Final Background Document
on the sector

# Industrial application of adhesives

**Prepared in the framework of EGTEI**

Prepared by CITEPA, Paris

# Summary

**Introduction (p.3)**
Sectors considered in this document as well as the methodology used are defined in the introduction.
As sectors using adhesives are very diverse, only one is defined in the following chapters for simplification reasons. It is assumed to be representative for the whole industry.
Two sub-sectors are defined (i.e. use of "traditional" solvent based adhesives and use of "high performance" adhesives) for modelling purposes.

**Background information (p.6)**
Data currently used in RAINS are just presented for comparison reasons. Data which should be used in the new version of the model are shown later in this document.
A short technology description and the summary of the EU regulation are also provided.

**Industrial application of adhesives: use of traditional solvent based adhesives (p.10)**
When "traditional" solvent based adhesives are consumed, substitution can be used to reduce VOC emissions. In some cases, end-of-pipe techniques will be installed.

**Industrial application of adhesives: use of high performance solvent based adhesives (p.16)**
This sub-sector is studied separately for modelling purposes.
Emission levels are the same as those defined in the previous paragraph but in the present case, no substitution is technically feasible. According to [4], there is no alternative to solvent based adhesives in the high quality range.
Only secondary measures are defined in this chapter.

# Introduction

**SNAP**: 06 04 02 or NFR 3C Chemical products, manufacture and processing

Glues and adhesives can be used for packaging, vehicle, electrical, construction, furniture and paper industries.

**ACTIVITY:** tonnes of adhesives consumed / year.
**POLLUTANT CONSIDRED:** VOC

## 1. General description

According to [4], sectors using adhesives are very diverse. Production processes and application techniques are also very different.
Relevant sectors are: the production of adhesive tapes, composite foils, the transportation sector (passenger cars, commercial vehicles, mobile homes, rail vehicles, aircrafts), the manufacture of shoes and leather goods and the wood material and furniture industry.

In Germany, the shares of the different market segments were as follows in 2000 [4]:
34% for the non-industrial sector (do-it-yourself and construction industry), 35% for the paper and packaging industry, 15% for the wood and furniture industry, 5% for transportation, 3% for the footwear and leather industry and 8% for others.

The following shares are given for UK in 1992 [2]:
34% for packaging (1% of total solvent based adhesives), 16% for non industrial application of adhesives (24% of solvent based adhesives), 14% for tapes and labels (46% of solvent based adhesives), 7% for wood and furniture industry (4% of solvent based adhesives), 3% for book binding (0% of solvent based adhesives), 2% for transportation (3% of solvent based adhesives), 2% for lamination (3% of solvent based adhesives), 2% for disposables (0% of solvent based adhesives), 1% for footwear (5% of solvent based adhesives), 9% for other (6% of solvent based adhesives) and 9% for sealants (7% of solvent based adhesives).

These figures are presented to define the priorities and the largest emitting sectors:
- ✓ The non-industrial use of adhesives is a large sector but it is studied separately,
- ✓ The packaging sector is also a large sector but it is already studied within the printing industry,
- ✓ The footwear industry is also studied separately as it is distinguished in the Directive 99/13/EC,
- ✓ For the transportation sectors, a lot of installations are equipped or will be equipped with add-on abatement techniques because they are regulated by the Solvent Directive.
- ✓ One of the largest remaining sectors is the production of tapes and labels.

## 2. Abatement techniques for the different sub-sectors as presented in [4]

- Paper and packaging industry: if solvent based adhesives are consumed, high-solid adhesive systems with solids contents of up to 60% can be used to reduce VOC emissions. Solvent-free adhesive systems are already in use for general purpose and medium performance adhesives applied for mass production. Water based adhesives are only suitable for bonding of materials with absorbent surface. For solvent-free UV or electron beam curing adhesive systems and hot melts, the adjustment of layer thickness has to be realized by mechanical rolling processes as opposed to dispersions and solvent-based adhesives. Hence layer thickness is more irregular.
Carbon adsorption or thermal oxidation can be installed to reduce VOC emissions from the use of solvent based adhesives.

- Automotive industry: techniques strongly reducing VOC emissions are already available.

  Production of passenger car: predominantly solvent-free adhesives are used in the passenger car serial production excluding few special applications. Emissions are however treated together with emissions from the paint application.

