



# **Emissions Estimation Technique Manual**

for

**Aggregated Emissions from  
Motor Vehicle Refinishing**

**November 1999**



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**EMISSIONS ESTIMATION TECHNIQUE MANUAL:  
AGGREGATED EMISSIONS FROM MOTOR VEHICLE REFINISHING**

**TABLE OF CONTENTS**

<b>1.0</b>	<b>Introduction .....</b>	<b>1</b>
<b>1.1</b>	<b><i>The NPI .....</i></b>	<b>1</b>
<b>1.2</b>	<b><i>Purpose and Scope of the Manual .....</i></b>	<b>1</b>
<b>1.3</b>	<b><i>Application of the Manual.....</i></b>	<b>1</b>
<b>2.0</b>	<b>Emissions Covered by the Manual.....</b>	<b>4</b>
<b>2.1</b>	<b><i>NPI Substances .....</i></b>	<b>4</b>
<b>2.2</b>	<b><i>Emission Sources and Related Processes .....</i></b>	<b>4</b>
<b>2.3</b>	<b><i>Emission Controls .....</i></b>	<b>5</b>
<b>3.0</b>	<b>Emissions Estimation Techniques.....</b>	<b>6</b>
<b>3.1</b>	<b><i>Approaches Employed.....</i></b>	<b>6</b>
<b>3.1.1</b>	<b><i>Estimating Total Solvent Emissions.....</i></b>	<b>6</b>
<b>3.1.2</b>	<b><i>Speciating VOC Emissions.....</i></b>	<b>8</b>
<b>3.2</b>	<b><i>Spatial Surrogates and Spatial Allocation .....</i></b>	<b>9</b>
<b>3.3</b>	<b><i>Emission and Speciation Factors.....</i></b>	<b>9</b>
<b>3.4</b>	<b><i>Sample Calculations.....</i></b>	<b>11</b>
<b>4.0</b>	<b>Uncertainty Analysis .....</b>	<b>14</b>
<b>4.1</b>	<b><i>Data Reliability .....</i></b>	<b>14</b>
<b>4.2</b>	<b><i>Reliability of Emission Factors.....</i></b>	<b>14</b>
<b>4.3</b>	<b><i>Problems and Issues Encountered.....</i></b>	<b>14</b>
<b>4.4</b>	<b><i>Recommendations for Further Work .....</i></b>	<b>14</b>
<b>5.0</b>	<b>Glossary of Terms and Abbreviations.....</b>	<b>15</b>
<b>6.0</b>	<b>References.....</b>	<b>16</b>

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**EMISSIONS ESTIMATION TECHNIQUE MANUAL:  
AGGREGATED EMISSIONS FROM MOTOR VEHICLE REFINISHING**

**LIST OF TABLES**

<b>Table 1: List of NPI Substances Typically Emitted by the Motor Vehicle Refinishing Industry .....</b>	<b>4</b>
<b>Table 2: Per Employee and Per Capita VOC Emission Factors .....</b>	<b>10</b>
<b>Table 3: VOC Content of Common Surface Coating Types.....</b>	<b>10</b>
<b>Table 4: VOC Speciation Profiles for Surface Coating Types.....</b>	<b>10</b>
<b>Table 5: Default VOC Speciation .....</b>	<b>11</b>
<b>Table 6: Sample Data on Product Consumption and VOC Content .....</b>	<b>11</b>

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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

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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 aggregated emissions 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 aggregated emissions 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

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expertise to employ a more sophisticated approach, or not see the need for highly reliable estimates in that particular part of the inventory.

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## 2.0 Emissions Covered by the Manual

### 2.1 NPI Substances

The motor vehicle industry uses primers, topcoats and hardeners to repair and refinish damaged motor vehicles. These products contain components (e.g. solvents) which are composed of mixtures of volatile organic compounds (VOCs). VOCs is a general term, which refers to a large and diverse group of chemicals including hydrocarbons, oxygenates and halocarbons. Solvents are also used as thinners and for cleaning.

