# Emissions Estimation Technique Manual

**for**

## Aggregated Emissions from Printing and Graphic Arts

## November 1999

*Version 1.0 - First Published 1 November 1999*

**EMISSIONS ESTIMATION TECHNIQUE MANUAL:**
**AGGREGATED EMISSIONS FROM PRINTING AND GRAPHIC ARTS**

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## 1.0 Introduction

### *1.1 The NPI*

The National Pollutant Inventory (NPI) was established under a National Environment Protection Measure (NEPM) made by the National Environment Protection Council (NEPC) under Commonwealth, State and Territory legislation on 27 February 1998. This Measure is to be implemented progressively through the laws and administrative arrangements of each of these participating jurisdictions (i.e. State and Territory Governments).

The NEPM and an associated Memorandum of Understanding for the NPI, which have been published as a single document by the NEPC, provide more details on the purpose and structure of the NPI, and the arrangements for implementation of the NEPM that have been agreed by the jurisdictions. Users of this Manual should read this publication if they are unfamiliar with the NEPM or the NPI.

### *1.2 Purpose and Scope of the Manual*

The NPI will be developed as an internet database designed to provide information on the types and amounts of certain chemical substances being emitted to the air, land and water environments. If the NPI is to achieve its aim of communicating useful and reliable information to the community, industry and governments on pollutants present in our environment, the emissions estimation techniques (EETs) used to generate inputs to the NPI need to be consistent, and the process for developing these techniques needs to be transparent. This Manual has been developed, reviewed and finalised in this context.

The NEPM contains a list of substances for which emissions will be reported on an annual basis to the Commonwealth Government, which will then compile and publish the NPI. The aggregated emissions manuals, of which this is one, have been prepared to assist State and Territory Governments in preparing these submissions, and to facilitate consistent reporting between these jurisdictions.

State and Territory Governments will also be compiling and submitting emissions data based on annual inputs from reporting facilities. These facilities are primarily industrial enterprises which use (or handle, manufacture or process) more than specified amounts of certain polluting substances, burn more than specified amounts of fuel, or consume more than certain amounts of energy. These amounts or “thresholds” (which are clearly defined in the NEPM) govern whether an industrial facility is required to report and what substances it is required to report on, and industry handbooks are being developed to help industries to prepare the information for these reports.

The aggregated emissions manuals complement these handbooks, and are intended to enable Governments to estimate emissions from non-industrial activities (e.g. transportation, domestic and commercial activities) and emissions from industry which are not reported because the relevant thresholds are not exceeded or are exempt from reporting.

Annual submissions are also to be prepared and submitted in conformance with the NPI Data Model and Data Transfer Protocol. For emissions to the air environment, this Protocol only requires jurisdictions to submit data on emissions into the particular airsheds that are listed in the Protocol, and not to the rest of each jurisdictional area. For example, under the 1998 to 2000 Memorandum of Understanding, in Victoria, emissions data are only required for the Port Phillip and Latrobe Valley Regions. In addition, emissions data are required to be submitted on a gridded basis, with each jurisdiction determining a grid domain and grid cell size necessary to meet its obligations under Section 7 of the NEPM.

Therefore, in addition to recommending and providing details and examples of appropriate emissions estimation techniques (EETs) for the relevant NPI substances, this Manual provides guidance on the spatial allocation of emissions and the use of area-based surrogates for accurately distributing the activities or sources in question.

### *1.3 Application of the Manual*

Each of the AE manuals provides details of:

- the NPI substances that are expected to be emitted from the relevant aggregated source type;
- the origins or sources of the emissions, and the processes that may generate them;
- the impacts of any control equipment or procedures on those emissions;
- the broad approaches that may be employed in the estimation and spatial allocation of emissions;
- details of emission factors to be used in the estimation of emissions; and
- a series of illustrative sample calculations for each estimation technique.

Each of the manuals also contains a section on "Uncertainty Analysis", which provides information and guidance to users on the reliability of the various estimation techniques, problems and issues associated with their development and application, and recommendations for their improvement. In preparing the AE manuals it has been recognised that some jurisdictions already undertake detailed emissions inventories on a regular basis, based on relatively sophisticated methodologies. For these jurisdictions the manuals offer techniques which represent commonly available best practice for emissions estimation in Australia (i.e. techniques of high quality which can be employed by larger or more experienced jurisdictions with an acceptable expenditure of time and effort). The most recent developments in inventory methodology in Australia and overseas have been considered in selecting and documenting these techniques.