  Production of commercial vehicles: no solvent containing adhesives are applied in the truck production. In the bus production, solvent based adhesives can be used for cementing of floor clothes and of isolations and sealing. VOCs emitted from the adhesive application amounts up to 24-28kg per bus produced. These emissions can be reduced to 2kg per vehicles if alternative techniques are used.

  Production of trailers and mobile homes: solvent based adhesives are only applied by a few producers for lamination. Otherwise, only BATs are in use.

  Component supplier industry: the main applications for adhesives are laminations of plastic facings with cloth for the interior decoration of the vehicle. Dispersion adhesive are used for lamination of indoor facings. It can be classified as BAT.

  Production of rail vehicles: construction parts of different materials have to be combined or bonded. Solvent containing adhesives are not in use anymore.

  Aircraft production: nowadays, solvent free adhesives or adhesives poor in solvents are processed in the structural aircraft construction. Currently no substitution is possible due to technological reasons such as compatibility with the adhesive system, long-term stability and corrosion resistance. Alternative water based primers are presently in a testing stage.

- Footwear industry: this sector is studied in a separate document.

- Leather goods industry: dispersion adhesives are more and more used. No major problem should be encountered.

- Wood and furniture industry: substitution products are already used to a large extent.

- Industrial assembly process: in the electrical engineering, conducting adhesives are used. These adhesives are solvent free systems. In the machine construction sector, welding and screwing are the predominant joining techniques. Small amounts of solvent based adhesives are applied.

## 3. Representation of these sectors in EGTEI

Application techniques and types of adhesives used differ widely from one sector to another. In the framework of EGTEI, it is impossible to represent each sector one by one: on one hand, data on costs are not sufficient and on the other hand, national experts usually do not have enough information to go in such detail.
Industrial application of adhesives is thus studied as a whole (one example is used to study this sector).

The production of adhesive tapes has been chosen for two reasons:
- It represents one of the largest sectors (in term of VOC emissions) which is not covered for the moment in other background documents,
- Reduction measures used for this sector are valid for other sectors: substitution with dispersion adhesives or hot melt or use of abatement techniques when substitution is not technically feasible.

For cost assessment, even if application techniques and adhesives are not similar from one sector to another, it is assumed, as a first estimate, that unit costs (€/t of VOC abated) are representative for the whole adhesive sector.

Costs taken into account are:
R&D costs to develop a new adhesive, investment for new application machines compatible with the new adhesive, energy costs and raw material costs. When abatement devices are considered, investments and operating costs are given.

This approach allows simplifying as much as possible this very complex sector.

*Two sub-sectors are defined to simplify the modelling process.*
*It has been highlighted during our research that no alternative exist for solvent based adhesives in the high quality range.*

*National experts have to define the total consumption of adhesives (activity level in the Industry: traditional solvent based adhesives + high performance solvent based adhesives + water based adhesives + hot melts and UV cross linking adhesives) and the shares of use of the different measures (primary and secondary).*

# Background information

# 1 Data from the bibliography

*Following data are just presented for comparison reasons.*

The category "Application of Glues and Adhesives" is considered in the model RAINS.
This sector is characterised by a wide range of processes and by many small plants and only a few large and medium size installations.

## 1.1 Control options

According to [1], emissions from this sector can be controlled by implementing the following measures:

- Measure 00 : Reference case;
- Measures 01: Modification of the application technique (brushing, rolling, spraying) to improve the transfer efficiency + housekeeping measures. (efficiency : about 15%; applicability depends on the plant's size);
- Measure 02: Substitution with water-based adhesives or hot melt. (efficiency: about 85%; applicability : about 60% of the activity).
- Measure 03: Add-on techniques: thermal oxidation (efficiency: 80%; applicable only to continuously operating large installations: 40% is used).

Measure combinations are also considered.