NPI substances typically emitted by motor vehicle refinishing activities are listed in Table 1.

**Table 1: List of NPI Substances Typically Emitted by the Motor Vehicle Refinishing Industry**

Acetone	Methyl ethyl ketone
Benzene	Methyl isobutyl ketone
Cyclohexane	Toluene
Dichloromethane	Xylenes
Ethyl acetate	Volatile organic compounds
Ethylbenzene	

### 2.2 Emission Sources and Related Processes

This manual deals with emissions from spray painters, smash repairers and panel beaters. It does not cover emissions from motor vehicle manufacturing.

Spray painters, smash repairers and panel beaters carry out most of their motor vehicle refinishing operations in garages and workshops. These operations are not usually required to be licensed by environmental authorities because of their relatively small scale.

Motor vehicle refinishing consists of applying primer, a topcoat and hardener to motor vehicle surfaces and aims to protect the substrates (usually metal) to which they are applied from corrosion, abrasion and decay, and damage from ultraviolet light and water.

VOCs are emitted during the application of coatings, the drying phase, and the cleaning equipment such as spray guns. Chemical reactions may also cause emissions to occur during the refinishing, drying, curing and hardening phases.

Particle emissions may occur if coatings are applied using spray guns in an uncontrolled environment. However, these emissions are considered to be comparatively very small in relation to those from other sources, and are not considered further in this manual.

Most surface coatings consist of resin, solvent and pigments. The resin component forms the final paint film after application and drying of the coating. The solvent acts as a carrier for the resins and pigments and

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evaporates as the paint film forms during the drying process. All surface coatings used in the industry are assumed to escape to atmosphere. Oil-based paints consist of 30 to 70% VOCs by weight, while water-based paints consist of about 6% VOCs. Thinners, used for cleaning, consist wholly of VOCs.

Pigments are used in the formulation of primers and paints and are an integral part of the coating formulation. The pigmented resin coats the vehicle body surface as the solvent dries. The chemical composition of the pigment changes with the desired colour.

Emissions of trichloroethylene used for surface cleaning are accounted for in the aggregated emissions manual for Use of Industrial Solvents (Sub-Threshold).

### **2.3 Emission Controls**

Industry practices for controlling and reducing emission controls include:

- using enclosed areas used for spraying (e.g. spray booths);
- using water-based paints;
- using high efficiency spray guns;
- recycling cleaning solvents; and
- recycling unused coatings

Motor vehicle refinishing activities sometimes occur in places which are only partially or minimally enclosed. When they take place in an enclosure, emissions can be captured and reduced with carbon scrubbers (with a collection efficiency of more than 90%) or afterburners. However, due to the high costs associated with both of these methods, they are rarely employed in the industry. Water curtains or filler pads are usually installed to remove particles, but these techniques have little effect on VOC emissions.



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### **3.0 Emissions Estimation Techniques**

#### **3.1 Approaches Employed**

The best practice method for estimating emissions from motor vehicle refinishing is to use a mass balance approach, in which it is assumed that all solvent purchased in a year is used in that year, and that all VOCs in the coating formulation evaporate and are emitted to the atmosphere. This approach is valid for both small and medium-sized refinishers. Larger facilities will be required to report individually to State and Territory Governments for the NPI.

This technique requires the following information to be obtained:

- the total consumption of automotive surface coatings by product type in the jurisdiction (or, preferably, the airshed in question); and
- the total VOC content of each product type and the VOC speciation (in terms of NPI substances) for each of these product types

The following additional information will help to improve the accuracy of the spatial allocation of emissions:

- the number and location of all motor vehicle refinishers in the airshed; and
- the number of full-time employees at each motor vehicle refinisher.

If the consumption of a product in an airshed cannot be obtained, it needs to be derived by scaling down from jurisdiction consumption by the ratio of employee numbers (or otherwise populations) in the airshed and jurisdiction.

