Final Background Document
on the sector

Manufacture of shoes

Prepared in the framework of EGTEI

Prepared by CITEPA, Paris

Summary

Sector : manufacture of shoes

SNAP 06 04 05 01 or NFR 3 D OTHER including products containing HMs and POPs.

This sector is not considered in the SNAP. It is a sub-sector of the application of glue : 06 04 05 which is studied separately for EGTEI purposes because it is considered in the EU Solvent Directive.

This sector covers the manufacture of all types of shoes. Application of adhesives represents the main VOC emission source of this sector. But other products containing solvents have to be taken into account. Information reported in this report is based on real examples. Two cases have been observed : industrial operators with high emission rates and industrial operators with emissions just above the European regulation threshold. Measures have been studied for both situations.

ACTIVITY : number of pairs of shoes produced by the cementing technique / 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], [8]

At its present stage of development, the RAINS model do not take this sub-sector specifically into account [1]. RAINS category "Other Use of Solvents in Industry" includes activities from three major sectors : application of glues and adhesives, preservation of wood, and other industrial use of solvents. Activity units for "application of glues and adhesives" and "other industrial use of solvents" are in kt of NMVOC emissions. For "preservation of wood", activity is given in quantity of solvents used (kt) or in volume of wood treated (m^3). For the aggregation of these sub-sectors, it was assumed that more than 30% of the emissions result from application of glues and adhesives, 20% from preservation of wood, and the rest from other sectors classified in this group, mostly *fat edible and non-edible oil extraction* (in some countries, other sectors like leather tanning, textile finishing or use of agrochemicals might be of importance).

1.2 Control options

Three control options are considered in RAINS for the "Application of glues and adhesives" :

- NoC : Reference case.
- HSE : modification of the application technique with other housekeeping measures (reduction efficiency around 15%);
- SUB : substitution with water-based adhesives or hot-melts (applicability : 60%; efficiency : 85%).
- INC : add-on techniques (secondary measures) as incineration (applicability : 40%; efficiency of 80%).

Combinations of these techniques are also considered in the RAINS model.

1.3 Abatement costs

As this sector is not specifically studied, only average costs at a European level are given in table 1.3.1.

Data at a country level are downloadable on http://www.iiasa.ac.at/~rains/voc_review/single.html

Table 1.3.1 : Abatement costs taken into account in the RAINS model

Technology	Unit cost range [€$_{1990}$ / t VOC]
NoC	0
HSE	< 20
SUB	~350
INC	~600

1.4 New data treatment in RAINS

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

1.5 Other data available in the bibliography

This sector is usually not treated specifically in the literature.

Costs presented in this study are a mix of data used in [5] and information from industrial experts [6].

2 Short technology description

Manual labour is predominant in shoe production because of the variety of models and materials used. Automation is only possible in some portions of the production process (e.g. molding injection).

The two main techniques of shoe production are the cementing and the molding techniques.

2.1 Cementing technique

For the stitching step, either solvent based or water based adhesives can be used. Solvent based products are applied with a paint-brush. Water based adhesives can be applied manually by spraying techniques or by paint-brushes. Then, the shoe upper part is fixed on the insole.
Parts like rubber soles have to be pre-treated with a halogenizer to ensure a strong adhesion of the adhesive. [3]
The insole is attached to the sole with solvent based adhesives. This operation is handled either manually or automatically.
Finishing products (color, protection, water repellent products…) are applied with a paint-brush or by automatic guns in spray booths.
Solvents are used as thinners for solvent based adhesives and as cleaners and are present in adhesives.

2.2 Injection molding technique

The sole is directly molded adhesive-free onto the shoe upper. The sole material is injected in a mould and forms a strong bond with the shoe upper while it cools off. Solvents are only used to withdraw the sole from the mould and during the finishing step. With this technique, the threshold of 25 g/pair is not attained. Emission factors are closer to 10 g/pair but injection is not applicable for all types of productions.

2.3 Adhesive systems

Different types of adhesives can be used.

2.3.1 Solvent based adhesives

- Polyurethane adhesives

Solvents used are acetone, butanone, toluene, MEK, ethyl acetate… These adhesives are used to fix the upper shoe to the insole.

- Neoprene adhesives

Solvents used can be hexane, cylohexane, heptane, toluene, ketones, ethyl acetate… These adhesives are usually used for the stitching step. The solid content of these products varies in the range of 20 to 30 % (solvent content is then between 70 to 80%).
The high concentration of solvents allows adhesives to penetrate into the leather fibers.