## 1.2 Abatement costs

Examples for three countries are displayed below (activity is in kt of VOC):

**Table 1.2.1:** French situation

**Activity level** 1990 : 30,954 kt VOC; 2010 : 35,039 kt VOC
**VOC emission scenario business as usual :** 1990 : 30,95 kt VOC; 2010 : 24,34 VOC

| Measure | Emission factor [kt VOC / kt of VOC] | Efficiency [%] | Technical Eff. [%] | Applicability [%] | Unit cost [€$_{1990}$/t VOC] |
|---|---|---|---|---|---|
| 00 | 1,0000 | 0 | 0 | 0 | 0 |
| 01 | 0,9250 | 8 | 15 | 50 | 10 |
| 02 | 0,5750 | 43 | 85 | 50 | 345 |
| 03 | 0,8432 | 16 | 78 | 20 | 559 |
| 01 + 02 | 0,5638 | 44 | 44 | 100 | 335 |
| 01 + 03 | 0,7917 | 21 | 21 | 100 | 469 |
| 01 + 02 + 03 | 0,5438 | 46 | 46 | 100 | 738 |

**Table 1.2.2:** German situation

**Activity level** 1990 : 4,470 kt VOC; 2010 : 4,977 kt VOC
**VOC emission scenario business as usual :** 1990 : 4,47 kt VOC; 2010 : 3,06 VOC

| Measure | Emission factor [kt VOC / kt of VOC] | Efficiency [%] | Technical Eff. [%] | Applicability [%] | Unit cost [€$_{1990}$/t VOC] |
|---|---|---|---|---|---|
| 00 | 1,0000 | 0 | 0 | 0 | 0 |
| 01 | 0,8950 | 11 | 15 | 70 | 10 |
| 02 | 0,4900 | 51 | 85 | 60 | 345 |
| 03 | 0,6864 | 31 | 78 | 40 | 559 |
| 01 + 02 | 0,4615 | 54 | 54 | 100 | 335 |
| 01 + 03 | 0,6284 | 37 | 37 | 100 | 469 |
| 01 + 02 + 03 | 0,4215 | 58 | 58 | 100 | 738 |

**Table 1.2.3:** Hungarian situation

| **Activity level** 1990 : 0,283 kt VOC; 2010 : 0,313 kt VOC<br>**VOC emission scenario business as usual :** 1990 : 0,28 kt VOC; 2010 : 0,31 VOC | | | | | |
|---|---|---|---|---|---|
| **Measure** | **Emission factor [kt VOC / kt of VOC]** | **Efficiency [%]** | **Technical Eff. [%]** | **Applicability [%]** | **Unit cost [€$_{1990}$/t VOC]** |
| 00 | 1,0000 | 0 | 0 | 0 | 0 |
| 01 | 0,8950 | 11 | 15 | 70 | 10 |
| 02 | 0,4900 | 51 | 85 | 60 | 345 |
| 03 | 0,6864 | 31 | 78 | 40 | 559 |
| 01 + 02 | 0,4615 | 54 | 54 | 100 | 335 |
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### 1.3 Situation in the UK [2]

The application of an adhesive coating to a substrate is a generic process and is used in a wide variety of industries.
In 1992, 60 200 tonnes of solvent based adhesives were used representing 17% of UK adhesive use. Tapes and labels manufacture account for 46% of the solvent based materials.

Although this sector is very fragmented in terms of process size, type of application method, type of substrate, and performance requirements of adhesive, there is a strong move towards low solvent or solvent free application systems.

Development costs for substitution product are very high but many companies are experiencing economic returns due to lower overall materials costs, and, in some cases, quicker production speeds and improved bond performance.

### 1.4 Situation in Germany [4]

In 1999, 690 million m² adhesive tapes were produced in Germany. In 1995, 15 560 tons of organic solvents were used as components in adhesive systems in Germany for the production of adhesive tapes and in 1997, VOC emissions were 415 t in this sector. This is a small amount when compared to the solvent consumption due to exhaust gas treatment installations.

## 2 Short technology description for the production of adhesive tapes [4]

Adhesive tape consists of a substrate, a coupling agent, a pressure-sensitive-adhesive and releasing agents.
The selection of the adhesive system depends on the technical application of the adhesive tape. At a European level, packaging adhesive tapes have a proportion of 74% and coating adhesive tapes only 10%.
Solvent-based adhesives (acrylate for double-sided adhesive tapes, natural rubber for packaging and cover adhesive tapes) have a proportion of 49% in the European adhesive tape production. Hot melts (acrylate for double-sided adhesive tapes and synthetic rubber for packaging, cover and double sided tapes) have a proportion of 33% and dispersions (acrylate for double-sided and packaging adhesive tapes), 18%.

