Final Background Document
on the sector

Manufacture of paints, inks and glues

Prepared in the framework of EGTEI

Prepared by CITEPA, Paris

Summary

Sector : Paint, ink and adhesives manufacturing

SNAP 06 03 07, **SNAP** 06 03 08, **SNAP** 06 03 09 or NFR 3C Chemical products, manufacture and processing

This sector covers the manufacturing of all types of paints, varnishes, stains as well as inks and adhesives. A wide number of products, formulated to meet a variety of service requirements, are available. These products are destined among others to aircrafts, automobiles, ships, wooden and metal furniture, packaging, textile fibres, domestic uses etc.

Manufacturing processes are very similar, that is why these three sectors are studied together.

ACTIVITY **:** total production of paints (except powder paints), inks and adhesives (except solvent free, mortar and cement adhesives) (tonnes of products / year)
POLLUTANT CONSIDERED **:** VOC

1 Data from the bibliography

Following data are just displayed for comparison reasons

1.1 Data currently used in the RAINS model [1], [10]

This sub-sector is not specifically treated in the RAINS model [1]. A category "Products incorporating Solvents" includes activities of which more than the half of NMVOC emissions originate from the production of paints and glues. Production of inks as well as asphalt blowing are also considered.

1.1.1 Control options

Three control options are considered in RAINS :

- NoC : Reference case.
- BEMT : Basic emission management techniques (solvent management plans, process modifications…; applicability : from 50 to 100%; reduction efficiency around 10%);
- REF : Reformulation (applicability : up to 80% in the future; efficiency of around 50%).
- BEMT+A_INC : Add-on techniques (secondary measures) as incineration. RAINS assumes a combination of primary and add-on techniques (an applicability of 75% is used with an efficiency of 95%).

Combinations of these techniques are also considered in the model.

1.1.2 Abatement costs

Examples for three countries are displayed below :

No comments are made on the figures displayed in the following tables because no further information is available.
Data on the other countries are downloadable on
http://www.iiasa.ac.at/~rains/voc_review/single.html

Table 1.1.2.1 : French situation

Activity level 1990 : 1660,000 kt product produced; 2010 : 1957,140 kt product produced, **VOC emission scenario business as usual :** 1990 : 20,58 kt VOC; 2010 : 8,74 kt VOC					
Measure	**Emission factor [kt VOC / kt of product produced]**	**Efficiency [%]**	**Technical Eff. [%]**	**Applicability [%]**	**Unit cost [€$_{1990}$/t VOC]**
00	0,0124	0	0	0	0
02	0,0081	35	50	70	10
01 + 03	0,0036	71	95	75	1 373
01 + 02 + 03	0,0033	73	73	100	1 526

Table 1.1.2.2 : German situation (Old Laender)

Activity level 1990 : 1526,000 kt product produced; 2010 : 2622,431 kt product produced, **VOC emission scenario business as usual :** 1990 : 98,63 kt VOC; 2010 : 61,32 kt VOC					
Measure	**Emission factor [kt VOC / kt of product produced]**	**Efficiency [%]**	**Technical Eff. [%]**	**Applicability [%]**	**Unit cost [€$_{1990}$/t VOC]**
00	0,0698	0	0	0	0
02	0,0454	35	50	70	10
01 + 03	0,0258	63	90	70	258
01 + 02 + 03	0,0234	67	67	100	278

Table 1.1.2.3 : German situation (New Laender)

Activity level 1990 : 250,000 kt product produced; 2010 : 429,625 kt product produced, **VOC emission scenario business as usual :** 1990 : 17,45 kt VOC; 2010 : 10,68 kt VOC					
Measure	**Emission factor [kt VOC / kt of product produced]**	**Efficiency [%]**	**Technical Eff. [%]**	**Applicability [%]**	**Unit cost [€$_{1990}$/t VOC]**
00	0,0698	0	0	0	0
02	0,0454	35	50	70	10
01 + 03	0,0258	63	90	70	258
01 + 02 + 03	0,0234	67	67	100	278

Table 1.1.2.4 : Hungarian situation

Activity level 1990 : 4,521 kt product produced; 2010 : 5,366 kt product produced, **VOC emission scenario business as usual :** 1990 : 0,07 kt VOC; 2010 : 0,08 kt VOC					
Measure	**Emission factor [kt VOC / kt of product produced]**	**Efficiency [%]**	**Technical Eff. [%]**	**Applicability [%]**	**Unit cost [€$_{1990}$/t VOC]**
00	0,0150	0	0	0	0
02	0,0098	35	50	70	10
01 + 03	0,0043	71	95	75	1 135
01 + 02 + 03	0,0041	73	73	100	1 261

1.1.3 New data treatment in RAINS

This sector being considered in the European Solvent Directive 1999/13/EC [2], it has been decided with IIASA to consider it as a specific sector in the RAINS model.

