Australian Government
Department of the Environment and Water Resources

National Pollutant Inventory

Emission estimation technique manual
for

Paint and ink manufacturing
Version 2.0
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Disclaimer

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EMISSION ESTIMATION TECHNIQUES
FOR
PAINT AND INK MANUFACTURING
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PAINT AND INK MANUFACTURING

LIST OF FIGURES, TABLES, EXAMPLES AND EQUATIONS

1 Introduction

The purpose of all emission estimation technique (EET) manuals 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 engaged in paint and ink manufacturing activities.

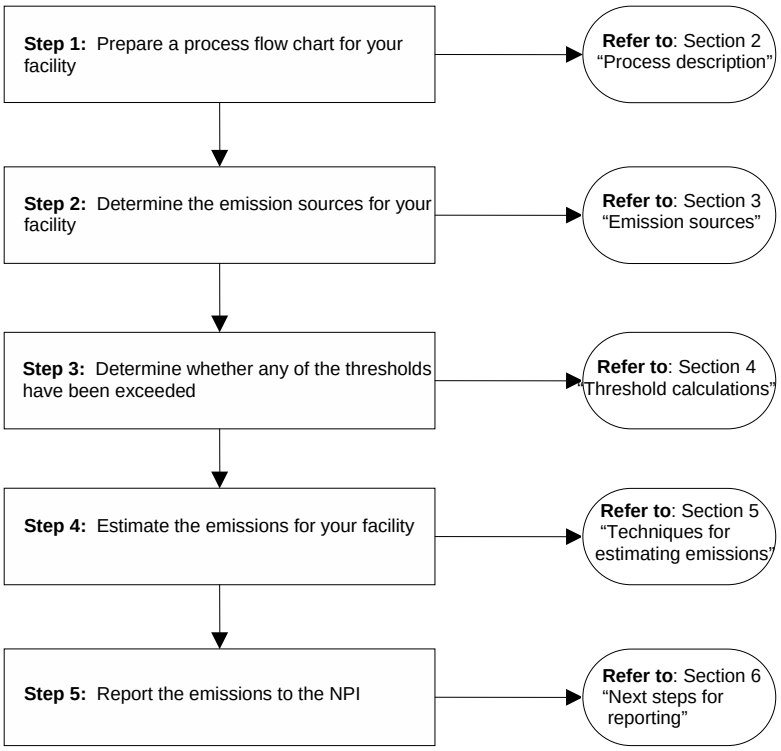
EET MANUAL		Paint and ink manufacturing
ANZSIC CODE	1993	2542 Paint manufacturing; 2547 Ink manufacturing
	2006	1916 Paint and coatings manufacturing
		1812 Basic organic chemical manufacturing
		1813 Basic inorganic chemical manufacturing

Note that the ANZSIC code is part of NPI reporting requirements. *The NPI Guide* contains an explanation of the ANZSIC code.

This manual has been developed through a process of national consultation involving state and territory environmental authorities and key industry stakeholders. Particular thanks are due to the Australian Paint Manufacturers' Federation and Orica, and their members, for their assistance in developing this manual.

1.1 The process for NPI reporting

The process for NPI reporting can be seen in the following flow chart:



1.2 Information required to produce an annual NPI report

The following data will need to be collated for the reporting period:

- solvent-based paints production data – m^3
- water-based paints production data – m^3 *and*
- ink type/s and production data – m^3.

If any fuel burning equipment has been used on the facility, including on-site vehicles, additional data will need to be collated including:

- type and amount of fuel burned
- pollution control devices employed *and*
- volume and throughput of fuels or organic liquids stored on site.

1.3 Additional reporting materials

This manual is written to reflect the common processes employed in paint and ink manufacturing. In many cases it will be necessary to refer to other EET manuals to ensure a complete report of the emissions for the facility can be made. Other applicable EET manuals may include, but are not limited to:

- combustion in boilers
- combustion in engines
- fuel and organic liquid storage
- fugitive emissions *and*
- sewage and waste water treatment.

2 Process description

The first step in working out the emissions of NPI substances from your facility is by creating a process flow diagram to highlight points in the process where emissions may occur.