If consumption data for the jurisdiction or airshed are unavailable, a default method based on an employment-based emission factor (i.e. emissions per industry employee) can be used. Employee numbers for the industry should be available from government organisations dealing with small business.

As a last resort per capita emission factors can be used if employee statistics are not available.

##### *3.1.1 Estimating Total Solvent Emissions*

The best practice EET is to use the mass balance approach, combined with local data on VOC content and speciation. Surface coating consumption data for the motor vehicle refinishing industry can be obtained from the Australian Paint Manufacturers Federation Inc (APMF). For smaller airsheds, other approaches such as surveying business may be more accurate.

The volumes of surface coatings and thinners which are consumed by industrial premises which are reporting facilities under the NPI, need to be subtracted from the total quantities consumed in the jurisdiction (or airshed).

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**Equation 1: Estimating emissions using the mass balance method**

Total VOC emissions can be calculated by multiplying the volume of each type of coating used in the jurisdiction by the VOC content for that coating type

$$E = \sum_i C_i \times EF_i$$

where

E	=	Total VOC emissions in a jurisdiction, kg yr <sup>-1</sup>
C <sub>i</sub>	=	Total consumption of coating type i in a jurisdiction, L yr <sup>-1</sup>
EF <sub>i</sub>	=	VOC content for coating type i, kg L <sup>-1</sup>

Total VOC emissions in an airshed can then be calculated by scaling emissions for the jurisdiction by the ratio of employee numbers (or populations) in the two regions

$$E_a = E * (N_a / N_j)$$

where

E <sub>a</sub>	=	Total VOC emissions in the airshed, kg yr <sup>-1</sup>
E	=	Total VOC emissions in the jurisdiction, kg yr <sup>-1</sup>
N <sub>a</sub>	=	Number of employees in the airshed
N <sub>j</sub>	=	Number of employees in the jurisdiction

Where data on the consumption of surface coatings in a jurisdiction or airshed are not available, emission factors can be used as a default estimation technique.

**Equation 2: Estimating VOC emissions using per employee emission factors**

Total VOC emissions in an airshed can be calculated using an appropriate employment-based emission factor (see Table 2 below)

$$E_a = EF_e * N_a$$

where

E <sub>a</sub>	=	Total VOC emissions in the airshed, kg yr <sup>-1</sup>
EF <sub>e</sub>	=	Emission factor, kg yr <sup>-1</sup> employee <sup>-1</sup>
N <sub>a</sub>	=	Number of employees in the airshed

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**Equation 3: Estimating VOC emissions using per capita emission factors**

As a last resort, a per capita emission factor (see Table 2) can be used to calculate total VOC emissions in an airshed

$$E_a = EF_p * P_a$$

where

$$\begin{aligned} E_a &= \text{Total VOC emissions in the airshed, kg yr}^{-1} \\ EF_p &= \text{Emission factor, kg per capita yr}^{-1} \\ P_a &= \text{Population of the airshed} \end{aligned}$$

### 3.1.2 Speciating VOC Emissions

VOC speciation profiles for particular coating or product types can be used to determine the emissions in an airshed of individual NPI substances.

**Equation 4: Speciating VOC emissions**

Emissions of a particular species in an airshed can be calculated using the following equation

$$E_k = \frac{N_a}{N_j} \sum_i \sum_k E_{ik} \quad [4.1]$$

where

$$E_{ik} = C_i * EF_i * (S_{ik} / 100) \quad [4.2]$$

and

$$\begin{aligned} E_k &= \text{Emissions of VOC species k in the airshed, kg yr}^{-1} \\ N_a &= \text{Number of employees (or population) in the airshed} \\ N_j &= \text{Number of employees (or population) in the jurisdiction} \\ E_{ik} &= \text{Emissions of VOC species k from use of coating type i in} \\ &\quad \text{the jurisdiction, kg yr}^{-1} \\ C_i &= \text{Total consumption of coating type i in the jurisdiction,} \\ &\quad \text{L yr}^{-1} \\ EF_i &= \text{VOC content for coating type i, kg L}^{-1} \\ S_{ik} &= \text{Concentration of species k in coating type i, \% by weight} \end{aligned}$$