1.2 Situation in UK [8]

According to [8], solvent based coatings are increasingly replaced by water based and other alternative coatings. For companies manufacturing solvent based coatings, two options are relevant :

- The use of improved vessel containment,
- The use of end-of-pipe treatment (upgrading of condensing unit or retrofitting of a range of abatement options).

In reference [8], this is considered that 20% of the 260 installations have to invest to be in compliance with the directive requirements.
In average, annual savings of around 450 €/year (300 £/y) are incurred by installation. The estimated error range on these costs are +50%, -30%.

1.3 Situation in Norway [9]

According to [8], 15 to 20 companies in Norway produce paints and varnishes. 90% of the paint and varnish production is divided among thirteen of these companies.
VOC emissions from big companies can be reduced by installing cleaning units. For smaller firms, in-house measures are more relevant.
Costs are aggregated for industries from the production of paint and varnish, the production of plastics and polyester, degreasing, car painting, the production of pharmaceutical products and tanneries.
It is considered that the total investment of cleaning ten major and fifteen minor point emissions source is about 8 155 000 € (NOK 63 million : Norway Kroner). Annual operating costs are estimated at about 2 000 € (NOK 15 000). This leads to a cost effectiveness of 375 €/tonne of NMVOC.

1.4 Other data available in the bibliography

Costs are a mix of data from real industrial examples [5],[7].

2 Short technology description [1]

Raw materials used in the products manufacturing process include solids, binders, solvents and all kinds of additives.

- Solids provide the coating with colour, opacity, and a degree of durability.
- Binders are components which form a continuous phase, hold the solids in the dry film, and cause it to adhere to the surface to be coated. The majority of binders are composed of resins and drying oils which are to a great extent responsible for the protective and general mechanical properties of the film (more significant in decorative paints).
- For viscosity adjustment, solvents are required. Materials that can be used as solvents include aliphatic and aromatic hydrocarbons, alcohols, esters, ketones, and esters and ether-esters of ethylene and propylene glycol.
- Additives are raw materials which are added in small concentrations (0.2 – 10 %). They perform a special function or give a certain property to the coating. Additives include driers, thickeners, antifoams, dispersing agents, and catalysts.

The function of each paint is the same whether it is based on alkyd or latex (based on styrene-butadiene polymers). The selection of which to use will depend on the substrate and desired performance.

Only physical processes as weighing, mixing, grinding, tinting, thinning, and packaging take place; no chemical reactions are involved. These processes are carried out in large mixing tanks at approximately room temperature.

Emission losses may arise from several steps in the process. Major emission sources are :
- fugitive losses during the manufacturing process,
- losses during filling and cleaning activities,
- losses from product clinging to the vessels and equipment,
- fugitive losses during mixing of preparations and storage of solvents.

3 EU regulation : Directive 1999/13/EC of 11 March 1999 [2]

Operators concerned can conform to the Directive in either of the following ways :
- by complying with the canalised and fugitive emission limit values (solution I);
- by complying with the total emission limit value (solution II).

Directive applies to installations with a solvent consumption above 100 t per year.

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

Table 3.1 : Emission limits

	Solution I		Solution II
Solvent consumption threshold [t/y]	**VOC emission limit value in residual gases [mg C / Nm^3]**	**Fugitive emissions % of solvent input***	**Total emissions % of solvent input***
100 – 1 000	150	5	5
> 1 000	150	3	3

* Solvent input : quantity of organic solvents used as input into the process in the time frame over which the mass balance is being calculated (purchased solvent) + quantity of organic solvents recovered and reused as solvent input into the process (recycled solvents are counted every time they are used in the installations).

