Category		Title
NFR	2.D.3.f	Dry cleaning
SNAP	060202	Dry cleaning
ISIC		
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Contents

1 Overview

Dry cleaning refers to any process to remove contamination from furs, leather, down leathers, textiles or other objects made of fibres using organic solvents.

The most significant pollutants from dry cleaning are non-methane volatile organic compounds (NMVOCs), including chlorinated solvents. Heavy metal and persistent organic pollutant (POP) emissions are unlikely to be significant.

2 Description of sources

2.1 Process description

Dry cleaning can be defined as the use of chlorinated organic solvents, principally tetrachloroethene, to clean clothes and other textiles. In general, the process can be divided into four steps:

- cleaning in a solvent bath
- drying with hot air and recovery of solvent
- deodorisation (final drying)
- regeneration of used solvent after the clothes have been cleaned.

Clothes are first cleaned in a solvent bath, followed by drying in hot air. The solvents are regenerated and the dirt and grease from the cleaning process are removed as a waste product.

Figure 2-1 Process scheme for source category 2.D.3.f Dry cleaning

2.2 Techniques

Two main types of machine are in use:

- open-circuit machines — deodorisation of the clothes take place with venting of drying air to atmosphere;
- closed-circuit machines — solvent is condensed from the drying air inside the machine and there is no general venting.

Please note that for EU Member States, the European Solvent Directive 1999/13/EC has led to a phase-out of the open-circuit machine, because their emissions exceed the limits.

In the European Union, the dry cleaning sector is essentially made up of small family units, using one to two machines of 10/12 kg capacity.

2.3 Emissions

Emissions arise from evaporative losses of solvent, primarily from the final drying of the clothes, known as deodorisation. Emissions may also arise from the disposal of wastes from the process.

The most widespread solvent used in dry cleaning, accounting for about 90 % of the total consumption, is tetrachloroethene (also called tetrachloroethylene or perchloroethylene (PER)).

To a lesser extent, hydrocarbon solvents are also used for dry cleaning. Hydrocarbon solvents are C_{10} to C_{13} aliphatic hydrocarbons with a vapour pressure of less than 0,1 kPa at 20 °C. More recently, silicone solvents have been introduced in dry cleaning, most notably decamethylcyclopentasiloxane (D5). Recent international agreements which address substances responsible for stratospheric ozone depletion have led to a ban on the use of certain solvents (e.g. chlorofluorocarbons, carbon tetrachloride and 1,1,1-trichloroethane).

Emissions of organic compounds from dry cleaning vary considerably with the type of process and solvent used. Solvent emissions come out of the cage, the air circulation system and the distillation column, the still boiler, the handling and storage of still residue and filter muck, and out of the pipe fittings, flanges and pumps of the transport system.

Solvent emissions from dry cleaning machines are highly dependent on correct operation and maintenance. Inadequate operating procedures and poor maintenance can result in an excessive loss of solvent, both in the workroom and to the outside atmosphere.

Further sources of emissions are the solvent-laden air discharged from storage tanks during filling and solvents retained on cleaned clothes and waste materials.

Perchloroethylene (PER) is the most important solvent in the European dry-cleaning branch, amounting to approximately 90 % within the Union, followed by hydrocarbons. All the other solvents are of minor importance. In the United States and Japan flammable petroleum solvents (white spirit) are also used, such as Stoddard or 140-F, which are inexpensive hydrocarbon mixtures similar to kerosene (US Environmental Protection Agency (USEPA), 1985).

Small amounts of detergents are normally added to aid cleaning, e.g. surface-active agents, solvents (alcohols, petroleum), optical whitener, resin finishing, disinfectant additives and aromatic substances. A profile for C_{10} - C_{13} hydrocarbon solvents in use in the United States is shown in Table 3.

2.4 Controls

In general, emission control techniques include:

- good operating procedures and end-of-pipe abatement techniques (such as condensation or carbon adsorption); or
- replacement of machine with one with better performance (e.g. totally enclosed machines rather than open circuit machines).