Where a more simplified methodology for emissions estimation of acceptable quality is available, it is recommended in the manual for the use of those jurisdictions which may, for the time being at least, lack the data, resources or expertise to employ a more sophisticated approach, or not see the need for highly reliable estimates in that particular part of the inventory.

## 2.0 Emissions Covered by the Manual

### *2.1 NPI Substances*

The predominant emissions from the printing and graphic arts industry are volatile organic compounds (VOCs) contained in the printing inks, fountain solutions and cleaning solutions. VOCs is a general term, which refers to a large and diverse group of chemicals including hydrocarbons, oxygenates and halocarbons. Some of these VOCs are NPI substances, and those typically emitted by printing operations are listed below.

***Table 1: NPI Substances Typically Emitted by Printing Operations***

| | |
|---|---|
| Acetone | Styrene |
| Ethanol | Toluene |
| Ethyl acetate | Total volatile organic compounds (VOCs) |
| Methyl ethyl ketone | Xylenes |
| Methyl isobutyl ketone | |

Emissions from the printing industry can also originate from presses, cleaning operations, ink mixing operations and ink storage tanks. Printing operations may use storage tanks to store inks, solvents, and other organic substances as fuel. Emissions from storage tanks will not be covered in this manual

Energy sources such as natural gas, oil and electricity are used to operate the dryers used in heatset printing (offset lithography and letterpress), gravure, and flexography. A boiler may be used to generate steam for steam- and water-based flexography and to regenerate the activated carbon beds used as emission control devices. Combustion emissions may include particulate matter (PM10), sulphur dioxide, oxides of nitrogen, carbon monoxide, and VOCs. Emissions from these combustion sources will also not be covered in this manual.

### *2.2 Emission Sources and Related Processes*

For this manual the term “printing” includes the five basic processes of the printing (and graphic arts) industry: gravure, offset lithographic, letterpress, flexography and screen-printing.

Printing may be performed on a variety of materials such as coated or uncoated paper, cardboard, plastic film, foil, metals, fabrics, and wall or floor coverings. A great variety of manufactured products undergo printing of some kind, including newspapers, magazines, packaging, stationery and other specialty products. The material that is subject to the printing process (i.e. receives the printing) is called the substrate.

Printing inks vary widely in composition, but all consist of three major components:

- pigments, which produce the desired colours and are composed of finely divided organic and inorganic materials;

- binders, which lock the pigments to the substrate and are usually composed of organic resins and polymers; and
- a liquid phase, usually composed of solvents (organic compounds) or water, that dissolves and disperses the pigments and binders, and evaporates from the ink during the drying process.

Emissions vary with the printing process, ink composition and coverage, press size and speed, production volume and operating time. The type of ink used is usually the most important factor in estimating emissions from printing operations. This is because most of the solvent contained in the inks and cleaning products eventually finds its way into the atmosphere. The type of substrate generally has little or no effect on emissions.

### *2.2.1 Gravure Printing*

Gravure is a printing process in which an image is engraved into the surface of a cylinder. The cylinder rotates in a single colour ink trough, from which the ink is picked up in the engraved area and transferred onto the substrate.

Gravure printing requires very fluid inks that flow from the cylinder to the substrate at high press speeds. Both solvent- and water-borne ink systems can be used in gravure printing but these systems are not interchangeable, as water-borne systems usually need additional drying.

For gravure printing it is important that the ink or other coating dries quickly between each colour. Therefore, the liquid phase carrier must be evaporated between stations. The main solvents contained in the inks used in this process are ethanol, ethyl acetate, methyl ethyl ketone, toluene and acetone (QDEH 1998).

In packaging gravure printing the inks contain 55 to 80 percent by volume of low boiling-point solvent (QDEH 1998). However, publication gravure presses in Australia now use water-borne ink systems to reduce emissions of VOCs from the press, which lowers the potential for worker and environmental impacts.