Requirements of the Directive are not all described in this chapter.

4 Definition of Reference installations

Two reference installations are described below according to their production output (expressed in tonnes of products / year) and their type of production (solvent or water based products). These descriptions are based on paint manufacturer examples but they are used for all product manufactures considered in this study.

- The type of production is considered because it greatly influences emission factors (kg COV / tonne of product).
- Only medium installations are described because the size do not significantly influence cost assessments. However, the size has an influence on the type of abatement measure which can be used (either primary or secondary) but this can be taken into account with the definitions of application rates in Chapter 6.

Table 4.1.1 : Reference installations [3]

Reference Installation Code RIC	Description
01	Medium Installation : product production : 15 000 tonnes / year Production mix : 45 % of water-based coatings (4 wt.-% average solvent content), 50 % high solvent-based coatings (50 wt.-% solvent content), 5 % other products (100 wt.% solvent content)
02	Medium Installation : product production : 15 000 tonnes / year Production mix : 80 % water-based coatings (4 wt.-% average solvent content), 15 % high solvent-based coatings (50 wt.-% solvent content), 5 % other products (100 wt.% solvent content)

5 Emission abatement techniques and costs

5.1 Definitions of primary measures

According to USEPA [3], the overall average emission factor for this sector is 3.4 % of the solvent input.

Only primary measures based on good practices are taken into account since emissions are presently low. These measures are [4] :

- Recovery of solvent vapours during raw material distribution,
- Unloading of the barrels with fork lifts to avoid leakages,
- Coverage of mobile reactors,
- Use of heavier solvents to reduce fugitive emissions,
- Use of cleaning agents containing less solvents,
- Use of automatic cleaning devices whenever possible,
- Recycling of cleaning solutions,
- …

Table 5.1.1 : Primary measures

Primary Measure Code PMC	Description
00	• Usual practices
01	• Good practices

5.2 Definition of secondary measures

Secondary measures can either be incineration or condensation to recycle lost solvents. Conditions are not optimal for incineration : many vents have to be treated leading to high flow rates with low VOC concentrations. In addition, solvents are raw materials which can be reused into the process. That's why incineration is not considered in this document.

Table 5.2.1 : Secondary measures

Secondary Measure Code SMC	Description
00	No secondary measure
01	Upgrading of the condensation units or carbon adsorption and solvent recovery

5.3 Emission factors and cost data for the different combinations

Combination PMC 01 with SMC 01 is not considered hereafter because it does not seem realistic.

Table 5.3.1 : Emission factors (EF) and abatement efficiencies for each relevant combination

RIC PMC SMC	NMVOC Emission Factor [g VOC / kg product]	Abatement efficiency [%]	% of solvent input	Q	CI %
01 00 00	11	0	3,5	3	20
01 01 00	8	27	2,5	3	20
01 00 01	5,5	50	1,75	3	20
02 00 00	5,5	0	3,5	3	20
02 01 00	4	27	2,5	3	20
02 00 01	2,75	50	1,75	3	20

Q : Quality of the data
CI : Coefficient of variation

Table 5.3.2 : Investments and operating costs

RIC PMC SMC	Investment [€]	Q	CI %	Variable OC [€/y]	Q	CI %	Fixed OC [€/y]	Savings [€/y]	Q	CI %
01 00 00	0	-	-	0	-	-	-	0	-	-
01 01 00	415 000	3	30	0	3	30	0	45 000	3	30
01 00 01	1 400 000	3	30	18 000	3	30	70 000	82 500	3	30
02 00 00	0	-	-	0	-	-	-	0	-	-
02 01 00	415 000	3	30	0	3	30	0	22 500	3	30
02 00 01	710 000	3	30	12 300	3	30	35 000	41 250	3	30

6 Data to be provided by national experts for the completion of the database for their own country

The following tasks are required :

6.1 Validation work

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

- Validate investments provided and,
- Validate the method of derivation of operating costs.

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.

6.2 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 6.2.1 : Country-specific data

Parameters	Default values	Country specific costs
Electricity [€/kWh] (net of taxes)	0,0686	
Steam [€/kg] (net of taxes)	0,016	
Wages [€/h]	25,9	

Table 6.2.2 : Sector specific data

Parameters	Default value	Sector specific costs
Price of recovered solvents [€/kg]	1,0	

- Respective shares (t products/y) of the total activity level carried out on each reference installation 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 6.2.3 : Activity levels on Reference Installations (t products manufactured / year)

Sum of paint (except powder paints), ink and adhesive (except solvent free, mortar and cement adhesives) productions.