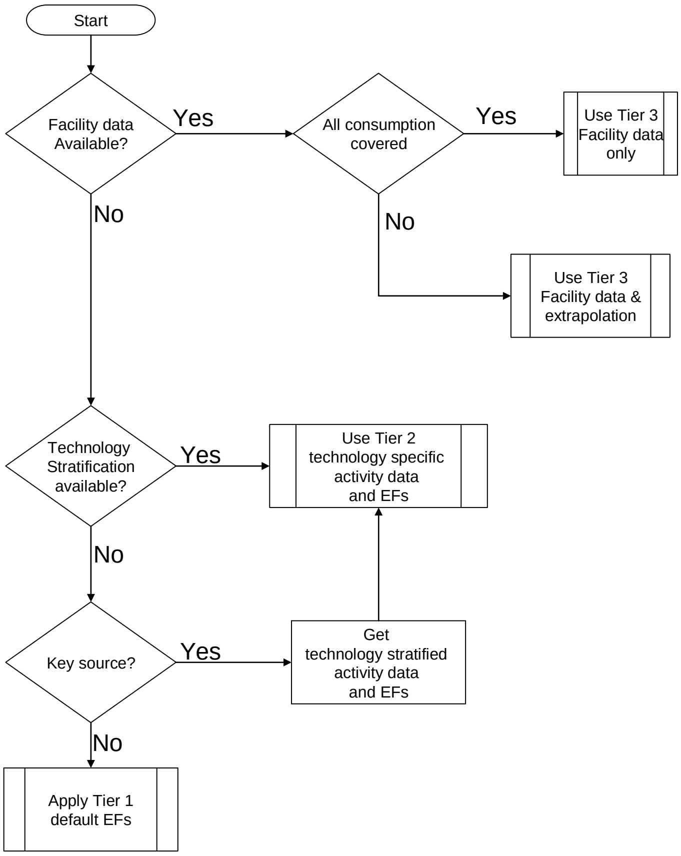
3 Methods

3.1 Choice of method

Figure 3-1 presents the procedure to select the methods for estimating emissions from dry cleaning. The basic idea is:

- if detailed information is available, use it;
- if the source category is a key category, a Tier 2 or better method must be applied and detailed input data must be collected. The decision tree directs the user in such cases to the Tier 2 method, since it is expected that it is more easy to obtain the necessary input data for this approach than to collect facility level data needed for a Tier 3 estimate;
- the alternative of applying a Tier 3 method, using detailed process modelling, is not explicitly included in this decision tree. However, detailed modelling will always be done at facility level and results of such modelling could be seen as 'facility data' in the decision tree.

Figure 3-1 Decision tree for source category 2.D.3.f Dry Cleaning



3.2 Tier 1 default approach

3.2.1 Algorithm

In the Tier 1 approach, the emissions are estimated from solvent consumption data. Most of the solvent is recycled, but some is lost to the environment. This needs to be replaced and it can be assumed that the quantity of solvent which is used for replacement is equivalent to the quantity emitted plus the quantity taken away with the sludge.

Solvent emissions directly from the cleaning machine into the air represent about 80 % of the solvent consumption (i.e. 80 % of solvent used for the replacement of lost solvent) for an open-circuit equipment and little more than 40 % for a closed-circuit machine. Open-circuit equipment, however, is no longer used within the EU following the European Solvents Directive coming into force. The remainder of the lost solvent is released to the environment in residues or retained on cleaned clothes. For the simpler methodology it can be assumed that this eventually finds its way to the atmosphere (Passant, 1993; UBA, 1989). Also, a significant amount of the solvent goes back to producers and to recyclers together with the sludge.

Solvent consumption data may be available from the industry and this can be compared with a per capita emission factor. In addition, the proportion of solvent lost directly from the machine can also be estimated.

In cases where specific abatement options are to be taken into account, a Tier 1 method is not applicable and a Tier 2 or Tier 3 approach must be used.

3.2.2 Default emission factors

The Tier 1 default emission factors for NMVOC emissions from dry cleaning is a weighted average, calculated from the sum of all activity and emission data from the Greenhouse Gas and Air Pollution Interactions and Synergies (GAINS) model (International Institute for Applied Systems Analysis (IIASA), 2008).