### *2.2.2 Flexography Printing*

Flexography is a printing process in which the image area is raised from the surface of a rubber printing plate, like a typewriter. The inks are applied to the plate with a metering cylinder, from which they are transferred directly onto the substrate. The process is usually web (continuous roll) fed and used for medium or long multi-colour runs on a variety of substrates.

The ink used is of low viscosity and is often about 75 percent organic solvent (USEPA 1995). Solvents must be compatible with the rubber plates, so aromatic solvents are not used. Some of the components of solvent-based flexographic ink are ethanol, n-propyl alcohol, isopropyl alcohol, acetates, glycols, ketones and ethers.

Publication printing generally uses inks that are entirely organic solvent-borne, but some flexography now uses water-borne inks (AWMA 1992). For example, water-borne inks can be used to print corrugated board, newsprint and most paperboard. However, fast-drying (solvent-borne) inks are required for plastic films so the web can be rewound or processed into the final product at the end of the press.

### *2.2.3 Offset Lithographic Printing*

Lithography is characterised by a planographic image carrier, where the image and non-image areas are on the same plane. The image area is ink wettable and water repellent, and the non-image area is chemically repellent to ink using a dampening solution. The graphic image is applied from an ink-covered print plate to a rubber-covered *blanket* cylinder and then transferred into the substrate, hence the name *offset* lithography.

There are two types of inks used in lithographic printing, heatset and non-heatset. With heatset inks the solvents are driven off in a hot air or direct-flame dryer to set the ink, while non-heatset inks dry under ambient conditions through oxidation and polymerisation. Both types of inks contain high-boiling point (>150°C) petroleum oils. The substrate in offset lithography can be either a web or a sheet. A web substrate can be used with either heatset or non-heatset inks, while a sheet fed substrate can only use non-heatset inks.

With heatset inks the high temperatures in the dryer evaporate the majority of solvent, leaving only 20 to 40 percent of the solvent in the substrate.

The dampening solution in the web fed method is about 15 to 30 % isopropyl alcohol (USEPA 1995), while the sheet fed solution is lower at 5 to 20 % (AWMA 1992). Dampening solutions containing lower VOCs and alcohol substitutes are gaining acceptance within the industry in Australia.

Offset lithographers also use cleaning solutions to clean the press and machine parts. These cleaning solutions have traditionally contained high levels of solvents (90 to 100 %) mixed with detergents. Some low- or no-solvent cleaners are becoming available, in which the solvent content ranges from nil to 30 percent.

### *2.2.4 Letterpress Printing*

In letterpress printing the image area is raised (like a rubber stamp) and the ink is transferred to the substrate directly from the image surface. Letterpress printing that uses a web is printed on both sides, one side at a time, and is dried in hot-air ovens after each colour is applied (heatset). For sheet-fed letterpress printing oxidative drying inks (non-heatset) are used and therefore result in very small emissions, and thus are not mentioned further in this manual.

Letterpress ink contains resins dissolved in aliphatic hydrocarbons (alkenes), usually about 40 % by volume of the solvent (QDEH 1998). Water washable letterpress inks are sometimes used for printing paper and corrugated boxes and these inks contain glycol-based solvents.

Letterpress printing uses cleaning solvents (with 90 to 100 % solvents) which are similar to those used in lithography.

#### *2.2.5 Screen-Printing*

Screen-printing involves forcing ink through a stencil in which the image areas are porous. The screens are generally made of silk, nylon or metal mesh. Most screen-printing work in Australia is conducted on textiles.

Depending on the substrate printed, the substrate can be dried after each printing station or, for absorbent substrates, after all colours are printed. Solvent- and water-borne inks are dried in hot-air or infrared drying ovens. Dryer gases are partially recycled and partially vented. Ink systems used in screen-printing include water-borne, solvent-borne, ultraviolet cure, and plastisol (polyvinyl chloride) which is mainly confined to textile printing.

Solvent-based ink systems have large amounts of VOCs, and contain aliphatic, aromatic and oxygenated organic solvents.

### *2.3 Emission Controls*

In recent years the printing industry in Australia has implemented emission prevention and control techniques that have improved efficiency and increased profits while at the same time minimising environmental impacts.