2.3.2 Water based adhesives

These adhesives are based on polyurethane, natural or synthetic rubber dispersed in water (these adhesives contain no solvent). They can be used for the stitching step. Because these products lack flexibility, changes in production processes are required. That is why water based products have not been widespread used yet. [4]

2.3.3 Hot Melts

These adhesives are based on polyester, polyamide and vinyl acetate. The application depends on the processing machines and temperature sensibility of materials being processed [3]. These are solvent-free.
These products are not included in the VOC reduction scheme in this study because they are already widely used whenever possible.

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

Operators concerned can conform to the Directive by complying with the total emission limit value.

Directive applies to installations with a solvent consumption higher than 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 / year]	**Total emissions [g VOC / pair]**
> 5	25

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

4 Definition of Reference Installations

Only installations using the cementing technique have been studied because installations using other manufacturing techniques are in compliance with the limit of 25 g VOC / pair of shoes.

Reference installations are presented in table 4.1.

Table 4.1 : Reference installations

Reference Installation Code RIC	Description
01	Small installation : 100 000 pairs of shoes / year
02	Large installation : 200 000 pairs of shoes / year

5 Emission abatement techniques and costs

5.1 Definition of primary measures

Emission levels in this sector are very sparse. Some installations emit 60 g/pair when others just emit 30 g/pair.
The main NMVOC emission sources are the use of adhesives, halogenizers, finishing products and cleaning agents.

Three options to reduce NMVOC emissions are of relevance in this sector :

- improvement of application efficiency : automatic devices can be used for the application of adhesives and halogenizer. These techniques can reduce product consumptions (i.e.: solvent consumption) by 25%.
- switching to low solvent.
- good housekeeping / solvent management : operations like the closure of adhesives or solvent containers and a better product management may reduce NMVOC-emissions by 10 %.

Measures 00 and 01 correspond to situations observed in the Industry.

- Measure 00 :

This measure represents the case of manufacturers using almost exclusively solvent based adhesives. No solvent management has been implemented : fugitive emissions are high and a lot of raw materials are lost by evaporation or are simply not used.

- Measure 01 :

The share of solvent based adhesives is reduced from 90% to 60%. Operations like stitching steps or pre-gluing of soles are done with water based products. Moreover, good housekeeping and solvent management are implemented and lead to solvent emissions reduction of 10%.

- Measure 02 :

This measure corresponds to 01 with, in addition, the use of automatic application devices for halogenizers and conventional adhesives. A 25% reduction of product consumption (i.e.: solvent consumption) can be reached.

Table 5.1.1 : Primary measures

Primary Measure Code PMC	Description
00	90% of solvent based adhesives / 10 % of water based
01	60% of solvent based adhesives / 40 % of water based Good housekeeping
02	60% of solvent based adhesives / 40 % of water based Good housekeeping / Automatic application

5.2 Definition of secondary measures

When the manufacturing process can not be modified, end-of-pipe devices like incineration or biofiltration can be implemented. Incinerators might be too expensive for small shoe manufacturing plants.
Biological treatment has already been implemented at Wellingborough-based R Griggs & Company Ltd [7].
These methods can give good abatement efficiencies only if a maximum of emission sources are collected and routed to the treatment device.

Table 5.2.1 : Secondary measures

Secondary Measure Code SMC	Description
00	No secondary measure
01	Incineration
02	Biofiltration

5.3 Emission factors and costs data for the different combinations

Combinations of PMC 02 with SMC 01 or 02 are not considered in this document. It is assumed that end-of-pipe devices will be used when the switch to water based products is not technically feasible.

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

RIC PMC SMC	Emission Factor [g VOC / pair]	Abatement efficiency [%]	Q	CI %
01 00 00	60	0	4	20
01 00 01	17,2	71	4	20
01 00 02	17,2	71	4	20
01 01 00	31	48	4	20
01 01 01	8,9	85	4	20
01 01 02	8,9	85	4	20
01 02 00	23	62	4	20
02 00 00	60	0	4	20
02 00 01	17,2	71	4	20
02 00 02	17,2	71	4	20
02 01 00	31	48	4	20
02 01 01	8,9	85	4	20
02 01 02	8,9	85	4	20
02 02 00	23	62	4	20