Table 3-1 Tier 1 emission factors for source category 2.D.3.f Dry cleaning

Tier 1 default emission factors					
	Code	Name			
NFR Source Category	2.D.3.f	Dry cleaning			
Fuel	NA				
Not applicable	NOx, CO, SOx, NH3, TSP, PM10, BC, Pb, Cd, Hg, As, Cr, Cu, Ni, Se, Zn, PCB, PCDD/F, Benzo(a)pyrene, Benzo(b)fluoranthene, Benzo(k)fluoranthene, Indeno(1,2,3-cd)pyrene, HCB				
Not estimated	PM2.5				
Pollutant	**Value**	**Unit**	**95% confidence interval**		**Reference**
			Lower	**Upper**	
NMVOC	40	g/kg textile treated	10	200	IIASA (2008)

If the amount of textile treated as activity data is not available, a default emission factor based on the inhabitants can be used. The factor is adopted from De Lauretis (1999) and is applicable to all machines. The factor is 0.3 kg/inhabitant/year and has a quality rating of E. Please refer to the General Guidance Chapter 5, Uncertainties, for the explanation of the quality ratings.

3.2.3 Activity data

Basic activity statistics for using the Tier 1 emission factor are the total quantity of material cleaned.

3.3 Tier 2 technology-specific approach

The Tier 2 technology-specific approach requires a comparison of solvent consumption data (available from the industry) or population, with emission statistics based on technology- and solvent-dependent emission factors and activity statistics.

3.3.1 Algorithm

The Tier 2 approach is similar to the Tier 1 approach. To apply the Tier 2 approach, both the activity data and the emission factors need to be stratified according to the different techniques that may occur in the country. The approach is as follows below.

Stratify the dry cleaning in the country to model the different process types occurring in the industry into the inventory by:

- defining the production using each of the separate product and/or process types (together called 'technologies' in the formulae below) separately; and
- applying technology-specific emission factors for each process type:

$$E_{pollutant} = \sum_{technologies} AR_{production,technology} \times EF_{technology,pollutant} \quad (2)$$

If no direct activity data are available, penetration of different technologies within the industry could be estimated from data on capacities, number of employees or other data that reflect relative sizes of facilities using the different technologies.

A country where only one technology is implemented is basically a special case of the above approaches. The penetration of this technology in such a case is 100 % and the algorithm in equation (2) reduces to:

$$E_{pollutant} = AR_{production} \times EF_{technology,pollutant} \quad (3)$$

The emission factors in this approach will still include all sub-processes.

3.3.2 Technology-specific emission factors

This section presents Tier 2 technology-specific emission factors for NMVOCs from dry cleaning. These emission factors are based on the Expert Group on Techno-economic Issues (EGTEI) background document for dry cleaning (EGTEI, 2003). Note there is a large difference between the Tier 1 and Tier 2 emission factors — this reflects an inconsistency between the information presented in the two references used.

Table 3-2 Tier 2 emission factors for source category 3.B.1 Dry cleaning, Open-circuit machine

Tier 2 emission factors					
	Code	Name			
NFR Source Category	2.D.3.f	Dry cleaning			
Fuel	NA				
SNAP (if applicable)	060202	Dry cleaning			
Technologies/Practices					
Region or regional conditions					
Abatement technologies	Open-circuit machine				
Not applicable	NOx, CO, SOx, NH3, TSP, PM10, BC, Pb, Cd, Hg, As, Cr, Cu, Ni, Se, Zn, PCB, PCDD/F, Benzo(a)pyrene, Benzo(b)fluoranthene, Benzo(k)fluoranthene, Indeno(1,2,3-cd)pyrene, HCB				
Not estimated	PM2.5				
Pollutant	**Value**	**Unit**	**95% confidence interval**		**Reference**
			Lower	**Upper**	
NMVOC	177	g/kg textiles cleaned	100	200	EGTEI (2003)

3.3.3 Abatement

A number of add-on technologies exist that are aimed at reducing the emissions of specific pollutants. The resulting emissions can be calculated by replacing the technology-specific emission factor with an abated emission factor as given in the formula:

$$EF_{technology,abated} = (1 - \eta_{abatement}) \times EF_{technology,unabated} \qquad (4)$$

The table below presents the reduction efficiencies for degreasing. The unabated emission factors are presented in Table 3-2.

