Emissions Estimation Technique Manual

for

Aggregated Emissions from Dry Cleaning

November 1999

Version 1.0 - First Published 1 November 1999

EMISSIONS ESTIMATION TECHNIQUE MANUAL:
AGGREGATED EMISSIONS FROM DRY CLEANING

TABLE OF CONTENTS

LIST OF TABLES AND FIGURES

1.0 Introduction

1.1 The National Pollutant Inventory

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

2.1 NPI Substances

Substances used in the dry cleaning industry include tetrachloroethylene, also known as perchloroethylene or Perc, and small amounts of white spirit, which contains xylene and toluene. Tetrachloroethylene, xylene and toluene are NPI substances. White spirit also contains other volatile organic compounds (VOCs). VOCs, also an NPI substance, is a general term, which refers to a large and diverse group of chemicals including hydrocarbons, oxygenates and halocarbons.

Table 1: NPI Substances Typically Emitted by Dry Cleaning Plants

Tetrachloroethylene	Toluene
Xylene	Total VOCs

2.2 Emission Sources and Related Processes

The dry cleaning industry provides a service for the cleaning of clothes, manchester, leather goods and other items made of fibres, including household furnishings and drapes.

Fabric or garment cleaning consists of three basic functions: (1) washing the fabric in solvent, (2) spinning to extract excess solvent, and (3) drying by tumbling in a hot air stream. Garments are pre-treated for stains and machine-cleaned in a solution of solvent and detergents. Solvent is extracted by draining, and then spinning the clothes. Finally, the garments are dried through a combination of aeration, heat and tumbling, examined for spots, cleaned, and pressed. This final step of (steam) pressing effectively eliminates any minute residue of the solvent that may remain in a garment at the end of the other processes.

Two general types of cleaning fluids are used in the industry: petroleum solvents and synthetic solvents. In Australia, the principal solvent used is tetrachloroethylene. A small amount of petroleum solvents, such as white spirit, is also used. The use of this solvent is very small compared to that of tetrachloroethylene, and accounts for only 2 to 3% of national dry cleaning solvent usage (EA 1999). More recently an iso-paraffin based solvent (white spirit with an additive) has been used (Williams, V. 1999, pers. comm.). CFC-11 has also been used but, in response to the Montreal Protocol, is being phased out and will cease altogether in the near future.

There are two basic types of dry cleaning machines, transfer and dry-to-dry. Transfer machines, using petroleum solvents such as white spirit, accomplish washing and drying in separate machines. Usually, the washer extracts excess solvent from the clothes before they are transferred to the drier, but some older plants have separate extractors for this purpose.

Dry-to-dry machines, using petroleum solvents or synthetic solvents, are single units that perform all of the washing, extraction, and drying operations.

The solvent itself is the primary emission from dry cleaning operations. Solvent is given off by washer, drier, solvent still, cooker, still residue, and filtercake storage areas, as well as by leaky pipes, flanges, and pumps.

A typical tetrachloroethylene plant uses two tanks for washing. One tank contains pure solvent, and the other contains "charged" solvent (used solvent to which small amounts of detergent have been added to aid in cleaning). Generally, clothes are cleaned in charged solvent and rinsed in pure solvent. A water bath may also be used.

After the clothes have been washed, the used solvent is filtered and part of the filtered solvent is returned to the charged solvent tank for washing the next load. The remaining solvent is then distilled to remove oils, fats and greases, and is returned to the pure solvent tank. The collected solids are usually removed from the filter once a day. Before disposal, the collected solids may be "cooked" to recover additional solvent. Still and cooker vapours are vented to a condenser and separator, where more solvent is reclaimed. In many tetrachloroethylene plants, the condenser off-gases are vented to a carbon adsorption unit for additional solvent recovery.

After washing, the clothes are transferred to the drier to be tumbled in a heated air stream. Exhaust gases from the drier, along with a small amount of exhaust gases from the washer/extractor, are vented to a water-cooled condenser and water separator. Recovered solvent is returned to the pure solvent storage tank. In some tetrachloroethylene plants, the condenser off-gases are vented to a carbon adsorption unit for additional solvent recovery. To reclaim this solvent the unit must be periodically desorbed with steam, usually at the end of each day. Desorbed solvent and water are condensed and separated, and recovered solvent is returned to the pure solvent tank.

