



Emissions Estimation Technique Manual

for

**Aggregated Emissions from
Use of Industrial Solvents
(Sub-Threshold)**

November 1999



**EMISSIONS ESTIMATION TECHNIQUE MANUAL:
AGGREGATED EMISSIONS FROM USE OF
INDUSTRIAL SOLVENTS (SUB-THRESHOLD)**

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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 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

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

Products containing solvents are used in a variety of industrial applications. The solvents in these products contain volatile organic compounds (VOCs) which are emitted to the atmosphere when these products are used.

This manual has been prepared for estimating emissions from the industrial use of solvents by those facilities that are not required to report to jurisdictions under the NEPM.

This manual considers emissions from products used by industry exclusively for *solvent degreasing and surface cleaning*. Techniques for estimating aggregated emissions from the industrial use of solvents for other purposes or applications are provided in the following NPI aggregated emissions manuals:

- Architectural Surface Coatings;
- Motor Vehicle Refinishing; and
- Printing and Graphic Arts.

In addition, there are expected to be other solvents or solvent-containing products used by smaller industrial facilities which would not be reported to the NPI. At present there is no means of identifying these additional uses or estimating the emissions that they may produce, although they are not considered to be as large as the emissions addressed in this manual and the other three manuals listed above.

2.1 NPI Substances

The main emissions from degreasing activities derive from solvents used in the cleaning process. These solvents contain VOCs, a large and diverse group of chemicals including hydrocarbons, oxygenates and halocarbons.

Non-aqueous solvents (e.g. petroleum distillates, chlorinated hydrocarbons, ketones, and alcohols) are often used in other countries for solvent degreasing. However, in Australia, trichloroethylene is the predominant solvent used (Bradley, A., Stelco Chemicals November 1999, pers. comm.). And, as with tetrachloroethylene in the dry cleaning industry, it is all used for one purpose (i.e. degreasing).

Other solvents used to a lesser extent for degreasing include white spirits and high flash kerosene. However, even if these other solvents are a significant fraction of the degreasing agents used, it is not possible with current information to separate their use for degreasing from other uses. However, some of them will probably be accounted for as surface coatings (e.g. through consumption figures for white spirits). Therefore, for the purpose of this manual, trichloroethylene is the only NPI substance considered.

Table 1: NPI Substances Emitted from Solvent Degreasing

Total volatile organic compounds (VOCs)
Trichloroethylene

2.2 Emission Sources and Related Processes

Solvent degreasing in industry is the physical process of using organic solvents to remove unwanted material that has adhered to hard surfaces. These unwanted materials include greases, fats, oils, waxes, soils and solder-flux residues. The surface to be degreased can include metal, glass, ceramic or plastic (USEPA 1994).

In the industrial sector, degreasing is normally conducted to prepare the surface for subsequent surface protection processes. For example, degreasing adherents from metals may be undertaken prior to painting, electroplating, galvanising, tin plating or varnishing.

Most industries use solvent degreasing to at least some degree in their operations. Metalworking industries, however, are the major users of solvent degreasing processes, and include the industry categories in Table 2.

Table 2: Metalworking Industries Using Solvent Degreasing^a

Airframe and automotive manufacturing	Machine parts manufacturing
Electronics manufacturing and assembling	Mechanical workshops
Glass fabrication and finishing	Repair, overhaul and equipment maintenance

^a USEPA (1994)

The types of equipment used for solvent degreasing are categorised as vapour degreasing, cold degreasing, and conveyerised degreasing. These are discussed below.

2.2.1 Vapour Degreasing

Vapour degreasing involves the exposure of a work-piece to pure solvent vapours released by a boiling solvent. Halogenated solvents (especially trichloroethylene) are used because they are non-flammable and have vapours that are much heavier than air.