Incinerators (afterburners), coupled with a condenser for oil/water separation, are the main forms of emission control in the printing industry. Incinerators can be catalytic, thermal or pebble bed. Pebble bed incinerators combine the functions of a combustion device and a heat exchanger in one system.

Carbon adsorption systems are used to recover the solvent using a bed of activated carbon. The emissions are passed over the bed where the solvent is attracted to the surface of the carbon. The solvents are washed from the carbon using steam, from which the solvent is then separated for further use.

The use of water-borne inks results in an effective reduction in emissions without requiring any emission control technology as mentioned above.

Automatic cleaning equipment can often be retrofitted to existing presses and operations. Therefore, lower volumes of cleaning formulations are used which reduces air contact and thus volatilisation. Most automatic cleaning systems are designed to enable recycling and reuse of cleaning solutions.

Other control methods that have gained wide industry acceptance include:

- improving housekeeping and better operating practices, such as covering reservoirs and containers, scheduling jobs according to increasing darkness of ink colour, and using wipes as long as possible;

- reducing ink use and vaporisation of ink by using automatic ink levellers and diaphragm pumps; and
- using fountain coolers to reduce evaporation form the dampening fountain.

It is difficult to make a quantitative estimate of the efficiency of each control method listed above. Abatement largely depends on the process being controlled, and printing may involve hundreds of different processes.

## 3.0 Emissions Estimation Techniques

This section provides an outline of the data required and techniques recommended for calculating emissions of total and speciated VOCs from area-based printing operations. The equations have been developed to deal with various printing processes, with different processes requiring particular inputs to the equations.

### *3.1 Approaches Employed*

#### *3.1.1 Estimating Total VOC Emissions*

Three techniques can be used, depending on the information available in the State or Territory (jurisdiction). They are presented here in order of preference, as some techniques are considered more accurate and reliable than others.

Best Practice Technique: Using a Mass Balance Approach

The best practice technique for estimating emissions from area-based printing operations is a mass balance approach.

When estimating total VOC emissions from printing operations, two types of printing processes need to be considered: non-heatset and heatset printing.

Non-heatset inks are used in all five printing processes. For non-heatset inks and their associated solvents, it is assumed that all of the VOCs in the solvents are eventually emitted to the atmosphere.

Heatset inks are only used in Offset Lithography and Letterpress printing processes. For heatset inks, some of the solvents are destroyed or retained in the substrate as a result of the process, so not all of the VOCs introduced into the process in the solvents are released to the air.

Because both types of processes (and inks) are usually used in a jurisdiction or airshed, their emissions need to be separately estimated (see Equations 1 and 2 below) and added together to give the total emissions for that region.

The information that is required for this EET includes:

- the total volume, and typical solvent content and density, of all inks used in *non-heatset* printing in the jurisdiction (or airshed) of interest;
- the volumes, solvent contents and densities, of inks used in the different *heatset* printing processes in the jurisdiction (or airshed); and
- the VOC speciation, in terms of relevant NPI substances, of the inks used in non-heatset and heatset printing processes.

As discussed in Section 3.1.1 below, there is a serious lack of solvent speciation data available from the industry at the present time, however the industry should be able to provide the other information.

Solvent emissions from non-heatset inks can be computed from Equation 1 using the mass balance concept. Typical values for VOC content (S) and density (d) for non-heatset inks are 75% and 0.70 respectively, which may be used as default values if data are unavailable.

**Equation 1: Estimating total VOC emissions from non-heatset inks**

$$E_1 = I * (S / 100) * d$$

where

- $E_1$ = Total VOC emissions from non-heatset inks in the jurisdiction, kg $yr^{-1}$
- I = Total annual ink usage in jurisdiction (or airshed), L $yr^{-1}$
- S = Typical solvent content of inks, volume percent
- d = Typical solvent density, kg $L^{-1}$

Where heatset inks are used, some of the solvent is thermally degraded and/or left in the substrate. This amount may vary with the printing process used. Equation 2 therefore provides an EET that should be used for each heatset printing process.

