Final Background Document
on the sector

Surface Cleaning

Prepared in the framework of EGTEI

Prepared by CITEPA, Paris

Summary

1. Data from the bibliography (p.3)

Data currently used in RAINS are displayed in this paragraph for three different countries. Data for other countries are downloadable on http://www.iiasa.ac.at/~rains/voc_review/single.html (old data not more available on RAINS web site).

2. Short technology description (p.7)

3. EU regulation : Directive 1999/13/EC of 11 march 1999 (p.7)

4. Definition of Reference Installations (p.8)

Three reference installations are defined according to the annual consumption of solvent (kg solvent/y).

5. Emission abatement techniques and costs (p.8)

Six primary measures and one secondary measure are defined.
Table 5.3.1 (p.12) summarizes the emission factors with the corresponding abatement efficiencies for each combination measure.
Table 5.3.2 (p.13) summarizes investments and operating costs for each combination. These costs are entered only once in the database.
Table 5.3.3 (p.14) presents installations in, or not in, compliance with the SED directive.

6. Data to be provided by national experts for the completion of the database for their own country (p.15)

Tables to be filled in by national experts are displayed:
Table 6.2.1: Country specific data.
Table 6.2.2: Activity levels of Reference Installations. Consumptions of solvent (t/y) in each type of reference installation (RI) are required.

- Total activity (t solvent/y) has to be estimated from 2000 to 2020 and distributed according to the different installations.
- If no detailed information is available in 2000, total activity can be divided equally between all RI (i.e.: 25% for each one).
- If no prevision on the structure of this sector is available (for 2005 to 2020), the proportions used in 2000 can be used. But total activity (t/y) should evolve.

Table 6.2.3: Application rate and applicability.

- If detailed information is available, table 6.2.3 can be filled in.
- If only sparse information is available, table 6.2.3 can be filled with default values provided in 6.2.4 and 6.2.5).

Table 6.2.6: Unabated emission factor

The default data mean can be modified in a range of ± 10%.
If a measure is missing in the document, national experts have to contact the Secretariat to add it in the background documents.

7. Explanatory notes (p.19)

Explanations about the figures are given in this paragraph. Investments and operating costs of primary and secondary measures have been provided by industrial experts.

8. References (p.26)

Surface Cleaning

SNAP 06 02 01 or NFR 3 B

This sector covers the operations of degreasing which aim is to clean parts or products, mostly metal, in industrial applications. Emissions due to this sector are VOC.

ACTIVITY: consumption of solvents (t/ year)
POLLUTANT CONSIDERED : NMVOC

1 Data from the bibliography

1.1 Data currently used in the RAINS model [3] [8]

RAINS category "surface cleaning" included in "solvent use" takes into account two sectors: dry cleaning and degreasing.
For degreasing, two basic types of machines are distinguished: open-top and enclosed.

1.1.1 Control options

The RAINS-VOC module distinguishes the following control options for this sector:

- Basic emission management techniques. It includes good housekeeping (proper operation and maintenance), improved containment achieved by improved covers (efficiency: 20%).
- Substitution, i.e., switch to water-based systems, possibly involving some modification (efficiency: 100%).
- Activated carbon adsorption (efficiency: 80%)
- Low temperature plasma process. This technique is already applied in some sectors (efficiency: 98%; applicability: 70%).
- Conveyorised degreasers with integrated carbon adsorption (efficiency: 95%; applicability :> 90%).

Combinations of these techniques are also considered in the RAINS model.
Activity unit used in RAINS: kt of solvents used.

1.1.2 Abatement costs

Costs of the combination of techniques range from < 150 to 4700 € $_{1990}$ / t VOC non-emitted.

Examples for three countries are displayed:

No comments are made on the figures displayed bellow because no further information is available. Data at a county level are downloadable on http://www.iiasa.ac.at/~rains/voc_review/single.html

Table 1.1.2.1: French situation

	Emission factors g VOC/kg solvent used	Applicability %	Technical efficiency %	Cost € 1990/t VOC
Activity level existing installations : 1990: 77 237 t solvent, 2010 : 17 486 t solvent; new installations : 1990 : - , 2010: 69 945 t solvent; **VOC emissions scenario business as usual**: existing installations : 1990: 63 330 t, 2010 : 3 530 t; new installations : 1990 : - , 2010: 17 330 t				
EXISTING				
No control	900	0	0	0
Basic emission management techniques	720	100	20	144
water-based systems	454.5	50	99	2973
activated carbon adsorption	252	90	80	1429
low temperature plasma process	459	50	98	1407
conveyorised degreasers with integrated carbon adsorption	216	80	95	1807
NEW INSTALLATIONS				
No control	720	0	0	0
water-based systems	363.6	50	99	3716
activated carbon adsorption	201.6	90	80	2011
low temperature plasma process	459	50	73	1874
conveyorised degreasers with integrated carbon adsorption	189	80	92	2192

Table 1.1.2.2: German situation (Old Landers)

	Emission factors g VOC/kg solvent used	Applicability %	Technical efficiency %	Cost € 1990/t VOC
Activity level existing installations : 1990: 243 000 t solvent, 2010 : -; new installations : 1990 : - , 2010: 254 883 t solvent; **VOC emissions scenario business as usual**: existing installations : 1990: 85 050 t, 2010 : -; new installations : 1990 : - , 2010: 13 650 t				
EXISTING				
No control	900	0	0	0
Basic emission management techniques	720	100	20	144
water-based	276.3	70	99	2985

systems				
activated carbon adsorption	324	80	80	1429
low temperature plasma process	282.6	70	98	1382
conveyorised degreasers with integrated carbon adsorption	216	80	95	1807
NEW INSTALLATIONS				
No control	720	0	0	0
water-based systems	221	70	99	3732
activated carbon adsorption	259.2	80	80	2011
low temperature plasma process	282.6	70	87	1531
conveyorised degreasers with integrated carbon adsorption	189	80	92	2192

Table 1.1.2.3: German situation (New Landers)