The work-piece is usually suspended in the vapours just above the boiling solvent (i.e. within the vapour zone). When the warm vapours touch the comparatively cool work-piece, a condensing action occurs which dissolves the contamination and flushes it away as it runs off the part. This cleaning action continues until the work-piece and the solvent vapour are the same temperature (Greco Brothers Inc. 1999).

Vapour rising past the work-piece is condensed to slow the eventual loss of solvent to the atmosphere. Cooling jackets and perimeter cooling coils are often used to facilitate the condensation process.

Residual liquid solvent on the work-piece rapidly evaporates as it is slowly removed from the vapour zone, and exhaust systems emit the solvent vapours.

Cleaning action can be increased by spraying the work-piece with solvent below the vapour level or by immersing it in the liquid solvent bath.

Most emissions from vapour degreasing occur due to diffusion and convection. Equipment operating methods including solvent carryout from wet parts and waste solvent evaporation also produce considerable emissions.

2.2.2 Cold degreasing

Cold cleaners are batch loaded and use non-boiling solvents that are applied at or near room temperature. The work-piece is normally immersed, sprayed or wiped with the solvent.

While cold cleaners vary widely in design, the two basic designs are the simple spray sink and the dip tank. Due to the wide application of these simple processes, there are large numbers of small cold degreasing sources within the industrial zones of urban areas.

Compared to a spray sink, a dip tank provides more thorough cleaning through immersion, and cleaning efficiency is often improved by agitation (USEPA 1995). After cleaning, the parts are either suspended over the tank to drain, or placed on an external rack that directs the drained solvent back into the cleaner.

Emissions from cold cleaners occur through:

- waste solvent evaporation (greatest emission source);
- solvent carryout (evaporation from wet parts);
- solvent bath evaporation;
- spray evaporation; and
- agitation.

2.2.3 Conveyorised degreasing

Conveyorised degreasers are continuously loaded and may operate with either cold or vapourised solvent. About 85% are vapour types, and 15 % non-boiling.

Because they are usually enclosed, conveyorised degreasers emit less solvent per part cleaned than vapour or cold degreasers. More so than operating practices, design and adjustment are major factors affecting emissions, the main source of which is carryout of vapour and liquid solvents.

2.3 Emission Controls

Emission control techniques that are relevant to the various methods of degreasing include:

- work-piece carryout; and
- product reformulation.

Work-piece carryout emissions are central to each degreasing method that has been discussed. Emissions can be controlled by draining the cleaned parts before removal and collecting emissions from areas where parts are racked to dry.

Product reformulation is another strategy that can reduce emissions from degreasing activities. There are a number of degreasing and cleaning solvents that may be used as alternatives to chlorinated solvents.

In general, these are medium to high flash point solvents formulated to remove oil and grease, and in some cases, soldering flux and wax. Because they all have lower rates of evaporation when compared to chlorinated solvents, a decrease in air emissions will result.

In some applications water-based cleaning substances can also be used, but aqueous-based cleaning may be impractical or unusable for certain types of work-pieces. However, the lower evaporation rate requires longer drying times or the need to install a drying operation (Bradley, A., Stelco Chemicals November 1999, pers. comm.).

2.3.1 Vapour Degreasing

As mentioned earlier, most emissions from vapour degreasing result from diffusion and convection. Emissions can be reduced by:

- using an automated cover;
- using a manual cover regularly;
- spraying below the vapour level; and
- using a refrigerated freeboard chiller (North Carolina Office of Waste Reduction 1995).

Safety switches and thermostats that prevent emissions during malfunctions and abnormal operation also reduce diffusion and convection of vapourised solvent (USEPA 1995).

2.3.2 Cold Degreasing

The biggest source of emissions is waste solvent loss. These emissions can be reduced through distillation and transport of waste solvent to special incineration plants.

Solvent bath evaporation is another significant emission source. Bath evaporation can be controlled by using a cover regularly, allowing an adequate freeboard height, avoiding excessive drafts in the workshop, and spraying at low pressure.