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### 3.2 *Spatial Surrogates and Spatial Allocation*

Spatial surrogates are required to distribute total airshed emissions to individual grid cells. The preferred method of allocation is to distribute emissions according to the numbers of premises in each grid cell, which effectively assumes the same level of emissions from each premises. If employee numbers at each site are also known, gridded emissions can be weighted according to total numbers of employees in each grid cell.

Addresses and numbers of employees for motor vehicle refinishers can be obtained from government organisations dealing with worker safety issues or, alternatively, addresses of these facilities can be found in the Electronic Yellow Pages. Addresses can then be converted to co-ordinates (AMG or latitude/longitude) by a process called geocoding in a Geographic Information System (GIS). If GIS is not available in-house, a GIS company can undertake this geocoding.

If information on the locations of motor vehicle refinishers is unavailable, emissions may be allocated on the basis of land use type (e.g. in proportion to the total area of industrial or commercial zonings in each grid cell) or population (which requires converting ABS data from Collection Districts to grid cells). Allocating emissions based on population distribution can lead to significant inaccuracies, as motor vehicle refinishers tend to cluster in industrial zones rather than in residential areas.

#### **Equation 5: Allocating emissions to a grid cell**

Emissions in a grid cell can be estimated as follows

$$E_{kn} = E_k * (N_n / N)$$

where

$E_{kn}$	=	Emissions of VOC species k in grid cell n, kg yr <sup>-1</sup>
$E_k$	=	Emission of VOC species k in the airshed, kg yr <sup>-1</sup>
$N_n$	=	Number of motor vehicle refinishers (or employees) in grid cell n
$N$	=	Number of motor vehicle refinishers (or employees) in the airshed

### 3.3 *Emission and Speciation Factors*

An employment-based emission factor derived for the South-East Queensland NPI Trial is provided in Table 2. A per capita emission factor developed by the USEPA (1995) is given in the same table.

Locally relevant data on VOC contents and speciation profiles for various coatings and products should be obtained from manufacturers or industry

associations . Where composition data are not available, the estimates in the following Tables can be used. Table 3 presents data on the VOC contents of various types of surface coatings. Table 4 provides indicative speciation profiles for various coating types, which will allow the emissions of specific NPI substances to be estimated. These data are considered to be indicative of the overall market, but may not be totally representative of specific regions.

**Table 2: Per Employee and Per Capita VOC Emission Factors**

<b>Employment Basis <sup>a</sup> (kg yr<sup>-1</sup> per employee)</b>	<b>Population Basis <sup>b</sup> (kg yr<sup>-1</sup> per capita)</b>
155	0.84

<sup>a</sup> QDEH (1998).

<sup>b</sup> USEPA (1995), for all non-methane VOCs.

**Table 3: VOC Content of Common Surface Coating Types**

<b>Surface Coating</b>	<b>VOC Content (kg L<sup>-1</sup>)<sup>a</sup></b>
Paint (solvent-based)	0.672
Enamel	0.420
Lacquer	0.732
Primer	0.792
Thinner	0.883
Adhesive	0.528

<sup>a</sup> EA (1999).