	Emission factors g VOC/kg solvent used	**Applicability %**	**Technical efficiency %**	**Cost € 1990/t VOC**
Activity level existing installations : 1990: - solvent, 2010 : - new installations : 1990 : - , 2010: -; **VOC emissions scenario business as usual** : existing installations : 1990: -, 2010 : - new installations : 1990 : - , 2010: -				
EXISTING				
No control	900	0	0	0
Basic emission management techniques	720	100	20	144
water-based systems	276.3	70	99	2913
activated carbon adsorption	324	80	80	1429
low temperature plasma process	282.6	70	98	1522
conveyorised degreasers with integrated carbon adsorption	216	80	95	1807
NEW INSTALLATIONS				
No control	720	0	0	0
water-based systems	221	70	99	3642
activated carbon adsorption	259.2	80	80	2011
low temperature plasma process	282.6	70	87	1728
conveyorised degreasers with	189	80	92	2192

integrated carbon adsorption				

Table 1.1.2.4 : Hungarian situation

	Emission factors g VOC/kg solvent used	**Applicability %**	**Technical efficiency %**	**Cost € 1990/t VOC**
Activity level : existing installations : 1990: 10 041 t solvent, 2010 : 5 563 t solvent new installations : 1990 : - , 2010: 5 563 t solvent; **VOC emissions scenario business as usual**: existing installation : 1990: 9 040 t, 2010 : 5 010 t new installation : 1990 : - , 2010: 4 010 t				
EXISTING				
No control	900	0	0	0
Basic emission management techniques	720	100	20	144
water-based systems	276.3	70	99	2100
activated carbon adsorption	324	80	80	1429
low temperature plasma process	282.6	70	98	3099
conveyorised degreasers with integrated carbon adsorption	216	80	95	1807
NEW INSTALLATIONS				
No control	720	0	0	0
water-based systems	221	70	99	2625
activated carbon adsorption	259.2	80	80	2011
low temperature plasma process	282.6	70	87	3954
conveyorised degreasers with integrated carbon adsorption	189	80	92	2192

Data on combinations of measures are also available on IIASA website [9].
Investments and operating costs are no more detailed in the current documents.

1.2 Situation in the UK [6]

Surface cleaning covers a wide range of operations and size of companies. The baseline figure for VOC emissions from the sector in UK is 75 000 [6]. A recent industry estimate suggests that between 20 000 t and 30 000 t of solvents were used in 1994 for all metal cleaning. It has been estimated that there are around 6 000 vapour degreasing plants in the UK using chlorinated solvents, distributed among 4 500 – 5 000 estimated installations.
According to [6], the majority (70-80%) of surface cleaning processes still use halogenated solvents. This has been discussed further with several suppliers of chemicals and in the past few years there has been a change in trends. Some industries have already tried to minimise emissions by using water based systems where possible, switching to more efficient plant and collecting solvents in a sump and recycling.

Costing estimations are based on the assumption that 50% of small and medium sized processes will change to the aqueous based cleaning systems and 50% to sealed chamber systems has been used.
According to [6], activated carbon adsorption systems are not considered viable control techniques since equipment suppliers will not guarantee that the technology will be able to consistently meet with the Directive.
Additional capital costs are estimated to be range from 30 200 to 302 000 € for aqueous cleaning depending the unit size and the level of cleaning required. For sealed chamber system, additional capital cost are estimated to be range from 45 300 to 377 500 € depending the unit size and the level of cleaning required. Additional capital cost for activated carbon unit is between 196 300 and 226 500 €. Additional operating costs would typically be in the order of 10 to 20% capital costs.
These costs assume that complete new systems will be installed rather than existing systems modified
According to [6], the average cost of complying with the Directive is around 7 550 € per installation with an estimated error range of ± 50%.

2 Short technology description

This description covers stack and fugitive emissions from the cleaning process.
Solvent degreasing (or solvent cleaning) is the process of using organic solvents to remove water-insoluble soils such as grease, fats, oils, waxes, carbon deposits, fluxes and tars from metal, plastic, fibreglass, printed circuit boards and other surfaces.
Several techniques for degreasing exist: use of solvents, of aqueous products, of chemical detergents, ultra sound degreasing, supercritical CO_2 …
Solvents mainly used in degreasing sector are chlorinated solvents because they are not flammable.
Solvent cleaning is most often used when the metallic part has to be dry after degreasing.
The following parameters have a great influence on the choice of the surface cleaning process and media:

- the medium to be cleaned,
- the type of impurity to be removed,
- the manufacturing process,
- the requirements induced by subsequent process steps.

The metalworking industries are the major users of solvent degreasing, i. e. automotive, electronics, plumbing, aircraft, refrigeration, and business machine industries. Solvent cleaning is also used in industries such as printing, chemicals, plastics, rubber, textiles, glass, paper, and electric power. Most repair stations for transportation vehicles and electric tools use solvent cleaning at least part of the time.

3 EU Regulation: directive 99/13/CE of 11 march 1999 [2]

At European level, the Montreal Protocol from 31/12/95 forbids the use of Trichlorethane 111 and CFC 113 (carbon tetrachloride) since year 2000. In July 2002, Trichlorethylene became classified R45 and Perchloroethylene and chloride of methylene became both classified R40. The VOC directive 99/13 of 1999 implements limit emission values: 75 mg/m^3 for non chlorinated solvents, 20 mg/m^3 for R40 solvents and 2 mg/m^3 for R45 solvents.

These limit values are reported in the table below:

	Solvent consumption threshold	Emission limit value	% fugitive emissions
Solvents with risk phrases	From 1 to 5 t /y	20 mg/m^3	15 %
	>5 t /y	20 mg/m^3	10 %
Other solvents	From 2 to 10 t /y	75 mg/m^3	20 %
	>10 t /y	75 mg/m^3	15 %

4 Definition of reference installations

Three reference installations are considered. They differ by their bath surface size.
Three sizes of installation are mainly encountered and are retained as reference installation [7]:

- installations with a bath surface around 0,4 m^2.
- installations with a bath surface around 1,5 m^2.
- installations with a bath surface around 3 m^2.

Reference installation 01 is considered to consume 0,82 t of solvent per year and to work 500 h per year [7].
Reference installation 02 is considered to consume 10 t of solvent per year and to work 1 500 h per year [7].
Reference installation 01 is considered to consume 35 t of solvent per year and to work 2000 h per year [7].

Table 4.1: Reference installation

Reference Installation Code	Description	Annual Solvent Consumption [t/y]	Working time [h/y]	Lifetime [y]
01	Small installation, bath surface : 0.4 m^2	0.82	500	10 to 20
02	Medium installation, bath surface : 1.5 m^2	10	1 500	10 to 20
03	Large installation, bath surface : 3 m^2	35	2 000	10 to 20

5 Emission abatement techniques and costs

5.1 Definitions of primary measures

Different types of process that lead to VOC emission reduction exist for surface cleaning. The main known and/or commonly encountered in the industry are described below.