2.3 Emission Controls

Solvent recovery is common in tetrachloroethylene plants due to the cost savings available and worker safety benefits. Recovery occurs on the washer, drier, still and cooker through the use of condensers, water/solvent separators and carbon adsorption units. Enhanced emission control can also be obtained by good housekeeping (maintaining all equipment and using good operating practices).

Liquids and solids containing tetrachloroethylene may be tightly controlled and appropriate methods for their disposal should be checked in each State. Victoria, for example, requires that any distillation or solvent recovery residue be transported and disposed of at a licensed waste disposal site. Victorian legislation also specifies chlorinated hydrocarbons as a priority waste and particular emphasis must be placed on minimising the generation of this waste (EPAV 1990). Similar controls may apply in other states.

White spirit plants have not generally employed solvent recovery, because of the low cost of petroleum-based solvents and the fire hazards associated with collecting vapours. Some emission control, however, can be obtained by proper equipment maintenance (e.g. by preventing lint accumulation and solvent leakage) and by using good operating practices (e.g. by not overloading machinery).

The main approaches used in minimising emissions for the industry are:

- making technological changes to equipment;
- improved housekeeping, including inspection and maintenance programs;
- employee training;
- capturing emissions before they are released to the atmosphere;
- changing the solvent used; and
- improving site practices, especially for tetrachloroethylene storage, handling and disposal.

Generally, modern technologies have penetrated the market more quickly in Australia than elsewhere, particularly in respect of closed circuit machinery. Similarly, the development of industry-wide practices regarding solvent management has been quite rigorous in this country, including the formulation of a code of practice for handling of tetrachloroethylene in the dry cleaning industry by the Dry Cleaning Institute of Australia in consultation with EPAV (DCIA 1996).

3.0 Emissions Estimation Techniques

This Section provides techniques for using data to calculate emission estimates for tetrachloroethylene, and total and speciated VOCs. These techniques can be used for either method of dry cleaning (i.e. transfer or dry-to-dry).

3.1 Approaches Employed

The "best practice" approach to estimating emissions from area-based dry cleaners is to use a mass balance equation. It is assumed that the solvent purchased by a dry cleaning facility will either be emitted through the process or carried out on clothes and subsequently evaporated to the atmosphere. This technique relies on the expectation that all of the solvent purchased in a particular year will be used in that same year.

Information that needs to be obtained for this estimation technique includes:

- the total consumption of dry cleaning solvents which contain NPI substances (tetrachloroethylene and white spirit) in the NPI region or airshed over the reporting period; or
- the amounts of these dry cleaning solvents which are supplied to the industry in the airshed by the major suppliers (and their market share for these solvents); and
- the total number and locations of all dry cleaners in the airshed that perform dry cleaning on site (some dry cleaning outlets act as agents and do not dry clean on their own premises).

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

- the total number and locations of all dry cleaners in the airshed that use white spirit; and
- the number of machines at each dry cleaning facility in the study area; or
- the number of full-time employees at each dry cleaning facility in the study area.

Consumption data obtained for an entire State or Territory (jurisdiction) need to be scaled down to the specific airshed. This can be done, in order of preference, by scaling consumption data according to the number of employees, the number of dry cleaning outlets, or population for the airshed and jurisdiction respectively.

A default EET based on typical emissions per employee can be used where solvent consumption data cannot be obtained for the airshed. As a last resort, per capita emission factors can be used where there are no employment data.

3.1.1 Estimating Total Solvent Emissions

Data on overall consumption of tetrachloroethylene and white spirit for the dry cleaning industry can be obtained from the chemical companies which supply dry cleaning solvents or from industry associations. A facility employing less than 20 persons is exempted from reporting to State or Territory authorities under the NPI. To ascertain the amounts of solvent to be used in calculating emissions from these smaller premises (i.e. the "aggregated emissions"), the amounts used in the larger (reporting) facilities have to be subtracted from the overall solvent usage data for the dry cleaning industry as a whole.

Best Practice Method

The mass balance approach assumes that all solvent used is eventually emitted, even if it is initially recycled or subjected to other processes.

