}

Source	PM ₁₀ ^c kg of PM ₁₀ /tonne of almonds processed
Unloading	ND
Precleaning Cyclone	0.41
Precleaning Baghouse ^d	0.0075
Hulling / Separating Cyclone	0.41
Hulling / Separating Baghouse	0.0065
Hulling / Shelling Baghouse	ND
Classifier Screen Deck Cyclone	0.16
Air Leg	ND
Roaster	ND

Source: USEPA, AP-42, section 9.10.2.1

^a Process weights used to calculate emission factors include nuts and orchard debris as take from the field, unless noted. ND = no data.

^b Emission factor uncertainty rating = E

^c PM₁₀ = Particulate matter with a diameter of less than or equal to 10 micrometres.

^d Emission factor is for a single air leg/classifier screen deck cyclone. Facilities may contain multiple cyclones.

Table 3 - Uncontrolled VOC Emission Factors for Snack Chip Deep Fat Frying^a

Process	VOC kg/t
Deep Fat Fryer - potato chips	0.0099
Deep Fat Fryer - other snack chips	0.043

Source: USEPA, AP-42, Section 9.13.3, 1995

^a Expressed as equivalent weight of methane (CH₄)/tonne of product

Table 4 - Particulate Matter Emission Factors for Snack Chip Deep Fat Frying^a

Process	Filterable PM		Condensable PM			Total
	PM	PM ₁₀	Inorganic	Organic	Total	PM ₁₀
Continuous deep fat fryer - potato chips	0.83	ND	ND	ND	0.19	ND
Continuous deep fat fryer - other snack chips	0.28	ND	ND	ND	0.12	ND
Continuous deep fat fryer with standard mesh pad mist eliminator - potato chips ^b	0.35 ^c	0.30	0.004 ^c	0.19 ^c	0.19	0.49
Continuous deep fat fryer with high efficiency mesh pad mist eliminator - potato chips ^d	0.12	ND	0.12	0.064	0.18	ND
Continuous deep fat fryer with standard mesh pad mist eliminator - other snack chips	0.11 ^c	0.088	0.017	0.022	0.039	0.13
Batch deep fat fryer with hood scrubber - potato chips	0.89 ^c	ND	0.66 ^c	0.17	0.83	ND

Source: USEPA, AP-42, Section 9.13.3, 1995

Emission Factor Rating: E (except as noted)

^a Factors are for uncontrolled emissions, except as noted. All emission factors in kg per tonne of chips produced. ND = no data

^b The standard mesh pad eliminator, upon which these emission factors are based, includes a single, 15.24 cm, 2 layer mist pad that operates with a pressure drop of about 1.27-cm water column (when clean)

^c Emission Factor Rating: D

^d The high-efficiency mesh pad eliminator, upon these emission factors are based, includes a course-weave 10.16-cm mist pad and a 15.24-cm fine weave pad, and operates with a 5-8 cm water column pressure drop (when clean).

Example 3 - Using Emission Factors

Table 2 shows that 0.41 kg of particulate matter (PM₁₀) are emitted from the precleaning cyclone, for each tonne of almond processed. If it is assumed that the facility operates 8 hour days, 320 d/yr and an overall control efficiency for particulate matter at 10% (CE), then

$$\begin{aligned}
 EF_{\text{particulate matter}} &= 0.41 \text{ kg/t} \\
 A &= 10 \text{ t/hr} \\
 \text{OpHrs} &= 8 \text{ hr/d} * 320 \text{ d/yr} \\
 &= 2560 \text{ hr/yr} \\
 CE_{\text{particulate matter}} &= 10 \% \\
 \\
 PM_{10} \text{ Emissions/year} &= [A * \text{OpHrs}] * EF * [1 - (CE/100)] \\
 &= [10 \text{ t/hr} * 2560 \text{ hr/yr}] * 0.41 \text{ kg/t} * [1 - (10/100)] \\
 &= 9446.4 \text{ kg/yr}
 \end{aligned}$$

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 that 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 snack foods roasting and frying 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 snack foods roasting and frying 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 aspects of production of salted and roasted nuts and seeds products.

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 snack foods roasting and frying facility using mass balance appears on the surface to be a straightforward approach to emissions estimations. However, it is likely that few Australian snack foods roasting and frying 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 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 salted and roasted nuts and seeds processes.

Use of emission equations to estimate emissions from snack foods roasting and frying 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

National Pollutant Inventory Homepage

<http://www.npi.gov.au>

USEPA, January 1995, *Compilation of Air Pollutant Emission Factors, Volume 1: Stationary Point and Area Sources, fifth edition, AP-42. Section 9.10.2. Salted and Roasted Nuts and Seeds*, United States Environmental Protection Agency, Office of Air Quality Planning and Standards, Research Triangle Park, NC, USA.

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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 Fuel & Organic Liquid Storage.