Single sealed chamber systems
This technique prevents direct exposure between the solvent and the atmosphere by a series of interlocks, and by the use of a vapour extraction and/or refrigeration system which

recycles the vapour back into the solvent sump. These provide an extremely high degree of solvent containment and reduce fugitive emissions. These machines can work either with chlorinated solvents or with other solvents like hydrocarbons A3 class (flash point larger than 55°C meaning these solvents are not flammable under current use but can become flammable during non controlled use (flammable solvents have a flash point < 55° C)), HFC or HFE.

Cold cleaners

Cold cleaners are mainly applied in maintenance and manufacturing. They are batch loaded, non-boiling solvent degreasers.
Cold cleaner operations include spraying, brushing, flushing, and immersion. In a typical maintenance cleaner, dirty parts are cleaned manually by spraying and then soaking in the tank. After cleaning, the parts are either suspended over the tank to drain or are placed on an external rack that routes the drained solvent back into the cleaner. The cover is intended to be closed whenever parts are not being handled in the cleaner. Typical manufacturing cold cleaners vary widely in design, but there are two basic tank designs: the simple spray sink and the dip tank. Of these, the dip tank provides more thorough cleaning through immersion, and often is made to improve cleaning efficiency by agitation.

Open-top vapours systems

Open-top vapour degreasers are batch loaded boiling degreasers that clean with condensation of hot solvent vapour on colder metal parts. Vapour degreasing uses halogenated solvents (usually perchloroethylene, trichloroethylene), because they are not flammable and their vapours are much heavier than air.
A typical vapour degreaser is a sump containing a heater that boils the solvent to generate vapours. Parts to be cleaned are immersed in the vapour zone, and condensation continues until they are heated to the vapour temperature. Residual liquid solvent on the parts rapidly evaporates as they are slowly removed from the vapour zone. Cleaning action is often increased by spraying the parts with solvent below the vapour level or by immersing them in the liquid solvent bath. Nearly all vapour degreasers are equipped with a water separator which allows the solvent to flow back into the degreaser.

Aqueous based cleaning systems

This technique consists of water, detergent and a small amount of solvents, and has been shown to provide a reasonable cleaning efficiency for certain applications. Besides acid cleaning baths, strong till weak alkaline and neutral products are used for industrial cleaning of hard surfaces. Neutral cleaners are predominantly applied for intermediate and final surface cleaning, whereas strong alkaline products aim at obtaining very clean surfaces before surface ennoblement, phosphatation or coating processes. Acid solvents are found in special applications. Water-based cleaning agents can be used for the cleaning of metals such as steel, aluminium, magnesium, copper, etc., but also for plastics, coated surfaces, glass and electronic parts. In large parts of industrial surface cleaning, water-based systems have been established, leading partly to even better cleaning results as former solvent-based systems. This effect is especially related to further processing of the substrate, such as coating. The two main techniques used in aqueous systems are immersion (small US tanks to multi-tanks system) and aspersion (small machines interoperations with complete tunnels).

Improvement of Equipment

For cold cleaners, bath evaporation can be controlled by using a cover regularly, by allowing an adequate freeboard height, and by avoiding excessive drafts in the workshop.
For open-top vapour systems, most emissions are due to diffusion and convection, which can be reduced by using an automated cover, by using a manual cover regularly, by spraying below the vapour level, by optimising work loads, or by using a refrigerated freeboard chiller (which may be replaced, on larger units, by a carbon adsorption device).

Emergent technologies can be encountered in specific cases for the time being, they are not considered in the document because only few application are suitable with those technique until now:

Plasma Degreasing

This technology is already applied in some specific production sectors and can be applied to a large variety of substrates leading partly to even better cleaning results than former solvent systems. This effect is especially related to further processing of the substrate, such as coating of certain plastics with water-based paints. Thus, a double emission reduction may be achieved in some cases. Within the plasma degreasing process, surface cleaning is carried out at temperatures below 100 °C and a pressure between 0.1 and 2Ÿ10^{-3} hPa. The vacuum chamber is filled with process gas, such as noble gases (e. g. argon, helium), fluorine containing gases (e. g. tetrafluoromethane) or oxygen. An electric field conveys energy to the system, resulting in ionised gas particles. Oxygen is mostly used as process gas. The radicals generated via excitation aim at cutting the hydrocarbon chains and oxidise them to form carbon dioxide and water; the cleaning effect of the plasma is based on this chemical reaction. Organic impurities can be removed by this degreasing process, but it is not adapted to inorganic impurities such as shavings, dust or salts.

Biological Cleaning Process

This technology is based on a water-based cleaning agent combined with an integrated microbiology for the degradation of oils and grease. The water-based cleaning solution is light alkaline to allow the degreasing of a wide range of metals (e. g. copper, iron, aluminium, zinc).The used micro organisms are natural, their living conditions are optimised and continuously controlled via a computer system in order to keep the determinant parameters of the milieu optimal. In order not to endanger the micro organisms, the cleaning temperature is kept between 40 and 45 °C (but can go down to 35°C in certain systems) and the pH-value must remain around 9. The cleaning agent is regenerated via automatic dosage. When comparing to conventional degreasing processes, the amount of generated waste water is in this case much smaller. Some substances cause damage to the micro organisms, or worse kill them; among these substances are chlorinated products, whose degradation has not yet been clarified. The main applications encountered are degreasing fountains for maintenance cleaning.

Supercritical CO_2

The principle of this technique is that at supercritical stage (beyond 75 bars and 35°C), intermediary between liquid and gas, CO_2 has solvent properties which have the advantage to be adjustable with the variation of temperature and pressure. This solvent is clean and easily recoverable in making it pass again in a gas stage at the end of the cycle. Nevertheless its cleaning power is limited: it works well for non-polar product but is more difficult with polar one. This difficulty can be surmounted by added few percent of co-solvent or a mechanical effect by ultra-sounds.