The following section presents a brief description of the paint and ink manufacturing industry, and identifies the likely sources of emissions. This represents a typical facility in the industry, but you should develop a process flow diagram specific to your site.

2.1 Paint and ink manufacturing process

Paint and ink are suspensions of finely separated pigment particles in a liquid that when spread over a surface in a thick layer will form a solid, cohesive, and adherent film. Types of paints currently manufactured include architectural coatings, product finishes, and special-purpose coatings. Currently around 85% of produced architectural paints are water-based. However, solvent-based paint is still predominantly used for product finishes and special-purpose coatings. Inks currently manufactured include letterpress, lithographic and offset, gravure, and flexographic inks. Letterpress and lithographic inks are typically classified as paste inks, whereas gravure and flexographic inks are typically water or solvent-based and are classified as liquid inks.

Paint and ink manufacturing can be classified as a batch process and generally involves the blending / mixing of resins, pigments, solvents, and additives. Traditional paint and ink manufacturing consists of four major steps:

1. Preassembly and premix

In the preassembly and premix step, liquid raw materials are assembled and then mixed in containers to form a viscous material to which pigments are added. Mixing is carried out in a number of ways depending on the batch size and type of coating being produced, from drums equipped with portable mixers for small batches, through to high-speed dispersers for large batches. Coating manufacturing facilities may use typical grinding equipment to accomplish the premix operations. This approach, common with water-based paints and inks, eliminates the need to transfer the material to alternate equipment for the grinding / milling step described below.

2. Pigment grinding / milling / dispersing

Pigment grinding or milling entails the incorporation of the pigment into the liquid base of the coating to yield a fine particle dispersion. Initially, a wetting agent, normally a surfactant, wets the pigment particles by displacing air, moisture, and gases that are adsorbed on the surface of the pigment particles. Grinding of the pigment then takes place to break up and separate the pigment clusters into isolated particles and may be facilitated by the use of grinding media such as pebbles, balls, or beads. The pigment particles are then dispersed into the body of the liquid vehicle to produce a particle suspension. The type of milling equipment used depends on the

types of pigments being handled. High-speed dispersion is the most universally used method of mixing in the paint and ink manufacturing industry, relying on dispersion for mixing the suspension, rather than using grinding media. On the other end of the scale, roller mills are a slow, labour intensive grinding media which are generally reserved for the manufacture of very high quality paints and inks.

3. Product finishing / blending

Final product specifications for colour, viscosity, and other coating characteristics are achieved in the product finishing step. This process generally consists of thinning, tinting, and blending through the addition of solvents, tints, and shades. Product finishing activities for solvent-based paints and inks involve adding various combinations of pigments, organic solvents, and resins. For water-based coatings, a preservative, an antifoaming agent, a polyvinyl acetate emulsion, and water are added at this step of the manufacturing process. Blending is the process of mixing the added ingredients to meet product specifications, which may entail additional milling, such as in a ball mill, or added mixing and dispersing in a portable mix tank / high-speed disperser setup.

4. Product filling / packaging.

The final step in the paint and ink manufacturing process is the product filling operation. During the filling step, filtration is performed to remove impurities and to catch small particles of grinding media. Filtration is performed using a variety of techniques ranging from cloth filtration through to strainers and sieves, with the filtration method determined by the end use of the product. Once the material has been filtered, the final product is transferred into containers for shipment.

Generic raw ingredients found in paints and inks are listed in Table 1. A generalised process flow diagram is shown in Figure 1.

Table 1: Generic paint and ink manufacturing ingredients

Water-based paints	Solvent-based paints	Inks
Water	Resins	Pigments
Ammonia	Organic solvents	Oils
Dispersant	Plasticisers	Resins
Pigment	Dry pigment	Solvents
Pigment extenders	Pigment extenders	Driers