If the solvent used is both insoluble and heavier than water, a layer of water (water cover) over the solvent can also reduce bath evaporation (USEPA 1995).

2.3.3 *Conveyorised Degreasing*

Conveyorised degreasers are usually enclosed and therefore emit relatively low amounts of solvent when compared to other methods of degreasing. The main source of emissions is carryout of vapour and liquid. Emissions in this case can be controlled by draining the cleaned parts before removal and through collecting emissions from areas where parts are racked to dry.

3.0 Emissions Estimation Techniques

This section provides an outline of the data requirements and techniques recommended for estimating emissions of VOCs (as trichloroethylene) from the industrial use of solvents for degreasing and surface cleaning.

3.1 Approaches Employed

Both best practice and default techniques for estimating emissions from sub-threshold use of industrial solvents are described below. The EETs rely on the assumption that all VOCs in the solvents evaporate into the atmosphere, and that the total amount of VOCs in degreasing products distributed within an airshed over a particular period (e.g. annually) is equivalent to the total airshed emissions of VOCs over that period (i.e. a mass balance method).

3.1.1 Best Practice EET

This EET requires the acquisition of accurate sales data for trichloroethylene, which is the only degreaser used in Australia. These data can be obtained at both a national and jurisdiction level from Stelco Chemicals, a subsidiary of Orica Australia (Bradley A., Stelco Chemicals November 1999, pers. comm.). As trichloroethylene is imported by Stelco from overseas manufacturers, data may also be available from the Australian Bureau of Statistics (ABS). If sales data are provided in litres, they must first be converted to kilograms.

These data must first be scaled from national/jurisdiction to airshed level for estimating emissions in the relevant airshed, by using either employment data (employee numbers) or population figures, both of which are obtainable from the ABS. Then, to derive aggregated airshed emissions of VOCs, the emissions of trichloroethylene reported by reporting facilities in an airshed must be subtracted from the total emissions derived from the scaled product distribution data for the airshed (see Equation 1).

Equation 1: Estimating airshed emissions by the mass balance method

$$E = S * (N_a / N_j) - R$$

where

E = Annual sub-threshold emissions in an airshed of VOCs (as trichloroethylene), kg yr⁻¹

S = Trichloroethylene distributed in the jurisdiction, kg yr⁻¹

N_a = Number of metalworking industry employees (or population) in the airshed

N_j = Number of metalworking industry employees (or population) in the jurisdiction

R = Total trichloroethylene emissions reported by industry in the airshed to the NPI, kg yr⁻¹

3.1.2 Default EET

The default method uses a per capita emission factor based on small cold degreasing operations (see Equation 2). As the emission factor has been calculated for small degreasing operations, the emissions are considered to be a reasonable estimate of sub-threshold emissions (USEPA 1995), so consideration of the emissions reported by the larger facilities is not required.

Equation 2: Estimating airshed emissions by using an emission factor (default method)

$$E = EF * P_a$$

where

E	=	Annual sub-threshold emissions in an airshed of VOCs (trichloroethylene), kg yr ⁻¹
EF	=	Emission factor, kg yr ⁻¹ per capita
P _a	=	Population of the airshed

3.1.3 Emission Speciation

Since trichloroethylene is the only solvent used in Australia, the VOC emissions are equivalent to the trichloroethylene emissions.

3.2 Spatial Surrogates and Spatial Allocation

A spatial surrogate is needed to allocate emissions from the airshed to individual grid cells. The preferred surrogate would be industrial/commercial zoning (according to land use planning information). That is, the emissions would be distributed in proportion to the area of industrial/commercially zoned land in each grid cell (Equation 3). This could be derived from GIS-based land use zoning information or estimated from planning maps.