Three main steps can be described in the production of adhesive tapes:

- ✓ Surface treatment of substrate and coating of adhesive onto the sheet-like substrate :
  - For processing of solvent based adhesives, doctor knife systems, accugravure- or reverse-roll-coater are used.
  - For adhesive dispersions, doctor knife systems, reverse-roll-coater or roll doctor knife systems are appropriate.
  - Hot melts are applied by doctor knife systems, slot die systems or extrusion techniques.
  - Spraying techniques are rarely used.
- ✓ Drying, cross-linking and cooling (for the hot melts) of the adhesive :
  - Air circulation dryers, infrared dryers and radiation systems (UV radiation or electron beams for cross-linking only) are predominantly used in industrial production.
  - Solvent-based adhesives and dispersions are dried thermally.
- ✓ Coiling up, cutting etc.

## 3 EU regulation : Directive 1999/13/EC of 11 March 1999 [3]

Operators concerned can conform to the Directive in either of the following ways:

- By complying with the canalized and fugitive emission values.
- By introducing a reduction scheme to obtain an equivalent emission level, (in particular by replacing conventional products with high solvent content by low-solvent or solvent-free products).

The EC Directive applies to installations with a solvent consumption above 5 t per year.

Emission limits for application of the Directive are presented in table 3.1.

**Table 3.1:** Emission limits

| **Solvent consumption threshold [t / y]** | **VOC emission limit value in residual gases [mg C / $Nm^3$]** | **Fugitive emissions [% of solvent input*]** |
|---|---|---|
| 5-15 | 50<br>150* | 25 |
| > 15 | 50<br>150* | 20 |

* If solvent recovery is used.

All obligations of the Directive are not described in this chapter.

# Industrial application of adhesives

**(Use of traditional solvent based adhesives)**

Only one reference installation is defined. As no better information is available, costs are assumed to be proportional to the size of the installation.

## 1 Definition of the Reference Installation

The reference installation presented in table 1.1 is defined according to its annual consumption of adhesives.

**Table 1.1:** Reference installation [5]

| Reference Installation Code RIC | Description |
|---|---|
| 01 | Large Reference Installation: 6000 t of adhesives used per year |

## 2 Definitions of primary measures [4]

Dispersions, UV cross-linking adhesives and hot melts distinguish themselves positively concerning solvent emissions.
Because of their chemical and physical characteristics, hot melts are suitable for coating and packaging adhesive tapes of a lower quality range.
Dispersions show better cohesiveness but have a very limited water resistance.
UV cross-linking acrylates and electron beam curing systems do not show the disadvantages of hot melts and dispersions and are distinguished by high cohesiveness and high adhesion strength.

However these systems cannot be used for all products, because the cohesiveness and adhesive strength that can be achieved with solvent-based adhesives can not be reached due to shorter polymer chains.
Therefore, no alternative to the solvent-based acrylate and rubber adhesives does exist for applications that require a high stress resistance (so-call high performance solvent based adhesives: see next sub-sector).
Improvements of application efficiencies are not considered in the definition of primary measures.

**Table 2.1:** Primary measures

| Primary Measure Code PMC | Description |
|---|---|
| 00 | "Traditional" solvent based adhesives<br>(65% solvent content – 35% solid content) |
| 01 | Emulsions (2 % solvent content - 50% solid content) |
| 02 | Hot melts or UV cross-linking acrylates or electron beam curing systems<br>(100% solid content) |

## 3 Definitions of secondary measures [6]

When no alternative to solvent based adhesives can be used, techniques such as carbon adsorption or thermal oxidation are available.

**Table 3.1:** Secondary measures

| Secondary Measure Code SMC | Description |
|---|---|
| 00 | No secondary measure |
| 01 | Activated carbon adsorption or condensation |
| 02 | Thermal or catalytic incineration |

## 4 Emission factors and cost data for the different combinations

**Table 4.1:** Emission factors and abatement efficiencies for relevant combinations

| RIC PMC SMC | NMVOC EF [kg / t adhesive used] | Abatement efficiency [%] | Q | CI [%] |
|---|---|---|---|---|
| 01 00 00 | 780 | 0,0 | 4 | 20 |
| 01 00 01 | 187,2 | 76,0 | 4 | 20 |
| 01 00 02 | 187,2 | 76,0 | 4 | 20 |
| 01 01 00 | 14 | 98,2 | 4 | 20 |
| 01 02 00 | 0 | 100,0 | 4 | 20 |