**Table 4: VOC Speciation Profiles for Surface Coating Types <sup>a</sup>**

<b>NPI Substance</b>	<b>Weight %</b>	<b>NPI Substance</b>	<b>Weight %</b>
<b>Solvent-Based Paint</b>		<b>Thinner</b>	
Acetone	1.27	Methyl ethyl ketone	2.5
Cyclohexane	0.52	Toluene	25
Ethyl acetate	2.04	Xylenes	20
Ethylbenzene	0.54	<b>Primer</b>	
Methyl ethyl ketone	0.54	Toluene	44.31
Methyl isobutyl ketone	0.36	Xylenes	2.68
Toluene	37.87	<b>Lacquer</b>	
Xylenes	8.17	Toluene	44.59
<b>Enamel</b>		Xylenes	4.18
Acetone	5.57	<b>Adhesive</b>	
Cyclohexane	2.27	Acetone	14.20
Ethyl acetate	8.96	Ethyl acetate	13.30
Ethylbenzene	2.36	Methyl ethyl ketone	5.30
Methyl ethyl ketone	2.36	Methyl isobutyl ketone	4.30
Methyl isobutyl ketone	1.57	Toluene	20.30
Toluene	15.9		
Xylenes	23.09		

<sup>a</sup> USEPA (1992).

The simplified speciation profile in Table 5 should be used for VOC emissions estimated from per employee or per capita emission factors.

**Table 5: Default VOC Speciation<sup>a</sup>**

Species	Weight %
Methyl ethyl ketone	17
Methyl isobutyl ketone	3
Xylenes	33
Toluenes	29

<sup>a</sup> Source: EPAV (1996)

### 3.4 Sample Calculations

Table 6 provides sample data for the following examples, with the consumption figures drawn from the South-East Queensland NPI trial (QDEH 1998). This table also illustrates how products in the surface coating categories typically used by the APMF can be matched to the surface coating types listed in Table 3.

**Table 6: Sample Data on Product Consumption and VOC Content**

Surface Coating Product	Consumption (L yr <sup>-1</sup> )	Coating Type	VOC Content from Table 3 (kg L <sup>-1</sup> )
<b>Primers</b>			
Lacquers	64 156	Lacquer	0.732
Two Pack	47 881	Primer	0.792
<b>Basecoats</b>	66 884	Paint	0.672
<b>Topcoats</b>			
Lacquers and Clears	127 269	Lacquer	0.732
Synthetic Enamels	64 476	Enamel	0.420
Two Pack	122 600	Paint	0.672
<b>Hardeners</b>			
Two Pack	70 369	Adhesive	0.528
<b>Thinners</b>			
Lacquers and Others	543 241	Lacquer	0.732
Two Pack	158 313	Thinner	0.883

#### Example 1: Estimating emissions using the mass balance method

Using the figures in Table 6 with Equation 1, and assuming there are 21,000 and 33,000 employees in the airshed and jurisdiction respectively, total VOC emissions in the airshed can be calculated as

$$\begin{aligned}
 E_i &= (N_a / N_j) * C_i * EF_i \\
 &= [2.1 * 10^4 / (3.3 * 10^4)] * [64156 * 0.732 + 47881 * 0.792 \\
 &\quad + 66884 * 0.672 + 127269 * 0.732 + 64476 * 0.420 + \\
 &\quad 122600 * 0.672 + 70369 * 0.528 + 543241 * 0.732 + \\
 &\quad 158313 * 0.883] \\
 &= 5.77 * 10^5 \text{ kg yr}^{-1}
 \end{aligned}$$

### Example 2: Using per employee emission factors

Assuming 6,000 people are employed in an airshed, Equation 2 and Table 2 can be used to derive total VOC emissions in the airshed as

$$\begin{aligned} E_a &= EF_e * N_a \\ &= 155 * 6.0 * 10^3 \\ &= 9.3 * 10^5 \text{ kg yr}^{-1} \end{aligned}$$

### Example 3: Using per capita emission factors

Assuming that ABS has estimated a population of 1,700,000 in an airshed, total VOC emissions can be calculated from Table 2 and Equation 3 as

$$\begin{aligned} E_a &= EF_p * P_a \\ &= 0.84 * 1.7 * 10^6 \\ &= 1.43 * 10^6 \text{ kg yr}^{-1} \end{aligned}$$