Primary measures considered are as follows to describe the current situation and the future need for compliance with directive 99/13:

Table 5.1.1: Primary measures

Primary Measure Code	Description
00	Open-top degreaser
01	Improvement of equipment : semi open-top degreaser and good house keeping
02	Sealed chamber system using chlorinated solvents
03	Cold cleaner
04	Closed degreaser using A3 solvents or fluoro solvents (HFC and HFE)
05	Aqueous cleaning process

5.2 Definitions of secondary measures

For open-top vapour systems, exhaust emissions can be reduced by a carbon adsorber that collects the solvent vapours for reuse. These systems are quite expensive due to the infrastructure required for disposal or recovery.
Other filter types exist such as membranes but they are not considered in the document due to unavailable data on costs.

Table 5.2.1: Secondary measures

Secondary Measure Code	Description
00	None
01	Activated carbon filter

5.3 Emission factors and costs data for the different abatement techniques

Table 5.3.1: Emission factors of VOC and abatement efficiencies for applied emission abatement techniques.

Combination code	EF NMVOC [g/kg cleaning products]	Abatement efficiency [%]	EF NMVOC CI %	Q
01 00 00	710	0	27	4
01 00 01	142	80	20	4
01 01 00	532,5	25	20	4
01 01 01	106,5	85	20	4
01 02 00	35,5	95	20	4
01 03 00	80	89	30	2
01 04 00	25	96	20	2
01 04 01	20	97	10	2
01 05 00	0	100	0	4
02 00 00	710	0	27	4
02 00 01	142	80	20	4
02 01 00	532,5	25	20	4
02 01 01	106,5	85	20	4
02 02 00	35,5	95	20	4
02 03 00	80	89	30	2
02 04 00	25	96	20	2
02 04 01	20	97	10	2
02 05 00	0	100	0	4
03 00 00	710	0	27	4
03 00 01	142	80	20	4
03 01 00	532,5	25	20	4
03 01 01	106,5	85	20	4
03 02 00	35,5	95	20	4
03 03 00	80	89	30	2
03 04 00	25	96	20	2
03 04 01	20	97	10	2
03 05 00	0	100	0	4

Q: data quality from 1 to 5 (see Annex 2)

Sources: [5, 8, 4, 9, 10]

The activity unit is represented by the cleaning products consumption (both organic solvents and water based cleaning agents).

It has been assumed that fixed operating costs (only for secondary measure) represent 5% of the investment but this value can be discussed.

Table 5.3.2: Costs for abatement techniques

Combination code	Invest [€] mean	Invest CI %	Q	Fixed OC [€/y] mean	OC^{fix} CI %	Q	Variable OC [€/y] mean	OC^{var} CI %	Q	Total OC [M€/y] mean	OC^{tot} CI %	Q
01 00 00	0	-	-	-	-	-	0	25	4	0	25	4
01 00 01	150 000	25	4	7 500	25	4	4 916	25	4	12 416	25	4
01 01 00	19 000	25	4	-	-	-	-183	25	4	-183	25	4
01 01 01	169 000	25	4	7 500	25	4	4 879	25	4	12 379	25	4
01 02 00	85 000	45	2	-	-	-	-694	25	4	-694	25	4
01 03 00	100	25	4	-	-	-	189	25	4	189	25	4
01 04 00	67 500	25	4	-	-	-	8	25	4	8	25	4
01 04 01	217 500	25	4	7 500	25	4	5 492	25	4	12 992	25	4
01 05 00	22 400	35	3	-	-	-	343	25	4	343	25	4
02 00 00	0	-	-	-	-	-	0	25	4	0	25	4
02 00 01	170 000	25	4	8 500	25	4	2 776	25	4	11 276	25	4
02 01 00	39 500	25	4	-	-	-	-2 226	25	4	-2 226	25	4
02 01 01	209 500	25	4	8 500	25	4	2 331	25	4	10 831	25	4
02 02 00	160 000	25	4	-	-	-	-8 459	25	4	-8 459	25	4
02 03 00	2 400	25	4	-	-	-	2 308	25	4	2 308	25	4
02 04 00	155 000	25	4	-	-	-	100	25	4	100	25	4
02 04 01	325 000	25	4	8 500	25	4	9 800	25	4	18 300	25	4
02 05 00	42 000	35	3	-	-	-	4 181	25	4	4 181	25	4
03 00 00	0	-	-	-	-	-	0	25	4	0	25	4
03 00 01	230 000	25	4	11 500	25	4	-4 933	25	4	6 567	25	4
03 01 00	65 000	25	4	-	-	-	-7 792	25	4	-7 792	25	4
03 01 01	295 000	25	4	11 500	25	4	-6 491	25	4	5 009	25	4
03 02 00	250 000	25	4	-	-	-	-29 608	25	4	-29 608	25	4
03 03 00	6 000	25	4	-	-	-	8 077	25	4	8 077	25	4
03 04 00	220 000	25	4	-	-	-	351	25	4	351	25	4
03 04 01	450 000	25	4	11 500	25	4	19 649	25	4	31 149	25	4
03 05 00	150 000	35	3	-	-	-	14 632	25	4	14 632	25	4

Q: data quality from 1 to 5 (see Annex 2) - : non applicable

Sources: [1, 4, 5, 6, 7, 10]

Variable costs for the combination codes 01 04, 02 04 and 03 04 with or without secondary measures are those for the use of A3 solvents (it must be noticed that variable costs for the use of HFE/HFC solvents are really higher). Respective costs for each case are presented in chapter 6.

Table 5.3.2 indicates what combination enables to be in compliance with the EC Directive 99/13 (see chapter 3).

Table 5.3.3: Combination in compliance with the EC Directive 99/13 (see chapter 3)