Equation 1: Estimating emissions using the mass balance method

Overall tetrachloroethylene or white spirit emissions are calculated by equating them with consumption as follows

$$E = T$$

where

E = total tetrachloroethylene or white spirit emissions, kg yr^{-1}
T = total tetrachloroethylene or white spirit consumed, kg yr^{-1}

Default Method

Where data on consumption or distribution cannot be obtained, emissions can be estimated from employee numbers using an appropriate emission factor.

Equation 2: Estimating tetrachloroethylene emissions using an employee-based emission factor

An emission factor based on employee numbers can be used for estimating dry cleaning emissions using the following equation

$$E = EF * C$$

where

E = tetrachloroethylene emissions, kg yr^{-1}
EF = emission factor, kg $employee^{-1}$ yr^{-1}
C = number of employees in the airshed

This simplified method assumes all solvent is tetrachloroethylene. Section 2.2 indicated that other solvents represent no more than 3% of total consumption.

Equation 3: Estimating tetrachloroethylene emissions using per capita emission factors

A per capita factor can be used for estimating dry cleaning emissions using the following equation

$$E = EF * P$$

where

E = tetrachloroethylene emissions, kg yr^{-1}
EF = emission factor, kg yr^{-1} per capita
P = population of the airshed

3.1.2 Speciating VOC Emissions

Equation 4: Speciating white spirit

White spirit emissions must be speciated because xylene and toluene are NPI substances. Speciated VOC emissions can be calculated using the following equation for dry cleaning processes using white spirit

$$E_i = E * C_i /100$$

where

E_i = emission of VOC species i, kg yr^{-1}
E = VOC emissions from dry cleaning process, kg yr^{-1}
C_i = concentration of VOC species i in the products used in the dry cleaning process, % by mass

3.2 Spatial Surrogates and Spatial Allocation

Spatial surrogates are needed to allocate emissions to each grid cell in the defined airshed. Emissions should be allocated according to the location (and, where possible, size) of dry cleaning facilities in the airshed. The emissions estimated for each dry cleaner can be calculated by assuming that the emissions from each facility are the same. A more accurate technique (if data are available) is to distribute the emissions according to the number of machines in use at each facility (this may be difficult to ascertain without a comprehensive survey) or the number of full-time employees at each facility (this information will be less accurate but may be available from industry associations).

Dry cleaning associations can provide the addresses of dry cleaners which can then be converted to co-ordinates (AMG or latitude/longitude) by a process called geocoding in a Geographic Information System (GIS). If a GIS is not immediately accessible, a GIS company can be engaged to undertake the geocoding.

Equation 5: Estimating emissions in a grid cell

Emissions in a grid cell are estimated by the following equation

$$E_i = E \times N_i / \sum_i N_i$$

where

E_i = emissions in grid cell i
E = total emissions in airshed
N_i = number of dry cleaning outlets in grid cell i

If the locations of dry cleaners cannot be obtained, the spatial allocation of emissions may be performed on the basis of population distribution. As most dry cleaners operate in or near urban areas, and close to their customers and workforce, emissions can be allocated with reasonable accuracy to grid cells in proportion to population density. The Australian Bureau of Statistics collects population data by Collection District (CD). This data can be converted to population by grid cells using a specific program or GIS. Emissions can then be assigned to each grid cell using Equation 5, but using population numbers instead of numbers of dry cleaning facilities.

3.3 Emission Factors

As discussed above, emission factors based on employment or population may be used where data on consumption or usage are not available. A factor based on employee numbers was calculated from the South Eastern Queensland Trial, and is recommended as a default estimation method. Emission factors based on population are available from USEPA (1995).

Table 2: Emission Factors for Dry Cleaning Emissions

Substance	Emission Factors	
	Employment (kg yr^{-1} per employee)[a]	**Population (kg yr^{-1} per capita)[b]**
Tetrachloroethylene	100.6	0.6
Total VOCs	100.6	0.6

[a] Referenced from QDEH (1997).
[b] Referenced from USEPA (1995).

Speciation of white spirit emissions is required because toluene and xylene are listed as NPI substances. Speciation of tetrachloroethylene is not required because it is not a mixture.

Table 3: VOC Speciation Profile for White Spirit

Species	% Weight[a]
Toluene	0.5
Xylene	18.3

[a] Barton et al (1980).