Table 3-3 Abatement efficiencies ($\eta_{abatement}$) for source category 2.D.3.f Dry cleaning

Tier 2 Abatement efficiencies					
	Code	Name			
NFR Source Category	2.D.3.f	Dry cleaning			
Fuel	NA	not applicable			
SNAP (if applicable)	060202	Dry cleaning			
Abatement technology	**Pollutant**	**Efficiency**	**95% confidence interval**		**Reference**
		Default Value	**Lower**	**Upper**	
Open-circuit machine with activated carbon filter	NMVOC	70%	60%	80%	EGTEI (2003)
Conventional closed-circuit PER machine	NMVOC	89%	80%	90%	EGTEI (2003)
Conventional closed-circuit PER machine with activated carbon filter	NMVOC	91%	90%	100%	EGTEI (2003)
New generation closed-circuit PER machine	NMVOC	95%	90%	100%	EGTEI (2003)
Hydrocarbon machines	NMVOC	95%	90%	100%	EGTEI (2003)
Wet cleaning	NMVOC	100%	100%	100%	EGTEI (2003)

3.3.4 *Activity data*

Basic activity statistics are solvent consumption for the simpler methodology and quantity of material cleaned per machine type for the detailed methodology.

3.4 Tier 3 emission modelling and use of facility data

Tier 3 is not available for this source category.

4 Data quality

4.1 Completeness

No specific issues.

4.2 Avoiding double counting with other sectors

No specific issues.

4.3 Verification

Verification is through the comparison of results using different methodologies:

- emissions estimates based on per-capita emission factors;
- emissions based on solvent consumption data from the industry, trade associations, etc;
- emissions based on emission factors per tonnage of material cleaned.

4.3.1 Best Available Technique emission factors

Information regarding emissions when using Best Available Techniques is available from the BREF documents for the Surface Treatment of Metals and the Surface Treatment using Organic Solvents.

4.4 Developing a consistent time series and recalculation

No specific issues.

4.5 Uncertainty assessment

No specific issues.

4.5.1 Emission factor uncertainties

Uncertainty depends on the methodology. The highest uncertainty, > 100 %, would result from the use of per-capita emission factors alone (see subsection 3.2.2 of the present chapter). Unverified solvent consumption data may also have a similar uncertainty. When using the Tier 1 and Tier 2 methodology emission factors, the assumed uncertainty is lower.

4.5.2 Activity data uncertainties

No specific issues.

4.6 Inventory quality assurance/quality control QA/QC

The weakest aspect of the methodology is the requirement for activity data on market share. This is likely to be difficult.

In addition, dry cleaning, in common with other processes using chlorinated solvents, is continually developing; solvents used will change and the efficiency of machines in use may improve rapidly. There will therefore be a need to review this chapter regularly.

4.7 Gridding

Spatial disaggregation criteria depend on the size of the units: emissions from smaller installations can be reasonably disaggregated according to the population distribution, assuming a constant value of per-capita cleaned material.

As mentioned above, the dry cleaning sector in the European Union essentially involves small family units, using one to two machines of 10/12 kg capacity. In some countries, grouping of shops in 'chains' may have a certain importance, but most of such groups operate only small units, so that pollution problems will be similar. For the whole EU, there are about 60 000 dry cleaning shops.

4.8 Reporting and documentation

No specific issues.

5 Glossary

Dry cleaning:	Any industrial or commercial activity using VOCs in an installation to clean garments, furnishing and similar consumer goods with the exception of the manual removal of stains and spots in the textile and clothing industry.

6 References

De Lauretis (1999). Personal communication (emission factor/inhabitant). ANPA, Rome, Italy.

EGTEI (2003). Final background document on the sector Dry cleaning. Prepared in the framework of EGTEI by CITEPA, Paris.

IIASA (2008). Greenhouse Gas and Air Pollution Interactions and Synergies (GAINS) model, www.iiasa.ac.at/rains/gains-online.html.

Passant N.R. (1993). Emissions of Volatile Organic Compounds from Stationary Sources in the United Kingdom: A Review of Emission Data by Process.

U.S. EPA (1985). Compilation of Air Pollutant Emission Factors: Stationary Point and Area Sources. Edited by the U.S. Environmental Protection Agency, PB89 — 128631, Research Triangle Park N.Y., 1985.

UBA (1989). Luftreinhaltung `89 — Tendenzen — Probleme — Lösungen. Edited by the German Federal Environmental Protection Agency (Umweltbundesamt), Erich Schmidt Verlag GmbH, Berlin 1989.

7 Point of enquiry

Enquiries concerning this chapter should be directed to the relevant leader(s) of the Task Force on Emission Inventories and Projection's expert panel on combustion and industry. Please refer to the TFEIP website (www.tfeip-secretariat.org/) for the contact details of the current expert panel leaders.