Combination code	Emissions	Total consumption	Emissions	flowrate	
	kg NMVOC / year	kg solvent or water based product / year	% of cleaning product consumption	kg NMVOC/hour	
01 00 00	582,2	820	71,0	1,164	Under the solvent consumption of 1 t per year
01 00 01	116,44	354,24	32,9	0,233	Under the solvent consumption of 1 t per year
01 01 00	436,65	674,45	64,7	0,873	Under the solvent consumption of 1 t per year
01 01 01	87,33	325,13	26,9	0,175	Under the solvent consumption of 1 t per year
01 02 00	29,11	267	10,9	0,058	Under the solvent consumption of 1 t per year
01 03 00	65,6	303	21,6	0,131	Under the solvent consumption of 5 t per year
01 04 00	20,5	258	7,9	0,041	Under the solvent consumption of 5 t per year
01 04 01	16,4	254	6,5	0,033	Under the solvent consumption of 5 t per year
01 05 00	0	820	0,0	0,000	In compliance in any case
02 00 00	7100	10000	71,0	4,733	Not in compliance (1)
02 00 01	1420	4320	32,9	0,947	Not in compliance (1)
02 01 00	5325	8225	64,7	3,550	Not in compliance (1)
02 01 01	1065	3965	26,9	0,710	Not in compliance (1)
02 02 00	355	3255	10,9	0,237	In compliance (2)
02 03 00	800	3700	21,6	0,533	In compliance (3)
02 04 00	250	3150	7,9	0,167	In compliance (4)
02 04 01	200	3100	6,5	0,133	In compliance (5)
02 05 00	0	10000	0,0	0,000	In compliance in any cases
03 00 00	24850	35000	71,0	12,425	Not in compliance (6)
03 00 01	4970	15120	32,9	2,485	Not in compliance (6)
03 01 00	18637,5	28787,5	64,7	9,319	Not in compliance (6)
03 01 01	3727,5	13877,5	26,9	1,864	Not in compliance (6)
03 02 00	1242,5	11392,5	10,9	0,621	Not compliance (7).
03 03 00	2800	12950	21,6	1,400	In compliance (8).
03 04 00	875	11025	7,9	0,438	In compliance (9).
03 04 01	700	10850	6,5	0,350	In compliance (10).
03 05 00	0	35000	0,0	0,000	In compliance in any cases

(1) Above the ELV for diffuse and stack emissions
(2) The degree of solvent recovery is not known. Taking into account total NMVOC emissions of 10.9% compared to consumption, it can be assumed that the machines comply with the EC ELV of 15% of solvent input + stack ELV (when solvent recovery is added to denominator the percentage decreases).
(3) The degree of solvent recovery is not known. Taking into account total NMVOC emissions of 21.9% compared to consumption, it can be assumed that the machines comply with the EC ELV of 20% of solvent input + stack ELV (when solvent recovery is added to denominator the percentage decreases).
(4) The degree of solvent recovery is not known. Taking into account total NMVOC emissions of 7.9% compared to consumption, it can be assumed that the machines comply with the EC ELV of 20% of solvent input + stack ELV (when solvent recovery is added to denominator the percentage decreases).
(5) The degree of solvent recovery is not known. Taking into account total NMVOC emissions of 6.5 % compared to consumption, it can be assumed that the machines comply with the EC ELV of 20% of solvent input + stack ELV (when solvent recovery is added to denominator the percentage decreases).
(6) Above the ELV for diffuse and stack emissions
(7) The degree of solvent recovery is not known. Taking into account total NMVOC emissions of 10.9 % compared to consumption, it can be assumed that, the machines comply with the EC ELV of 10% of solvent input + stack ELV (when solvent recovery is added to denominator the percentage decreases).

(8) Not in compliance. The degree of solvent recovery is not known. Taking into account total NMVOC emissions of 21.9 % compared to consumption, it can be hardly assumed that the machines can comply with the EC ELV of 15 % of solvent input + stack ELV (even if when solvent recovery is added to denominator the percentage decreases, the gap seems too large).
(9) The degree of solvent recovery is not known. Taking into account total NMVOC emissions of 7.9% compared to consumption, it can be assumed that the machines comply with the EC ELV of 15 % of solvent input + stack ELV (when solvent recovery is added to denominator the percentage decreases).
(10) The degree of solvent recovery is not known. Taking into account total NMVOC emissions of 7.9% compared to consumption, it can be assumed that the machines comply with the EC ELV of 15 % of solvent input + stack ELV (when solvent recovery is added to denominator the percentage decreases).

6 Data to be provided by national experts

The following tasks are required:

6.1 Validation work

For representing costs for dry cleaning, the national expert can use the default values provided in this report or use other costs data if justified.

- Validation of the default investment cost data provided for his own country, and
- Validation of the method of derivation of operation cost data for his country.
- Or
- Provide other costs data for the same combination of techniques and justify these cost data.

Comments have to be sent to the secretariat in the two weeks after electronic publication of the document.

6.2 Provision of specific data

Tables to be filled in with country specific data by national experts

- Determination of country specific data to calculate variable costs (*Specific values for energy, man power…are valid for all NMVOC sectors and have to be entered in the tool only once).*

Table 6.2.1: Country-specific data

Parameters	Default specific costs (€ net of taxes/kg)	Country specific costs (€ net of taxes/kg)
Trichloroethylene	1,25	To be provided by national experts
Cleaning agent for aqueous cleaning process	4,01	
A3 solvents	4,01	
HFC or HFE solvents	28,43	
Cold cleaning agentS	1,67	

- Respective shares (t solvent consumed/y) of the total activity level carried out on each reference installation in 2000, 2005, 2010, 2015, 2020.

The solvent input to be considered is the total solvent input for the dry cleaning sector. Table 6.2.2 must be completed. Some default values for the confidence interval are provided. They can be used by one Party if no data is available.

The methodology used in Rains for estimating the future activity level will be described in the methodology. It can be used or information can be obtained from the industry.

Table 6.2.2: Activity levels on reference installations (t solvent consumed / year)

RIC	2000	CI%	2005	CI%	2010	CI%	2015	CI%	2020	CI%
01										
02										
03										
Default values proposed for CI		10		20		50		100		100

For explanation on the confidence interval refer to the methodology chapter.

- Respective percentage of combinations of reduction measures in 2000 for each reference installation and
- as well as if possible, the percentage of use in 2005, 2010, 2015, 2020 due to the VOC Directive or national regulations and applicability according to the definition used in the RAINS model.

Some default values for the applicability factor are provided in table 6.2.4. They can be used by one Party if no data is available.