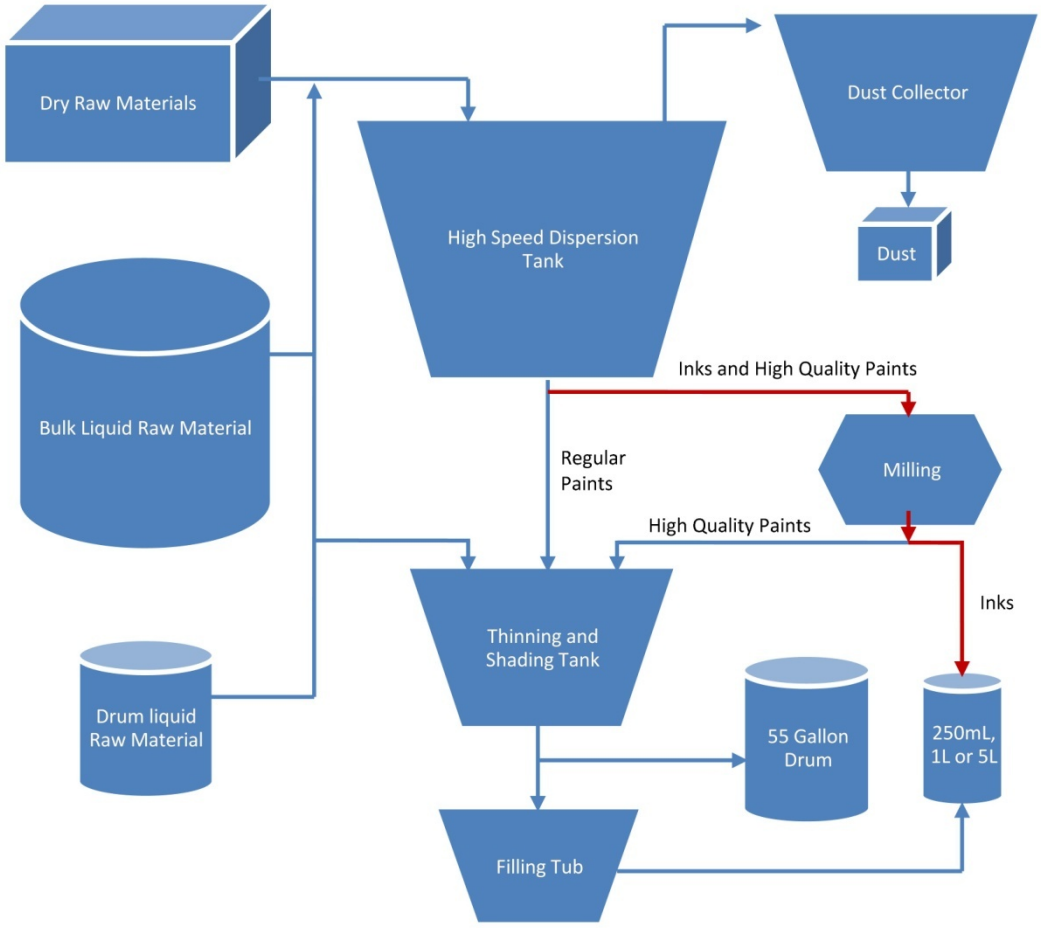


Figure 1: Generic process flow diagram for paint and ink manufacturing.

3 Emission sources

General information regarding emission sources can be located in *The NPI Guide.*

3.1 Emissions to air

Air emissions may be categorised as fugitive emissions or point-source emissions.

3.1.1 Fugitive emissions

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

Fugitive emissions of volatile organic compounds are the predominant source of emissions in the paint and ink manufacturing industry. These emissions may emanate from the following sources:

- materials handling
- filling and loading of tanks and containers
- mixing and heat up emissions (surface evaporation)
- storage tank breathing emissions
- cleaning
- solvent reclamation
- leaks *and*
- spills.

3.1.2 Point source emissions

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

Point sources are generally not found in paint and ink manufacturing plants, however possible examples of point sources could include exhaust stacks from pollution control devices such as dust collectors or condensers.

The collection efficiency of the abatement equipment needs to be considered where such equipment has been installed, and where emission factors from uncontrolled sources have been used in emission estimations.

3.2 Emissions to water

Emissions to water are not expected from paint and ink manufacturing facilities.