Equation 3: Spatially allocating airshed emissions to a grid cell

$$E_i = E * (A_i / A_a)$$

where

E = Annual sub-threshold emissions in an airshed of VOCs (as trichloroethylene), kg yr⁻¹

E_i = Annual emissions of VOCs (trichloroethylene) in a grid cell, kg yr⁻¹

A_i = Area of industrial/commercial zoning in the grid cell, ha

A_a = Total area of industrial/commercial zoning in the airshed, ha

If industrial zoning data cannot be obtained, population can be used as a default spatial surrogate. This is a reasonable approximation as most industrial enterprises will be located in or near urban areas and close to their customers, workforce and transportation facilities.

3.3 Emission Factors

The value of the emission factor for the default method is 1.8 kg yr⁻¹ per capita (USEPA 1995). This factor was developed for non-methane VOC emissions, which are all considered to be trichloroethylene for Australian applications.

3.4 Sample Calculations

The sample calculations are provided to guide users of the manual in the application of the equations outlined in the EETs.

Example 1: Using the mass balance method

Using Equation 1, and assuming that annual sales of trichloroethylene in jurisdiction are 14,500,000 kg, 5,700,000 kg are reported by industry in the airshed, and the jurisdiction and airshed have populations of 4.7 and 3.4 million respectively, total airshed emissions are

$$\begin{aligned} E &= S * (N_a / N_j) - R \\ &= (14.5 * 10^6) * (3.4 / 4.7) - (5.2 * 10^6) \\ &= 5.3 * 10^6 \text{ kg yr}^{-1} \end{aligned}$$

Example 2: Using the default method (emission factor)

Using Equation 2, and assuming a jurisdiction population of 3.4 million

$$\begin{aligned} E &= EF * P \\ &= 1.8 * 3.4 * 10^6 \\ &= 6.1 * 10^6 \text{ kg yr}^{-1} \end{aligned}$$

Example 3: Spatially allocating emissions

Using Equation 3 with the result from Equation 1, and assuming total areas of industrial/commercial zoning in grid cell and airshed of 55 ha and 6400 ha respectively, emissions in the cell can be calculated as

$$\begin{aligned} E_i &= E * (A_i / A_a) \\ &= 5.3 * 10^6 * (55 / 6400) \\ &= 4.55 * 10^4 \text{ kg yr}^{-1} \end{aligned}$$

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 technique is critically dependent on the quality of the data that is available in the jurisdiction. As the product importers are supplying data it is likely to be of high reliability.

The data supplied by reporting facilities is also considered to be of high reliability, as facilities will usually keep reliable records of the amount of solvent used in a year.

The reliability of the emission factor used in the default method is low as the emission factor has been developed in the USA. Also, it is assumed that all VOC emitted are trichloroethylene. The population data required would be of high reliability.

4.2 Problems and Issues Encountered

As discussed in Section 2.0, other solvents are used by industry that are not addressed in any of the Aggregated Emissions manuals. The total amounts of these solvents which are used in particular airsheds are seldom available from manufacturers or industry associations, and it is not possible at this time to provide an EET for these sub-threshold emissions.

4.3 Recommendations for Further Work

Further development of the estimation techniques is not required. However, the derivation of an Australian emission factor based solely on emissions of trichloroethylene would be useful.

5.0 Glossary of Terms and Abbreviations

ABS	Australian Bureau of Statistics
EET	Emissions estimation technique
EF	Emission factor
GIS	Geographic information system
NEPM	National Environment Protection Measure
NEPC	National Environment Protection Council
NPI	National Pollutant Inventory
USEPA	United States Environmental Protection Agency
VOC	Volatile organic compound

6.0 References

Greco Brothers Inc. (1999). Web-site: www.grecobrothers.com/chlorin.htm, Rhode Island, USA.

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USEPA (1994). *Guide to Cleaner Technologies: Alternatives to Chlorinated Solvents for Cleaning and Degreasing*, Office of Research and Development, Ohio, USA.

USEPA (1995). *Compilation of Air Pollutant Emission Factors, vol I, Stationary Point and Area Sources*, AP-42, 5th edn, Research Triangle Park, North Carolina, USA.