**Table 4.2:** Investments and operating costs

| RIC PMC SMC | Investment [k€] | R&D [k€] | Q | CI [%] | Variable OC [k€/y] | Fixed OC [k€/y] | Savings [k€/y] | Q | CI [%] |
|---|---|---|---|---|---|---|---|---|---|
| 01 00 00 | 0 | 0 | - | - | 5 017 | - | - | 3 | 20 |
| 01 00 01 | 2 100 | 0 | 3 | 20 | 5 409 | 103 | 533,5 | 3 | 20 |
| 01 00 02 | 2 690 | 0 | 3 | 20 | 5 356 | 135 | - | 3 | 20 |
| 01 01 00 | 2 000 | 1 250 | 3 | 20 | 7 960 | - | - | 3 | 20 |
| 01 02 00 | 4 000 | 1 250 | 3 | 20 | 3 980 | - | - | 3 | 20 |

## 5 Data to be provided by national experts for the completion of the data basis for their own country

The following tasks are required:

### 5.1 Validation work

For representing costs in this sector, the national expert is invited to comment the methodology defined by the Secretariat.

- Validate investments and operating costs provided,

Or

- Provide other costs for the same combination of techniques and justify them.

*Comments have to be sent to the Secretariat in the two weeks after having received the document.*

### 5.2 Provision of specific data

**Tables to be filled in by national experts**

- Determination of country specific data to calculate variable costs (they are valid for all VOC sectors and only have to be entered in the tool once).

**Table 5.2.1:** Country-specific data

| Parameters | Costs used in the tool | Country specific costs |
|---|---|---|
| Electricity [€/kWh] | 0,0686 | |
| Natural gas [€/kWh] | 0,0192 | |
| Wages [€/h] | 25,9 | |
| Steam [€/kg] | 0,016 | |

**Table 5.2.2:** Sector and country specific data

| Parameters | Default costs [5] | Country specific costs |
|---|---|---|
| "Traditional" solvent based adhesives [€ / kg] | 0,8 | |
| Emulsion adhesives [€ / kg] | 1,8 | |
| Hot melts or UV cross-linking acrylates or electron beam curing systems [€ / kg] | 1,8 | |
| Cleaning solvents [€ / kg] | 0,15 | |
| Solvents recovered [€ / kg] | 0,15 | |

- Total activity level carried out in 2000, 2005, 2010, 2015, 2020. Some default values for the confidence interval are given. They can be used by the Party if no data are available.

**Table 5.2.3:** Total activity level in absolute value (tonnes of adhesives consumed / y)

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

For explanations on the coefficient of variation (CI), please refer to the Methodology.

- Respective percentage of combinations of reduction measures in 2000 for the reference installation 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.

**Table 5.2.4:** Application rate and Applicability

| RIC PMC SMC | Application rate in 2000 [%] | Application rate in 2005 [%] | Appl. [%] | Application rate in 2010 [%] | Appl. [%] | Application rate in 2015 [%] | Appl. [%] | Application rate in 2020 [%] | Appl. [%] |
|---|---|---|---|---|---|---|---|---|---|
| 01 00 00 | | | | | | | | | |
| 01 00 01 | | | | | | | | | |
| 01 00 02 | | | | | | | | | |
| 01 01 00 | | | | | | | | | |
| 01 02 00 | | | | | | | | | |
| **Total RIC 01** | **100** | **100** | | **100** | | **100** | | **100** | |

**Table 5.2.5:** Unabated emission factor [kg VOC / tonne of adhesives used]

| PMC SMC | Default data mean | CI % | User input mean | CI % |
|---|---|---|---|---|
| 00 00 | 780 | 30 | | |

*"Default data means" 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.*

# 6 Explanatory notes

## 6.1 Definition of consumption factors (CF)

As solid contents vary according to the type of adhesives considered, annual consumptions will also vary from one measure to another.

**Table 6.1.1:** Adhesive consumptions

| PMC SMC | Consumption per year [t / year] |
|---|---|
| 01 00 00 | 6 000 |
| 01 00 01 | 6 000 |
| 01 00 02 | 6 000 |
| 01 01 00 | 6 000 × 0,35 / 0,5 = 4 200 |
| 01 02 00 | 6 000 × 0,35 / 1,0 = 2 100 |

Consumption of cleaning solvents: this is assumed that cleaning solvents are used when solvent based adhesives are consumed. This represents 20% of the solvents consumed for PMC 00 and 01.