**Equation 2: Estimating emissions from heatset inks**

$$E_i = I * (S_i / 100) * d_i * \{(100 – R_i) / 100\}$$

where

- $E_i$ = Total VOC emissions from heatset printing process i in the jurisdiction, kg $yr^{-1}$
- I = Annual ink usage in the jurisdiction for process I, L $yr^{-1}$
- $S_i$ = Solvent content of ink used in process i, % by volume
- $d_i$ = Solvent density of ink used in process i, kg $L^{-1}$
- $R_i$ = Amount of solvent destroyed or fixed in substrate with printing process i, percent

and

$$E_2 = \sum_i E_i$$

where

- $E_2$ = Total VOC emissions from all heatset printing inks used in the jurisdiction, kg $yr^{-1}$

Typical values for terms in Equation 2 can usually be obtained from industry associations and ink manufacturers. If the required data are not available, the values in Table 2 can be used as a guide. Typical default values for heatsetting inks as a whole would be as follows: S = 40 %, d = 0.70 kg $L^{-1}$ and R = 40 %.

***Table 2: Typical Parameters for Heatset Printing Processes***

| Printing Process | Use | Solvent Content of Ink [S] (volume %) | Solvent Destroyed or Fixed in Substrate [R] (volume %) |
|---|---|---|---|
| Offset Lithography | Publications | 40 | 40 (hot air dryer)<br>60 (direct flame dryer) |
| Letterpress | Publications | 40 | 40 |

Source: QDEH (1998)

Total VOC emissions for the jurisdiction (E) can then be derived as the sum of the emissions for non-heatset inks ($E_1$) and heatset inks ($E_2$), the latter being the sum of emissions from individual heatset printing processes (if data are available to make this distinction).

When using this technique consideration must be given to the ink and solvent usage (and resulting emissions) of those facilities that will be reporting individually under the NPI. Either the amounts of solvent and ink usage by reporting facilities must be subtracted from the usage figures in Equations 1 and 2 before calculating and summing the emissions, or the reported emissions must be subtracted from the aggregated total.

Default Technique: Using an Employee-Based Emission Factor

As a default technique of lesser reliability, emissions can be calculated from the overall employee-based emission factor provided in Table 3. Data can be obtained from Australian Bureau of Statistics (ABS) for the number of employees in various industries such as printing and publishing. Production employee numbers would provide better estimates than total workplace employee numbers, but these data are more difficult to obtain.

**Equation 3: Estimating emissions using employee-based emission factors**

$$E = EF_e * N_e$$

where

$E$ = Total VOC emissions in the jurisdiction, kg $yr^{-1}$
$EF_e$ = Employee-based emission factor, kg $employee^{-1}$ $yr^{-1}$
$N_e$ = Number of industry employees in the jurisdiction

Again, when using this technique, emissions from reporting facilities must be subtracted from the total emissions from Equation 3, since the employment figure is usually for the whole printing and publishing industry sector.

Default Technique: Using a Per Capita Emission Factor

A further default method of even less accuracy, based on a per capita emission factor, can be used when employment statistics cannot be obtained for the industry. The emission factor in Table 3 was developed for the US situation, and provides a basic indicator of emissions arising from the demand for printing services over large geographical areas, but reduced to a per capita basis. Use of this factor implies a range of assumptions about similarities between the economies, societies and printing industries in Australia and the USA, which may not be entirely valid.

**Equation 4: Estimating emissions using population-based emission factors**

$$E = EF_p * P$$

where

$E$ = Total VOC emissions in the jurisdiction, kg $yr^{-1}$
$EF_p$ = Population-based emission factor, kg $yr^{-1}$ per capita
$P$ = Population of the jurisdiction

With this EET there is no need to subtract emissions from reporting facilities because this emission factor has been developed for estimating emissions from small to medium print shop and in-house printing services in general industries, which is a reasonable approximation of non-reporting facilities.

### *3.1.2 Speciating VOC Emissions*

**Equation 5: Speciating VOC emissions from a printing process**

$$E_{ij} = E_i * C_{ij} / 100$$

where

$E_{ij}$ = Emissions of VOC species j from printing process i, kg $yr^{-1}$
$E_i$ = Total VOC emissions from printing process i, kg $yr^{-1}$
$C_{ij}$ = Concentration of VOC species j in the solvents used in printing process i, % by mass

and

$$E_j = \sum_i E_{ij}$$

where

$E_j$ = Total emission of VOC species j in the jurisdiction, kg $yr^{-1}$

Unfortunately, at the present time, there is a serious lack of reliable VOC speciation data on solvents used in the various printing processes. There are no comprehensive local data currently available on solvent speciation. Although attempts have been made in the past to bring together data on the composition of local solvents, there are such a variety of inks and solvents used (even in the same process) that this task has so far proven to be too challenging.