Emissions of paints, inks and their constituents to waterways may pose environmental hazards. Most facilities emitting NPI-listed substances are required by their state or

territory environment agency to closely monitor and measure these emissions. These existing sampling data can be used to calculate annual emissions to the NPI.

3.3 Emissions to land

Emissions of substances to land include solid wastes, slurries, sediments, spills and leaks, storage, and distribution of liquids. Such emissions may contain NPI-listed substances. Emission sources can be categorised as:

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

Due to the highly volatile nature of both the paint and ink products and constituents, most leaks and spills are likely to end up as an atmospheric fugitive emission (see Section 3.1.1 above).

4 Threshold calculations

A facility is required to report emissions to the NPI in the event a threshold, or thresholds, are exceeded. Details of thresholds are available in the *NPI Guide*, however for paint and ink manufacturing it is expected that reporting will be required as a result of "usage" of individual, or the total of all, volatile organic compounds (VOCs).

The reporting threshold for individual VOCs is 10 tonnes, total VOCs (TVOCs) is 25 tonnes.

4.1 Reporting individual VOCs

The NPI is aware of industry concerns that reporting of individual VOCs may reveal commercially sensitive paint and ink formulations. Facilities with a concern of this nature should contact your state or territory environmental agency for advice.

5 Techniques for estimating emissions

The emissions to air, land and water for every NPI substance that trips a threshold must be reported from all sources in the facility to determine the total point source and total fugitive source emissions. *The NPI Guide* outlines detailed information on thresholds and identifying emission sources.

There are five types of emission estimation techniques (EETs) that may be used to calculate emissions from your facility. These are:

- sampling data or direct measurement
- mass balance
- emission factors, *and*
- an approved alternative.

Generally, paint and ink manufacturing activities report emissions for TVOCs using a number of techniques. The above EETs are described in this section. *The NPI Guide* can be referred to for further information relating to EETs.

Select the EET (or mix of EETs) that is most appropriate for your purposes. For example, you might choose a mass balance to 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 manual, 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 the paint and ink industry. However, the absence of an EET for a substance in the manual does not 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 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 (e.g. spills) will also need to be estimated. Emissions to land, air, and water from spills must be estimated and added to process emissions when calculating total emissions for reporting purposes. The emission resulting from a spill is the net emission, i.e. the quantity of the NPI reportable substance spilled, less the quantity recovered or consumed immediately (within 24 hours) during clean up operations.

5.1 Emission factors

An emission factor is a tool that is used to estimate emissions to the environment. In this manual, it relates to the quantity of substances emitted from a source to some common activity associated with those emissions. Emission factors are usually expressed as the weight of a substance emitted multiplied by the unit weight, volume,

distance, or duration of the activity emitting the substance (e.g. kilograms of TVOCs per cubic metre of paint or ink produced).

When using emission factors, you should be aware of the associated emission factor rating (EFR) code and what the rating implies. An A or B rating indicates a greater degree of certainty than a D or E rating. A rating of U indicates that the emission factor uncertainty has not been rated, such as in the case of emission factors generated by modelling rather than actual test results. 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:

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

Emission factors are used to estimate a facility's emissions by the general equation shown as Equation 1.

Equation 1

$$E_{TVOC} = EF_{TVOC} \times Q_P$$

Where:

E_{TVOC}	=	total emissions of TVOCs from the facility, kg/yr
EF_{TVOC}	=	TVOC emission factor, kg/t product
Q_P	=	amount of product produced, t/yr

Example 1 - Using emission factors

Based on a review of purchasing data, a paint manufacturing facility has established that they have used more than 25 tonnes of VOCs in the year and therefore have a requirement to report to the NPI.

A paint manufacturing facility produces 5000 m^3 of solvent-based paint and 50,000 m^3 of water-based paint in the reporting period. Using the emission factors listed in Appendix B, the TVOC emissions for the facility can be estimated from Appendix B.