### Example 4: Speciating VOC emissions

The total VOC emissions from consumption of thinner in a jurisdiction can be calculated from Table 6 and Equation 1 as

$$\begin{aligned} E_{\text{thinner}} &= [543241 * 0.732 + 158313 * 0.883] \\ &= 5.37 * 10^5 \text{ kg yr}^{-1} \end{aligned}$$

Using the weight fraction of xylenes in thinner (20%) from Table 4, the total emissions of xylenes from thinner use in the airshed can be derived from Equation 4.2 as

$$\begin{aligned} E_{\text{thinner,xylenes}} &= C_i * EF_i * (S_{ik} / 100) \\ &= 5.37 * 10^5 * (20 / 100) \\ &= 1.07 * 10^5 \text{ kg yr}^{-1} \end{aligned}$$

This calculation is repeated for each coating type which contains xylene, and total xylene emissions in the *airshed* are then obtained by summing the xylene emissions from each coating type, and then scaling in accordance with Equation 4.1, assuming jurisdiction and airshed populations of 5.1 and 3.7 million respectively

$$\begin{aligned} E_{\text{xylene}} &= \frac{N_a}{N_j} \sum_i \sum_k C_i \times EF_i \times \frac{S_{ik}}{100} \\ &= [3.7 * 10^6 / (5.1 * 10^6)] * [1.07 * 10^5 + E_{\text{paint,xylenes}} + E_{\text{enamel,xylenes}} \\ &\quad + E_{\text{primer,xylenes}} + E_{\text{lacquer,xylenes}}] \text{ kg yr}^{-1} \end{aligned}$$

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**Example 5: Allocating emissions to a grid cell**

Assuming that total airshed emissions of xylenes are  $1,300,000 \text{ kg yr}^{-1}$ , and that there are 750 and 24 motor vehicle refinishers in the airshed and a grid cell respectively, xylene emissions in that grid cell can be calculated from Equation 5 as

$$\begin{aligned} E_{kn} &= E_k * (N_n / N) \\ &= 1.3 * 10^6 * (24 / 750) \\ &= 4.16 * 10^4 \text{ kg yr}^{-1} \end{aligned}$$



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## **4.0 Uncertainty Analysis**

### **4.1 Data Reliability**

The accuracy of the documented best practice technique is dependent on the quality of data on the consumption and composition of various products used by the industry. If all of this information is obtained from local sources, its reliability is considered to be high. Use of default information on VOC content and speciation is considered to have medium reliability.

### **4.2 Reliability of Emission Factors**

Using employment or population-based emission factors is considered to have no better than medium reliability. The use of these factors assumes that they are directly transferable from the regions where they were developed. The employment-based factor developed in the South-East Queensland Trial should provide more accurate results because it is derived for Australian conditions, and from a measure of industry activity (employment) rather than simple population.

Speciation profiles provided by paint manufacturers will be more accurate than those tabulated in this manual. However, comprehensive information on speciation is often difficult to obtain, and the use of these profiles is considered an acceptable alternative of medium reliability.

### **4.3 Problems and Issues Encountered**

The main problem with application of the best practice technique will be the anticipated difficulty in getting representative composition and speciation data, given the very wide range of surface coatings and thinners that are used.

### **4.4 Recommendations for Further Work**

The wider availability of compositions data for common surface coatings would facilitate quicker and more reliable emissions estimation. Alternatively, development of more widely applicable and verified emission factors would increase the accuracy of the default method.

The development of airshed databases on facility location, employee numbers and emission control details would also improve estimation and allocation accuracy.

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## 5.0 Glossary of Terms and Abbreviations

ABS	Australian Bureau of Statistics
AE	Aggregated emissions
APMF	Australian Paint Manufacturers Federation Inc
EET	Emissions estimation technique
EF	Emission factor
EPAV	Environment Protection Authority of Victoria
GIS	Geographic information system
NEPC	National Environment Protection Council
NEPM	National Environment Protection Measure
NPI	National Pollutant Inventory
US	United States
USEPA	United States Environmental Protection Agency
VOC	Volatile organic compound

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## 6.0 References

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