Q : Quality of data
CI : Coefficient of variation

Table5.3.2 : Investments and operating costs

RIC PMC SMC	Investment [€]	Q	CI %	Variable OC [€ / year]	Q	CI %	Fixed OC [€ / year]	Q	CI %
01 00 00	0	-	-	18 200	4	25	0	-	-
01 00 01	236 000	3	25	23 000	4	25	11 800	3	25
01 00 02	42 800	3	25	22 100	4	25	2 200	3	25
01 01 00	22 900	3	25	15 800	4	25	0	-	-
01 01 01	187 500	3	25	19 700	4	25	8 200	3	25
01 01 02	48 300	3	25	19 300	4	25	1 300	3	25
01 02 00	100 000	3	25	13 500	4	25	0	-	-
02 00 00	0	-	-	36 400	4	25	0	-	-
02 00 01	350 000	3	25	43 000	4	25	17 500	3	25
02 00 02	75 800	3	25	41 200	4	25	3 800	3	25
02 01 00	45 750	3	25	31 600	4	25	0	-	-
02 01 01	286 750	3	25	36 500	4	25	12 000	3	25
02 01 02	89 950	3	25	35 500	4	25	2 200	3	25
02 02 00	200 000	3	25	27 000	4	25	0	-	-

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	
Natural gas [€/kWh] (net of taxes)	0,0192	
Wages [€/h]	25,9	

Table 6.2.2 : Sector and country specific data

Parameters	Default values	Country specific costs
Solvent based adhesives [€/kg] (net of taxes)	3,0	
Water based adhesives [€/kg] (net of taxes)	3,9	
Halogenizers [€/kg] (net of taxes)	3,0	

- Respective shares (shoes produced by the cementing technique/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 (shoes produced by the cementing technique/year)

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									

- Total activity (pairs of shoes/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 (pairs of shoes/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 for each combination of reduction measures

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 00 01									
01 00 02									
01 01 00									
01 01 01									
01 01 02									
01 02 00									
Total RIC 01	**100%**	**100%**		**100%**		**100%**		**100%**	
02 00 00									
02 00 01									
02 00 02									
02 01 00									
02 01 01									
02 01 02									
02 02 00									
Total RIC 02	**100%**	**100%**		**100%**		**100%**		**100%**	

Notice :

- It can be considered that a very small proportion of installations are equipped with end-of – pipe devices (one does exist in UK).

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 (this table does not appear in the tool)

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. 00 01									
Aggreg. 00 02									
Aggreg. 01 00									
Aggreg. 01 01									
Aggreg. 01 02									
Aggreg. 02 00									
Total aggreg.	**100**	**100**		**100**		**100**		**100**	

Aggreg. : Aggregation

Table 6.2.6 : Unabated emission factor

Default data mean	CI %	User input mean	CI %
60	20		

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 so we can add it in the background documents.

7 Explanatory notes

7.1 Consumption factors (CF)

PMC 00 consumption factors have been derived from [5].

To establish PMC 01 consumption factors, it has been considered that the dry extract has to remain the same. (i.e. 11,9 g / pair). PMC 02 consumption factor is derived from PMC 01 (+ reduction by 25 % of conventional adhesive and halogenizer consumptions).

Table 7.1.1 : Product consumption factors

Products	Consumption factor (g product / pair of shoes)				
	PMC 00	Dry extract	PMC 01	Dry extract	PMC 02
Conventional adhesives	48,6	48,2 × 0,2 = 9,71	25,5	25,5 × 0,2 = 5,1	25,5× 0,75 = 19,1
Water based adhesives	5,4	5,4 × 0,4 = 2,16	17	17 × 0,4 = 6,8	17
Cleaner and thinners	15		8		6
Halogenizer	5		5		5 × 0,75 = 3,75
Finishing products	6		6		6
Total		**11,9**		**11,9**	

7.2 Emission factors

Emission factors (EF) are calculated with the following equation :

EF (g solvent / pair) = CF (g product / pair) × Product VOC content (g solvent / g product)

Table 7.2.1 : Product solvent contents [4] ,[5]

Products	VOC content (w. %)	Dry extract (w. %) [1]
Conventional adhesives	80	20
Water based adhesives	0	40
Cleaner and thinners	100	
Halogenizer	97	
Finishing products	20	

- If no secondary abatement device is used, it is assumed that 100 % of solvents used evaporate.
- A fugitive emission level of 25% is assumed. So 75% of total emissions can be treated by the abatement device with an efficiency of 95%.

Table 7.2.2 : Emission factors (EF)

Products	Emission factors (g VOC / pair)		
	Primary measure 00	Primary measure 01	Primary measure 02
Conventional adhesives	48,6 × 0,8 = 39	20	15
Water based adhesives	5,4 × 0 = 0	0	0
Cleaner and thinners	15	8	6
Halogenizer	5 × 0,97 = 4,9	4,9	3,6
Finishing products	6 × 0,2 = 1,2	1,2	1,2
Total	**60**	**34**	**26**
Total with good housekeeping		34 × 0,9 = 31	23
With Secondary Measure	60×(0,75×0,05+0,25)=17,2	31×(0,75×0,05+0,25)=8,9	

7.3 Derivation of cost data

Primary measures

- Heater costs

Costs for the adaptation of existing installations to water based adhesives are derived form [5].