US data are available separately from the USEPA and the California Air Resources Board, but these data do not agree and it is difficult to reconcile them in any meaningful way. Some sketchy USEPA data is provided in Table 4, but it is far from comprehensive. The US data are focussed more on photochemically reactive VOCs than the types of substances listed in the NPI NEPM. No speciation data at all are provided for some of the NPI substances.

Therefore, until there are reliable and comprehensive data that can be used with confidence in Australia, it is recommended that emissions should be estimated simply as total VOCs. This data should ideally take the form of representative VOC speciations for both heatset and non-heatset printing inks, which take into account the types of inks and printing processes associated with each of these ink types.

### *3.2 Spatial Surrogates and Spatial Allocation*

Spatial allocation may be needed to apportion emissions from a jurisdictional level to an airshed if data on ink usage and composition are not available at the airshed level. This speciation is usually undertaken with a population scaling factor equal to the ratio of airshed population to overall jurisdiction population.

Spatial surrogates are also needed to allocate emissions from the airshed to individual grid cells. The surrogate used will depend on which EET has been employed for calculating total emissions for the jurisdiction or airshed. If Techniques 1 or 2 have been used, the preferred spatial surrogate would be industrial zoning (according to planning information). That is, the emissions would be distributed in proportion to the area of industrially zoned land in each grid cell. This could be derived from GIS-based land use zoning information or estimated from planning maps. However, if Technique 3 has been used or the industrial zoning data cannot be obtained, population density can be used as the default spatial surrogate. This is a reasonable approximation as most printing enterprises will be located in or near urban areas and close to their customers, workforce and transportation facilities.

### 3.3 Emission Factors

The emission factors and speciation profiles that may be used for printing and graphic arts activities are shown in Table 3 and Table 4 respectively. In the case of Table 3, these are emission factors to be used with default EETs.

***Table 3: VOC Emission Factors for Printing Operations***

| Type of Emission Factor | Emission Factor (kg VOC $person^{-1}$ $yr^{-1}$) |
|---|---|
| Employee emission factor | 169[a] |
| Per capita emission factor | 0.4[b] |

[a] QDEH (1998).
[b] USEPA (1995).

The following table provides some information on VOC speciation of solvents used in the printing industry in the US. However, as remarked in S 3.1.2, this is information is not sufficiently reliable or comprehensive (e.g. it does not deal with all NPI substances that are emitted) to generate full speciations using Equation 5.

***Table 4: Weight Percentages of Speciated VOCs in Some US Solvents***

| Type of Printing | Speciated VOC | Weight (%)[a] |
|---|---|---|
| Flexography | Acetone | 24.47 |
| | Methyl ethyl ketone | 54.27 |
| | Methyl isobutyl ketone | 14.78 |
| | Toluene | 6.48 |
| Offset Lithography | Formaldehyde | 21.8 |
| Gravure | Cyclohexane | 10 |
| | Methanol | 6 |
| | Ethylbenzene | 6 |
| General (others) | Cyclohexane | 4.57 |
| | Dibutyl phthalate | 9.99 |
| | Toluene-2,4-diisocynate | 0.03 |

[a] USEPA (1992).

### 3.4 Sample Calculations

**Example 1: Using the mass balance method**

Using Equation 1 with a total annual usage of 1,500,000 L of non-heatset inks with a typical VOC content of 70 % and density of 0.72 kg $L^{-1}$, total annual VOC emissions from non-heatset printing inks are

$$E_1 = I * (S / 100) * d$$
$$= 1.5 * 10^6 * (70 / 100) * 0.72$$
$$= 7.56 * 10^5 \text{ kg yr}^{-1}$$