First, calculate the TVOC emissions from solvent-based paint manufacturing:

E_{TVOC}	=	$EF_{TVOC} \times Q_P$
EF_{TVOC}	=	2.1 kg/m^3
Q_P	=	5000 m^3/yr
E_{TVOC}	=	2.1×5000
	=	10,500 kg TVOC/year from the manufacture of solvent-based paint

Next, calculate the TVOC emissions from water-based paint manufacturing:

E_{TVOC} = $EF_{TVOC} \times Q_P$
EF_{TVOC} = 0.32 kg/m^3
Q_P = 50,000 m^3/yr

E_{TVOC} = $0.32 \times 50{,}000$
= 16,000 kg TVOC/year from the manufacture of water-based paint

Finally, add the TVOC emissions from both solvent-based paint and water-based paint production to provide the total TVOC emissions for the facility for the reporting period:

E_{TVOC} = E_{TVOC} (solvent-based paint) + E_{TVOC} (water-based paint)
= 10,500 + 16,000
= 26,500 kg/yr

The reported value will be 26,500 kg (which is reported to the NPI as a fugitive emission to air).

Emission factors applicable to this manual are listed in Appendix B. You must ensure that you estimate emissions for all substances relevant to your process.

Emission factors developed from measurements for a specific process may sometimes by used to estimate emissions at other sites. For example, a company may have several units of similar model and size; if emissions were measured from one facility, an emission factor could be developed and applied to similar sources. If you wish to use a site-specific emission factor, you should first seek approval from your state or territory environment agency before its use for estimating NPI emissions.

5.2 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. If this is the case, the NPI does not require you to undertake additional sampling and measurement, rather simply reporting the emissions will be adequate. Any emissions test data for paint and ink manufacturing plants are typically in the form of exposure monitoring results. Occupational health data may be used in conjunction with exhaust system flow rates to calculate fugitive emissions from a room, floor, or building. Equation 2 should be used in calculating these emissions.

Equation 2

$$E_X = FR \times 60 \times OH \times C_x \times M_x \div [V_{m,\,amb} \times 10^6 \times 10^3]$$

Where:
E_X = emissions of VOC species x, kg/yr
FR = flow rate through the exhaust ventilation system, m^3/min
60 = 60, min/hr

OH	=	hours per year that the exhaust system is operational, hr/yr
C_x	=	concentration of VOC species x, ppmv
M_x	=	molecular weight of VOC species x, g/mol
$V_{m, amb}$	=	molar volume of gas at ambient temperature, m^3/mol
10^6	=	1,000,000, ppmv
10^3	=	1,000, g/kg

The use of Equation 2 is demonstrated in Example 2.

Example 2 - Using direct measurement
This example shows how Equation 2 is used to calculate toluene emissions from a building where several mixing vessels are located. For this example, the building exhaust flow rate (FR) is 500 m^3/min. The exhaust system operates for 8,160 hr/yr (OH). Ambient emissions testing for the building indicates that the concentration of toluene is 0.1 ppmv at an ambient concentration of 25°C.

Emissions of toluene can be estimated from Equation 2.

E_X	=	$FR \times 60 \times OH \times C_x \times M_x \div [V_{m, amb} \times 10^6 \times 10^3]$
FR	=	500 m^3/min
OH	=	8,160 hr/yr
C_x	=	0.1 ppmv
M_x	=	92.1 g/mol
$V_{m, amb}$	=	0.02479, m^3/mol
E_X	=	$500 \times 60 \times 8{,}160 \times 0.1 \times 92.1 \div [0.02479 \times 10^6 \times 10^3]$
	=	90.948 kg toluene/year
	=	91 kg toluene/year

TVOC emissions can be calculated from the sum of all individual VOC emissions measured and subsequently calculated in this manner – only the TVOC emissions are required to be reported.

5.3 Mass balance

The material balance method requires the totalling of all materials received at the plant and then subtracting out all of the known losses or transfers of the material off-site (including finished product and waste material). The difference is assumed to have been emitted to the atmosphere. The quantity received and the quantity lost or used should be for the same time period, typically July 1 to June 30 for the reporting year.

Use Equation 3 for calculating emissions using the material balance approach.