## 6.2 Definition of Emission Factors (EF)

It is assumed that:

- In installations where the application is not enclosed and without abatement devices, all the solvent used is emitted into the air : EF = 1 g solvent/g solvent consumed,
- In installations with secondary abatement devices, where the application is enclosed, only fugitive emissions occur (20 % of the total solvent consumption). Abatement techniques are assumed to have an efficiency of 95%.

To be consistent with the data used in the RAINS model, emission factors have all to be compared to the reference case (PMC 00).

**Table 6.2.1:** Emission factors for the different combinations

| PMC SMC | Calculations | Emission Factors [g solvent/kg adhesives] | EF [compared to PMC 00] | Efficiency [%] |
|---|---|---|---|---|
| 00 00 | 650 × 1,2 | 780 | 780 | 0,00 |
| 00 01 | 780 × (0,2 + 0,8 × 0,05) | 187,2 | 187,2 | 76,00 |
| 00 02 | 780 × (0,2 + 0,8 × 0,05) | 187,2 | 187,2 | 76,00 |
| 01 00 | 20 | 20 | 20 × 4200/6000 = 14 | 98,21 |
| 02 00 | 0 | 0 | 0 | 100,00 |

## 6.3 Derivation of Cost Data [5]

***Primary Measures***

Several costs are taken into account. They have been derived from information provided by an expert of the industry [5]:

- ✓ R&D costs: according to [5], to develop a new adhesive takes 2 years or more. This roughly corresponds to an investment of 1,25 million Euros (these costs are considered only once and are amortized on 10 years).
- ✓ Investments: the cost to change a medium sized solvent coater in an emulsion coater is around 1 million euro. To change it into a hot melt coater, this cost is estimated to be around 3 millions (1,5 million in mixing and 1,5 million in coating and delivery system). Significant cost is added when the coater is in full production: 1 million euros can be added build up and related business continuity (investments are amortized on 20 years).
- ✓ Operating costs: raw materials and energy are considered.

**Table 6.3.1:** Raw material costs

| PMC | Costs of material [€/y] |
|---|---|
| 00 | 6 000 [t adhesive] × 800 [€/t] + 780 [t solvent] × 150 [€/t] = 4 917 000 |
| 01 | 4 200 × 1 800 = 7 560 000 |
| 02 | 2 100 × 1 800 = 3 780 000 |

According to [5], energy consumptions are as follows:

**Table 6.3.2:** Energy consumptions

| PMC | Energy consumption [kWh/y] | Costs [€/y] |
|---|---|---|
| 00 | 1 450 000 | 1 450 000 × 0,0686 = 99 470 |
| 01 | 5 800 000 | 5 800 000 × 0,0686 = 398 880 |
| 02 | 2 900 000 | 2 900 000 × 0,0686 = 198 940 |

***Secondary Measures***

Investments and operating costs for the secondary measures are derived from the estimated flow rates and VOC concentrations.
Annual working time: 6 000 h / y.

The VOC-concentration in the waste gas stream is assumed to be 3 g/m$^3$.
Flow rate is calculated from the following equation:

**Flow rate [m$^3$/h] = 0,8 × [(g COV / kg adhesives)] × (kg adhesives/y)] / [(g VOC/m$^3$) × (h/y)]**

Theoretical flow rate is around 200 000 m$^3$/h. Costs for the different combinations are given in table 6.3.3.

**Table 6.3.3:** Emission factors (EF), flow rates, investments, operating costs and technical lifetime for secondary measures

| RIC PMC SMC | VOC EF [kg / t adhesives] | Flow rate [m$^3$/h] | Investment [k€] | Variable OC [k€/y] | Fixed OC [k€/y] | Savings [k€/y] | Tech. Lifet. [y] |
|---|---|---|---|---|---|---|---|
| 01 00 01 | 187,2 | 200 000 | 2 100 | 392 | 103 | 535,5 | 10 |
| 01 00 02 | 187,2 | 200 000 | 2 690 | 339 | 135 | - | 10 |

# Industrial application of adhesives

**(Use of high performance solvent based adhesives)**

Only the use of high performance solvent based adhesives is considered in this chapter.

## 1 Definition of the Reference Installation

The reference installation presented in table 1.1 is defined according to its annual consumption of adhesives.