Using Equation 2 with a total annual usage of 1,200,000 L of heatset inks, and assuming a typical VOC content of 40 %, density of 0.70 kg $L^{-1}$ and R value of 0.45 (i.e. a single VOC content, density and R value for all heatsetting applications), total annual VOC emissions from heatset printing inks are

$$E_2 = I * (S / 100) * d * [(100 – R) / 100]$$
$$= 1.2 * 10^6 * (40 / 100) * 0.7 * [(100 – 45) / 100]$$
$$= 1.85 * 10^5 \text{ kg yr}^{-1} \text{ of VOCs}$$

Adding the results from Equations 1 and 2, total VOC emissions in the jurisdiction from all printing operations are

$$E = [7.56 + 1.85] * 10^5$$
$$= 9.41 * 10^5 \text{ kg yr}^{-1} \text{ of VOCs}$$

**Example 2: Using the population-based emission factor**

Using Equation 4 with a population of 3 million the total annual VOC emissions are

$$E = EF_p * P$$
$$= 0.4 * 3 * 10^6$$
$$= 1.2 * 10^6 \text{ kg of VOCs}$$

**Example 3: Calculating speciated VOCs**

Using Equation 5 with the result from Example 1 and a weight fraction for acetone of 25 % for heatset printing activities, acetone emissions from this type of printing process are

$$E_{heatset, acetone} = E_2 * C_{heatset,acetone} / 100$$
$$= 1.85 * 10^5 * 25 / 100$$
$$= 4.63 * 10^4 \text{ kg yr}^{-1}$$

# 4.0 Uncertainty Analysis

This section discusses the reliability of the data and emission factors presented, any problems or issues encountered, and recommendations for further work to improve the accuracy of the data being collected for the NPI.

## *4.1 Data Reliability*

The accuracy of the best practice technique is dependent on the quality of the data that are employed on ink usage, solvent content and density, and amount of solvent retained in the various printing processes. If industry associations and ink manufacturers can provide these data, then the figures are likely to be have medium to high reliability.

The large numbers of ink formulations in use necessitate the use of average VOC contents and speciation profiles for different printing processes. The accuracy of these profiles can vary considerably, as work of varying levels of relevance and thoroughness has been undertaken in producing the available data. For these reasons average figures for key solvent parameters such as solvent content in ink are considered to have low to medium reliability, while currently available data on VOC speciation are considered to have little use at this stage.

## *4.2 Reliability of Emission Factors*

Estimating printing emissions using ink usage data will be considerably more accurate than using employee-based or per capita emission factors, particularly where the emission factors have developed for a substantially different area. The use of employee-based or per capita emission factors assumes that the types, quantities and formulations of ink used in the airshed are similar to those in the area for which the emission factors were developed. This implies a range of assumptions about similarities between the economies, societies and printing industries in the two regions.

The employee-based factor used in this manual was developed for Queensland and is preferred to the per capita emission factor which was developed in US. The former is considered to have medium reliability, the latter to have low accuracy.

## *4.3 Problems and Issues Encountered*

There is a general lack of data compiled on emissions from the different printing processes. A lot is known about the various technologies, but not a great deal about their specific implications for emissions. For this manual it has not really been possible to do much more than distinguish between those processes using heatset and non-heatset inks.

As remarked in Section 3 and immediately above, the lack of reliable and comprehensive solvent speciation data, in terms of the NPI substances that are present, is a serious problem that currently prevents any worthwhile attempt at emissions speciation.

### *4.4 Recommendations for Further Work*

Further development of the estimation techniques is not required, as the basic factors affecting emissions can be readily expressed in the EET equations. However, the acquisition of improved data (such as accurate composite data on solvents used in the different processes and their speciations) based on locally used ink formulations and local levels of consumption, would be highly beneficial to developing more accurate and highly resolved estimates.

## 5.0 Glossary of Terms and Abbreviations

| | |
|---|---|
| AE | Aggregated emissions |
| ABS | Australian Bureau of Statistics |
| AWMA | Air and Waste Management Association |
| EET | Emissions estimation technique |
| EF | Emission factor |
| GIS | Geographic information system |
| NEPC | National Environment Protection Council |
| NEPM | National Environment Protection Measure |
| NPI | National Pollutant Inventory |
| PM10 | Particulate matter less than or equal to 10 μm |
| QDEH | Queensland Department of Environment and Heritage |
| USEPA | United States Environmental Protection Agency |
| VOC | Volatile organic compound |

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