RIC	2000	CI%	2005	CI%	2010	CI%	2015	CI%	2020	CI%
01										
02										
Default values for CI		10		20		50		100		100
Total	Calculated automatically by the tool									

For explanations on the coefficient of variation, please refer to the "Methodology".

- Total activity (t products/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.: 50% 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.

- Respective percentage of combinations of reduction measures in 2000 for each 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 6.2.4 : Application rate and Applicability

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

If detailed information is available, table 6.2.4 can be filled in.
If only sparse information is available, then table 6.2.4 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 : Aggregated table

RIC PMC SMC	Application rate in 2000 [%]	Application rate in 2005 [%]	Applicability [%]	Application rate in 2010 [%]	Applicability [%]	Application rate in 2015 [%]	Applicability [%]	Application rate in 2020 [%]	Applicability [%]
Aggreg. 00 00									
Aggreg. 01 00									
Aggreg. 00 01									
Total aggreg.	**100**	**100**		**100**		**100**		**100**	

Aggreg. : Aggregation

Table 6.2.6 : Unabated emission factor [g VOC/kg product]

RI	Default data mean	CI %	User input mean	CI %
01	11	20		
02	5,5	20		

"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.

7 Explanatory notes

7.1 Derivation of Consumption Factors

Consumption factors are calculated as indicated below in table 7.1.1.

Table 7.1.1 : Solvent consumption factor (g solvent / kg product)

RIC	Consumption factors [g solvent / kg product]
01	1000 × (0,45 × 0,04 + 0,5 × 0,5 + 0,05 × 1) = 318
02	1000 × (0,80 × 0,04 + 0,15 × 0,5 + 0,05 × 1) = 157

7.2 Derivation of Emission factors

According to USEPA [3], average emission factor for the whole sector is 3,4% of paint's solvent content.
According to [6] the average emission factor for production with usual working practices is around 3,5%. When good practices are implemented, one can assume that emissions are reduced around 2,5% (below the directive limit) [6].
Secondary measure costs are calculated for an efficiency of 50% [7].

Table 7.2.1 : Emission factors (g VOC / kg product)

RIC PMC SMC	Emission factors [g VOC / kg product]	% of solvent input
01 00 00	0,035 × 318 = 11	3,5
01 01 00	0,025 × 318 = 8	2,5
01 00 01	0,035 × 318 × 0,5 = 5,5	1,75
02 00 00	0,035 × 157 = 5,5	3,5
02 01 00	0,025 × 157 × = 4	2,5
02 00 01	0,035 × 157 × 0,5 =2,75	1,75

7.3 Derivation of Cost Data

Costs of primary and secondary measures have been derived from references [1],[5], [7].

Primary measures

According to [6], the installation considered in [5] corresponds to our reference installation. These costs correspond to the enclosure of the different processes and the recovery of the cleaning agents. Solvent consumption is reduced which leads to savings (a cost of 1,0 € / kg of solvent recovered is assumed).

Table 7.3.1 : Costs of primary measures

RIC PMC SMC	Investment [€]	VOC emissions [t / year]	Savings [€ / y]	Tech. Lifetime [year]
01 00 00	0	165	0	15
01 01 00	415 000	120	(165-120)[t/y] × 1,0[€/kg] × 1000[kg/t]=45 000	15
02 00 00	0	82,5	0	15
02 01 00	415 000	60	(82,5-60)×1,0×1000 = 22 500	15

Secondary measures

Costs for secondary measure are derived from [7].
LAKROM is a leading producer of paints and varnishes, epoxy resins and plasticisers in Bulgaria. Its annual solvent input is 1 630 tonnes for 48 tonnes of VOCs emissions (2,9 % of solvent input). Costs to reduce by one half these emissions have been assessed to be around 415 000 Euros. This investment is incurred for :

- the replacement of unsuited condensers (at least 5 items),
- the adaptation of the software to automatic control the heating-up and cooling-down during reaction
- the purchase of instruments to control physical and chemical elements (flow measurement, FID, gas chromatography and spectrometer).