**Table 1.1:** Reference installation [5]

| Reference Installation Code RIC | Description |
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## 2 Definitions of primary measures [4]

Dispersions, UV cross-linking adhesives and hot melts distinguish themselves positively concerning solvent emissions.
Because of their chemical and physical characteristics, hot melts are suitable for coating and packaging adhesive tapes of a lower quality range.
Dispersions show better cohesiveness but have a very limited water resistance.
UV cross-linking acrylates and electron beam curing systems do not show the disadvantages of hot melts and dispersions and are distinguished by high cohesiveness and high adhesion strength.

However these systems cannot be used for all products, because the cohesiveness and adhesive strength that can be achieved with solvent-based adhesives can not be reached due to shorter polymer chains.

Therefore, no alternative to the solvent-based acrylate and rubber adhesives does exist for applications that require a high stress resistance (so-call high performance solvent based adhesives: see next sub-sector).

Only one primary measure is then defined in table 2.1.

**Table 2.1:** Primary measure [5]

| Primary Measure Code PMC | Description |
|---|---|
| 00 | High performance - solvent based adhesives<br>(65% solvent content – 35% solid content) |

## 3 Definitions of secondary measures [6]

When no alternative to solvent based adhesives can be used, techniques such as carbon adsorption or thermal oxidation are available.

**Table 3.1:** Secondary measures

| Secondary Measure Code SMC | Description |
|---|---|
| 00 | No secondary measure |
| 01 | Activated carbon adsorption or condensation |
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## 4 Emission factors and cost data for the different combinations

**Table 4.1:** Emission factors and abatement efficiencies for relevant combinations

| RIC PMC SMC | NMVOC EF [kg / t adhesive used] | Abatement efficiency [%] | Q | CI [%] |
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**Table 4.2:** Investments and operating costs

| RIC PMC SMC | Investment [k€] | R&D [k€] | Q | CI [%] | Variable OC [k€/y] | Fixed OC [k€/y] | Savings [k€/y] | Q | CI [%] |
|---|---|---|---|---|---|---|---|---|---|
| 01 00 00 | 0 | 0 | - | - | 14 616 | - | - | 3 | 20 |
| 01 00 01 | 2 100 | 0 | 3 | 20 | 15 008 | 103 | 533,5 | 3 | 20 |
| 01 00 02 | 2 690 | 0 | 3 | 20 | 14 955 | 135 | - | 3 | 20 |

## 5 Data to be provided by national experts for the completion of the data basis for their own country

The following tasks are required:

### 5.1 Validation work

For representing costs in this sector, the national expert is invited to comment the methodology defined by the Secretariat.

- Validate investments and operating costs provided,

Or

- Provide other costs for the same combination of techniques and justify them.

*Comments have to be sent to the Secretariat in the two weeks after having received the document.*

### 5.2 Provision of specific data

**Tables to be filled in by national experts**

- Determination of country specific data to calculate variable costs (they are valid for all VOC sectors and only have to be entered in the tool once).

**Table 5.2.1:** Country-specific data

| Parameters | Costs used in the tool | Country specific costs |
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| Natural gas [€/kWh] | 0,0192 | |
| Wages [€/h] | 25,9 | |
| Steam [€/kg] | 0,016 | |

**Table 5.2.2:** Sector and country specific data

| Parameters | Default costs [5] | Country specific costs |
|---|---|---|
| "High performance" solvent based adhesives [€ / kg] | 2,4 | |
| Cleaning solvents [€ / kg] | 0,15 | |
| Solvents recovered [€ / kg] | 0,15 | |

- Total activity level carried out in 2000, 2005, 2010, 2015, 2020. Some default values for the confidence interval are given. They can be used by the Party if no data are available.

**Table 5.2.3:** Total activity level in absolute value (tonnes of high performance solvent based adhesives consumed / y)

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

For explanations on the coefficient of variation (CI), please refer to the Methodology.

- Respective percentage of combinations of reduction measures in 2000 for the reference installation 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.