Table 7.3.1 : Investments (€) for heaters

Reference installation	Primary measure 00	Primary measure 01	Primary measure 02
01	0	22 900	22 900
02	0	45 750	45 750

- Automatic device costs

Costs of automatic devices for Primary measure 02 have to be taken into account. These application methods lead to product consumption gains of about 25%.

Table 7.3.2 : Investments (€) for automatic devices [6]

Reference installation	Adhesives application devices	Halogenizer application devices
01	15 300	62 000
02	30 000	120 000

- Operating costs

Costs have been derived from [5]. It is assumed that costs of water based products are 30% higher than those of conventional adhesives (3,9 €/kg vs. 3,0 €/kg respectively). This difference is compensated by the higher dry content of water based products. Halogenizers are assumed to cost 3,0 €/kg.
Gains in consumption of halogenizer are realized with the use of automatic application devices. This reduce operating costs for this product by 25%.

Table 7.3.3 : Operating costs for adhesives (€ /y)

RIC	PMC 00	PMC 01	PMC 02
01	[48,6(g/pair) × 3(€/kg)+5,4 × 3,9]×100 000(pairs/y)/1 000(g/kg)=16 690	14 280	12 360
02	33 370	28 560	24 720

Table 7.3.4 : Operating costs for halogenizer (€/y)

RIC	PMC 00	PMC 01	PMC 02
01	4,9(g product/pair) × 3(€/kg) × 100 000/1000 = 1 500	1 500	1 125
02	3 000	3 000	2 250

Table 7.3.5 : Emission factors, investments, operating costs and technical lifetime for primary measures

RIC PMC	Emission Factor [g VOC / pair]	Investments [€]	Variable OC [€ / year]	Tech. Lifetime [year]
01 00	60	0	18 200	20
01 01	31	22 900	15 800	20
01 02	23	100 000	13 500	20
02 00	60	0	36 400	20
02 01	31	45 750	31 600	20
02 02	23	200 000	27 000	20

Secondary measure

Two types of abatement techniques can be used : incineration or biofiltration. Adsoprtion is not suitable for this sector because a large range of solvents among which ketones is used. It would not be easy to distillate the solvents for recycling and ketones may lead to carbon ignition.

Investments and operating costs for both techniques are calculated from a software tool (cost curve) which will be provided to all the Parties. Processes may have to be modified but costs incurred by these modifications are not taken into account.

The following assumptions on annual working times for each reference installation and on VOC concentrations in the waste gas streams have been made :

Small reference installations : 1 840 h / y
Large reference installations : 1 840 h / y
VOC-concentration is assumed to be **1 g / m^3** in the gas stream.

Gas flow rates are calculated thanks to the previous figures assuming that 75% of the total VOC-emissions are captured.

Flow rate (g/m^3) = 0,75 × [(g VOC/pair) × (pairs/y)] / [(g VOC / m^3) × (h/y)]

Investments and operating costs are based on the equations displayed in the document "Methodology" .Operating costs are country specific : figures in table 7.3.6 are displayed as examples.

Table 7.3.6 : Emission factors, investments, operating costs and technical lifetime for secondary measures

RIC PMC SMC	Emission Factor [g VOC / pair]	Flow rate [m^3 / h]	Investment [€]	Fixed OC [€ / year]	Variable OC [€ / year]	Tech. Lifetime [year]
01 00 01	17,2	2 400	236 000	11 800	4 800	10
01 00 02	17,2	2 400	42 800	2 200	3 900	10
01 01 01	8,9	1 250	164 600	8 200	3 900	10
01 01 02	8,9	1 250	25 400	1 300	3 500	10
02 00 01	17,2	4 900	350 000	17 500	6 600	10
02 00 02	17,2	4 900	75 800	3 800	4 800	10
02 01 01	8,9	2 500	241 000	12 000	4 900	10
02 01 02	8,9	2 500	44 200	2 200	3 900	10

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.

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[6] Personal communication : M. RICO – BERAUD. September 2002.

[7] Biotechnology successfully treats solvent emissions at R Griggs Group Limited. Howard Johnstone Group Administration Director. R. Griggs Group Limited.

[8] 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

No comment has been made on the draft document.

Chapter 6 : A table 6.2.2 “sector and country specific data” has been added to take into account new country specific factors. Product’s costs (as adhesives and halogenizers) can be very different from country to country. It has been decided during the steering group meeting of April 4th, to let the opportunity to National Experts to use country and sector specific costs for certain parameters. If these costs are modified then, corresponding operating costs will be automatically re-calculated by the tool.