Equation 3

$$E_X = Q_r - Q_p - Q_{rec} - Q_w - Q_{xi}$$

Where:

E_X	=	emissions of VOC species x, kg/yr

Q_r	=	quantity of VOC species x that is received as a raw material, kg/yr
Q_p	=	quantity of VOC species x that is shipped out in the final product, kg/yr
Q_{rec}	=	quantity of VOC species x that is recovered by all methods, kg/yr
Q_w	=	quantity of VOC species x that is contained in all waste generated during the reporting period, kg/yr
Q_{xi}	=	quantity of VOC species x that remains in the raw material inventory, kg/yr

The use of Equation 3 is demonstrated in Example 3.

Example 3 - Using mass balance
This example shows how total ethanol emissions may be calculated for a paint manufacturing facility using Equation 3. In a given year, a paint facility receives 50 tonnes (50,000 kg) of ethanol (Q_r).

Based on the total amount of product shipped off-site and records of product composition, the facility estimates that the amount of ethanol shipped out in product form (Q_p) is 30,000 kg. The amount of ethanol recovered (Q_{rec}) by the facility's solvent recovery unit is 6,000 kg. Based on waste composition analysis, the facility estimates that the amount of ethanol that was found in all wastes generated during the year (Q_w) is 3,500 kg. The amount of ethanol that was found to be in the facility's inventory at the end of the reporting period (Q_{xi}) is 10,000 kg.

Emissions of ethanol can be estimated from Equation 3.

$E_X = Q_r - Q_p - Q_{rec} - Q_w - Q_{xi}$
Q_r = 50,000 kg/yr
Q_p = 30,000 kg/yr
Q_{rec} = 6,000 kg/yr
Q_w = 3,500 kg/yr
Q_{xi} = 10,000 kg/yr

E_X = 50,000 – 30,000 – 6,000 – 3,500 – 10,000
= 500 kg ethanol/year

TVOC emissions can be calculated from the sum of all individual VOC emissions calculated in this manner – only the TVOC emissions are required to be reported.

5.4 Approved alternative

You are able to use emission estimation techniques that are not outlined in this document. You must, however, seek the consent of your state or territory environmental agency. For example, if your company has developed site-specific emission factors, you may use these if they have been approved by your local environmental agency.

6 Next steps for reporting

This manual has been written to reflect the common processes employed in the paint and ink manufacturing industry. To ensure a complete report of the emissions for your facility, it may be necessary to refer to other EET manuals. These may include, but are not limited to:

- combustion in boilers
- combustion in engines
- fuel and organic liquid storage
- fugitive emissions *and*
- sewage and waste water treatment.

When you have a complete report of substance emissions from your facility, report these emissions according to the instructions in *The NPI Guide*.

7 References

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Appendix A: Definitions and abbreviations

Cx	Concentration of VOC species x, ppmv
EETs	Emission estimation techniques
EFR	Emission factor rating
hr	Hour
g	Grams
kg	Kilograms
m^3	Cubic meters
min	Minute
mol	Moles
M_x	Molecular weight of species x, g/mol
NPI	National Pollutant Inventory
ppmv	Parts per million by volume
t	Tonnes = 1,000 kg
TVOCs	Total volatile organic compounds
$V_{m, amb}$	Molar volume at ambient temperature (m^3/mol)
VOCs	Volatile organic compounds
yr	Year

Appendix B: Emission factors

Process	Substance	Emission factor (kg/m^3)	Rating[1]
Solvent-based paint manufacturing[2]	TVOCs	2.1	U
Water-based paint manufacturing[3]	TVOCs	0.32	U
Ink manufacturing[4]			
General	TVOCs	60	U
Bodying Oils	TVOCs	20	U
Oleoresinous	TVOCs	75	U
Alkyds	TVOCs	80	U
Acrylic	TVOCs	10	U

Notes:
1. Details on the emission factor rating (EFR) can be found in this manual at Section 5.1.
2. Based on calculation of generic solvent-based paints utilising the EIIP methodology
3. Based on calculation of generic water-based paints utilising the EIIP methodology
4. Based on data from Section 6.4, AP-42

Appendix C: Modifications to the paint and ink manufacturing emission estimation technique (EET) manual (Version 2.0 June 2007)

Page	Outline of alteration
Throughout	Removed emission estimation methodology for PM_{10} Updated emission factors Updated examples Updated process description and diagrams