**Table 5.2.4:** Application rate and Applicability

| RIC PMC SMC | Application rate in 2000 [%] | Application rate in 2005 [%] | Appl. [%] | Application rate in 2010 [%] | Appl. [%] | Application rate in 2015 [%] | Appl. [%] | Application rate in 2020 [%] | Appl. [%] |
|---|---|---|---|---|---|---|---|---|---|
| 01 00 00 | | | | | | | | | |
| 01 00 01 | | | | | | | | | |
| 01 00 02 | | | | | | | | | |
| **Total RIC 01** | **100** | **100** | | **100** | | **100** | | **100** | |

**Table 5.2.5:** Unabated emission factor [kg VOC / tonne of adhesives used]

| PMC SMC | Default data mean | CI % | User input mean | CI % |
|---|---|---|---|---|
| 00 00 | 780 | 30 | | |

*"Default data means" 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.*

# 6 Explanatory notes

## 6.1 Definition of consumption factors (CF)

**Table 6.1.1:** Adhesive consumption

| RIC PMC | Consumption per year [t / year] |
|---|---|
| 01 00 | 6 000 |

Consumption of cleaning solvents: this is assumed that cleaning solvents are used when solvent based adhesives are consumed. This represents 20% of the solvents consumed for PMC 00.

## 6.2 Definition of Emission Factors (EF)

It is assumed that:

- In installations where the application is not enclosed and without abatement devices, all the solvent used is emitted into the air : EF = 1 g solvent/g solvent consumed,
- In installations with secondary abatement devices, where the application is enclosed, only fugitive emissions occur (20 % of the total solvent consumption). Abatement techniques are assumed to have an efficiency of 95%.

**Table 6.2.1:** Emission factors for the different combinations

| RIC PMC SMC | Calculations | Emission Factors [g solvent/kg adhesives] | Efficiency [%] |
|---|---|---|---|
| 01 00 00 | 650 × 1,2 | 780 | 0,00 |
| 01 00 01 | 780 × (0,2 + 0,8 × 0,05) | 187,2 | 76,00 |
| 01 00 02 | 780 × (0,2 + 0,8 × 0,05) | 187,2 | 76,00 |

## 6.3 Derivation of Cost Data [7]

***Primary Measures***

Only operating costs (i.e. raw materials and energy costs) are taken into account. They have been derived from information provided by an expert of the industry [5]:

**Table 6.3.1:** Raw material costs

| PMC | Costs of material [€/y] |
|---|---|
| 00 | 6 000 [t adhesive] × 2 400 [€/t] + 780 [t solvent] × 150 [€/t] = 14 517 000 |

According to [5], energy consumption is as follows:

**Table 6.3.2:** Energy consumption

| PMC | Energy consumption [kWh/y] | Costs [k€/y] |
|---|---|---|
| 00 | 1 450 000 | 1 450 000 × 0,0686 = 99 470 |

### *Secondary Measures*

Investments and operating costs for the secondary measures are derived from the estimated flow rates and VOC concentrations.
Annual working time: 6 000 h / y.

The VOC-concentration in the waste gas stream is assumed to be 3 g/$m^3$.
Flow rate is calculated from the following equation:

**Flow rate [$m^3$/h] = 0,8 × [(g COV / kg adhesives)] × (kg adhesives/y)] / [(g VOC/$m^3$) × (h/y)]**

Theoretical flow rate is around 200 000 $m^3$/h. Costs for the different combinations are given in table 6.3.3.

**Table 6.3.3:** Emission factors (EF), investments, operating costs and technical lifetime for secondary measures

| RIC PMC SMC | VOC EF [kg / t adhesives] | Flow rate [$m^3$/h] | Investment [k€] | Variable OC [k€/y] | Fixed OC [k€/y] | Savings [k€/y] | Tech. Lifet. [y] |
|---|---|---|---|---|---|---|---|
| 01 00 01 | 187,2 | 200 000 | 2 100 | 392 | 103 | 533,5 | 10 |
| 01 00 02 | 187,2 | 200 000 | 2 690 | 339 | 135 | - | 10 |

# References

[1] RAINS-VOC model, September 1998. http://www.iiasa.ac.at/~rains/databases.html

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

[3] 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.

[4] N. PETERS, S. NUNGE, J. GELDERMANN, O. RENTZ. Best Available Techniques (BAT) for the Adhesive Application in Germany. Volume II. Adhesive Application. DFIU/TH. Karlsruhe. August 2002.
http://www.umweltdaten.de/nfp-bat-e/vol2adhe.pdf

[5] Anonymous contact. Industrial. 12/09/03.

[6] N. ALLEMAND, R. BOUSCAREN, N. AVCI, T. ZUNDEL. Impact économique de la directive européenne sur la limitation des émissions de COV en provenance de l'utilisation des solvants en France. Tome III. Février 2000.