Table 6.2.3: Percentage of use and applicability factor for each combination of reduction measures

RIC PMC SMC	Percentage of use in 2000 %	Percentage of use in 2005 %	Applicability factor 2005 %	Percentage of use in 2010 %	Applicability factor 2010 %	Percentage of use in 2015 %	Applicability factor 2015 %	Percentage of use in 2020 %	Applicability factor 2020 %
01 00 00									
01 00 01									
01 01 00									
01 01 01									
01 02 00									
01 03 00									
01 04 00									
01 04 01									
01 05 00									
Total RIC 01	**100**	**100**		**100**		**100**		**100**	
02 00 00									
02 00 01									
02 01 00									
02 01 01									
02 02 00									
02 03 00									
02 04 00									
02 04 01									
02 05 00									
Total RIC 02	**100**	**100**		**100**		**100**		**100**	
03 00 00									
03 00 01									
03 01 00									
03 01 01									
03 02 00									

03 03 00									
03 04 00									
03 04 01									
03 05 00									
Total RIC 03	**100**	**100**		**100**		**100**		**100**	

Table 6.2.4 provides default values for technical applicability factor without considering regulation impact. Table 6.2.5 provides default values for technical applicability factor considering application of the EC directive 99/13 (it has to kept in mind that national regulation can implement stricter emission limit values than the EC directive, consequently applicability can be different from country to country).

Table 6.2.4: Default values for applicability factor for each combination of reduction measures considering only technical feasibility

RIC PMC SMC	**Applicability factor 2005 %**	**Applicability factor 2010 %**	**Applicability factor 2015 %**	**Applicability factor 2020 %**
Reference installation 01				
01 00 00	100	100	100	100
01 00 01	100	100	100	100
01 01 00	100	100	100	100
01 01 01	100	100	100	100
01 02 00	100	100	100	100
01 03 00	20	30	30	30
01 04 00	60	80	80	80
01 04 01	60	80	80	80
01 05 00	50	60	70	80
Reference installation 02				
02 00 00	100	100	100	100
02 00 01	100	100	100	100
02 01 00	100	100	100	100
02 01 01	100	100	100	100
02 02 00	80	100	100	100
02 03 00	10	20	20	20
02 04 00	60	80	80	80
02 04 01	60	80	80	80
02 05 00	30	40	60	70
Reference installation 03				
03 00 00	100	100	100	100
03 00 01	100	100	100	100
03 01 00	100	100	100	100
03 01 01	100	100	100	100
03 02 00	80	100	100	100
03 03 00	10	20	20	20
03 04 00	60	80	80	80
03 04 01	60	80	80	80
03 05 00	30	40	60	70

If detailed information is available, table 6.2.3 can be filled in.
If only sparse information is available, then table 6.2.3 can be filled in with the same "Application rates" for all RI (this corresponds to the filing of table 6.2.5).

Table 6.2.5: Default values for applicability factor for each combination of reduction measures considering application of the EC directive 99/13 from 2007

RIC PMC SMC	Applicability factor 2005 %	Applicability factor 2010 %	Applicability factor 2015 %	Applicability factor 2020 %
Reference installation 01				
01 00 00	100	100	100	100
01 00 01	100	100	100	100
01 01 00	100	100	100	100
01 01 01	100	100	100	100
01 02 00	100	100	100	100
01 03 00	20	30	30	30
01 04 00	60	80	80	80
01 04 01	60	80	80	80
01 05 00	50	60	70	80
Reference installation 02				
02 00 00	100	100	0	0
02 00 01	100	100	0	0
02 01 00	100	100	0	0
02 01 01	100	100	0	0
02 02 00	80	100	100	100
02 03 00	10	20	20	20
02 04 00	60	80	80	80
02 04 01	60	80	80	80
02 05 00	30	40	60	70
Reference installation 03				
03 00 00	100	100	0	0
03 00 01	100	100	0	0
03 01 00	100	100	0	0
03 01 01	100	100	0	0
03 02 00	80	100	100	00
03 03 00	10	20	0	0
03 04 00	60	80	80	80
03 04 01	60	80	80	80
03 05 00	30	40	60	70

Table 6.2.6: Aggregated table (this table does not appear in the tool)

RIC PMC SMC	Percentage of use in 2000 %	Percentage of use in 2005 %	Applicability factor 2005 %	Percentage of use in 2010 %	Applicability factor 2010 %	Percentage of use in 2015 %	Applicability factor 2015 %	Percentage of use in 2020 %	Applicability factor 2020 %
Aggreg. 00 00									
Aggreg. 00 01									
Aggreg. 01 00									
Aggreg. 01 01									
Aggreg. 02 00									
Aggreg. 02 00									
Aggreg. 03 00									
Aggreg. 04 00									
Aggreg. 04 01									
Aggreg. 05 00									
Total aggreg.	**100**	**100**		**100**		**100**		**100**	

Aggreg. : Aggregation

The total of percentages of uses of each combination or reduction technique must be 100 since all the combinations are assumed to represent the different situations in this activity.
The percentage of use of the different techniques depends on the Party's regulation. If the directive is applied, combination with primary measure 00 and should be forbidden in 2007.
In the tool the absolute terms are directly entered (% for a given combination multiplied by the total activity).

Table 6.2.7: Unabated emission factor [g / kg of cleaning product]

Default data mean	CI %	User input mean	CI %
710	27		

The "default data mean" can be modified in a range of ± 10%.

7 Explanatory notes

7.1 Derivation of emission factors

Emission factors in the literature are expressed as grams of VOC per kilogram of solvent consumed. They do not depend on the capacity of the machine. Emission factors used in this study (average values) are presented in table 7.1.1.

Table 7.1.1: NMVOC emission factors expressed in g VOC/kg of solvent consumed

Type of machine	Emission factor NMVOC g/kg solvent consumed	source
Open-top	710	[5,8]
Improvement of equipment : semi open-top degreaser	532,5	[5, 8]
Sealed chamber system using chlorinated solvents	35,5	[5]
Cold cleaner	80	[4, 9]
closed degreaser using A3 solvents or fluoro solvents (HFC and HFE)	25	[4, 9]
Aqueous cleaning process	0	[5, 8]

According to [5], activated carbon units have an emission reduction potential of 80%.

7.2 Derivation of cost data

Primary measure investments

- Investments for new generation sealed chamber system using chlorinated solvents are derived from different sources ([1], [4] to [7], [10]).
- Investments for aqueous cleaning process are derived from [5], [6], [7] and [10] in accordance with information from industry.
- According to [1], a difference of 50% on investments exists between open and semi open-top degreaser. Investments for semi open-top degreaser are then derived from those of open-top degreaser given in [5] and with help of industry [10].
- Investments for closed degreaser using A3 solvents or fluoro solvents and investments for cold cleaner are given by industry [1], [4], and [10].

Additional investment costs taken into account in this document for primary measures are presented in table 7.2.1.