These investments correspond to a ratio of 17 300 €/tonne of VOC abated.

As costs are defined per tonne of VOC abated, an efficiency of 50% is taken into account. This abatement efficiency is sufficient to be in compliance with the Directive requirements.

For RIC 01, a device with an abatement efficiency of 50% (leading to a reduction of 82,5 tonnes of VOC emissions) would cost around 1 400 000 €.
For RIC 02, a device with an abatement efficiency of 50% (leading to a reduction of 41 tonnes of VOC emissions) would cost around 710 000 €.

Gas flow rates are calculated thanks to the previous figures assuming that 50% of the total VOC-emissions are captured.

Flow rate (g/m^3) = 0,5 × [(g VOC/kg product) × (kg product/y)] / [(g VOC / m^3) × (h/y)]

As condensation and adsorption are considered together, operating costs have been calculated from the equations of the document "Methodology" for secondary measure "Carbon adsorption".

Parameters taken into account are derived from [3] :
For RIC 01 : working hours : 4 000 h/y; VOC concentrations : 1 g/m^3;
For RIC 02 : working hours : 4 000 h/y; VOC concentrations : 1 g/m^3;

Costs induced by secondary measure implementation are summarized in table 7.3.2.1.

Table 7.3.2.1 : Investment and operating costs for secondary measures

RIC PMC SMC	Eff. [%]	Flow rates [m^3/h]	Investment [€]	Variable OC [€ / y]	Fixed OC [€/y]	Saved costs * [€ / y]	Tech Lifetime [year]
01 00 01	50	20 600	1 400 000	18 000	70 000	82 500	10
02 00 01	50	10 300	710 000	12 300	35 000	41 250	10

* Value of solvent recovered = 1,0 €

8 References

[1] Z. KLIMONT; M. AMANN; J. COFALA. Estimating costs for Controlling Emissions of Volatile Organic Compounds (VOC) from Stationary Sources in Europe. Interim Report IR-00-51. IIASA. August 1, 2000. http://www.iiasa.ac.at/~rains/voc_review/voc_ir-00-51.pdf

[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] IFARE. Task force on the assessment of abatement options and techniques for VOC from stationary sources. Draft background document prepared for UN/ECE-May 1999.

[4] US EPA. Control of VOC emissions from ink and paint manufacturing processes. Report 450/3-92-013-1992.

[5] FIPEC. Guide de rédaction d'un schéma de maîtrise des émissions dans le cas du secteur de la fabrication des Peintures, Vernis, Encres d'imprimerie, Colles et Adhésifs.20/03/02.

[6] M. JOLY. Personal communication to CITEPA. FIPEC. July 2002.

[7] MILHAU A., BOUSCAREN R., BERRINI P. Technical report on Task4 Solvent Use Directive 99/13/EC. Report for the Bulgarian Ministry of Environment.

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

[9] Measures for Reducing NMVOC Emissions in Norway. Cost Estimate. SFT. 1997.

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

9. Modifications compared to the draft document

Comments have been made on the background document :

Activity : productions of paints, inks and glues (t/y) are considered in this document. But powder paints, solvent free adhesives, mortar and cement adhesives are not taken into account. These products do not contain solvents and are not taken into account in the definition of the Reference Installations.

Chapter 3 : Solvent consumption threshold is 100 tonnes / year.

Chapter 4 : Reference Installations defined are based on paint manufacturer examples but they are used for all products manufactures considered in this study.

Chapter 5 : Variable operating costs for secondary measures have been modified (see explanations in chapter 7).

Chapter 7 : As condensation and adsorption are considered together, operating costs have been calculated from the equations of the document "Methodology" for secondary measure "Carbon adsorption".

Specific flow rate have been re-calculated according to the parameters defined in this study :

Flow rate (g/m^3) = 0,5 × [(g VOC/kg product) × (kg product/y)] / [(g VOC / m^3) × (h/y)]

RIC PMC SMC	Calculations of flow rates [m^3/h]
01 00 01	0,5 × (11 × 15 000 000) / (1 × 4 000) = 20 600
02 00 01	0,5 × (5,5 × 15 000 000) / (1 × 4 000) = 10 300