3.4 Sample Calculations

Example 1: Using the emission factor method

Using Equation 3, tetrachloroethylene emissions may be calculated for an airshed with a population of 100,000 as follows

$$E = EF * P$$
$$= 0.6 * 10^5$$
$$= 60 * 10^4 \text{ kg yr}^{-1}$$

Example 2: Calculating speciated white spirit emissions

Table 2 indicates that xylene is present in white spirit at a concentration of 18.3 % by weight. Assuming 6000 kg of white spirit is used in an airshed, emissions of xylene may be estimated as follows

$$E_i = E * C_i / 100$$
$$= (6000 * 18.3) / 100$$
$$= 1100 \text{ kg yr}^{-1} \text{ of xylene}$$

where

E_i = emissions of VOC species i, kg yr^{-1}
E = white spirit emissions from dry cleaning, kg yr^{-1}
C_i = concentration of VOC species i in the products used by dry cleaning process, mass %

4.0 Uncertainty Analysis

4.1 Data Reliability

The accuracy of the best practice method is dependent on the quality of the data obtained. A reasonably accurate figure should be obtained if dry cleaning associations and the solvent suppliers are consulted about consumption figures.

4.2 Reliability of Emission Factors

Emission factors should only be used where consumption data related to tetrachloroethylene and white spirit cannot be obtained.

The employment-based emission factors developed for the South Eastern Queensland trial are considered to be more accurate than the population-based emission factors developed for the USA, because the Australian figures are considered more relevant and the employment basis is intrinsically more accurate. The employment approach is considered to have a moderate reliability, while the EET using population-based factors should be used only as a last resort.

4.3 Recommendations for Further Work

The development of emission factors based on the local dry cleaning industry would increase the accuracy of the default method. Information such as the numbers of machines and full-time employees at each facility could be found by surveying dry cleaning facilities. While this would be time consuming and costly, it would aid emission distribution accuracy.

5.0 Glossary of Terms and Abbreviations

AE	Aggregated Emissions
CFC	Chlorofluorocarbons
DCIA	Dry Cleaning Institute of Australia
EA	Environment Australia
EET	Emissions estimation technique
EPAV	Environment Protection Authority of Victoria
GIS	Geographic information system
NEPC	National Environment Protection Council
NEPM	National Environment Protection Measure
NPI	National Pollutant Inventory
QDEH	Queensland Department of Environment and Heritage
USEPA	United States Environmental Protection Agency
VOC	Volatile organic compound

6.0 References

Barton, S.L., Johnson, G.M., Mulcahy, M.F.R., Nelson, P.F., Quigley, S.M. and Smith, M.Y. (1980). *Smog-forming Hydrocarbons in the Atmosphere in Sydney*, Fifth report to SPCC.

DCIA (1996). *Code of Practice and Training Program for Safe Handling of Perchloroethylene Solvent in the Dry Cleaning Plant*, Dry Cleaning Institute of Australia.

EA (1998). *National Pollution Inventory Guide*, Environment Australia.

EA (1999). *NPI, Emissions Estimation Technique Manual for Dry Cleaning*, Environment Australia

EPAV (1990). *Industrial Waste Management Policy (Waste Minimisation)*, Gazette Special No. S52, 29 October 1990, Victoria.

EPAV (1996). *National Pollutant Inventory: Report on the Air Emissions Trials for the National Pollutant Inventory*, vol 2, AGPS, Commonwealth of Australia.

EPAV (1998). *Air Emissions Inventory, Port Phillip Region*, Publication Number 632, Environment Protection Authority, Victoria.

QDEH (1997). *Area-Based Emissions Estimation Workbook: Dry Cleaners*, Queensland Department of Environment and Heritage.

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

USEPA (1980). *Perchloroethylene Dry Cleaners — Background Information For Proposed Standards*, United States Environmental Protection Agency, EPA-450/3-79-029a, Research Triangle Park, North Carolina, USA.

USEPA (1978). *Control Of Volatile Organic Emissions From Perchloroethylene Dry Cleaning Systems*, United States Environmental Protection Agency, EPA-450/2-78-050, Research Triangle Park, North Carolina, USA.

USEPA (1981). *Control Of Volatile Organic Emissions From Petroleum Dry Cleaners (Draft)*, Office Of Air Quality Planning And Standards, U. S. Environmental Protection Agency, Research Triangle Park, North Carolina, USA.