Table 7.2.1: Additional investment costs for primary measures

Type of equipment	Additional investment cost (€)		
	Small installation	Medium installation	Large installation
Semi open-top degreaser	19 000	39 500	65 000
Sealed chamber system using chlorinated solvents	85 000	160 000	250 000
Cold cleaner	100	2400	6000
Closed degreaser using A3 solvents or fluoro solvents (HFC and HFE)	67 500	155 000	220 000
Aqueous cleaning process	22 400	42 000	150 000

Fixed operating costs are only considered for secondary measures. For primary measures fixed operating costs are assumed to be the same, consequently no additional fixed operating cost (maintenance, insurances, etc.) is considered.

Secondary Measure investments and operating costs

- Investments for activated carbon filter are derived from ENTEC [6] and from reference [5] which give costs range from 75 000 to 210 000 €. According to CETIM [10] this range is 100 000 to 225 000 for medium and large installation. Mean values are taken into account.

Investment cost taking into account in this document for secondary measures are presented in table 7.2.2.

Table 7.2.2: Investment costs for secondary measures

Type of equipment	Investment cost (€)		
	Small installation	Medium installation	Large installation
Activated carbon filter	150 000	170 000	230 000

Fixed operating costs are assumed to represent 5% of the investment but this value can be discussed.

According to [5], activated carbon unit are supposed to lead to additional variable operating costs presented in table 7.2.3.

Table 7.2.3: Additional operating variable cost for secondary measures

RIC	Variable operating cost (€)
01	5 500
02	9 900
03	20 000

Table 7.2.4: Emission factors, investments, operating costs, abatement efficiencies for secondary measures

RIC PMC SMC	NMVOC Emission Factor [g/kg solvent used]	Investment [€]	Variable OC for secondary measures [€/y]	Fixed OC for secondary measures [€/y]	Abatement efficiency [%]
01 00 01	142	150 000	5500	7 500	80
01 01 01	106,5	169 000	5500	7 500	85
01 04 01	20	217 500	5500	7 500	97
02 00 01	142	170 000	9900	8 500	80
02 01 01	106,5	209 500	9900	8 500	85
02 04 01	20	325 000	9900	8 500	97
03 00 01	142	230 000	20000	11 500	80
03 01 01	106,5	295 000	20000	11 500	85
03 04 01	20	450 000	20000	11 500	97

Cleaning product consumption costs

Variable operating costs due to cleaning product consumption are considered for primary and secondary measures.
Variable operating costs presented in this document are calculated with default value of cleaning product costs (country specific data) [4] [10] given in table 7.2.5

Table 7.2.5: Default values for cleaning solvent costs [4] [10]

Type of cleaning products	Price [€ net of taxes / kg]
Trichloroethylene	1,25
Cleaning agent for aqueous cleaning process	4,01
A3 solvents	4,01
HFC or HFE solvents	28,43
Cold cleaning agent	1,67

Table 7.2.6 and 7.2.7 present how cleaning product consumption is calculated and costs estimated. For a given reference installation it is assumed that the need in degreasing is the same for each technique (820 kg for RIC 01 (table 4.1), 10000 kg for RIC 02, 35000 kg for RIC 03, associated with any primary and secondary combinations) but the consumption of cleaning product is more or less important according to technique efficiencies.

Table 7.2.6: Annual cleaning product consumption

Combination code	Need in degrea-sing	Emission factor	Abatement efficiency	Emissions	Basic need in cleaning products	Need in cleaning products to compensate atmospheric emissions	Total consumption
	kg cleaning product	[g NMVOC/kg cleaning product]	[%]	kg NMVOC / year	Kg	kg	kg cleaning product / year
01 00 00	820	710	0,0	582,2	237,8	582,2	820
01 00 01	820	142	80,0	116,44	237,8	116,44	354,24
01 01 00	820	532,5	25,0	436,65	237,8	436,65	674,45
01 01 01	820	106,5	85,0	87,33	237,8	87,33	325,13
01 02 00	820	35,5	95,0	29,11	237,8	29,11	267
01 03 00	820	80	88,7	65,6	237,8	65,6	303
01 04 00	820	25	96,5	20,5	237,8	20,5	258
01 04 01	820	20	97,2	16,4	237,8	16,4	254
01 05 00	820	0	100,0	0	820	0	820
02 00 00	10000	710	0,0	7100	2900	7100	10000
02 00 01	10000	142	80,0	1420	2900	1420	4320
02 01 00	10000	532,5	25,0	5325	2900	5325	8225
02 01 01	10000	106,5	85,0	1065	2900	1065	3965
02 02 00	10000	35,5	95,0	355	2900	355	3255
02 03 00	10000	80	88,7	800	2900	800	3700
02 04 00	10000	25	96,5	250	2900	250	3150
02 04 01	10000	20	97,2	200	2900	200	3100
02 05 00	10000	0	100,0	0	10000	0	10000

03 00 00	35000	710	0,0	24850	10150	24850	35000
03 00 01	35000	142	80,0	4970	10150	4970	15120
03 01 00	35000	532,5	25,0	18637,5	10150	18637,5	28787,5
03 01 01	35000	106,5	85,0	3727,5	10150	3727,5	13877,5
03 02 00	35000	35,5	95,0	1242,5	10150	1242,5	11392,5
03 03 00	35000	80	88,7	2800	10150	2800	12950
03 04 00	35000	25	96,5	875	10150	875	11025
03 04 01	35000	20	97,2	700	10150	700	10850
03 05 00	35000	0	100,0	0	35000	0	35000

Table 7.2.7: Annual cleaning product consumption costs

Combination code	Cost of cleaning product consumption	Additional cleaning product consumption costs
	€/Year	€/Year
01 00 00	1028	0
01 00 01	444	-584
01 01 00	846	-183
01 01 01	408	-621
01 02 00	335	-694
01 03 00	1218	189
01 04 00	1037	8
01 04 01	1020	-8
01 05 00	1371	343
02 00 00	12542	0
02 00 01	5418	-7124
02 01 00	10316	-2226
02 01 01	4973	-7569
02 02 00	4082	-8459
02 03 00	14849	2308
02 04 00	12642	100
02 04 01	12441	-100
02 05 00	16722	4181
03 00 00	43896	0
03 00 01	18963	-24933
03 01 00	36105	-7792
03 01 01	17405	-26491
03 02 00	14288	-29608
03 03 00	51973	8077
03 04 00	44247	351
03 04 01	43545	-351
03 05 00	58528	14632

Total costs are presented in table 7.2.8.

Table 7.2.8: Investments and operating costs for each combination.

Reference installation	Investment	Variable operating costs		Fixed operating costs	Total operating costs
		Cleaning product consumption	Secondary measure operating costs		
	€/year	€/year	€/year	€/year	€/year
01 00 00	0	0			0
01 00 01	150000	-584	5500	7500	12416
01 01 00	19000	-183		0	-183
01 01 01	169000	-621	5500	7500	12379
01 02 00	85000	-694		0	-694
01 03 00	100	189		0	189
01 04 00	67500	8		0	8
01 04 01	217500	-8	5500	7500	12992
01 05 00	22400	343		0	343
02 00 00	0	0		0	0
02 00 01	170000	-7124	9900	8500	11276
02 01 00	39500	-2226		0	-2226
02 01 01	209500	-7569	9900	8500	10831
02 02 00	160000	-8459		0	-8459
02 03 00	2400	2308		0	2308
02 04 00	155000	100		0	100
02 04 01	325000	-100	9900	8500	18300
02 05 00	42000	4181		0	4181
03 00 00	0	0		0	0
03 00 01	230000	-24933	20000	11500	6567
03 01 00	65000	-7792		0	-7792
03 01 01	295000	-26491	20000	11500	5009
03 02 00	250000	-29608		0	-29608
03 03 00	6000	8077		0	8077
03 04 00	220000	351		0	351
03 04 01	450000	-351	20000	11500	31149
03 05 00	150000	14632		0	14632

Table 7.2.9: Investments and operating costs for each combination

Reference installation	Investment	Total operating costs	Annual total costs	Unit cost	Unit cost
	€/year	kg/year	€/year	€/kg cleaning products	€/kg NMVOC non emitted
01 00 00	0	0	0	0.00	
01 00 01	150000	12416	25907	31.59	55.62
01 01 00	19000	-183	1526	1.86	10.49
01 01 01	169000	12379	27579	33.63	55.73
01 02 00	85000	-694	6951	8.48	12.57
01 03 00	100	189	198	0.24	0.38
01 04 00	67500	8	6079	7.41	10.82
01 04 01	217500	12992	32554	39.70	57.54
01 05 00	22400	343	2357	2.87	4.05
02 00 00	0	0	0	0.00	
02 00 01	170000	11276	26566	2.66	4.68
02 01 00	39500	-2226	1327	0.13	0.75
02 01 01	209500	10831	29674	2.97	4.92
02 02 00	160000	-8459	5931	0.59	0.88
02 03 00	2400	2308	2524	0.25	0.40
02 04 00	155000	100	14041	1.40	2.05
02 04 01	325000	18300	47531	4.75	6.89
02 05 00	42000	4181	7958	0.80	1.12
03 00 00	0	0	0	0.00	
03 00 01	230000	6567	27253	0.78	1.37
03 01 00	65000	-7792	-1945	-0.06	-0.31
03 01 01	295000	5009	31541	0.90	1.49
03 02 00	250000	-29608	-7123	-0.20	-0.30
03 03 00	6000	8077	8617	0.25	0.39
03 04 00	220000	351	20138	0.58	0.84
03 04 01	450000	31149	71622	2.05	2.97
03 05 00	150000	14632	28123	0.80	1.13

8 References

1 Jean-Claude GERDIL, UNITECH Annemasse. privates communications to Sonia SAMBAT in February 2003.

2 Council Directive 1999/13/EC of 11 March 1999 on the limitation of emissions of volatile organic compounds due to the use of organic solvents in certain activities and installations

3 KLIMONT Z, ; Amann M, ; COFALA J,Estimating costs for controlling emissions of VOC from stationary sources in Europe, Report IR – 00- 51, IIASA – August 2000. http://www.iiasa.ac.at/~rains/voc_review/voc_ir-00-51.pdf

4 Technotheme, le dégraissage des pièces mécaniques, Service Information Scientifique et Technique (IST) – C.T.DEC – Nov 2002.

5 Task force on the assessment of abatement options and techniques for VOC from stationary sources. Draft background document – Prepared by IFARE for UN/ECE-May 1999.

6 Regulatory and Environmental Impact Assessment for the Implementation of the EC Solvent Emissions Directive, Final Report, Entec UK Limited, 20 December 1999.

7 Impact économique de la directive européenne sur la limitation des émissions de COV en provenance de l'utilisation des solvants en France. CITEPA, IFARE, 28 février 2000.

8 Review of data used in RAINS-VOC model. http://www.iiasa.ac.at/~rains/voc_review/single.html

9 Experts estimations

10 Jacques JAY, CETIM Saint Etienne. privates communications to Sonia SAMBAT in June 2003

9 Modifications made to the draft document

No comment has been made on the draft document. However some additional explanations are given especially for solvent saving calculation in April 2005. These savings were not considered clearly in the previous background document.

Modifications of chapter 5

Fixed operating costs have been corrected in table 5.3.2 for combinaison codes that include both primary and secondary measures: the 5% of investment has only to be applied for secondary measure what was not the case before.

Modifications of chapter 7 and 5 in April 2005

Chapter 7 is completely modified to presents explanations on solvent savings. Operating costs have been modified due to systematic review of the method. Default solvent costs are nox considered as net of taxes.

Table 5.3.2 has been modified consequently for operating costs.

Other minor corrections have been carried out.

Correction made on April 2005

The methodology developed does not take into account the saving in solvent consumption provided by the use of not emitting degreasing machines. The methodology has been modified for incorporating solvent saving.

Abbreviations

CIAM	Centre Integrated Assessment Modelling
CITEPA	Centre Interprofessionnel Technique d'Etude de la Pollution Atmosphérique
CI%	Confidence interval
CO	Organic Components
EF	Emission factor
EPA	Environmental Protection Agency
EU	European Union
GJ	Giga Joules
IFARE	Institut Franco-Allemand de Recherches sur l'Environnement
IIASA	International Institute for Applied Systems Analysis
kW	kiloWatt
n.a.	not available
-	not existing
NFR	New Format Reporting
PMC	Primary Measure Code
Q	Quality
RAINS	Regional Air pollution Information and Simulation model
RIC	Reference Installation Code
SMC	Secondary Measure Code
SNAP	Selected Nomenclature for Air Pollution
VOC	Volatile Organic Compounds